

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

**by**

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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.

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## CONTENTS

SECTIONS	PAGES
1. ACKNOWLEDGEMENTS -----	iii
2. Contents -----	iv
3. List of Tables:	
Chapter 2 -----	vii
Chapter 3 -----	viii
4. List of Figures:	
Chapter 2 -----	x
Chapter 3 -----	xi
5. ABSTRACT -----	xviii
6. CHAPTER 1 GENERAL INTRODUCTION -----	1
7. CHAPTER 2 A STUDY ON THE CHANGES AND DISTRIBUTION OF THE INITIAL AND APPLIED P INTO THE DIFFERENT P POOLS IN HIGH AND LOW P FIXING SOILS AFTER DIFFERENT INCUBATION PERIODS -----	18
INTRODUCTION -----	18
MATERIALS AND METHODS -----	21
1. MATERIALS -----	21
1. (a). SOILS -----	21
2. (b) INCUBATION MATERIALS -----	21
2). SOIL INCUBATION TRIALS -----	21
3). SOIL ANALYSES -----	28
4). STATISTICAL ANALYSIS -----	30
RESULTS AND DISCUSSION -----	31
1). Chemical, physical and, mineralogical characteristics of Rustenburg and Loskop soils -----	31
2). Sequential fractionations of soil P into various inorganic P (P <sub>i</sub> ), and organic P (P <sub>o</sub> ) pools -----	31

SECTIONS	PAGES
3). The effects of different P treatments and incubation time on the sequentially extracted inorganic P, organic P, percent P recovered, and P distribution into different P pools -----	33
a). The effects of the added P and incubation time on plant – available P - solution- (DMT-HFO-P <sub>i</sub> ) and labile-P (0.5M NaHCO <sub>3</sub> -P <sub>i</sub> ) -----	34
b). The effects of the added P and incubation time on the adsorbed P - 0.1M NaOH- and 1.0M HCl-extracted P (Al- Fe-) oxihydroxide P, and Ca- bound-P) -----	51
c). The effects of the added P and incubation time on the occluded and residual P – conc. HCl- and H <sub>2</sub> SO <sub>4</sub> + H <sub>2</sub> O <sub>2</sub> – extracted P -----	58
4). The effectiveness and limitations of the methodologies used--	65
CONCLUSIONS -----	66

### CHAPTER 3

SECTIONS	PAGES
CHAPTER 3 A STUDY OF THE EFFECTS OF DIFFERENT P APPLICATION RATES AND INCUBATION PERIODS ON P DESORPTION RATES AND CHANGES IN P POOLS WITH SUCCESSIVE DMT-HFO EXTRACTIONS ON A HIGH AND LOW P FIXING SOILS -----	68
INTRODUCTION -----	68
MATERIALS AND METHODS -----	71
1). MATERIALS -----	71

SECTIONS	PAGES
2). SOIL INCUBATION TRIALS -----	71
3). SOIL ANALYSES -----	72
4). STATISTICAL ANALYSIS -----	73
RESULTS AND DISCUSSION -----	74
1). Chemical, physical, and mineralogical, characteristics of Rustenburg (R) and Loskop (L) soils -----	74
2). The effects of applied P and incubation times on the successive DMT-HFO-P extractions and subsequent- changes in the P contents of the different P pools -----	74
a). The effects of added P and the incubation time on the successive DMT- HFO extractions from the Rustenburg and Loskop -----	81
b). The effects of the added P, incubation time, and the successive DMT-HFO extractions on the changes and distribution of plant-available or labile-P pool (0.5M NaHCO <sub>3</sub> -P <sub>i</sub> and P <sub>o</sub> ). -----	90
c). The effects of the added P, incubation time, and the successive DMT-HFO extractions on the changes and distribution of adsorbed or slowly labile P (0.1M NaOH- and 1M HCl-extracted P) after successive (DMT-HFO) extractions -----	114
d). The effects of the added P, incubation time, and the successive DMT-HFO extractions on the changes and distribution of insoluble P (conc. HCl-extracted P “C/HCl-P <sub>i</sub> and P <sub>o</sub> ” conc. H <sub>2</sub> SO <sub>4</sub> + H <sub>2</sub> O <sub>2</sub> -extracted P -----	141
CONCLUSIONS -----	167
CHAPTER 4 SUMMARIES AND CONCLUSIONS -----	169
CHAPTER 5 LITERATURE CITED -----	174
CHAPTER 6 APPENDICES -----	185

SECTIONS	PAGES
APPENDICES I -----	185
APPENDICES II -----	210

### LIST OF TABLES – CHAPTER 2

TABLES	PAGES
1. Some chemical, physical, and mineralogical characteristics of Rustenburg and Loskop soils -----	32
2. The effects of the added P and incubation period on the sequentially extracted inorganic P, organic P, and percent P recovered from Rustenburg soil. -----	36
3. The effects of the added P and the incubation period on the sequentially extracted inorganic P, organic P, and percent P recovered from Loskop soil -----	37
4. The effects of the added P on the changes and distribution of P into different P pools after 1 day of incubation of (a) Rustenburg and (b) Loskop soil. -----	46
5. The effects of the added P on the changes and distribution of P into different P pools after 60 days of incubation of (a) Rustenburg and (b) Loskop soil. -----	47
6. The effects of the added P on the changes and distribution of P into different P pools after 120 days of incubation of (a) Rustenburg and (b) Loskop soil. -----	48
7. The effects of the added P on the changes and distribution of P into different P pools after 180 days of incubation of (a) Rustenburg and (b) Loskop soil. -----	49

TABLES	PAGES
8. The effects of the added P on the changes and distribution of P into different P pools after 240 day of incubation of (a) Rustenburg and (b) Loskop soil. -----	50

### LIST OF TABLES – CHAPTER 3

TABLES	PAGES
1. The effects of successive DMT-HFO-P extractions on the P contents of different P pools as influenced by different P application rates after 1 day of incubation for (a) Rustenburg and (b) Loskop soil. -----	75
2. The effects of successive DMT-HFO-P extractions on the P contents of different P pools as influenced by different P application rates after 120 days of incubation for (a) Rustenburg and (b) Loskop soil. -----	76
3. The effects of successive DMT-HFO-P extractions on the P content of different P pools as influenced by different P application rates after 120 days of incubation for (a) Rustenburg and (b) Loskop soil. -----	77
4. The effects of the added P on the changes and distribution of P into different P pools after 1 day of DMT-HFO extractions and 1 day of incubation for (a) Rustenburg and (b) Loskop soil. -----	91
5. The effects of the added P on the changes and distribution of P into different P pools after 7 days of DMT-HFO extractions and 1 day of incubation for (a) Rustenburg and (b) Loskop soil. -----	91



TABLES	PAGES
6. The effects of the added P on the changes and distribution of P into different P pools after 14 days of DMT-HFO extractions and 1 day of incubation for (a) Rustenburg and (b) Loskop soil. -----	91
7. The effects of the added P on the changes and distribution of P into different P pools after 28 days of DMT-HFO extractions and 1 day of incubation for (a) Rustenburg and (b) Loskop soil. -----	92
8. The effects of the added P on the changes and distribution of P into different P pools after 56 days of DMT-HFO extractions and 1 day of incubation for (a) Rustenburg and (b) Loskop soil. -----	92
9. The effects of the added P on the changes and distribution of P into different P pools after 1 day of DMT-HFO extractions and 120 days of incubation for (a) Rustenburg and (b) Loskop soil. -----	93
10. The effects of the added P on the changes and distribution of P into different P pools after 7 days of DMT-HFO extractions and 120 days of incubation for (a) Rustenburg and (b) Loskop soil. -----	93
11. The effects of the added P on the changes and distribution of P into different P pools after 14 days of DMT-HFO extractions and 120 days of incubation for (a) Rustenburg and (b) Loskop soil. -----	93
12. The effects of the added P on the changes and distribution of P into different P pools after 28 days of DMT-HFO extractions and 120 days of incubation for (a) Rustenburg and (b) Loskop soil. -----	94
13. The effects of the added P on the changes and distribution of P into different P pools after 56 days of DMT-HFO extractions and 120 days of incubation for (a) Rustenburg and (b) Loskop soil. -----	94
14. The effects of the added P on the changes and distribution of P into different P pools after 1 day of DMT-HFO extractions and 240 days of incubation for (a) Rustenburg and (b) Loskop soil. -----	95
15. The effects of the added P on the changes and distribution of P into different P pools after 7 days of DMT-HFO extractions and 240 days of incubation for (a) Rustenburg and (b) Loskop soil. -----	95

TABLES	PAGES
16. The effects of the added P on the changes and distribution of P into different P pools after 14 days of DMT-HFO extractions and 240 days of incubation for (a) Rustenburg and (b) Loskop soil. -----	95
17. The effects of the added P on the changes and distribution of P into different P pools after 28 days of DMT-HFO extractions and 240 days of incubation for (a) Rustenburg and (b) Loskop soil. -----	96
18. The effects of the added P on the changes and distribution of P into different P pools after 56 days of DMT-HFO extractions and 240 days of incubation for (a) Rustenburg and (b) Loskop soil. -----	96

### **LIST OF FIGURES – CHAPTER 2**

FIGURES	PAGES
1. Flow chart of the sequential P extractions -----	29
2. The effects of the added P and incubation time on the DMT-HFO extracted inorganic P from the (a) Rustenburg and (b) Loskop soil. -----	38
3. The effects of the added P and incubation time on the bicarbonate extracted inorganic P from the (a) Rustenburg and (b) Loskop soil. -----	42
4. The effects of the added P and incubation time on the bicarbonate extracted organic P from the (a) Rustenburg and (b) Loskop soil. -----	43
5. The effects of the added P and incubation time on the hydroxide extracted inorganic P from the (a) Rustenburg and (b) Loskop soil. -----	52
6. The effects of the added P and incubation time on the hydroxide extracted organic P from the (a) Rustenburg and (b) Loskop soil. -----	53

FIGURES	PAGES
7. The effects of the added P and incubation time on the dilute hydrochloric acid extracted inorganic P from the (a) Rustenburg and (b) Loskop soil. -----	56
8. The effects of the added P and incubation time on the concentrated hydrochloric acid extracted inorganic P from the (a) Rustenburg and (b) Loskop soil. -----	59
9. The effects of the added P and incubation time on the concentrated hydrochloric acid extracted organic P from the (a) Rustenburg and (b) Loskop soil. -----	60
10. The effects of the added P and incubation time on the concentrated sulphuric acid extracted residual P from the (a) Rustenburg and (b) Loskop soil. -----	64

### LIST OF FIGURES – CHAPTER 3

FIGURES	PAGES
1. The effects of the added P on cumulative DMT-HFO extractable $P_i$ after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	78
1.1. The effects of the added P on percentage P recovered with DMT-HFO-P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	79
1.2. The effects of the added P on DMT-HFO-P desorption rates ( $\text{mg kg}^{-1} \text{ day}^{-1}$ ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubations of Rustenburg soil. -----	80

FIGURES	PAGES
2. The effects of the added P on cumulative DMT-HFO extractable $P_i$ after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	84
2.1. The effects of the added P on percentage P recovered with DMT-HFO-P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	85
2.2. The effects of the added P on DMT-HFO-P desorption rates ( $\text{mg kg}^{-1} \text{ day}^{-1}$ ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	86
3. The effects of the added P and DMT-HFO extractions on the $\text{-HCO}_3\text{-extractable } P_i$ after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	97
3.1. The effects of the added P and DMT-HFO extractions on percentage $P_i$ recovered with $\text{-HCO}_3\text{-P}$ extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	98
3.2. The effects of the added P and DMT-HFO extractions on $\text{-HCO}_3\text{-}P_i$ desorption rates ( $\text{mg kg}^{-1} \text{ day}^{-1}$ ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	99
4. The effects of the added P and DMT-HFO extractions on the $\text{-HCO}_3\text{-extractable } P_o$ after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	101
4.1. The effects of the added P and DMT-HFO extractions on percentage $P_o$ recovered with $\text{-HCO}_3\text{-P}$ extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	102
4.2. The effects of the added P and DMT-HFO extractions on $\text{-HCO}_3\text{-}P_o$ desorption rates ( $\text{mg kg}^{-1} \text{ day}^{-1}$ ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	103

FIGURES	PAGES
5. The effects of the added P and DMT-HFO extractions on the -HCO <sub>3</sub> -extractable P <sub>i</sub> after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	105
5.1. The effects of the added P and DMT-HFO extractions on percentage P <sub>i</sub> recovered with -HCO <sub>3</sub> -P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	106
5.2. The effects of the added P and DMT-HFO extractions on -HCO <sub>3</sub> -P <sub>i</sub> desorption rates (mg kg <sup>-1</sup> day <sup>-1</sup> ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	107
6. The effects of the added P and DMT-HFO extractions on the -HCO <sub>3</sub> -extractable P <sub>o</sub> after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	110
6.1. The effects of the added P and DMT-HFO extractions on percentage P <sub>o</sub> recovered with -HCO <sub>3</sub> -P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	111
6.2. The effects of the added P and DMT-HFO extractions on -HCO <sub>3</sub> -P <sub>o</sub> desorption rates (mg kg <sup>-1</sup> day <sup>-1</sup> ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	112
7. The effects of the added P and DMT-HFO extractions on the -OH-extractable P <sub>i</sub> after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	115
7.1. The effects of the added P and DMT-HFO extractions on percentage P <sub>i</sub> recovered with -OH-P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	116

FIGURES	PAGES
7.2. The effects of the added P and DMT-HFO extractions on -OH-P <sub>i</sub> desorption rates (mg kg <sup>-1</sup> day <sup>-1</sup> ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubations of Rustenburg soil. -----	117
8. The effects of the added P and DMT-HFO extractions on the -OH-extractable P <sub>o</sub> after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	119
8.1. The effects of the added P and DMT-HFO extractions on percentage P <sub>o</sub> recovered with -OH-P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	120
8.2. The effects of the added P and DMT-HFO extractions on -OH-P <sub>o</sub> desorption rates (mg kg <sup>-1</sup> day <sup>-1</sup> ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	121
9. The effects of the added P and DMT-HFO extractions on the -OH-extractable P <sub>i</sub> after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	124
9.1. The effects of the added P and DMT-HFO extractions on percentage P <sub>i</sub> recovered with -OH-P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	125
9.2. The effects of the added P and DMT-HFO extractions on -OH-P <sub>i</sub> desorption rates (mg kg <sup>-1</sup> day <sup>-1</sup> ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	126
10. The effects of the added P and DMT-HFO extractions on the -OH-extractable P <sub>o</sub> after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	129
10.1. The effects of the added P and DMT-HFO extractions on percentage P <sub>o</sub> recovered with -OH-P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	130

FIGURES	PAGES
10.2. The effects of the added P and DMT-HFO extractions on -OH-P <sub>o</sub> desorption rates (mg kg <sup>-1</sup> day <sup>-1</sup> ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	131
11. The effects of the added P and DMT-HFO extractions on the D/HCl-extractable P <sub>i</sub> after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	133
11.1. The effects of the added P and DMT-HFO extractions on percentage P <sub>i</sub> recovered with D/HCl-P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	134
11.2. The effects of the added P and DMT-HFO extractions on D/HCl-P <sub>i</sub> desorption rates (mg kg <sup>-1</sup> day <sup>-1</sup> ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	135
12. The effects of the added P and DMT-HFO extractions on the D/HCl-extractable P <sub>i</sub> after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	137
12.1. The effects of the added P and DMT-HFO extractions on percentage P <sub>i</sub> recovered with D/HCl-P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	138
12.2. The effects of the added P and DMT-HFO extractions on D/HCl-P <sub>i</sub> desorption rates (mg kg <sup>-1</sup> day <sup>-1</sup> ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	139
13. The effects of the added P and DMT-HFO extractions on the C/HCl-extractable P <sub>i</sub> after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	142
13.1. The effects of the added P and DMT-HFO extractions on percentage P <sub>i</sub> recovered with C/HCl-P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	143

FIGURES	PAGES
13.2. The effects of the added P and DMT-HFO extractions on C/HCl-P <sub>i</sub> desorption rates (mg kg <sup>-1</sup> day <sup>-1</sup> ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	144
14. The effects of the added P and DMT-HFO extractions on the C/HCl-extractable P <sub>o</sub> after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	145
14.1. The effects of the added P and DMT-HFO extractions on percentage P <sub>o</sub> recovered with C/HCl-P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	146
14.2. The effects of the added P and DMT-HFO extractions on C/HCl-P <sub>o</sub> desorption rates (mg kg <sup>-1</sup> day <sup>-1</sup> ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	147
15. The effects of the added P and DMT-HFO extractions on the C/HCl-extractable P <sub>i</sub> after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	149
15.1. The effects of the added P and DMT-HFO extractions on percentage P <sub>i</sub> recovered with C/HCl-P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	150
15.2. The effects of the added P and DMT-HFO extractions on C/HCl-P <sub>i</sub> desorption rates (mg kg <sup>-1</sup> day <sup>-1</sup> ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	151
16. The effects of the added P and DMT-HFO extractions on the C/HCl-extractable P <sub>o</sub> after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	154
16.1. The effects of the added P and DMT-HFO extractions on percentage P <sub>o</sub> recovered with C/HCl-P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	155



FIGURES	PAGES
16.2. The effects of the added P and DMT-HFO extractions on C/HCl-P <sub>o</sub> desorption rates (mg kg <sup>-1</sup> day <sup>-1</sup> ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	156
17. The effects of the added P and DMT-HFO extractions on the H <sub>2</sub> SO <sub>4</sub> -extractable P <sub>i</sub> after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	158
17.1. The effects of the added P and DMT-HFO extractions on percentage P <sub>i</sub> recovered with H <sub>2</sub> SO <sub>4</sub> -P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	159
17.2. The effects of the added P and DMT-HFO extractions on H <sub>2</sub> SO <sub>4</sub> -P <sub>i</sub> desorption rates (mg kg <sup>-1</sup> day <sup>-1</sup> ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Rustenburg soil. -----	160
18. The effects of the added P and DMT-HFO extractions on the H <sub>2</sub> SO <sub>4</sub> -extractable P <sub>i</sub> after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	162
18.1. The effects of the added P and DMT-HFO extractions on percentage P <sub>i</sub> recovered with H <sub>2</sub> SO <sub>4</sub> -P extractions after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	163
18.2. The effects of the added P and DMT-HFO extractions on H <sub>2</sub> SO <sub>4</sub> -P <sub>i</sub> desorption rates (mg kg <sup>-1</sup> day <sup>-1</sup> ) after (a) 1 day, (b) 120 days, and (c) 240 days of incubation of Loskop soil. -----	164

## 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<sup>-1</sup>), 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<sub>3</sub>, 0.1M NaOH-P, 1.0M HCl, concentrated HCl, and concentrated H<sub>2</sub>SO<sub>4</sub> + H<sub>2</sub>O<sub>2</sub>.

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<sub>i</sub> 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<sup>-1</sup>) 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 envisaged 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<sup>-1</sup>) is toegedien en vir verskillende tye geïnkubeer (1, 60, 120, 180, en 240 dae). Opeenvolgende fraksionering is gedoen om die P-inhoud van verskillende P-poele te bepaal om aan te dui waarheen die toegediende-P omgeskakel is. Die opeenvolgende fraksionering het bestaan uit ekstraksies met ferrihidreerde ysteroksied in dialisemembraanbuise (DMT-HFO), 0.5 M NaHCO<sub>3</sub>, 0.1 M NaOH, 1.0 M HCl, gekonsentreerde HCl en gekonsentreerde H<sub>2</sub>SO<sub>4</sub> + H<sub>2</sub>O<sub>2</sub> – 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 desorpsie tempo van toegediende P is nadat transformasie plaasgevind het. Dit is opgevolg deur opeenvolgende ekstraksies om te bepaal uit watter P poele die P geëkstraheer is. Die twee grondtipes van Rustenburg en Loskop is behandel met verskillende P-toedienings (0, 25, 50, 10, en 200 mg P kg<sup>-1</sup>) en inkubasie-tye (1, 120 en 240 dae).

Die kumulatiewe ekstraksies met DMT-HFO vir 56 dae het aangetoon dat desorpsie 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-adsorpsie 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.