



UNIVERSITI PUTRA MALAYSIA

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

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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**

January 2006



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

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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 superphosphates 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 ($6\text{--}11 \text{ t ha}^{-1}$) was attained at $150\text{--}200 \text{ kg P ha}^{-1}$ and over time, DMY increased to a maximum (11 t ha^{-1}) and then declined to a constant yield ($2\text{--}4 \text{ t ha}^{-1}$) 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
TROIKA**

Oleh

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Januari, 2006

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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 menggunakan 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 tanaman ujian yang dituai setiap dua bulan selama 14 bulan di ladang. Keputusan menunjukkan jumlah P diekstrak dari tanah yang dirawat menggunakan tiga kaedah pengestrak: Mehlich-3 (M3P), Bray-1 (B1P) dan Pi-strip (Pi-P) mengikut turutan M3P>B1P (85% M3P) >PiP (53% M3P) dan mempunyai 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) (didefinisikan sebagai nisbah P terjerap kepada keupayaan penyerapan P oleh tanah) juga berbeza mengikut sumber P (5.1 hingga 15.8%) dan larutan pengestrak 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 berulang 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 tingkatan 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 tingkatan RV diperingkat awal ke 180, 160 dan 110% untuk rawatan TSP, CIPR dan GPR. Hasil seterusnya menunjukkan 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 bahawa 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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I certify that an Examination Committee met on 13th December 2005 to conduct the final examination of Esther Wakiuru Gikonyo on her Doctor of Philosophy thesis entitled "Dynamics of Current and Residual Phosphorus in Tropical Acid Soil" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the degree of Doctor of Philosophy. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



ESTHER WAKIURU GIKONYO

Date: 13th January 2006

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