UNIVERSITI PUTRA MALAYSIA

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

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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

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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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Chairman : Associate Professor Aminuddin Bin Hussin, Ph.D.

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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 mg kg^{-1}) after 90 days of incubation in soil. On average, the highest (310.98 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.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains Pertanian

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

Oleh

SUSILAWATI BINTI KASIM

Julai 2003

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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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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^+	Hidrogen ion
$(NH_4)H_2PO_4$	ammonium phosphate
$Ca(H_2PO_4)_2$	monocalcium phosphate
KCl	Potassium chloride
H_2SO_4	Sulfuric acid
$K_2Cr_2O_7$	Potassium dikromat
H_3PO_4	Orthophosphoric acid
$C_{12}H_{10}NH$	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 loose 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, used 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 NH_3 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 NH_4^+. 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 NH_4^+ (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 NH_4^+ 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 NH_3 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 NH_3 volatilization and PR dissolution in pure system and in an acid soil.