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Full Length Research Paper

Ammonia loss, soil exchangeable ammonium and available nitrate contents from mixing urea with zeolite and peat soil water under non-waterlogged condition

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Efficient utilization of urea-N in most agricultural systems is impeded by ammonia volatilization. This study investigated the effect of mixing urea with zeolite and peat soil water on ammonia volatilization, soil exchangeable ammonium and available nitrate contents, compared with urea without additives under non waterlogged condition. The mixtures significantly reduced ammonia loss by 5 to 14% compared with urea without additives (straight urea, 46% N). The pH of the soil with the mixtures was also significantly different compared with that of urea without additives. All the mixtures of zeolite and peat soil water with urea significantly improved soil exchangeable ammonium (by 42 to 76 ppm) retention compared with urea without additives. Only one mixture significantly increased soil available nitrate content. The temporary reduction of soil pH may have retarded urea hydrolysis. This encouraged beneficial formation of ammonium over ammonia hence, the significant reduction of ammonia volatilization upon the use of the mixtures produced in this study. It could be possible to improve the efficiency of urea surface-applied to high value crops by addition of zeolite and peat soil water.

Key words: Ammonia volatilization, urea-N use efficiency, peat soil water, exchangeable ammonium, zeolites, available nitrate.

INTRODUCTION

Ammonia loss from urea occurs in acid soils because rapid increase in soil microsite pH and ammonium ions during hydrolysis urea (Rosliza et al., 2009). This phenomenon reduces urea-N use efficiency in agriculture (Sparks, 2005). To overcome this problem, attempt has been made to use acidic material such as triple super phosphates to control ammonia loss via reduction of microsite pH (Ahmed et al., 2009b). However, amending urea with these acidic materials is expensive. Additionally, because the mixture of these acidic materials and urea is corrosive, the mixtures require special precautions in handling and storage. Even if the use of these acidic materials favour formation of ammonium ions over ammonia gas, without good retention of the ammonium ions in the soil, efficient use of these ions by plants cannot be guaranteed. This is because both ammonium and nitrate ions are subject to leaching (Brady and Weil, 2002). Furthermore, while plant N can be decreased by the biological transformation of ammonium to nitrate, under anaerobic conditions, and nitrate can also be biologically denitrified to gases which lead to additional loss of N from soil (Brady and Weil, 2002). In this regard, if urea is mixed with peat soil water (high in organic acids) and zeolite (has high affinity for ammonium ions), peat soil water could be used to control soil microsite pH through inhibition of ureolytic activity of microorganisms while zeolite may help to retain and release ammonium ions timely for plant use.

Peat soil water (pH 3 to 4) is abundant in Malaysia as for instance, the State of Sarawak alone has 1.5 million peatland (Andriesse, 1998). Before and after a peatland is opened for cultivation, peat water is drained out and usually the drained water becomes more of a liability than asset. It is in line with that this study seeks to put to good

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Table 1. Evaluated treatments per 250 g of soil.

Treatment no.	Treatment detail
T0	Soil only
T1	2.02 g urea
T2	2.02 g urea + 0.75 g zeolite + 175 ml peat soil water
T3	2.02 g urea + 1.00 g zeolite + 175 ml peat soil water
T4	2.02 g urea + 175 ml peat soil water (T4)

use of peat water which is drained from peatlands when they are opened for inevitable cultivation. On the other hand, zeolites can be used to reduce ammonia loss because of their high CEC (cation exchange capacity) and great affinity for ammonium ions (Latifah et al., 2010). The zeolites have the potential to reduce ammonia loss because their small internal channels can protect ammonium ions from excessive nitrification by microbes (Latifah et al., 2010). Therefore, the objective of this study was to determine the effect of mixing urea with zeolite and peat water on ammonia volatilization, soil exchangeable ammonium and available nitrate contents, compared with applied urea without additives under non waterlogged condition.

MATERIALS AND METHODS

The clinoptilolite zeolite used in this study was imported from Indonesia. Peat soil water (waste water) was collected from natural flows of peat water at Suai Miri Sarawak, Malaysia. The mineral soil used was Bekenu Series (Fine loamy, siliceous, isohyperthermic, red-yellow to yellow Tipik Tualemkuts). It was sampled in an undisturbed area of Universiti Putra Malaysia Bintulu Sarawak Campus, Malaysia using an auger. The soil taken at 0 to 15 cm depth was air dried and ground to pass 2.0 mm sieve for laboratory experiment. The soil texture was determined using the hydrometer method (Tan, 2005) and its field capacity and bulk density determined by the method described by Tan (2005). The pH of the soil and zeolite were determined in a 1:2 soil: distilled water suspension and KCl using a glass electrode (Tan, 2005). However, the pH of the peat soil water was determined directly from filtered samples using a glass electrode. The soil total carbon was determined using the loss-on-ignition method (Tan, 2005). Soil available P was extracted using the double acid method (Tan, 2005) followed by blue method (Murphy and Riley, 1962). The Kjedhal method was used to determine total N (Bremner, 1965). Exchangeable cations were extracted using the leaching method (Tan, 2005) and their concentrations were afterwards determined using Atomic Absorption Spectrometry (AAS). Soil CEC was determined by the leaching method followed by steam distillation (Bremner, 1965). The CEC of clinoptilolite zeolite was determined using the CsCl method (Ming and Dixon, 1986). It must be noted that the CsCl method used is the most suitable method because the leaching method tends to underestimate CEC of zeolites because of trapping of ammonium ions in the zeolites channels.

The treatments evaluated per 250 g soil are as shown in Table 1. These materials were mixed thoroughly to get homogenous mixture. The 250 g soil samples in 500 ml volumetric flask were moistened with distilled water at 70% field capacity. The daily loss of NH_3 from urea was measured by using a closed-dynamic air flow system method (Siva et al., 1999; Ahmed et al., 2006a, b). The system consisted of an exchange chamber of 500 ml conical flask containing 250 g soil sample and 250 ml conical flask containing 75 ml of boric acid which were both stop and fit with an inlet/outlet. The inlet of the chamber was connected to an air pump and the outlet was connected by polyethylene tubing which contains boric acid and indicator solution to trap ammonia gas (Ahmed et al., 2006a, b). Air was passed through the chamber at the rate of 3.5 L^{-1} min^{-1} $chamber^{-1}$. This rate of air flow was maintained throughout the incubation period using a Gilmont flow meter (Gilmont Instrument, Great Neck, New York) to measure and adjust the air flow when necessary.

The released ammonia captured in a trapping solution which contains 75 ml of boric acid with bromocresol green and methyl red indicator was titrated with 0.1 M HCl to estimate the amount of NH_3 (g) released. The entire incubation was conducted at room temperature. The boric acid indicator which was used to capture ammonia was replaced every 24 h during incubation for 13 days, a period when ammonia loss was less than 1% (Ahmed et al., 2006a, b). After 13 days of incubation, soil samples were analyzed for pH, exchangeable ammonium and available nitrate. Soil pH was determined by the method previously stated.

The method of Keeney and Nelson (1982) was used to extract soil exchangeable ammonium and available nitrate followed by steam distillation. The experimental design was a completely randomized design with three replicates for each treatment. Analysis of variance was used to test treatment effects and means of treatments were compared using Duncan's test (SAS version 9.2).

RESULTS AND DISCUSSION

The selected physical and chemical properties of Bekenu Series are summarized in Table 2. The chemical properties were consistent with those reported by Paramananthan (2000) except for exchangeable Ca, which was relatively high probably because of liming.

The pH of the peat soil water and zeolite were acidic while the pH of urea was basic (Table 3). The CEC and the exchangeable Ca, Mg and K contents of the zeolite were high.

Soil alone did not contribute to ammonia loss throughout the 13 days of incubation (Figure 1). The ammonia volatilization started a day after the treatments were applied but the volatilization with urea alone (T1) was higher than those of the mixtures (T2, T3, and T4) who were urea amended with zeolite and peat soil water (Figure 1). Afterwards, the loss significantly declined regardless of treatment to less than 1%. The total amounts of ammonia volatilized over the 13 days of incubation are summarized in Table 4. All the

Table 2. Selected physico-chemical properties of Bekenu series.

Property	Value obtained	Standard data range*
pH (water)	4.11	4.6 - 4.9
pH (KCl)	3.86	3.8 - 4.0
CEC (cmol kg^{-1})	7.33	3.86 - 8.46
Texture	SCL	SCL
Bulk density (gcm^{-3})	1.51	nd
Organic matter (%)	2.28	nd
Available P (mg kg^{-1})	2.39	nd
Total Nitrogen (%)	0.15	0.04 - 0.17
Organic carbon (%)	0.57	0.57 - 2.51
Exchangeable Ca (mg kg^{-1})	2.05	0.05 -0.19
Exchangeable Mg (mg kg^{-1})	0.18	0.07 - 0.21
Exchangeable K (mg kg^{-1})	0.16	0.05 - 0.19

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

Table 3. Selected chemical properties of zeolite, peat soil water and urea.

Property	Zeolite	Peat soil water	Urea
pHw	6.52	3.90	8.00
pH (KCl)	5.38	nd	nd
CEC (cmol kg^{-1})	100.33	nd	nd
Total Nitrogen (%)	nd	0.16	nd
Exchangeable Ca (mg kg^{-1})	20.19	0.42	nd
Exchangeable Mg (mg kg^{-1})	31.50	0.12	nd
Exchangeable K (mg kg^{-1})	28.16	0.02	nd

CEC, Cation exchange capacity; nd, not determined.

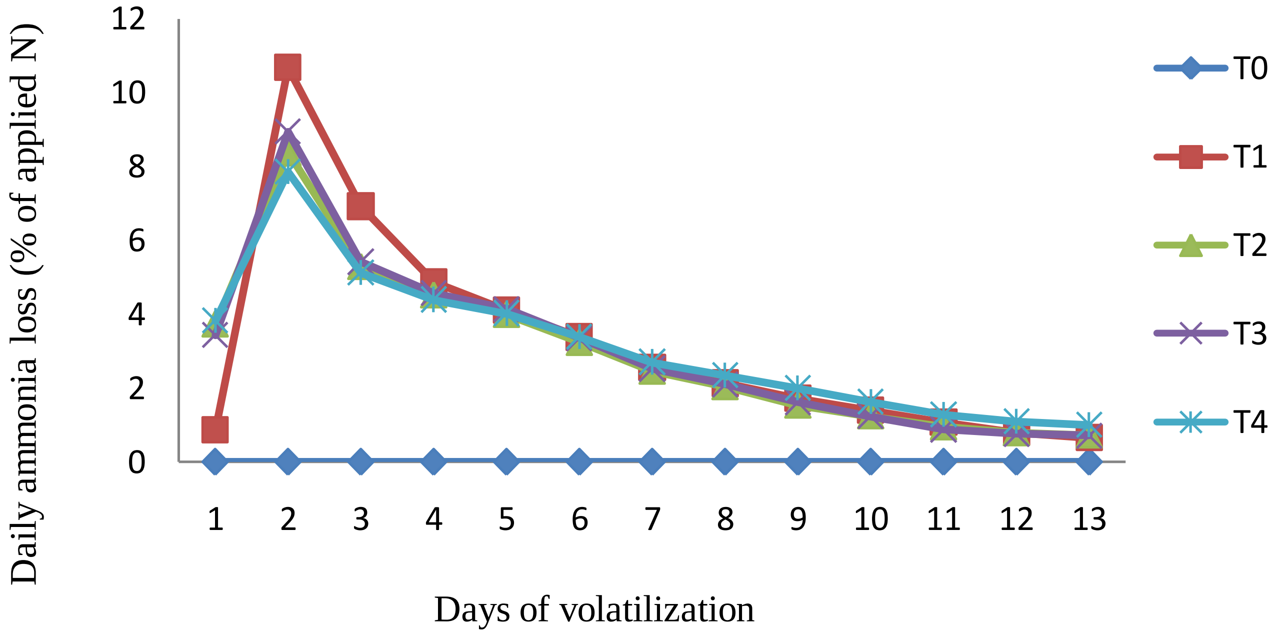

Figure 1. Ammonia volatilization over 13 days of incubation under non-waterlogged condition.

Table 4. Daily ammonia loss and soil pH from incubation in non-waterlogged condition.

Treatment	Ammonia loss (%)	soil pH (water)
T0	0^e	5.14^c
T1	41.50^a	7.68^a
T2	39.45^b	7.17^b
T3	35.58^d	7.27^b
T4	37.44^c	7.23^b

Means with the same letter are not significantly different by DNMRT at $p \leq 0.05$.

Table 5. Accumulation of exchangeable ammonium and available nitrate at 13 days of incubation under non waterlogged condition.

Treatment	NH_4^-N (ppm)	NO_3^- N (ppm)
T0	11.98^d	2.46^c
T1	85.80^c	4.30^b
T2	153.55^a	4.55^b
T3	161.42^a	8.42^a
T4	127.44^b	4.44^b

Means with the same letter are not significantly different by Duncan's test at $p \leq 0.05$.

treatments with zeolite and peat soil water (T2, T3, and T4) significantly reduced ammonia volatilization compared with urea without additives (T1). At 13 days of incubation, the pH of the soils treated with the mixtures was significantly lower than that of urea without additives (Table 4). The significant reduction ammonia volatilization caused by the mixtures could be partly attributed to the inclusion peat soil water in the treatments because considering the acidic nature of the peat soil water, it might have temporary acidified the soil surrounding urea-zeolite-peat soil water mixture because observation has shown that when the soil pH is less than 5.5, urea hydrolyzes slowly (Fan and Mackenzie, 1993).

As a result, this process might have effectively increased the volume soil with which urea mixes, and also increased the time required for complete hydrolysis (Fan and Mackenzie, 1993). Furthermore, during urea hydrolysis, lower soil pH favoured formation of ammonium ions over ammonia, hence the significant reduction in ammonia loss observed.

The significant content of soil exchangeable NH_4^+ with all the mixtures compared with urea without additives as presented in Table 5 was comparable with that of Fan and Mackenzie (1993). However, with the exception of T3, the other mixtures (T2 and T4) did not significantly affect the soil available nitrate compared with urea without additives (T1).

This observation was consistent with the work of Ahmed et al. (2008) but it is contrary to the findings of Fan and Mackenzie (1993). The high accumulation of soil exchangeable ammonium ions suggests that the inclusion of zeolite has improved the soil ammonium retention (Ahmed et al., 2010; Latifah et al., 2010). The inclusion of zeolite also minimized the conversion of ammonium to nitrate as the available nitrate content was generally low (Ahmed et al., 2010; Latifah et al., 2010).

The high retention of ammonium observed may also be associated with the high CEC (100.33 cmol kg^{-1}) of the zeolite in the mixtures (T2, T3, and T4). This was possible because the channels in the zeolite might have effectively absorbed the ammonium ions and released them slowly. In a related study, Lewis et al. (1984) reported that ammonium-exchanged clinoptilolite zeolite acted as a slow-release fertilizer in a medium textured, porous soil. They also observed that clinoptilolite zeolite reduced ammonia volatilization when urea and clinoptilolite were applied to a coarse-textured alkaline soil.

In relation to this, the high loss of ammonia from urea without additives was possible because of the increased alkalinity from urea hydrolysis exceeding the localized buffer capacity of the soil or its ammonium retention ability.

Conclusion

Mixing urea with zeolite and peat soil water can effectively reduce ammonia loss than urea without additives. This approach also encourages the formation of ammonium and available nitrate ions over ammonia hence, ensuring good retention of ammonium and nitrate within the soil.

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REFERENCES

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. Intl. J. Agric. Res., 1: 25-31.

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.

Ahmed OH, Braine CHY, Nik Muhamad AM (2010). Minimizing ammonia loss from urea through mixing with zeolite and acid sulphate soil. Intl. J. Phy. Sci., 5(14): 2198-2202.

Ahmed OH, Aminuddin H, Husni MHA (2008). Enhancing the urea-N use efficiency in maize (Zea mays) cultivation on acid soils amended with zeolite and TSP. Scientific World J., 8: 394-399.

Andriesse JP (1998). Nature and management of tropical peat soils. FAO. Soils Bull., 59: 1-165.

Brady NC, Weil RR (2002). The nature and properties of Soils (13th ed.), New York, USA.

Bremner JM (1965). Total Nitrogen. In, Method of soil analysis, Part 2, Black CA, Evants DD, Ensminger LE, White JL, Clark FE, Dinauer RC (eds.), Am. Soc. Agron., Madison, Wisconcin, pp. 1149-1178.

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.

Keeney DR, Nelson DW (1982). Nitrogen-inorganic forms. In, Method of Soil Analysis, Part 2 (2nd ed), Page AL, Keeney DR, Baker DE, Miller RH, Ellis R, Rhoades JD (eds.). Agron. Monograph, 9. ASA and SSSA, Madison, Wisconsin.

Latifah O, Ahmed OH, Nik Muhamad AM (2010). Minimizing ammonia volatilization in waterlogged soils through mixing of urea with zeolite and peat soil water. Intl. J. Phy. Sci., 5(11): 2193-2197.

Lewis MD, Moore FD III, Goldsberry KL (1984). Ammonium-exchange clinoptilolite and granulated clinoptilolite with urea as nitrogen fertilizers. In, Zeo-agriculture: use natural zeolites in agriculture and aquaculture, Pond WG, Mumpton FA (eds.), Westview Press, Boulder, CO.

Ming DW, Dixon JB (1986). Clinoptilolite in South Texas soils. Soil Sci. Soc. Am. J., 50: 1618-1622.

Murphy J, Riley JI (1962). A modified single solution method for the determination of phosphate in natural waters. Anal. Chim. Acta., 27: 31-36.

Paramananthan S (2000). Soils of Malaysia: Their characteristics and identification. (Volume 1). Acad. Sci. Malaysia, Kuala Lumpur, Malaysia.

Rosliza S, Ahmed OH, Nik Muhamad AM, Jalloh MB (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 KB, 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 Analy., 30: 785-804.

Sparks DL (2005). Advances in agronomy, Newark: Academic Press Elseiver, USA.

Tan KH (2005). Soil sampling, preparation, and analysis (2nd ed.), Boca Raton, Florida, USA.