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STATUS AND FORMS OF SULPHUR IN SOILS OF WUDIL AND GAYA, KANO STATE, NIGERIA.

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ABSTRACT

An investigation study was carried out to determine the status and forms of sulphur in soils of Wudil and Gaya, Kano state, Nigeria. Soils were collected using grid sampling method across two farming communities, Gaya and Wudil Local Government areas of Kano state. A total of 297 samples were collected at a depth of 0 - 30 cm. The samples were subjected to routine soil tests while the forms of sulphur were determined using turbidmetric method. Descriptive analysis was used for the interpretation of the data. The result obtained showed that soils from both locations were sandy loam with slightly acidic to neutral pH and low content of organic matter (0.38 and 0.24%) and nitrogen (0.06 and 0.04%). The sulphur level in both locations was sufficient. Differences in the concentration of the forms of sulphur were observed. Total sulphur had the highest amount of sulphur 498.30 mg kg^{-1}, while non-sulphate sulphur had the least amount 0.74 mg kg^{-1}. The low amounts of adsorbed and non-sulphate sulphur observed were attributed to the texture (sandy loam) and pH (6.24 and 6.99) of the soil. It can be concluded that the sulphur levels in both locations; Gaya and Wudil were high. Therefore, management strategies that will enable sulphur mineralization in the soil should be maintained by farmers to enhance availability of sulphate in the soil.

Keywords: Total sulphur; sulphate sulphur; inorganic sulphur; adsorbed sulphate and non-sulphate sulphur.

INTRODUCTION

Sulphur (S) is an essential plant macronutrient element necessary for the growth and development of crops. It is ranked as the fourth major essential nutrient element. Sulphur plays an important role in the primary metabolism of higher plants and it is involved in the synthesis of secondary metabolic products in certain groups of plants (Głowacka, 2016). Similar to nitrogen, sulphur plays an important role in cycling, however, this element has no atmospheric reserve (Głowacka, 2016). Sulphur is involved in the structural component of protein and peptides, the conversion of inorganic N into protein, a catalyst in chlorophyll production, promotes nodule formation in legumes, the structural component of various enzymes, a structural component of the compounds that give the characteristic odours and flavours to mustard, onion and garlic. Sulphur exists in organic and inorganic forms and may also be found in the soil as adsorbed S, ester sulphate, elemental S, carbon bonded S, extractable S, and water-soluble S among others (Sutar *et al.,* 2017). The organic form of Sulphur cannot be readily taken up by plants except it is converted to inorganic form. Organic S generally become available to plants through mineralization to sulfate. The inorganic S fraction in soils may occur as SO_4-S and compounds of lower oxidation states, but in well-drained agricultural soils, most of the inorganic Sulphur (S) normally occurs as SO_4-S, and the amounts of reduced S compounds are generally very low. They need to be converted or mineralized to the sulfate (SO_4^{2-}) form to become available to the crop (Sutar *et al.*, 2017). Also, the amount of inorganic S found in the soil depends on its texture, organic matter content, pH, temperature and presence of substrates. In well-drained agricultural soil, sulphate may occur as water–soluble mainly as sulphates of Ca, Mg and Na , sulphates ions adsorbed on soil colloids (at low pH) or as insoluble sulphates of Ca, Mg, Na and K (Bappa *et al.,* 2014). For instance, the surface horizons of well-drained temperate soil contain a small amount of water-soluble sulphate, while large quantities may accumulate in an arid or poorly drained condition with high salt accumulation (Bappa *et al.*, 2014).

To improve crop productivity, fertilizer use has become more important due to the cultivation of high-yielding crop varieties and multiple cropping systems. There are variations in the sulphur requirements of crops. Generally, the sulphur requirements of oil seeds are different from that of legumes as well as cereal grains. For instance, the amount of Sulphur required to produce one ton of seed is about 3-4 kg Sulphur for cereals; 8 kg Sulphur for legume crops; and 12 kg Sulphur for oil crops. (Abou Seeda *et al.,* 2020). Majority of the crops cultivated in Gaya and Wudil farms are sorghum, millet and cowpea with few vegetables. Although the sulphur requirement to produce one ton of cereals is rather low, its uptake per unit area becomes high due to the higher productivity of cereals (Safaa *et al.,* 2013). The newly evolved high-yielding varieties of maize are more fertilizer responsive and have accelerated the depletion of S reserves in the soil, even from lower soil depths (Xue *et al.*, 2012). In addition to the continuous crop residue removal, this also results in S deficiency in these soils.

However, many reports on the properties of the soils of Gaya and Wudil have been presented (Amin *et al.*, 2022; Almu *et al.,* 2021), there has been no clear information on the actual status of sulphur in the soils of these locations. Considering the key role sulphur plays in plant metabolism such as protein synthesis, photosynthesis, production of oils and vitamins, disease resistance etc.

And the synergistic relationship between sulphur and nitrogen nutrition, sulphur deficiency will reduce the uptake of nitrogen and phosphorus with consequent effect on crop growth. Thus, there is a need to improve the sulphur levels in Gaya and Wudil soils to attain higher crop productivity. Hence, this study was carried out to determine the status and forms of sulphur in the soils of Gaya and Wudil local government area of Kano state.

MATERIALS AND METHODS

Study area

The study was carried out in two Local Government Areas (LGA) of Kano state Wudil and Gaya. Gaya is situated on the border of Kano and Jigawa states and is surrounded by Ajingi, Wudil and Albasu local government areas of Kano state. Gaya has an area of 613 km^2 with latitude $11^0\ 52^{I}\ 5^{II}$ N and longitude $9^0\ 0^I\ 40^{II}$E. While Wudil has latitude $11^0\ 49^{I}$ N^1 and longitude $8^0\ 5^I$ E^1 with an area of 362 km² (NIPOST, 2009). From the top downwards, the basement complex is deeply weathered to a reported depth of 7 to 9 m and forms a dissected peneplain landscape (Adamu and Aliyu, 2012). Wudil is a Local Government Area in Kano State**,** Nigeria**.** The geology of the region is characterized by three major rock formations; Basement Complex rocks, metamorphic rocks, and younger granite. The soils were classified as Entisols, Inceptisols and Alfisols (Adamu and Aliyu, 2012).

Soil sampling and collection

Soils were collected from 297 intensively cultivated (cereal-based) farmland using the grid sampling method in both Gaya and Wudil communities. A total of 297 samples were collected altogether. A grid of 300m by 400m was superimposed on each farm and sampling points were identified at the centre of each grid. Soil samples were collected to a depth of 30cm. Soil samples were taken to the laboratory and air-dried. The samples were gently crushed and passed through a 2mm sieve. All samples were stored in an air-tight container pending analysis

Laboratory methods

Soil texture was determined using the Bouyoucos hydrometer method as described by Gee and Bauder (1986). Soil pH was determined based on the IITA (1982) procedure and the pH was measured using Jenway 3520 glass electrode. Organic carbon was determined using Walkley-Black wet oxidation method (Nelson and Sommers, 1982). Total N was determined using the micro-Kjeldahl digestion method (Bremmer, 1996). Available phosphorus in soil samples with pH below 7 was determined using Bray 1 method (Bray and Kurtz, 1945), while in samples with pH above 7, available P was determined using the Olsen method (Olsen, 1950). Exchangeable cations were extracted with 1N NH_4OAC solution buffered at pH 7.0 as described by Anderson and Ingram (1998), the concentration of potassium and sodium was determined using the flame photometer while calcium and magnesium were determined by the atomic absorption spectrophotometer. Exchangeable acidity was determined with 1N KCl and titrated with 0.05N NaOH (Maclean, 1965).

Available sulphur was determined using the turbidimetric method described by Chesnin and Yien (1950). Sulphate sulphur was determined with 0.15% $CaCl_2$ extractant (Williams and Steinbergs, 1959). Adsorbed sulphate was analyzed by deducting the values obtained from the $CaCl_2$ extractant from those with the KH_2PO_4 extractant (Fox *et al.,* 1964). Organic sulphur was calculated by subtracting 0.01M KH_2PO_4 extractable sulphur from total sulphur (Evans and Rost, 1945). Total sulphur was determined using diacid digest (Chapman and Pratt, 1961). Non-sulphate sulphur was calculated by subtracting organic and inorganic sulphur from total sulphur (Virmani and Kanwar, 1971). Sulphur content in all extracts was determined using the turbidimetric method (Chesnin and Yien, 1951).

Data analysis

Descriptive analysis was used to summarize the results generated from routine analysis while analysis of variance was used to generate the results of the different forms of sulphur. The significance differences in mean values was assessed using the Tukey test at a 5% level of significance. All analyses were done with Genstat (17.0).

RESULTS AND DISCUSSION

Physical and chemical properties of both farms

The result of the physical and chemical properties of the soils in both locations are as shown in Tables 1 and 2. The particle size distribution showed most of the sampling points fall within the sandy loam textural class. The sandy nature of both farms could be attributed to the parent materials which were developed from pre-Cambrian basement complex rocks such as granitic sand-stones (Shehu, *et al.,* 2015). Malgwi *et al.,* (2000) has suggested that the dominance of sand contents of soils in northern Nigeria is a result of the sorting of materials by clay eluviation and wind erosion. This could be associated with the high sand fraction observed in both locations. It was observed that the mean pH $_{(water)}$ across Gaya farm was 6.99 (Table 1) while Wudil was 6.24 (Table 2) and was categorized as slightly acidic. The slightly acidic to neutral pH observed in both locations may be partly due to the management practices which are considered ideal for most cultivated crops (Brady and Weil, 2002). Such as a diversified cropping system (mixed and intercropping of cereals and legumes) adopted by the farmers. This is a common practice among farmers in Wudil and Gaya communities that grow crops on sustainable production to satisfy subsistence and commercial needs. They mostly combine sorghum/millet/cowpea, millet/cowpea and sorghum/millet. This method ultimately minimizes organic matter depletion. Sorghum itself has a greater untapped potential serving as a source of food, fodder and roof/fencing material. Organic carbon is an important component of the soil which serves as a storehouse for plant nutrients, and was observed to be low with the mean organic carbon 0.34% and 0.24% in Gaya and Wudil respectively. The low content of organic matter could be attributed to the poor land cover in both locations. According to Shehu *et al.,* (2015), soil productivity declines when vegetation cover is lost and appropriate management practices are not adopted which could result in the depletion of organic matter and reduced agricultural productivity. This could be related to the complete removal of crop residue along with the product after harvest in both locations. This leads to a considerable reduction of organic matter and even other nutrient elements in the soil. The average sulphur content in Gaya farm was 0.14 % with a range of 0.043 % to 0.66 % (Table 1) while Wudil has an average of 0.09% with a range of 0.07% to 0.11% (Table 2). The sulphur level in the soil of both farms was categorized as sufficient (Esu, 1991) because the critical concentration of sulphur in the soils of the Nigerian savanna is 0.06 %, below which it is considered deficient. The majority of the farms in both locations are cereal-based cropping systems and legumes which are known to require a low amount of sulphur compared to oil seed crops or other high-yield crop varieties that will require a large amount of sulphur. Sawyer, Lang and Baker (2015) reported that high-yield crops extract more S and also create additional crop residue high in sulphur content. During the decomposition process, inorganic S may be preferentially utilized by soil microbes making it unavailable to the crop (immobilization). This could be related to the sufficient level of sulphur observed in both locations which may be associated with the cropping of low sulphur-requiring crops. Also, the low to moderate (Wudil, 5.98% and Gaya, 12.50%) amount of P observed in both locations could also be related to the sufficient level of available S. Camberato, Maloney, Casteel and Johnson (2012) reported that soils with high P level can displace available S contributing to deficiency of sulphur in the soil. The mean exchangeable potassium in Gaya (0.14cmolkg^{-1}) and Wudil (0.08 cmolkg-^{1}) were rated as low according to Esu (1991). Considering the spatial distribution of potassium across the farm, it was observed that a large portion of the land has low potassium content, while some areas are high in potassium. These showed that the farm requires a different potassium management strategies, such that places with high potassium levels should be allocated for high potassium-demanding crops like tree crops. The mean exchangeable calcium, magnesium and sodium across Wudil farm as shown in Table 2 were 0.94, 0.21 and 0.19, respectively. Calcium and magnesium were rated as low while sodium was rated as moderate according to Esu (1991). The available iron content in Gaya farm ranged between 0.01 to 101.30 mg kg^{-1} with an average content of 83.13 mgkg^{-1}. The available iron content in Wudil farm ranged between 4.50 to 59.72 mgkg^{-1} with an average content of 21.55mgkg^{-1}(Table 2). The low contents of total nitrogen (N), organic C, available P and CEC in both locations could be related to the low inherent status, such as the parent materials which are mostly of aeolian origin with a low weatherable mineral reserve and partly due to the complete crop removal by the farmers (Manu *et al.*, 1991).

Table 1: Physiochemical properties of soils in Gaya

Soil parameter	Mean	Min	Max	CV
Sand (%)	76.47	73.80	78.00	1.14
Silt (%)	12.11	6.24	19.69	20.97
Clay (%)	11.41	5.14	16.22	16.54
pH (1:1)	6.99	4.54	8.90	15.73
Nitrogen (%)	0.06	0.00	0.39	69.44
Organic C (%)	0.38	0.09	1.97	56.12
Sulphur (%)	0.14	0.04	0.66	50.88
P (mgkg^{-1})	12.50	0.52	51.34	94.55
K (cmolkg^{-1})	0.14	0.00	7.07	394.63
Ca (cmolkg^{-1})	1.13	0.05	8.47	95.58
Na (cmolkg^{-1})	0.44	0.01	8.37	154.66
Mg (cmolkg$^{-1)}$	0.54	0.00	5.89	136.25
Fe (mgkg^{-1})	83.13	0.01	101.30	106.25
Zn (mgkg^{-1})	2.75	0.012	128.50	342.61
Cu (mgkg^{-1})	2.24	0.048	5.32	42.14
Mn (mgkg^{-1})	0.14	0.002	3.58	213.83

Table 2: Physical and chemical properties of soils in Wudil

Soil parameter	Mean	Min	Max	CV
Sand (%)	75.10	74.50	75.70	0.35
Silt (%)	16.29	7.89	20.33	17.16
Clay (%)	8.59	4.93	17.22	31.79
pH (1:1)	6.24	4.44	8.11	14.68
Nitrogen (%)	0.03	0.02	0.05	22.63
Organic C(%)	0.24	0.16	0.30	15.60
Sulphur (%)	0.09	0.07	0.11	13.36
P (mgkg^{-1})	5.98	0.94	11.92	55.23
K (cmolkg^{-1})	0.08	0.01	0.38	113.36
Ca (cmolkg^{-1})	0.94	0.09	5.47	116.14
Na (cmolkg^{-1})	0.19	0.03	0.33	42.85
Mg (cmolkg^{-1})	0.21	0.02	1.31	119.42
Fe (mgkg^{-1})	21.55	4.50	59.72	58.53
Zn (mgkg^{-1})	1.62	0.084	11.59	145.14
Cu (mgkg^{-1})	2.42	0.446	4.19	38.24
Mn (mgkg^{-1})	2.58	0.221	17.46	122.29

Forms of sulphur across the two farming communities

From the result of the experiment, the highest form of sulphur was with total S. Total sulphur encompasses all forms of sulphur in the soil. The high amount of total sulphur (429.20 and 412.41 mgkg^{-1}) in both locations as shown in Table 3 could be attributed to the sufficient level of sulphur in the initial physiochemical analysis. Organic sulphur represents majority of total sulphur in the soil. This is in line with earlier work carried out by Solomon *et al.*, (2001). Dead sulphur oxidizing microbes and decomposed organic residues contributed more to the organic form of sulphur. A similar hypothesis was recorded by Das and Saha (2003). In addition, a large shrubland was observed in Gaya which have not been cleared and cultivated by the farmers. This could be attributed to the higher amount of total sulphur in Gaya as a result of the fertile nature of the soils in that location and the natural structure of the soil has not been tampered with. However, Gaya having a low to moderate organic carbon (Table 1) implies that the native organic matter from the previous crops as well as the presence of large shrubland within the farm contributed more to the organic sulphur content observed in Gaya. This could be attributed to the high amount of inorganic 36.36 mgkg^{-1} and sulphate sulphur 35.15 mgkg^{-1} observed in Gaya farm (Table 3). A similar trend of results was observed with Gharmaker *et al.,(*2009). A higher amount of inorganic 37.56 mgkg^{-1} and sulphate sulphur 36.67 mgkg^{-1} were observed in Wudil. This was attributed to the faster mineralization of sulphur in soils of Wudil. Non-sulphate sulphur was observed to be low in both farms 0.851 mgkg^{-1} and 0.580 mgkg^{-1} in Wudil and Gaya respectively (Table 3). This was attributed to the low salt content from the initial physiochemical properties. This implies that little amount of sulphur was occluded in insoluble sulphur compounds which remains unextractable after the removal of sulphate sulphur (Balangoudar and Satyaranayana, 1990). Non-sulphate sulphur is known to be important in calcareous soils with high salt content (Bappa, *et al.*, 2014). Similarly, there was a decrease in adsorbed sulphate in both farmers' fields. The decrease could be attributed to the pH and sandy nature of the soil. Studies have shown that adsorbed sulphate is negligible at pH above 6, and increase with the clay content and hydrous oxides of Fe and Al (Tabatai, 1987).

Table 3

	Total S	**Inorganic S**	**Sulphate S**	**Organic S**	**Non-sulphate S**	**Adsorbed S**
			(mgkg^{-1})			
Soil sample						
Gaya	429.20	36.36	35.15	393.50	0.58	1.22
SE	13.89	2.61	0.99	13.17	0.20	0.50
Wudil	412.41	37.56	36.67	374.90	0.851	0.891
SE	3.000	0.297	0.211	2.740	0.041	0.042

CONCLUSION AND RECOMMENDATION

From the result obtained from the present investigation, it was observed that the soil from both locations has sufficient level of sulphur (Gaya 0.14% and Wudil 0.09%). The sufficiency was attributed to the cultivation of low-sulphur-demanding crops. However, total S, Organic sulphur, Inorganic S and sulphate S were observed to be high from the present study. Therefore, management strategies that will enhance the mineralization of sulphur in the soil such as recycling of crop residues, addition of organic matter, application of sulphur fertilizer at the right place, time and amount should be encouraged by farmers. This is to maintain sulphate availability in the soil to improve productivity.

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