

Full Length Research Paper

Improving formulated nitrogen, phosphorus and potassium compound fertilizer using zeolite

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Ammonia volatilization from urea and ammonium containing compound fertilizers cause higher cost of fertilization in agriculture. In this study, an incubation experiment was carried out to compare the effect of different ratios of compound fertilizer amended with clinoptilolite zeolite on NH₃ volatilization, soil exchangeable NH₄ and available NO₃ contents on Bekenu Series (Tipik Tualemkuts) with surface-applied urea without additives. Treatments with zeolite significantly reduced NH₃ loss when compared with urea without additives. They also improved retention of exchangeable NH₄ and NO₃ and this was possible because zeolite favoured formation of ammonium and nitrate over ammonia. There is a potential for compound fertilizer with zeolite to improve nitrogen efficiency by lowering ammonia volatilization and increasing accumulation of exchangeable NH₄ and NO₃.

Key words: Ammonia volatilization, compound fertilizers, clinoptilolite zeolite, soil exchangeable ammonium, available nitrate.

INTRODUCTION

Compound fertilizers supply nutrients to plants. Ammonia volatilization from urea and ammonium containing compound fertilizers cause higher cost of fertilization in agriculture (Hanafi et al., 1999). About 1 to 60% of NH₃ volatilize (Christianson, 1989), hence causing low N use efficiency. Many laboratory studies such as coating urea with polymers (Hanafi et al., 1999; Junejo et al., 2011), urease inhibitors (Khalil et al., 2009) and acidifying materials to reduce NH₃ volatilization have been conducted. Technical processes with relatively high cost may lead to a risk of soil pollution (Watson, 2000; Ahmed et al., 2006; Junejo et al., 2011). In recent years, clinoptilolite zeolite approach has attracted much attention in the fertilizer industry.

According to Payra and Dutta (2003), clinoptilolite zeolite is a hydrated aluminosilicate having three-dimensional rigid crystalline networks that are 10⁻⁹ m in

size containing internal exchange sites that have high affinity for ammonium ion exchange. Clinoptilolite zeolite serves as excellent carrier regulator and stabilizes mineral fertilizer and is a source of nutrients such as K, Ca and Mg (Bagdasarov et al., 2004). In various studies, clinoptilolite zeolite has proven to reduce NH₃ volatilization. In an incubation experiment, Ahmed et al. (2006) found that treatments with larger amounts of humic acid and zeolite had the greatest effect when compared with urea alone in improving soil retention of NH₄ as well as minimizing the conversion of NH₄ to NO₃. In their study, Junrungreang et al. (2002) reported that chemical fertilizer with zeolite improved soil chemical properties, sugarcane growth and yield. Combination of higher dose of chemical fertilizer and higher dose of zeolite showed the highest effect on height, diameter and yield of sugarcane. However, according to Bernardi et al. (2010), amending urea with zeolite requires a relatively small increase in dry matter. Yet, by blending the compound fertilizer with clinoptilolite zeolite where clinoptilolite zeolite acts as supplementary nutrients could be an alternative way of formulating desired fertilizers in

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Table 1. Selected chemical and physical properties of Bekenu Series and clinoptilolite zeolite.

Property	Soil (0 to 15 cm)		Clinoptilolite zeolite (Value obtained)
	Value obtained	Standard data range	
pH(water)	4.70	4.6-4.9	7.03
pH(0.01M KCl)	3.43	3.8-4.0	6.37
Total organic carbon (%)	3.6	0.57-2.51	Nd
CEC(cmol kg ⁻¹)	12.8	3.86-8.46	75.4
Exchangeable K (cmol kg ⁻¹)	0.174	0.05-0.19	22.29
Exchangeable Ca (cmol kg ⁻¹)	0.717	0.05-0.19	50.06
Exchangeable Mg (cmol kg ⁻¹)	0.525	0.07-0.021	2.21
Texture	SL	SL	Nd
Bulk density(gm ⁻³)	1.01	Nd	Nd

CEC, Cation exchange capacity; SL, sandy loam; SCL, sandy clay loam; nd, not determined; standard data range (Paramanathan, 2000).

agriculture. In this study, an incubation experiment was conducted to compare the effect of different ratios of compound fertilizer incorporated with zeolite on NH₃ volatilization, soil exchangeable NH₄ and available NO₃ contents of an acid soil.

MATERIALS AND METHODS

The soil used in this study was a Tipik Tualemkuts (Bekenu Series). Soil samples were taken at 0 to 15 cm depth using an auger, air dried and ground to pass a 5 mm sieve. The clinoptilolite zeolite used was in powder form. Soil and clinoptilolite zeolite were analyzed for their selected physio-chemical properties using standard procedures. The pH of soil and clinoptilolite zeolite were determined in a ratio of 1:2.5 soil : distilled water suspension and 1 M KCl solution using a glass electrode (Peech, 1965). Soil organic carbon was determined using Walkley and Black (1934). Soil CEC was determined by leaching with ammonium acetate buffer adjusted to pH 7.0 followed by steam distillation (Bremner, 1965) and exchangeable K, Ca and Mg using by atomic absorption spectrophotometry (AAnalyst 800, Perkin Elmer Instruments, Norwalk, CT). The CEC of clinoptilolite zeolite was determined using CsCl method (Ming and Dixon, 1986). Exchangeable K, Ca and Mg of the clinoptilolite zeolite were extracted using Ming and Dixon (1986) and their concentrations determined as previously outlined. The soil texture was determined using hydrometer method (Tan, 2005).

Eight treatments were used to compare the percent of ammonia volatilization loss in sandy loam soil. The treatments per 250 g of soil evaluated were:

1. 14.88 g commercial compound fertilizer with ratio of 15:15:15 (control) (T1);
2. Compound fertilizer with ratio of 15:15:15 (4.85 g urea + 4.85 g TSP + 3.72 g MOP) mixed with 1.46 g clinoptilolite zeolite (T2);
3. Compound fertilizer with ratio of 13:15:13 (4.85 g urea + 5.61 g TSP + 3.73 g MOP) mixed with 3.01 g clinoptilolite zeolite (T3);
4. Compound fertilizer with ratio of 10:10:10 (4.85 g urea + 4.85 g TSP + 3.73 g MOP) mixed with 8.92 g clinoptilolite zeolite (T4);
5. Compound fertilizer with ratio of 8:8:8 (4.85 g urea + 4.85 g TSP + 3.71 g MOP) mixed with 14.46 g clinoptilolite zeolite (T5);
6. Compound fertilizer with ratio of 5.5:5.5:5.5 (4.85 g urea + 4.85 g TSP + 3.72 g MOP) mixed with 27.04 g clinoptilolite zeolite (T6);

7. 2.425 g urea without additives (control) (T7);
8. Soil alone (T8).

The amount of compound fertilizer used was calculated from the standard recommendation for mature Masmadu maize (Malaysian Agricultural Research and Development Institute, 1990). Only treatment 7 (urea alone) was scaled down to half, the other treatments (1 until 6) had 4.85 g of urea. Ammonia volatilization from soil was measured by a closed dynamic airflow system (Siva et al., 1999) with modifications. The treatments were applied on soil surface. Air was passed through the chambers at a rate of 3.5 L min⁻¹ and released NH₃ captured in the trapping solution containing 75 ml of boric acid with bromocresol green and methyl red indicator. Rate of air flow was maintained throughout the incubation period using a Gilmont flow meter (Gilmont Instrument, Great Neck, NY, USA) to measure and adjust air flow at room temperature. Boric acid was replaced 24 h and back titrated with 0.01 or 0.1 M HCl to estimate NH₃ released. Measurement was continued until the loss declined to 1% of the N added in the urea (Ahmed et al., 2008).

After incubation, the soil samples were taken and pH, exchangeable NH₄ and available NO₃ were determined. The exchangeable NH₄ and available NO₃ were extracted from the soil by the method of Keeney and Nelson (1982), and their amounts were determined using steam distillation method. The experimental design was fully randomized with three replications for all treatments. Analysis of variance (ANOVA) was used to test the treatment effects and means of treatments were compared using Tukey's test.

RESULTS AND DISCUSSION

The selected physio-chemical properties of Bekenu Series and clinoptilolite zeolite are summarized in Table 1. Values obtained for pH (water), exchangeable K and texture were consistent with those reported by Paramanathan (2000). Total organic carbon, CEC, exchangeable Ca and Mg contents were higher than the standard range probably due to cultivation.

The daily loss of ammonia (NH₃) recorded during the experiment is shown in Figure 1. The NH₃ started on the first day of incubation for T1 and T7 only. For T2, T3, T4, T5 and T6, NH₃ loss occurred on third day of incubation.

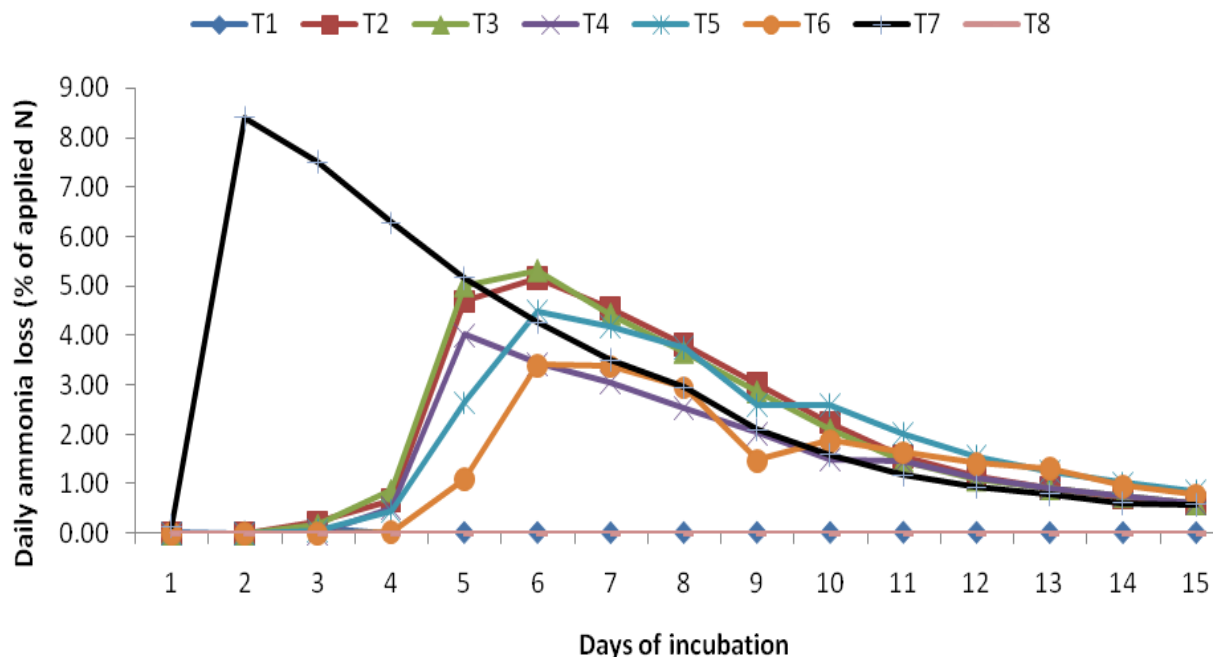


Figure 1. Daily loss of ammonia from incubation. For key to treatments see materials and methods.

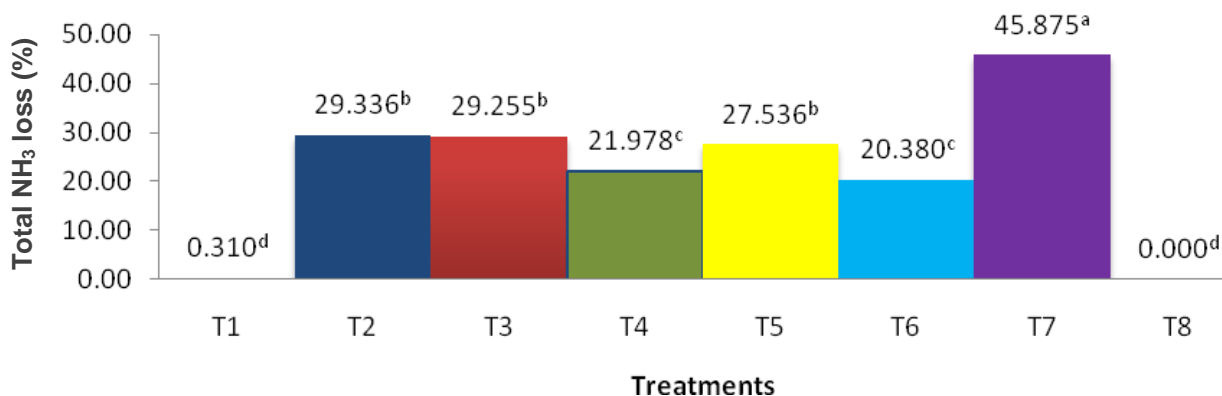


Figure 2. Total amounts of ammonia lost over 15 days of incubation. Different letters (within column) indicate significant difference between means using Tukey's test at $P = 0.05$. For key to treatments see materials and methods.

Treatments T1, T2, T3, T4, T5, T6 reduced maximum of NH_3 loss from 8.4 to 0.12, 5.16, 5.31, 4.02, 4.5 and 3.41% (of the N added as urea), respectively (Figure 1). The maximum NH_3 loss of the treatments occurred on days 2 (T7), 3 (T1), 4 (T4) and 5 (T2, T3, T5 and T6) of incubation after which there was a general decline until day 15 when the NH_3 loss was about 1% of the N added as urea (Figure 1). All the treatments (T2, T3, T4, T5 and T6) significantly reduced NH_3 loss when compared with urea without additives (T7) but lower than T1. The total amounts of NH_3 lost at the end of the incubation period as a percentage of urea-N were 0.310, 29.336, 29.255, 21.978, 27.538, 20.380, 45.875 and 0 (note: mean of

values with different letters are significantly different at $p \leq 0.05$ as determined by Tukey's test) for T1, T2, T3, T4, T5, T6, T7 and T8, respectively (Figure 2). All the treatments with clinoptilolite zeolite (T2, T3, T4, T5 and T6) significantly reduced NH_3 loss as compared to urea without additives (T7). T6 and T4 with greater amounts of clinoptilolite zeolite had the greatest effect on ammonia loss. The amount of N applied based on treatments (T2, T3, T4, T5 and T6) were twice that of urea only (T7); however the treatments significantly minimized total NH_3 loss as compared to urea only. The significant reduction of ammonia volatilization could be due to the retention of NH_4 on the cation-exchange sites of the zeolite and as

Table 2. Soil pH during 15 days of incubation.

Treatment	pH (H ₂ O)	pH (0.01 M KCl)
T1	5.13 ^c	4.92 ^c
T2	6.84 ^b	6.76 ^{ab}
T3	6.86 ^b	6.70 ^{ab}
T4	6.79 ^b	6.69 ^{ab}
T5	6.76 ^b	6.76 ^{ab}
T6	6.89 ^b	7.06 ^a
T7	7.72 ^a	6.41 ^b
T8	4.48 ^d	3.34 ^d

Different letters (within column) indicate significant difference between means using Tukey's test at P=0.05. For key to treatments see materials and methods.

Table 3. Effect of treatments on exchangeable ammonium and nitrate accumulation at 15 days of incubation.

Treatment	Exchangeable NH ₄ -N (mg L ⁻¹)	NO ₃ -N (mg L ⁻¹)
T1	15.64 ^a	0.21 ^b
T2	6.75 ^b	0.17 ^b
T3	6.55 ^b	0.04 ^b
T4	6.90 ^b	0.11 ^b
T5	7.07 ^b	0.21 ^b
T6	8.24 ^b	0.63 ^a
T7	3.07 ^c	0.07 ^b
T8	0.19 ^d	0.03 ^b

Different letters (within column) indicate significant difference between means using Tukey's test at P=0.05. For key to treatments see materials and methods.

CEC of the zeolite (75.4 cmol kg⁻¹) was substantial. Clinoptilolite zeolite may have served as a slow release fertilizer. Similar observation has been reported by Latifah et al. (2011) and Ahmed et al. (2008).

On the 15th day of incubation, soil pH (H₂O and KCl) of all treatments were significantly different (Table 2). This was because NH₃ loss varied much among treatments (Figure 2). The phosphoric acid produced by hydrolysis of acidic phosphates may have acidified the soil surrounding the acid zeolite mixture (Fan and Mackenzie, 1993).

There was significant difference in accumulation of exchangeable NH₄ for all treatments (Table 3). T1 had the highest accumulation of exchangeable NH₄, while T6 had the highest accumulation of available NO₃. Treatments amended with zeolite (T2, T3, T4, T5 and T6) caused higher accumulation of exchangeable NH₄ as compared to urea only (T7). For accumulation of NO₃, all treatments except T6 were not significantly different. The high accumulation of exchangeable NH₄ could be because of the high CEC of clinoptilolite zeolite (75.4

cmol kg⁻¹) as clinoptilolite zeolite effectively absorbs exchangeable NH₄ ions and releases it slowly. A similar finding has been reported by Latifah et al. (2011). This could be one of the reasons why there was loss of ammonia for urea without additives.

Conclusion

There is a potential for compound fertilizer with zeolite to improve nitrogen efficiency by lowering ammonia volatilization and increasing accumulation of exchangeable NH₄ and NO₃.

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