UNIVERSITI PUTRA MALAYSIA

NITROGEN EFFICIENCY OF UREA AMENDED WITH INHIBITORS AND CATIONS APPLIED TO RICE

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By

SHREE CHANDRA SHAH

Dissertation Submitted in Fulfilment of the Requirements for the Degree of Doctor of Philosophy in the Faculty of Agriculture, Universiti Pertanian Malaysia

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DEDICATED

TO

MY BELOVED MOTHER

NIRASIA DEVI

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LIST OF ABBREVIATIONS

AE	=	Atom Excess
CRD	=	Completely Randomised Design
DCD	=	Dicyandiamide
DNMRT	=	Duncan's New Multiple Range Test
DS	=	Direct-seeded Rice
Eh	=	Redox Potential
HQ	=	Hydroquinone
IFDC	=	International Fertilizer Development Centre
IAAS	=	Institute of Agriculture and Animal Science
MARDI	=	Malaysian Agricultural Research and Development Institute
MOP	=	Muriate of Potash
MT	=	Maximum Tillering Stage
NBPT	=	N-(n-Butyl) Thiophosphoric Triamide
NdfF	=	Nitrogen derived from Fertilizer
OM	=	Organic Matter
PI	=	Panicle Initiation Stage
PAU	=	Punjab Agricultural University
PMA	=	Phenyl-Mercuric Acetate
P. Puteh	=	Pasir Puteh
PPD	=	Phenyl Phosphorodiamidate
PT	=	Planting Time

RCBD	=	Randomised Complete Block Design
SAS	=	Statistical Analysis System
T 1/2	=	Half Life
TP	=	Transplanted Rice
TSP	=	Triple Superphosphate
UPM	=	Universiti Pertanian Malaysia
USAID	=	United States Agency for International Development

Abstract of the Dissertation Submitted to the Senate of Universiti Pertanian Malaysia in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Chairman : Mohd. Khanif Yusop, Ph.D.

Faculty : Agriculture

Urea, the major source of nitrogen (N), is subjected to extensive gaseous N losses to the atmosphere. Ammonia (NH_3) volatilisation and denitrification losses are important mechanisms for N losses from urea and are causes of poor fertilizer use efficiency by lowland rice. The study was undertaken in a series of five experiments to evaluate means of increasing the efficiency of urea-N under flooded rice soil conditions. A laboratory incubation experiment of different rice soils was conducted to study the kinetics and transformations of urea in flooded soils. A greenhouse experiment was carried out on marine and riverine alluvial soils to evaluate urea-N efficiency in direct-seeded (DS) rice and transplanted (TP) rice under similar N management practices using ^{15}N-labelled urea. Two greenhouse and one field studies were conducted to evaluate the effectiveness of inhibitors and cations on marine and riverine alluvial rice soils on the efficiency of urea-N using ^{15}N recovery techniques.

Urea hydrolysis followed the first-order kinetics and rate constants ranged from -0.032 to -0.076 ha^{-1}. A lag phase existed in flooded soil conditions and it varied from 6 to 15 hours. The half-life of urea ranged from 12 to 26 hours. Urea conversion to NH_4^+-N was initially rapid with about three-fourths being converted within 48 hours of incubation and total conversion completed within 108 hours.

Urea hydrolysis in the floodwater of marine and riverine alluvial soils was completed within five days after urea application. The rate of urea-N and NH_4^+-N disappearance from floodwater at MT (Maximum Tillering) and PI (Panicle Initiation) stages was faster than at PT (Planting Time). Urea-N and NH_4^+-N concentration in floodwater of DS rice was lower than of TP rice. Lower fertilizer N losses and higher fertilizer N use efficiency by DS rice in both soils gave significantly higher yield of rice than by TP rice at MT stage and at maturity. Fertilizer N losses occurred mainly before maximum tillering.

Significantly higher urea-N and lower NH_4^+-N concentrations persisted in the floodwater of Phenyl phosphorodiamidate (PPD) amended urea than of Hydroquinone (HQ), Dicyandiamide (DCD) and urea alone at PT, MT and PI stages. Hydroquinone was not effective in retarding urea hydrolysis in floodwater but it was probably very effective in retarding denitrification. Uptake of fertilizer N and total N were increased with the addition of HQ, PPD and DCD amended urea as compared to urea alone in both soils. Fertilizer N use efficiency was higher in Bakau soil than in Cempaka soil. Hydroquinone and PPD treated urea enhanced retention of fertilizer N in soils. Higher fertilizer N use efficiency due to HQ and DCD treated urea increased grain yield over urea alone. However, PPD amended urea did not increase yield of rice despite increased fertilizer N uptake. Soluble salts amended urea increased NH_4^+-N concentration in the floodwater than urea alone or soluble salts applied one week after urea application. Additions of soluble salts amended urea increased plant uptake of fertilizer N by reducing fertilizer N losses in both soils. Bakau soil immobilised more fertilizer N than Cempaka soil. Grain yield obtained from urea amended with Ca and K was significantly higher than from urea alone under greenhouse and field studies. In the field study, inhibitors and soluble salts co-applied with urea significantly increased N uptake by plants.

Higher efficiency of fertilizer N use in DS rice could be further exploited to increase grain yields. Effect of HQ on denitrification in lowland rice soils needs further testing. Effects of PPD on the N uptake and metabolism of urea within the plant need to be tested. Urea amended with Ca and K may offer a significant advantage over urea alone in reducing NH_3 losses from urea in flooded rice soil by Ca precipitation mechanism but further research to quantify those effects is needed.

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NITROGEN EFFISIENSI UREA YANG DIRAWAT DENGAN BAHAN PENGHALANG DAN KATION YANG DIGUNAKAN KEPADA PADI

OLEH

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Urea ialah suatu baja pembekal nitrogen yang penting, mengalami kehilangan N yang tinggi ke atmosfera dalam bentuk gas. Pemeruapan ammonia dan denitrifikasi suatu mekanisme kehilangan N dari urea yang penting dan ia merendahkan effisiensi penggunaan baja N oleh padi. Kajian yang mengandungi lima ujikaji dijalankan bertujuan untuk menilai kaedah yang boleh meninggikan effisiensi N daripada urea dalam keadaan tanah sawah yang terendam. Satu kajian pemeraman di makmal ke atas berbagai jenis tanah sawah di jalankan bagi mengkaji kinetik dan transformasi urea dalam tanah terendam. Satu kajian di rumah kaca dijalankan ke atas tanah lanar laut dan sungai untuk menilai effisiensi N dari urea untuk padi tabur terus (TT) dan padi tanam semai (TS) dengan pengurusan N yang sama dengan menggunakan urea yang ditanda dengan ^{15}N. Dua kajian rumah kaca dan satu kajian ladang, dijalankan bagi menilai keberkesanan bahan penghalang dan kation pada tanah lanar laut dan sungai ke atas effisiensi N dari urea dengan menggunakan teknik ^{15}N.

Hidrolisis urea mengikuti kinetik tertib pertama dan pemalar kadar dalam julat -0.032 - -0.076 ha^{-1}. Fasa lambat berlaku dalam tanah terendam air dan tempohnya di antara 6 hingga 15 jam. Nilai setengah hayat urea adalah di antara 12 hingga 26 jam. Kadar perubahan urea kepada NH_4-N adalah cepat pada peringkat awal dengan tiga suku daripadanya di tukarkan dalam masa 48 jam semasa pemeraman dan pertukaran kesemuanya berlaku dalam 108 jam.

Hidrolisis urea dalam air pada tanah lanar laut dan sungai tamat dalam masa 5 hari selepas penaburan urea. Kadar kehilangan urea dan NH_4 daripada air pada pengeluaran anak maksimum (PM) dan permulaan pembentukan bulir (PB) adalah lebih cepat daripada mula menanam (MM). Kepekatan urea dan NH_4-N dalam air bagi padi TT adalah lebih rendah daripada padi TS. Padi TT mempunyai hasil yang lebih tinggi daripada padi TS, kerana kehilangan baja N yang rendah dan effisiensi penggunaan baja N yang tinggi. Kebanyakan kehilangan baja N berlaku sebelum PM.

Di dalam air yang menerima rawatan phenyl phosphorodiamidate (PPD), kandungan urea adalah lebih tinggi dan NH_4 lebih rendah daripada kandungan dalam air yang dirawat dengan urea bersamaan Dicyandiamide (DCD) dan urea sahaja pada MM, PM dan PB. Hydroquinone (HQ) tidak berkesan menghalang hidrolis urea dalam air tetapi mungkin berkesan menghalang denitrifikasi. Jumlah penyerapan N dan penyerapan baja N bertambah dengan rawatan urea bersama HQ, PPD dan DCD berbanding dengan rawatan urea sahaja pada kedua-dua tanah yang dikaji. Effisiensi penggunaan baja N pada tanah Bakau adalah lebih tinggi daripada tanah

Cempaka. Hydroquinone dan PPD meningkatkan kehadiran baja N dalam tanah. Peningkatan effisiensi penggunaan baja N oleh urea yang dirawat dengan HQ dan PPD menambah hasil bijirin pada berbanding dengan rawatan urea sahaja. Urea yang dirawat dengan PPD tidak meningkatkan hasil padi walaupun pengambilan baja N meningkat.

Urea yang dirawat dengan garam larut meningkatkan kepekatan NH_4^+-N dalam air berbanding dengan rawatan urea sahaja atau rawatan garam larut yang ditambah selepas satu minggu penambahan urea. Penambahan urea yang dirawat dengan garam larut meningkatkan pengambilan baja N dengan mengurangkan kehilangan N daripada kedua jenis tanah. Tanah Bakau mengikat lebih banyak baja N daripada tanah Cempaka. Di rumah kaca atau di ladang hasil bijirin yang diperolehi dari rawatan urea yang dirawat dengan Ca dan K adalah lebih tinggi daripada rawatan urea sahaja. Dalam kajian di ladang kimia penghalang dan garam larut yang dirawat bersama urea meningkatkan pengambilan N oleh tumbuhan.

Effisiensi penggunaan baja N yang lebih tinggi oleh padi TT boleh dieksploitasikan bagi peningkatan hasil. Kesan HQ terhadap denitrifikasi dalam tanah sawah perlu kajian lanjut. Kesan PPD terhadap pengambilan N dan metabolisme urea di dalam tumbuhan perlu kajian lanjut. Urea yang dirawat dengan Ca dan K memberikan kesan yang baik berbanding dengan rawatan urea sahaja dengan mengurangkan kehilangan NH_3 dari urea dalam tanah sawah dengan mekanisma perecipitasi Ca tetapi kajian yang lebih lanjut diperlukan untuk mengkaji kesan tersebut secara kuantitatif.