



UNIVERSITI PUTRA MALAYSIA

**AMMONIA VOLATILIZATION AND PHOSPHATE RELEASE FROM
COMPACTED MIXED FERTILIZERS IN PURE SYSTEM
AND IN AN ACID SOIL**

SUSILAWATI BINTI KASIM

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**MASTER OF AGRICULTURAL SCIENCE
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2003**



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By

SUSILAWATI BINTI KASIM

**Thesis Submitted to the School of Graduate Studies,
Universiti Putra Malaysia, in Fulfilment of the Requirements for the
Degree of Master of Agricultural Science**

July 2003



Dedicated to.....

All my family members especially my mother, father and siblings who have supported me along my way to success.....

I love you all.....



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in
Fulfilment of the requirements for the degree of
Master of Agricultural Science

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Faculty : Agriculture

Urea and phosphate rock (PR) have been widely used in Malaysian agriculture. However, ammonia (NH_3) volatilization and slow release of P are two major problems encountered when urea and PR fertilizers were used. High pH, Al and Fe oxides content and low cation exchange capacity (CEC) have been identified as causing these problems in soil. Peat and triple superphosphate (TSP) may be mixed to supply humic substances from peat to reduce P fixation, N loss and proton (H^+) from TSP to solubilize PR in water and soil. Thus, a study was initiated to investigate the effect of these mixed fertilizers on NH_3 volatilization and dissolution of PR in a pure system and in an acid soil. Various combinations of urea, TSP, CIPR fertilizers and peat were compacted and studied in the two systems in the laboratory. In pure system, the N loss following addition of peat (5.09%) is better than TSP (28.15%). Four combinations of fertilizers gave the second highest P



dissolution (70.53%) at day one and day 10 (71.15%) based on changes in P released (ΔP) method after urea plus TSP and peat. Almost 40% of changes in Ca released (ΔCa) was detected in solution when any combination of TSP and Christmas Island Phosphate Rock (CIPR) was used in the mixture after 10 days. This is due to the production of phosphoric acid by TSP. Surface application of compacted mixed fertilizer on the soil showed that urea plus TSP and CIPR and urea plus TSP and peat managed to decrease the loss of N by nearly 50% compared to only urea. This is due to the production of Ca^{2+} by P sources and additional CEC by peat. Delay in the peak N loss differed with fertilizer combinations: urea + TSP + CIPR (3 days), urea + TSP + CIPR + peat (7 days), urea + TSP + peat (7 days) and urea + peat (5 days). The CIPR and peat mixture showed the highest ΔP value ($394.66 \text{ mg kg}^{-1}$) after 90 days of incubation in soil. On average, the highest ($310.98 \text{ mg kg}^{-1}$) P dissolution as measured by ΔP method was obtained using urea plus TSP, CIPR and peat. This was attributed to the protons supplied by TSP and Ca-sink from peat which promoted the dissolution of PR in mixed fertilizer. Thus, compacted mixed fertilizer is an effective way to decrease NH_3 volatilization and increase ΔP in soil and pure system. However, this depends on the combination of the fertilizers used.



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sebagai memenuhi keperluan untuk ijazah Master Sains Pertanian

**PEMERUAPAN AMONIA DAN PELEPASAN FOSFAT DARI CAMPURAN
BAJA DALAM SISTEM TULEN DAN DALAM TANAH BERASID**

Oleh

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Urea dan batuan fosfat (PR) telah digunakan dengan meluas dalam pertanian di Malaysia. Walaubagaimanapun, pemeruapan ammonia (NH_3) dan pelepasan phosphorus (P) yang perlahan merupakan dua masalah utama apabila kedua-dua baja ini digunakan. Nilai pH serta kandungan oksida Al dan Fe yang tinggi dan keupayaan pertukaran kation (KPK) yang rendah telah dikenalpasti sebagai punca masalah ini. Gambut dan baja triple supersphosphate (TSP) boleh dicampur untuk membekalkan bahan humik bagi mengurangkan pengikatan P dan kehilangan N, dan punca proton (H^+) bagi merangsang pelarutan PR. Oleh itu, satu kajian telah dijalankan untuk menyelidik kesan campuran baja ini terhadap pemeruapan NH_3 dan pelarutan PR dalam sistem tulen dan tanah berasid (Siri Munchong). Beberapa kombinasi baja urea, TSP, CIPR dan gambut telah dipadatkan untuk kajian dalam sistem tulen dan pengeraman dengan tanah yang dilakukan di makmal. Dalam sistem tulen, kehilangan N oleh urea dengan

penambahan gambut (5.09%) adalah lebih baik dari TSP (28.15%). Kombinasi empat jenis baja memberikan pelarutan P kedua tertinggi pada hari pertama (70.53%) dan 10 (71.15%) selepas campuran urea, TSP dan gambut. Hampir 40% perubahan Ca (ΔCa) telah dikesan di dalam larutan apabila TSP dan Christmas Island Phosphate Rock (CIPR) digunakan sebagai sebahagian daripada campuran baja selepas 10 hari. Ini disebabkan oleh penghasilan asid fosforik oleh TSP. Pemberian baja di permukaan tanah menunjukkan, kombinasi urea dengan TSP dan CIPR dan urea dengan TSP dan gambut menurunkan kehilangan N hampir 50%. Ini disebabkan oleh penghasilan Ca^{2+} dari sumber P dan penambahan KPK dari gambut. Perlambatan nilai tertinggi kehilangan N berbeza mengikut kombinasi baja: urea + TSP + CIPR (3 hari), urea + TSP + CIPR + gambut (7 hari), urea + TSP + gambut (7 hari) dan urea + gambut (5 hari). Campuran gambut dan CIPR memberikan ΔP tertinggi (394.66 mg kg^{-1} - hari ke 90). Secara puratanya, nilai tertinggi (310.98 mg kg^{-1}) pelarutan sumber P, diukur berdasarkan ΔP diberikan oleh urea, TSP, CIPR dan gambut. Ini disebabkan oleh penambahan proton (H^+) dari TSP dan takungan Ca (*Ca-sink*) dari gambut telah merangsang pelarutan sumber P dalam campuran baja. Maka, campuran baja merupakan cara yang efektif untuk mengurangkan pemeruapan NH_3 dan meningkat ΔP dalam tanah dan sistem tulen. Walaubagaimanapun, ianya bergantung kepada kombinasi baja yang digunakan.

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TABLE OF CONTENTS

	Page
DEDICATION.....	ii
ABSTRACT.....	iii
ABSTRAK.....	v
ACKNOWLEDGEMENTS.....	vii
APPROVAL.....	viii
DECLARATION.....	x
LIST OF TABLES.....	xiv
LIST OF FIGURES.....	xvi
LIST OF ABBREVIATIONS.....	xviii
CHAPTER	
1 INTRODUCTION.....	1.1
2 LITERATURE REVIEW.....	2.1
2.1 Soil Phosphorus.....	2.1
2.2 Reactions of Phosphate Fertilizers in Soils.....	2.1
2.3 Phosphorus Retention.....	2.2
2.3.1 Soil Properties.....	2.3
2.3.1.1 Clay Content	2.3
2.3.1.2 pH.....	2.4
2.3.1.3 Hydrous Oxides of Fe and Al.....	2.4
2.4 Phosphate Rock	2.5
2.5 Phosphate Mineralogy	2.7
2.6 Factor Affecting Released and Available P in Soil.....	2.8
2.6.1 Soil Factor.....	2.9
2.6.1.1 Acidity.....	2.9
2.6.1.2 Soil Moisture.....	2.10
2.6.1.3 Ca Sink.....	2.10
2.6.1.4 P Sink.....	2.11
2.6.1.5 Organic Matter.....	2.12
2.7 Soil Nitrogen.....	2.12
2.8 Urea.....	2.13
2.9 Ammonia Volatilization.....	2.14
2.10 Factors Affecting Losses of Ammonia.....	2.14
2.10.1 Soil Factor.....	2.15
2.10.1.1 pH	2.15
2.10.1.2 Organic Matter.....	2.16
2.10.1.3 Cation Exchange Capacity.....	2.16
2.10.2 Environmental Factor.....	2.17



2.10.2.1	Soil Moisture.....	2.17
2.10.2.2	Temperature	2.17
2.11	Control of Ammonia Volatilization.....	2.18
2.11.1	Coating	2.18
2.11.2	Urease Inhibitors.....	2.19
2.11.3	Altering the N Fertilizer Microsite.....	2.19
2.12	Peat	2.20
2.13	Mixed Fertilizer.....	2.21
2.13.1	Mixture of PR with Urea.....	2.22
2.13.2	Mixture of PR with Soluble Phosphate Fertilizer..	2.22
2.13.3	Mixture of Soluble Phosphate Fertilizer with Urea	2.23
2.13.4	Mixture of PR with Organic Matter.....	2.24
2.13.5	Mixture of Organic Matter with Urea.....	2.25
2.14	Interaction of N and P Fertilizer.....	2.25
2.15	Summary.....	2.26
3	MATERIALS AND METHODS.....	3.1
3.1	Soils and Peat.....	3.1
3.1.1	Soil and Peat Sampling.....	3.1
3.1.2	Soil and Peat Preparation.....	3.1
3.1.3	Soil and Peat Analyses.....	3.2
3.2	Phosphate Sources.....	3.3
3.2.1	Description of P Sources.....	3.3
3.2.2	Preparation of P Sources.....	3.4
3.2.3	Solubility of P Fertilizer.....	3.4
3.2.4	Total Ca and P in PR and TSP.....	3.4
3.3	Preparation of Fertilizer Pellet.....	3.5
3.4	Ammonia Volatilization and PR Dissolution in Pure System.....	3.5
3.5	Ammonia Volatilization in Soil.....	3.7
3.5.1	Estimation of Ammonia Volatilization.....	3.7
3.6	Phosphate Rock Dissolution in Soil.....	3.9
3.6.1	Soil Analysis.....	3.10
3.7	Statistical Analysis.....	3.11
4	RESULTS AND DISCUSSION.....	4.1
4.1	Physical and Chemical Characteristic of Soil and Peat....	4.1
4.2	Chemical Characteristic of the P Sources.....	4.2
4.3	Ammonia Volatilization and PR Dissolution in Pure System.....	4.3
4.3.1	Losses of N.....	4.3
4.3.2	Urea-N and Ammonium-N Recovery.....	4.11
4.3.3	Dissolution of PR.....	4.18
4.3.3.1	ΔP	4.18



4.3.3.2 ΔCa	4.23
4.4 Effect of Compacted Mixture Fertilizer Placement on Ammonia Volatilization in Soil.....	4.27
4.4.1 Surface Application.....	4.27
4.4.2 Mixed Method.....	4.33
4.5 Phosphate Rock Dissolution in Soil.....	4.35
4.5.1 Dissolution of PR Measured by ΔP	4.35
4.5.2 Dissolution of PR Measured by ΔCa	4.45
5 CONCLUSIONS.....	5.1
REFERENCES.....	R.1
VITA.....	V.1



LIST OF TABLES

Table	Page
3.1 Treatment used in NH ₃ Volatilization and PR Dissolution in Pure System.....	3.7
3.2 Treatment used in Ammonia Volatilization in Soil.....	3.9
3.3 Treatment used in PR Dissolution in Soil.....	3.11
4.1 Chemical and Physical Properties of the Soil and Peat used in the Laboratory Experiment.....	4.2
4.2 Solubility of P Fertilizer and Total P and Ca.....	4.4
4.3 Effect of Compacted Mixture Fertilizer on Losses of N at Day Ten.....	4.7
4.4 Changes in Pure System pH in Urea plus Peat Mixture.....	4.8
4.5 The IP Value and Status of (NH ₄)H ₂ PO ₄	4.10
4.6 Changes in Pure System pH in Urea plus TSP Mixture.....	4.11
4.7 Effect of Compacted Mixture Fertilizer on Urea-N and NH ₄ ⁺ -N Recovery at Day Ten.....	4.15
4.8 ΔP Measured in Pure System at Day One.....	4.19
4.9 ΔP Measured in Pure System at Day Ten.....	4.20
4.10 ΔCa Measured in Pure System at Day One.....	4.24
4.11 ΔCa Measured in Pure System at Day Ten.....	4.25
4.12 Cumulative of N Loss in All Treatments at the End of Incubation.....	4.31
4.13 Comparison of pH, P, Ca and NH ₄ ⁺ ion in Different Treatments.....	4.31



4.14	Effect of Mixing of Fertilizer with Soil on NH_4^+ -N Recovery...	4.34
4.15	ΔP and pH Value Measured at Day One.....	4.38
4.16	ΔP and ΔpH Measured in Urea plus CIPR and Peat Mixture	4.39
4.17	ΔP Measured from Compacted Mixture Fertilizer.....	4.42
4.18	ΔP Measured at Day 90.....	4.42
4.19	ΔP Measured in 90 Days.....	4.45
4.20	ΔCa Measured at Day One.....	4.47
4.21	ΔCa Measured at Day 90.....	4.49
4.22	Relationship between ΔCa Measured and the Ca-sink Size of Mixed Fertilizer Incubated with Munchong Soil at 90 Days	4.53



LIST OF FIGURES

Figure		Page
4.1 (A)	Daily N Loss in Pure System.....	4.5
4.1 (B)	Daily N Loss in Pure System.....	4.6
4.2 (A)	Daily Urea-N Recovery in Pure System.....	4.13
4.2 (B)	Daily Urea-N Recovery in Pure System.....	4.14
4.3 (A)	Daily NH_4^+ -N Recovery in Pure System.....	4.16
4.3 (B)	Daily NH_4^+ -N Recovery in Pure System.....	4.17
4.4	Relationship between pH and NH_4^+ -N Recovery.....	4.19
4.5	Effect of Compacted Mixture Fertilizer on mean PR Dissolution.....	4.22
4.6	Effect of Compacted Mixture Fertilizer on Dissolution of PR Measured by ΔP Method.....	4.23
4.7	Effect of Compacted Mixture Fertilizer on Dissolution of PR Measured by ΔCa Method.....	4.25
4.8	Effect of Compacted Mixture Fertilizer on ΔCa	4.27
4.9	Daily NH_3 Volatilization Loss from Surface Applied Mixed Fertilizers.....	4.28
4.10	Cumulative NH_3 Volatilization Loss from Surface Applied Mixed Fertilizers.....	4.30
4.11	The Dissolution of P Sources as Measured by ΔP in 90 Days Incubation Period.....	4.36
4.12	Relationship between ΔP and ΔpH in Urea plus CIPR	4.40
4.13	Relationship between ΔP and ΔpH in CIPR.....	4.41



4.14	The Dissolution of P Sources as Measured by ΔCa in 90 Days Incubation Period.....	4.46
4.15	Effect of Compacted Mixture Fertilizer on ΔCa Measured in 90 Days.....	4.51
4.16	Relationship between % ΔP and % ΔCa from Compacted Mixture Fertilizer.....	4.54



LIST OF ABBREVIATIONS

Non Symbolic

UPR	Udaipur phosphate rock
CIPR	Christmas island phosphate rock
CEC	Cation exchange capacity
FC	Field capacity
UPM	University Putra Malaysia
AAS	Atomic absorption spectrophotometer
CRD	Completely randomised design
AA	Auto analyser
ANOVA	Analysis of variance
DMRT	Duncan's multiple range test
DCPD	Dicalciumphosphate dehydrate
NaOH	Sodium hydroxide
TSP	Triple superphosphate
SSP	Single superphosphate
PR	Phosphate rock
MAP	Monoammonium phosphate
WSP	Water-soluble phosphate
NH ₃	Ammonia
IP	Ion Product
K _{sp}	Solubility Product
SE	Standard Error



Symbolic

OH^-	Hydroxyl ion
NH_4^+	Ammonium ion
H^+	Hydrogen ion
$(\text{NH}_4)\text{H}_2\text{PO}_4$	ammonium phosphate
$\text{Ca}(\text{H}_2\text{PO}_4)_2$	monocalcium phosphate
KCl	Potassium chloride
H_2SO_4	Sulfuric acid
$\text{K}_2\text{Cr}_2\text{O}_7$	Potassium dikromat
H_3PO_4	Orthophosphoric acid
$\text{C}_{12}\text{H}_{10}\text{NH}$	Diphenylamine
Na_2SO_4	Sodium sulphate
HClO_4	Perchloric acid
KOH	Potassium hydroxide
NaOAc	Sodium acetate
NO_2^-	Nitrite
NO_3^-	Nitrate
NO	Nitric oxide
N_2	Nitrogen gas

CHAPTER 1

INTRODUCTION

The use of fertilizer has been the forefront in the struggle to increase world food production. Over the past two-and-a-half decades, the aggregate consumption of fertilizers has increased substantially. Malaysian fertilizer consumption has steadily increased with time and the fertilizer application rate is relatively high at about 111 kg of nutrient per ha (Maene *et al.*, 1988). Total fertilizer consumption in Malaysia increased from 964,000 Mt (1992) to 1,130,717 Mt (2001) and the use of phosphate fertilizer in 2001 is 158,800 Mt (FAO, 2003). According to Malaysia Agricultural Directory and Index 1999 - 2000, changes in Malaysian agriculture increased the fertilizer consumption.

Nitrogen (N) is the major nutrient used in the fertilization of crops. More than 75% of the total fertilizer N use in Asia is in the form of urea (Mikkelsen, 1987). It is the leading N fertilizer used in the world agriculture with an N content of approximately 46%; has the edge in terms of price per unit N, storage space and transportation costs over other N sources (Harre and Bridges, 1988). Usage of urea in Malaysia in 2001 is 134,000 Mt (FAO, 2003).



Although urea has been the choice fertilizer used in supplying N, the efficiency of this fertilizer is low. One major problem encountered in using urea is loss through volatilization. Eighty percent of applied urea-N may be lost within 2 - 3 weeks after application (Torella *et al.*, 1983). In flooded condition, increased in pH and ammonium ion (NH_4^+) concentration occurred especially when the fertilizer is broadcast and when the water level is low (Vlek and Stumpe, 1978). It is common for farmers to lose 70% of the applied urea (Wetselaar *et al.*, 1984; Pasandaran *et al.*, 1999).

Surface application of urea often resulted in high ammonia (NH_3) volatilization. High urease activity and excessive increase in microsite pH that occurred during urea hydrolysis gave significant losses of N through volatilization (Khanif and Pancras, 1988). Previous research in this area suggests that the efficiency of urea can be improved by correct time of applications, deep placement, slow release, or the use of biological inhibitors (Craswell, 1988).

Another approach in reducing NH_3 volatilization is applying urea together with acidic phosphatic fertilizer. Combining urea with phosphate fertilizer offer several advantages; simultaneous and uniform application of several nutrients and save on distribution costs (Fan *et al.*, 1996). The agronomic efficiency of urea can be improved when combined in an intimate



mixture with triple superphosphate (TSP) or monoammonium phosphate (MAP), while urea hydrolysis rate in acid soils could be reduced with addition of TSP (Fan and MacKenzie, 1993^a, Fan and MacKenzie, 1994, Fan *et al* , 1996)

Generally, the amount of plant available phosphorus (P) in Malaysian soils is low. This is due to high soil acidity and high fixation of P by Fe and Al oxides and hydroxides (Havlin *et al* , 1999). Water soluble-P fertilizers, such as TSP and single superphosphate (SSP) have normally been used to fulfill the P requirement of plants. In developing countries, use of these fertilizers are limited primarily by their higher costs. To reduce production and capital cost, the use of phosphate rock (PR) as direct application has been suggested (Chien *et al* , 1996)

Although direct application of PR may be a cost effective mean to supply P, PRs with low and medium reactivity often do not perform as well as soluble P fertilizers (Chien *et al* , 1990, Chien and Friesen, 1992). Mixing PR with soluble P fertilizer (TSP) significantly increased the available P and solubility of PR (Chien *et al* , 1996)

In some developing countries, there is a growing interest in the use of mixtures of PR with N fertilizer for direct application (Chien, 1978). Nitrogen

fertilizer increases the availability of P from PR to the plants, whilst Ca content in P fertilizer influences NH₃ volatilization (Fenn *et al.*, 1981).

There are some good advantages offered when organic matter was mixed together with urea and P fertilizer. Hydrolysis of urea which was occurred as soon as it was introduced into the soil leads to dissolved organic matter due to the increase in pH and NH₄⁺. Dissolution of this organic matter could increase the transport of P in soils (Qualls and Haines, 1991), decrease P fixation and improve P availability (Chien *et al.*, 1987). However, humic and fulvic acids from organic matter would form soluble salt with NH₄⁺ (Stevenson, 1982). These two beneficial processes make P and N available in soil solution.

Addition of acidic phosphate fertilizer to this mixture may result in reactions that will influence the solubility of PR and availability of NH₄⁺ in soil. Hence, the general objective of the present research was to investigate the effect of fertilizer mixture consisting of urea, P and organic matter on the NH₃ volatilization and dissolution of PR in pure system and in an acid soil. The specific objectives were to determine and compare the effect of various mixture fertilizers on NH₃ volatilization and PR dissolution in pure system and in an acid soil.

