

Ammonia Volatilization from Malaysian Soils Following Application of Urea

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ABSTRAK

Penambahan baja urea dipermukaan tanah selalunya menyebabkan kehilangan N melalui pengruapan ammonia. Kajian keatas pengruapan ammonia di tanah tropika adalah kurang. Kajian ini dijalankan untuk menentukan kehilangan N melalui pengruapan ammonia bagi tanah di Malaysia dan mengkaji kesan beberapa sifat tanah terhadap kadar kehilangan ini. Penentuan aktiviti urease dan kehilangan pengruapan ammonia ditentukan di makmal keatas 22 tanah permukaan (0-15 sm) yang biasa terdapat di Malaysia. Penentuan pengruapan ammonia ditentukan dengan menggunakan teknik "force draft". Pengruapan ammonia ditentukan pada tiap-tiap hari selama tujuh hari. Kehilangan pengruapan ammonia daripada 22 tanah yang dikaji adalah pada julat 0.5 hingga 53% daripada N yang ditambah kebanyakan tanah mempunyai nilai dilingkungan 35%. Kehilangan pengruapan ammonia pada tanah asid sulfat adalah rendah. Sebahagian besar daripada kehilangan berlaku dalam 3-4 hari selepas baja urea ditambah. Aktiviti urease adalah pada julat 12.20 hingga 150.50 ug/g N/h dan nilainya tidak dipengaruhi oleh tekstur tanah dan kandungan C. Aktiviti urease memberi kesan yang bermakna terhadap kehilangan pengruapan ammonia.

ABSTRACT

Surface application of urea often results in high ammonia volatilization loss. Information on ammonia volatilization in tropical acid soils is limited. This study was carried out to determine ammonia volatilization loss from surface-applied urea in Malaysian soils and to study the effects of soil properties on the rate of loss. Measurement of urease activity and ammonia volatilization loss in the laboratory was carried out on topsoil (0-15 cm) of 22 soils commonly found in Malaysia using a force-draft technique. Ammonia volatilization loss was recorded daily for seven days. Ammonia volatilization loss from the 22 soils studied ranged from 0.5 to 53% of N applied with most soils having values around 35%. The ammonia loss in acid sulfate soil was low. Most of the loss occurred during the first 3-4 days after urea application. The urease activity of soils ranged from 12.20 to 150.50 ug/g N/h and was not affected by soil texture and C content. Urease activity had a significant effect on ammonia volatilization loss.

INTRODUCTION

Surface application of urea often results in high ammonia volatilization loss which is not only an economic loss but is also a serious environmental problem. Urea is widely used in the tropics because it is a cheap source of N and is easily available.

Urea, when added to soils, is rapidly hydrolysed to $(\text{NH}_4)_2\text{CO}_3$ and subsequently to NH_4OH and CO_2 (Bremner and Mulvaney 1978). The hydrolysis results in a high pH increase at the urea microsite, which favours liberation of NH_3 (Ferguson *et al.* 1984). The magnitude of pH increase depends on the soil buffering capacity (Ferguson *et al.* 1984) while the rate of urea hy-

drolysis is influenced by the urease activity (Bremner and Mulvaney 1978). Thus in tropical soils although the soil pH is generally low, ammonia volatilization can occur in soils with high pH increase at the urea microsite during urea hydrolysis.

Urease activity and soil buffering capacity are very important soil properties affecting ammonia volatilization (Bremner and Mulvaney 1978; Ferguson *et al.* 1984). Other soil properties such as cation exchange capacity, soil texture and organic matter content also affect ammonia volatilization.

This study was carried out to determine ammonia volatilization loss derived from surface-

applied urea in Malaysian soils and to study the effect of soil properties on the rate of loss.

MATERIALS AND METHODS

Measurement of ammonia volatilization loss was carried out on topsoils (0-15 cm) of 22 soil series (Table 1). Loss was determined using the force-draft technique described by Fenn and Kissel (1973). Urea at the rate of 400 ug/g was applied on the soil surface. Soil moisture was maintained at 30% (w/w). The ammonia evolved was trapped in boric acid containing mixed indicators (bromocresol green and methyl red). The ammonia loss was determined daily by titration with standard HCl for a period of one week. Each determination was replicated three times.

Urease activity was determined on all the soils using the method described by Tabatabai (1982). In this method the urea remaining 5 h after application at the rate of 1 mg/10 g soil was used for urease activity determination.

Soils were analysed for particle size distribution (Day 1973), organic carbon (Nelson and Sommers 1982) and pH (Peech 1965).

RESULTS AND DISCUSSION

Ammonia Loss

Loss of ammonia from different soils during the first weeks after urea application is presented in Table 2. The loss varied between 0.5 to 52.8%. However, in most soils the loss was around 35%. High ammonia loss was also observed even in soils with high clay content. Ammonia volatilization was generally low in Carey (Sulfic Trophaquept) and Sedu (Typic Sulfaquept) series which are acid sulfate soils. These soils have low pH and high buffering capacity, which do not favour excessive ammonia volatilization loss.

The volatilization loss obtained in this study might overestimate losses under field conditions because of the high wind speed used in the force-draft measurement technique (Hargrove *et al.*, 1987). These results, however, indicated that there is a potential for high ammonia volatilization loss in tropical acid soils and this will lead to low urea N utilization efficiency.

Cumulative urea loss by volatilization of ammonia in one week from soils is presented in Fig.

TABLE 1
Some properties of the soils used

Soils	Sand	Clay	Organic C	pH
Bungor (Typic Paleudult)	66	18	2.21	4.83
Munchong (Tropeptic Haplorthox)	54	35	1.39	4.80
Serdang (Typic Paleudult)	60	41	1.74	4.70
Holyrood (Oxic Dystropept)	72	21	0.80	5.20
Prang (Tropeptic Haplorthox)	8	82	1.69	4.61
Sedu (Typic Sulfaquept)	17	47	4.58	2.86
Carey (Sulfic Trophaquept)	60	19	1.27	3.50
Segamat (Haplic Acrorthox)	4	83	2.75	5.14
Baging (Typic Quartzipsamment)	98	0	0.43	5.20
Kuantan (Haplic Acrorthox)	8	70	1.51	5.50
Lanchang (Typic Paleudult)	42	51	2.10	4.70
Beserah (Tropeptic Haplorthox)	88	10	2.05	4.97
K.Berang (Typic Tropudult)	33	20	1.90	4.25
Renggam (Typic Paleudult)	43	21	3.40	4.61
Durian (Typic Paleudult)	6	45	1.89	5.39
B. Anam (Aquoxic Tropudult)	14	22	1.32	4.40
Jerangau (Haplic Acrorthox)	44	48	0.85	4.50
Chat (Typic Paleudult)	57	57	1.80	4.70
Kuah (Oxic Dystropept)	31	24	1.12	4.50
Jitra (Tropeptic Haplorthox)	20	61	3.03	4.94
Gajah Mati (Tropeptic Haplorthox)	15	75	3.06	4.50
Tai Tak (Typic Paleudult)	49	38	1.73	4.40

TABLE 2

Total ammonia volatilization and urease activity in soils

Soils	Ammonia loss*	Urease activity**
	%	ug N/g/h
Bungor	14.4	12.18
Munchong	13.2	44.37
Serdang	33.0	49.61
Holyrood	49.2	126.90
Prang	33.2	132.60
Sedu	0.5	93.61
Carey	16.4	93.61
Segamat	40.0	105.20
Baging	42.4	144.21
Kuantan	33.7	88.13
Lanchang	52.8	150.50
Beserah	19.3	84.95
Kuala Berang	28.6	66.76
Rengam	44.5	10.07
Durian	41.6	53.19
Batu Anam	40.4	82.61
Jerangau	13.9	59.13
Chat	42.3	92.44
Kuah	30.5	46.07
Jitra	30.7	56.13
Gajah Mati	37.4	87.83
Tai Tak	45.8	76.11

* Loss as a percentage of the maximum possible

** ug Urea-N hydrolysed per g per hour

I. In most soils maximum loss occurred in the first 3-4 days after urea application and it decreased subsequently with time. This is because urea hydrolysis accompanied by pH increase occurred during this period. The soil pH at urea microsites increased to a maximum pH of 8 to 9 (Khanif and Pancras 1988). At this pH excessive ammonia volatilization will take place. Thus, although the pH of the soils studied was low (pH < 5), urea hydrolysis could increase soil pH at urea microsites sufficiently for ammonia volatilization to be significant.

The total ammonia volatilization loss from most of the soils could be described by the following equation (Table 3):

$$Y = a + b \ln x$$

where Y = ammonia volatilization loss (%)

a = intercept (%)

b = slope (%/day)

x = time (day)

The rate of ammonia loss was initially high but it decreased with time. The slopes of the lines ranged between 6.6 and 23.9% day and varied with the soil type. The regressions were highly significant for most of the soils.

Urease Activity

The enzyme urease is responsible for urea hydrolysis, a prerequisite for ammonia volatilization loss. The urease activities of the soils studied are presented in Table 2, and range from 12.20 to 150.50 ug/g N/h. The urease activity was not related to sand, clay and carbon content. The values obtained were generally high, thus rapid urea hydrolysis and ammonia volatilization can be expected in most of the soils studied.

TABLE 3
Regression equations of ammonia loss as a function of time

Soils	Equation	R	F
Bungor	Y = 0.64 + 7.27 ln x	0.99	27.6 **
Munchong	Y = 0.03 + 6.67 ln x	0.99	88.9 **
Serdang	Y = 8.32 + 15.40 ln x	0.93	24.8 **
Holyrood	Y = 8.86 + 23.90 ln x	0.91	67.5 **
Prang	Y = -2.39 + 18.30 ln x	0.97	224.0 **
Carey	Y = -4.96 + 12.20 ln x	0.78	12.1 **
Segamat	Y = 8.08 + 20.90 ln x	0.95	97.5 **
Baging	Y = 2.48 + 16.50 ln x	0.93	80.3 **
Kuantan	Y = 4.32 + 15.10 ln x	0.97	136.0 **
Lanchang	Y = 18.90 + 19.70 ln x	0.87	34.6 **
Beserah	Y = 12.20 + 8.36 ln x	0.54	5.3 **
K.Berang	Y = -3.77 + 17.50 ln x	0.92	79.1 **

Soil Properties Affecting Ammonia Loss

Soil properties most likely to affect ammonia loss were included in a stepwise regression to determine their importance in influencing ammonia volatilization loss. The factors considered were urease activity, sand, clay and organic carbon content. The statistical analysis indicated that only urease activity had a significant effect on the rate of ammonia volatilization while the other factors were not significant (Table 4). Although the sand and clay contents were expected to influence ammonia loss, the effect could not be clearly

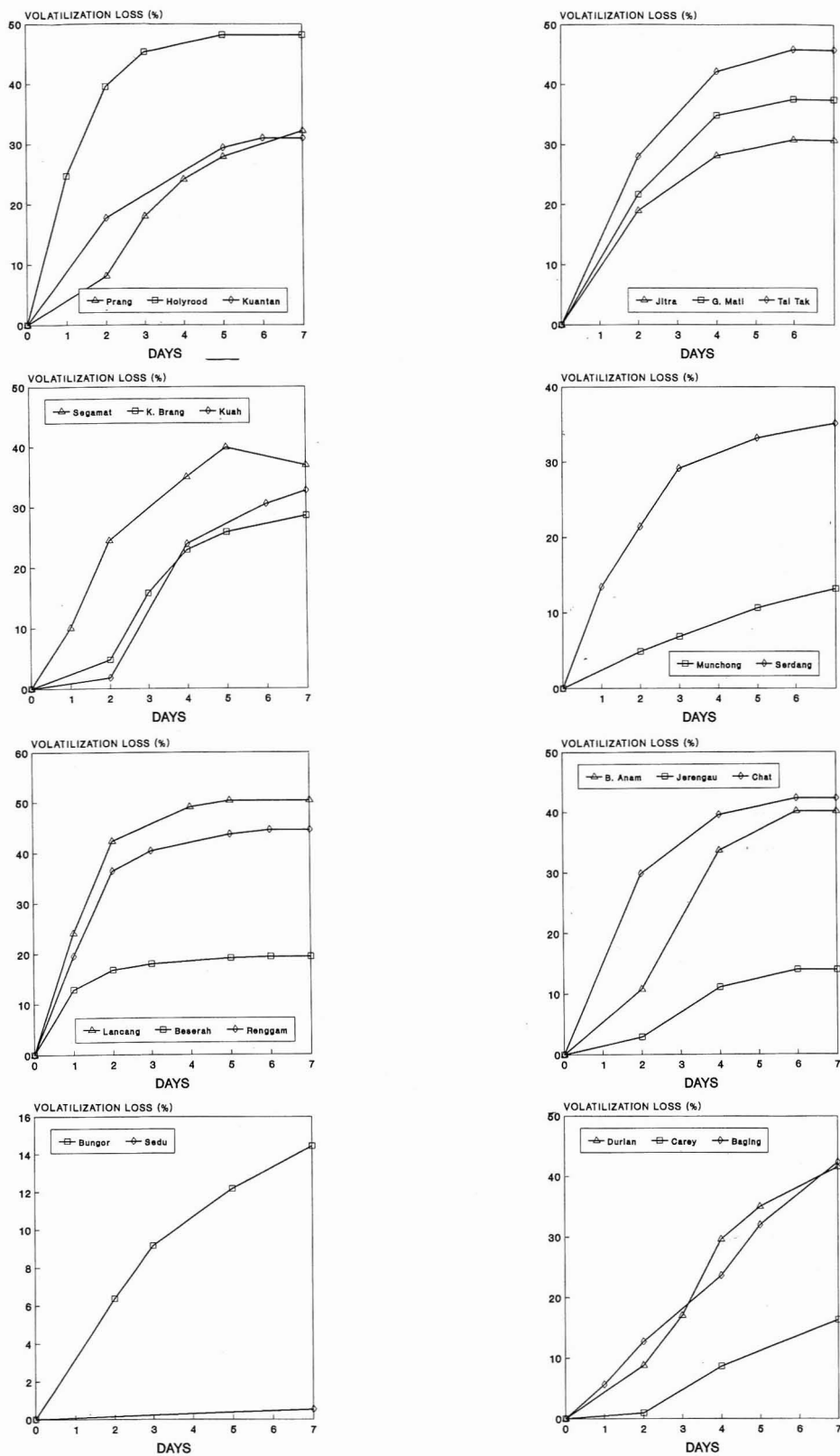


Fig 1: Ammonia volatilization from 22 soils after application of urea

demonstrated, most probably due to the presence of iron coated clay or "pseudo sand" which behaved like sand. "Pseudo sand" is abundant in all soils studied but was especially high in the Oxisol. Thus even for soil with a high clay content, high loss of ammonia following urea application occurred (Table 2).

TABLE 4
Summary of regression analysis of ammonia volatilization loss with urease activity, sand, clay and organic carbon

Variable	Partial R	Model R	F
Urease activity	0.2642	0.2642	6.4624*
Organic carbon	0.0824	0.3466	2.1435
Clay	0.0286	0.3751	0.7317
Sand	0.0279	0.4031	0.7021

CONCLUSION

Significant ammonia volatilization loss occurred from tropical soils following urea application. The ammonia loss, however, was low in acid sulfate soils with low pH values. Soil urease activity was significantly related to the rate at which ammonia was volatilized from soil.

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REFERENCES

- BREMNER, J.M. and R.L. MULVANEY. 1978. Urease Activity in Soils. In *Soil*. ed. L. Burns. London: Academic Press. pp. 149-196.
- DAY, P.P. 1973. Particle Fractionation and Particle Size Analysis. In *Methods of Soil Analysis Part 1*. ed. C.A. Black *et al.* Am. Soc. Agron. (USA) pp. 545-567.
- FENN, L.B. and D.E. KISSEL. 1978. Ammonia Volatilisation from Surface Application of Ammonium Compounds in Calcaerous Soils : General Theory. *Soil Sci. Soc. Am. Proc.* **37**:855-859.
- FERGUSON, R.B., D.E. KISSEL, J.K. KOELLIKER and W. BASEL. 1984. Ammonia Volatilisation from Surface Applied Urea : Effects of Hydrogen Ion Buffering Capacity. *Soil Science Soc. Am. J.* **48**:578-582.
- HARGROVE, W.L., B.R. BOCK, R.A. RAVINIKAR and W.J. URBAN. 1987. Comparison of a Force Draft Technique to ¹⁵N Recovery of Measuring Ammonia Volatilisation under Field Conditions. *Soil Science Soc. Am. J.* **51**: 124-128.
- KHANIF, Y.M. and H. PANCRAS. 1988. Urea Transformation in Malaysian Soils. Proc. Int. Symp. on Urea Technology and Utilization. pp. 259-266.
- NELSON, W.D. and L.E. SOMMERS. 1982. Total Carbon, Organic Carbon and Organic Matter: In *Methods of Soils Analysis*. Part 2. ed. A.L. Page *et al.* 2nd ed. Am. Soc. Agron (USA) pp. 539-580.
- PEECH, H.M. 1965. Hydrogen-Ion Activity. In *Methods of Soil Analysis Part 2*. ed. C.A. Black *et al.* Am. Soc. Agron. (USA) pp. 914-926.
- TABATABAI. 1982. Soil Enzymes. In *Methods of Soil Analysis Part 2*. 2nd ed. A.L. Page. American Soc. of Agronomy, Wisconsin, pp. 903-948.

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