The dynamics of phosphorus extractability, adsorption, and desorption rates as influenced by phosphorus applications and incubation times

by

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Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy

in the

DEPARTMENT OF PLANT PRODUCTION AND SOIL SCIENCE
FACULTY OF NATURAL AND AGRICULTURAL SCIENCES
UNIVERSITY OF PRETORIA
PRETORIA

April 2002

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DEDICATION

This work is dedicated to the fond memories of Veronica Awor, Salmon Obbo, Simon Onyango, Matayo Owora, and Maltilda Nyafwono.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Prof. E.N. Sabiiti, the Dean, Faculty of Agricultural Sciences, Makerere University, and the National Agricultural Research Organization (NARO) Uganda, for the financial support that enabled me to undertake this study. I am equally grateful to Prof. P.J.M. Ssebuwufu, the Vice-Chancellor, Makerere University, for granting me study leave. I wish to thank Dr. D.G. Joubert, Director, ARC – Institute for Industrial Crops, Rustenburg, for allowing me to carry out this research at his Institute, providing me with a decent accommodation facility, and for the provision of research facilities and technical support.

I am highly appreciative to my supervisor Prof. A.S. Claassens for having been a constant source of inspiration and guidance. I wish to sincerely thank him for his friendship, kindness, encouragement, and inspiring discussions. I further, wish to express my sincere thanks to Ms. Elise Eulitz for kindly assisting me with the statistical analysis, and to Ms. R. Steyn and Ms. D. Venter for giving me some very valuable lessons on computer applications and to Ms. Alfreda Pohl for proof-reading part of the draft. My special thanks go to Mr. A. Cornelissen for the brotherly love, technical, and moral support he unreservedly afforded me for the duration of my stay in South Africa.

Special appreciations also go to Mr. H. Boshoff, Dr. M. Dippenaar, Dr. C.J. Steenkamp, C. de Jager, Mr. J. Tlou, Ms. K. Smook, Ms. M. Venter, and Ms. N. Meyer for the technical assistance they offered me. I wish also to thank my friends Gloria Poonyane, Simon Molope, Thomas Areke, John Ramashala, Ismail Moosa, Johannah Molwantwa, and all other colleagues at the IIC, Rustenburg and the University of Pretoria, for their assistance and friendship, and for making it possible for me to enjoy my stay at the Institute.

Last but definitely not least I want to thank my family and especially my wife Virginia M. Ochwoh, my daughters Nicky Nyafwono, Lilian Akoth, Rovita Nyamwenge, and Phyllis Awor, and my son Simon Onyango for their physical and moral support, encouragement, and patience without which the research and therefore this thesis would not have been completed.

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ABSTRACT

In a study to investigate the fate of the applied P in soils, a red-sandy clayey soil (Ferric Luvisols) from Rustenburg (high P fixing) and a red-sandy loam soil (Ferric Acrisols) from Loskop (low P fixing) were used. Sequential P fractionations were used to determine the content of the different P pools to show which pool the applied P was transformed to. The soils treatments consisted of different P rates (0, 25, 50, 100, 150, and 200 mg kg^{-1}), and incubation periods (1, 60, 120, 180, and 240 days) under a laboratory conditions. The sequential P fractionation procedure consisted of extraction with hydrous ferric oxide in a dialysis membrane tube (DMT-HFO), 0.5M $NaHCO_3$, 0.1M NaOH-P, 1.0M HCl, concentrated HCl, and concentrated H_2SO_4 + H_2O_2.

Approximately 30 to 60 % of the added P were transformed into less labile P pools within one day and 80-90 % after 60 days. This transformation was faster in the Rustenburg than in the Loskop soil showing a higher P fixation capacity. A major part of the P transformation was to the –OH-P_i pool with a recovery of about 30 %.

In the second experiment an attempt was made to determine P desorption rates by successive DMT-HFO extractions (1, 7, 14, 28, and 56 days) after the transformations of the applied P. This was followed by the sequential extractions to determine the changes and distribution of the added P into different P pools as well as which pools the P was desorbed from. The Rustenburg and Loskop soils were treated to different P rates (0, 25, 50, 100, and 200 mg P kg^{-1}) and incubation periods (1, 120, and 240 days).

The cumulative DMT-HFO extraction curves for 56 days showed that desorption could continue for a much longer period. This property is important in the economical management of fertilizer applications rates. Results showed the transformations and distribution of the applied P during incubation periods and proved that all the stable soil P pools contributed to the labile P pool by different proportions after prolonged successive DMT-HFO extractions.

Although Rustenburg soil is considered a high P fixing soil, the P release rates under laboratory conditions were high enough to meet the requirements of cotton and tobacco crops. Root systems of these crops do not exploit 100 % soil volume as this laboratory method, which could explain why these crops experience P deficiencies.

It is envisage that by using this method the P releasing properties of a soil could be used to develop a P desorption model to determine how much extractable P, with a specific extractant, in a particular soil, should be available at the beginning of a growing season to sustain a high enough P releasing rate to meet the requirements of a certain crop up to the end of the growing season. To do this, a model to describe root development that represents the percentage of the soil exploited P desorption rates that simulate P uptake by plant roots will be necessary.

Keywords: Adsorbed P, immobile and residual P, labile P, labile and stable P pools, P adsorption and desorption, P desorption rates, P fractionations, P percent recovery, P transformations and distribution, sequential P extractions.

UITTREKSEL

In 'n studie om die transformasie van die toegediende P te ondersoek, is 'n rooi sanderige-klei grond (Ferriese Luvisol) van Rustenburg (hoë vasleggingspotensiaal) en 'n rooi sandleem grond (Ferriese Acrisol) vanaf Loskop (lae P-vasleggingspotensiaal) gebruik. Verskillende vlakke van P (0, 25, 50, 100, 150, en 200 mg kg^{-1}) is toegedien en vir verskillende tye geinkubeer (1, 60, 120, 180, en 240 dae). Opeenvolgende fraksionerings is gedoen om die P-inhoud van verskillende P-poele te bepaal om aan te dui waarheen die toegediende-P omgeskakel is. Die opeenvolgende fraksionerings het bestaan uit ekstraksies met ferrihidreerde ysteroksied in dialisemembraanbuise (DMT-HFO), 0.5 M$NaHCO_3$, 0.1 M NaOH, 1.0 M HCl, gekonsentreerde HCl en gekonsentreerde $H_2SO_4 + H_2O_2$ – P.

Tussen 30 - 60% van die toegediende P is getransformeer na minder labiele P-poele en het verhoog tussen 80 - 90 % na 60 dae. Die transformasie was vinniger in die Rustenburg- as in die Loskopgrond en vertoon dus 'n hoër P- vasleggingsvermoë.

In die tweede eksperiment is daar gepoog om vas te stel wat die desorbsie tempo van toegediende P is nadat transformasie plaasgevind het. Dit is opgevolg deur opeenvolgende ekstraksies om te bepaal uit watter P poele die P geekstraheer is. Die twee grondtipes van Rustenburg en Loskop is behandel met verskillende P-toedienings (0, 25, 50, 10, en 200 mg P kg^{-1}) en inkubasie-tye (1, 120 en 240 dae).

Die kumulatiewe ekstraksies met DMT-HFO vir 56 dae het aangetoon dat desorbsie vir langer periodes kon plaasvind. Hierdie eienskap is belangrik vir die ekonomiese bestuur van kunsmistoedienings. Die transformasies en verspreiding van toegediende P en inkubasie tye dui daarop dat die stabiele grond- P-poele bygedra het tot die labiele P-poel.

Alhoewel die Rustenburg grondtipe 'n hoë P-adsorbsie kapasiteit het, is die P-vrystelling voldoende om aan die behoeftes van katoen en tabak te voldoen. Die

wortelstelsel van die gewasse benut die grond egter nie tot in dieselfde mate as wat met die laboratorium metode bereik word nie en ondervind die plante P-tekorte.

Met behulp van die desorpsie tempos sou dit moontlik wees om 'n model te ontwikkel, waarmee voorspel kan word hoeveel ekstraheerbare P met 'n sekere ekstraksiemiddel nodig sal wees aan die begin van die groeiseisoen om te voldoen aan die P behoefte van 'n gewas aan die einde van die groeiseisoen.

Om hierdie metode te kan implementeer sal die wortelontwikkeling van 'n gewas in aanmerking geneem moet word om te bepaal watter persentasie van die grond deur die wortels geekstraheer word.

Sleutelwoorde: adsorbeerde-P, onbeweeglike- en residuele-P, labiele-P, labiele en stabiele P- poele, P- adsorpsie en desorpsie, P- desorpsie-tempo, P- fraksionerings, P- persentasie herwinning, P- transformasie en verspreiding, opeenvolgende P- ekstraksies.