Nitrogen and Sulfur Mineralization in Saline Soils Treated with Different Organic Material

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There is very little information available in the literature dealing with the effects of salinity on sulfur mineralization. Therefore, information on N and S mineralization in various soil - organic systems, particularly in salt affected soils, is needed for better prediction of N and S requirements and to make the most efficient use of available cropland to supply food and energy. The objectives of the present study were: /i/ to compare the rates of N and S mineralization in saline soils treated with organic material; /ii/ To assess the effects of incubation temperatures, type of organic material and enzyme activities on the relationship between mineralization of these two elements in soils.

Materials and methods

The five soils /Table 1/ selected for the study represent some soils occurring in the southern part of Iraq with a wide range of chemical and physical properties.

Samples of field moist soils /0-30 cm/ were screened through a 2-mm sieve and divided into two portions. One portion was placed in a polyethylene bag and stored in a refrigerator at 4 °C, a subsample of which was used in the incubation experiments to study the mineralization of N and S. The second portion was used to determine chemical properties.

The three organic materials /Table 1/ were obtained from the College Research Farm in Hartha /Basrah/. After drying the organic materials were ground to pass a 20-mesh seive and stored at 4 °C.

pH was determined with glass electrode /soil:water ratio 1:1/, electrical conductivity /EC/ by the saturation extract procedure, organic C by chromic acid /JACKSON, 1958/, total N by the semimicro-Kjeldahl procedure /BREMNER, 1965/, total S by the NaOBr oxidation method /TABATABAI and BREMNER, 1970/, particle size distribution by the pipette analysis /KILMER and ALEXANDER, 1949/, protease activity was assayed by the method of LADD and BUTLER /1972/, and arylsufatase activity according to TABATABAI and BREMNER /1970/.

In the incubation experiments, a 25 g sample /on an oven-dry basis/ of field moist soil and an equal weight of sand washed with 1 N HCl were mixed with organic material /quantity of each, organic material was calculated to

Table 1
Some chemical and physical properties of the studied soils and organic materials

Place of origin of soil, and type of organic material	pH	EC dS/m	$CaCO_3$	Total N	Total S	Organic C	Clay	Sand
					g/kg			
Soils								
Zubair	7.8	0.8	28.3	0.02	0.03	0.17	89	836
Missan	7.7	2.5	39.6	0.05	0.04	0.54	224	160
Khumasat	7.6	3.9	39.4	0.09	0.08	0.78	336	434
Alkhasib	7.8	8.1	46.4	0.11	0.17	1.15	424	33
Dair	7.5	13.6	45.0	0.09	0.29	0.92	481	59
Organic material								
Organic fertilizer	7.4	6.5	-	20.6	9.4	152.8	-	-
Chicken manure	7.7	19.8	-	22.3	29.5	174.9	-	-
Alfalfa hay	7.2	17.3	-	35.8	13.2	418.0	-	-

give an equivalent of 2% organic C/. The soil-sand-organic material mixture was retained in a leaching tube /with 3.5 cm diameter and 15 cm length/ by means of a glass wool pad and a layer of washed fine sand. A thin glass-wool pad was placed over the soil to avoid disperion when solution was poured over the treated soil. The control was a soil-sand mixture without organic material. All treatments were carried out in duplicate. The leaching tube was placed on a suction flask. The soil-sand mixture was leached with 0.01 M KCl in 4 to 5 increments to remove the mineral N and S in soil, and the excess water was removed under vacuum /60 cm Hg/.

Two sets of leaching tubes were prepared, each with 40 tubes /duplicate leaching tubes of 5 soils with 4 organic material treatments/. One set of soil-sand mixtures was incubated at 25 °C and the other at 35 °C. After 2 weeks, each leaching tube was placed on a 250 ml suction flask and leached with 100 ml of 0.01 M KCl in 4 to 5 increments. The leaching procedure was repeated every 2 weeks up to 16 weeks. The moisture contents of the columns were adjusted by weighing the columns every 5 days and by adding distilled water. The leachate thus obtained was made to 100 ml with distilled water and mixed, and aliquots were taken for analysis of NH_4-N, NO_3-N and SO_4-S /JOHNSON and NISHITA, 1952/. No NO_2-N could be detected in any of the leachate analyses.

Results and discussion

Mineralization of N and S

The cumulative amounts of N and S mineralized in the Dair and Zubair soils treated with organic fertilizer, chicken manure and alfalfa hay as a function of time during 16 weeks of incubation at 35 °C are shown in Fig.1. The results obtained in the other three soils are reported in Table 2 as

Table 2

Parameters and correlation coefficients /r/ of linear relationships between cumulative N and S mineralized in soils treated with organic material / µg/g soil/, Y, at 25 °C or 35 °C and incubation time /weeks/ X

Soil treatments	Mineralized N						Mineralized S					
	at 25 °C			at 35 °C			at 25 °C			at 35 °C		
	Intercept	Slope	r *	Intercept	Slope	r *	Intercept	Slope	r *	Intercept	Slope	r *
Missan												
Non	-14.7	14.5	0.97	- 9.8	13.7	0.99	446.3	82.8	0.96	395.9	78.7	0.97
Org	-25.6	18.4	0.98	-18.3	19.2	0.98	390.5	67.2	0.97	484.5	88.7	0.98
Chi	137.4	18.5	0.98	82.3	26.0	0.99	108.7	98.7	0.89	345.1	155.6	0.99
Alf	4.4	20.9	0.99	86.4	29.1	0.99	263.9	56.8	0.99	239.7	109.6	0.99
Khumasat												
Non	-22.8	15.6	0.99	-24.4	16.6	0.98	508.5	102.2	0.95	658.1	47.1	0.93
Org	-17.5	18.2	0.99	-36.3	19.9	0.98	527.1	86.4	0.92	647.8	84.6	0.96
Chi	126.2	18.4	0.99	184.6	13.1	0.99	521.5	168.6	0.95	474.9	151.7	0.99
Alf	47.1	18.6	0.99	93.0	28.5	0.99	432.7	90.6	0.99	490.7	88.3	0.95
Alkhasib												
Non	-25.6	14.7	0.98	-26.1	16.8	0.99	387.9	52.4	0.97	337.9	113.1	0.99
Org	-29.2	16.3	0.98	-26.1	16.8	0.99	544.1	66.9	0.97	377.9	131.8	0.95
Chi	150.4	15.8	0.99	124.6	33.6	0.99	575.2	109.5	0.99	136.5	157.7	0.98
Alf	80.4	28.4	0.99	126.3	33.5	0.98	427.7	82.1	0.99	282.6	106.3	0.97

Non = no organic material, Org = organic fertilizer, Chi = chicken manure, and Alf = alfalfa hay

* significant at P = 0.01

parameters and correlation coefficient of linear relationships between mineralized N and S and time of incubation at 25 °C and 35 °C. All the relationships were significant at 0.01 probability level. However, the rate of S mineralization was found to be greater than N mineralization.

The linear relationship obtained for cumulative mineralized N and time of incubation /Fig. 1 and Table 2/ do not support the findings of STANFORD and SMITH /1972/ and DEANS et al. /1986/ in samples that had been dried and sieved previously. In contrast, results obtained in this study were in agreement with those obtained by TABATABAI and AL-KHAFAJI /1980/ in 12 non-treated field moist soils, with organic C content ranging from 12.6 to 53.2 g/kg. In an other work, CHAE and TABATABAI treated 5 of the above 12 soils with waste materials. They found that N mineralization varied considerably depending on the soil type and organic waste materials. In general, however, they found that among the organic materials studied, the plotting of cumulative mineralization of N from alfalfa treated soils against

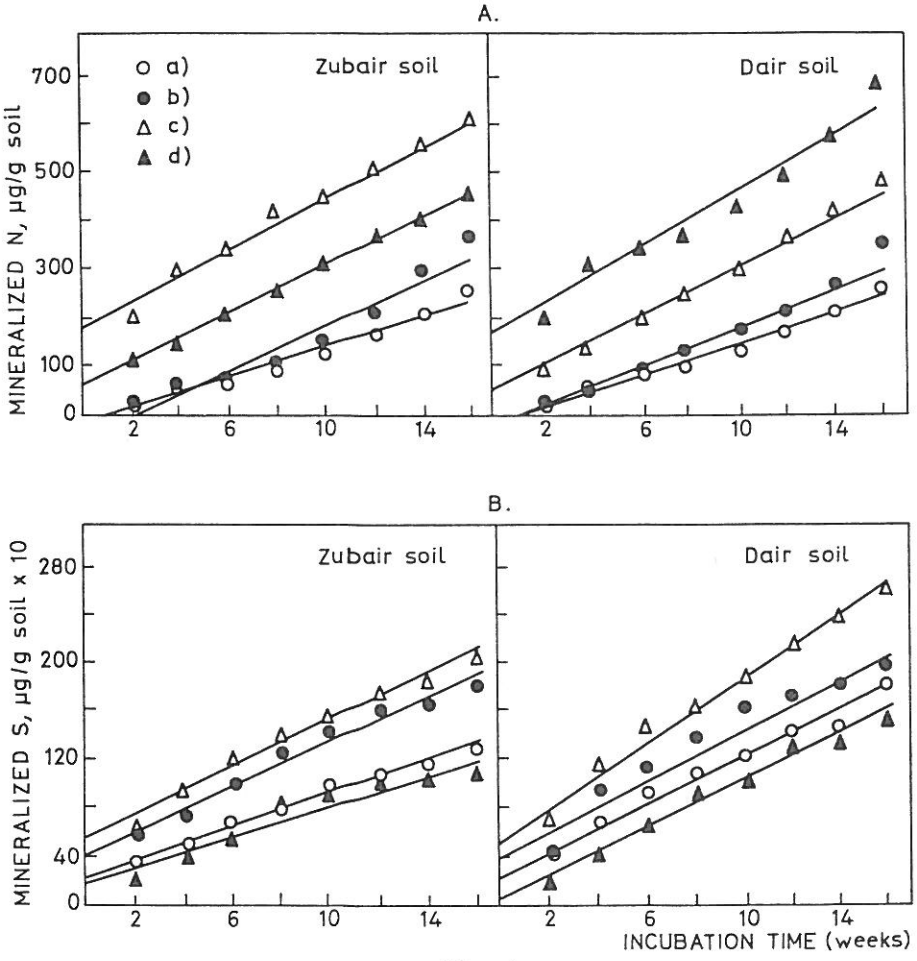

Fig. 1

Cumulative amounts of N and S mineralized in Dair and Zubair soils treated with different organic materials at 35 °C. a/ Control; b/ organic fertilizer; c/ chicken manure; d/ alfalfa hay

incubation time showed exponential curves. The disagreement with our results may be attributed to the differences in the indigenous energetic materials of the soils. Soils in our study had a low organic C content /1.7 to 9.7 g/kg/, therefore the stimulating effect of added energy materials on the organic matter transformation /priming action/ is expected to be different.

Information dealing with S mineralization in soils, particulary in saline soils, treated with organic material is lacking. Results reported in Fig. 1B and Table 2 are describing the linear relationship between cumulative mineralized S and time of incubation at 25 °C and 35 °C. Comparing N and S mineralization, results obtained /Table 3/ indicated that S mineralization was faster and greater than N mineralization. The cumulative amounts of

Table 3

Amounts of N and S mineralized / μgN/g soil/ in soils treated with organic material and incubated at 25 °C and 35 °C for 16 weeks

Soil treatment	Amount of N mineralized		Amount of S mineralized	
	at 25 °C	at 35 °C	at 25 °C	at 35 °C
Zubair				
Non	263.1	268.7	1250.4	1320.3
Org	323.1	372.0	1757.2	1538.2
Chi	563.7	624.0	2031.9	2235.8
Alf	492.3	471.9	1180.4	1410.5
Missan				
Non	230.7	220.2	1672.1	1591.9
Org	284.7	312.1	1414.3	1044.1
Chi	435.9	525.9	1707.0	2709.2
Alf	339.1	568.0	1130.0	1945.7
Khumasat				
Non	243.4	262.6	1997.7	1386.8
Org	294.5	308.2	1763.5	1909.2
Chi	436.2	688.8	2990.2	2842.1
Alf	357.7	567.9	1830.6	1754.1
Alkhasib				
Non	227.7	260.2	1201.8	2075.8
Org	252.2	334.8	1516.0	2370.3
Chi	407.1	667.1	2192.2	2499.4
Alf	440.6	652.6	1605.6	1859.9
Dair				
Non	239.6	271.4	1600.4	2503.5
Org	297.2	350.7	1949.3	3082.0
Chi	504.9	489.4	2666.4	2708.7
Alf	451.4	697.7	2062.7	2062.7

See Table 2 for soil treatments.

mineralized S ranged from 1130.4 to 2666.4 µg/g soil and from 1370.3 to 3082.0 µg/g soil at 25 °C and 35 °C incubation temperatures, respectively. This finding does not support the results reported by TABATABAI and AL-KHAFAJI /1980/.

Factors affecting N and S mineralization

Analysis of variance /Table 4/ indicated that added organic materials /O/ and incubation temperatures /T/ were the primary factors /p=0.01/ affecting N and S mineralization. Soils used /S/ also exerted a significant effect /p=0.01/ on N mineralization, whereas, little effect /p=0.05/ was found in N mineralization. TABATABAI and BREMNER /1972/ and others have not been able to demonstrate such relationships. Nevertheless, results obtained in this study support incubation investigations carried out by many authors. Greater amounts of obtained mineralized S compared with mineralized N may be attributed to the low N/S ratios of the incubation soil-sand mixtures. The low N/S ratios would cause greater immobilization of N relative to S. Additionally, soils used in this study had a high $CaCO_3$ content /Table 1/ and this may enhance volatilization of mineralized N /TERMAN, 1979/.

The influence of osmotic tension on N and S mineralization in treated saline soils was evaluated. The content of salts was measured in all soil treatments. Results obtained are presented in Fig. 2 for N and S mineralization. Results indicated that mineralized N significantly increased with increasing soil salinity at both incubation temperatures /25 °C and 35 °C/.

The stimulating effects of soil salinity on the mineralization of N are not clearly understood. However, WESTERMAN and TUCKER attributed the possibilities of stimulating to the solubilization of organic N with increasing salt concentration and becomes more easily mineralized. BROADBENT and NAKASHIMA /1971/ concluded that osmotic effect contributed to the mineralization of organic N in soil, but that the magnitude depends on

Table 4
Analysis of variance of soil treatments affecting N and S mineralization

Source of variance	d.f	Mineralized N	Mineralized S
		F-ratio	
Soils /S/	4	3.51*	17.53**
Organic material /O/	3	176.19**	46.44**
Temperature /T/	1	74.83**	34.79**
SxO	12	2.25*	1.79
SxT	4	4.00**	8.18**
OxT	3	12.10**	0.82
SxOxT	12	2.82**	2.64*
Error	40		

** Denotes significance at 0.01 level
* Denctes significance at 0.05 level

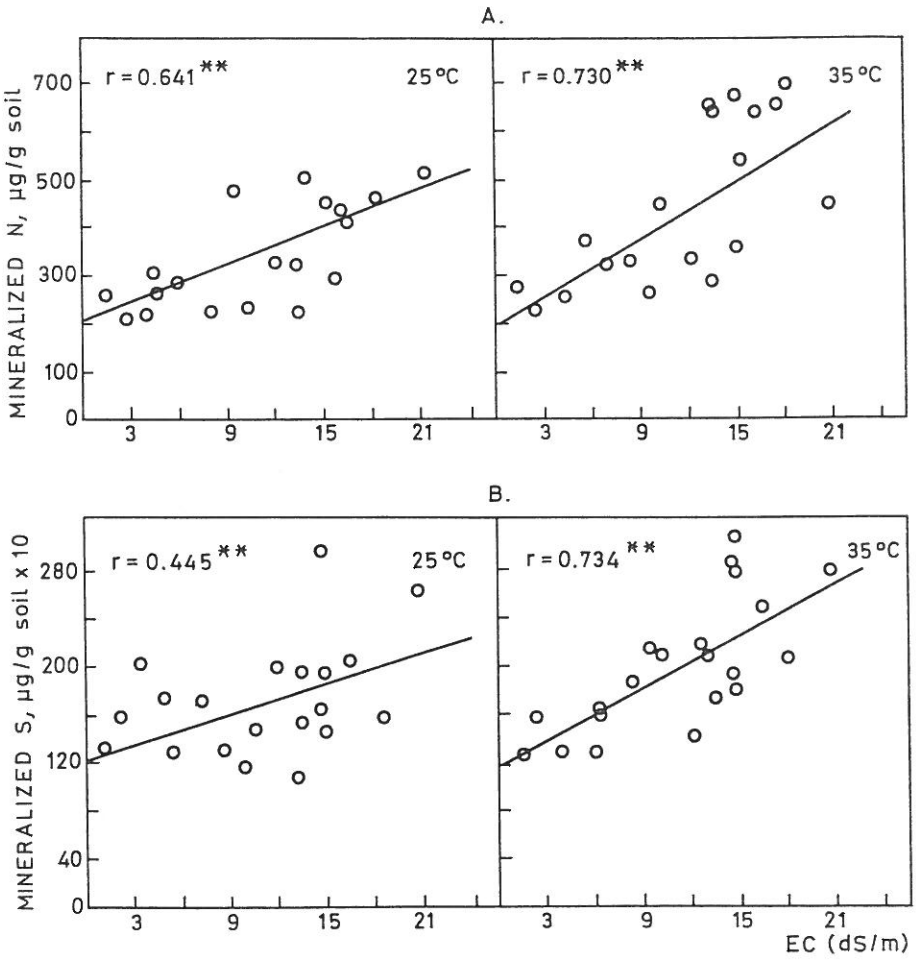

Fig. 2
Effect of salinity on N mineralization and S mineralization at 25 °C and 35 °C

the salt and the nature of soil. In fact, the soils used have been affected by salinity, therefore adaptation of indigenous heterotrophic microorganisms may be expected to tolerate high osmotic tensions. Sulfur mineralization shows the same tendency as N at various salinity levels. These findings indicate that there is a close relationship between the microbial conversion of N and S.

We studied the relationship between protease activity and the total amount of N mineralized during 16 weeks of incubation at 25 °C and 35 °C. Protease activity obtained at 25 °C was significantly correlated with total mineralized N /r=0.569/. This relationship was not significant when protease activity was assayed at 35 °C /r=0.422/. Little information is available on the relationship between protease activity and N mineralization. It is known that proteolytic reactions play an important role in N turnover in soils. Therefore this relationship would be useful in predicting N mineralization

potentials of soils treated with organic N by relatively simple enzyme assay.

Statistical analysis of the results of this study showed that arylsulfatase activity was not correlated with total S mineralization during 16 weeks of incubation at 25 °C and 35 °C. Arylsulfatase activity was negatively correlated /r=-0.178/ with total mineralized S at 35 °C. This inverse relationship was not expected and it needs further investigation. Results obtained in this study, however, do not support the findings of KOWALENKO and LOWE /1975/ in four Canadian soils during 14 weeks of incubation at 30 °C. In another work, TABATABAI and BREMNER /1972/ reported that arylsulfatase activity of 12 Iowa soils was not correlated with mineralized S during 10 weeks of incubation at 30 °C.

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