ASSESSMENT OF SELECTED COATED UREA IN ENHANCING NITROGEN USE EFFICIENCY IN OIL PALM SEEDLING GROWTH

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By

MARDHATI HAZIRAH BINTI HASSAN

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

November 2018

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DEDICATION

Dedicated to my beloved parents, aunty, sisters, supervisors and family for their endless love, support, understandings, sacrifices, motivation, advice and encouragement.

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

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Chairman : Roslan Bin Ismail, PhD
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Sustainable cultivation of agricultural crops on the highly weathered, low nutrient soils of Malaysia requires adequate fertilizer input and proper soils management. Effective management of plants in terms of nutrient, especially nitrogen (N) is important because it highly influences plant growth and yield. However, N losses are often high in tropical soils due to denitrification, volatilization and leaching processes causing economic loss and environmental problems. A potential management of N is needed to overcome the problems through coated urea as slow release fertilizer. Thus study was conducted to determine the efficacy of coated urea as a means of improving nitrogen-use efficiency (NUE) with the aim of minimizing nitrogen loss and increasing its uptake. Nitrogen availability were quatified in 2 different types of soils (mineral soils and peat soil). A total of six treatments were evaluated , namely; common uncoated urea (U), geopolymer coated urea (GeoU), biochar coated urea (BioU), copper coated urea (CuU), zinc coated urea (ZnU), and copper-zinc coated urea (CuZnU) in both incubation and polybag studies. A laboratory study was first conducted to determine the effects of coated urea on Nitrogen availability in a mineral soil (an Oxisolss belonging to Munchong series) and in peat (organic soil). Treatment BioU (42%N) and CuZnU (36%N) gave the most significant result in mineral soil, with both treatments had positive Nitrogen availabilitys and N availability exhibited in ammonium release, nitrate release, urea-N retention and reduction of ammonia loss (by volatilization) (302.95 ug g^{-1}- BioU, 333.83 ug g^{-1} - CuZnU). In contrast , CuU (43%N), ZnU (36%N) and CuZnU (34%N) gave higher N availability in peat with respective values of 287.24 ug g^{-1}, 303.00 ug g^{-1} and 341.94 ug g^{-1}. The cumulative ammonia volatilization percentage in treatments with CuU, ZnU and CuZnU also resulted in low ammonia loss with values 4.96%, 5.57% and 5.23% respectively. In conclusion, after 8 weeks of incubation, CuZnU was found the best coated urea treatment for bothpeat and mineral soils with high amount of urea-N retained, reflecting the slow release effects and low N losses. The treatments were further examined in a nursery study on oil palm seedlings grown in polibegs containing

mineral soil (Munchong series) and peat (organic soil), which wascarried out in open field environment at Ladang 2, UPM for 12 months. This study involved 3 sampling time (6, 9 and 12 months seedling age) to evaluate the effects of coated urea on oil palm seedlings growth and nitrogen uptake in both soils. Application of coated urea significantly P (<0.05) improved oil palm growth and NUE by 7-10 % compared to control (uncoated urea). In mineral soil, oil palm seedlings treated with BioU and ZnU performed better with increased chlorophyll contents (BioU at 6 and 9 months old, ZnU at 12 months old), higher plant height (BioU found at 6 and 9 months old) and biomass (dry weight) (BioU – 6 and 9 months old, ZnU – 12 months old). Notably, at the second harvest (9 months old) and third harvest (12 months old), seedlings treated with BioU and ZnU were shown to increase N uptake and NUE. Meanwhile in peat, increased chlorophyll, plant height and dry weight were observed in oil palm seedlings grown in treatment of urea coated with micronutrients (CuU, ZnU and CuZnU).Oil palm seedlings treated with CuZnU showed increased N uptake at 6 and 12 months, and similar observation was observed in ZnU and CuU treatments at 9 and 12 months, respectively. Similar trend in N uptake also reflected the NUE. This can be attributed to the fact that nitrogen in coated urea are readily and slowly available for plant uptake over a given period of time. Biochar coated urea (BioU) have showed the best performance in mineral soil in both experiments, notably in highly significant urea N until week 8, increased nitrogen uptake and NUE in all stage (6 months old, 9 months old and 12 months old). The use of biochar as the coating material have positive effect on the soil and plant dynamic with increased nutrient availability, improved moisture holding capacity and improved nutrient holding capacity, thus making the soil fertile for agricultural activities (Lehman and Joseph, 2009;Rao et al.,2012). Meanwhile in peat, application of copper-zinc coated urea (CuZnU) showed the best effects in terms of urea N transformation to available form of N (ammonium and nitrate release), urea N, and stimulation in oil palm seedlings growth performance (N uptake and NUE). Coating micronutrients (copper and zinc) to urea also helped to slow down hydrolysis process, with both acting as urease inhibitors (Junejo et al.,2012; Khan et al., 2015). Furthermore, copper and zinc are micronutrients required for good plant growth. Thus, for the best coated urea efficacy and improved plant N uptake, coating urea with combination of Cu and Zn can be considered and further inspected. In conclusion, coated urea with waste material especially biochar, or with combination of micronutrients especially Zn and Cu has the potential as effective N fertilizer choices in increasing nitrogen uptake, NUE as well as in decreasing N losses (reducing ammonia loss) in oil palm seedlings cultivation.

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

PENILAIAN SALTUAN UREA TERHADAP KECEKAPAN PENGGUNAAN NITROGEN (NUE) DAN PERTUMBUHAN KELAPA SAWIT

Oleh

MARDHATI HAZIRAH BINTI HASSAN

November 2018

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Penanaman secara lestari di tanah yang telah terluluhawa dengan kritikal dan mempunyai kandungan nutrien yang rendah di Malaysia memerlukan input baja yang mencukupi dan pengurusan tanah yang sesuai. Pengurusan tumbuhan yang berkesan dari segi nutrien, khususnya nitrogen (N) adalah penting kerana ianya kuat mempengaruhi pertumbuhan tumbuhan dan hasil. Walau bagaimanapun, kehilangan N yang tinggi sering berlaku di tanah tropika disebabkan denitrifikasi, pemeruwapan dan proses larut resap yang menyebabkan kerugian ekonomi dan masalah alam sekitar. Antara kaedah yang mempunyai potensi yang baik dalam pengurusan N ialah dengan menyalut urea sebagai baja pelepasan yang perlahan. Kajian ini dijalankan untuk menentukan keberkesanan urea bersalut sebagai cara meningkatkan kecekapan penggunaan nitrogen (NUE) dengan tujuan meminimumkan kehilangan nitrogen dan meningkatkan pengambilannya. Transformasi Urea dikaji dalam 2 jenis tanah (tanah mineral dan gambut). Sebanyak enam rawatan telah diuji, iaitu; urea tidak bersalut biasa (U), urea bersalut geopolimer (GeoU), urea bersalut biochar (BioU), urea bersalut tembaga (CuU), urea bersalut zink (ZnU), dan urea bersalut tembaga-zink (CuZnU) . Kajian makmal terlebih dahulu dijalankan untuk menentukan kesan urea bersalut pada transformasi urea dalam tanah mineral (Oxisol - Munchong series) dan dalam gambut (tanah organik). Rawatan BioU (42% N) dan CuZnU (36% N) memberikan hasil yang paling ketara dalam tanah mineral, dengan kedua-dua rawatan mempunyai perubahan urea positif dan ketersediaan N yang dipamerkan dalam pelepasan ammonium, pelepasan nitrat, pengekalan urea-N dan pengurangan kehilangan ammonia (volatilization) (302.95 dan g-1 BioU, 333.83 dan g-1 - CuZnU). Sebaliknya, CuU (43% N), ZnU (36% N) dan CuZnU (34% N) memberikan ketersediaan N yang lebih tinggi (menunjukkan jumlah N yang boleh dimanfaatkan) di gambut dengan nilai masing-masing 287.24 dan g-1, 1 dan 341.94 dan g-1. Peratusan pemeruapan ammonia kumulatif oleh rawatan CuU, ZnU dan CuZnU juga mengakibatkan kehilangan ammonia yang rendah dengan nilai masing-masing 4.96%, 5.57% dan 5.23%. Kesimpulannya, selepas 8 minggu inkubasi, CuZnU didapati

rawatan urea bersalut terbaik untuk kedua-dua tanah dan mineral mineral dengan jumlah urea-N yang tinggi, mencerminkan kesan pelepasan yang perlahan dan kehilangan N rendah. Baja bersalut ini seterusnya diuji dalam kajian nurseri pada benih kelapa sawit yang ditanam di dalam polibeg yang mengandungi tanah mineral (siri Munchong) dan tanah gambut (tanah organik), yang dijalankan di persekitaran lapangan terbuka di Ladang 2, UPM selama 12 bulan. Kajian ini melibatkan 3 masa pensampelan (umur 6, 9 dan 12 bulan) untuk menilai kesan urea bersalut pada pertumbuhan benih kelapa sawit dan pengambilan nitrogen di kedua-dua tanah. Pemakaian urea bersalut dengan ketara ($P < 0.05$) menghasilkan pertumbuhan kelapa sawit yang lebih baik dan NUE sebanyak 7-10% lebih tinggi berbanding kawalan (urea tidak bersalut). Di dalam tanah mineral, benih kelapa sawit yang dirawat dengan BioU dan ZnU membesar dengan lebih baik dengan peningkatan kandungan klorofil (BioU pada usia 6 dan 9 bulan, ZnU pada usia 12 bulan), ketinggian tumbuhan yang lebih tinggi (BioU ditemui pada umur 6 dan 9 bulan) dan biomas (berat kering) (BioU - 6 dan 9 bulan, ZnU - 12 bulan). Pada musim menuai kedua (9 bulan) dan penuaian ketiga (12 bulan), anak benih yang dirawat dengan BioU dan ZnU telah menunjukkan kadar pengambilan dan NUE yang lebih tinggi. Untuk tanah gambut pula, peningkatan klorofil, ketinggian tumbuhan dan berat kering diperhatikan benih kelapa sawit yang ditanam dalam rawatan urea yang disalut dengan mikronutrien (CuU, ZnU dan CuZnU). Anak benih sawit yang dirawat dengan CuZnU menunjukkan meningkatnya pengambilan N pada 6 dan 12 bulan, dan pemerhatian yang serupa telah diperhatikan dalam rawatan ZnU dan CuU pada bulan ke 9 dan ke 12. Trend yang sama dalam pengambilan N juga mencerminkan NUE. Ini boleh dikaitkan dengan hakikat bahawa nitrogen dalam urea bersalut telah tersedia untuk pengambilan tumbuhan selama tempoh tertentu. Biochar (BioU) telah menunjukkan prestasi terbaik dalam tanah mineral dalam kedua-dua eksperimen, terutamanya untuk kandungan urea-N yang sangat ketara sehingga minggu ke-8, peningkatan pengambilan nitrogen dan NUE dalam semua peringkat (umur 6 bulan, 9 bulan dan 12 bulan). Penggunaan biochar sebagai bahan salutan mempunyai kesan positif ke atas dinamik tanah dan tumbuhan dengan ketersediaan nutrien yang meningkat, keupayaan memegang kelembapan yang lebih baik dan keupayaan memegang nutrien yang lebih baik, sehingga menjadikan tanah subur untuk kegiatan pertanian (Lehman dan Joseph, 2009; Rao et al ., 2012). Sementara itu di gambut, penggunaan urea bersalut tembaga-zink (CuZnU) menunjukkan kesan terbaik dari segi transformasi urea N kepada bentuk yang tersedia N (amonium dan nitrat), urea N, dan rangsangan dalam prestasi pertumbuhan anak benih kelapa sawit (Pengambilan N dan NUE). Mikroutrien salutan (tembaga dan zink) kepada urea juga membantu memperlahankan proses hidrolisis, dengan kedua-duanya bertindak sebagai perencat urease. Selain itu, tembaga dan zink adalah mikronutrien yang diperlukan untuk pertumbuhan yang baik. Oleh itu, untuk keberkesanan urea bersalut terbaik dan pengambilan tanaman N yang lebih baik, urea salutan dengan gabungan Cu dan Zn boleh diuji selanjutnya. Kesimpulannya, urea bersalut dengan bahan buangan terutamanya biochar, atau dengan kombinasi mikronutrien terutamanya Zn dan Cu mempunyai potensi sebagai pilihan yang berkesan dalam meningkatkan pengambilan nitrogen, NUE serta mengurangkan kehilangan N (kehilangan ammonia) dalam penanaman benih kelapa sawit.

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This thesis was submitted to the Senate of the 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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N	Nitrogen
NH_4	Ammonium
NO_2^-	Nitrite
NO_3	Nitrate
NH_3	Ammonia
H^+	Hydrogen ion
CEC	Cation exchange capacity
ANOVA	Analysis of variance
NUE	Nitrogen use efficiency
EEF	Enchanced Efficiency Fertilizer
Ha	Hectare
H_2O	Water
Cu	Copper
Na	Sodium
Zn	Zinc
Cd	Cadmium
Fe	Iron
C	Carbon
CO_2	Carbon dioxide
H_2SO_4	Sulphuric acid
HCl	Hydrocloric acid
KCl	Potassium chloride
P	Phosporus

TSP	triple Super phosphate
µg	microgram

CHAPTER 1

INTRODUCTION

Fertilizer is considered an important input in any plant production including oil palm and normally accounted for the largest cost in any agricultural activities. Perennial plant like oil palm generally require large amount of fertilizer to achieve good yields (Shamshuddin et al., 2018). In terms on N fertilization, urea is commonly used in Malaysia as well as in most agricultural activities as the main N fertilizer source.

However, N losses from urea fertilizer in the form of ammonia volatilization, denitrification and nitrate leaching have limit urea application and N (from urea) being taken up by plant (Gowariker et al., 2009; Fageria et al., 2015). These losses are associated with factors such as rainfall intensity (moisture), soil properties and fertilizer management practices (Christoper et al., 2010; Chislock et al., 2013). Previous study by Yishang et al. (2010) showed that 30% of nitrogen were loss as ammonia gas after urea application to soil. As stated by McAllister et al. (2008), only 30-50% of nitrogen were utilized by plant following farmer's practice recommendation. Thus, the loss from urea fertilizer resulted in low N use efficiency (NUE) and associated to environmental problems. Rahman et al. (2009) reported that urea application is associated with low crop utilization efficiency, causing negative effects to the environment.

In view of the urea-associated problems, controlled-release fertilizers has been widely found as the better alternative for common nitrogen and urea fertilizer. Controlled-release fertilizer especially coated urea are classify as well known approach to reduce nitrogen loss by slowing down the rate of dissolution, retarding urea hydrolysis, reduce ammonia volatilization, nitrous oxide and leaching (Muaz et al.,2016). Hence, coated urea application is expected to improve nitrogen use efficiency and plant growth. However, currently only 1% of controlled-release fertilizer especially coated urea was used in agricultural field (Timilsena et al., 2014).

In addition, studies on coated urea fertilizer in Malaysia so far only limited to short term crops and not perennial crops (Rosmarina et al., 2016; Muaz et al., 2017). Muaz et al. (2017) reported better plant height, SPAD reading, 1000-grain weight and harvest index (HI) in rice treated with both biochar impregnated and palm stearin coated urea.

At previous study, sulphur coated urea applied to oil palm to overcome the N losses problem and increase N uptake by plant (Najib et al., 2014). Thus, the potential of applying coated urea to perennials such as oil palm could be exploited. However, limited studies so far has reported the effects and provide understanding of urea transformation in soils where oil palm is normally grown, which are the mineral soils and peat (organic soils). Oil palm which is a heavy nutrient feeder would require

proper agronomic and N fertilizer management to obtain and/or maintain a robust growth. In oil palm plantation, oil palm require 250 kg/ha/year N at rate of application with frequent application (Goh et al., 2000).

Coated urea can potentially be used to control N losses problems and act as controlled-release fertilizer in both soils and plants. However, the main reason that prevents the use of coated urea by farmers is its high price. The price of coated fertilizer in the market could be as high as 8 to 12 times more than the conventional fertilizer (Lamel, 2005). According to Trenkel (2010), the increase in the cost of coated urea normally attributed to high production costs which involved complicated processes and uses of expensive materials. This has discouraged coated urea application in oil palm plantation or any other crops.

Therefore, economical coated urea are needed to be developed to increase its appeals to users. Coating materials to develop coated urea must be considered; with best option is using cheaper and commonly available (abundantly available materials) and environmental friendly. The use of industrial wastes, such as palm stearin, rubber wood sawdust and fly ash as materials for coated urea development could potentially produce high quality and effective cost (Hatfield and Vanterea, 2014). While recycling the industrial waste as the coating materials for coated urea, issues such as environmental and economic problems can be solved and lead to sustainability with regards that the coated urea could reduce N losses and improve plant NUE. Further researches and understandings prior to its recommendation or use are required. Thus, this research was undertaken to determine the effects of coated urea (produced using coating materials from industrial wastes) as the N fertilizer on the urea-N transformation, N losses in soils that oil palm normally grown in Malaysia and their effects on oil palm seedlings growth.

1.1 Problem statements

Fertilizer is one of the most important inputs in the cultivation of oil palm accounting for about 40% of production cost (MPOB, 2016). About 90% of fertilizers in Malaysia are imported, amounting to several million US dollar in expense incurred on fertilizer purchase. Urea as the most common source of N fertilizer is highly susceptible to volatilization and loss, translating into wastage of millions ringgit spent. Research conducted by Khanif (1992) stated that up to 53% of applied N was loss to the atmosphere as ammonia. As such, it is imperative to seek an efficient method of minimizing N loss thereby ensuring proper utilization of funds spent on fertilizer acquisition. Research has shown that coating urea is an effective method of minimizing urea loss, however, only 1% of farmers use coated urea in their farming practice. This was thought to be due high cost of coated urea arising from the complex process in its production and relatively expensive materials used in producing coated urea. Therefore, this study seeks to develop and test the efficacy of coated urea made from relatively inexpensive agricultural waste on two types of soils and oil palm seedlings.

1.2 Objectives

The objective of this study was to assess the efficacy of selected coated urea in enhancing nitrogen use efficiency (NUE) and its effect on oil palm seedling growth. The specific objectives were to study the;

1) Effects of coated urea on nitrogen availability in mineral and peat soils
2) Effects of coated urea on nitrogen uptake and growth performance of oil palm seedlings

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