UNIVERSITI PUTRA MALAYSIA

EFFECTS OF COATED UREA FERTILIZERS ON GROWTH AND YIELD OF MR219 RICE (Oryza sativa L.)

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By

NUR SYAMIMI BINTI A.RAHMAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Master of Science

December 2015

For Ayah, Mama, Nadiah (Along), Abg Mizi, Aqilah (Acik) and Syazana (Adik)
You are my life's greatest blessing and unstoppable loves will never end

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

EFFECTS OF COATED UREA FERTILIZERS ON GROWTH AND YIELD OF MR219 RICE (*Oryza sativa* L.)

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Chairman: Professor Robiah Yunus, PhD
Institute: Institute of Advanced Technology

Urea is widely used as a nitrogen fertilizer. However, the efficiency of urea is generally low due to the rapid hydrolysis which has resulted in the low N uptake and contributed to the hazardous environmental effect. The improvement in urea efficiency can be achieved by coating the urea with selected coating materials. The coated fertilizer is known as a slow release fertilizer which ultimately can reduce fertilizer consumption and minimize the environmental pollution. Experiments were conducted under laboratory incubation and glass-house conditions with the following objectives (i) to determine the losses of nitrogen from urea coated fertilizers via ammonia volatilization and nitrogen mineralization, (ii) to determine the growth performance and yield of *Oryza sativa* (MR219) in response to various dosages of urea coated fertilizers. The optimization of the rate and the time of N fertilizer application as well as investigation of different N fertilizer formulation were conducted to determine the effects of these parameters on growth performance in terms of N release in accordance to the rice plant requirement. The incubation studies were conducted to investigate nitrogen losses via ammonia volatilization and mineralization (nitrate leaching). The fertilizers labeled as uncoated urea (U), sulfur coated urea (SCU), gypsum and sulfur coated urea using rotating drum (GSCUD). The rates of fertilizer used were 50, 100, and 200 kg N/ha. The results revealed that sulfur coated urea (SCU) was the best fertilizer since it reduced the rate of ammonia volatilization followed by GSCU and U. The ammonium and nitrate accumulations were also studied using the same nitrogen fertilizers including control (no fertilizer added) at 100 kg N/ha. Coating the urea with either 100% sulfur as in the commercial SCU or 50:50 ratio of gypsum and sulfur in GSCUD demonstrated the reduction in urea losses via both ammonia volatilization and nitrate leaching. As much as 25% reduction in ammonia losses via volatilization was observed using SCU and 14% using GSCUD. The results from this study also showed that the losses via nitrate in solution are relatively lower compared to ammonium in solution (4.35 mg/L compared to 0.73 mg/L). The effects of three fertilizers (Urea, SCU, GSCUD) using five rates (0, 50, 100, 150, 200 kg N/ha) and two times of application (single application at 25 DAT (Day after Planting) and two times application at 25, and 55 DAT) were evaluated under glass-house conditions. The plants were harvested at 120 DAT. A glass-house study of

first planting showed that fertilizer with a single application at the rate of 100 kg N/ha showed acceptable plant growth performance in terms of vegetation and yield parameters particularly for GSCUD fertilizer. Using GSCUD (100 kg N/ha with single application) resulted in 100 grain weight of 4.21 g/pot compared to the other treatments. However, as expected two times of application showed higher productivity. Using GSCUD (two-times; 200 kg N/ha) gave higher plant biomass 65.43 g/pot and markedly higher in grain yield at 39.52 g/pot. Moreover, the highest level for two-times application increased the uptake of nitrogen by plant up to 52.55 g/pot for the treatment using GSCUD. The second planting was also carried out under glass-house condition, to repeat the earlier glasshouse experiments and adding few other new coated fertilizers. The rate of application was at 100 kg N/ha, single application. Six different types of fertilizers were tested, namely U, SCU, GSCUP (gypsum and sulfur coated urea using rotating pan), GSCUD (gypsum and sulfur coated urea using rotating drum), DCU (dolomite coated urea), and KCU (kaolinite coated urea). The outcomes showed that the application of DCU to the crop improved the growth as well as the productivity of the rice yield. The use of DCU increased the plant biomass to 31.60 g, grain yield at 14.84 g/pot and higher in nitrogen uptake at a 16.36 g/pot. The next best fertilizers were GSCUD and KCU fertilizer. The grain yield was 13.01 g/pot and 13.31 g/pot, plant biomass at 34.96g and 24.82g, and nitrogen uptake 14.65 g/pot and 13.83 g/pot, respectively.

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

KESAN PENGGUNAAN BAJA UREA BERSALUT TERHADAP PERTUMBUHAN DAN HASIL PADI MR219 (*Oryza sativa* L.)

Oleh

NUR SYAMIMI BINTI A.RAHMAN

Disember 2015

Pengerusi: Professor Robiah Yunus, PhD
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Urea digunakan secara meluas sebagai sumber baja nitrogen. Walau bagaimanapun, kecekapan urea umumnya rendah disebabkan oleh hidrolisis yang cepat berlaku yang telah menyebabkan pengambilan N yang rendah dan menyumbang bahaya kepada kesan alam sekitar. Peningkatan kecekapan urea boleh dicapai dengan salutan urea dengan bahan-bahan salutan terpilih. Baja yang bersalut dikenali sebagai baja pembebasan perlahan yang akhirnya boleh mengurangkan penggunaan baja dan mengurangkan pencemaran alam sekitar. Satu siri eksperimen telah dijalankan di dalam makmal dan di dalam rumah kaca dengan objektif seperti berikut (i) untuk menentukan kehilangan nitrogen melalui pemeruapan ammonia (ii) untuk menentukan jumlah bentuk bukan organik nitrogen boleh didapati (iii) untuk menentukan prestasi pertumbuhan dan hasil padi, *Oryza sativa* (MR219) sebagai tindak balas kepada baja urea yang bersalut. Pengoptimuman kadar dan masa pembajaan N dan juga kajian terhadap formulasi baja yang berbeza kandungan N telah dijalankan untuk menentukan kesan parameter ini kepada prestasi pertumbuhan dari segi N pelepasan mengikut keperluan tanaman padi.Kajian pengeraman didalam makmal telah dijalankan untuk mengkaji kehilangan nitrogen melalui pemeruapan ammonia dan mineral (larut lesap). Baja dilabelkan sebagai; urea tidak bersalut (U), urea bersalut sulfur (SCU), urea bersalut gypsum dan sulfur (GSCUD). Kadar baja yang digunakan adalah 50, 100, dan 200 kg N / ha. Keputusan menunjukkan bahawa urea bersalut sulfur (SCU) adalah baja yang terbaik kerana ia mengurangkan kadar ammonia pemeruapan diikuti oleh GSCUD dan U. Pengumpulan ammonium dan nitrat telah dikaji menggunakan baja nitrogen sama termasuk kawalan (tiada baja ditambah) pada kadar 100 kg N/ha. Salutan urea dengan sama ada 100% sulfur seperti dalam SCU komersial atau nisbah 50:50 gypsum dan sulfur dalam GSCUD menunjukkan pengurangan kehilangan urea melalui pemeruapan ammonia dan nitrat larut lesap. Pengurangan sebanyak 25% dalam kehilangan ammonia melalui pemeruapan diperhatikan menggunakan SCU dan 14% menggunakan GSCUD. Hasil daripada kajian ini juga menunjukkan bahawa kerugian melalui nitrat larut lesap adalah agak rendah berbanding dengan pemeruapan ammonia (4.35 mg/l berbanding 0.73 mg/l).Kesan tiga jenis baja (U, SCU, GSCUD) menggunakan lima kadar pembajaan

(0, 50, 100, 150, 200 kg N/ha) dan dua kali pembajaan (pembajaan tunggal pada 25 hari selepas penanaman (DAT) dan dua kali pembajaan pada 25, 55 hari selepas penanaman (DAT) telah ditentukan di rumah kaca. Hasil padi dituai pada 120 hari selepas penanaman (DAT). Satu kajian rumah kaca untuk penanaman pertama menunjukkan bahawa baja dengan satu aplikasi pada kadar 100 kg N/ha menunjukkan prestasi tumbesaran adalah baik dari segi parameter pertumbuhan dan hasil terutamanya bagi baja GSCUD. GSCUD (100 kg N/ha dengan permohonan tunggal) menghasilkan berat 100 biji ialah 4.21 g/pasu berbanding rawatan lain. Walau bagaimanapun, seperti yang dijangka dua kali perngaplikasian menunjukkan produktiviti yang lebih tinggi. Rawatan GSCUD (dua kali; 200 kg N/ha) memberi hasil biojisim yang lebih tinggi 65.43 g/pasu dan ketara lebih tinggi dalam hasil bijian pada 39.52 g/pasu. Selain itu, tahap tertinggi untuk dua kali permohonan meningkat pengambilan nitrogen oleh tumbuhan sehingga 52.55 g/pasu untuk rawatan menggunakan GSCUD.Penanaman kedua juga dijalankan di bawah rumah kaca, untuk mengulangi eksperimen rumah kaca sebelum ini dan menambah beberapa baja bersalut baru yang lain. Kadar pembajaan adalah pada 100 kg N/ha, aplikasi tunggal. Enam jenis baja telah diuji, iaitu U, SCU, GSCUP (gypsum dan salutan sulfur menggunakan putaran *pan*), GSCUD (gypsum dan salutan sulfur menggunakan putaran *drum*), DCU (urea bersalut dolomit), dan KCU (urea bersalut kaolinit). Hasil menunjukkan bahawa penggunaan dolomit telah memberikan pertumbuhan dan produktiviti hasil padi yang berlipat ganda. Penggunaan DCU telah meningkatkan biojisim tumbuhan sebanyak 31.60 g, hasil bijirin pada 14.84 g/pasu dan lebih tinggi dalam pengambilan nitrogen ialah 16.36 g/pasu. Baja terbaik seterusnya adalah GSCUD dan baja KCU . Hasil biji padi adalah 13.01 g/pasu dan 13.31 g/pasu, biojisim tumbuhan pada 34.96 g dan 24.82 g, dan nitrogen pengambilan 14.65 g/pasu dan 13.83 g/pasu secara berasingan.

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I certify that a Thesis Examination Committee has met on 4 December 2015 to conduct the final examination of Nur Syamimi bt A.Rahman on her thesis entitled "Effects of Coated Urea Fertilizers on Growth and Yield of MR219 Rice (*Oryza sativa* L.)" 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 Master of Science.

Members of the Thesis Examination Committee were as follows:

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This thesis was submitted to the senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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This is to confirm that:

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LIST OF ABBREVIATIONS

%	Percent
°C	Celcius
$CaCO_3$	Calcium Carbonate
CEC	Cation Exchange Capacity
cm	Centimetre
g	Gram
g/L @ gL^{-1}	Gram Per Litre
g/pot	Gram Per Pot
H^+	Hidrogen Ion
H_2O_2	Hydrogen Peroxide
H_2SO_4	Hydrogen Sulfate
HCl	Hydrogen Chloride
KCN	Potassium Cyanide
kg	Kilogram
kg N/ha	Kilogram Nitrogen Per Hectare
mg/L	Milligram Per Liter
mL	Milliliter
mM	Milli Molar
N	Nitrogen
NH_3	Ammonia
NH_4^+	Ammonium
NO_2^-	Nitrite
NO_3^-	Nitrate
TC	Total Carbon
uL	Micro Litre
uM	Micro Molar
U	Urea
GSCUD	Gypsum Sulfur Coated Urea (Rotating Drum)
GSCUP	Gypsum Sulfur Coated Urea (Rotating Pan)
DCU	Dolomite Coated Urea
KCU	Kaolinite Coated Urea

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, food security has become an important issue to the world regarding the overgrowing population. This scenario also happen to Malaysia where population size in Malaysia has just reached over 29 million people in 2012 excluding outside population. Besides, rice is a basic everyday dietary for Malaysians and the demand of rice in Malaysia also increase throughout the years. The plantation area is enough to produce rice however Malaysia still rely on the other countries such as Vietnam and Thailand on producing rice (Razak et al., 2013). Malaysia needs to achieve the 8% of self-sufficiency level by 2010 and still not achieved the target. In order to ensure food securing, everyone especially government institutions have to take an obligation. This is due to agriculture sector which is an important sector for food security and the overall national economic development (Siwar et al., 2014). Furthermore, today the value of Malaysia ringgit is decreasing. The farmers also depending the rice production for a living. Hence, the efforts to identify the issues and challenging encountered in the production of rice is required. Controlled and slow release fertilizers are one of the solutions to enhance the crop yield with minimizing the environmental pollution (Ali et al., 2015).

1.2 Problem statement

Plant needs the nutrient and another element to growth and produces higher yield. This also applied to human where requires air, water, nutrition to survive and healthy. The physical appearance of the plant will express the symptom if a deficiency of nutrient. Plant's growth depends on soil fertility. Soil fertility defines as rich with nutrient including nitrogen, phosphorus, and potassium, sufficient mineral, soil organic matter, a range of microorganism, good soil texture, and soil pH. Some of the soils are lacking nutrient due to the losses and leaching, hence, the additional of the nutrient from fertilizer is required.

Fertilizer application is an essential in Malaysia agriculture, as it plays a major role in improving growth and yields in Malaysian soil. Nitrogen fertilizer especially urea is the most widely used source of nitrogen fertilizer. This is due to its high nitrogen content (46%) and comparatively low cost of production (Ni et al., 2009) and easy application and availability. Despite, the efficiency of urea uptake by the plant is generally below 50%. This is due to the surface runoff, leaching and vaporization of nitrogen compounds. About 40-70% of nitrogen in the applied normal fertilizers escapes to the environment causes the environmental pollution (Qi et al., 2007). The emissions of greenhouse like nitrous oxide (N_2O) and ammonia (NH_3) is from the application of nitrogen fertilizers (Siavoshi et al., 2011).

Therefore, many new types of fertilizers and placement methods have been developed to increase nutrient use efficiency, such as slow-release urea, urease inhibitors, super granules, neem cake, N deep-placement, and split application (Chien et al., 2009).

One possible way to improve nutrient and particularly nitrogen use efficiency while reducing the environmental hazards is by using controlled-release or slow release fertilizers (Shaviv, 2000). Many coated fertilizers have been developed for agricultural and horticultural crops during the last three decades (Wu, 2013). In general, slow-or controlled-release fertilizers demonstrate many advantages over the traditional type, such as decreased rates of losses of fertilizer from the soil by rain or irrigation water, sustained supply of nutrition for a prolonged time, increased utilization efficiency of fertilizer, lowered frequency of application, minimized potential negative effects associated with over dosage, and reduced toxicity (Tomaszewska, 2003).

The limitation usage of slow and controlled release fertilizer on agricultural crops is due to higher prices. Initially these products established niches in highly specialized market sectors (Kafkafi, 1996; Trenkel, 2010). The price is economical for use the high value crop in the European Union States and the United States of America (Shoji, 1999). Resin-coated controlled-release urea (CRU) has received little attention because the high cost of CRU production is the main obstacle for extensive use of CRU in agriculture (Shaviv and Mikkelsen, 1993). The use of Meister, a controlled-release urea developed in Japan, for rice production greatly improved N utilization efficiency and reduced N loss (Wada et al., 1991; Trenkel, 1997). However, this type of CRU is still too costly to be adopted by countries such as China and India, where rice is the main grain crop.

A lot of research have been done to develop various coating materials and techniques. Sulfur and polymer materials are common materials however have limitations. Sulfur alone cannot be effectively used as a coating material to produce control released coated urea (CRCU) due its amorphous nature. Many sealants, binders, and protective agents have therefore been used to control the immediate burst effect. This will increase process complexity and costs. Thus, it is important to reduce the sulfur content of SCU without lowering the quality of SCU as slow release fertilizer. CRCUs based on polymer or superabsorbent materials widely used due to extended controlled release and water retention, nonetheless the complexity of processing, elevated costs and the non-environmentally friendly side effects (Azeem et al., 2014).

Various coated fertilizer are available in current market, nevertheless their efficacy under Malaysian conditions is not comprehensively documented and large scale use of these product has not been applied. Hence, the evaluation of new formulation of fertilizer should be tested for tropical condition with suitable rates and application.

1.3 Research objectives

The main aim of this thesis is to market and promote the new formulation of coating urea fertilizer to the industrial and government. This the new formulation of coating urea fertilizer is developed by the cheapest coating material and reduce the cost production. The target of this study is tested new formulation of coating urea fertilizer to improve the crop performance as well as reduced the amount of urea to the environment where this new formulation will give significant contribution to the agricultural sector. This aim was achieved through the analysis of ammonia loss and nitrogen mineralization in the incubation study and tested the new product to the selected crop (rice).
The specific objectives of this study are listed below:

(i) To determine the losses of nitrogen via ammonia volatilization and nitrogen mineralization from urea coated fertilizers

(ii) To determine the growth performance and yield of Oryza sativa (MR219) in response to various urea coated fertilizers.

1.3.1 Calculation for economic objective.

Table 1.1 : Calculation for the cost production of sulfur coated urea and gypsum sulfur coated urea

SULFUR COATED UREA				
SYMBOL	COMPONENT	AMOUNT (%)	COST ($ /ton)	
SCU				
AVERAGE TOTAL COST ($/METRIC TON)				
340				
GYPSUM SULFUR COATED UREA				
GSCU	UREA	80	300	240
	GYPSUM	10	200	20
	SULFUR	10	200	20
	WATER	0.3	2.2	0.66
	Mycrostaline wax	3	1410	42.3
TOTAL MATERIAL COST($/METRIC TON)				
322.96≈ 323				
5% reduction in the cost of coating formulation				

1.3.2 Expected result

The new formulation which coating with the inexpensive material produce the least amount of ammonia loss and contribute to higher yield of rice.

1.4 Scope of work

1.4.1 Significance of the study

1. In this research, sulfur coated urea and urea are chosen due to the commercial fertilizer and used as upper limit and baseline benchmark. Gypsum sulfur coated urea rotating drum is the new formulation of coated urea fertilizer which is developed by Ibrahim et al. (2014). The incubation study was conducted under room temperature. The soil used was taken from Tanjung Karang, Kuala Selangor, Selangor which are paddy soil type. Three rates of fertilizer is used which 50, 100, 200 kg N /ha. 100 kg N/ha is taken due to the recommended rate for rice plantation. Second incubation which nitrogen mineralization is only tested for concentration of nitrate and ammonium in the soil solution. The recovery urea N in the soil is not taken due to the undisturbed experimental. In this experimental study also focusing one type of soil and 100 kg N/ha fertilizer is used.

2. To find the effectiveness of the coated urea fertilizer to the crop production, inexpensive material like gypsum, kaolin clay and dolomite have been chosen as coating material. This is based on the price and potential of nutrient containing for plant. Sulfur coated urea also tested in this study as a upper limit benchmark. Besides, a new formulation of coating urea were also tested for crop growth and performance. Soil is analyzed before the fertilizer is applied. Soil is selected based on only the nitrogen content in soil. Besides, the analysis of this study only focusing on the vegetative performance (plant height, productive tiller) and reproductive parameter (aboveground biomass, grain yield, 100 grain weight, harvest index and nutrient uptake). Identification of suitable rates and times of application the coated urea fertilizer to the yield of rice is tested on first study. Rice is chosen due to the major crop production in Malaysia. The second study is investigated the efficacy of new formulation of coated urea fertilizer to the crop growth and performance) at 100 kg N/ha at one time application.

1.5 Thesis outline

This thesis consists of five chapters. Chapter one introduces the research background, problem statement and objectives of the study. Chapter two presents the detailed literature review associated with eco-physiology of rice, the nitrogen and the relation to soil and plant, and the fertilizers. Chapter three describes the materials and the methodology involved in this study. This includes the identification of the effectiveness of fertilizer in the laboratory incubation study, the design and analysis the experiment of the yield and growth performance of Oryza *sativa* (MR219) in response to the urea coated fertilizers. Discussions on data analysis and interpretation are presented in chapter four. Finally, the conclusion for the objectives, recommendations and suggestions for further work is presented in chapter five.

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