UNIVERSITI PUTRA MALAYSIA

# DYNAMICS OF CURRENT AND RESIDUAL PHOSPHORUS IN TROPICAL ACID SOIL

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# DYNAMICS OF CURRENT AND RESIDUAL PHOSPHORUS IN TROPICAL ACID SOIL

By

ESTHER WAKIURU GIKONYO

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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## DEDICATION

**This work is dedicated to my lovely husband:**

**JOHN GIKONYO**

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

**DYNAMICS OF CURRENT AND RESIDUAL PHOSPHORUS IN TROPICAL ACID SOIL**

By

**ESTHER WAKIURU GIKONYO**

**January 2006**

**Chairperson: Professor Zaharah Abdul Rahman, DSc**

**Faculty: Agriculture**

The use of phosphate rocks (PRs) has been proposed as an agro-economically sound alternative to the more expensive superphoshates particularly, for P 'recapitalization' based on their purportedly high residual effects in acid tropical soils. To understand the current and residual dynamics of P from different P sources, one laboratory incubation trial and two field experiments were conducted. Experimental treatments comprised factorial combinations (3x4x2) of three P sources [Triple superphosphate (TSP), Gafsa PR (GPR) and Christmas Island PR (CIPR)] at four P rates with and without manure in three replications. Setaria grass (***Setaria Anceps Stapf*. Cv. Kazungula**) was used as the test crop and was sequentially harvested bimonthly for 14 months in the field. Results indicated that the amounts of P extracted from treated soils using three soil tests: Mehlich-3 (M3P), Bray-1 (B1P) and Pi-strip (Pi-P) were in the order: M3P>B1P (85% M3P) >Pi-P (53% M3P) and were significantly related ($R^2$=0.42 to 0.83, n=294). Phosphorus extracted from the different P sources was in the order: TSP>GPR>CIPR and increased with increasing P rates. When P rates were raised from 0 to 300 kg

decreased substantially at the highest P rate. The degree of phosphorus saturation (DPS) (defined as a ratio of P already adsorbed to P adsorption capacity of a soil) also varied with P sources (5.1 to 15.8%) and extractants (2.1 to 44%) following a similar order to extractable P. The variously estimated DPS values were all significantly correlated (r =0.91 to 0.98) and therefore were equally suitable in estimating DPS. Sequential strip P indicated that P released was described by power ($R^2$=0.79 to 0.95) (TSP) and exponential (PR) functions ($R^2$=0.77 to 0.99), while from the field trial, a power function described RV of P in both PRs and TSP ($R^2$=0.64 to 0.96). Total extracted Pi-P was related to $NaHCO_3$-inorganic and organic P (Bic-Pi and Po), and HCl-P. However, though the Pi-strip could estimate P release, it could not estimate residual value (RV). Residual value is the ratio of amount of freshly applied TSP required to produce yield X to the amount of previously applied fertilizer required to produce the same yield X. The dry matter yield (DMY) exhibited a quadratic relationship with P rates. The maximum DMY (6-11 t $ha^{-1}$) was attained at 150-200 kg P $ha^{-1}$ and over time, DMY increased to a maximum(11 t $ha^{-1}$) and then declined to a constant yield (2-4 t $ha^{-1}$) after one year. Manure-CIPR integration increased DMY while, manure-GPR and manure-TSP integration depressed yields except in the initial harvest. Setaria DMY was found to be related to NaOH-organic and -inorganic P (Hyd-Po and Hyd-Pi, respectively), and Bic-Po fractions, which are not accounted for in M3P or B1P thus explaining the low $R^2$ between DMY and M3P ($R^2$=0.08) or B1P ($R^2$=0.10). The current RVs of the three fertilizers determined in the field were 100, 100 and 140% for CIPR, GPR and TSP, respectively at 100 kg P $ha^{-1}$. At the same rate, fertilizer-manure integration increased initial RV to 180, 160 and 110% in TSP, CIPR and GPR treatments. With an exception of CIPR-manure, RV was depressed by manure in the other fertilizers in subsequent harvests after the initial one. The RV also declined with increasing P rates as evidenced by current RV decline to 20, 60 and 50% in CIPR, GPR and TSP, respectively when P rate was raised from 100 to 300 kg P $ha^{-1}$. The RV declined to 30-40% for the first six months and then gradually to 10 – 20% after one year (power function). These results indicated that GPR and CIPR-manure combination were as good as TSP and the optimal P rate was 100 - 150 kg P $ha^{-1}$. The results did not support P 'recapitalization' in this soil but annual applications. The RV could be estimated from the P fractions: Bic-Po, Hyd-Pi and Hyd-Po, and DPS computed from Mehlich extracted Al, Fe and P. The RV had no relationship with M3P or B1P.

**Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah**

**DINAMIK FOSFORUS SEMASA DAN RESIDU DALAM TANAH ASID TROPIKA**

Oleh

**ESTHER WAKIURU GIKONYO**

**Januari, 2006**

**Pengurusi: Profesor Zaharah Abdul Rahman, DSc**

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Batuan fosfat (PRs) telah dicadangkan sebagai satu alternatif baja P yang agronomik dan ekonomik berbanding baja superfosfat (kebiasaannya TSP), terutama sekali sebagai sumber untuk membekal unsur P dalam jangkamasa panjang. Ini berdasarkan kemampuan batuan fosfat meninggalkan kesan residunya yang lama dalam tanah-tanah asid tropika. Untuk memahami dinamik semasa dan residu unsur P dari berbagai sumber baja P, satu kajian pemeraman di makmal dan dua kajian ladang telah dijalankan. Kajian dijalankan dengan menggunankan rawatan kombinasi faktorial (3x4x2) yang terdiri dari tiga sumber baja P: Triple superphosfat (TSP), batuan fosfat Gafsa (GPR) dan batuan fosfat Pulau Christmas (CIPR) pada empat kadar dengan/tanpa baja kandang dalam tiga replikasi. Rumput Setaria (*Setaria anceps* Staff.Cv. Kazungula) digunakan sebagai tamanan ujian yang dituai setiap dua bulan selama 14 bulan di ladang. Keputusan menunjukkan jumlah P diekstrak dari tanah yang dirawat menggunakan tiga kaedah pengekstrak: Mehlich-3 (M3P), Bray-1 (BIP) dan Pi-strip (Pi-P) mengikut turutan M3P>B1P (85% M3P) >PiP (53% M3P) dan mengpunyai kaitan yang bererti ($R^2$=0.42 hingga 0.83, n=294). Fosforus terekstrak dari

sumber-sumber baja yang digunakan mengikut turutan TSP>GPR>CIPR dan meningkat dengan bertambahnya kadar baja yang diberi. Apabila kadar P ditingkatkan dari 0 hingga 300 kg P $ha^{-1}$, BIP meningkat sebanyak 470% (TSP) dan 160% (PRs). Kelarutan PR sangat menurun pada kadar P tertinggi. Kadar ketepuan P (DPS) (didefinasikan sebagai nisbah P terjerap kepada keupayaan penjerapan P oleh tanah) juga berbeza mengikut sumber P (5.1 hingga 15.8%) dan larutan pengekstrak yang digunakan (2.1 hingga 44%) mengikut turutan yang sama dengan P yang terekstrak. Nilai anggaran DPS yang dilakukan semuanya menunjukkan kaitan yang bererti (r=0.91 hingga 0.98) dan dengan itu semuanya sesuai untuk digunakan untuk menanggar nilai DPS. Pengekstraktan berulangan menggunakan kertas disaluti ferum oksida (Pi-strip) menunjukkan P yang dilepaskan boleh di terangkan dengan fungsi kuasa ($R^2$=0.79 hingga 0.95) (TSP) dan eksponen ($R^2$=0.79 hingga 0.95) (PR), manakala daripada kajian ladang, fungsi kuasa menerangkan RV baja P untuk kedua-dua PR dan TSP ($R^2$=0.64 hingga 0.96). Jumlah Pi-P didapati berkaitan dengan bikarbonat tak organik dan P organik, dan HCl-P. Tetapi, sungguhpun Pi-P mampu menganggar perlepasan P, ianya tidak dapat diguna untuk menganggar keberkesanan relatif nilai residu (RV). Nilai residu ialah nisbah jumlah TSP segar diberi diperlukan untuk menghasilkan hasil X kepada jumlah baja yang diberi terdahulu untuk menghasilkan hasil X yang sama. Hasil berat kering (DMY) menunjukkan kaitan kuadratik dengan kadar P digunakan. DMY.maksimum (6-11 t $ha^{-1}$) diperolehi apabila 150-200 kg P $ha^{-1}$ digunakan. Dengan meningkatnya masa, DMY meningkat ke maksimum (11 t $ha^{-1}$) dan menurun sehingga ke tahap stabil (2-4 t $ha^{-1}$) selepas setahun.

Campuran baja kandang dan CIPR tingkatkan DMY, manakala campuran dengan GPR dan TSP turunkan hasil, kecuali pada hasil pertama. Hasil rumput setaraia didapati ada kaitan dengan Hyd-Po dan Hyd-Pi, dan pecahan Bic-Po yang tidak diekstrak oleh Mechlich-3 dan Bray-1. Keberkesanan relatif nilai residu (RV) semasa ketiga-tiga sumber baja yang ditentukan di ladang menunjukkan 100, 100 dan 140% untuk CIPR, GPR dan TSP pada kadar 100 kg P $ha^{-1}$. Pada kadar yang sama, campuran dengan baja kandang tingkatkan RV diperingkat awal ke 180, 160 dan 110% untuk rawatan TSP, CIPR dan GPR. Hasil seterusnya menunjukan penurunan RV dengan campuran baja kandang, kecuali CIPR. RV juga didapati menurun dengan meningkatnya kadar baja P, dimana didapati RV menurun ke 20, 60 dan 50% bagi CIPR, GPR dan TSP apabila kadar P ditingkatkan dari 100 ke 300 kg P $ha^{-1}$. Dalam masa 6 bulan pertama, RV menurun ke 30-40% dan seterusnya ke 10-20% selepas satu tahun (fungsi "power"). Keputusan kajian menunjukkan bahawe campuran GPR dan CIPR dengan baja kandang adalah sama baik dengan TSP. Kadar yang optimum ialah 100-150 kg P $ha^{-1}$. Keputusan yang didapati dari kajian ini tidak menyokong konsep "P recapitalization" dalam tanah, malah disyorkan agar P diaplikasikan setiap tahun. Keberkesanan relatif nilai residu (RV) boleh dianggar daripada pecahan-pecahan P: Bic-Po, Hyd-Pi, dan Hyd-Po, dan DPS-M3P, tetapi tiada kaitan dengan M3P atau B1P.

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## TABLE OF CONTENTS


| | | Page |
|---|---|---|
| DEDICATION | | 2 |
| ABSTRACT | | 3 |
| ABSTRAK | | 6 |
| ACKNOWLEDGEMENTS | | 9 |
| APPROVAL | | 11 |
| DECLARATION | | 13 |
| LIST OF TABLES | | 19 |
| LIST OF FIGURES | | 21 |
| LIST OF ABBREVIATIONS/NOTATION/GLOSSARY OF TERMS | | 26 |
| CHAPTER | | |
| I | INTRODUCTION | 30 |
| II | LITERATURE REVIEW | 38 |
| | Importance of Phosphorus | 38 |
| | Phosphorus Fertilizer Inputs | 39 |
| | Direct Application of PRs | 40 |
| | Dissolution of PR | 41 |
| | Phosphate Rock Physical Factor | 42 |
| | Phosphate Rock Chemical Factors | 42 |
| | Soil Chemical Parameters | 43 |
| | Plant Factors | 44 |
| | Effect of Organic Manures on PR Dissolution | 44 |
| | Fate of Fertilizer Phosphorus in the Soil | 45 |
| | Effects of Organic Matter on P Sorption | 47 |
| | Soil Testing Methods | 48 |
| | Degree of Phosphorus Saturation | 50 |
| | Phosphorus Release Kinetics | 54 |
| | Soil Phosphorus Pools/Fractions and Transformations | 55 |
| | Residual P | 57 |
| | Justification of the Study | 60 |
| III | GENERAL METHODOLOGY | 62 |
| | Materials | 62 |
| | Characterization of Experimental Materials | 63 |
| | Other Methods Used in the Study | 70 |
| | Phosphorus Fractionation and Analysis | 70 |
| | Extractable Aluminium and Iron Oxides | 72 |
| | Dithionite-Citrate Extractable Al and Fe Acid Oxalate | 72 |

| | | |
|---|---|---|
| | Extractable Al and Fe | 73 |
| | Mehlich-3 Extractable Al and Fe | 73 |
| | Phosphate Sorption Index | 73 |
| | Calculation of the Degree of Phosphorus Saturation | 74 |
| | Statistical Analysis | 75 |
| IV | **PHOSPHATE DESORPTION BY SUCCESSIVE EXTRACTIONS WITH IRON OXIDE IMPREGNATED PAPER STRIP FROM SOILS TREATED WITH DIFFERENT P FERTILIZERS** | 76 |
| | Introduction | 76 |
| | Materials and Methods | 78 |
| | Soil Sampling and Preparation | 78 |
| | Soil Treatment and Equilibration Procedure | 78 |
| | Sequential Extraction of P with Pi-Strip Procedure | 79 |
| | Analysis of Other Soil Parameters | 79 |
| | Results | 80 |
| | Effect of Treatments on Extractable Mehlich-3 and Bray-1 P | 80 |
| | Effect of Treatments on Phosphate Sorption Index | 83 |
| | The DPS Computed From Available P and PSI | 83 |
| | Effect of Treatments on Al, Fe, P and DPS Extracted by Different Reagents | 86 |
| | Ammonium Oxalate Extractable Al, Fe, P and DPS | 86 |
| | Mehlich-3 Extractable Al, Fe, P and DPS | 88 |
| | Citrate Dithionite Extractable Al, Fe, P and DPS | 91 |
| | Correlation between PSI, Al, Fe, and Al + Fe Extracted by Different Reagents | 92 |
| | Correlation between DPS and PSI | 94 |
| | Sequentially Extracted P Using Pi-strip | 95 |
| | Phosphorus Fractions | 103 |
| | Bicarbonate Inorganic Fraction | 103 |
| | Bicarbonate Organic P Fraction | 105 |
| | Hydroxide Inorganic P Fraction | 107 |
| | Hydroxide Organic P Fraction | 109 |
| | HCl-P Fraction | 111 |
| | Discussion | 113 |
| | Extractable P | 113 |
| | Phosphate Sorption Index | 114 |
| | Extractable Fe, Al, P and Resulting DPS for Various Reagents | 115 |
| | Oxalate Extractable Fe, Al, P and DPS | 115 |
| | Mehlich 3 Extractable Al, Fe, P and DPS | 117 |
| | Citrate Dithionite Extractable Al, Fe, P and DPS | 117 |
| | Correlation between PSI and Fe, Al and Fe + Al Extracted by Different Reagents | 118 |
| | Correlation between DPS and PSI | 119 |
| | Phosphorus Sequentially Extracted Pi-strip | 119 |

Phosphorus Fractions 121
Conclusions 122

V CURRENT AND RESIDUAL P AVAILABILITY IN AN ACID SOIL FERTILIZED WITH DIFFERENT P INPUTS 125
Introduction 125
Materials and methods 129
Experimental Treatments 129
Experimental Layout and Experimental Design 130
Rainfall Pattern 132
Soil Sampling 133
Soil Preparation 133
Setaria Grass Establishment 133
Plant Harvesting and Sampling 134
Plant Material Preparation 134
Plant Tissue Analysis for Nutrients Content 135
Soil Analysis 135
Calculations 136
Residual Effectiveness of Fertilizers 136
Degree of Phosphorus Saturation 137
Statistical Analysis 137
Results 137
Available Soil P 137
Mehlich-3 Extractable P 137
Bray 1 Extractable P 138
Pi-Strip P 141
Sesquioxides 146
Mehlich-3 Extractable Sesquioxides 146
Oxalate Extractable Al, Fe and P 150
Citrate Dithionite Extractable Al, Fe and P 156
Comparison of Al, Fe and P Extracted by Mehlich 3, Citrate Dithionite and Ammonium Oxalate Methods 162
Degree of Phosphorus Saturation 164
Sequential P fractions 169
Total Bicarbonate P 169
Bicarbonate Inorganic Fraction 170
Bicarbonate Organic P Fraction 170
Hydroxide Total P 174
Hydroxide Inorganic Fraction 174
Hydroxide Organic P 177
HCl- P Fraction 177
Residue P Fraction 180
Total P 180
Comparison of All the P Fractions 181
Plant Parameters 185
Dry Matter Yield 185

Phosphorus Content in Plant Tissue 189
Phosphorus Uptake 194
Zinc content and uptake 195
Potassium and Magnesium Contents 198
Residual Effectiveness of the Different Fertilizers 199
Residual Effectiveness of the Different Fertilizers Computed from the Slopes of Response Curves 199
Residual Effectiveness of the Different Fertilizers at Different Rates of Application 203
Relationship between Yield Parameters and the Various Soil Parameters 209
Relationship between Yield Parameters and Available P 209
Relationship between Yield Parameters and Degree of Phosphorus Saturation 214
Relationship between Yield Parameters and Different P Fractions 216
Relationship between Residual Value and the Different P Fractions 221
Relationship between Residual Value and Available P by the different Methods 223
Discussion 223
Sesquioxides 223
Degree of Phosphorus Saturation 225
Sequential Phosphorus Fractions 225
Relationship between P Fractions and Sesquioxides 228
Available P 232
Setaria Dry Matter Yields 234
Residual Value 237
Conclusions 239

VI **ASSESSMENT OF PHOSPHORUS LEACHING IN 'P RECAPITALIZED SOILS USING DIFFERENT P SOURCES IN THE FIELD** 242
Introduction 242
Materials and Methods 243
Experimental Site 243
Experimental Treatments and Design 245
Preparation of Resin Bags 245
Installation of Intact Leaching Columns and Resin Bags in the Field 246
Resin Sampling 248
Elution of P and Analysis 249
Calculation of P leached. 249
Statistical Analysis 249
Results 250

Effects of Different Treatments on P Leached from the Leaching Columns 250
Mehlich-3 Extractable P and Ca from the Top Soil Samples at the End of Experiment 251
Mehlich 3 Extractable P and Ca from the Sub Soil Samples at the End of the Experiment 255
Discussion 257
Phosphorus Leached in Relation to P Sources, P Rates and Manure from the Leaching Columns 257
Phosphorus Leached Based on Extractable Mehlich-3 P in the Top and Sub-Soil Samples. 259
Conclusions 260

VII **SUMMARY AND CONCLUSIONS** 262

**REFERENCES** 272

**BIODATA OF THE AUTHOR** 289

## LIST OF TABLES


| Table | | Page |
|---|---|---|
| 3.1 | Chemical characteristics of the soil used | 67 |
| 3.2a | Characteristics of fertilizers and manure used | 68 |
| 3.2b | Additional characterization of the dry cattle manure | 69 |
| 4.1 | Pearson correlation coefficients / probabilities between Al, Fe, Al+Fe extracted by different reagents and PSI | 92 |
| 4.2 | Simple Statistics for DPS and PSI | 95 |
| 4.3 | Pearson correlation coefficients between the different DPS and PSI | 96 |
| 4.4 | Summary of the statistical analysis of the individual Pi-strip P extractions | 98 |
| 4.5 | Equation and regression coefficients of the P desorption of the various P sources with and without manure at different P application rates | 100 |
| 5.1 | Effect of different factors on Mehlich-3 extractable Fe and Al | 147 |
| 5.2 | Effect of various factors on oxalate extractable Al, Fe, and P | 151 |
| 5.3 | Effect of various factors on citrate dithionite extractable Fe, Al and P | 157 |
| 5.4 | Simple statistics for Fe, Al and P extracted by Mehlich-3, citrate dithionite and ammonium oxalate | 163 |
| 5.5 | Pearson correlation coefficients /probability for the Fe, Al and P extracted by citrate dithionite, ammonium oxalate and Mehlich-3 ) reagents | 164 |
| 5.6 | Simple statistics of the nine P fractions and total P | 184 |
| 5.7 | Pearson correlation coefficients/probability of all the fractions and total P | 185 |
| 5.8 | Slopes of the three point linear response functions for fresh TSP and the other fertilizers with and without manure for yields at 2 to 14 months (excluding yield at 4 months) | 201 |
| 5.9 | Regression parameters for Bray-1, M3P and Pi-Strip P on P uptake and on yield | 211 |

5.10 Stepwise multiple regression summary for P fractions vs. B1P, M3P, P content and DMY for; (a) All data minus control (b) Control 217

5.11 Multiple regression summaries of data partitioned into TSP and PRs 219

5.12 Multiple regression summaries of the data partitioned by P rates at 100 and 300 kg P $ha^{-1}$ 220

5.13 Multiple regression summaries of the various P fractions on residual value for: all data, partitioned into 100 and 300 kg P $ha^{-1}$ and partitioned into PRs and TSP 222

5.14 Pearson correlation coefficients of different P fractions and extractable sesquioxides by different reagents 230

## LIST OF FIGURES


| Figure | | Page |
|---|---|---|
| 3.1 | X-ray diffractograms of GPR and CIPR. | 66 |
| 3.2 | Flow chart of the sequential P fractionation procedure in soil modified from Hedley et al. (1982). The Pi, Pt and Po, represent inorganic, total and organic phosphorus | 71 |
| 4.1 | Effects of P source x P rate x manure on extractable P by (a) Bray-1, and (b) Mehlich-3 | 81 |
| 4.2 | Relationship between Bray-1 and Mehlich-3 extractable P from soil treated with different P sources | 82 |
| 4.3 | Effects of P source x P rate x manure on PSI | 84 |
| 4.4 | Effects of P source x P rate x manure on (a) DPS-BrayPSI and (b) DPS-MehPSI | 85 |
| 4.5 | Effect of P sources x P rate x manure on (a) Ox-Al, (b) Ox-Fe, (c) Ox-P, and (d) DPS-Ox | 88 |
| 4.6 | Effects of P source x P rate x manure on Mehlich-3 extractable (a) Meh-Al, (b) Meh-Fe, (c) Meh-P, and (d) DPS-MehPSI | 90 |
| 4.7 | Effects of P source x P rate x manure on (a) CD-Al, (b) CD-Fe, (c) CD-P, and (d) DPS-CD | 93 |
| 4.8 | Relationships between the different DPS (a) DPS-MehPSI vs. DPS-MehAF, (b) DPS-BrayPSI vs. DPS-MehAF, (c) DPS-CD vs. DPS-MehAF, (d) DPS-CD vs. DPS-Ox, (e) DPS-MehPSI vs. DPS-CD, (f) DPS-BrayPSI vs. DPS-CD, (g) DPS-BrayPSI vs. DPS-Ox, (h) DPS-MehPSI vs. DPS-Ox, and (i) DPS-MehPSI vs. DPS-BrayPSI | 97 |
| 4.9 | Effect of different P sources with and without manure on Pi-strip P at P rates (a) 0 (control), (b) 100, (c) 200, and (d) 400 mg P $kg^{-1}$ | 99 |
| 4.10 | Relationship between (a) Constant 'a' vs. initial Pi-strip P and (b) Total P vs. initial Pi-strip P | 102 |
| 4.11 | Constant b vs. (a) DPS-CD, (b) DPS-MehAF, (c) DPS-Ox, and x-exponent vs. (d) DPS-CD, (e) DPS-MehPSI, and (f) DPS-Ox | 102 |

4.12 Relationship between total P and (a) DPS-CD, (b) DPS-Ox, (c) DPS-MehPSI, and (d) DPS-BrayPSI 103

4.13 Effects of P source x P rate x manure on Bic-Pi (a) Prior and (b) After the Pi-strip P extraction 106

4.14 Effects of P source x P rate x manure on Bic-Po (a) Prior and (b) After the Pi-strip P extraction 106

4.15 Effects of P source x P rate x manure on Hyd-Pi (a) Prior and (b) After the Pi-strip P extraction 110

4.16 Effects of P source x P rate x manure on Hyd-Po (a) Prior and (b) After the Pi-strip extraction 111

4.17 Effects of P source x P rate x manure on HCl-P (a) Prior and (b) After the Pi-strip P extraction 112

5.1 Experimental site location showing residual (left) and fresh TSP (right) plots location before planting 131

5.2 Bimonthly total rainfall for the experimental period between June 2003 and July 2004 132

5.3 Effects of different P sources with and without manure at rates (a) 0 (b) 100, and (c) 300 kg P $ha^{-1}$ on extractable M3P over time 140

5.4 Effects of different P sources with and without manure at rates (a) 0, (b) 100, and 300 kg P $ha^{-1}$ on extractable Bray 1 P over time 142

5.5 Effects of the different P sources with and without manure at rates (a) 0, (b) 100, and (c) 300 kg P $ha^{-1}$ P on Pi-strip P. 143

5.6 Relationship between the three soil tests (a) M3P vs. B1P, (b) B1P vs.Pi-Strip P and (c) M3P vs. Pi-Strip P 145

5.7 Effect of different P sources with and without manure at rates (a) 0, (b) 100 and 300 kg P $ha^{-1}$ on Mehlich 3 extractable Al over time 148

5.8 Effect of different P sources with and without manure at rates (a) 0, (b) 100 and 300 kg P $ha^{-1}$ on Mehlich 3 extractable Fe over time 149

5.9 Effect of different P sources with and without manure at rates (a) 0, (b) 100, and (c) 300 kg P $ha^{-1}$ on oxalate extractable Fe over time 152

5.10 Effect of different P sources with and without manure at rates (a) 0, (b) 100 and 300 kg P $ha^{-1}$ on oxalate extractable Al over time 153

5.11 Effect of different P sources with and without manure at rates (a) 0, (b) 100, and (c) 300 kg P $ha^{-1}$ on oxalate extractable P over time 155

5.12 Effect of different P sources with and without manure at rates (a) 0, (b) 100 and 300 kg P $ha^{-1}$ on citrate dithionite extractable Al over time 158

5.13 Effect of different P sources with and without manure at rates (a) 0, (b) 100, and (c)300 kg P $ha^{-1}$ on citrate dithionite extractable Fe over time 159

5.14 Effect of different P sources with and without manure at different rates (a) 0, (b) 100, and (c) 300 kg P $ha^{-1}$ on citrate dithionite extractable Fe over time 161

5.15 Effect of different P sources with and without manure at rates (a) 0, (b) 100, and (c) 300 kg P $ha^{-1}$ on citrate dithionite DPS over time 166

5.16 Effect of different P sources with and without manure at rates (a) 0, (b) 100 and 300 kg P $ha^{-1}$ on oxalate DPS over time 167

5.17 Figure 5.17: Effect of different P sources with and without manure at rates (a) 0, (b) 100, and (c) 300 kg P $ha^{-1}$ on Mehlich DPS over time 168

5.18 Effects of different P sources with and without manure at the rates (a) 0 (control), (b) 100, and (c) 300 kg P $ha^{-1}$ on total inorganic bicarbonate fraction 171

5.19 Effects of different P sources with and without manure at rates (a) 0, (b) 100, and (c) 300 kg P $ha^{-1}$ on inorganic bicarbonate P fraction 172

5.20 Effect of P Sources with and without manure at P rates (a) 0, (b) 100, and (c) 300 kg P $ha^{-1}$ on organic bicarbonate fraction 173

5.21 Effect of P sources with and without manure at rates (a) 0, (b) 100, and (c) 300 kg P $ha^{-1}$ on total hydroxide P fraction. 175

5.22 Effect of P sources with and without manure at P rates (a) 0, (b) 100, and (c) 300 kg P $ha^{-1}$ on inorganic hydroxide P fraction 176

| | | |
|---|---|---|
| 5.23 | Effect of P sources with and without manure at rates (a) 0, (b) 100, and (c) 300 kg P $ha^{-1}$ on organic hydroxide P fraction over time | 178 |
| 5.24 | Effect of P sources with and without manure at rates (a) 0, (b) 100, and (c) 300 kg P $ha^{-1}$ on hydrochloric acid P fraction | 179 |
| 5.25 | Effect of P sources with and without manure at rates (a) 0, (b) 100, and (c) 300 kg P $ha^{-1}$ on residue-P fraction | 182 |
| 5.26 | Effects of different P sources with and without manure at rates (a) 0, (b) 100 and (c) 300 kg P $ha^{-1}$ on total P | 183 |
| 5.27 | Yield response curves for the different P sources with and without manure for harvests one to seven excluding harvest six, (since it was similar to harvest seven) | 187 |
| 5.28 | Photograph of a general view of the crop at different harvests | 188 |
| 5.29 | Changes of cumulative setaria dry matter yields as influenced by different P sources with and without manure | 190 |
| 5.30 | Setaria DMY changes of all the harvests as influenced by different P sources with and without manure at rates (a) 0 (control) & 100 (b) 200, and (c) 300 kg P/ha | 191 |
| 5.31 | Effect of P rates on average P content in plant tissue for the different P sources with and without manure | 192 |
| 5.32 | Setaria P content in plant tissue over time as influenced by different P sources with and without manure at rates (a) 0 (control) &100 (b) 200 and (c) 300 kg P $ha^{-1}$ | 193 |
| 5.33 | Setaria P uptake changes over time as influenced by different P sources with and without manure at rates (a) 0 (control) & 100 (b) 200 and (c) 300 kg P $ha^{-1}$ | 196 |
| 5.34 | Effects of P fertilizer rate on cumulative P uptake for all the fertilizers with and without manure | 197 |
| 5.35 | Effect of manure addition on Zn uptake by setaria grass | 197 |
| 5.36 | Zinc uptake changes over time for the different fertilizer rates | 198 |
| 5.37 | Three point linear response functions for all fertilizer treatments and fresh TSP response for harvests one to seven excluding harvest two which showed no response to any P source | 200 |