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EVALUATION OF SELECTED COATED UREA ON NITROGEN USE EFFICIENCY OF RICE

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Abstract of the thesis submitted to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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Urea is the main nitrogen (N) fertilizer sources applied in the rice production. However, the efficiency of urea in rice system is generally low. A part of applied N will be loss due to ammonia (NH_3) volatilization, nitrification and denitrification. In order to minimize N losses, urea was coated with urease inhibitor, nitrification inhibitor, inorganic materials or supplemented with biochar. This study was carried out with the following objectives: to evaluate the effect of different coated urea on N transformation, NH_3 volatilization, nitrous oxide (N_2O) gas emissions in selected rice soils and rice production; to determine N utilization and the pattern of fertilizer N uptake by hybrid rice in comparison of inbred varieties. Copper (Cu) and zinc (Zn) acted as urease inhibitors and dimethylpyrazol-phosphate (DMPP) was selected as nitrification inhibitor. The N fertilizers compared were urea, Cu coated urea (CuU), Zn coated urea (ZnU), Cu + Zn coated urea (CuZn), DMPP coated urea (DMPPU), DMPP + Cu + Zn coated urea (DMPPCuZn), sulfur coated urea (SU), dolomite coated urea (DU) and OneBaja (urea impregnated biochar). Copper, Zn and DMPP coated urea were prepared by coating them with palm stearin. Laboratory evaluation of coated urea was conducted to measure N transformation, NH_3 volatilization and N_2O emission in Selangor and Chempaka soil. Results indicated that treatments consisting of urease inhibitor slowed urea hydrolysis. Copper coated urea, ZnU, CuZn, DMPPCuZn, SU, OneBaja were effective in reducing NH_3 loss as compared to urea by 12.12 - 37.48%. Furthermore, SU, CuU, ZnU, CuZn, DMPPU and DMPPCuZn reduced N_2O emission over urea by 14.86 - 48.65%. Glasshouse study was carried out to measure fertilizer N utilization and pattern of fertilizer N uptake by hybrid rice named Siraj in comparison to MR219 by using ^{15}N isotopic label technique. Rice plants were harvested at two weeks interval starting from 2nd week (DAT-day after transplant) until 14th week. Fertilizer N uptake and utilization reached a peak between 10th and 12th week. Relatively, Siraj recorded better fertilizer N utilization and N uptake as compared to MR219 variety. A second glasshouse study was carried out to determine the effect of coated urea on rice yield. Siraj and MR220 variety were grown in one growing season in Selangor and Chempaka soil. Pots treated with OneBaja, CuU, ZnU, CuZn, DMPPU and DMPPCuZn showed an improvement of grain yield by 32.96 - 39.05% over urea in Chempaka soil. Higher

grain yield was recorded in pots applied with CuU, CuZn, DMPPCuZn and SU as compared to urea in Selangor soil. Field study was conducted at Sungai Besar Selangor. The rice were directly seeded by manual broadcasting practice. Results demonstrated that, coated urea (CuU, CuZn, DMPPU, DMPPCuZn) and OneBaja treated plots produced better rice yield and N uptake with an increment of 17.43 - 28.44% and 20.72 - 42.28% respectively. Siraj outperformed MR220 in increasing grain yield and N uptake. This suggests that there is a prospect of using urease and nitrification inhibitor coated urea and OneBaja to improve N efficiency of urea and rice yield.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

PENILAIAN KEBERKESANAN UREA BERSALUT TERPILIH TERHADAP KECEKAPAN PENGGUNAAN NITROGEN PADA TANAMAN PADI

Oleh

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Urea merupakan sumber baja N utama digunakan dalam pengeluaran padi. Walau bagaimanapun, kecekapan urea dalam pengeluran padi adalah rendah. Sebahagian daripada baja N yang ditabur hilang melalui pemeruwapan NH_3, nitrifikasi dan denitrifikasi. Dalam usaha untuk mengurangkan kehilangan N, urea telah disalut dengan perencat urease, perencat nitrifikasi, bahan bukan organik atau ditambah dengan biochar. Kajian dijalankan dengan objektif : untuk menilai kesan urea bersalut terhadap transformasi N, pemeruwapan NH_3, pelepasan N_2O dalam tanah padi dan pengeluaran padi; untuk menentukan penggunaan N dari baja dan corak pengambilan N dari baja oleh varieti padi hibrid berbanding varieti padi inbred. Kuprum (Cu) dan zink (Zn) digunakan sebagai perencat urease manakala dimethylpyrazol-fosfat (DMPP) dipilih sebagai perencat nitrifikasi. Rawatan baja terdiri daripada urea, urea bersalut Cu (CuU), urea bersalut Zn (ZnU), urea bersalut Cu + Zn (CuZn), urea bersalut DMPP (DMPPU), urea bersalut DMPP + Cu + Zn (DMPPCuZn), urea bersalut sulfur (SU), urea bersalut dolomite (DU) dan OneBaja (urea impregnated biochar). Untuk penyediaan urea bersalut Cu, Zn dan DMPP, baja tersebut disaluti dengan lapisan palm stearin. Kajian di makmal dijalankan untuk mengukur transformasi N, pemeruwapan NH_3 dan pelepasan N_2O pada tanah siri Selangor dan Chempaka. Keputusan menunjukkan hidrolisis urea adalah perlahan pada rawatan yang mengandungi perencat urease. Urea bersalut kuprum (CuU), ZnU, CuZn, DMPPCuZn, SU, OneBaja didapati berkesan untuk mengurangkan kehilangan NH_3 berbanding urea sebanyak 12.12 -37.48%. Selain dari itu, CuU, ZnU, CuZn, DMPPU dan DMPPCuZn mengurangkan pelepasan N_2O sebanyak 14.86 - 48.64%. Kajian rumah kaca dijalankan untuk mengukur penggunaan N dan corak pengambilan N dari baja oleh padi hibrid Siraj berbanding padi MR219 dengan menggunakan kaedah ^{15}N label isotop. Tanaman padi dituai berselang dua minggu bermula dari minggu ke 2 (HLU- hari lepas ubah) sehingga minggu ke 14. Penggunaan N dan pengambilan N dari baja adalah maksimum di antara minggu ke 10 dan minggu ke12. Penggunaan N dan pengambilan N dari baja yang lebih baik direkodkan oleh Siraj beras hibrid berbanding varieti MR219. Kajian

rumah kaca yang kedua dijalankan untuk menentukan kesan urea bersalut terhadap hasil padi. Padi Siraj dan MR220 ditanam dalam bekas untuk satu musim penanaman pada tanah siri Selangor dan Chempaka. Pada tanah siri Chempaka, bekas yang dirawat dengan OneBaja CuU, ZnU, CuZn, DMPPU, DMPPCuZn meningkatkan hasil bjirin padi sebanyak 32.96 - 39.05% berbanding urea. Hasil bijirin yang lebih tinggi telah direkodkan dengan rawatan CuU, CuZn , DMPPCuZn dan SU berbanding dengan urea di dalam tanah siri Selangor. Kajian di ladang telah dijalankan untuk menilai keberkesanan urea bersalut terhadap prestasi varieti Siraj dan MR220. Kajian dijalankan di Sungai Besar Selangor. Biji benih padi ditabur terus secara manual. Keputusan kajian menunjukkan bahawa, plot yang dirawat dengan urea bersalut (CuU, CuZn, DMPPU, DMPPCuZn) dan OneBaja menunjukkan hasil padi dan pengambilan N yang lebih baik daripada plot yang dirawat dengan urea dengan peningkatan sebanyak 17.43 - 28.44% dan 20.72 - 42.28% setiap satu. Keputusan ini menunjukkan bahawa penggunaan urea yang disalut dengan perencat urease dan perencat nitrifikasi dan juga OneBaja mempunyai prospek bagi meningkatkan kecekapan N baja urea dan juga meningkatkan hasil padi.

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I certify that a Thesis Examination Committee has met on 13 October 2016 to conduct the final examination of Rosmarina binti Ahmad Khariri on her thesis entitled "Evaluation of Selected Coated Urea on Nitrogen use Efficiency of Rice" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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LIST OF ABBREVIATIONS

C	Carbon
Cu	Copper
CEC	Cation exchange capacity
CO_2	Carbon dioxide
CO_3	Carbonate ion
CRD	Completely randomized design
$CuSO_4$	Copper sulphate
CuU	Cu coated urea
CuZn	Cu + Zn coated urea
DCD	Dicyandiamide
DMPP	Dimethylpyrazol-phosphate
DMPPCuZn	DMPP + Cu + Zn coated urea
DMPPU	DMPP coated urea
DU	Dolomite coated urea
H	Hydrogen ion
HCL	Hydrochloric acid
HNO_3	Nitric acid
H_2SO_4	Sulfuric acid
IPCC	Intergovernmental Panel on Climate Change
MARDI	Malaysia Agriculture Research Development Institute
MOP	Muriate of potash
N	Nitrogen
N_2	Dinitrogen
N_2O	Nitrous oxide
NBPT	N-(n-Butyl) thiophosphoric triamide
NH_3	Ammonia
NH_4	Ammonium ion
Nar	Nitrate reductase
Nir	Nnitrite reductase
NO_2	Nitrite ion
NO_3	Nitrate ion
O	Ozone
OH	Hydroxyl ion
PPD	Phenylphosphorodiamidate
RCBD	Randomized completely block design
SU	Sulfur coated urea
TSP	Triple superphosphate
Zn	Zinc
$ZnSO_4$	Zinc sulphate
ZnU	Zn coated urea

CHAPTER 1

INTRODUCTION

The world is currently facing a new set of multiple challenges. Achieving food security on existing agricultural land without causing undue damage to the environment is a major challenge. World population is continuing to grow, the current world population of 7.3 billion is projected to reach 8.5 billion by 2030 and 9.7 billion in 2050 and with that, food demand is estimated to escalate substantially (United Nations, 2015). Rice production has to be increased, as it is the main staple food for nearly half of the world's population (Muthayya et al., 2014). Hence, rice yield should increase without further increase in rice cultivated area. In order to address the matter, more grain per area must be produced and this requires more fertilizer input (Zhang et al., 2012).

Among nutrients required by plants, nitrogen (N) is applied at the highest quantities and has the greatest potential for losses (Linquist et al., 2013). Urea is extensively being used as a source of N in rice cropping and it is the cheapest source of N in addition to its ease of handling Unfortunately, recovery of applied urea is low in rice system. The recovery efficiency of applied N was reported to be at 26 - 50% in Malaysian rice soils implying that a large portion of the applied N is not being used for productive purposes (Hashim et al., 2015; Khanif, 1988; Sariam and Khanif, 2006).

The inefficient use of N in rice cultivation can be attributed to synchronization release of N from fertilizers with the plant demand due to the N losses *via* various pathways such as volatilization, nitrification and denitrification. Nitrogen losses result in significant yield loss and environmental consequences with respect to the emissions of gases such as nitrous oxide (N_2O), ammonia (NH_3) and aquatic pollution through nitrate (NO_3) leaching (Chen et al., 2014; Saggar et al., 2013). Recent report, revealed that N export to the environment from rice fields accounted for 13.1 - 31.7% of the N input (Yang et al., 2015). Yield loss also pararrels with economic implication to the farmers and increase expense for the rice production.

For the above reasons, it is desirable to reduce N losses so as to improve N use efficiency, improve rice yields for food demand, reduce cost of production and maintain environmental quality. The minimal modifications and improvement of the fertilizer itself is one of the approaches to reduce losses (Junejo et al., 2011a; Zaman et al., 2009). The use of specially formulated form of fertilizer by coating and supplemented with inhibitors or inorganic material might have a great prospect. Application of nitrification inhibitor has proven to be efficient in mitigating N_2O emission and improving N use efficiency (Qiao et al., 2105). Addition of urease inhibitor to urea increase the efficiency of fertilizer by reducing NH_3 volatilization in flooded soil (Xue et al., 2013).

The use of micronutrients such as copper (Cu) and zinc (Zn) as urease inhibitor was recorded to be effective in reducing NH_3 volatilization loss and improved crop N uptake (Junejo et al., 2011b; Junejo et al., 2012). Application of these elements as urease inhibitors can give double benefits; in addition to inhibit urease activity, these elements can serve as micronutrients for plant growth particularly in micronutrients deficient soil. To the date, there have been limited studies of the inhibitory effect of micronutrient as urease inhibitor.

In addition, the use of nitrification inhibitor should be part of fertilizer N. Among the nitrification inhibitors, dimethylpyrazol-phosphate (DMPP) has been reported by many researchers as the most efficient in improving efficiency of N fertilizer and effective at low rate (Liu et al., 2013; Weiske et al., 2001). Many compounds are capable of inhibiting urease activity and nitrification process. However their efficacy under tropical condition especially in flooded soil have not been documented and the study to evaluate the efficacy of Cu, Zn as urease inhibitor, DMPP as nitrification inhibitor and combination of these in rice cultivation system is limited.

Instead of fertilizer technologies, hybrid rice technology is one of the most important and practically feasible technologies to boost rice productivity. Hybrid rice was first developed in China in the 1960s and has a yield advantage over the inbred rice varieties, facilitating a 44.1% increment in rice production (Cheng et al., 2007). With concern about the sustainable food production and environmental issue, there is a need to conduct comprehensive studies on urease and nitrification inhibitor on rice in order to improve N use efficiency and enhancing rice production. With this in view, the current study was carried out with the following objectives:

1. To evaluate the effect of different coated urea on N transformation, N_2O emission and NH_3 volatilization in selected Malaysian rice soil under laboratory and glasshouse conditions,
2. to determine the pattern of N fertilizer uptake and utilization by selected hybrid rice variety in comparison to non-hybrid rice variety and
3. to determine the efficacy of different coated urea on yield and nutrient uptake of hybrid and non-hybrid rice under glasshouse and field conditions.

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