UNIVERSITI TEKNOLOGI MARA

EFFECTS OF DIFFERENT LIMING RATES ON SELECTED SOIL CHEMICAL PROPERTIES AND THE VEGETATIVE GROWTH OF YOUNG OIL PALM ON TROPICAL PEATLANDS

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Thesis submitted in fulfilment
of the requirements for the degree of
Master of Science

Faculty of Plantation and Agrotechnology

October 2025

ABSTRACT

Tropical peat soils pose unique agronomic challenges due to their high acidity and low fertility. Liming with calcium carbonate ($CaCO_3$) is a common practice to improve soil pH and fertility; however, the substantial buffering capacity of peat soil complicates optimal lime application rates. Many studies focus on the effects of liming on soil pH and crop yield, but less is known about its wider impact on the chemical properties of tropical peat soils. This study evaluated lime effects through both a laboratory incubation and a 5.5-year field experiment to assess soil chemistry, nutrient dynamics, and young oil palm growth, while examining whether controlled-condition soil responses correspond with long-term field observations. The study includes lime rates: Control (L0), 3 t ha^{-1} (L1), 6 t ha^{-1} (L2) and 12 t ha^{-1} (L3). Under controlled conditions, lime application significantly increased soil pH from 3.2 to 7.5 ($p < 0.05$) and decreased cation exchange capacity (CEC) from 49.5 to 30.1 cmol kg^{-1} ($p < 0.001$). However, lime rates above 6 t ha^{-1} did not further increase soil pH or reduce CEC, likely due to Ca^{2+} saturation of exchange sites and the strong buffering capacity of peat. Lime increased calcium (Ca) concentrations but decreased magnesium (Mg) and potassium (K), as Ca^{2+} displaced Mg^{2+} and K^{+} from exchange sites. Lime also significantly decreased net mineralization ($p < 0.001$), indicating nitrogen (N) immobilization. In the field trial, lime application significantly increased topsoil pH (3.50 to 4.00) and enhanced total Ca and Mg concentrations, while reducing exchangeable Al toxicity. However, CEC, soil organic matter (SOM) content, and electrical conductivity (EC) remained statistically unaffected. While vegetative growth parameters such as leaf area index (LAI) showed no significant changes, fruit bunch production increased significantly at moderate lime rates, indicating improved nutrient balance and reduced soil acidity. These findings highlight that lime application at moderate lime rates (6 t ha^{-1}, L2) can effectively improve soil fertility and support yield performance without adversely affecting vegetative traits, offering practical guidance for oil palm cultivation on tropical peat.

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to all those who have been instrumental in making my MSc journey a meaningful and enriching experience. First and foremost, I extend my heartfelt thanks to my main supervisor, Assoc. Prof. Dr. Hasmah bt Mohidin, for her guidance, support, and invaluable insights throughout the research process. Their mentorship has been instrumental in shaping the trajectory of my academic pursuits.

I am indebted to the faculty members of the Faculty of Plantation and Agrotechnology and the Center of Postgraduate Studies, Universiti Teknologi MARA (UiTM), Jasin Campus, Melaka, as well as UiTM Samarahan Campus, Sarawak, whose commitment to excellence in teaching and research has been a constant source of inspiration. Their passion for the subject matter has fuelled my curiosity and broadened my intellectual horizons. Special thanks go to my friends who have been companions on this academic voyage. The camaraderie we shared, the dusk till dawn study sessions, and the collaborative spirit have made this journey memorable.

I would like to extend my sincere appreciation to the Sarawak State Government, and particularly the Sarawak Research and Development Council (SRDC), for their unwavering support throughout my master's study. I also gratefully acknowledge to former Sarawak Tropical Peat Research Institute (TROPI), which is now fully integrated under SRDC, for their earlier contributions to my research journey. The opportunities to work with dedicated professionals and access state-of-the-art facilities have been pivotal in shaping my research experience. I am deeply grateful for the financial support provided by the Sarawak State Government and Sarawak Plantation Berhad. This support played a crucial role in facilitating data acquisition, lab work, fieldwork, and various aspects of my research, contributing significantly to the overall success of my study.

To my dearest love, Amelia Jackob, my beloved daughter Kylisha Aurelia Agatha, and my cherished family members, including my parents, parents-in-law, brother, sister-in-law, and other relatives, I want to express my heartfelt appreciation for your unwavering support and understanding throughout my Master's journey. Your encouragement, love, and understanding have been my pillars of strength, providing the motivation to overcome challenges and pursue academic excellence. I am profoundly grateful for the sacrifices you've made and the encouragement you've given, which have played an integral role in my success. Your support has made this academic achievement even more meaningful, and I am blessed to have such a loving and understanding family by my side.

Thank you.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

Tropical peatlands develop through the accumulation of partially decayed woody vegetation under waterlogged conditions, where oxygen deficiency restricts the decomposition of organic materials (Melling et al. 2008; Dargie et al. 2017; Sapar et al. 2020). In line with Sustainable Development Goals (SDGs), particularly SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 15 (Life on Land), efforts to boost food production, improve livelihoods, and support sustainable agricultural practices have led to the conversion of extensive areas of tropical peatland into agricultural land. This is particularly evident in Southeast Asia, where Indonesia and Malaysia are the leading global palm oil producers (FAO 2017; Goh et al. 2020; Uning et al. 2020).

Over the last decade, oil palm (*Elaeis guineensis* Jacq.) has emerged as the predominant vegetable oil globally, with Southeast Asia (SEA) accounting for 90% of the world's consumption (Danylo et al., 2021; Ng et al., 2012). The oil palm (OP) signifies the most of consumable oil (Lam et al., 2019; Pirker et al., 2016), with a prevailing global cultivation area that exceeds 23 million hectares (MHa) (Bai et al., 2018). As reported by the Malaysian Palm Oil Board (MPOB) (2024), the total land area allocated for OP cultivation amounted to 5.61MHa in 2024, with Sarawak emerging as the predominant state for OP development, accounting for 1.62MHa or 28.9% of the total OP area in Malaysia. Peatland is often used in Sarawak to grow sago and oil palm (Sim et al., 2019). Oil palm started off as an ornamental plant in Malaysia and has since developed into a major industrial sector, producing 19.34 million tons of crude palm oil (CPO) and 16.70 tons per hectare of fresh fruit bunches (FFB) (MPOB, 2024). The average production of FFB in Sarawak in 2024 was 14.89 tons per hectare (MPOB, 2024)

However, converting tropical peatlands for agricultural purposes poses considerable challenges owing to the inherent characteristics of peat soils. One of the primary agronomic challenges for crop production in peat soil is its high acidity (pH: 3.3–3.5), which renders vital nutrients inaccessible and results in low fertility (Busman