EVALUATION OF SULPHUR STATUS OF SOME SELECTED SOILS OF BENUE STATE FOR GROUNDNUT PRODUCTION

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ABSTRACT

Occurrence of sulphur deficiency in Nigerian soils is becoming frequent and extensive due to intensive cultivation and shift from low analysis fertilizers to high analysis fertilizers, which do not contain sulphur. Information is required on the parameters for evaluating sulphur status and requirement of crops in the country. Studies were conducted in the laboratory, greenhouse and farmers fields to evaluate the sulphur status and requirement of groundnut in some soils of Benue state. The soils included Abinsi, Ikpayongo, Yandev, Gbatse, Tse-mker and Makurdi. The greenhouse experiment consisted of 4 sulphur treatments (0, 10, 20 and 30 kg S ha^{-1}) applied as K_2SO_4. The crop was grown in the pots and harvested after 12 weeks. The result of the study indicated that the soils were very low in their total sulphur content and ranged from 60.0 mg Kg^{-1} at Yandev, Gbatse and Tse-mker to 93.0 mg Kg^{-1} at lkpayongo. Correlation study showed that the sulphur content was significantly related to soil organic matter and clay content of soils. Groundnut dry matter and pod yield were significantly related to the rate of sulphur application. Response to sulphur application was observed up to 30 kg S ha^{-1}. It was concluded that the probability of obtaining groundnut response to sulphur application will be high.

Keywords: Groundnut, Fertilizer, Sulphur, Requirement, Crop.

INTRODUCTION

Groundnut (*Arachis hypogaea L.*) is an annual leguminous crop, one of the important oil seed crops in the world. Its seed contains about 45–55% oil and 27–33% of protein (Janila *et al.*, 2013). It is the 13th most important food crop of the world and the world's 4th most important source of edible oil and 3rd most important source of vegetable protein. It is grown in nearly 100 countries with China, India, Nigeria, USA, Indonesia and Sudan as the leading groundnut producing countries in the world (Ajeigbe *et al.*, 2014). In Nigeria, areas where commercial groundnut is produced traditionally include the Sahel, Sudan and derived savanna, Northern Guinea and most parts of the Southern Guinea vegetation zone. The main groundnut producing states are Kano, Katsina, Kaduna, Jigawa, Sokoto, Zamfara and Kebbi in the Northwest; Adamawa, Bauchi, Yobe and Borno in the Northeast; and Benue, Plateau, Taraba, Nasarawa, FCT Abuja, Kogi, Niger and Kwara in the Central Zone (Ajeigbe *et al.*, 2014).
Groundnut is one of the major cash crops grown in Benue State. It is normally grown in rotation after yams apparently to benefit from the residual effect of fertilizers applied to yams the

previous year, most of which are Sulphur free. It is preferred to rice because of its relatively low labor requirement in terms of weeding and the perennial problem of birds experienced in rice production. Apart from being a cash crop, it is consumed in large quantities in various forms and serves as one of the major sources of dietary protein. As groundnut are highly nutritious, groundnut and products based on groundnut can be promoted as nutritional foods to fight energy, protein, and micronutrient malnutrition among the poor (Janila *et al.*, 2015).

Sulphur is one of the essential nutrients for plant growth and yield (Rathore *et al.,* 2015). It is an immobile element in plants and being a constituent of proteins, it is vital for the synthesis of the sulphur-containing amino acids - cysteine, cystine and methionine three of the 21 amino acids which are the essential building blocks of proteins (Brady and Weil, 2014). However, with the increase in the use of high analysis fertilizers in recent years, many sulphur free fertilizers are on the market and the average sulphur content of fertilizers has decrease. Moreover, sulphur containing pesticides so commonly used in the past have largely been replaced by organic materials free of sulphur. Nevertheless, the practice of slash and burn agriculture which leads to sulphur loss is still very common among the people. Despite all these, the general assumption that Sulphur deficiency is not widespread and therefore does not constitute a significant problem to crop yield still persists. This may be due to part of the problems usually associated with accurate diagnosis of sulphur needs of crops in many Nigerian soils, especially where information on Sulphur status of soils is unavailable. Benue state falls in that category.

More work is therefore needed in order to accurately predict Sulphur needs of various crops in different ecological zones of Nigeria.

This study was therefore carried to evaluate the major forms of sulphur and the critical level of sulphur for groundnut production in Benue state.

MATERIALS AND METHODS

The sampled sites fall under the savanna grassland vegetation zone of Benue Sate. The Federal Department of Agricultural Land resources report (1990) is adopted for the description of these soils (Table 1). The soils are predominantly Alfisols.

The experiment involved laboratory studies, pot experiment and farmers fields. Surface soil samples (0-20cm) were collected from six sites corresponding to four deterrent parent materials in the groundnut producing areas of Benue State that have no previous history of Sulphur fertilization (Table 1).

LABORATORY ANALYSIS

Sub samples of the soils were sieved to pass through 2mm sieve for laboratory analysis. The samples were analyzed for soil pH, Total Nitrogen (Kjeldahl digestion method), and organic carbon (dichromate oxidation). Exchangeable cations, available phosphorus by Bray -1 procedure and Particle size analysis was determined by the hydrometer method. The physical and chemical properties of the soils at the study areas are presented in table 2.

Table 1: Description of Sampled Sites

Loction	Geology	Relief	Soil description
ABINSI (Guma L G. A) MAKURDI (Makudi L G A)	Recent alluvium	Nearly level to gently undulating plains.	Deep well drained and deep drained soils: sand, sandy loam, loamy sand or sandy loam clay surfaces over sand, sandy clay, sandy clay loam, clay, clay loam or loamy sand, sometimes gravelly sub soils.
IKPA-YONGO (Gwer L G. A) YANDEV (Gboko L. G. A)	Shales	Gently undulating plans	Mostly deep well drained Few poorly drained soils; loamy sand to sandy loam surfaces over Sandy clay and few ferriginised sub soils.
GBATSE (Ushongo L. G. A) TSE-MK (Vandeikya L. G. A)	Undifferentiated basement complex	Gently undulating Plains with scattered rock outcrop and inselbergs.	Generally deep well drained soils; loamy sand surfaces over Sandy loam to sandy clay loam and sometimes gravelly sub soils.

Total Soil sulphur was determined by digesting the Samples using wet acid digestion. Activated charcoal, 0.05g per 25cm^3 of the extracts and or digest was used for decolorizing the extracts and or digests, while gelatin was used as a stabilizer. Sulphur in the extracts and or digests was determined turbidimetrically as $BaSO_4$.

POT EXPERIMENT

The soil samples were air dried and sieved to pass 2mm sieve for pot experiment. 4kg of the sieved soils was weighed into experimental pots the treatments were 0, 10, 20 and 30 kg S ha^{-1} and the pots were arranged in a randomized complete block design. The treatments were replicated four times. Nitrogen was added as urea at the rate of 40kg ha^{-1}, P as KH_2PO_4, at the rate of 30kg ha' and K as MOP in the 0kg S ha^{-1} to make up the rate of 30kg ha^{-1} as the P and S sources (KH_2PO_4, and K_2SO respectively) were expected to have met the K requirements in the 10kg S ha^{-1} to 30 kg S ha^{-1} treatments. The crop was grown to maturity in the pots.

Agronomic Data Collected

Agronomic data collected included the following:

a. Dry matter yield at harvest (12 WAP).
b. Number of kernels per plant per pot at harvest.
c. Fresh weight of kernels at harvest.

Data Analysis

Data collected was subjected to analysis of variance (ANOVA) and means separated by the Fischer's least significant difference (LSD) to test the significance of the various treatments on the response of the crop. Correlation analysis was carried out.

RESULTS

The properties of the soils used in the pot experiment are shown in Table 2. The pH values ranged from 5.29 at Abinsi to 6.83 at Gbatse with a mean value of 5.88. The soils are sand, loamy sand and sandy loam in texture. Organic matter content varied widely from 1.04 to 3.21% at Abinsi with a mean value of 1.89%. Available P (Bray-1) values ranged from 3.20 in Gbatse to 11.20 %. Total nitrogen ranged from 0.025% at Ikpayongo to 0.14% at Abinsi. The highest available sulphur was 13.0 mg kg^{-1} at Ikpayongo while the least value of 6.0 mg kg^{-1} was recorded at Yandev, Gbatse and Tse-mker.

Table 2: Some Properties of the Experimental Soils

Location	pH	Clay	O.M	N	Av.P	Texture	Exchangeable Cations (c mol kg^{-1})			
		→	%	←	mg kg^{-1}		K	Na	Ca	Mg
Abinsi	5.29	10.00	3.21	0.140	11.20	SL	0.31	0.24	4.40	2.20
Ikpayongo	5.70	10.04	1.55	0.025	3.80	SL	0.46	0.29	6.40	4.40
Yandev	5.77	4.60	1.04	0.084	9.00	S	0.35	0.19	4.00	2.20
Gbatse	6.82	6.88	1.90	0.062	3.20	LS	0.52	0.21	7.20	3.40
Tse-mker	5.83	6.48	1.73	0.115	4.60	S	0.51	0.25	8.70	4.20
Makurdi	5.63	11.04	2.14	0.056	6.50	SL	0.40	0.21	3.20	2.80
Mean	5.88	7.60	1.89	0.080	6.38		0.43	0.23	5.65	3.20

* SL - Sandy loam, S - Sand, LS - Loamy Sand

Table 4 shows the effect of increasing the sulphur levels on the pod yield of groundnuts in the experimental soils. This shows that there were highly significant differences among the treatments applied in all the soils specifically, Makundi and Ikpayongo soils showed a consistent increase in pod yield with increasing levels of sulphur. Tse-mker soil attains a maximum pod yield with 20 kg S ha^{-1} and then decreases as the rate is increased to 30 kg S ha^{-1} Abinsi. Yandev and Gbatse soils showed an increase in pod yield as the sulphur rate is increased from 0 to 10 kg S ha^{-1}, drops marginally from 10 to 20 kg S ha^{-1} and again shows a marginal increase from 20 to 30 kg S ha^{-1}. The implication of thus is that only 10 kg ha^{-1} would be required to achieve profitable pod yield for groundnuts in Abnsi; Yandev and Gbatse soils. 20kg S ha^{-1} would be needed for Tse-mker, while Makurdi and lkpayongo soils will show response up to 30kg S ha^{-1}. The effect of the various treatment levels on the dry matter yield of groundnuts on the experimental soils (table 5) show that Abinsi, lkpayongo, Yandev, Gbatse and Makurdi soils showed a consistent increase in dry mater yield with increasing levels of added sulphur whereas Tse-ker soils showed a consistent increase and attains a maximum at 20 kg S ha^{-1} and decreases as the sulphur level is increased from 20 kg to 30 kg S ha^{-1}. This implies that fertilizing Tse-mker soil beyond 20 kg S ha^{-1} would be unnecessary if the aim is to improve the dry matter yield.

Table 3: Sulphur Fractions of the Experimental Soils (mg kg^{-1})

S/No	Location	Water soluble - S	Available -S	Adsorbed -S	Total -S
1	Abinsi	4.0	10.0	1.0	75.0
2	Ikpayongo	6.0	13.0	2.0	93.0
3	Yandev	7.0	6.0	5.0	60.0
4	Gbatse	6.0	6.0	0.0	60.0
5	Tse-mker	5.0	6.0	1.0	63.0
6	Makurdi	12.0	8.0	10.0	69.0
	Mean	6.67	8.17	3.16	70.0

Table 4: Effect of Sulphur Rates on Pod yield (g pot^{-1})

Sulphur Rates (kg ha^{-1})	Abinsi	Ikpayongo	Yandev	Gbatse	Tse-mker	Makurdi
0	5.2	2.5	6.0	6.0	4.8	4.6
10	8.4	5.2	6.1	6.8	5.5	6.2
20	7.1	5.2	5.6	6.5	7.0	7.0
30	7.1	13.8	5.6	8.3	6.3	8.3
LSD 0.05	0.5116	0.2180	0.1277	0.3248	0.1006	0.1601

Table 5: Effect of Sulphur Rates on Dry Matter yield (g pot^{-1})

Sulphur Rates (kg ha^{-1})	Abinsi	Ikpayongo	Yandev	Gbatse	Tse-mker	Makurdi
0	6.0	9.9	5.4	5.1	7.0	6.1
10	8.5	10.5	7.0	5.3	7.8	7.3
20	14.2	11.4	7.0	6.1	8.7	11.9
30	14.2	15.1	7.3	13.0	8.5	14.3
LSD 0.05	0.1281	0.0628	0.0751	0.0891	0.0931	0.1710

Table 6: Effect of Sulphur Rates on Pod Number

Sulphur Rates (kg ha^{-1})	Abinsi	Ikpayongo	Yandev	Gbatse	Tse-mker	Makurdi
0	8.7	7.9	6.3	8.1	7.1	9.3
10	9.1	7.9	5.4	6.3	5.3	7.7
20	7.0	9.0	6.1	5.6	6.4	7.8
30	8.5	8.7	5.6	5.9	5.5	7.0

LSD = 0.4

RELATIONSHIP BETWEEN SOIL PROPERTIES AND SULPHUR STATUS

The relationship between soil organic matter and total S as well as extractable sulphur were positive and significant (Table 7).

Table 7: Correlation Table between Sulphur Fractions and Soil Properties

	Soil S	Available S	Adsorbed S	Total S	Clay	pH	OM
Sol S	1.00						
Avail S	0.249						
Avail S	0.55						
Adsor S	-0.303	0.848					
Adsor S	0.47	0.01**					
Total S	0.249	0.982	0.830				
Total S	0.55	<0.0001**	0.01*				
Clay	0.390	0.791	0.565	0.762			
Clay	0.34	0.02*	0.15	0.03*			
pH	0.132	0.002	0.075	0.043	-0.192		
pH	0.76	1.00	0.86	0.91	0.65		
OM	0.107	0.753	0.683	0.721	0.746		
OM	0.80	0.03	0.06	0.04*	0.03*		
Carbon	0.101	0.768	0.701	0.735	0.757	-0.006	0.997
Carbon	0.81	0.03*	0.05	0.04*	0.03*	1-00	<0.0001**
Nitrogen	0.392	0.036	0.250	0.007	-0.051	-0.274	0.36
Nitrogen	0.34	0.93	0.55	0.99	0.90	0.51	0.17
Ex. Acid	0.069	-0.487	-0.516	-0.569	0.073	-0.284	-0.071
Ex. Acid	0.87	0.22	0.19	0.14	0.86	0.50	0.87
Avail. P	-0.014	0.460	0.461	0.496	0.360	-0.373	0.574
Avail. P	0.97	0.25	0.25	0.21	0.38	0.36	0.14

Significant at 5%   **significant at 1%

DISCUSSION

The total sulphur contend of the soils in the study areas is generally low. This is may be as a result of the low pH of the soils. Clain (2016) reported that Macronutrients including Sulphur (S), Calcium (Ca) and Magnesium (Mg) are mostly available in slightly acid (6.1 - 6.5) to moderately alkaline soils (7.4 - 8.4). However, the pH of these soils falls below this range except for Gbatse soils. This may also be probably due to the fact that apart from these soils being from the savannah grassland area which is reported to have lower sulphur status than forest soils, the practice of slash and burn is still very common among the people of the state as well as the seasonal indiscriminate burning of vegetation by wild fires which prevent the accumulation of organic matter that is the storehouse of most soil nutrients, sulphur inclusive. The positive significant correlation of organic matter with the sulphur status of these soils supports this fact.

Abinsi and Makurdi have the same geology (recent alluvium, with their total sulphur status at 75 and 69 mg kg^{-1} respectively. Geology appear to be responsible for this however, their organic matter values appears to be within the same range too with Abinsi having a higher value than Makurdi. Their available S values also follow the same trend i.e. l0 and 8 mg kg^{-1} respectively.

Gbatse and Tse-mker are on basement complex rocks, their sulphur values are 60 mg kg^{-1} and 63 mg kg^{-1}. This shows that their total sulphur status is within the same range. They also have the same value of 6.0 mg kg^{-1} for available sulphur. The organic matter values for these soils also fall within the same range.

Ikpayongo and Yandev are on shales; their total sulphur status is 93 and 60 mg kg^{-1}. These Values are significantly different, available sulphur values for these soils are 13.0 and 6.0 mg kg^{-1} respectively. These are equally far apart. Organic matter values of these soils however are within the same range.

From the foregoing, it is clear that the six experimental soils belong to three different parent materials. Of the three, the soils from recent alluvium (Abinsi and Makurdi) have about the same sulphur status; also the basement complex soils have about the same sulphur status. However, the soils found on shales have sulphur status that shows so relationship with each other.

The positive and highly significant relationship between available sulphur and total sulphur indicates that the amount of sulphur available to the crop (groundnut) in these soils depend on the total sulphur content of these soils, the implication of this is that, the total sulphur content of a soil is directly responsible for the available sulphur status of such a soil. The amount of sulphur available to groundnut (crops) in a soil with low total sulphur status will thus be limiting. Low sulphur status limited yield in Yandev, Gbatse, and Tse-mker. The available sulphur values for these soils was also well below the critical value of 7.8 mg kg^{-1}. Higher yields from lkpayongo, Abinsi and Makurdi are in direct agreement with the fact that sulphur is a yield limiting nutrient in these soils. The mechanism of yield increase by sulphur as shown by the parameters studied indicate that increasing the sulphur rate dose not (necessarily) increase the number of pods, however increased sulphur rate increases the size of the groundnut seed thus, resulting in weight increase (as shown by the pod weight). This has been reported by Ibrahim *et al*., (2019) that increase in sulphur rates had significant differences in weights of pods per plant and the pod yield per hectare. Consequently, kernel and or pod shell size is also increased so as to accommodate the bigger seed.

It can be deduced therefore, from the foregoing that, groundnut plant grown on soils with an adequate supply of sulphur would be more properly filled than on sulphur deficient soils.

Available sulphur and total sulphur also showed a positive and significant relationship with the clay content of these soils. This can be explained by the fact that clay produces the active sites for the attachment of sulphate anion (SO_4^{2-}). It is interesting to note here that the sulphur status of these soils showed a significant and positive relationship with the organic matter content of these soils as well as the clay content. This is in line with the findings of Singh *et al.,* (2018) that Sulphur in the soil occurs in combination with organic matter. From these relationships, it can be deduced therefore that the sulphur released during the process of organic matter mineralization is adsorbed onto the active clay sites and made available to crops in the soil. On soils with low clay content, sulphur released as a result of organic matter mineralization will be leached from the profile due to the absence of active sites for absorption. Desorption will therefore be the predominant process as was observed in the Yandev soil. Available sulphur in such soils will therefore be a balance between adsorption and leaching losses.

Increasing the sulphur rates significantly increased the yield of groundnuts in terms of dry matter yield in all the soils. However, for Tse-mker soil, the highest yield is obtained with 20 kg S ha^{-1}, increasing the sulphur rate to 30 kg S ha^{-1} significantly lowered the yield. The Tse-mker soil with very low sulphur status could not have attained an optimum fertilization level at 30 kg S ha^{-1}. Nutrient imbalances could be responsible for the drop n yield.

Generally, increasing the sulphur rates significantly increased the dry matter yield with the highest mean value obtained with 30 kg S ha^{-1} and the least mean value with 0 kg S ha^{-1}.

Increase in sulphur rates also results in increases in pod yield. Abinsi, lkpayongo and Makurdi soils showed a consistent and significant increase in pod yield up to 30 kg S ha^{-1} while the Tse-mker soil attained a maximum weight increase at 20 kg S ha^{-1}. Yandev and Gbatse soils showed an inconsistent pattern i.e. achieving an increase in pod weight with increased sulphur rate from 0 to 10 kg S ha^{-1} and then a decrease in weight as the rate is increased from 10 to 20 kg S ha^{-1} and then achieving the highest weight gain as the rate is increased from 20 to 30 kg S ha^{-1}. It is worth mentioning that all the soils showed a consistent weight increase with increased sulphur rates especially those that had their available sulphur status above the critical value of 7.8 mg kg^{-1} while those that showed inconsistent response had their sulphur (available) status below the critical value. This implies that at sulphur values below this, high response to the application of sulphur fertilizer is probable whereas little or no response is expected for soils with 0.10M LiCl extracted (available) sulphur above 7.8 mg kg^{-1}. This is also in agreement with the study by Ibrahim *et al*., (2019) that the crops with S fertilization performed better than crops without S fertilization.

CONCLUSION

Sulphur is an essential nutrient required for crop growth and development, but due to intensive cultivation and shift from low analysis fertilizers to high analysis fertilizers, which do not contain sulphur has lead to an extensive deficiency of sulphur in Nigerian soils. Based on the findings in this study, Benue State soils with available sulphur values below 7.8 mg kg^{-1} is sulphur deficient. Among the experimental soils, Abinsi, Ikpayongo and Makurdi had sulphur (Available) value of above 7.8 mg kg^{-1}. This means that these soils are not sulphur deficient whereas Yandev, Gbatse, and Tse-mker are sulphur deficient. High response to applied sulphur fertilizers is thus probable on this second group of soils. Nevertheless, soil types, climatic conditions, locations, and cultivars should be taken into consideration when recommending fertilizer.

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