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TEMPORAL EFFECT OF AMMONIUM SULFATE ON SOIL NITROGEN CONTENT, GROWTH AND YIELD OF OIL PALM CULTIVATED ON ALAN FOREST TROPICAL PEAT, SARAWAK, MALAYSIA

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By

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

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

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March 2016

Chairman : Associate Prof. Ahmad Husni Mohd Hanif, PhD
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Tropical peatland is the last frontier of arable land available for agricultural development in Sarawak, Malaysia.There are three main types of forests in Sarawak; mixed peat swamp, alan bunga/batu and padang paya. The study of suitable nitrogen rates are limited in Alan bunga forest for good oil palm yield. The purpose of this study is to determine the growth response of oil palm on alan bunga tropical peat to different N fertilizer application rates on total N and available N in the soil, leaf N concentration, vegetative growth and oil palm yield. A study was carried out from 2010 to 2012 at an oil palm plantation in Sibu, Sarawak, Malaysia. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The six-year-old mature palms were planted in a triangular pattern with a planting distance of 8.5 × 8.5 × 8.5 m. Ammonium sulphate (AS) was used as N source with four different rates: 0 kg nitrogen (N1), 0.21kg nitrogen (N2), 0.42 kg nitrogen (N3) and 0.84 kg nitrogen (N4)/palm/year.

In the first objective, the effect of N fertilizer rates on soil total N is significant at 0 - 25 cm (P = 0.012) and 25 - 50 cm (P = 0.041). Results for NH_4^+ showed that there were no significant interactions between time and N fertilizer rates (P = 0.25; P = 0.58) at both soil depths. For NO_3^-, only 0 – 25 cm (P = 0.041) displayed significant interactions effect. This indicates that NO_3^- responses over time were different among treatments in which N2 and N3 contributed to the change. Effect of different N fertilizer rates on leaf N concentration illustrates that only time effect was significant (P = 1.762×10^{-5}). There were no statistically significant effects of different N fertilizer towards LAI (P = 0.14) and frond dry weight (P = 0.19). However, there were statistically significant for time (P = 7.412×10^{-8}) and (P=2.378×10^{-8}) towards both of them. Association between time and treatments (P = 0.62; P = 0.29) were not significant in both LAI and frond dry weight. Analysis for palm yield reveal that different level of N fertilizer application did not have any significant effect on either bunch number or FFB (P = 0.26 and P = 0.31). However, the effect of N fertilizer rates on FFB and bunch number can be seen through the association with time (P = 0.006) and (P = 0.029). The significant quadratic trend shown by N4 indicates that N4 produced the most FFB within the shortest time.

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

KESAN DUNIAWI AMMONIUM SULFAT TERHADAP KANDUNGAN NITROGEN TANAH, PERTUMBUHAN DAN HASIL KELAPA SAWIT DITANAM PADA TANAH GAMBUT TROPIKA HUTAN ALAN, SARAWAK, MALAYSIA

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Tanah gambut tropika adalah sumber terakhir tanah pertanian untuk pembangunan pertanian di Sarawak, Malaysia. Ada 3 jenis hutan di Sarawak, mixed peat swamp, alan bunga/batu dan padang paya. Setakat ini, jarang ada kajian dijalankan di ex-hutan alan bunga untuk mendapat hasil tuaian yang bagus. Kajian ini bertujuan untuk mengenal pasti kesan kadar pembajaan nitrogen (N) di ex-hutan alan bunga yang berbeza terhadap ciri-ciri kimia tanah, kandungan N dalam daun, pertumbuhan vegetatif dan penghasilan buah bagi kelapa sawit yang ditanam atas tanah gambut tropika. Eksperimen dijalankan dalam reka bentuk blok lengkap rawak (RCBD) dengan tiga replikasi. Pokok-pokok kelapa sawit yang berusia enam tahun ditanam dalam bentuk segi tiga dengan jarak penanaman 8.5×8.5×8.5 m. Sumber N yang digunakan ialah ammonium sulfat (AS) dan empat jenis kadar pembajaan yang digunakan iaitu 0 kg nitrogen (N1), 0.21 kg nitrogen (N2), 0.42 kg nitrogen (N3) dan 0.84 kg nitrogen (N4)/ pokok/tahun.

Untuk objektif pertama, kesan kadar baja N ke atas jumlah tanah N adalah signifikan pada pada 0 - 25 cm (P = 0.012) dan 25 - 50 cm (P = 0.041). Keputusan untuk NH_4^+ menunjukkan bahawa tidak ada interaksi yang signifikan antara masa dan kadar baja N (P = 0.25; P = 0.58) terhadap kedua-dua kedalaman tanah. Manakala bagi hasil dapatan nitrat (NO_3^-), hanya NO_3^- pada 0 - 25 cm (P = 0.041) menunjukkan kesan yang ketara. Tindak balas NO_3^- dari masa ke masa adalah berbeza antara kadar pembajaan di mana N2 dan N3 menyumbang pada perubahan itu. Kesan kadar baja N yang berbeza pada kepekatan N daun menggambarkan hanya masa memberi kesan yang signifikan (P =1.762x10^{-5}) .Secara statistik, baja N yang berbeza tidak memberi kesan kepada luas permukaan daun (LAI) (P = 0.14) dan berat kering pelepah (FDW) (P = 0.19). Akan tetapi, kesan masa (P =7.412x10^{-8}) and (P=2.378x10^{-8}) adalah signifikan bagi kedua-dua LAI dan FDW. Interaksi antara masa dan kadar baja (P = 0.62; P = 0.29) adalah tidak signifikan terhadap kedua-dua LAI dan FDW. Hasil sawit menunjukkan bahawa tahap pembajaan N yang berbeza tidak memberi kesan yang ketara ke atas sama ada bilangan tandan atau buah tandan segar (FFB) (P =

0.26 dan *P* = 0.31). Namun, interaksi kesan kadar baja N dan masa pada FFB serta bilangan tandan adalah signifikan (*P* = 0.006) dan (P = 0.029). Trend kuadratik signifikan yang ditunjukkan oleh N4 bermakna N4 menghasilkan FFB yang terbanyak dalam masa yang paling singkat.

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I certify that a Thesis Examination Committee has met on 23 March 2016 to conduct the final examination of Siaw Ting Chuan on his thesis entitled "Temporal Effect of Ammonium Sulfate on Soil Nitrogen Content, Growth and Yield of Oil Palm Cultivated on Alan Forest Tropical Peat, Sarawak, Malaysia" 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.

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CHAPTER 1

INTRODUCTION

1.1 Background

Tropical peatland is a very precious non-renewable natural resource that can be a new frontier for agriculture development and therefore, play a vital role in economic growth of the country (Melling *et al*., 1999). Peatlands occupy an area of 2.458 million hectares in Malaysia which accounts for about 7.45% of the total land areas (Wetlands International, 2010). About 1.7 million hectares of these peat soils are located in Sarawak, equivalent to 13.7% of Sarawak total land area (Wetlands International, 2010). Generally, the depth of peat in Sarawak range from 5 m to 10 m; the peat depth is shallower near the coastal areas and increases inwards where the depth sometimes can be more than 20 m (Tie and Melling, 1999; Melling *et al*., 2006). In addition to peatland, other problematic soils in Sarawak are steep land (58%) and potential acid sulphate soil (1%) (Uyo, 2007). Thus, suitable land for oil palm cultivation in Sarawak is scarce as there is only 26% of land is suitable for conventional commercial agriculture (Uyo, 2007).

Melling *et al.* (2008) stated that oil palm is one of the economical perennial crops that can be successfully cultivated on peatland with proper land management. Mohd. Tayeb (2005) reported that oil palm grown on peat can produce yields more than 30 tonnes/hectare/year during mature years and comparable to coastal mineral soil. To achieve that, good water and nutrient management are essential for cultivation of oil palm on peat apart from proper initial land development such as drainage and compaction. Furthermore, a better understanding of the variability of different forest types is very crucial to manage the peat since physical and chemical characteristics are unique in each respective forest types (Melling *et al.,* 2007a).

1.2 Economic Contribution of Oil Palm Cultivation

Oil palm is a perennial oil-yielding tree-crop which has become a critical component of many national economies in the tropics. Being the most efficient oil crop in the world, oil palm yields production is eleven times higher than soya bean; eight times greater than sunflower seed and five times higher than rapeseed (Oil World, 2010). Over the past few decades, the area under oil palm cultivation has increased rapidly in Southeast Asia as a result of fast growing global demand for palm oil. Potts *et al*. (2014) stated that Malaysia accounted for 36% of world palm oil production in 2012 and 29% of world exports in 2013. About five million hectares of land in Malaysia has been planted with oil palm plantations and the export earnings from palm oil products has reached RM 71.4 billion in 2012 (Lee, 2012). Thus, being one of the main sources of exports in Malaysia, oil palm contributes significantly to the earning

of Malaysia and subsequently becomes one of the key contributors to poverty alleviation and better living standards of Malaysians.

1.3 Controlling Factors for Soil Nitrogen

Peat soils are not suitable for cultivation of most crops because of high acidity (pH 2.8 to 4.5) and low available nutrients (Mutert *et al.*, 1999; Melling *et al.*, 1999). Nitrogen (N) content in peat soil is rather high with the range of 1.69 - 1.94% (Andriesse, 1988; Melling *et al.*, 2008). However, its availability for plant uptake is limited due to high carbon/nitrogen (C/N) ratio. High C/N ratio indicates low mineralization rate in the soil (Springob and Kirchmann, 2003). Other factors influencing the availability of N in peat soil are soil temperature, pH, fertilization, rate of mineralization in relation to drainage, presence of nitrogen fixing bacteria and amount of lignin present in organic matter. High lignin content in Alan forest soils may slow downthe rate of N mineralization (Walela *et al.*, 2014) and thus available N may not be sufficient for plant uptake.

1.4 Nitrogen Fertilizer Application Rates

Previous studies have shown that N fertilizer rates are varied for oil palm grown on peat soils. Mohd. Tayeb *et al*. (1996) reported that N fertilizer rate in peat soils should not exceed 0.46 kg N/palm/year, while Xaviar and Gurmit (1999) revealed that an estimated rate of 0.68 kg N/palm/year were required for palms planted on peat. The recommended rates are based on trials done mostly in mixed peat swamp area which is less woody and may not be suitable for Alan forest area in which the peat is very woody. Uyo (2007) mentioned that although similar treatment is carried out, there were significant yield differences for oil palm cultivated on peat soil across Sarawak. The yield obtained from oil palms planted on tropical peat i.e. Alan Batu and mixed peat swamp areas were 2.37 tonnes/hectare/year (2^{nd} year) and 9.88 tonnes/hectare/year (2^{nd} year), respectively, even though the same fertilizer rates were used (Melling *et al.*, 2007a).

1.5 Problem Statement

Oil palm cultivation requires significant amount of N fertilizer for optimum growth and yield production. The study of N fertilization for oil palm grown on tropical peat soil is very limited especially for the peat formed under Alan Bunga forest (Uyo, 2007). Therefore**,** more researches and developments are required in this area to identify the suitable N rates for sustainable oil palm production (Goh and Hardter, 2003).

1.6 Objectives of Study

The aim of this study was to determine the growth response of oil palm on tropical peat to different N fertilizer application rates. The specific objectives were to investigate the effect of different N fertilizer application rates on:

i) total N and available N in the soil
ii) leaf N concentration
iii) vegetative growth of oil palm
iv) oil palm FFB yield

1.7 Scope of Study

This study was carried out on six years old oil palms grown on tropical peat, particularly on Alan forest. Ammonium sulphate (AS) ($(NH_4)_2SO_4$) fertilizer was used as N source. All of the data were collected from 2010 to 2012 in which the randomised complete block design (RCBD) was used for the experimental design.

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