**UNIVERSITI PUTRA MALAYSIA**

# THE DEVELOPMENT OF COPPER-COATED UREA FOR RICE PRODUCTION

**TAI KIN LEONG**

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# THE DEVELOPMENT OF COPPER-COATED UREA FOR RICE PRODUCTION

By

**TAI KIN LEONG**

**Thesis Submitted to The School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of The Requirement for The Degree of Master of Agriculture Science**

**March 2002**

*Dedicated*

*to*

*my*

*family*

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Agriculture Science

**THE DEVELOPMENT OF COPPER-COATED UREA FOR RICE PRODUCTION**

**By**

**TAI KIN LEONG**

**March 2002**

**Chairman : Associate Professor Dr. Mohd Khanif Yusop**

**Faculty : Agriculture**

Urea is the main fertilizer used in the rice production in the world. Like other N fertilizers, the efficiency of urea in rice soils generally low due to high losses through volatilization, denitrification and leaching. Slow release fertilizers can be used to minimize loss of N. The rice yields in some area in Malaysia are low due to Cu deficiency. The objective of this study is to develop Cu-coated urea to increase the rice production. In this study, five types of materials consisting chitosan, poly-vinyl chloride (PVC), palm oil sludge (POS), neem oil (NE) and palm stearin (PS) were used as coating materials and Cu carrier. However, due to some technical problems only POS, NE and PS were used in this study. The source of Cu used was copper sulphate. These Cu-coated urea fertilizers were evaluated their effectiveness as Cu carrier and slow-release capabilities in rice soils conditions under laboratory incubation and greenhouse studies using two types of rice soils:– Kangar sries (Typic Endoaquert) and Kundor series (Typic Tropaquept). The

PS-coated Urea had the most N content (43.87%) followed by NE (42.08%) and POS (41.19%). The POS has the most Cu content (1320 $\mu g\ g^{-1}$) and total coating (11.62%). In a laboratory incubation using Kangar and Kundor soils added with 120 kg N $ha^{-1}$ of Cu-coated urea, showed that the rate of urea release decrease in the order: – PS>POS>NE>uncoated urea (control). In Kangar soils, PS (544.47 $\mu g\ g^{-1}$) had the most $NH_4^+$–N accumulation followed by POS (400.15 $\mu g\ g^{-1}$) and NE (377.85 $\mu g\ g^{-1}$). In Kundor soils, the highest accumulation of $NH_4^+$–N was recorded in PS (1474.54 $\mu g\ g^{-1}$) followed by POS (1344.79 $\mu g\ g^{-1}$) and NE (1223.78 $\mu g\ g^{-1}$). In Kangar series, POS (0.086 $\mu g\ g^{-1}$) treatment gave the highest concentration of copper in the soil followed by NE (0.06 $\mu g\ g^{-1}$) and PS (0.044$\mu g\ g^{-1}$). In Kundor series, the highest Cu concentration in the soil was observed in POS (0.104 $\mu g\ g^{-1}$) followed by NE (0.063 $\mu g\ g^{-1}$) and PS (0.058 $\mu g\ g^{-1}$). The greenhouse study showed that Cu-coated urea fertilizers increased the rice yield. In Kangar series, POS, NE and Ps increased the yield by 34% (2.19 kg $ha^{-1}$), 29% (2.02 kg $ha^{-1}$) and 23% (1.86 kg $ha^{-1}$) respectively over the control (urea). In Kundor series, treatments of POS, NE and PS have increased the yield by 8% (5.40 kg $ha^{-1}$), 5% (5.28 kg $ha^{-1}$) and 18% (5.89 kg $ha^{-1}$) respectively over the control. The greater availability of Cu and N throughout crop growth and low N loss had increased the grain yield. The effectiveness of the Cu-coated urea was as follow: – PS>POS>NE>urea. These findings suggest that there is a prospect of using Cu-coated urea to increase rice yield and N agronomic efficiency.

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia bagi memenuhi keperluan untuk ijazah Master Sains Pertanian

**PENYEDIAAN UREA BERSALUT KUPRUM UNTUK PENGELUARAN PADI**

**Oleh**

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Urea adalah baja utama untuk pengeluaran padi di dunia. Seperti baja N yang lain, effisiensi urea dalam tanah sawah adalah rendah disebabkan kehilangan melalui proses pemeruapan, denitrifikasi dan larutlesap. Baja bebas perlahan boleh digunakan untuk mengurangkan kehilangan N. Di beberapa kawasan di Malaysia, hasil padi adalah rendah disebabkan oleh kekurangan unsur Cu. Objektif eksperimen ini adalah untuk menghasilkan baja urea bersalut Cu untuk meningkatkan hasil padi. Dalam eksperimen ini, lima jenis bahan penyalut yang terdiri daripada kitosan, poli-(vinilklorida), palm oil sludge (POS), minyak neem (NE) dan palm stearin (PS) telah digunakan untuk menyediakan baja urea bersalut Cu. Oleh kerana masalah teknikal, cuma POS, NE dan PS yang digunakan dalam eksperimen ini. Sumber Cu yang digunakan adalah kuprum sulfat. Keberkesanan urea bersalut Cu dikaji sebagai pembawa Cu dan baja bebas perlahan di dalam makmal dan rumah kaca dengan menggunakan dua jenis tanah sawah iaitu Siri Kangar (Typic Endoaquert) dan Siri Kundor (Typic Tropaquept). Baja urea yang disalut PS (43.87%) mencatatkan kandungan N yang paling tinggi

diikuti oleh NE (42.05%) dan POS (41.19%). Manakala, baja POS mencatatkan jumlah Cu (1320 µg $g^{-1}$) dan jumlah penyalutan (11.62%) yang paling tinggi. Di dalam kajian pemeraman menggunakan tanah siri Kangar dan Kundor dengan kadar pembajaan adalah 120 kg N $ha^{-1}$, didapati bahawa kadar pembebasab urea berkurang dalam turutan berikut:- PS>POS>NE>urea (kawalan). Di dalam tanah siri Kangar, PS (544.47 µg $g^{-1}$) mencatatkan pengumpulan $NH_4^+$–N yang paling tinggi diikuti oleh POS (400.15 µg $g^{-1}$) dan NE (377.85 µg $g^{-1}$). Dalam tanah siri Kundor pula, PS (1474.54 µg $g^{-1}$) mencatatkan pengumpulan $NH_4^+$–N yang paling tinggi diikuti oleh POS (1344.79 µg $g^{-1}$) dan NE (1223.78 µg $g^{-1}$). Dalam tanah siri Kangar, POS (0.086 µg $g^{-1}$) mencatatkan kepekatan Cu yang paling tinggi diikuti oleh NE (0.06 µg $g^{-1}$) dan PS (0.044 µg $g^{-1}$). Manakala di dalam tanah siri Kangar, POS (0.104 µg $g^{-1}$) juga mencatatkan kepekatan Cu yang paling tinggi diikuti oleh NE (0.063 µg $g^{-1}$) dan PS (0.058 µg $g^{-1}$). Dalam kajian rumah kaca, kesemua baja urea bersalut Cu telah meningkatkan hasil padi. Dalam tanah siri Kangar, rawatan POS, NE dan PS telah meningkatkan hasil padi sebanyak 34% (2.19 kg $ha^{-1}$), 29% (2.02 kg $ha^{-1}$) dan 23% (1.86 kg $ha^{-1}$) masing-masing berbanding kawalan. Dalam siri Kundor pula, rawatan POS, NE dan PS telah mencatatkan peningkatan sebanyak 5% (5.40 kg $ha^{-1}$), 8% (5.28 kg $ha^{-1}$) dan 18% (5.89 kg $ha^{-1}$) masing-masing. Kehadiran sumber Cu dan N yang tinggi serta kehilangan N yang minima telah meningkatkan hasil padi. Effisiensi urea bersalut sebagai baja bebas N perlahan dan sebagai pembawa Cu adalah seperti berikut:- POS>PS >NE>urea Hasil kajian ini menunjukkan bahawa urea bersalut Cu dapat meningkatkan hasil padi serta keberkesanan N secara agronomik.

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I certify that an Examination Committee met on 20th March 2002 to conduct the final examination of Tai Kin Leong on his Master of Agriculture Science thesis entitled "The Development of Copper-coated Urea for Rice Production" in the accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Agriculture Science.

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I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

TAI KIN LEONG

Date: 11/6/2002

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| | | |
|---|---|---|
| CEC | = | Cation Exchange Capacity |
| DLM | = | Department of Land Management |
| DMRT | = | Duncan's Multiple Range Test |
| FAO | = | Food and Agriculture Organization |
| IRPA | = | Intensification of Research in Priority Areas |
| IRRI | = | International Rice Research Institute |
| MARDI | = | Malaysian Agricultural Research and Development Institute |
| MOA | = | Ministry of Agriculture |
| MOP | = | Muriate of Potash |
| NE | = | Neem Oil |
| POS | = | Palm Oil Sludge |
| PS | = | Palm Stearin |
| TSP | = | Triple Superphosphate |
| UKM | = | Universiti Kebangsaan Malaysia |
| UPM | = | Universiti Putra Malaysia |

# CHAPTER I

# INTRODUCTION

For many centuries, rice has been the staple food for more than half the world population especially in Asia. However, the yield of rice is the lowest among other grains. The average yield of rice in Malaysia is 3.20 ton $ha^{-1}$ (FAO, 2000). Since 1996, the average production of rice yield in Malaysia has become stagnant. Malaysia is currently 70% self-sufficient in rice production and has to import rice from the neighboring countries especially Thailand and Vietnam to meet the demand. The value of the rice imports is at RM 500 million per year (Ariffin, 1998). By year 2020, the Asian countries except Thailand and Myanmar, will face severe rice shortage due to scarcity of land for rice production (Ariffin, 1998). To meet the demand for rice, the world's annual rice production must increase to 758 million tons by 2020 (IRRI, 1989). This increase in rice production is only possible if soil, water, nutrients and other production inputs are used more efficiently in the future.

Nitrogen Use Efficiency (NUE) is a measure of the extent to which a crop transforms available N to economic yield. Rice is a poor user of N with the NUE not exceeding 50% (Mahapatra *et al.*, 1985). Most of the N applied is lost through many processes like ammonia volatilization, denitrification, leaching and immobilization. In order to improve the NUE of rice, many methods have been developed. One of the methods is the slow release N fertilizers. These fertilizers can regulate the N supply in consonance with the demand of the crop at various stages of growth (Amy and Ware, 1964). In 1998, the world fertilizer consumption was at 137 million metric ton with N fertilizers' consumption at 82 million metric ton (FAO, 2000).

Urea is the main N fertilizer used worldwide especially in rice production (Harre and Bridges, 1988). Urea is widely used because: (i) the cost of production is competitive, (ii) low salt content which prevents injury to plants, (iii) urea can be applied in many forms like solid and liquid (Nayan, 1982) and (iv) it has high N content, 46% N. Malaysia is one of the urea producers, where 1.4 million ton of urea fertilizers is produced annually to cater the local and foreign requirements.

In order to increase the NUE, slow release fertilizers are developed to minimize the loss of N by releasing N over a longer period of time. The sulphur coated urea (SCU) is perhaps the best-known slow release fertilizer. Throughout the years, many types of fertilizers, such as urea rubber matrices, lac-coated urea, urea supergranule (USG), neem-coated urea and others have been developed. These modified forms of urea (Patil *et al.,* 1987) and USG (Pal *et al.,* 1984) were capable of increasing the yield of rice.

Besides increasing the NUE, slow release fertilizers are able to reduce adverse effects on the environment by reducing the leaching of nitrate and by reducing the emissions of nitrous oxide and volatilization losses of ammonia. Even a small increase of 1% in NUE is estimated to save more than

US$234,000,000 in fertilizer costs worldwide (Raun and Johnson, 1999). However, the commercial availability of the (well-performing) slow release fertilizers remains very limited. Due to high cost, slow release fertilizers are usually reserved for use in high-value production systems, such as turf and horticultural crops (Hauck, 1985).

High input of N does not promise a much higher rice yield. The micronutrient deficiency in soil can reduce the rice yields. Micronutrient, which also referred to as trace elements or minor elements, comprise seven of the 16 elements essential to plant growth (Harmsen and Vlek, 1985). Although required in small amount, these elements play major roles in plant growth and development. Moreover, a micronutrient is important when biological activity occurs only with the complexed ligand. Micronutrients can be applied in many ways including foliar application, seed treatment, root dipping of transplanted seedlings and application with pesticides (Mortvedt, 1985).

The largest irrigation scheme in Malaysia is the Muda Irrigation Scheme, which is located in Kedah. The area of the scheme is about 96,558 ha and is the largest irrigation scheme in Malaysia. The production of rice in this scheme is 4.129-ton $ha^{-1}$ in 1999 (DOA, 2000). Over the years, micronutrient has been over-mined by intensive farming. Most of the sites investigated in the irrigation scheme are deficient in copper (Cu) and magnesium (Mg), which resulted in the declined of rice yield (Samy *et al.*, 1992a). The deficiency of copper is attributed to low soil Cu content.

Farmers are applying a single dose of NPK (80 kg N $ha^{-1}$, 30 kg $P_2O_5$ $ha^{-1}$ and 20 kg $K_2O$ $ha^{-1}$) in rice fields throughout the irrigation scheme. Investigations showed that there was a significant response to Cu with 16% increase in yield (Samy *et al.*, 1992a).

The prices of fertilizers have increased very drastically especially in the developing nations due to higher foreign exchange. Some of the small-scale rice cultivators of these countries have been forced out from the business, as they are unable to cope with the rising cost of production. The rising costs of production have encouraged the research on development of cheaper, easily available, environment-friendly fertilizers and with the ability to correct micronutrient deficiency.

With the increasing demand for micronutrients, many questions have been raise as to how small amounts of such materials can be added to fertilizers satisfactorily. Addition to fertilizers is of interest because it is much more practical to apply micronutrients together with fertilizers than in separate application. The most popular method is to apply the micronutrients in admixture with the primary nutrient fertilizer that farmers regularly use. The first reason for this popularity is convenience; the farmer does not have to devote extra labor to micronutrient application if the micronutrient carrier is a fertilizer that he is using. A second reason is that uniformity of application is much easier when the micronutrient material is mixed with much larger volume of fertilizer. However, very limited research has been conducted on slow release of N fertilizers containing micronutrient. Therefore, this study plan to develop a new micronutrient coated N fertilizer to increase the rice production.

## Objectives

The present study is focused on the development of micronutrient-coated urea for rice production. The objectives of this study are: -

i ) To prepare and evaluate selected physical properties of copper-coated urea using low cost and easily available materials,

ii ) To study the degradation rate of the coated urea under rice field conditions

iii) To assess the effectiveness of the coating materials as copper carrier, and

iv) To evaluate the effectiveness of copper- coated urea in increasing rice production under greenhouse condition.