UNIVERSITI PUTRA MALAYSIA

FIELD EVALUATION OF AMMONIA VOLATILISATION LOSS FROM UREA AND ITS CONTROL USING UREASE INHIBITORS AND SOLUBLE SALTS

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By

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SPECIALLY DEDICATED TO MY HUSBAND CHANDRAN

AND MY CHILDREN NISHA AND NIRAJ

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TABLE OF CONTENTS

CHAPTER		Page

CHAPTER Page

LIST OF TABLES

Table		Page

LIST OF FIGURES

Abstract of thesis submitted to the Senate of Universiti Pertanian Malaysia in fulfilment of the requirements for the degree of Master of Agricultural Science.

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April 1991

Supervisor : Assoc. Prof. Dr. Mohd. Khanif b. Yusop

Faculty : Agriculture

Urea, when surface-applied to soils often resulted in high losses due to volatilisation of ammonia. This study was undertaken to measure ammonia volatilisation loss from urea on two soils under field conditions and to study the effect of urease inhibitors and soluble salts on ammonia volatilisation loss from urea. The N-15 recovery technique was employed because it posed no disturbance to the field micro-environment. Experimental evidence showed that other pathways of nitrogen loss such as denitrification did not occur during the period of the experiment. Leaching losses were taken into account by sampling deeper in the soil profile until no

further fertilizer nitrogen was recovered. Therefore any N-15 lost from the soil profile was due to ammonia volatilisation process alone. Ammonia volatilisation loss was calculated by taking the difference between the added and the recovered N-15.

Volatilisation loss from the Bungor and Munchong series ranged from 40% to 53% in four weeks following application of 100, 200 and 400 kgN/ha of urea. Urea loss increased with time and rate of urea application. Urea was initially transformed to ammonium and subsequently to nitrate. The rate of transformation of ammonium to nitrate decreased with increasing nitrogen rates.

Ammonia volatilisation loss from urea in the field was controlled using urease inhibitors and soluble salts. Addition of PPD and hydroquinone at 1% rate (w/w of urea) reduced ammonia volatilisation loss from 28% to 8% and 10% respectively in one week following application of 150 kgN/ha of urea. Increasing PPD and hydroquinone rates to 2% did not further reduce loss. Addition of calcium, magnesium and potassium at a cation/N ratio of 0.5 reduced urea loss from 28% to 12%, 13% and 12% respectively in one week following application of 150 kgN/ha of urea. Similarly, increasing their rates to a cation/N of 1.0 did not further reduce loss.

In the glasshouse study, addition of PPD and hydroquinone to urea at 1% and 2% rates reduced ammonia volatilisation loss from urea and increased fertilizer utilization efficiency, total nitrogen uptake and fertilizer nitrogen recovery in plant. Dry matter yield was increased with PPD treatment at 1% rate. Calcium and magnesium added to urea at a cation/N ratio of 0.5 reduced ammonia volatilisation loss and increased fertilizer utilization efficiency, total nitrogen uptake and fertilizer nitrogen recovery in plant. Potassium had to be increased to a cation/N ratio of 1.0 to give similar benefits. Dry matter yield was increased with magnesium treatment at a cation/N ratio of 1.0. Increase in fertilizer utilization efficiency, total nitrogen uptake, fertilizer nitrogen recovery in plant and dry matter yield ocurred as a result of reduced ammonia volatilisation loss and not a direct effect of the salts on plant growth.

Abstrak tesis yang dikemukakan kepada Senat Universiti Pertanian Malaysia bagi memenuhi syarat-syarat Ijazah Master Sains Pertanian.

PENENTUAN KEHILANGAN UREA MELALUI PEMERUAPAN AMMONIA DI LADANG SERTA KAWALANNYA DENGAN MENGGUNA KIMIA PENGHALANG UREASE DAN GARAM-GARAM LARUT

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Urea yang ditabur ke atas permukaan tanah biasanya dihilangkan melalui pemeruapan ammonia. Kajian ini dibuat untuk menentukan kadar kehilangan urea melalui pemeruapan ammonia diladang dari dua tanah di Malaysia serta untuk mengkaji kesan kimia penghalang urease dan garam-garam larut ke atas kehilangan urea melalui pemeruapan ammonia. Teknik pemulihan N-15 digunakan kerana ia tidak menggangu sekitaran mikro ladang. Data-data eksperimen menunjukkan bahawa kehilangan nitrogen melalui cara-cara lain saperti denitrifikasi tidak berlaku dalam tempoh kajian dilakukan. Kehilangan baja melalui larut-lesap dikawal dengan mengambil sampel jauh

ke dalam tanah sehingga tidak ada baja yang dipulihkan. Oleh yang demikian, kesemua N-15 yang hilang dari profail tanah adalah melalui proses pemeruapan ammonia. Kehilangan urea melalui pemeruapan ammonia dikira dari perbezaan jumlah nitrogen berlabelkan N-15 yang ditambah dan jumlah nitrogen berlabelkan N-15 yang dipulihkan dari tanah.

Kehilangan urea melalui pemeruapan ammonia dari Siri Bungor dan Siri Munchong berubah-ubah dari 40% hingga 53% dalam empat minggu selepas penaburan 100, 200 dan 400 kgN/ha urea. Jumlah kehilangan urea melalui pemeruapan ammonia bertambah dengan masa dan pertambahan kadar nitrogen. Urea ditransformasikan kepada ammonium dan seterusnya kepada nitrat. Kadar pertukaran ammonium kepada nitrat berkurangan dengan penambahan kadar nitrogen.

Kehilangan urea melalui pemeruapan ammonia diladang telah dikawal dengan mengguna kimia penghalang urease dan garam-garam larut. Campuran PPD dan hydroquinone dengan urea pada kadar 1% (berdasarkan berat urea) mengurangkan kehilangan urea dari 28% ke 8% dan 10% dalam satu minggu selepas penaburan 150 kgN/ha urea. Kenaikan kadar PPD dan hydroquinone pada 2% tidak seterusnya mengurangkan lagi kehilangan urea dengan bermakna. Campuran kalsium, magnesium dan kalium dengan urea pada kadar nisbah kation/N 0.5 mengurangkan kehilangan urea dari 28% ke 12%, 13% dan 12% dalam satu minggu selepas penaburan 150 kgN/ha urea. Kenaikan kadar garam-garam tersebut kepada kadar nisbah kation/N 1.0 tidak mengurangkan kehilangan urea dengan bermakna.

Dalam kajian di rumah kaca, campuran PPD dan hydroquinone dengan urea pada kadar 1% dan 2% mengurangkan kehilangan urea melalui pemeruapan ammonia serta meninggikan kecekapan penggunaan baja, pengambilan nitrogen dan pemulihan baja nitrogen dalam pokok. Hasil berat kering bertambah dengan rawatan PPD pada kadar 1%. Campuran kalsium dan magnesium pada urea pada kadar nisbah kation/N 0.5 mengurangkan kehilangan urea melalui pemeruapan ammonia serta meninggikan kecekapan penggunaan baja, pengambilan nitrogen dan pemulihan baja nitrogen dalam pokok. Kalium perlu dinaikkan pada kadar nisbah kation/N 1.0 untuk mendapat faedah yang sama. Hasil berat kering ditinggikan dengan rawatan magnesium dengan kadar nisbah kation/N 1.0 dengan urea. Pertambahan kecekapan pengunaan baja, pengambilan nitrogen dalam pokok serta hasil berat kering adalah diakibatkan oleh pengurangan kehilangan urea melalui pemeruapan ammonia dan bukan kerana kesan terus garam-garam tersebut ke atas pertumbuhan pokok.

CHAPTER I

INTRODUCTION

Nitrogen fertilizer is a key ingredient in cropping systems. Urea is the main form of nitrogen fertilizer used in Asia, accounting for more than 75% of the total. As for the rest of the world, urea accounts for almost all of the increase in nitrogen usage since 1976. In Malaysia a urea plant was set up in Bintulu, Sarawak, to meet the increasing demand for this fertilizer. As such, the annual urea consumption increased from a mere 56,000 tonnes of N in 1979/80 to 115,000 tonnes in 1984/85 and 124,000 tonnes in 1985/86 (Maene *et al.*, 1987).

Urea has distinct advantages over other nitrogen fertilizers. It has a high analysis (46% N) and low cost per unit of nitrogen, therefore reducing handling, storage and transportation costs. Urea uses least energy and creates least pollution during manufacture. No explosion or fire hazards are encountered during storage. Urea is suitable for application either as solid materials, solution, foliar spray or as components of high analysis compound fertilizer and bulk blends (Nayan, 1982). Moreover by using locally produced urea, foreign exchange can be saved.

One major problem encountered in using urea is loss due to volatilisation of ammonia. Urea, when applied to soils is rapidly hydrolyzed by the enzyme urease to produce ammonium carbonate. The presence of ammonium carbonate increases the pH in the vicinity of the urea granule which encourages volatilisation of ammonia. The ammonia thus formed is easily lost to the atmosphere thus greatly reducing the value of urea as a nitrogen source. Subsequent hydrolysis of the intermediate, ammonium carbonate can cause an increase in soil pH through the generation of hydroxide and bicarbonate ions. This results in localized areas around the fertilizer granule having high pH. This effect of increase in soil pH is one of the principal causes of ammonia volatilisation loss from urea.

Increased ammonia volatilisation loss is associated with high initial soil pH, high urease activity, high temperature, low ammonium absorption capacity and drying of the soil too soon after hydrolysis of urea (Nommik, 1973). Several studies have shown that ammonia volatilisation loss is a problem on Malaysian soils, where volatilisation loss as high as 53% of the applied urea occurred on a light sandy clay soil (Khanif and Husin, 1987).

Various methods have been proposed to estimate urea volatilisation loss in the field. The N-15 recovery technique is currently one of the better ways to measure ammonia volatilisation loss because it minimizes the disturbance of the field micro-environment.

Attempts to reduce ammonia volatilisation loss from urea have been made either by delaying urea hydrolysis using urease inhibitors or by changing the chemistry of the urea reaction zone using soluble salts. Several urease inhibitors have been tested and gave promising results. Among the more promising and effective ones are hydroquinone and phenyl phosphorodiamidate (PPD). Several reports have shown that volatilisation loss can be reduced and plant uptake increased with PPD treatments.

Addition of soluble salts such as calcium, potassium and magnesium have been shown to reduce ammonia volatilisation

uptake. The addition of calcium and magnesium reduced formation of ammonium carbonate by precipitation of calcium and magnesium carbonate and by depression of soil pH. Potassium reduced ammonia loss by indirectly increasing calcium precipitation by replacing the calcium on the exchange sites of high calcium soil.

Most studies on use of urease inhibitors and soluble salts to reduce ammonia volatilisation loss from urea have been concentrated on flooded and calcareous soils respectively. Studies on tropical upland soils have been limited. Moreover, most of these studies were carried out under laboratory conditions where environmental conditions differ greatly from that in the field. Therefore this study was undertaken to directly measure urea volatilisation loss in the field on two upland tropical soils by using the N-15 recovery technique.

The objectives of this study are:

(i) To measure ammonia volatilisation loss from urea under field conditions by N-15 recovery.

(ii) To control ammonia volatilisation from urea in the field using urease inhibitors and soluble salts.

(iii) To study the effect of the urease inhibitors and soluble salts on fertilizer utilization efficiency of maize.

CHAPTER II

LITERATURE REVIEW

Urea is an attractive source of nitrogen due to its low cost and high nitrogen content. However, one main disadvantage encountered with use of urea is the loss due to ammonia volatilisation (Vlek and Carter, 1983). The problem of ammonia volatilisation loss from urea has been studied for many decades.
1935, Screenivasan and Subrahmanyan (1935) reported high volatilisation from urea applied to flooded soils. Gasser (1962) pointed the advantages and disadvantages of using this fertilizer. Over the years, problems associated with urea considering different agroclimatic conditions, soil types and changing crop systems has been discussed in various papers. Despite this, the problem still exists today.

Urea Hydrolysis

The processes leading to ammonia volatilisation loss from urea are complex, involving various biochemical and physico-chemical steps, (Vlek and Craswell, 1981). The rate of ammonia volatilisation can be controlled at any of these stages, (Bouwmeester and Vlek, 1981b). Hydrolysis of urea is the first step in this chain reaction. Urea when applied to soils can rapidly undergo urea hydrolysis by the soil enzyme urease, to produce ammonium carbonate as shown below:

$$CO(NH_2)_2 + 3H_2O \xrightarrow{\text{urease}} (NH_4)_2CO_3.H_2O \qquad [1]$$

The presence of ammonium carbonate increases soil pH in the vicinity of the applied fertilizer to high levels encouraging liberation of ammonia (Vlek and Stumpe, 1978; Ferguson *et al.*,1984)

$$(NH_4)_2CO_3.H_2O + 2H^+ \longrightarrow 2NH_4^+ + CO_2 + 2H_2O \qquad [2]$$

$$NH_4^+ + OH^- = NH_4OH = NH_3 + H_2O \qquad [3]$$

Thus the complete hydrolysis of one molecule of urea consumes two hydrogen ions which increases soil pH in the vicinity of the fertilizer to very high levels. This effect of increase in soil pH is one of the principal causes of ammonia volatilisation loss from urea (Stumpe *et al.*, 1984). Studies by Khanif and Pancras (1987) showed that application of 400 ppm of urea on an upland Malaysian soil increased soil pH from 4 to 9 in two days. The highest volatilisation loss also occurred during the first two days when the pH was the highest.

Factors Affecting Ammonia Volatilisation Loss

Ammonia volatilisation loss from urea is dependent on factors such as soil characteristics, agroclimatic conditions and crop management.

Soils

It has been generally observed that volatilisation loss from surface-applied urea increases with an increase in soil pH, (Ernst and Massey, 1960; Vlek and Stumpe, 1978). Volk (1959) demonstrated that in the field, top-dressed urea created alkaline microsites due to the alkaline reaction of urea hydrolysis by the enzyme urease. Ventura and Yoshida (1977) showed in their greenhouse experiment that under submerged conditions, ammonia volatilisation loss was relatively small when pH was below 7.5. Urea hydrolysis usually resulted in accumulation of ammonium and increase in pH (Terman, 1979; Fenn *et al.*, 1981a; Vlek and Carter, 1983). The magnitude of pH increase depended on soil buffering capacity (Ferguson *et al.*(1984), while the rate of ammonium formation is influenced by urease activity (Bremner and Mulvaney, 1978). Thus, soils with low buffering capacity and high rate of urea hydrolysis are likely to have high volatilisation loss.

Reynolds and Wolf (1987b) found that the rate of ammonia volatilisation was negatively correlated with