

Full Length Research Paper

# Reducing ammonia volatile concentration from compound fertilizers modified with zeolite

Nolan Yore, Ipah Kalpana and Tan Saya

Department of Plant Protection, Faculty of Agriculture, University of Putra Malaysia, Serdang, Selangor, Malaysia.

Accepted 29 June, 2013

Ammonia volatilization is a direct loss of available nitrogen in agriculture. The objective of this study was to determine the effect of amending NPK fertilizer with different rates of clinoptilolite zeolite on ammonia volatilization, soil exchangeable ammonium, and available nitrate. Seven treatments evaluated were: 250 g soil alone (T1), 3.28 g ammonium nitrate (AN) without additive (T2), 44.6 g 5:3:2 formulated fertilizer + 31.77 g zeolite (T3), 44.6 g 5:5:5 formulated fertilizer + 26.36 g zeolite (T4), 37.17 g 6:6:6 formulated fertilizer + 18.92 g zeolite (T5), 22.30 g 10:10:10 formulated fertilizer + 4.06 g zeolite (T6), and 14.87 g 15:15:15 commercial fertilizer (T7). The ammonia loss was measured using close-dynamic air flow system method. Soil pH, exchangeable ammonium and available nitrate at the end of this study were determined using standard procedures. The mixture of formulated fertilizer and zeolite significantly reduced ammonia volatilization. Zeolite in the formulated compound fertilizers did not significantly affect soil exchangeable ammonium and available nitrate. Amending N, P, and K compound fertilizer could minimize ammonia loss.

**Key words:** Ammonium nitrate, zeolite, ammonia volatilization, soil exchangeable ammonium, soil available nitrate.

## INTRODUCTION

The use of nitrogen fertilizers worldwide is about 80 million tons N per annum (Follett et al., 1991; Freibauer et al., 2001). However, nitrogen fertilizers such as ammonium nitrate and urea are noted for high N loss through ammonia volatilization (Prasertsak et al., 2001; Cai et al., 2002). Ammonia volatilization is an important problem in agriculture. It is a direct loss of available N for plant uptake (Asman et al., 1994).

Some researchers used acidic materials to reduce ammonia volatilization in acidic soils. For example, triple superphosphate and humic acids (HA) have been used to minimize ammonia loss but HA alone was not effective in controlling ammonia volatilization (Ahmed et al., 2006b,

2008; Shamsuddin et al., 2009). Furthermore, ammonia loss has also been controlled using phosphoric acid through reduction of microsite pH (Fenn and Richards, 1989; Fenn et al., 1990; Fan and Mackenzie, 1993; Siva et al., 1999). However, this material is not only expensive, but it also produces corrosive end product when it is mixed with urea. Additionally, it requires special precautions in handling and storage.

Zeolites can be used to minimize ammonia loss because they can absorb important nutrients such as ammonium (NH<sub>4</sub>) (Ahmed et al., 2010) and potassium (K). These nutrients absorbed are timely released for optimum plant uptake. Clinoptilolites can be used to amend NPK fertilizer to reduce ammonia loss. This is possible partly because of their high cation exchange capacity (CEC) and great affinity for NH<sub>4</sub> (Stumpe et al., 1984; 1985; Ming and Dixon, 1986; Ferguson and Pepper, 1987; He et al., 2002).

To date, there is lack of information on ammonia volatilization via mixing ammonium nitrate (AN), Egypt

---

\*Corresponding author. Email: [N\\_yore19@yahoo.com](mailto:N_yore19@yahoo.com)

**Abbreviation:** DNMRT, Duncan's new multiple range test.

**Table 1.** Selected physical and chemical properties of soil and zeolite.

Property	Soil	Zeolite
pH <sub>water</sub>	4.7	7.03
pH <sub>KCl</sub>	3.43	6.37
Organic carbon (%)	3.6	nd
Texture	SL	nd
CEC (cmol/kg)	12.8	75.4
Total N (%)	0.084	0.037
Total P (%)	0.009	NA
Total K (%)	0.023	0.709
Exchangeable K (cmol/kg)	0.174	22.29
Exchangeable Ca (cmol/kg)	0.717	50.06
Exchangeable Mg (cmol/kg)	0.525	2.21

CEC, Cation exchange capacity; SL, sandy loam; nd, not determined; NA, not available.

rock phosphate (ERP), muriate of potash (MOP), and zeolite. This kind of compound fertilizer with clinoptilolite may not only minimize ammonia loss from AN but it could improve retention of nutrients and their timely release for plant uptake. A laboratory study was carried out to evaluate the effect of different amounts of zeolite added to NPK fertilizer from AN, ERP and MOP on ammonia loss.

## MATERIALS AND METHODS

The soil used in this experiment was sandy loam, Typic Tualemkuts (Bekenu series) taken from Universiti Putra Malaysia Bintulu Campus at 0 to 15 cm depth. The soil was air dried and sieved to pass a 5 mm sieve and its pH was determined in water at a ratio of 1:2.5 soil: distilled water suspension and 1 M KCl using a glass electrode (Peech, 1965). Soil CEC was determined by the leaching method followed by steam distillation technique (Bremner, 1965).

Total N of the soil and zeolite were determined by the kjeldahl method described by Bremner (1965). Total P and K in the soil and zeolite were extracted by Aqua Regia method. Soil available P and exchangeable cations were extracted using the leaching method (Cottenie, 1980). Total P and available P were determined using the blue method.

Total cations and exchangeable cations (K, Ca and Mg) were determined using atomic absorption spectrophotometry (AAS). Soil texture was determined using the hydrometer method. Organic carbon of soil was determined using loss of ignition method (Piccolo, 1996). CEC of zeolite was determined using CsCl method (Ming and Dixon, 1986).

Treatments were surface-applied and the amount of fertilizers used was calculated from the standard recommendation of Malaysian Agricultural Research and Development Institute (MARDI, 1990) for Masmadu maize (*Zea mays* L). The treatments per 250 g of soil evaluated were:

- A. 250 g soil alone (T1).
- B. 3.28 g AN without additive (T2).
- C. 44.6 g 5:3:2 formulated fertilizer (12.83 g compound fertilizer + 31.77 g zeolite) (T3).
- D. 44.6 g 5:5:5 formulated fertilizer (18.24 g compound fertilizer + 26.36

g zeolite) (T4).

E. 37.17 g 6:6:6 formulated fertilizer (18.25 g compound fertilizer + 18.92 g zeolite) (T5).

The closed-dynamic air flow system method (Siva et al., 1999; Ahmed et al., 2006a, b) was used to determine the daily ammonia loss for 12 days. The system consisted of an exchange chamber 500 ml Erlenmeyer flask containing 250 g of soils and 250 ml Erlenmeyer flask containing 75 ml of boric acid, bromocresol green and methyl red indicator as ammonia trap. Both Erlenmeyer flasks were stoppered and fitted with an inlet/outlet. The inlet of the chamber was connected to an air pump and the outlet was connected by polyethylene tubing to the ammonia trap. Air was passed through the chambers at a rate of 2.50 L/min/chamber. This incubation study was conducted at room temperature for 12 days. The boric acid indicator traps were replaced every 24 h. The release ammonia was captured in the trapping solution and back-titrated with 0.01 M HCl, until the colour changed from green to purple to measure the ammonia released. The measurement process was continued until the loss of less than 1% of the N added to the AN was recorded. A 250 g of soil were placed in the exchange chamber and moistened to 70% field capacity.

After 12 days of incubation, incubated soil was air dried and crushed to mix well with applied fertilizer. The pH, exchangeable NH<sub>4</sub> and available NO<sub>3</sub> of incubated soil was determined. The pH of the soil was determined as mentioned previously. For exchangeable NH<sub>4</sub> and available NO<sub>3</sub>, they were extracted using 2 M KCl and determined by steam distillation (Keeney and Nelson, 1982). The experimental design was a completely randomized design with three replications for each treatment. Analysis of variance (ANOVA) was conducted to test treatment effect and means of treatments were compared using Duncan's new multiple range test (DNMRT) (SAS, 2001).

## RESULTS AND DISCUSSION

The selected physical and chemical properties of Bekenu series are presented in Table 1. The selected chemical and physical properties of this soil were comparable with those reported by Paramanathan (2000) except for organic carbon and CEC. The selected physical and chemical properties of zeolite are also shown in Table 1. The CEC of zeolite was relatively lower than expected 12 days of ammonia (NH<sub>3</sub>) loss were daily recorded during

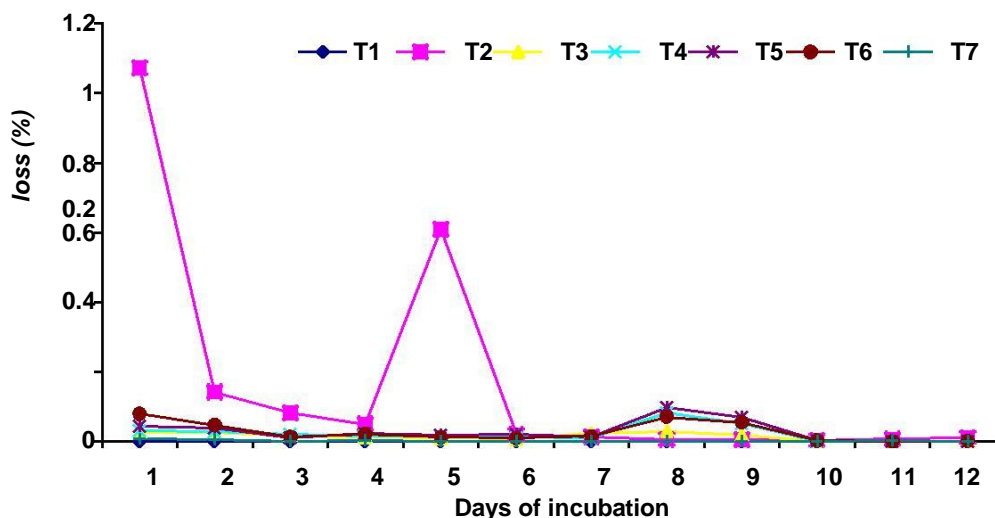


Figure 1. Daily ammonia volatilization from incubation.

Table 2. Effect of treatment on pH, exchangeable ammonium and nitrate accumulation with soil over 12 days of incubation.

Treatment	NH <sub>3</sub> -N loss	pH <sub>water</sub>	pH <sub>KCl</sub>	NH <sub>4</sub> -N (%)	NO <sub>3</sub> -N (%)
T1	0 <sup>d</sup>	4.68 <sup>b</sup>	3.67 <sup>d</sup>	0.007 <sup>b</sup>	0.0005 <sup>c</sup>
T2	1.860 <sup>a</sup>	3.77 <sup>e</sup>	3.63 <sup>c</sup>	0.061 <sup>b</sup>	0.0047 <sup>b</sup>
T3	0.273 <sup>bcd</sup>	3.68 <sup>e</sup>	3.70 <sup>c</sup>	0.044 <sup>b</sup>	0.0070 <sup>a</sup>
T4	0.401 <sup>bc</sup>	3.9 <sup>d</sup>	4.03 <sup>b</sup>	0.025 <sup>b</sup>	0.0054 <sup>ab</sup>
T5	0.513 <sup>b</sup>	3.93 <sup>d</sup>	4.06 <sup>b</sup>	0.043 <sup>b</sup>	0.0061 <sup>ab</sup>
T6	0.501 <sup>b</sup>	4.29 <sup>c</sup>	4.05 <sup>b</sup>	0.052 <sup>b</sup>	0.0042 <sup>b</sup>
T7	0.050 <sup>cu</sup>	5.02 <sup>d</sup>	4.75 <sup>d</sup>	0.416 <sup>d</sup>	0.0056 <sup>au</sup>

Mean values with different letters within the column are significant different at  $p = 0.05$  as determined by DNMR's test.

the incubation (Figure 1). The ammonia loss started on the first day of incubation for all of the treatments except for T1. The NH<sub>3</sub> loss started to decrease on the second day of incubation until day 12 except for T2. Ammonia loss for treatment T2 increased on day five and it decreased on day six (Figure 1). According to Ahmed et al. (2008), maximum ammonia loss occurred on day three of incubation. This observation may be due to differences in soil chemical and physical properties such as organic matter, texture, total organic carbon and pH. This observation was also possible because of sources of NPK fertilizers. The total ammonia loss over 12 days of incubation is shown in Table 2. Interestingly, ammonia losses for treatments with zeolite (T3, T4, T5 and T6) were significantly lower than that of ammonium nitrate alone (T2). There was no ammonia loss for soil alone (T1). This suggests that zeolite can reduce NH<sub>3</sub> loss when compound fertilizers are amended with clinoptilolite zeolite.

There were significant differences in pH. Even though ammonium nitrate alone (T2) reduced soil pH compared to most of the fertilizers with zeolite, ammonia loss was

higher for T2 because it had no zeolite to control retention of ammonium ions in the soil. As shown in Table 2, there was no significant accumulation of exchangeable NH<sub>4</sub> for soil only and treatments with zeolite compared with commercial fertilizer.

A study has shown that ammonium-exchange zeolite does only act as a slow-release fertilizer in a medium textured and porous soil (Lewis et al., 1984; Latifah et al., 2010). There was significant difference between treatments in terms nitrate accumulation. T3 caused higher accumulation of available nitrate compared to T2 and T6 because of the treatment had the highest amount of zeolite which could have ensured a better equilibrium between ammonium and nitrate.

## Conclusion

Formulated fertilizer with higher amount of zeolite (T3, T4, T5 and T6) effectively reduced ammonia volatilization compared to a commercial compound fertilizer and AN alone. However, the treatments had no effect on

exchangeable ammonium and available nitrate (except for T3 which had the highest amount of zeolite) accumulation.

## ACKNOWLEDGEMENTS

The authors acknowledge the financial support of this research by Ministry of Higher Education Malaysia and Universiti Putra Malaysia, Malaysia.

## REFERENCES

- Ahmed OH, Aminuddin H, Husni MHA (2008). Ammonia volatilization and ammonium accumulation from urea mixed with zeolite and triple superphosphate. *Acta Agric. Scandinavica Section B. Soil and Plant Sci.* 58:182-186.
- Ahmed OH, Aminuddin H, Husni MHA (2006a). Effect of urea, humic acid, and phosphate interactions in fertilizer microsites on ammonia volatilization, soil ammonium and nitrate contents. *Int. J. Agric. Res.* 1:25-31.
- Ahmed OH, Braine CH, Muhamad AM (2010). Minimizing ammonia loss from urea through mixing with zeolite and acid sulphate soil. *Intl. J. Phys. Sci.* 5(14):2198-2202.
- Ahmed OH, Aminuddin H, Husni MHA (2006b). Reducing ammonia loss from urea and improving soil-exchangeable ammonium retention through mixing triple superphosphate, humic acid and zeolite. *Soil Use Manage.* 22:315-319.
- Asman WAH, Sutton MA, Schjorring JK (1994). Ammonia: emission, atmospheric transport and deposition. *New Phytol.* 139:27-48.
- Bremner JM (1965). Total nitrogen. In: Black et al. (eds) *Method of soil analysis, Part 2*, American Society of Agronomy, Madison, Wisconsin, pp. 1149-1178.
- Cai GX, Chen DL, Ding H, Pacholski A, Fan XH, Zhu ZL (2002). Nitrogen losses from fertilizers applied to maize, wheat and rice in the North China Plain. *Nutr. Cycl. Agroecosyst.* 63:187-195.
- Cottenie A (1980). Soil testing and plant testing as a basis of fertilizer recommendation. *FAO Soils Bull.* 38:70-73.
- Fan MX, Mackenzie AF (1993). Urea and phosphate interactions in fertilizer microsites: Ammonia volatilization and pH changes. *Soil Sci. Soc. Am. J.* 57:839-845.
- Fenn LB, Richard J (1989). Ammonia loss from surface applied urea caacid products. *Fertilizer Res.* 9:265-275.
- Fenn LB, Tatum G, Horst G (1990). Ammonia loss from surface-applied mixtures of urea-calcium-potassium salts in the presence of phosphorus. *Fertilizer Res.* 21:125-131.
- Ferguson GA, Pepper G (1987). Ammonium retention in sand amended with clinoptilolite. *Soil Sci. Soc. Am. J.* 51:231-234.
- Follett RF, Keeney DR, Crusel RM (1991). *Managing Nitrogen for Groundwater Quality and Farm Profitability* (eds), SSSA, Madison, WI.
- Freibauer A (2001) Biogenic emissions of greenhouse gases caused by arable and animal agriculture (ed.), *Nutr. Cycling Agroecosyst. Special Issue* 60:1-3, 1-326.
- He ZL, Calvert DV, Alva AK, Li YC, Banks DJ (2002). Clinoptilolite zeolite and cellulose amendments to reduce ammonia volatilization in a calcareous sandy soil. *Plant and Soil* 247:253-260.
- Keeney DR, Nelson DW (1982). Nitrogen-inorganic Forms. In, Page et al. (eds) *Methods of Soil Analysis, Part 2*, (2nd ed), Agron. Monograph, 9. ASA and SSSA, Madison, Wisconsin.
- Latifah O, Ahmed OH, Nik AM (2010). Minimizing ammonia volatilization in waterlogged soils through mixing of urea with zeolite and sago waste water. *Intl. J. Phy. Sci.* 5(14):2193-2197.
- Lewis MD, Moore FDI, Goldsberry KL (1984). Ammonium-exchanged clinoptilolite and granulated clinoptilolite with urea as nitrogen fertilizers. In, Pond WG, Mumpton FA (eds) *Zeo-Agriculture: Use Natural Zeolites in Agric. and Aquaculture*, Westview Press, Boulder, CO.
- Malaysia Agriculture Research and Development (MARDI) (1990). *Jagung Manis Baru (New sweet corn): Masmadu*. MARDI, Kuala Lumpur.
- Ming DW, Dixon JB (1986). Clinoptilolite in South Texas soils. *Soil Sci. Soc. Am. J.* 50:1618-1622.
- Paramananthan S (2000). *Soils of Malaysia: Their characteristics and identification (Volume 1)*. Acad. Sci. Malaysia, Kuala Lumpur, Malaysia, p. 616.
- Peech HM (1965). Hydrogen-ion activity. In, Black et al. (eds) *Methods of soil analysis part 2*, American Society of Agronomy, Madison, Wisconsin, pp. 914-926.
- Piccolo A (1996). Humus and soil conservation. Humic substances in terrestrial ecosystem. Piccolo A, (ed.) Elsevier, Amsterdam, p. 225-264.
- Prasertsak P, Freney JR, Saffiga PG, Denmead OTm, Prove BG (2001). Fate of urea nitrogen applied to a banana crop in the wet tropics of Queensland. *Nutr. Cycl. Agroecosyst.* 59:65-73. DOI: 10.1023/A:1009806826141
- SAS (2001). *SAS/STAT Software*. SAS Institute, NC., ISBN: 1580258506.
- Shamsuddin R., O.H. Ahmed, Nik Muhamad A.M. and M.B. Jalloh. (2009). Reduction of Ammonia Volatilization through Mixing Urea with Humic and Fulvic Acids isolated from Palm Oil Mill Effluent Sludge. *Am. J. Environ. Sci.* 5(3):382-386.
- Siva K B, Aminuddin H, Husni MHA, Manas AR (1999). Ammonia volatilization from urea as affected by tropical-based palm oil effluent (pome) and peat. *Comm. Soil Sci. Plant Anal.* 30:785-804.
- Stumpe JM, PLG Vlek, WL Linday (1984). Ammonia volatilization from urea and urea phosphates in calcareous soils. *Soil Sci. Soc. Am. J.* 48:921-926.