Nigerian Journal of Soil Science
Journal homepage:www.soilsjournalnigeria.com

SUITABILITY OF EXTRACTANTS FOR THE DETERMINATION OF AVAILABLE SULPHUR FOR GROUNDNUT PRODUCTION IN SOME SOILS OF BENUE STATE, NIGERIA

B. Anjembe[1] and M.T Adetunji[2]
[1]*Department of Soil Science, University of Agriculture, Makurdi*
[2]*Department of Soil Science and Land Management*
University of Agriculture, Abeokuta.

ABSTRACT

Occurrence of sulphur deficiency in Nigerian soils is becoming frequent and more extensive due to intensive cultivation and shift from low analysis to high analysis fertilizers which do not contain sulphur. Information is still required on the parameters of evaluating sulphur status and requirement of crops in the country. Studies were conducted in the laboratory, greenhouse and farmers' fields in 2004 and 2005 to evaluate four extractants (0.16 M KH_2PO_4, 0.10 M Ca $(HPO_4)_2$, 0.10 M LiCl and distilled water, for the determination of available sulphur for groundnut production in some soils of Benue State. The soils include Abinsi, Adaka, Ikpayongo, Tyowanye, Yandev, Gbatse, Tse-mker and Makurdi. Fields of 8 farmers cultivating groundnut as sole crop were used to verify the findings of the laboratory and pot experiments. Among the extractants, 0.10 M LiCl related significantly with pod yield and pod number. There was also, significant relationship between the lithium chloride extractable S and the total S values of the soils.

INTRODUCTION

Sulphur as a yield limiting nutrient is becoming increasingly important in many Nigerian soils. Occurrences of deficiency in various crops are becoming more frequent and extensive (Kang *et al.,* 1981, Adetunji and Adepetu 1990, Obasi *et al.*, 2001). Information is still required to adequately quantify the extent and spread of the deficiency problem as well as the parameters for evaluating the status and requirement of crops in the country. Sulphur occurs in soils in both organic and inorganic forms, but only a fraction of it is available for crop growth (Beaton *et al.,* 1968; Metson, 1979; Tabatabai, 1982). Sulphate may be present in the soil solution adsorbed on soil surfaces or as insoluble compounds such as gypsum (Nelson, 1982) or associated with calcium carbonates (Roberts and Bettany, 1985). Adsorption of sulphate occurs on positive charges that are pH dependent and these sites are negligible above pH 6.5 (Tabatabai, 1982). The insoluble sulphate compounds are probably not taken up directly by the plant. On a theoretical basis then, the solution and adsorbed forms of sulphate are the primary pools of sulphate in the soil that are immediately available for plant uptake. Although there is a good theoretical basis for the solution and adsorbed pools being present in the soil, there are some practical limitations to their quantification. Limitations occur in both the extraction and subsequent chemical quantification. Before choosing a method and interpreting the results, these limitations should be thoroughly understood. The choice of the extractant will depend on analytical equipment available and the type of soil to be analyzed. Numerous extractants have been used for soil sulphate (Beaton *et al*., 1968). Extractants may include water, acetates, carbonates, chlorides, phosphates, citrates, and oxalates (Beaton *et al*., 1968, Jones, 1986, Kilmer and Nearpass, 1960). The nature of the anion influences the ability of the extractant to displace adsorbed sulphate. The choice of a method for extracting available sulphur from soils then should be made carefully taking into consideration the purpose of the analysis, the soil type involved, the nature of the extractant and the analytical method to quantify the sulphur extracted.

This study was therefore, carried out to evaluate four extractants for the determination of available sulphur for the production of groundnuts in some eight selected soils covering Abinsi, Adaka, Ikpayongo, Tyowanye, Yandev, Gbatse, Tse-mker, and Makurdi, in the groundnut producing areas of Benue state.

MATERIALS AND METHODS

The experiment involved laboratory studies, pot experiment and farmers' fields. Surface soil samples (0-20cm) were collected from the eight sites corresponding to four different parent materials in the groundnut producing areas of Benue state that have no previous history of S fertilization. Sub samples of the soils were sieved to pass 2mm sieve for laboratory analysis. The samples were analyzed for the following parameters using standard procedures; pH was measured by glass electrode in a 1: 2 soil, water ratio. Exchange acidity was determined by the titration method (Page *et al.,* 1982). Exchangeable bases were extracted with neutral ammonium acetate solution buffered at pH 7, Na and K in the extracts were determined using flame photometer while Ca and Mg were determined by Atomic Absorption Spectrophotometer (AAS) (Page *et al.*, 1982). Organic matter was determined by wet acid digestion (Walkey and Black, 1934). Total Nitrogen by the Kjeldahl digestion method, phosphorus by Bray-1 procedure (Bray and Kutz, 1945). Particle size analysis by the hydrometer method (Bouyoucos, 1951).

Four extractants were evaluated for the determination of available Sulphur. These were distilled water, 0.016 M KH_2PO_4, 0.10 $Ca(HPO_4)_2$ and 0.10M LiCl. Each extractant was employed for the extraction of available sulphur in all the samples.

Water soluble sulphur or solution sulphur was extracted in distilled water and determined turbidimetrically as $BaSO_4$. Surface adsorbed sulphur was estimated as the difference between available sulphur and water-soluble sulphur. Total soil sulphur was determined by digesting the Samples using wet acid digestion (Page *et al.*, 1982). Activated charcoal, 0.05g per $25cm^3$ of the extracts and or digest was used for decolourising the extracts and digests, while gelatin was used as a stabilizer. Sulphur in the extracts and digests was determined turbimetrically as $BaSO_4$ (Adetunji, 1989).

The crop was grown in the pots and harvested after 12 weeks. 4 kg 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 40 kg ha^{-1}, P as KH_2PO_4 at the rate of 30 kg ha^{-1}. K was applied as MOP in the 0 kg S ha^{-1} to make up the rate of 30kg ha^{-1} (Yusuf and Idowu, 2001) as the P and S sources (KH_2PO_4 and K_2SO_4 respectively) were expected to have met the K requirements in the 10 kg S ha^{-1} to 30 kg S ha^{-1} treatments.

Agronomic data collected included the following:

a. Dry matter yield at harvest (12 WAP).

b. Number of pods per plant per pot at harvest.

c. pod weight at harvest.

Eight farmers' fields cultivated with groundnut as sole crop were selected. On each farmer's farm, an area of land covering 5m x 5m was measured out. Soil samples were taken from that measured area. Yield of groundnut from that area was collected and weighed. The soil samples taken from these areas were analyzed for available sulphur using the four extractants (above). Average plant population per plot was 52. The sulphur values were then correlated with the yield of groundnuts.

DATA ANALYSIS

Correlation analysis was carried out. The amount of available sulphur extracted by the four extractants was correlated with the groundnut yield with the aim of determining the best extractant for the determination of available sulphur in the soils under study. Data were also subjected to analysis of variance and means separated by the Duncan Multiple Range Test.

RESULTS

Soil Properties

The properties of the soils used in the pot experiment are shown in Table 1. The pH values ranged from 5.29 at Abinsi to 6.82 at Gbatse with a mean value of 5.85. The soils are sand, loamy sand and sandy loam in texture. Organic matter content varied widely from 0.70% at Tyowanye to 3.21% at Abinsi with a mean value of 1.98%. Available P (Bray – 1) values ranged from 3.20 in Gbatse to 12.90 at Adaka. Total nitrogen ranged from 0.025% at Ikpayongo to 0.14% at Abinsi. Exchangeable acidity ranged from 0.20 Cmol kg^{-1} at Abinsi to 1.20 Cmol kg^{-1} at Makurdi.

Table 2 shows the yield data in the pot experiment. This indicates that in all the yield parameters, Adaka soil performed better. This is followed by Ikpayongo in terms of pod yield and number. Tyowanye soil produced the poorest yield in all the parameters studied.

Table 3 shows the yield of groundnut on the farmers' plots. The yield ranged from 300 kg ha^{-1} (0.30 t ha^{-1}) at Tyowanye to 920 kg ha^{-1} (0.92 t ha^{-1}) at Ikpayongo. Adaka has 880 kg ha^{-1} (0.88 t ha^{-1}), Abinsi 800 kg ha^{-1} (0.80 t ha^{-1}). Makurdi and Gbatse had 560 kg ha^{-1} (0.56 t ha^{-1}), Yandev had 480 kg ha^{-1} (0.48 t ha^{-1}), while Tsemker had 320 kg ha^{-1} (0.32 t ha^{-1}).

Table 1: Some Properties of the Experimental Soils

	←	%	→	mg kg^{-1}		K	Na	Ca	Mg	Exch.	ECEC	Acidity
Abinsi	5.29	10.00	3.21	0.140	11.20	SL	0.31	0.24	4.4	2.2	1.00	8.15
Adaka	6.10	12.00	3.55	0.087	12.90	SL	0.42	0.22	6.1	2.6	0.20	9.54
Ikpayongo	5.70	10.04	1.55	0.025	3.80	SL	0.46	0.29	6.4	4.4	0.60	12.05
Tyowanye	5.67	6.48	0.70	0.053	7.30	S	0.37	0.23	1.8	1.6	0.80	4.8
Yandev	5.77	4.60	1.04	0.084	9.00	S	0.35	0.19	4.0	2.2	0.40	7.14
Gbatse	6.82	6.88	1.90	0.062	3.20	LS	0.52	0.21	7.2	3.4	0.80	12.13
Tse-mker	5.83	6.48	1.73	0.115	4.60	S	0.51	0.25	8.7	4.2	0.80	14.46
Makurdi	5.63	11.04	2.14	0.056	6.50	SL	0.40	0.21	3.2	2.8	1.20	7.81
*	SL	Sandy	Loam.S	-	Sand	LS	-				Loamy	Sand

Table 2: Yield data in the pot experiment (g pot^{-1})

S/No.	Location	Pod Yield	Dry matter yield	Pod number per plant
1.	Abinsi	21.40^{c}	13.87^{b}	8.27^{a}
2	Adaka	38.09^{a}	18.24^{a}	8.92^{a}
3.	Ikpayongo	23.42^{b}	9.88^{c}	8.29^{a}
4.	Tyowanye	11.57^{h}	10.1^{c}	5.70^{b}
5.	Yandev	13.26^{g}	11.65^{d}	5.84^{b}
6.	Gbatse	14.63^{f}	13.75^{b}	6.47^{b}
7.	Tse-mker	15.88^{e}	11.82^{d}	6.06^{b}
8.	Makurdi	19.78^{d}	13.00^{c}	7.93^{a}

Within each parameter, means with the same letters are not significantly different according to DMRT.

Table 3: Yield Data on Farmers' Field

Location	Yield (kg plot^{-1})	Yield (kg ha^{-1})	Yield (t ha^{-1})
Yandev	1.20	480	0.48
Tyowanye	0.75	300	03.0
Abinsi	2.00	800	0.80
Ikpayongo	2.30	920	0.92
Makurdi	1.40	560	0.56
Tsemker	0.60	320	0.32
Adaka	2.20	880	0.88
Gbatse	1.40	560	0.56

Evaluation of Extractants for Sulphur in the Experimental Soils

Table 4 shows that Water extracted 12 mg kg^{-1} of sulphur from Makurdi soil. This was the highest amount extracted by this extractant from the experimental soils. This was followed by Adaka (8.0 mg kg^{-1}). Yandev had (7.0 mg kg^{-1}), Ikpayongo and Gbatse 6.0 mg kg^{-1}, Tsemker 5 mg kg^{-1}, Tyowanye 4 mg kg^{-1} while the least amount of 3 mg kg^{-1} was extracted from Abinsi soil.0.016 M KH_2PO_4 extractable sulphur was highest (11 mg kg^{-1}) in Tyowanye. This was followed by Adaka (6 mg kg^{-1}), Gbatse and Tsemker soils. 4.0 mg kg^{-1} was extracted from Abinsi and Ikpayongo soils. The least amount of 2 mg kg^{-1} was extracted from Yandev and Makurdi soils.O.010M $Ca(HPO_4)_2$ extracted the highest amount of sulphur (10 mg kg^{-1}) from Gbatse. This was followed by 8.0 mg kg^{-1}from Abinsi, Adaka and Tsemker soils. 7.0 mg kg^{-1} was extracted from Ikpayongo, Makurdi 6.0 mg kg^{-1}, Tyowanye 4.0 mg kg^{-1} and 2.0 mg kg^{-1} from Yandev. This was the least amount of sulphur extracted by this extractant. 0.10 M LiCl extracted the highest amount of 18 mg kg^{-1} from Adaka, this was followed by 13.0 mg kg^{-1} from Ikpayongo, 10.0 mg kg^{-1} from Abinsi, Makurdi 8.0 mg kg^{-1} Yandev, Gbatse and Tsemker 6.0 mg Kg^{-1} each while the least amount of 2 mg Kg $^{-1}$ was extracted from Tyowanye.

The value of Sulphur extracted by the four extractants from the farmers' plots indicated that the soils are generally low in their sulphur status (Table 5). Water extracted the highest amount of 12 mg kg^{-1} from Tsemker. The least amount of 1.0 mg kg^{-1} was extracted from Abinsi.

0.016 M KH_2PO_4 extracted the highest amount of 18.0 mg kg^{-1} from Ikpayongo, 0.10 M Ca $(HPO_4)_2$ extracted 14.0 mg kg^{-1} from Yandev, while the least amount of 4.0 mg kg-^{1} was extracted by this extractant from Abinsi.0.10 M LiCl extracted 18.0mg kg^{-1} from Adaka, the least amount of 2.0 mg kg^{-1} was extracted from Tyowanye.

Table 6 shows that only the LiCl extractable S correlated positively and significantly with the fresh weight of pods and the pod number.

Table 7, again shows that only the LiCl extractable sulphur correlated positively and significantly with the yield parameters studied.

Table 4: Values of Sulphur Extracted by the Extractants (Mg kg^{-1}) in the Experimental Soils

		Extractants		
Location	**Water**	**0.016M KH_2PO_4**	**0.01M $Ca(HPO_4)_2$**	**O.10M LiCl**
Abinsi	3.0	4.0	8.0	10.0
Adaka	8.0	6.0	8.0	18.0
Ikpayongo	6.0	4.0	7.0	13.0
Tyowanye	4.0	11.0	4.0	2.0
Yandev	7.0	2.0	2.0	6.0
Gbatse	6.0	6.0	10.0	6.0
Tse-mker	5.0	6.0	8.0	6.0
Makurdi	12.0	2.0	6.0	8.0
Mean	6.4	5.1	6.6	8.6

Table 5: Evaluation of Extractants for Sulphur on Farmers' Field

Location	**Water**	**0.016M KH_2PO_4**	**0.01M $Ca(HPO_4)_2$**	**O.10M LiCl**
Yandev	6	2	14	6.0
Tyowanye	10	3	13	2.0
Abinsi	1	1	4	10.0
Ikpayongo	2	18	7	13.0
Makurdi	2	3	11	8.0
Tse-mker	12	1	6	6.0
Adaka	2	3	9	18.0
Gbatse	2	8	6	6.0
Mean	4.63	4.88	8.63	7.38

Table 6: Correlation table for the four Extractants under Evaluation and Groundnut yield in the Pot Experiment

		r-values		
Parameter	**Distilled water**	**KH_2PO_4**	**$Ca(HPO_4)_2$**	**LiCl**
Pod yield	0.277	-0.149	0.380	0.964**
Dry matter yield	0.273	-0.099	0.459	0.648
No. of pods per plant	0.266	-0.357	0.429	0.886**

** Correlation is significant at 1%

*Correlation is significant at 5%

Table 7: Correlation table for the four Extractants under Evaluation and Groundnut yield on farmers' fields

	r-values			
Parameter	**Distilled water**	**KH_2PO_4**	**$Ca(HPO_4)_2$**	**LiCl**
Pod yield	-0.777	0.500	-0.419	0.967**

** Correlation is significant at 1%
*Correlation is significant at 5%

DISCUSSION

The sulphur values of the experimental soils indicated that Adaka soil had the highest S status with total S value at 129.0 mg kg-^{1}, while Tyowanye had the least value of 48.0 mg kg-^{1}. The amount of S extracted by the extractants under evaluation showed that LiCl extracted the highest amount from Adaka, Ikpayongo and Abinsi, the extracted values by the other extractants from these soils were lower. The LiCl extractable S values followed the same trend with the total S values of the soils. Interestingly, the values of S extracted by LiCl from the other locations were lower compared to these three above, unlike the other extractants that extracted significantly higher amounts from locations other than these three. Also, among the experimental soils, Tyowanye had the least total S status of 48.0 mg kg-^{1}, LiCl, again extracted the least amount of 2.0 mg kg^{-1} from this soil. The total S values of the soils also indicated that, Yandev, Gbatse and Tse-mker had the same S status; the LiCl extractable values also gave the same results. Water extractable S values for these soils are in a progressively decreasing order. Yield data in terms of pod yield showed that the highest pod yield was obtained in Ikpayongo soil at 20 kg s ha-^{1}. However, on the average, Adaka had the highest mean yield. Tyowanye and Yandev gave yield values that were significantly lower than the other soils. Dry matter yield was also highest at Adaka (20 kg s ha-^{1}), the least yield at that S level was again obtained at Tyowanye and Yandev following the same trend with the total S status and the LiCl extractable S. The extractable S values from the farmers' plots followed the same trend. Correlating the extractable S values and yield shows that only the LiCl extractable S correlated positively and significantly with pod yield and number at harvest. There was also positive and significant relationship between LiCl extractable S and total S content of the soils.

CONCLUSION

Since the LiCl extractable S correlated most significantly both the total S values of the soils as well as the yield parameters of the test crop, LiCl can thus, be referred to as the best extractant for available S in these soils. The LiCl extractable S can also be referred to as the available S in these soils.

REFERENCES

Adetunji, M.T. (1989). Effect of post sampling treatments on the turbimetric determination of available sulphur in the soil. *Nigeria Journal of Agronomy* 4: (3): 1-7

Adetunji M.T. and Adepetu, J.A. (1987). Sulphur sorption characteristics of soils in South Western Nigeria. *Nigeria Journal of Soil Science*. 7: 63-65.

Beaton, J.D., Burns, G.R. and Platou, J. (1968). Determination of sulphur in soils and plants material. Technical bulletin (14). The sulphur institute, Washington D.C pp.56.

Bouyoucos, G.H. (1975). A recalibration of the hydrometer for testing mechanical analysis of soils. *Agricultural Journal*. 43:434 –438.

Bray, R.H. and L.T.Kutz (1945). Determination of total, organic and available forms of phosphorus in soils. *Soil Science*. 59 : 45-59

Federal Department of Agriculture Land Resources (1990). *Soils Report* 4: 70-221

Jones, M.B. (1986). Sulphur availability indexes. In: *Sulphur in Agriculture* M.A. Tabatabai ed. Agronomy 27: American Society of Agronomy, Madison W.I. pp 549-566.

Kang, B.T. Okoro, E., Acquaye, D. and Osiname, O.A. (1981) Sulphur status of some Nigerian soils from the savannah and forest zones. *Soil Science*. 132(1): 220-227.

Kilmer, V.J. and Nearpass, D.C. (1960). The determination of available sulphur in soils. *Soil Science and Plant Analysis* 16:289-300.

Metson, A.J. (1979). Sulphur in New Zealand soils I.A. review of sulphur in soils with particular reference to adsorbed sulphate sulphur. *New Zealand Journal on Agricultural Research*. 22:95-114.

Nelson, R.E. (1982). Carbonate and gypsum. In: A.L. Page R.H. Miller and D.R. Keeny Eds. *Methods of Soil Analysis. Part 2. Chemical and microbiological properties Agronomy* No. 9. America Society of Agronomy. Madison, W.I. pp 181-197.

Obasi, M.N., Isirimah, N.O. and Ikpe, F.N. (2001). A preliminary study on the response of maize to sulphur application in selected soil parent materials in South Eastern Nigeria. In: *Proceedings of the 35th Annual Conference of the Agricultural Society of Nigeria* September 16-20, 2001. Pp 155-159.

Page, A.L. Ed. (1982). Methods of soil Analysis Part 2: Chemical and Microbiological properties 2nd ed. Agricultural Science Society of America, Madison Pp 502-537.

Roberts, T.I. and Bettany J.R. (1985). The influence of topography on the nature and distribution of Soil Sulphur across a narrow environmental gradient. *Canadian Journal of Soil Sciences* 65: 419-434.

Walkey, A. and Black, I.A. (1934). An examination of the Degtjareff methods for determining soil organic matter and proposed modification of the chromic acid organic titration method. *Soil Science*. 37:29-38.

Yusuf, I.A. and Idowu, A.A. (2001) NPK requirement for soybean production in the Southern Guinea Savannah. *Tropical Oil Seeds Journal* 6:50-56.