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EVALUATION OF GYPSUM BASED MATERIAL AS COATING AGENT TO IMPROVE THE EFFICIENCY OF GRANULAR UREA FERTILISER

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By

KHAIRUL RIDZWAN MOHD IBRAHIM

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

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DEDICATION

This thesis is dedicated to my mother and father, for their love and support...

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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February 2015

Chair: Robiah binti Yunus, PhD

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This study was motivated by the fact that even though urea is the most efficient nitrogen carrier in solid form, it is not efficient in delivering the nutrient to the plant. Approximately 70% of the applied urea fertiliser may be lost to the environment. These losses are due to leaching, decomposition and ammonium volatilization in soil, water and air. The common solutions that are available now which is by coating the urea with polymer or sulphur is not being used by farmers in Malaysia primarily due to the high cost. The effect of these coating materials to the environment after prolonged usage is also now being questioned. The study seeks to explore common readily available materials as an alternative coating material. These materials were Portland cement, gypsum plaster, sulphur and zeolite. The materials were also selected based on their availability, processability and price. All these materials also doubles as either nutrients or conditioner to plant and soil. The materials were varied and blended to produce several coating formulations. A coating drum was used to coat the urea with the formulated materials in a dry blend process. The coated urea samples produced were tested for its particles size distribution, crushing strength and dissolution properties. Its dissolution properties were used to benchmark the effectiveness of the coating. Scanning electron microscope was used to further investigate at a microscopic level the coating thickness and the surface morphology of the samples. Cavities were identified in the coating layer of samples and not seen on SCU which may be the cause for a faster diffusion of the samples compared to SCU. Gypsum plaster and sulphur based coating material were found to have performed better than the other formulations which was 13.8% higher than uncoated urea based on the dissolution analysis performed. This formula was further improved where paraffin wax was experimented as a sealant and showed an improvement in dissolution concentration at 24.2% improved efficiency compared to uncoated urea. The final product achieved the highest efficiency at 26%, a marked improvement in dissolution properties than an uncoated urea. This was produced by pretreating (sieving) the base materials (gypsum plaster and sulphur). It is hope that this product will be commercialized and made

available to the farmers as an affordable alternative and solution in the near future. The environment will also be benefitting from a more efficient use of nitrogen fertiliser.

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

PENILAIAN BAHAN BERASASKAN GIPSUM SEBAGAI EJEN SALUTAN BAGI MENINGKATKAN KECEKAPAN BAJA UREA BUTIRAN

Oleh

KHAIRUL RIDZWAN MOHD IBRAHIM

Februari 2015

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Kajian ini didorong oleh fakta bahawa walaupun urea adalah pembawa nitrogen paling cekap dalam bentuk pepejal, namun ia tidak cekap dalam menyampaikan nutrien kepada tumbuhan. Kira-kira 70% daripada baja urea yang digunakan berkemungkinan hilang ke persekitaran. Kehilangan ini adalah disebabkan oleh larut lesap, penguraian, dan pemeruapan ammonium dalam tanah, air dan udara. Penyelesaian yang sering didapati kini ialah menyalutkan urea dengan polimer atau sulfur, namun ini tidak digunakan oleh para petani di Malaysia disebabkan oleh kos yang tinggi. Kini juga terdapat persoalan tentang kesan bahan-bahan salutan ini kepada alam sekitar apabila digunakan untuk jangka masa panjang. Kajian ini bertujuan untuk meneroka bahan-bahan biasa yang sedia ada sebagai bahan penyalutan alternatif. Bahan-bahan ini ialah, simen Portland, plaster gipsum kontang, sulfur, dan zeolit. Bahan-bahan ini dipilih berdasarkan ketersediaan, keupayaan memproses dan harga. Semua bahan-bahan ini juga mempunyai dwifungsi sama ada sebagai nutrien atau sebagai bahan perapi kepada tumbuhan dan tanah. Bahan-bahan ini divariasikan dan dicampur untuk menghasilkan beberapa rumusan salutan. Mesin gelendong salutan digunakan untuk menyalut urea dengan bahan yang dirumuskan di dalam proses campuran kering. Sampel urea bersalut yang dihasilkan diuji dari segi taburan saiz zarah, kekuatan hancur, dan sifat pelarutan. Sifat pelarutan digunakan sebagai tanda aras keberkesanan penyalutan. Mikroskop elektron imbasan digunakan untuk mengetahui ketebalan salutan dan morfologi permukaan sampel di tahap mikroskopik. Liang-liang halus dapat dilihat pada permukaan sampel dan tiada pada SCU mungkin faktor pelarutan yang lebih cepat pada sampel dan tidak berlaku pada SCU. Penyalutan berasaskan plaster gipsum kontang dan sulfur menunjukkan prestasi yang lebih baik berbanding rumusan-rumusan lain iaitu 13.8% berbanding urea yang tidak disalut berdasarkan dari analisa pelarutan yang dijalankan. Rumusan ini ditambahbaikkan di mana lilin parafin digunakan sebagai bahan pengadang telah dapat meningkatkan kepada 24.2% kadar keberkesanannya berbanding urea tanpa sulutan. Produk akhir berjaya mencapai 26% kadar keberkesanan, jelas lebih baik sifat pelarutan berbanding urea asal tanpa disalut. Sampel ini

dihasilkan dengan menjalankan prarawatan (mengayak) bahas asas (gipsum dan sulfur). Adalah diharapkan produk ini akan dikomersilkan dan tersedia kepada para petani sebagai bahan alternatif yang mampu dimiliki dan sebagai penyelesaian dalam jangka masa terdekat. Alam sekitar turut mendapat manfaat daripada penggunaan baja nitrogen yang lebih cekap.

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- Sayang, for being here for me, all the time! I love you…

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

GDP	Gross Domestic Product
EEF	Enhanced-Efficiency Fertiliser
TVA	Tennessee Valley Authority
IFA	International Fertilizer Association
N	Nitrogen
P	Phosphorous
K	Potassium
SCU	Sulphur Coated Urea
UF	Ureaform
IBDU	Isobutylidene Diurea
USG	Urea Super Granules
NBPT	N-(n-butyl) Thiophosphoric Triamide
DCD	Dicyandiamide (DCD)
ANS	Ammonium Nitrosulphate
LDPE	Low-density polyethylene
SCPU	Silicate-Polymer Coated Urea
KAIST	Korea Advance Institute of Science and Technology
IFDC	International Fertilizer Development Centre
POP	Plaster of Paris
W/W	Weight over Weight
HPLC	High-performance Liquid Chromatography
SEM	Scanning Electron Microscope
MSDS	Material Safety Data Sheet
SDS	Safety Data Sheet

CHAPTER 1

INTRODUCTION

1.1 General Background

The agriculture sector has been identified as the third engine of growth in the 9th Malaysian Plan. In 2013, it contributed RM55.9 billion to Malaysia's GDP representing 7.1% of total GDP, an increase from RM54.8 billion in 2012. The sector employs about 1.7 million workers, representing 13% of the country's total workforce (Malaysia Productivity Corporation, 2014). The outcome is consistent as Malaysia is known as a major player in the world's scene for oil palm and rubber products. Major commodity crops which are oil palm, rubber and padi cover 90% of Malaysian planted soils of which oil palm comprises 63.4% of the total planted area (Arshad et al., 2007)

Fertilisers are important for plant growth. Just like men need food which consist of protein, carbohydrates, fibers and minerals – plant requires nutrient which are categorized as primary and secondary macro micro nutrients. Major nutrients include Nitrogen, Phosphorus, Potassium, Sulfur, Calcium and Magnesium which enable plants to meet optimum growth and function (FAO, IFA, 2000).

Nitrogen is the most important nutrient for plant growth. Nitrogen fertiliser has been widely produced in the world since the process of fixing nitrogen from the air was discovered in the early 20th century in Germany and is known as the Haber-Bosch process. Since then, fertiliser consumption grew rapidly, largely in parallel with an accelerating expansion of the world population which can be correlated to the world food production providing adequate food supply to feed the world (Erisman et al., 2008). Though famine is still a serious issue in certain parts of the world, without the mass production of nitrogen fertilisers, it is impossible for the world to feed the current 6.2 billion people on earth.

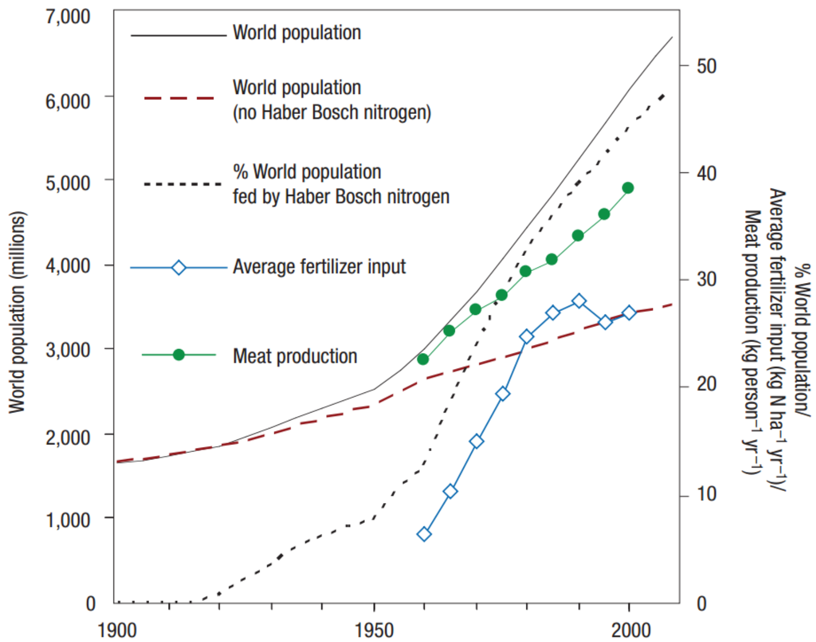

Figure 1.1. World fertiliser consumption and population in the past century (Erisman et al., 2008)

In general, nitrogen fertilisers are hypothesized to have an efficiency of between 30-50% and even more in severe conditions (Jones et al., 2013). This means, from the amount of fertiliser applied, 30-50% is absorbed by the plant and the rest is lost through various means including surface run-off, leaching and volatilization. Plant yield could be further optimized should the efficacy of fertiliser be improved. To improve the efficiency of fertiliser, many products have been available in the market and many studies were done to address the issue. The term currently coined to describe these products is Enhanced-Efficiency Fertiliser (EEF). Some of the main products available and known in the market includes polymer coated fertilisers, sulfur coated urea and urease inhibitors (Trenkel, 2010).

Studies began as early as 1960s in Japan to address the inefficiency of Nitrogen (N) fertilisers. Japanese scientist came out with a polymer coated fertiliser (Shoji, 1999). On the other side of the globe around the same time, the Tennessee Valley Authority (TVA) based in Alabama, USA saw the advantage of a high efficiency fertiliser (Rindt et al., 1968). With the abundant supply of sulfur from the oil refineries and knowing sulfur is an important nutrient to the plant, molten sulfur was sprayed coated onto urea and then came the sulfur coated urea. Though sulfur was later found to be too brittle as a coating, wax and other polymers have been used as a secondary coating to solve the problem.

Now, several decades from the first commercially available enhanced fertiliser, growth and acceptance by the industry has been very slow as it only represents 0.47% of the total market. Such simple question is why a scientifically proven product has not been able to capture the demand of the industry? The answer is also simple – cost! Due to its high nitrogen concentration per unit which is 46%, urea is the most consumed nitrogen fertiliser in the world and used as core for most coated nitrogen fertiliser. As urea is the core, it is made as price reference. A polymer-coated product has been said to be 4-8 times the price of urea and sulfur coated products are less than 2 times (Trenkel, 2010).

1.2. Problem Statement

Nitrogen fertiliser is very important for plant's wellbeing as this nutrient is often the limiting factor to enable other nutrient uptake. Urea is a nitrogen fertiliser with 46% nitrogen content which is the highest percentage of nitrogen per unit weight (Jones et al., 2013). As the most widely the most widely synthesized inorganic nitrogen fertiliser, the high content of nitrogen makes urea preferred in many ways including savings in logistics cost per unit nitrogen.

Despite all the advantages of urea, efficiency is a major concern which has been estimated at 50%. This directly translated that money spent on urea for fertiliser application is 50% straight to the drain.

Measures have been taken to address these losses with the booming of the EEF products in the market. Though the most advances in coated fertilisers are polymer coated, the price is only economical for use in high value crops in the European Union states and the United States of America. As the move to adapt high efficiency technology in the agriculture sector increases, this has led to the use in Japanese rice production (Shoji, 1999). They also incorporated total mechanization of the planting and fertilisation process which was able to produce high yielding crops (Trenkel, 2010).

A research to develop novel EEF fertiliser by examining the effect of gypsum based material as coating agent to urea fertiliser is proposed. Urea has been chosen for the advantages mentioned above. Gypsum is chosen as coating material due to the low cost and availability. Gypsum is also known as a strong binder and it is also sparingly used as a fertiliser for source of both sulfur and calcium (Kost et at., 2007).

1.3. Objectives of the Study

The efficiency of urea is low and estimated at average 50% (Dobermann, 2005). Improving the efficiency would be very beneficial especially moving towards sustainable resource utilization. EEF has not been accepted in Malaysian market primarily due to the high price. The development of cost competitive coated fertiliser is best achieved by following a logical sequence of testing and evaluation procedures in a variety of settings from the laboratory to the field. The effect of gypsum based coating material and additives to the leaching rate of the urea will be investigated. The specific objectives are:

- To establish the base line properties of uncoated urea and commercial sulfur coated urea.

- To evaluate the effectiveness of various coating formulations of gypsum based materials according to its crushing strength, surface morphology and dissolution properties.
- To investigate the efficiency improvement of coated urea by varying coating thickness, drying time, adding wax as sealant and by sieving the coating material.

1.4. Scope of the Study

This study examined gypsum and several gypsum based formulation to coat urea in order to improve the efficiency of the urea fertiliser. Coating was done using a lab scale coating pan. Characterization of the coated urea was done by analysing its particle size distribution which indicates the uniformity level of the process in coating the urea. The mode sample size were further analysed for its crushing strength to investigate the durability of the coating layer. Dissolution properties was also investigated to determine the efficiency improvement effect of the coating layer. Morphology of the surface was further studied to examine the microsite structure in relations to the other characteristics observed.

Further improvement works on the coating material was also carried out and studied by varying the coating thickness, drying time, adding wax as top coat and sieving coating material. Similarly, the improvised samples characteristics were studied for its uniformity, strength, dissolution properties and surface morphology.

Although field procedures are better as environmental factors are considered, it requires a long time for plant N uptake and analysis (Rice & Havlin, 1994). As such, the coated urea developed were not tested for its performance on plants. As the scope of this research was fundamentally coating formula selection, methods adopted were to quickly screen the many formulations and samples developed. This has resulted in a more effective product development prototyping.

1.5. Significance of the Study

The common and expensive method in reducing fertiliser losses is by coating with polymer which products are available but not affordable to the farmers. By using the gypsum based coated material it is expected that it could lower the cost of production of a more efficient urea fertiliser and will be affordable to all. This would also solve the environmental problems and minimize the loss of resources.

1.6. Structure of Thesis

This thesis is presented in chapters. Chapter 1 covers the general background of the subject, problem statements, significance of study, objectives including the scope of study.

A literature review on previous research work in various topics which is relevant to this research is presented in Chapter 2. The literature starts with a general overview of fertiliser and agriculture. Challenges faced by the industry are also presented. A comprehensive literature survey on the works done on development of EEF is also done and more emphasis is given to coated urea. A review of the international market scene of coated urea is also included in this chapter.

The methodology of the study is described in Chapter 3. This chapter presents the materials and equipment used in this study. The process of preparation of the samples is also presented. Analytical techniques used to analyse samples are discussed in detail.

Chapter 4 covers the results of the research. Design of the equipment is presented. Summary and finding of the research are deliberated. The limitations of the study will are also discussed in this chapter.

Finally, Chapter 5 is to summarize and to conclude the research exercise. Recommendations for future research are also put forward.

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