Ammonia Loss Mitigation from Urea Amended Sandy and Calcareous Soils Using Zeolite

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ABSTRACT: The objective of this study was to examine the influence of various zeolite levels on NH_3 volatilization from urea fertilizer applied to sandy and calcareous soils. A laboratory incubation experiment in a closed dynamic air flow system was conducted in a completely randomized design with three replications. Four zeolite (clinoptilolite) levels of 0, 12.5, 25 and 50 g kg^{-1} soil and two urea levels of 250 and 500 kg urea fed^{-1} (wt/wt) were used. The treated soils was moistened with distilled water at field capacity level and incubated for 29 days. The volatilized NH_3 from the soil chambers was collected and titrated every 24 hours during incubation period. The results indicated that zeolite applications reduced the average percentage of ammonia loss from 26.07 and 67.09% for the control treatment to 5.04 and 15.64% for the highest (50 g kg^{-1}) level of zeolite added to the sandy and calcareous soils, respectively. Therefore, additions of zeolite as a soil conditioner reduce ammonia loss and increase the use efficiency of urea applied to sandy or calcareous soils.

Keywords: Nitrogen, Ammonia volatilization, Zeolite, Sandy soil, Calcareous soil.

INTRODUCTION

Nitrogen is an essential element of plants amino acids which are the building blocks of plant proteins, the important components in the growth and development of vital plant cells and tissues such as membranes and chlorophyll (Xia *et al*., 2011). The ammonium and urea-based fertilizers are susceptible to nitrogen loss as an ammonia (NH_3) gas, especially when they are left on the soil surface. Ammonia volatilization is one of the main factors that are responsible for the low efficiency of nitrogen fertilizer and the significant economic loss (Alberto, 2014). Urea is considered the cheapest nitrogen fertilizer and widely used in plant nutrition. Urea produces excessive amounts of ammonium carbonate by the biological hydrolysis in soil within 4 days after application. The presence of $(NH_4)_2CO_3$ raises the soil pH to more than 9.0 which favors the production of NH_3 and its loss into the atmosphere (Gameh, 1991). The proportion of nitrogen lost from nitrogen fertilizers due to NH_3 volatilization may reach to 50%, depending on fertilizer type, environmental conditions (temperature, wind speed, and rain), and soil properties (calcium content, cation exchange capacity and acidity) (Sommer *et al*., 2004).

Zeolite minerals are crystalline hydrated aluminosilicates (tectosilicates) of alkali or alkaline earth cations, structured in three dimensional rigid crystalline network and formed by the silica and alumina tetrahedral which come together to compose a system of canals, cavities and pores (Ming and Mumpton,1989). Kaduk and Faber (1995) characterized the pore structure as cages of approximately 1.2 nm in diameter, which are interlinked through channels of about 0.8 nm in diameter and composed of rings of 12 linked tetrahedra. The honeycomb micro-porous structure of zeolite is generally very open, containing pores, long wide channels and cavities, which are filled with cations and water molecules (Karapinar, 2009). Natural zeolite is highly selective for NH^{+}_{4} and K^{+} relative to Na^{+} or divalent cations such as Ca^{+2} and Mg^{+2} due to the negative charge location and density in the structure and the dimension of interior channels (0.40 – 0.72 nm diameter) (Ming and Boettinger, 2001). It is clear that the zeolite can retain ammonium ions which are produced during urea hydrolysis and release these ions timely to minimize the rate of converting ammonium to NH_3 (Palanivell *et al*., 2015). He *et al*. (2002) indicated that the application of zeolite with nitrogen fertilizer to fine sandy soil significantly reduced NH_3 volatilization compared to the fertilized soil without zeolite addition because of its high cation exchange capacity (CEC) and great affinity for NH_4. In a study, mixing zeolite with dairy slurry reduced ammonia volatilization (Lefcourt and Meisinger, 2001), Moreover, Ahmed *et al*. (2006 a,b) indicated that zeolite mixed with triple superphosphate and humic acids controlled the ammonia loss from urea in non-waterlogged soils. Also in waterlogged soils, mixing zeolite with peat water decreased ammonia loss from urea and ensured N, P, K uptake and their use efficiency and at the same time causing soil NH_4, K, Ca, Mg, P, and NO_3 ions to be available for plant use (Omar *et al*., 2010; Latifah *et al*., 2011). Sandy soil amended with clinoptilolite zeolite (CZ) showed lower NO^{-}_{3} and NH^{+}_{4} concentrations in the leachate and to increase the moisture retention in the soil due to the increased soil surface area and CEC (Huang and Petrovic, 1994). In addition, application of $(NH_4)_2SO_4$ with clinoptilolite to sandy soils was found to minimize N leaching and increase N utilization by crops compared to adding $(NH_4)_2SO_4$ alone (Perrin *et al*., 1998).This study aims to evaluate the effect of zeolite application on the NH_3 volatilization loss from sandy and calcareous soils fertilized with urea.

MATERIALS AND METHODS

Soil sampling

Two soil samples were used in this study. The first sample was sandy soil which collected from uncultivated area (26̊.27`.38.1`` N and 31̊.39`.50.6`` E) near El-Kawamel farm, Sohag University, Sohag, Egypt (Table 1). The second soil sample was calcareous soil which collected from the cultivated area (26̊ 35` 27.6`` N and 31̊ 48`11`` E) in El-Kawsar farm, Sohag University, Sohag , Egypt (Table 1). The soil samples were air-dried, passed through 2 mm sieve, mixed thoroughly and kept for this study. The naturally occurring zeolite (clinoptilolite) mineral powder used in this study was obtained from Alex-Zeolite Company, Giza, Egypt (Table 1).

Soil and zeolite analysis

The particle-size distribution of the soil samples was determined using the pipette method (Richards, 1954).The pH of the soil samples and zeolite was measured using a pH meter with a glass electrode (pH 211,Microprocessor pH meter, HANNA Instruments) in a 1:2.5 water suspension (Jackson, 1973). The electrical conductivity of the soil samples was estimated in the soil saturated paste extract and in 1:5 water extract for zeolite using an electrical conductivity meter (Orion model 150) according to Hesse (1998) as well as the soluble cations and anions in these extracts were determined according to Jackson, 1973. The cation exchange capacity (CEC) of soil and zeolite samples was determined using 1 M ammonium acetate at pH 7.0 (Chapman and Pratt, 1961). The calcium carbonate ($CaCO_3$) was estimated using a volumetric calcium carbonate calcimeter (Jackson, 1973).The total N content of the soil samples was determined by micro-kjeldahl method (Jackson, 1973). The specific surface area of zeolite (S_{Bet}) was measured using the N_2 adsorption/desorption analysis by micromeritics (ASAB 2000, USA), in the Department of Chemistry, Faculty of Science, Sohag University. The X-ray diffraction (XRD) analysis of zeolite powder was carried out to determine its mineral composition using a Philips X-ray diffraction equipment model PW/1710, Department of Physics, Faculty of Science, Assiut University (Table 2).

Table (1). Some selected properties of the two soils and zeolite mineral

Property	Sandy soil	Calcareous soil	Zeolite
pH (1:2.5) suspension	7.34	8.33	7.53
EC (dS/m)	1.18 (soil paste extract)	4.10 (soil paste extract)	0.376 (1:5 extract)
$CaCO_3$ (%)	2.17	18.57	0.29
Sand (%)	92.16	87.13	
Clay (%)	5.11	6.11	-
Silt (%)	2.73	6.76	
Texture grade	Sandy	Loamy sand	-
CEC (cmol +/kg)	5.04	8.01	149.00
Total N (%)	0.003	0.023	Nil
S_{Bet} (m^2/g)	-	-	279
Soluble cations (meq/l)			
Ca^{+2}	4.15	13.50	1.05
Mg^{+2}	2.50	9.75	0.30
Na^{+}	2.03	10.01	0.68
K^{+}	1.88	5.24	1.11
Soluble anions (meq/l)			
HCO_3^{-}	3.68	20.12	0.86
Cl^{-}	4.55	14.00	1.00
SO_4^{+2}	2.33	4.38	1.28

Table (2). Philips X-ray diffraction analysis of Zeolite sample

Mineral (%)	
Clinoptilolite	Montmorillonite
85.70	14.30

The laboratory experiment

A laboratory incubation experiment was carried out in the soil and water Dep., Faculty of Agriculture, Sohag University to study the effect of four levels of zeolite as a soil conditioner on NH_3 loss from urea amended sandy and calcareous soils under room temperature using the system described by Gameh (1987) consisted of an air compressor which pumped the air to pass through distilled water container to produce filtered and humidified air which was distributed through a manifold into soil chambers connected to the system. The soil chambers were glass bottles of 400 cm^3 in volume, 6.5 cm in diameter and 14 cm in height. The outgoing air was immersed in 25 ml of 2% boric acid mixed with bromo-cresol green and methyl red indicators which were placed in Bochner flasks to capture the NH_3 gas. The flasks were periodically replaced every 24 hours and titrated using 0.01 N H_2SO_4 for 29 days of incubation. Four hundred grams of air dried sandy (S) or calcareous (C) soil samples were placed in each glass bottle. Zeolite powder was added to the soil samples at four levels (0, 5, 10 and 20 g/bottel). These levels were equivalent 0, 12.5, 25 and 50 g Kg^{-1} soil (0, Z1, Z2 and Z3, respectively) which mixed thoroughly with the soil samples. The soil sample in each bottle was moistened to the field capacity level, and then urea fertilizer (46.5 % N) was added to the soil surface at two levels of 0.1 g (U1) and 0.2 g (U2) per bottle. These respective urea levels were equal to 250 and 500 kg urea fed^{-1} (w/w) then, the bottles were immediately closed, and connected to the system. All treatments were arranged in a completely randomized design with three replications (Table 3). The amounts of evolved NH_3 were calculated and daily recorded and the cumulative loss was estimated as a percentage of the applied urea-N. The nitrogen (N) recovery was plotted as a function of the time and fitted through an exponential decay model according to Cohen *et al.* (2010):

$$[N]_t = [N]_0 \, e^{-kt}$$

Where:
$[N]_0$, $[N]_t$ = N amount (mg) at time 0 and t days, respectively.
K = constant, i.e. depletion rate of N.

Table (3). The treatments of both sandy and calcareous soils

Treatment No	Sandy soil	Treatment No	Calcareous soil
T1	U1Z0 (control)	T9	U1Z0 (control)
T2	U1Z1	T10	U1Z1
T3	U1Z2	T11	U1Z2
T4	U1Z3	T12	U1Z3
T5	U2Z0 (control)	T13	U2Z0 (control)
T6	U2Z1	T14	U2Z1
T7	U2Z2	T15	U2Z2
T8	U2Z3	T16	U2Z3

U1 and U2 = 250 and 500 kg fed^{-1} urea. Z0, Z1, Z2 and Z3 = 0, 12.5, 25 and 50 g zeolite Kg, respectively.

RESULTS AND DISCUSSION

1- **Ammonia loss from the urea amended sandy soil**

a. Daily ammonia loss

The daily ammonia (NH_3) loss from the urea treated sandy soil that was recorded during the incubation time was greater at the high urea level (U2) than that of the low one (U1). However, it decreased with increasing the zeolite applied level (Figures 1 and 2). The highest daily NH_3 loss for the sandy soil treated with 250 kg fed^{-1} of urea (U1) occurred between the 8th to 11th days of incubation period. It was 0.81, 0.61 and 0.38% for Z1, Z2 and Z3, respectively, compared to 2.59% for the control (Z0) (Figure 1). However, for the soil amended with 500 kg urea fed^{-1} level (U2), the maximum daily NH_3-N loss (%) was between the 8th to 10th day of incubation period (Figure 2) and recorded 1.14, 0.63 and 0.51% for Z1, Z2 and Z3, respectively, compared to 2.74% for the control (Z0) (Figure 2). Then, the daily NH_3 loss decreased gradually with the incubation time.

b. Cumulative ammonia loss

The cumulative volatilized NH_3 from the sandy soil fertilized with urea and amended with different zeolite levels at the end of incubation period is present in Table 4. For the sandy soil amended with urea at a level of 250 kg urea (U1), the application of zeolite significantly reduced the total NH_3 loss from 24.79% in the control treatment (Z0) to 10.18, 5.80 and 4.08% of the total applied urea-N for Z1, Z2 and Z3 respectively at the end of incubation period (29 days) (Table 5). Moreover, for the soil fertilized with urea at 500 kg fed^{-1} level (U2), zeolite applications exhibited a reduction in the total NH_3 loss from 27.35% for the control treatment (Z0) to 11.67, 7.75 and 6.05% of the total applied urea-N for Z1, Z2 and Z3 respectively (Table 5).

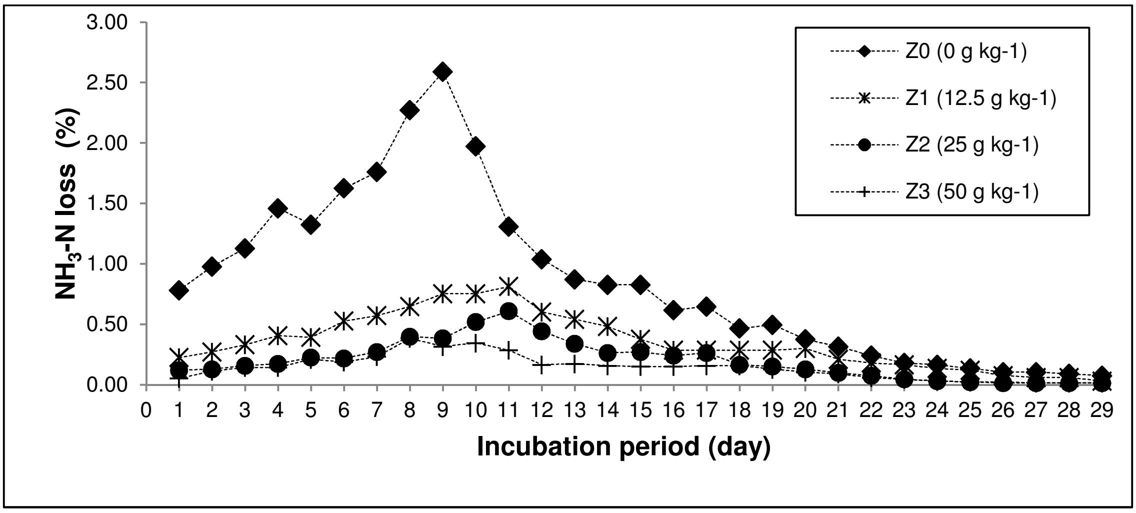

Figure (1). Daily NH_3 loss (%) from the sandy soil treated with 250 kg fed^{-1} of urea (U1) and amended with Z0, Z1, Z2 and Z3 levels of zeolite

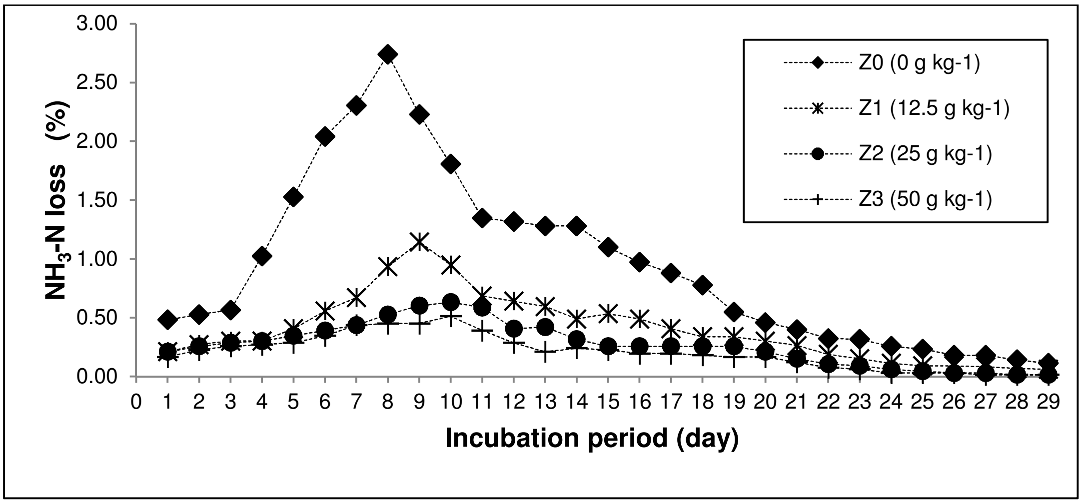

Figure (2). Daily NH_3 loss (%) from the sandy soil treated with 500 kg fed^{-1} urea (U2) and amended with Z0, Z1, Z2 and Z3 levels of zeolite

Table (4). Effect of zeolite levels (Z0, Z1, Z2 and Z3) on the cumulative ammonia loss (%) from urea fertilizer levels (U1 and U2) amended sandy soil

Treatment	Incubation period (days)							
	1	5	9	13	17	21	25	29
T1 (U1Z0)	0.78	5.68	13.92	19.12	22.04	23.69	24.42	24.79
T2 (U1Z1)	0.23	1.63	4.12	6.83	8.26	9.35	9.95	10.18
T3 (U1Z2)	0.12	0.81	2.08	3.99	5.03	5.57	5.74	5.80
T4 (U1Z3)	0.05	0.66	1.78	2.75	3.37	3.85	4.01	4.08
T5 (U2Z0)	0.48	4.12	13.44	19.19	23.42	25.60	26.73	27.35
T6 (U2Z1)	0.21	1.49	4.79	7.66	9.58	10.82	11.37	11.67
T7 (U2Z2)	0.21	1.40	3.36	5.40	6.49	7.36	7.66	7.75
T8 (U2Z3)	0.17	1.20	2.89	4.29	5.15	5.78	5.98	6.05

U1 and U2 = 250 and 500 kg urea fed^{-1} Z0, Z1, Z2 and Z3 = 0, 12.5, 25 and 50 g kg^{-1} soil, respectively.

Table (5). Effect of zeolite levels (Z0, Z1, Z2 and Z3) on total volatilized NH_3 (%) from the sandy and calcareous soils fertilized with 250 (U1) and 500 kg fed^{-1} (U2) after 29 days of incubation.

Sandy soil					
Urea level	Z0	Z1	Z2	Z3	Mean
U1	24.79^{b}	10.81^{c}	5.80^{de}	4.04^{e}	11.20^{a}
U2	27.34^{a}	11.67^{c}	7.75^{d}	6.05^{de}	13.20^{a}
Mean	26.07^{a}	10.92^{b}	6.78^{c}	5.04^{d}	
L.S.$D_{5\%}$	U = 3.09		Z = 1.66	UXZ = 2.30	
Calcareous soil					
U	Z0	Z1	Z2	Z3	Mean
U1	61.74^{b}	33.04^{d}	21.83^{fe}	12.13^{f}	32.18^{b}
U2	72.45^{a}	45.67^{c}	26.33^{de}	19.16^{fe}	40.90^{a}
Mean	67.09^{a}	39.36^{b}	24.08^{c}	15.64^{d}	
L.S.$D_{5\%}$	U = 2.17		Z = 7.26	UXZ = 10.37	

Z0, Z1, Z2, Z3 = 0, 1.25, 2.5 and 5.0 % zeolite.
Different letters indicate statistically significant differences between variables according to their least significant difference (LSD) at 0.05 probability level.

2-Ammonia loss from urea amended calcareous soil

Daily and cumulative NH_3-N losses (%) of the applied urea-N to the calcareous soil during the incubation period (29 days) are present in Figures 3, 4 and Table 6.

a. Daily ammonia loss

The highest daily values of NH_3 loss from urea treated calcareous soil were recorded between the 3^{th} and 8^{th} day of incubation (Figures 3 and 4). The highest daily NH_3 loss from U1 amended calcareous soil was 3.46, 2.12 and 1.38 % for Z1, Z2 and Z3, respectively, compared to 10.27 % for the control (Z0) (Figure 3). In addition, in the U2 treated calcareous soil, the respective daily NH_3 loss showed maximum values of 7.22, 2.40 and 1.76% for Z1, Z2 and Z3, respectively, compared to 11.30% for Z0 treatment (Figure 4). After reaching the maximum loss, the daily volatilized ammonia (%) gradually decreased until the end of incubation period.

b. Cumulative ammonia loss

The cumulative ammonia loss (%) from urea amended calcareous soil which was treated with zeolite (Z0, Z1, Z2 and Z3) levels is present in Table 6. For the lower urea level (U1), the addition of zeolite significantly minimized the total NH_3 loss (%) in the calcareous soil at the end of experiment from 61.73% for the control (Z0) to 33.04, 21.83 and 12.13% of the added urea-N for Z1, Z2 and Z3, respectively (Table 5). However, for the higher urea level (U2), zeolite showed a significant effect in reducing the total NH_3 loss from 72.45% for the control (Z0) to 45.67, 26.33 and 19.16% of the total applied urea-N for Z1, Z2 and Z3, respectively (Table 5).

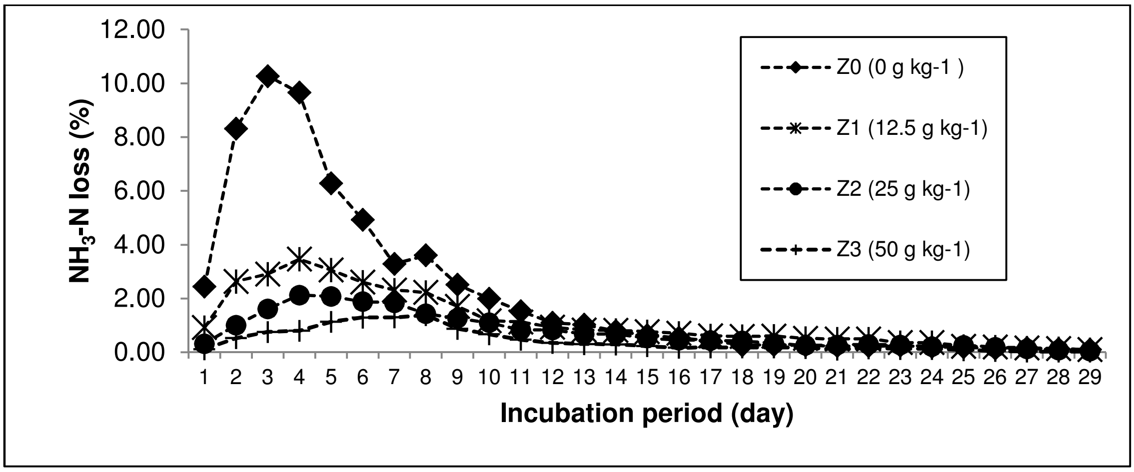

Figure (3). The daily NH_3 loss (%) from the calcareous soil fertilized with 250 kg urea fed^{-1} (U1) and amended with Z0, Z1, Z2 and Z3 levels of zeolite

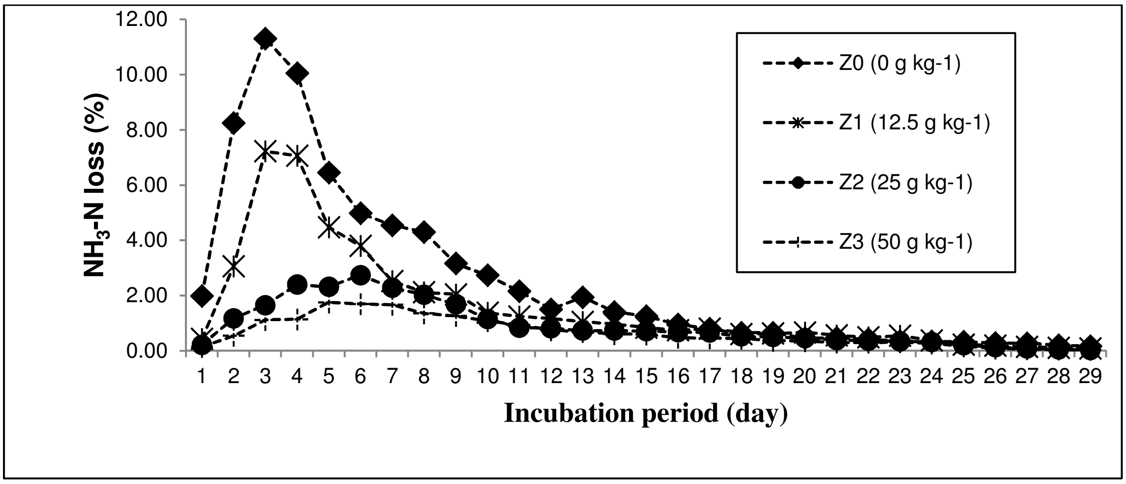

Figure (4). The daily NH_3 loss (%) from the calcareous soil treated with 500 kg urea fed^{-1} (U2) and amended with Z0, Z1, Z2 and Z3 levels of zeolite

Table (6). Zeolite effect on the cumulative ammonia loss (%) from urea fertilized calcareous soil

Treatment	Incubation period (days)							
	1	5	9	13	17	21	25	29
T9 (U1Z0)	2.44	36.96	51.29	56.94	59.33	60.34	61.20	61.73
T10(U1Z1)	0.92	12.98	21.83	25.90	28.80	31.00	32.44	33.04
T11(U1Z2)	0.32	7.14	13.55	16.99	19.08	20.36	21.39	21.83
T12(U1Z3)	0.12	3.34	8.19	9.99	10.86	11.49	11.99	12.13
T13(U2Z0)	1.99	38.03	55.02	63.36	67.81	70.07	71.52	72.45
T14(U2Z1)	0.44	22.26	32.76	37.62	41.00	43.47	45.13	45.67
T15(U2Z2)	0.22	7.78	16.52	20.08	22.89	24.77	26.02	26.33
T16(U2Z3)	0.14	4.72	10.72	14.20	16.35	17.84	18.91	19.16

U1 and U2 = 250 and 500 kg urea fed^{-1} Z0, Z1, Z2 and Z3 = 0, 12.5, 25 and 50 g kg^{-1} soil, respectively.

It is noticeable that nitrogen volatilization loss from the calcareous soil is higher than that from the sandy soil. It may be attributed to the higher pH value and the higher $CaCO_3$ content of the calcareous soil. Calcium carbonate ($CaCO_3$) increases $(NH_4)_2CO_3$ production from urea that hydrolyzed into NH_3 gas, CO_2 gas and H_2O (Gameh, 1991; Jones *et al.*, 2013). The results also indicate that increasing the applied urea-N level results in more NH_3 loss in both soils leading to a reduction in the nitrogen use efficiency as the amount of applied urea fertilizer increases (Ibrahim, 1999; El-Mamlouk, 2006 ; Rochette *et al.*, 2013). It is obvious that the NH_3 loss from the soil decreases as the applied level of zeolite increases. The effective role of zeolite in reducing the volatilization loss of NH_3 may be due to the presence of clinoptilolite which is the most dominant mineral in the used zeolite ore. Clinoptilolite zeolite is a mineral with a unique structure which allows trapping or releasing various cations due to its high cation exchange capacity (Kamarudin *et al.*, 2003). It can be used to control N loss from urea because of its small molecular size of the open-ring structure which physically protects NH_4^+ ions against microbial nitrification (Ferguson and Pepper, 1987). The slow retention and liberation ability of NH^+_4 ions that have been incorporated in the channels forming crystalline structure is generally attributed to zeolites, and particularly clinoptilolite (Allen *et al*., 1996; Kithome *et al*., 1998). Adsorption of ammonium by clinoptilolite zeolite reduces the NH_3 volatilization loss, maximizes N use efficiency and water use efficiencies and may decrease the excessive and unbalanced use of N fertilizers in agriculture (McGilloway *et al*., 2003).

3-Kinetics of NH_3 loss from urea amended sandy and calcareous soils

The average values of N recovery (mg) from urea fertilizer applied to the sandy and calcareous soils as a function of the incubation time are present in Figures 5,6 ,7 and 8 respectively. The higher ammonia volatilization loss from the calcareous soil resulted in higher nitrogen depletion rate (k) compared to those of the sandy soil. Amending the sandy soil with zeolite reduced the depletion rate (k value) from 0.010 for the control (Z0) to 0.004, 0.002 and 0.001 in Z1, Z2 and Z3, respectively for the U1 (250 kg urea fed^{-1}) treatment, and from 0.012 for the control (Z0) to 0.005 , 0.003 and 0.002 in Z1, Z2 and Z3, respectively, for U2 (500 kg urea fed^{-1}) treatment (Table 7). However, for the zeolite amended calcareous soil, the nitrogen depletion rate (k) reduced from 0.027 for the control (Z0) to 0.013, 0.08 and 0.004 in Z1, Z2 and Z3, respectively for the U1 (250 kg urea fed^{-1}) treatment, and from 0.041 in the control (Z0) to 0.019, 0.011 and 0.008 in Z1, Z2 and Z3, respectively for that fertilized at the U2 (500 kg urea fed^{-1}) treatment (Table 7). Similar results were showed by Ibrahim (1999) who recorded an increase in the depletion rate (k) of ammonium as the zeolite level increased and a decrease in that rate as the fertilization level increased for sandy soil.

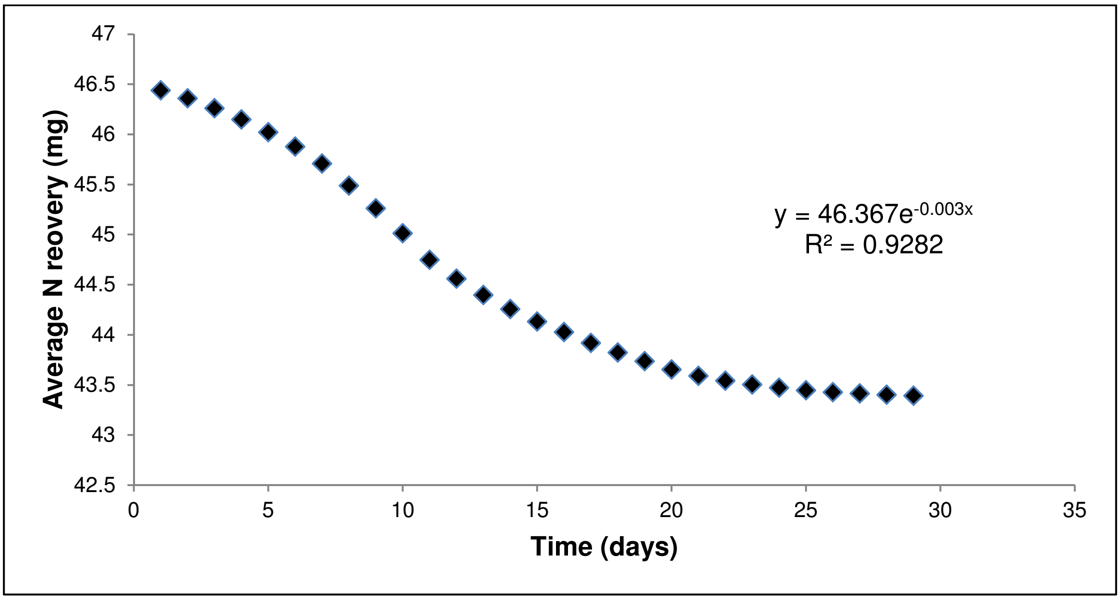

Figure (5). Nitrogen recovery (average values) from the sandy soil treated with 250 kg urea fed^{-1} (U1) after zeolite additions as a function of the incubation time

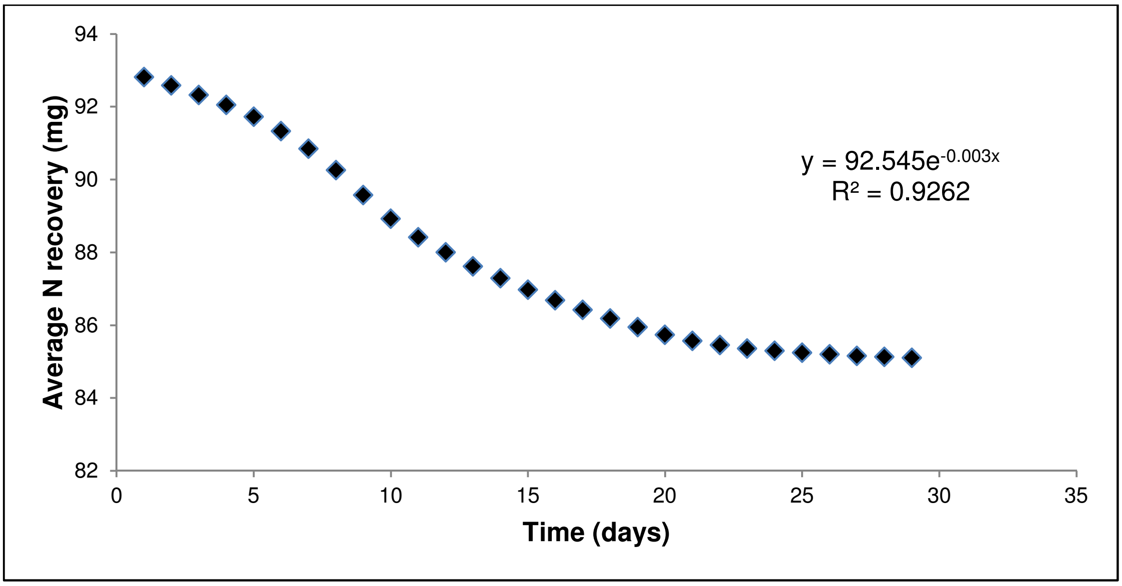

Figure (6). Nitrogen recovery (average values) from the sandy soil treated with 500 kg urea fed^{-1} (U2) after zeolite additions as a function of the incubation time

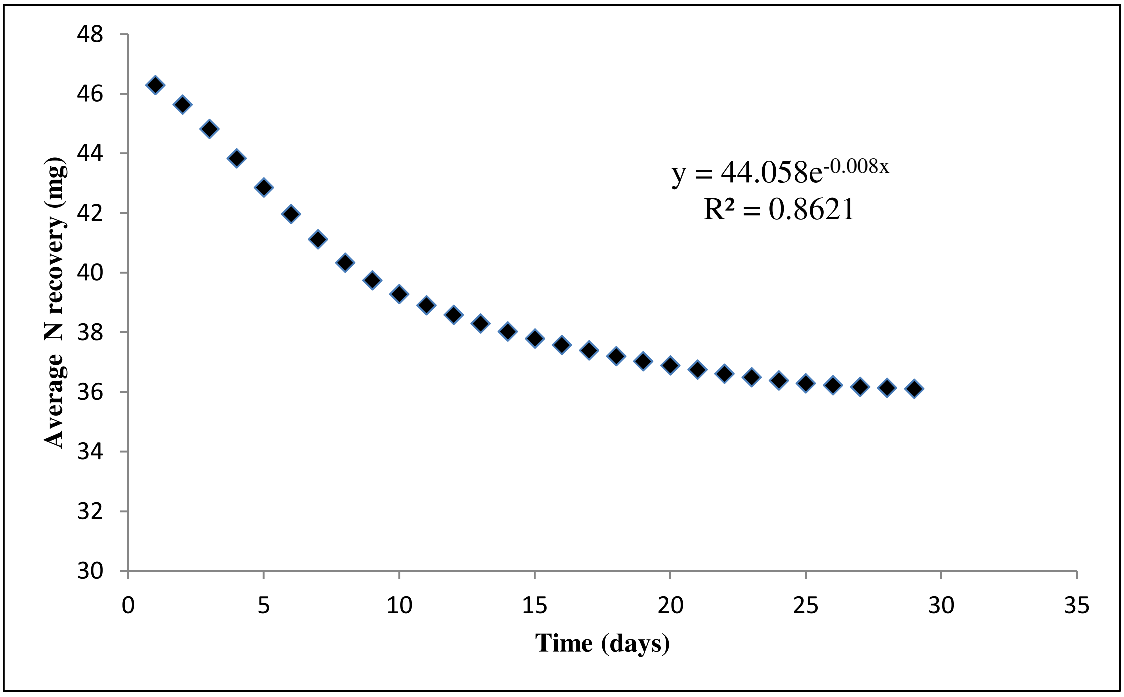

Figure (7). Nitrogen recovery (average values) from the calcareous soil amended with 250 kg fed^{-1} urea (U1) after zeolite additions as a function of the incubation time

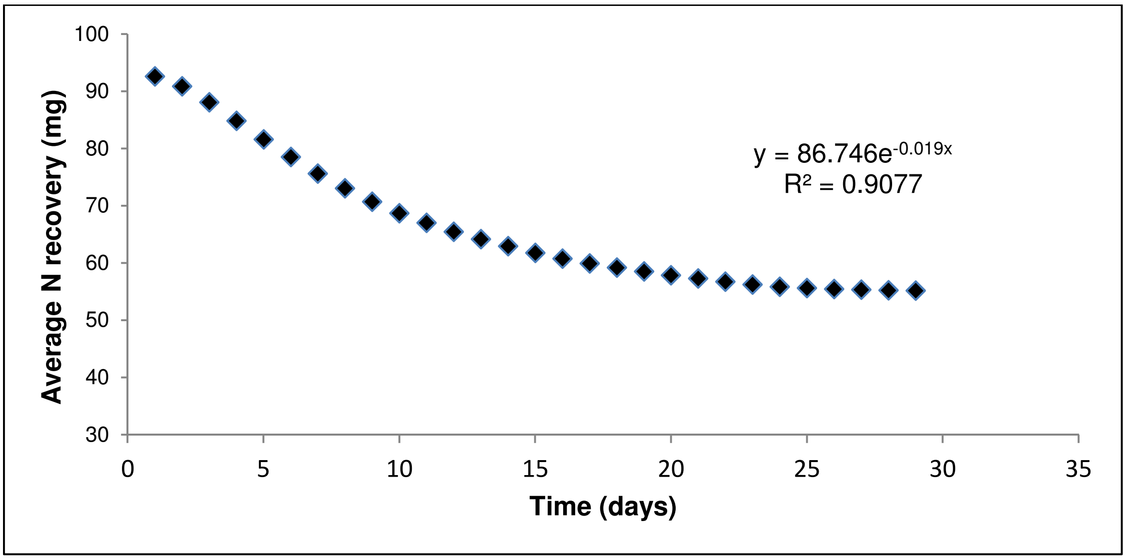

Figure (8). Nitrogen recovery (average values) from the calcareous soil treated with 500 kg urea fed^{-1} (U2) after zeolite additions as a function of the incubation time

Table (7). Nitrogen reduction rate constant (k) and coefficient of determination (R^2) of the sandy and calcareous soils fertilized with 250 (U1), 500 kg urea fed^{-1} (U2) and amended with zeolite (Z0, Z1, Z2 and Z3)

			Sandy soil		
Treatment	**K (day^{1})**	**R^2**	**Treatment**	**K(day^{1})**	**R^2**
T1 (U1Z0)	0.010	0.886	T5 (U2Z0)	0.012	0.918
T2 (U1Z1)	0.004	0.937	T6 (U2Z1)	0.005	0.934
T3 (U1Z2)	0.002	0.915	T7 (U2Z2)	0.003	0.924
T4 (U1Z3)	0.001	0.924	T8 (U2Z3)	0.002	0.913
			Calcareous soil		
T9 (U1Z0)	0.027	0.842	T13 (U2Z0)	0.041	0.855
T10 (U1Z1)	0.013	0.878	T14 (U2Z1)	0.019	0.843
T11 (U1Z2)	0.008	0.871	T15 (U2Z2)	0.011	0.882
T12 (U1Z3)	0.004	0.818	T16 (U2Z3)	0.008	0.900

Z0, Z1, Z2 and Z3 = 0, 12.5, 25 and 50 g zeolite kg^{-1} soil respectively.

CONCLUSION

The present study indicates that using zeolites as soil amendment in the sandy or calcareous soils reduces the volatilization loss of ammonia as well as increases the nitrogen recovery efficiency as a result of remaining the N nutrient in the form of NH^{+}_{4} or NO^{-}_{3} in the soil.

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الملخص العربى

تقليل تطاير الأمونيا من الأراضى الرملية والجيرية باستخدام الزيوليت

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تم اجراء تجربة تحضين فى معمل قسم الأراضى والمياه– كلية الزراعة – جامعة سوهاج لدراسة تأثير استخدام الزيوليت من نوع كلينوبتيلوليت لتقليل فقد الأمونيا بالتطاير من سماد اليوريا المضاف الى التربة الرملية والجيرية. وكانت المستويات المستخدمة من الزيوليت هى (صفر– ١٢,٥ – ٢٥ – ٥٠ جم كجم $^{-١}$) والمستويات المستخدمة من سماد اليوريا هى ٢٥٠ – ٥٠٠ كجم يوريا فدان$^{-١}$ على أساس الوزن وتم ترتيب هذه العوامل فى تصميم كامل العشوائية مكون من ثلاثة مكررات لكل معاملة . تمت اضافة الزيوليت الى التربة وريها وتسميدها وتحضينها لمدة ٢٩ يوما فى اوانى زجاجية متصلة بنظام تدفق الهواء المغلق لتجميع الأمونيا المتطايرة من التربة وقياسها كل ٢٤ ساعة. وقد اوضحت النتائج ما يلى:

١- انخفاض متوسط نسبة تطاير الأمونيا الكلية خلال فترة التحضين من ٢٦,٠٧ % فى معاملة الكنترول الى ٥,٠٤ % عند اضافة المستوى الأعلى من الزيوليت الى التربة الرملية.
٢- أنخفاض متوسط نسبة تطاير الأمونيا الكلية خلال فترة التحضين من ٦٧,٠٩ % فى معاملة الكنترول الى ١٥,٦٤ % عند اضافة المستوى الأعلى من الزيوليت الى التربة الجيرية.
٣- زيادة مستوى سماد اليوريا المضاف من ٢٥٠ الى ٥٠٠ كجم للفدان أدى الى زيادة نسبة الأمونيا المفقودة بالتطاير فى التربة الرملية والتربة الجيرية.
٤- ارتباط انخفاض نسبة الأمونيا المتطايرة معنويا بزيادة مستوى الزيوليت المضاف الى كلا التربتين.

لذلك فـإن إضافة الزيوليت كمصلح للأراضى الرملية والجيرية المستصلحة يؤدى الى تقليل نسبة الأمونيا المتطايرة وزيادة كفاءة سماد اليوريا.