A COMPARATIVE STUDY OF THE PHOSPHORUS CHARACTERISTICS OF OIL PALM VOLCANIC SOILS IN PAPUA NEW GUINEA AND NEW ZEALAND VOLCANIC SOILS

A thesis presented in partial fulfillment of the requirements for the
Degree of Master of Applied Science in Soil Science at
Massey University, Palmerston North, New Zealand

Murom Banabas

1998

ABSTRACT

Oil Palm (*Elaeis guineensis* Jacq.) grown on volcanic ash soils in Papua New Guinea (PNG) generally respond well to N fertilisers but shows a lack of consistent response to inorganic phosphorus (P) fertilisers. This is true even on soils with high phosphate retention (PR) and where Olsen P values highlighted in the preliminary survey of PNGOPRA field trial data are very low (<10 mg/kg). A notable exception occurs at Bialla (Trial 201) where significant responses (yield and growth parameters) to P fertilisers have been found on soils with very low Olsen P (< 4 mg/kg) and very high PR values (>90% to at least 60 cm depth).

This study was done to characterise the PNG oil palm growing volcanic soils in relation to P responsiveness, to identify P fractions and their relative amounts, to determine the fate of applied P fertilisers and to compare chemical and mineralogical characteristics of PNG soils with some New Zealand (NZ) equivalent soils.

Mineralogical analysis indicates that the PNG soils used in this study are relatively young as evidenced by the presence of very high amounts of readily-weatherable volcanic glass in the sand, silt and clay fractions. Soils at Hoskins, Kapiura and Bialla, all in West New Britain (WNB) Province, contain similar amounts and types of primary and secondary minerals. Soils at Bialla are probably older than those at Hoskins and Kapiura and contain large amounts of secondary amorphous minerals (allophane and ferrihydrite) in the clay fraction. Soils at Popondetta are different from those in WNB with high amounts of hornblende and no augite or hypersthene in the heavy mineral fraction. Allophane levels in the clay fraction are high to very high in soil surface layers at Hoskins and Kapiura and at all depths in Bialla soils. At Popondetta, allophane content is very low at all depths

PR in all soils and at all depths was highly correlated with acid oxalate extractable Al (Al_o) ($r = 0.84$*) and iron (Fe_o) ($r = 0.89$*). The sources of these 2 extracts (allophane and ferrihydrite) are largely responsible for the high PR in the soils studied. High allophane and ferrihydrite levels at all depths in Bialla soils correspond well with very

high PR values (>90%) to at least 2 m depth. Low levels of these 2 minerals in Popondetta soils correspond well with low PR values (30%). Intermediate PR values (60 - 70%) for Hoskins and Kapiura surface soils correlates well with the occurrence of intermediate levels of allophane and ferrihydrite.

In all PNG soils, a P fractionation scheme showed that the major P fractions are organic. At Hoskins, NaOH-Po accounts for 38 to 48% of total P. For Kapiura NaOH-Po accounts for approximately 50% of total P, and Bicarb.-Po accounts for 59% of total bicarbonate-extractable P. For Bialla soils, NaOH-Po and Bicarb.-Po comprise between 74 and 76%, on average, of their respective total extracted P for all depths. At Popondetta, NaOH-Po comprises 62% and Bicarb.-Po 63% of their respective total extractable P contents.

P fertiliser accumulation in Hoskins and Kapiura soils occurs mostly in organic forms and within the top 10 cm of soil. At Hoskins, 83% of total added P accumulated in the top 10 cm (53% being NaOH-Po) while 17% was found in the next 10 cm depth (31% being NaOH-Po). At Kapiura, 74% of total accumulated P was found in the top 10 cm of soil (61% being NaOH-Po) and 26% within the 20 - 30 cm layer (81% being NaOH-Po).

The presence of amorphous minerals explains much of the behaviour of P in trial soils, with the major P source/sink in PNG soils being as organic forms.

In relation to soil mineralogical and chemical characteristics, PNG soils were classified into one of the major 3 groups in terms of responsiveness to P fertilisers; (a) soils with very high PR (>90%) and Olsen P values of less than 4 mg/kg which are considered most likely to respond to inorganic P fertilisers e.g. Bialla soil, (b) soils with medium to high PR (60 - 70%) will likely show inconsistent responses to P fertilisers and P responses are most likely to be secondary to N e.g. Hoskins and Kapiura soils and
(c) soils with low PR (30 - 40%) which are unlikely to respond to P fertilisers at least in the foreseeable future e.g. Popondetta soils.

This study highlights a future need for further study of the dynamics of P nutrient cycling, specifically the mineralisation rates of organic matter and the release of Pi for plant uptake in PNG oil palm growing soils. Also there is a need to re-establish the leaf critical concentration because in PNG soils though leaf levels are generally less than 0.150% DM, palms do not always respond to P fertilisers. This suggests that the "critical" P concentrations under PNG conditions is probably less than the international standard at 0.150% DM.

Mineralogical and P sorption characteristics of young volcanic ash soils in NZ are sufficiently similar to those in PNG to provide useful information about the general behaviour of P fertilisers and P reaction products in oil palm production systems.

ACKNOWLEDGMENTS

I express my gratitude to the following people for their help in doing this thesis.

Firstly to my 2 supervisors, Dr. Max Turner and Professor Russ Tillman for their encouragement, supervision and critical suggestions.

To the New Zealand Landcare staff; Dr. Roger Parfitt for helpful suggestions and analysis for allophane and ferrihydrite, Mr. Joe Whitton for helping with mineralogical analysis and Ms. Linda Hill for carbon and nitrogen analysis.

To Mr. Bob Toes for assistance with Olsen P tests.

To Soil Science Department technicians for assistance in use of various laboratory equipment.

To Mr. Ian Orrell (DOR-PNGOPRA) for help in making this study possible for me.

To Mr.Graham King and Mr. Allan Oliver for providing literature review materials and Joe Yambun and Doreen for helping in soil sampling and handling. Also to all PNGOPRA workers who actually helped in sampling the soils.

A special thanks to my wife, Nambua for looking after our 3 children; Enzeng, Serah and Yandisao during my absence. Also a special thanks to my parents at home for their never ending support.

Finally, this piece of work though may not be the best, I would like to dedicate it to the 20 people in my village (Mataya, Wantoat Sub-District, Morobe Province, PNG) who were covered by landslide while gardening in 1993.

TABLE OF CONTENTS

CHAPTER 4

RESULTS AND DISCUSSION

LIST OF TABLES

LIST OF FIGURES