UNIVERSITI PUTRA MALAYSIA

EFFECTS OF COATED AND INCORPORATED N-(N-BUTYL) THIOPHOSPHORIC TRIAMIDE UREA-NITROGEN DYNAMICS IN SOILS ON GROWTH AND YIELD OF MAIZE (Zea mays L. VAR. THAI SUPER SWEET)

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By

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

March 2020

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

TITLE OF THESIS EFFECTS OF COATED AND INCORPORATED N-(N-BUTYL) THIOPHOSPHORIC TRIAMIDE UREA-NITROGEN DYNAMICS IN SOILS ON GROWTH AND YIELD OF MAIZE (Zea mays L. VAR. THAI SUPER SWEET)

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March 2020

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Urea fertilizer is the most convenient nitrogen (N) fertilizer commonly being applied to soils for crop production due to its high N percentage (46%). Nonetheless, N in urea could be lost due to rapid hydrolysis which resulted in increased N loss through ammonia volatilization, leaching and denitrification. Currently, urea fertilizer treated with N-(n-butyl) thiophosphoric triamide (NBPT) has been developed to overcome loss of nitrogen from urea by inhibiting the urease activity which slow down urea hydrolysis. However, the effectiveness of urea treated with NBPT on crops in Malaysian highly weathered soils are not known. Thus, this research was undertaken to study N transformation and volatilization from NBPT treated urea fertilizer comprising of NBPT coated urea (NCU) and NBPT incorporated urea (NIU) in selected Malaysian soils, as well as to determine their effects on nitrogen use efficiency (NUE), N uptake and growth of maize under field conditions. Laboratory trials were conducted to study N mineralization, volatilization and soil leaching from three types of fertilizers (NCU, NIU and urea) in three different soil series (Morib, Bungor and Serdang). Results indicated after 7 days of incubation, all NCU and NIU treated soils showed significantly ($P \leq 0.05$) higher total inorganic N and reduced NH_3 volatilization by 45.13% - 53.27% compared to untreated urea. The resulted on soil leaching showed that NBPT treated urea had higher ammonium content compared to urea during 3rd – 4th pore volume. With regards to soil series, Bungor was found to have more inorganic N and reduced NH_3 losses than Serdang and Morib. It showed that NCU and NIU had capability to reduce ammonia volatilization losses in all three different soil series. For the first field study, maize plant were subjected to six treatments: two of which were controls, T0 = unfertilized and T1 = 120 kg N ha^{-1} of urea, and four NCU treatments at 144 kg N ha^{-1} (T2), 120 kg N ha^{-1} (T3), 96 kg N ha^{-1} (T4) and 72 kg N ha^{-1} (T5). Plant growth, yield, N uptake, NUE and soil inorganic N were measured at v6 (32 DAP), v10 (53 DAP), VT (60 DAP) and harvesting time (79

DAP). Relatively, NCU at 120 kg N ha^{-1} and 96 kg N ha^{-1} were effective in increasing growth, yield, N uptake and NUE. Improvement of NUE by 45% over urea was recorded in the treatment of NCU at 96 kg N ha^{-1}. This showed that almost 20% of fertilizer usage could be saved rather than the usual 120 kg N ha^{-1}. While in second field study, T1 (control) and best 3 NCU treatments (T3, T4 and T5) from first field study were selected and further tested and compared to NIU at similar rate as T3, T4 and T5. Growth data were measured 1 week after basal fertilization (21 DAP), 1 week after side dressing (49 DAP) and harvesting time (75 DAP) which included plant growth, yield and N uptake. Results demonstrated that NCU and NIU treatments at 120 kg N ha^{-1} and 96 kg N ha^{-1} significantly ($P \leq 0.05$) increased maize growth and yield compared to untreated urea. Also, our findings exhibited no significant difference ($P > 0.05$) between NCU and NIU at 120 kg N ha^{-1} and 96 kg N ha^{-1}. Thus, NIU at 96 kg N ha^{-1} was recommended as it could prolonged more storage time compared to NCU. This study provided evidences that NBPT can reduce N loss, thus ensuring more N for longer period in soils, enabling more N available for plant N uptake, hence promote growth and yield for grain crop in highly weathered soils.

.

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

KESAN BERSALUT DAN DIPERBADANKAN N-(N-BUTYL) THIOPHOSPHORIC TRIAMIDE UREA-NITROGEN DINAMIK DALAM TANAH KEPADA PERTUMBUHAN DAN HASIL JAGUNG (Zea Mays L. VAR. THAI SUPER SWEET)

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Urea merupakan baja N yang paling mudah digunakan dan banyak digunakan untuk pengeluaran tanaman kerana kandungan N yang tinggi (46%). Namun begitu, kehilangan N boleh terjadi disebabkan oleh proses hidrolisis yang cepat di mana mengakibatkan kehilangan N yang tinggi melalui pemeruwapan amonia, larutan dan denitrifikasi. Pada era ini, untuk mengurangkan kehilangan N, baja urea yang dirawat dengan 'N-(n-butyl) thiophosphoric triamide (NBPT)' telah dibangunkan dengan melambatkan aktiviti 'urease'. Walau bagaimanapun, kesan urea yang dirawat dengan NBPT pada tanaman dan tanah di Malaysia masih tidak diketahui. Oleh itu, kajian ini dijalankan untuk mengkaji kesan urea yang disalut dengan NBPT (NCU) dan yang diperbadankan NBPT (NIU) terhadap transformasi N, pemeruwapan amonia, kecekapan penggunaan N, corak pengambilan N dan tumbesaran jagung. Kajian di makmal telah dijalankan untuk mengkaji transformasi N, pemeruwapan amonia dan pelepasan N dari tiga jenis baja yang berbeza (NCU, NIU dan urea) pada tiga siri tanah yang berbeza iaitu Morib, Bungor dan Serdang. Keputusan menunjukkan selepas 7 hari proses inkubasi, NCU dan NIU memberi kesan yang dengan meninggikan jumlah mineral N dalam tanah dan mengurangkan pemeruwapan ammonia sebanyak 45.13% - 53.27% berbanding dengan urea pada semua siri tanah yang dikaji. Kajian menunjukkan urea yang dirawat dengan NBPT mempunyai lebih banyak kandungan ammonia berbanding urea setelah 3 - 4 kali air ditambah di dalam paip. Selain dari itu, Bungor siri didapati mempunyai lebih banyak N dan mengurangkan pemeruwapan amonia berbanding Serdang dan Morib siri. Ini menunjukkan NCU dan NIU ada keupayaan untuk mengurangkan kehilangan ammonia dalam ketiga-tiga siri tanah. Kajian di lapangan juga telah dijalankan di mana, 6 rawatan telah dipilih: dua daripadanya adalah rawatan kawalan, T0 = tiada baja dan T1 = 120 kg N ha^{-1} urea, dan 4 daripadanya rawatan NCU pada kadar yang berbeza iaitu, 144 kg N ha^{-1} (T2), 120 kg N ha^{-1} (T3), 96 kg N ha^{-1} (T4) dan 72 kg N ha^{-1} (T5). Data pertumbuhan tanaman, hasil tanaman,

penggunaan N, corak pengambilan N dan jumlah mineral N dalam tanah diambil pada v6 (32 hari selepas tanam), v10 (53 hari selepas tanam), VT (60 hari selepas tanam) dan masa penuaian (79 hari selepas tanam). Secara relatif, NCU pada 120 kg N ha^{-1} dan 96 kg N ha^{-1} meningkatkan pertumbuhan, hasil jagung, pengambilan N oleh jagung dan penggunaan N. Peningkatan penggunaan N sebanyak 45% berbanding urea telah dicatatkan dalam rawatan NCU pada kadar 96 kg N ha^{-1}. Ini menunjukkan bahawa hampir 20% penggunaan baja boleh dikurangkan berbamding dengan kadar biasa (120 kg N ha^{-1}). Dalam kajian lapangan kedua, T1 (kawalan) dan tiga rawatan terbaik dari kajian lapangan pertama (T3, T4 dan T5) telah dipilih dan dibandingkan dengan NIU pada kadar yang sama seperti T3, T4 dan T5. Data pertumbuhan, hasil dan corak pengambilan N oleh jagung diambil pada 1 minggu selepas pembajan pertama (21 hari selepas tanam), 1 minggu selepas pembajaan kedua (49 hari selepas tanam) dan pada masa penuaian (76 hari selepas tanam). Keputusan menunjukkan bahawa NCU dan NIU pada kadar 120 kg N ha^{-1} dan 96 kg N ha^{-1} telah meningkatkan pertumbuhan hasil tanaman jagung berbanding dengan baja urea. Penemuan kami menunjukkan tiada perbezaan antara NCU dan NIU pada kadar 120 kg N ha^{-1} dan 96 kg N ha^{-1}. Oleh itu, NIU pada 96 kg N ha^{-1} disyorkan kerana baja tersebut lebih lama boleh disimpan sebelum penggunaan. Kajian ini membuktikan bahawa NBPT boleh mengurangkan kehilangan N dan memastikan N di dalam tanah lebih lama, seterusnya dapat meningkatkan pengambilan N oleh tanaman dan menaikkan hasil tanaman bijirin di Malaysia.

ACKNOWLEDGEMENTS

Alhamdulillah, all praise to Allah SWT, the Most Gracious and the Most Merciful, May peace and blessing be upon Prophet Muhammad SAW for the chances given to me in completing this Master's Project. It gives me much pleasure to thank many individuals for their significant contribution during the entire course of this study. Firstly, I would like to express my sincerest gratitude to my supervisor, Dr. Noraini Md. Jaafar for her patience, constructive critical comments, guidance and appreciation for her approachable manner which made this experiment a pleasant one. I am also indebted to my fertilizer sifu, Professor Dr. Mohd Khanif Yusop for sacrificing a lot of his time to help me in all stages of this research work as well as providing expert guidance for the project's report. My gratitude also goes to the staff of Department of Land Management assistant especially Pn. Umi Kalthom Asmaon, En. Aziz Abdullah and Pn. Noriza Idris for their guidance and assistance in conducting the experiment during the course of this programme. Similar appreciation is extended to Associate Professor Dr. Siti Zaharah Sakimin as a co-supervisor. Their earnestness and hardwork were the decisive factors in making this study a reality.

Furthermore, I am also grateful to my beloved parents Mohd Zuki Muda and Razanawati Mahmood for their prayers and unfailing support in whatever I pursue. I would like to acknowledge to the financial and material support of Koch Agronomic Services, Wichita, KS. I am in debt to my Msc. scholarship provider, GRF from UPM for the financial assistance. To all my friends, Muhammad Faris Md Yusoff, Annur Razib, Azim Syahmi Zafri and Anwar Ibrahim thank you for your willingness to help and support in the field and laboratory. It is an honour for me to have friends like them.

Finally, my deepest thanks to all who were involved directly or indirectly in assisting as well as supporting me during the strenuous times in complete this study. I wish them every success in this world and hereafter under the guidance and in the path of Allah.

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

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LIST OF ABBREVIATIONS

CEC	Cation exchange capacity
CO_2	Carbon dioxide
DAF	Days after fertilization
DAP	Days after planting
H^+	Hydrogen ion
H_2O	Water
H_2SO_4	Sulphuric acid
HCl	Hydroclhoric acid
IFA	International fertilizer association
IPNI	International plant nutrition institute
K	Potassium
K_2O	Potassium oxide
KCL	Potassium chloride
M	Molarity
MOP	Muriate of potash
N	Nitrogen
N_2	Nitrogen gas
NBPT	N-(n-butyl) thiophosporic triamide
NBPTO	N-(n-butyl) thiophosporic triamide oxide
NH_3	Ammonia
NH_4	Ammonium
NO_2	Nitrous oxide
NO_3	Nitrate
NCU	NBPT coated urea

NIU	NBPT incorporated urea
NUE	Nitrogen use efficiency
P	Phosphorus
P_2O_5	Phosphorus pentoxide
PMA	Penyl mercuric acetate
SLA	Surface leaf area
TSP	Triple super phosphate

CHAPTER 1

INTRODUCTION

Nitrogen (N) is the main nutrient required by plant for their growth. Despite the fact that it is found in the form of nitrogen gas (N_2 of 78%) in the atmosphere, it has been insignificant to most plants because it must first be transformed whether through biological or chemical fixation (Bundy, 1998). The N_2 gas is fixed chemically by lightning or by biological N fixation carried out by N fixing bacteria as well as free living organisms (Mus et al., 2016). Nonetheless, both N_2 fixation pathways are still unable to fulfill N required for plant growth. Thus, N fertilizers in the form of inorganic or organic fertilizers are seen as the most convenient ways to manage N demand and supply in soil and plants.

Inorganic nitrogen fertilizers are commercially produced using Harber Bosch technique to meet the plant N requirement and widely used in the agricultural industry (Leghari et al., 2016). Urea is one of the most convenient N fertilizer being applied to field and highly feasible for its transport, storage and spreading in the field as well as due to its high N content (46% N) (Watson et al., 2008; Kiran et al., 2010; Mahfuzah et al., 2018). However, applied N fertilizer, especially urea may not entirely taken up by the crop due to N being immobilized in soil organic N pools (both in microbial biomass and soil organic matter) as well as N in urea itself is vulnerable to losses from volatilizations, denitrification and leaching (Kenneth et al., 2002; Sariam and Khanif, 2006; Muaz et al., 2017).

Nitrogen that is released to soil from any N fertilizer is normally subjected to ammonia volatilization through the activity of urease enzyme found commonly in soil (Kissel et al., 2008; Rosmarina et al., 2016). This indicated the loss of N applied in gaseous forms, while other N losses pathways such as leaching and denitrification processes also negatively impacted the environment via soil and surface water acidification, nitrate contamination of ground water, eutrophication of lakes, increased toxicity and fatality to aquatic organisms and plants, increased greenhouse gas and depletion of stratospheric ozone (Jazzen, 1999; Anbessa and Juskiw, 2012; Mathialagan et al., 2019). In dominos effects, these N losses would contribute to global warming as major threat to the environment (Snyder et al., 2007).

Understanding N transformation related to urea and the associated N losses is crucial to ensure the fertilization impact of urea in N cycles before taken up by the plant. Among the contributing factors in this process include temperature, soil pH, soil moisture and CEC which also influence the type of N losses (Rawluk et al., 2001; Bache, 2006). In details, when urea is surface applied to soils, it will be rapidly hydrolysed by urease enzymes in soil which resulted in high ammonia volatilization. Several studies have shown that almost 50% of applied urea had been lost to the atmosphere (Choudry and Khanif, 2001;

Zhang et al., 2010). Ammonia (NH_3) losses from urea occurred rapidly as early as first 3 days after application (Watson et al., 1990). Other N losses pathways such as denitrification (conversion of NO_3^- to N_2O or N_2 gas) and leaching consequently take place during urea hydrolysis and N transformation from urea fertilizer.

These N losses jeopardized plant growth and N related plant growth indicators such as plant N uptake, nitrogen use efficiency (NUE), and yield of plants. As one of the indicators, NUE which is the term used to describe the ratio of N utilized by the plant to the amount of N applied to the soil, would determine the effectiveness of N in urea being used up by plants for the growth processes (Lea and Azevedo, 2006). To be feasibly productive and economic, high yield production, NUE and the cost of fertilizer are also the main factor being considered in agriculture. Urea application has been associated with relatively poor NUE due to heavy N losses via ammonia emission, especially when applied under hot and dry soil conditions, high pH and high wind (Khalil et al., 2003; Leghari et al., 2016).

Various researchers have proposed various ways to improve urea use efficiency by ensuring a continuous and maximum supply of N as well as reduce N losses. Urea utilization can be enhanced either by physical (altering the rate, timing and method of application and producing large granule urea) or chemical approaches (coating urea with different materials and chemicals) (Sariam and Khanif, 2006; Dawar et al., 2011). The most efficient way to overcome any mishandling of urea during field application is by coating or incorporating urea with urease inhibitors (Watson et al., 2008; Nasima et al., 2012).

Use of urease inhibitors can be one of the ways to reduce N losses (Saboury et al., 2010). Various products of N inhibitor and urea have been tested, however, the mechanisms of the N transformation may vary between the technology by which urease inhibitors are trated ti urea, inhibitors type and environmental conditions as well as the soils they are being applied. Amongst the several options available to achieve high crop yield production and enhance NUE, coating or incorporated the granular urea with urease inhibitor such as N-(n-butyl) thiophosphoric triamide (NBPT) are among the promising ways being considered nowadays (Zaman et al., 2008; Khan et al., 2014; Rech et al., 2017; Cantarella et al., 2018). Granular urea with urease inhibitor such as NBPT can improve NUE (Zaman et al., 2013). Moreover, others also reported improvement in yield and N uptake of wheat (by 37.5% and 38.0%, respectively) was obtained in the treatment of urea treated with NBPT than untreated urea (Khan et al., 2014). Similar results have been found by other reserachers (Watson et al., 2008; Dawar et al., 2010; Li-Min et al., 2010; Espindula et al., 2013) showing NBPT’s potential to reduce N losses at lower concentration and improved crop productivity.

At present, the urease inhibitor, NBPT under trade name of Agrotain® either coated or incorporated to urea has the potential to restrain urease activity, decrease N loss, increase NUE and increase yield of crops (Chien et al., 2009; Dawar et al., 2010; Li-Min et al., 2010; Silva et al., 2017). Even so, the effects of NBPT in urea transformation and the effects on crop in Malaysian highly weathered soils are not clear. Hence, this research is conducted with the aims:

1. To quantify NBPT coated urea (NCU) and NBPT incorporated urea (NIU) on on N mineralization, ammonia volatilization loss and NO_3 leaching from 3 different soil types.
2. To investigate the effects of NBPT coated urea (NCU) at varying rates on the nitrogen dynamics in soil, nitrogen use efficiency (NUE), N uptake, growth and yield of maize.
3. To determine the effects of NBPT coated urea (NCU) and NBPT incorporated urea (NIU) on the nitrogen dynamics in soil, N uptake, growth and yield of maize.

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BIODATA OF STUDENT

Muhammad Muhaymin b Mohd Zuki was born in Jerteh, Terengganu on May 1994. He grew up in Terengganu city, Kuala Terenganu, eventually studying at SK Bukit Tumbuh for his primary and at SMK Lembah Bidong, Terengganu for his secondary education. His leadership was prominently named as president of MNS School Nature Club, Police Cadet Association and school sport house while at secondary school.

In 2012, he completed his Agriculture Science Foundation at Universiti Putra Malaysia, pursuing his interest in the course of agriculture. Finally, he graduated from one of the finest agriculture universities in Malaysia, UPM with a Bachelor of Agricultural Science. Throughout his degree's life, he participated and conducted a lot of programmes in which not only in the field of agriculture, but also in recreation. He was done his internship in Nagano, Japan and learned a lot of new farming technologies. His FYP concentrated on converting of POME sluge from industry into fertilizer.

Having dedicated himself to the development of fertilizers, he enrolled in February, 2018 for Master of Science with specialization in urea fertilizer enhancement and soil fertility. The author was offered the research assistantship under the Graduate Research Fellowship, UPM. He availed this oppurtunity and completed his master's study on time.

LIST OF PUBLICATIONS

Muhaymin M. Z., Noraini M. J., Zaharah S. S. and Khanif M. Y. (2018). Effects of Agrotain treated urea (ATU) on growth performance and yield of maize. In: 8th Internationl of Agriculture Congress 2018 and 6th International Symposium for Food and Agriculture 2018

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Muhaymin M. Z., Noraini M. J., Zaharah S. S. and Khanif M. Y. (2020). N-(n-Butyl) Thiophosphoric Triamide (NBPT) coated urea (NCU) improved maize growth and nitrogen use efficiency (NUE) in highly weatherd tropical soils

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