

## Effect of Mixing Urea with Humic Acid and Acid Sulphate Soil on Ammonia Loss, Exchangeable Ammonium and Available Nitrate

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**Abstract: Problem statement:** Ammonia loss due to rapid hydrolysis of urea in soil following surface application can be substantial. Ammonia loss in agriculture is estimated to be 1 to 60%. This laboratory study compared the effect of three different urea-humic acid-acid sulphate soil mixtures on  $\text{NH}_3$  loss and soil ammonium and nitrate contents, with loss from surface applied urea without additives (urea alone). **Approach:** Humic acid, acid sulfate soil and soil use in the incubation study was analyzed for selected soil physical-chemical properties. The fertilizers mixture and ammonia loss was done using standard methods. The treatments were evaluated in Randomized Complete block Design with 3 replications. The data obtained at the end of the study on total ammonia loss, soil pH, exchangeable ammonium and available nitrate were analyzed using analysis of variance and the means were compared using Duncan's test using Statistical Analysis System (SAS) version 9.2. **Results:** The soil used to test treatments was a sandy clay loam Typic Paleudults (Nyalau series). The mixture significantly reduced  $\text{NH}_3$  loss by between 31.5 and 36.7% compare with urea alone with larger reductions with higher rate of humic acid (0.75 and 1 g  $\text{Kg}^{-1}$  of soil) and acid sulphate soil (0.75 g  $\text{Kg}^{-1}$  of soil). The impact of the treatment also showed significant effect on the soil pH and ammonium content at the end of study. **Conclusion:** Amending urea with acid sulphate soil and humic acid can reduce ammonia loss in acid soils by improving ammonium retention. This may in effect improve urea-N use efficiency as well as reducing environmental pollution in agriculture.

**Key words:** Ammonia volatilization, humic acid, acid sulphate soil, urea, ammonium, nitrate.

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### INTRODUCTION

Urea is noted for being the most widely used Nitrogen (N) fertilizer in agriculture, because of its high N and low price. Ammonia loss due to rapid hydrolysis of urea in soil following surface application can be substantial<sup>[1,2]</sup>. An approach to solve this problem involves control of the dissolution and hydrolysis of urea-N availability by reducing the microsite pH with acid materials such as acid phosphates and phosphoric acid<sup>[3-5]</sup>. The cost of amendments, however, prohibits their use and effective low-cost, readily available amendments would encourage their application. Urea phosphate, which is a mixture of urea and phosphoric acid, has been reported to reduce ammonia ( $\text{NH}_3$ ) volatilization from urea and reduces seedling damage<sup>[6,7,8]</sup>. However, these mixtures are corrosive and require special precautions in handling and storage.

Considering the low pH (usually less than 3.5) and low cost of acid sulphate soil (ASS) and humic acid (HA) from peat soils, a paradigm approach could be the use of little amount of these soils to amend urea before soil application. This could be of a great benefit to Malaysia and elsewhere because an alternative such as this encourages the usage of acid sulphate soils and peat soils in the country where these soils have estimated to be 0.5 million ha<sup>[9]</sup> and 2.5 million ha<sup>[10]</sup>, respectively. At the moment, Malaysia imports HA based fertilizers from China and Australia at a high cost.

The new approach of reducing ammonia loss at the same time increasing N use efficiency in agriculture is worth investigating because the cultivation of crops such as oil palm, coconut, rice and so on and so forth has not be successful on acid sulphate and peat soils in Malaysia as desired<sup>[9]</sup>.

Thus in this study, the effects of mixing urea with HA and ASS on ammonia loss, exchangeable

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ammonium (NH<sub>4</sub>) and available nitrate (NO<sub>3</sub>) under laboratory condition were investigated.

### MATERIALS AND METHODS

Urea, HA and ASS were the materials used to produce Urea-N fertilizer mixtures using the method described by Ahmed *et al.*<sup>[3]</sup> with some modification where the materials were weighed separately based on the treatments below before mixing them in a plastic vial by using reciprocal mechanical shaker (200 rpm).

The HA was isolated from tropical peat soil by the method described by<sup>[11,12]</sup> with 4 h extraction and fractionation periods. The oven dried yield of HA was express as percentage (%) of the weight of soil used. Functional group analysis was conducted by the method described by Inbar *et al.*<sup>[13]</sup>. Level of humification of HA was determined by E<sub>4</sub>/E<sub>6</sub> method using spectroscopy<sup>[14]</sup>. The model of the spectrometer used was Lambda 25 UV/VIS (Shelton, CT, USA).

The ASS was collected from Kuching, Sarawak (Telaga Air mangrove and Rempagi) at 0-15 cm depth. The soil was air dried, meshed and sieved to pass a 2 mm sieve before it was characterized for pH<sup>[15]</sup>, Cation Exchange Capacity (CEC) by leaching with 1 N ammonium acetate (adjusted to pH 7) followed with steam distillation technique<sup>[16,19]</sup>, total N by the Microkjedhal method<sup>[17]</sup>, exchangeable cations (K, Ca, Mg, Na) by atomic absorption spectrophotometry (A Analyst 800, Perkin Elmer Instruments, Norwalk, CT)<sup>[18]</sup> and inorganic N (NO<sub>3</sub> and NH<sub>4</sub>)<sup>[19]</sup>. Both HA and ASS were meshed again to pass sieve less than 1 mm after which they were used to mix urea.

The soil used for the incubation study on daily ammonia loss was Nyalau series (Typic Paleudults) and its texture was sandy clay loam. This soil was collected from UPM Bintulu Sarawak campus at 0-15 cm depth, air dried, meshed and sieve to pass a 2 mm sieve. This soil was analyzed for field capacity, bulk density, soil pH, total N, available NO<sub>3</sub> and exchangeable NH<sub>4</sub>, Ca, Mg, Fe, Cu and K.

Closed-dynamic air flow system described by<sup>[3]</sup> was used to evaluate the treatments below:

- Soil alone (T1)
- 2.02 g urea alone (T2)
- 2.02 g urea + 0.75 g HA + 0.75 g ASS (T3)
- 2.02 g urea + 0.75 g HA (T4)
- 2.02 g urea + 1.00 g HA (T5)

The daily ammonia loss was determined for 22 days in Complete Randomized Design (CRD) with three replications.

Analysis of variance was used to test for treatments effects and means were compared using Duncan's test<sup>[20]</sup>.

### RESULTS

The selected chemical properties of the soil (Table 1) were typical of Nyalau series and were consistent with those reported by Paramanathan<sup>[21]</sup>. pH and CEC of the ASS were similar to those reported by Shamsuddin<sup>[9]</sup> who also give the properties of tropical ASS. The carbon, phenolic, carboxylic and total acidity of HA were comparable with those reported by Schnitzer<sup>[22]</sup> and Tan<sup>[23]</sup>.

The daily loss of NH<sub>3</sub> is shown in Fig. 1. The treatments with urea additives (T3, T4 and T5) significantly reduced NH<sub>3</sub> loss compared to urea alone (T2).

Table 1: Selected chemical and physical characteristics of HA, ASS and soil (Nyalau series)

Property	HA	ASS	Soil
pH (water)	nd	3.45	4.85
pH (1 M KCl)	nd	nd	3.65
Total organic carbon (%)	55.59	nd	nd
CEC (cmol kg <sup>-1</sup> )	<sup>a</sup>	40.50	21.25
Carboxylic group (cmol kg <sup>-1</sup> )	300	nd	nd
Phenolic group (cmol kg <sup>-1</sup> )	220	nd	nd
Total acidity <sup>a</sup> (cmol kg <sup>-1</sup> )	520	nd	nd
Total N	nd	nd	0.4132
Exchangeable K (cmol kg <sup>-1</sup> )	nd	nd	0.8016
Exchangeable Mg (cmol kg <sup>-1</sup> )	nd	nd	0.0177
Exchangeable Ca (cmol kg <sup>-1</sup> )	nd	nd	0.0001
Exchangeable Na (cmol kg <sup>-1</sup> )	nd	nd	0.0280
Exchangeable NH <sub>4</sub> <sup>+</sup>	nd	nd	0.1540
Available NO <sub>3</sub> <sup>-</sup>	nd	nd	0.1243
Field capacity (%)	nd	nd	75.57
Texture	nd	nd	SCL

HA: Humic Acid; ASS: Acid Sulphate Soil; CEC: Cation Exchange Capacity; SCL: Sandy Clay Loam; nd: Not determined; <sup>a</sup>CEC of humic acid = total acidity

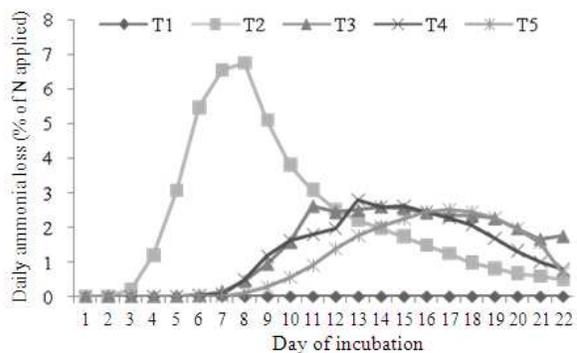


Fig. 1: Daily loss of ammonia from incubation. For key to treatments see materials and method

Table 2: Total amount of ammonia loss and soil pH over 22 days of incubation

Treatment	NH <sub>3</sub> -loss (% of urea-N)	pH water
T1	0.000 <sup>c</sup>	4.5733 <sup>c</sup>
T2	48.757 <sup>a</sup>	7.2300 <sup>b</sup>
T3	33.235 <sup>b</sup>	7.5900 <sup>a</sup>
T4	31.355 <sup>b</sup>	7.5000 <sup>a</sup>
T5	36.720 <sup>b</sup>	7.5250 <sup>a</sup>

**Note:** Different alphabets indicate significant difference between means using Duncan's test at p = 0.05

Table 3: Effect of treatments on exchangeable ammonium and nitrate accumulation

Treatment	Exchangeable NH <sub>4</sub> <sup>+</sup> -N (mg Kg <sup>-1</sup> )	Available NO <sub>3</sub> <sup>-</sup> -N (mg Kg <sup>-1</sup> )
T1	29.03 <sup>c</sup>	14.015 <sup>a</sup>
T2	994.71 <sup>a</sup>	21.020 <sup>a</sup>
T3	693.50 <sup>b</sup>	21.017 <sup>a</sup>
T4	697.00 <sup>b</sup>	21.020 <sup>a</sup>
T5	1099.79 <sup>a</sup>	14.010 <sup>a</sup>

**Note:** Different alphabets indicate significant difference between means using Duncan's test at p = 0.05

Table 2 is shows the total amount of NH<sub>3</sub> loss for the 22 days of incubation. Even though the pH for T3, T4 and T5 were significantly higher than that for T2 at the end of the incubations the former treatments (T3, T4 and T5) significantly reduced NH<sub>3</sub> loss compared to the latter (T2).

The soil exchangeable NH<sub>4</sub> and available NO<sub>3</sub> accumulation at the end of the study is presented in Table 3. There was no significant effect of T2, T3, T4 and T5 on available nitrate. In terms of exchangeable ammonium, those of T3 and T4 were significantly lower than those of T2 and T5.

### DISCUSSION

The reduction of ammonia loss for all treatments with HA and ASS (T3, T4 and T5) compared treatments with urea alone (T2) was because of the temporary acidic condition at the urea micro-site during urea hydrolysis. This observation was consistent with the work of Ahmed *et al.*<sup>[3]</sup> and Siva *et al.*<sup>[5]</sup> who also found a reduction in NH<sub>3</sub> loss when urea was mixed with HA or TSP. This may have effectively increased the volume of soil with which urea was mixed with and also increased the time required for complete hydrolysis<sup>[4]</sup>.

The significant increase in soil pH for T2, T3, T4 and T5 treatments shows that the urea hydrolysis occurred but this process was significantly for T3, T4 and T5. This suggests that the more hydrogen ions were consumed under these treatments. The sharp increase in soil pH could be due to the soil texture (Table 1).

There was significant accumulation of exchangeable NH<sub>4</sub> of mixtures with HA and ASS (T3 and T4) compared with mixture of 1 g HA (T5) as high amount of HA (phenolic and carboxylic group) can help to retain more NH<sub>4</sub> nevertheless the available nitrate did not have any significant effect. The insignificant effect of available nitrate for all treatments is respected to the similar effect of ammonia loss where the N from urea has been volatilized. This observation was consistent with the research of<sup>[3-4]</sup>.

### CONCLUSION

Amending urea with ASS and HA can reduce ammonia loss in acid soils by improving ammonium retention. This may in effect improve urea N use efficiency as well as reducing environmental pollution in agriculture.

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### REFERENCES

1. Cai, G.X., D.L. Chen, H. Ding, A. Pacholski, Z.H. Fan and Z.L. Zhu, 2002. Nitrogen losses from fertilizers applied to maize, wheat and rice in the North China Plain. *Nutr. Cycl. Agrosyst.*, 63: 187-195. DOI: 10.1023/A:1021198724250
2. Preasertsak, P., J.R. Freney, P.G. Saffiaga, O.T. Denmead and B.G. Prove, 2001. Fate of urea nitrogen applied to a banana crop in the wet tropics of Queensland. *Nutr. Cycl. Agrosyst.*, 59: 65-73. DOI: 10.1023/A:1009806826141
3. Ahmed, O.H., H. Aminuddin and M.H.A. Husni, 2006. Ammonia volatilization and ammonium accumulation from urea mixed with zeolite and triple superphosphate. *Acta Agric. Scandinavica, Section B-Plant Soil Sci.*, 58: 182-186. DOI: 10.1080/09064710701478271
4. Fan, M.X. and A.F. Mackenzie, 1993. Urea and phosphate interactions in fertilizers microsites: Ammonia volatilizations and pH changes. *Soil Sci. Soc. Am. J.*, 57: 839-845. <http://soil.scijournals.org/cgi/content/abstract/57/3/839>

5. Siva, K.B., H. Aminuddin, M.H.A. Husni and A.R. Manas, 1999. Ammonia volatilization from urea as affected by tropical-based Palm Oil Mill Effluent (POME) and peat. *Commun. Soil Sci. Plant Anal.*, 30: 785-804. DOI: 10.1080/00103629909370246
6. Bremner, J.M. and L.A. Douglas, 1971. Decompositions of urea phosphate in soils. *Soil Sci. Soc. Am. Proc.*, 35: 575-578. <http://soil.scijournals.org/cgi/content/abstract/35/4/575>
7. Fenn, L.B. and J. Richards, 1989. Ammonia loss from surface applied urea-acid products. *Fertil. Res.*, 9: 265-275. DOI: 10.1007/BF01050352
8. Fenn, L.B., G. Tatum and G. Horst, 1990. Ammonia loss from surface applied mixture of urea-calcium-potassium salts in the presence of phosphorus. *Fertil. Res.*, 21: 125-131. DOI: 10.1007/BF01087421
9. Shamsuddin, J., 2006. Acid Sulfate Soils in Malaysia. University Putra Malaysia Press Serdang, Selangor, ISBN: 9832871875, pp: 137.
10. Andriessse, J.P., 1988. Nature and management of tropical peat soil. *FAO Soils Bulletin* 59. FAO., Rome. ISBN: 92-5-102657-2, pp: 178.
11. Susilawati, K., O.H. Ahmed, A.M. Nik Muhamad and M.Y. Khanif, 2008. Simple method purifying humic acids isolated from tropical hemists (peat soil). *Am. J. Applied Sci.*, 5: 1812-1815. <http://www.scipub.org/fulltext/ajas/ajas5121812-1815.pdf>
12. Ahmed, O.H., M.H.A. Husni, A.R. Anuar, M.M. Hanafi and E.D.S. Angela, 2004. A modify way of producing humic acid from pineapple leaves. *J. Sustain. Agric.*, 25: 129-139. <http://direct.bl.uk/bld/PlaceOrder.do?UIN=161720160&ETOC=RN&from=searchengine>
13. Inbar, Y., Y. Chen and Y. harder, 1990. Humic substance formed during the composting of organic matter. *Soil Sci. Soc. Am. J.*, 54: 1316-1323. <http://soil.scijournals.org/cgi/content/abstract/54/5/1316>
14. Stevenson, F.H., 1994. *Humus Chemistry: Genesis, Composition, Reactions*. John Wiley and Son, New York, ISBN: 0471594741, pp: 378-486.
15. Brady, N.C. and R.R. Weil, 2002. *The Nature and Properties of Soils*. 13th Edn., Pearson Education, Inc., New Jersey, ISBN: 0130167630, pp: 498-540.
16. Cottenie, A., 1980. Soil testing and plant testing as a basis of fertilizer recommendation. *FAO. Soils Bull.*, 38: 70-73.
17. Jones, J.B., 2001. *Laboratory Guide for Conducting Soil Tests and Plant Analysis*. CRC Press, USA., ISBN: 0849302064, pp: 384.
18. Tan, K.H., 1996. *Soil Sampling, Preparation and Analysis*. Marcel Dekker, Inc., New York, ISBN: 0824796756, pp: 408.
19. Keeney, D.R. and D.W. Nelson, 1982. Nitrogen-Inorganic Forms. In: *Methods of Soil Analysis, Part 2*, Page, A.L., A.L. Page, D.R. Keeney, D.E. Baker, R.H. Miller, R. Jr. Ellis and J.D. Rhoades (Eds.). 2nd Edn., *Agron. Monogr.* 9. ASA and SSSA, Madison, WI., ISBN: 0891180729.
20. SAS., 2001. *SAS/STAT Software*. SAS Institute, Cary, NC., ISBN: 10: 1580258506.
21. Paramanathan, S., 2000. *Soils of Malaysia: Their Characteristics and Identification*. Academy of Sciences Malaysia, Kuala Lumpur. ISBN: 9839445065.
22. Schnitzer, M. and C.M. Preston, 1986. Analysis of humic acids by solution and solid state carbon-13 nuclear magnetic resonance. *Soil Sci. Soc. Am. J.*, 50: 326-331. <http://soil.scijournals.org/cgi/content/abstract/50/2/326>
23. Tan, K.H., 2003. *Humic Matter in Soil and the Environment: Principles and Controversies*. Marcel Dekker, Inc., New York, ISBN: 0-8247-4272-9, pp: 408.