Egypt. J. Soil Sci. 44, No. 1, pp. 19 – 26 (2004)

Nitrification Rate in a Clay Soil as Influenced by some N-Sources, Sulphur and Organic Matter Application

M.S. Abd El-Fattah* and A.A. Abd El- Kader

**Plant Nutrition Department and Soils; and Water Use Department, National Research Center, Cairo, Egypt.*

INCUBATION experiments were carried out under the laboratory conditions on a clay loam soil sample from Giza Governorate to examine the effect of elemental sulphur and organic matter mixture on minimizing nitrogen losses from soil. Elemental sulphur and nitrogen were added at a rate of 100 mg Kg^{-1} soil, organic matter at a rate of 2% of soil weight. Nitrogen was in the form of ammonium sulphate and urea. Samples were taken every one week for the determination of soil pH, NO^-_3 – N and NH_4^+ -N and $SO^=_4$ .The inhibition rate was calculated and statistically evaluated. The results indicated that nitrification rate depends on the kind of N- fertilizer added , time of application , temperature and pH. The addition of elemental sulphur and organic matter decreased the conversion of ammonium to nitrate which is due to the accumulation of S in the humic substances which increase the organic matter efficiency. Ammonium sulphate treatment was more evident than urea treatment because urea hydrolysis is time dependent and thus soil pH was lower than in treatment urea.

Keywords: Nitrification rate, N-source, Sulphur, Organic matter, Clay soil.

Nitrogen is often the most limiting nutrient for plant growth under arid conditions, there has been a considerable interest over the years to estimate plant–available soil N to predict fertilizer N requirements (Bremner, 1965 and Keeney, 1982). The dynamics of N mineralization and nitrification in the soil cannot be properly understood without repeated estimation during the year because their seasonal pattern is impossible to predict using only a single determination in the beginning of the vegetation period (Franzluebbers *et al.*, 1995). In arable soils, these processes are significantly influenced by cultural practices (Campbell *et al.*, 1999a). Nitrogen losses from soils are considered a momentous problem in the present. Denitrification and leaching are regarded as the main loss processes that are major and significant in practical agriculture.

When sulphur oxidation in soils occurs, the following oxidation products are to be present : sulphate, sulphite, thiosulphate and tetrathionat whereas sulphate is the stable form under aerobic conditions. Elemental sulphur application causes a decrease in extracted NO_3 and an increase in NH_4^+ indicating inhibition of nitrification, Abd El-Fattah *et al.* (1990) and Mostafa & Hassan (1995) reported that on the other hand, addition of plant organic matter with sulphur enhanced the effect of sulphur on soil properties. Yousry *et al.* (1984) and Abd El- Latif & Abd El-Fattah (1985) found that pH values decreased and electrical conductivity values were positively affected-also DTPA extractable Fe, Mn and Zn had been increased as a result of sulphur and organic matter application. Organic matter has a positive effect on increasing cations and anions exchangeable capacity and so keeping nutrients from being leached out. Barbaria and patel (1980) pointed out that application of organic matter and sulphur at various soil moisture increased the availability of nutrients significantly as a result of increasing the exchangeable capacity of soils.

The objective is to study the extent to which nitrification could be reduced by applying elemental sulphur and organic matter with different nitrogen sources, ammonium sulphate $(NH_4)_2$ SO_4 or urea $CO(NH_2)_2$ through incubation experiments for twelve weeks under laboratory conditions.

Material and Methods

Clay samples from Giza Governorate were collected in early spring. Incubation experiments were performed in Soils and Water Use Dept. on the clay loam soil to examine the effect of some N- sources or / and elemental sulphur and organic matter on nitrate release and nutrients availability. Nitrogen was added as ammonium sulphate or urea at the rate of 100 mg/ kg soil. Elemental sulphur and the nitrogen sources were added with rate of 100 mg sulphur or nitrogen for each kg soil, organic matter was added at rate 2% of soil weight and mixed with the soil.

Selected soil properties are shown in Table 1. A hundred grams portions of soil were put in plastic cups. All treatments were incubated under laboratory conditions at room temperature about 25°C.

TABLE 1. Characteristics of the soil used .

pH : 2.5	EC dSm^{-1} 1:5	NH^+_4 ppm	NO^-_3 ppm	$SO^=_4$ ppm	OM %	Total CaCO3	Particle size distribution			
							Sand %	Silt %	Clay %	Soil Texture
8.2	1.8	8.0	12.0	87.6	1.67	2.33	32.3	35.4	32.3	C.loam

During the experiment, soil moisture content was maintained at (80%) of the field capacity through periodical substitution by distilled water. Samples were taken every week for the determinations of soil pH, $SO^{=}_4$, NH^+_4– N and NO^-_3 – N according to the methods described by Cottenie *et al.* (1982).

Statistical evaluation

Correlation coefficients were used to establish the relationships among the studied parameters. SPSS/PC$^+$ computer statistical program was used for all calculations.

Results and Discussion

Weekly measurements were performed from March until June to assess the parameters NO^-_3- N; NH^+_4– N; SO^{2-}_4 concentrations and pH units as shown in Table 2 that nitrogen addition in the form of ammonium sulphate or urea. Soil nitrate concentrations reflect maximal nitrification rate at the beginning of incubation period followed by minimal after 28 and 35 days with ammonium sulphate and urea, respectively. The amounts of ammonium ions in studied soil were remarkably lower compared to the nitrate level in both N- sources, such effect was obtained with Maly *et al.* (2002). Also, Mulvaney (1994) pointed out in a laboratory incubation experiment to compare the rate of nitrification for different N fertilizers showed that production of (NO^-_3 + NO^-_2)-N decreased in the order : urea > DAP > $(NH_4)_2$ SO_4 > NH_4NO_3 > MAP. This decrease was attributed in part to an increase in acidity, but the difference between urea and $(NH_4)_2SO_4$ was not eliminated by pH adjustment with NaOH. The low rate of nitrification observed with NH_4NO_3 was attributed largely to inhibition of NH^-_4 oxidation by NO^-_3.

Representative data in Table 2 show that nitrogen addition in the form of ammonium sulphate or urea has slightly affected soil pH decreasing it about 0.2 to 0.44 unit through the incubation periods. During the first two weeks urea hydrolysis raised soil pH as a result of the transitory production of ammonium carbamate or ammonia, such favorable effect was obtained with Song *et al.* (2002), who found in laboratory experiments that the hydrolysis of urea was faster at 20, 30°C. Soil pH started to decrease gradually thereafter due to nitrate production as a result of the nitrification process . After 28 days of the incubation period, almost all of ammonium (NH_4^+) was oxidized to nitrate (NO_3^-). Nitrate is exposed to be lost rabidly as denitrification processes.

Data in Table 3 indicated the effectiveness of sulphur and organic matter addition on soil pH and NH_4/NO_3 ratio, soil pH was significantly decreased, maximum by at least 0.65, 0.4 unit in each of ammonium sulphate or urea treatments, respectively, this may be a result of increasing sulphate concentration in ammonium sulphate treatment. The obtained results stood in confirmation with Heter (1985); Shadfan & Hussen (1985) and Mostafa & Hassan (1995). They found that addition of sulphur to soils decreased soil pH. The rate of decrease was induced with the rate of sulphur, application and duration period. The gradual decrease continued till the end of incubation period the effect of sulphur application on decreasing soil pH is a direct result of its oxidation to sulphuric acid and hence reducing soil alkalinity. Decreasing of soil pH is always the aim of the agricultural practices in most of the alkali soils of Egypt.

TABLE 2. Nitrification ratio in the clay loam soil as affected by some nitrogen sources and periods incubation.

Incub. / day	Ammonium Sulphate					Urea				
	PH	NO_3-N	NH_4-N	NH_4/NO_3	SO_4	PH	NO_3-N	NH_4-N	NH_4-N/NO_3	SO_4
	ppm									
0	8.21	11.3	106	9.38	160	8.21	11.3	6.57	0.58	87.6
7	8.00	36.4	78.5	2.16	158	8.35	28.8	21.2	0.74	86.3
14	7.94	58.3	50.9	0.87	150	8.42	35.3	29.7	0.84	84.2
21	7.89	86.6	23.4	0.27	142	8.27	52.4	27.6	0.53	81.6
28	7.88	107	1.65	0.015	140	8.05	76.4	30.5	0.40	77.5
35	7.77	106	0.89	0.008	137	7.91	98.6	3.42	0.03	73.6
42	7.79	108	0.95	0.009	133	7.95	109	0.125	0.001	69.5
49	7.70	106	0.67	0.006	131	7.98	107	0.226	0.002	68.5
56	7.71	105	0.42	0.004	128	8.00	105	0.405	0.004	66.4
63	7.73	104	0.73	0.007	124	8.01	104	0.603	0.006	64.2
70	7.75	103	0.21	0.002	121	8.00	102	0.554	0.005	64.5
77	7.76	102	0.11	0.001	118	8.00	101	0.656	0.006	62.9
84	7.76	101	0.573	0.006	115	8.01	93.7	0.734	0.007	63.4

TABLE 3. Nitrification rate in the clay loam soil as affected by addition of some nitrogen sources, sulphur and organic matter.

Incub./ day	Ammonium Sulphate+S+OM					Urea+S+OM				
	PH	NO_3-N	NH_4-N	NH_4-N/NO_3	SO_4	PH	NO_3-N	NH_4-N	NH_4-N/NO_3	SO_4
	ppm									
0	8.21	11.3	106	9.38	160	8.21	11.3	6.57	0.58	87.6
7	8.14	25.5	94.6	3.71	155	8.69	18.5	39.1	2.11	111
14	8.05	37.2	81.3	2.19	180	8.88	29.7	40.5	1.36	134
21	7.89	45.6	66.7	1.46	205	8.35	39.8	52.3	1.31	156
28	7.77	59.3	56.2	0.95	220	8.12	64.2	30.7	0.48	184
35	7.64	75.2	43.5	0.58	235	7.93	89.6	15.4	0.17	184
42	7.48	81.6	31.8	0.39	230	7.85	97.8	9.33	0.095	182
49	7.51	90.7	16.9	0.17	228	7.67	109	0.58	0.005	182
56	7.55	101	5.68	0.06	225	7.69	106	0.69	0.006	180
63	7.53	104	4.47	0.04	221	7.73	104	1.43	0.14	179
70	7.54	105	3.26	0.03	219	7.79	108	0.98	0.01	177
77	7.56	105	2.05	0.02	217	7.80	105	0.56	0.005	173
84	7.56	112	0.839	0.007	213	7.81	101	0.132	0.001	171

Data in Table 3 showed the effect of sulphur and organic matter on NH_4 / NO_3 ratio where it is noticed that sulphur and organic matter have a positive effect on hindering the nitrification process and thus maintaining ammonium in soil where it is adsorbed on clay surface and thus protected from losses by denitrification , while nitrogen as Nitrate form $(NO_3)^-$ is very soluble in soil solution and is not adsorbed on clay surface, subsequently it's more exposed to losses by denitrification. Sulphur oxidation in soil may have inhibition effect on nitrification where continued entity ammonium in soil up to 49.42 days of incubation ammonium sulphate or urea treatments, respectively, ammonium sulphate was more effective than urea treatment which led to increasing sulphate concentration in ammonium sulphate treatment which led to decreasing of soil pH, this in turn may be reflected on reducing nitrogen losses from soil as noticed at the end of the experiment after 84 days of incubation. Bitzer and Sims, (1988) reported that organic materials addition may have effect on delaying nitrification and reducing nitrate leaching. Data in Table 3 clarify that gradual sulphate concentration as a result of slulphur oxidation maintained high level of ammonium sulphate treatment due to the presence of sulphate as an accompanying anion, also, through 28 days was sulphur oxidized then slight decrease started in sulphate concentration in each of two treatments even at the end experiment may be due to assimilation of microorganisms or reduction sulphate. Marina *et al.* (2000) pointed out that organic matter can accumulate S in the humic substances and then serve as a source of S for plants.

The high level of sulphate concentration in ammonium sulphate treatment may be the reason for decreasing nitrogen losses in comparison to urea treatment where existed (3.8, 13.8)% in ammonium sulphate and urea treatments, respectively (Table 3). This shows that the limiting factor is substrate availability. The nitrification rate can be limited by sort the N- fertilizer which is supported by the correlation between NO^-_3 and NH^+_4 concentration as shown in Table 4 a, b, c, and d for ammonium sulphate and urea with and without S and OM (Table 4).

In conclusions, it could be said that timing of added fertilizer, sort of N–fertilizer, temperature, substrate availability are the most efficient factors. The variability of nitrification rate especially with urea is on pH. The elemental sulphur and organic matter decreased the conversion ammonium to nitrate which is due to the accumulation of S in the humic substances which affects soil pH and nitrogen losses particularly with ammonium sulphate fertilizer. Addition of sulphur and organic matter may be useful in reducing nitrate leaching resulting from nitrification of ammoniacal N sources.

TABLE 4. Correlation coefficient of the studied parameter under some N- sources and sulphur +organic matter.

a. Ammonium sulphate

Studied parameters	Incubation /day	NO^-_3 -N	NH^+_4-N	SO^{--}_4	Soil pH
1-Incub./day	1.000				
2- NO^-_3 -N	.741**	1.000			
3- NH^+_4-N	- .782**	- .997**	1.000		
4- SO^{--}_4	- .987**	- .825**	.869**	1.000	
5- Soil pH	- .817**	- .930**	.941**	.862**	1.000

**Correlation is significant at the 0.01 level

b. Ammonium sulphate and S+OM

Studied parameters	Incubation /day	NO^-_3 -N	NH^+_4-N	SO^{--}_4	Soil pH
1-Incub./day	1.000				
2- NO^-_3 -N	.970**	1.000			
3- NH^+_4-N	- .967**	-.997**	1.000		
4- SO^{--}_4	.677*	.807**	-.800**	1.000	
5- Soil pH	- .860**	-.948**	.945**	-.925**	1.000

**Correlation is significant at the 0.01 level--*Correlation is significant at the 0.05 level

c.Urea

Studied parameters	Incubation /day	NO^-_3 -N	NH^+_4-N	SO^{--}_4	Soil pH
1-Incub./day	1.000				
2- NO^-_3 -N	.831**	1.000			
3- NH^+_4-N	-.673*	-.657*	1.000		
4- SO^{--}_4	-.971**	-.926**	.743**	1.000	
5- Soil pH	-.706**	-.887**	.759**	.813**	1.000

**Correlation is significant at the 0.01 level--*Correlation is significant at the 0.05 level

d.Urea and S+OM

Studied parameters	Incubation /day	NO^-_3 -N	NH^+_4-N	SO^{--}_4	Soil pH
1-Incub./day	1.000				
2- NO^-_3 -N	.897**	1.000			
3- NH^+_4-N	-.706**	-.734**	1.000		
4- SO^{--}_4	.712**	.879**	-.367	1.000	
5- Soil pH	-.862**	-.987**	.652*	-.920**	1.000

**Correlation is significant at the 0.01 level--*Correlation is significant at the 0.05 level

References

Abd EL. Fattah, A.; Bakry, M.O.; Selim, A.M. and El-Habbasha, K.M. (1990) Response of garlic to sulphur and phoshporus application. *Middle East Sulphur Symposium*, 12-16 Feb. 1990, Cairo, Egypt.

Abd El-Latif, L.A. and Abd Al- Fattah, K.S. (1985) Extraction of available micro-nutrients from calcareous soils amended with organic materials. *Egypt. J. Soil Sci.* **25**, 183.

Barbaria, C.J. and Patel, C.L. (1980) Effect of application of Iron, farmyard manure and sulphur on the availability of iron in medium black calcareous soil at different moisture regime. *J. Indian Soc. Sci.* **28**, 302.

Bitzer, C. and Sims, J.T. (1988) Estimating the availability of nitrogen in organic matter through laboratory and field studies. *J. Environ. Qual.* **17**, 47.

Bremner, J.M. (1965) Nitrogen availability indexes. In: "Methods of Soil Analysis," C.A. Black *et al.* (Ed.). Part 2, WI. PP. 1324-1345, Agron. Monogr. 9. ASA. Madison.

Campbell, C.A.; Biederbeck, O.V.; Wen, G.; Zeater, R.P.; Schoenau, J. and Haha, D. (1999a) Seasonal trends in soil biochemical attributes: Effect of crop management on a black chernozem . *Can. J. Soil Sci.*, **79**, 73.

Cottenie, A.; Verloo, M.; Kiekens, L.; Velg, he G. and Comerlynch, R. (1982) *"Chemical Analysis of Plant and Soils"*, Hand book, pp. 1-63.

Franzluebbers, A.J.; Hons, F.M. and Zuberer, D.A. (1995) Tilland crop effects on seasonal soil carbon and nitrogen dynamics. *Soil Sci. Soc. Amer. J.* **59**, 1618.

Heter, B. (1985) Utilization of sulphur for amendment of calcareous soil in Jordan. *Proc. 2nd Arab Regional Conf. on Sulphur and Its Usage*, Vol. **1**, pp. 85-100.

Keeny, D.R. (1982) Nitrogen availability indexes. In : *"Methods of Soil Analysis,"* C.A. Black *et al.* (Ed.), Part 2, PP. 711-734, Agron. Monogr.9, ASA. Madison, WI.

Maly, S.; Sarapatka, B. and Krskova, M. (2002) Seasonal variability in soil N – mineralization and nitrification as influenced by N fertilization. *Rostlinna vyroba* **48**, (9), 389.

Marina, A.; Silvia, H. and Schung, E. (2000) *"Sulphur Nutrition Assimilation in Higher Plants"*, C. Brunold *et al.* (Ed.), paul Houpt, Bern, Switerland.

Mostafa, M.M. and Hassan, M.A.M. (1995) The effect of sulphur application and nitrogen water salinity on nitrification and salt tolerance of wheat plant. *Annals of Agric. Sci. Moshtohor* **33**, 409.

Mulvaney, R.L. (1994) Nitrification of different nitrogen fertilizers. *Illinois Fertilizer Conference Proceedings*, January 24-26.

Shadfan, H. and Hussen, A. A. (1985) Effect of sulphur application on the arailability of P, Fe, Zn and Cu in selected Saudi Soils. *Proc. 2nd Arab Regional Conf. on Sulphur and Its Usages,* Vol. 1 pp. 185-199.

Song, S.J.; Kang, T.W.; Sohn, S.M. and Zang, K. (2002) Transformation of ^{15}N – urea and N utilization and nitrate accumulation of Chinese cabbage in two soils. 17th WCSS, 14-21 August 2002, Thailand. Paper No. 1216.

SPSS. (1999) SPSS Base 9.0 . Application guide. SPSS Inc., Chicago. USA.

Yousry, M.; El- Leboudi, A. and Khater, A. (1984) Effect of sulphur and petroleum by products on soil characteristics. I. Availability of certain nutrients in calcareous soil intermittent leaching. *Egypt .J. Soil. Sci.* **24**, 185.

Received 10/2002

معدل إنطلاق النترات من بعض مصادر النيتروجين في الأراضـــي الطينية وتأثرها بإضافة الكبريت والمادة العضوية

محمد سيد عبد الفتاح وعبدالقادر عبدالفتاح عبدالقادر
قسم تغذية النبات وقسم الاراضى واستغلال المياة - المركز القومي للبحـــوث – الـــدقي – القاهرة – مصر.

خلال تجربة تحضين أجريت علي عينة من أرض طينية طمية من محافظة الجيزة وذلك تحت ظروف المعمل لدراسة تأثير إضافة السماد النتروجينى مع كـــل مـــن الكبريـــت العنصرى و المادة العضوية علي إنطلاق النترات خلال عملية التـــأزت حيـــث اســـتخدم مصدرين من النيتروجين كبريتات الامونيوم واليوريا. اضيف كل من الكبريت العنصري والنيتروجين بمعدل ١٠٠مجم / كجم تربة واضيفت المادة العضوية النباتية بنسبة ٢% من وزن التربة (١٠٠جم) وتم التحضين في اكواب بلاستيك ســـعة (٢٠٠جـــم) واســـتمرت التجربة لمدة ٨٤ يوما وكان يؤخذ كل أسبوع مكررين من كل معاملة وذلك لتقدير رقـــم الحموضة وكذلك النترات والامونيوم و الكبريتات. تمت المحافظة علي نســـبة رطوبـــة ٨٠% من السعة الحقلية للتربة طوال فترة التجربة. ويمكن تلخيص أهم النتائج التي تـــم الحصول عليها فيما يلي:

يعتمد معدل النترتةعلى نوع السماد النتروجينى المضاف ووقت الاضافة و درجـــة الحرارة و رقم الpH

أدت اضافة الكبريت العنصري مع المادة العضوية الى خفض رقم الحموضة فـــي كل من كبريتات الامونيوم واليوريا وكان أكثر معنوية مع المعاملة الاولي وقدرالانخفاض (٠,٦٥ – ٠,٤٠) وحدة في كل منهما علي الترتيب.

في معاملات الكبريت والمادة العضوية كان التأثير ايجابيا في إعاقة انطلاق النترات واستمر تواجد الامونيوم في التربة لمدة ٤٩ ، ٤٢ يوما في كل من معـــاملتي كبريتـــات الامونيوم واليوريا علي الترتيب يرجع ذلك الى تجمع الكبريت فى صورة هيومات ممـــا يزيد من كفاءة المادة العضوية. بينما انطلقت النترات من مصدري النيتروجين في خلال ٢١ ، ٢٨ يوما في كل من كبريتات الأمونيوم واليوريا مع عدم وجود الكبريت والمـــادة العضوية مما اكد دور العوامل السابقة.