



**UNIVERSITI PUTRA MALAYSIA**

**MINERALOGICAL AND CHEMICAL PROPERTIES OF SOME ACID  
SULFATE SOILS IN MALAYSIA AND THEIR EFFECTS ON THE  
GROWTH PERFORMANCE OF OIL PALM SEEDLINGS  
(ELAEIS RUINEENSIS, JACQ)**

**EDGARDO ANTIGA AUXTERO**

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MINERALOGICAL AND CHEMICAL PROPERTIES OF SOME ACID  
SULFATE SOILS IN MALAYSIA AND THEIR EFFECTS ON THE  
GROWTH PERFORMANCE OF OIL PALM SEEDLINGS  
(*Elaeis guineensis*, Jacq)

by

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With great appreciation to: My Mother,  
Auntie Regina and  
Late Grandfather



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## LIST OF ABBREVIATIONS

DID	: Drainage Irrigation Department
dS/m	: deciSiemens per meter
FAO	: Food and Agriculture Organization
HMPB	: Harrisons Malaysia Plantation Berhad
ICPEAS	: Inductively Coupled Plasma Emission Atomic Spectrophotometer
kPa	: kilo Pascal
MARDI	: Malaysian Agricultural Research and Development Institute
PUSPATI	: Pusat Penyelidikan Atom Tun Ismail
RRIM	: Rubber Research Institute of Malaysia
SEM	: Scanning Electron Microscope
SEM-EDXRA	: Scanning Electron Microscope-Energy Dispersive X-Ray
TEM	: Transmission Electron Microscope
UPM	: Universiti Pertanian Malaysia
XRD	: X-ray Diffraction Analysis



Abstract of the thesis presented to the Senate of Universiti Pertanian Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy.

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Acid sulfate soils are characterized by a very low pH and a high aluminium concentration resulting from the chemical and biological oxidation of pyrite upon drainage. These soils have low agricultural potential due to high acidity and poor physical conditions, which adversely affect crop growth. Successful reclamation and management of acid sulfate soils would require an in-depth understanding of the soil's chemical and mineralogical properties.

In this study, acid sulfate soils at Pulau Lumut, Kelang were mapped, characterized morphologically and chemically, and classified. Soil solutions were extracted on samples from soil



pit, limed and oxidized soils and a pot experiment at the matrix suction of 10 kPa and the activities of the major cations and anions were calculated by Geochem. XRD and TGA were carried out to determine the mineralogy of the various soil horizons. The morphological features of the minerals in the soils were studied by TEM and SEM. A controlled pot experiment was conducted to assess the performance of oil palm seedlings grown on acid sulfate soils under freely drained and waterlogged conditions.

Drainage resulted in the development of true acid sulfate soils. Sulfic Tropaquepts (Tongkang and Jawa series) and Sulfaquepts (Sedu and Parit Botak series) occur in the banded area drained 25 years ago. A juvenile Sedu silty type (Sulfaquepts) also occur in the area drained about 8 years ago. SEM study showed that these soils originated from marine alluvial deposits as confirmed by the presence of marine biorelicts.

Results of XRD analysis showed that kaolinite, smectite, mica and mica-mixed layers were the dominant minerals in the clay fraction of all soils. Gibbsite, polygonally-shaped and tubular forms of halloysite were also found. Jarosite crystals of about 1  $\mu\text{m}$  believed to be formed from precipitation in soil solutions were found in the soils. Activities of  $\text{K}^+$ ,  $\text{Fe}^{3+}$  and  $\text{SO}_4^{2-}$  in the soil solution were found to be supersaturated with respect to jarosite. High activities of  $\text{Al}^{3+}$  and  $\text{SO}_4^{2-}$  in the



soil solution resulted in the precipitation of alunite, basalunite and jurbanite. Application of lime at 5 t/ha increased the pH of the Ap horizon from about 3.5 to 5.0. This reduced the activities of aluminium, iron and manganese to a minimal level.

Over 90% of the aluminium in the soil solution was in the inorganic monomeric form, with  $Al^{3+}$  and  $Al(SO_4)^+$  as the major aluminium species. These aluminium species reduced the relative tap root length of oil palm seedlings.  $Al^{3+}$  and  $Al(SO_4)^+$  corresponding to 90% relative tap root length were about 100  $\mu M$  and 500  $\mu M$  respectively. Respective aluminium and iron concentrations in the root corresponding to a 10% reduction in the relative tap root length of oil palm seedlings were 1.3% and 0.2%.

Oil palm seedlings grown on soils with low activities of aluminium and iron exhibited good growth. This was obtained on freely drained top soils. It is advisable to flush out sulfate as much as possible, and thereafter, maintain the pyritic horizon in a flooded condition.



Abstrak tesis yang diserahkan kepada Senat Universiti Pertanian Malaysia sebagai memenuhi syarat yang diperlukan untuk mendapatkan Ijazah Doktor Falsafah.

SIFAT-SIFAT MINERALOGI DAN KIMIA BEBERAPA TANAH ASID SULFAT  
DI MALAYSIA DAN KESANNYA KE ATAS PERTUMBUHAN ANAK BENIH  
KELAPA SAWIT (*Elaeis guineensis*, Jacq)

Oleh

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Tanah asid sulfat dicirikan oleh pH yang sangat rendah dan kandungan aluminium yang tinggi, hasil daripada pengoksidaan pirit melalui saliran. Tanah-tanah ini kurang berpotensi untuk pertanian kerana keasidan yang tinggi dan keadaan fizikal yang lemah, iaitu sifat-sifat yang mempengaruhi pertumbuhan tanaman. Kejayaan penubusgunaan dan pengurusan tanah asid sulfat bergantung kepada kefahaman yang mendalam tentang ciri-ciri kimia dan mineralogi tanah.

Dalam kajian ini, tanah asid sulfat di Pulau Lumut, Kelang dipeta, dicari dari segi morfologi dan kimia, dan dikelaskan.





Larutan tanah yang wujud di tahap sedutan matrik 10 kPa diekstrak daripada sampel-sampel lelubang tanah, tanah yang telah dikapur dan tanah yang teroksid. Aktiviti-aktiviti kation dan anion utama diramalkan dengan menggunakan program Geochem; Kaedah-kaedah XRD dan TGA telah digunakan untuk penentuan mineralogi di berbagai-bagai horizon tanah. Morfologi mineral tanah ditentukan dengan kaedah-kaedah SEM dan TEM. Ujian kawalan berpasu telah dijalankan untuk menentukan pertumbuhan anak benih kelapa sawit pada tanah asid sulfat di bawah keadaan tersalir dan terendam air.

Penyaliran mengakibatkan terbentuknya tanah asid sulfat jenis Sulfic Tropaepts (siri Tongkang dan Jawa) dan Sulfaquepts (siri Sedu dan Parit Botak), yang terdapat di sekitar kawasan yang telah disalirkan selama 25 tahun. Tanah jenis Sedu berkelodak (juga Sulfaquepts) dijumpai di kawasan yang telah disalirkan lebih kurang 8 tahun yang lepas. Kajian SEM menunjukkan bahawa tanah-tanah ini terbentuk daripada penimbunan lanar laut sebagaimana ditunjukkan oleh kehadiran biorelik lautan.

Keputusan analisis XRD menunjukkan kaolinit, smectit, mika dan lapisan bercampur-mika merupakan mineral utama di dalam bahagian lempung bagi semua siri tanah. Gibsit dan haloisit yang terbentuk poligonal serta tiub juga terdapat. Kristal jarosit yang berukuran 1  $\mu\text{m}$  yang terdapat di dalam tanah,

