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Characterizing phosphate desorption kinetics from soil: An approach to predicting plant available phosphorus

by

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Declaration

I, Abi Taddesse Mengesha, hereby declare that this dissertation for a PhD degree at the University of Pretoria is my own work and has never been previously submitted by myself at any other university

Abi Taddesse Mengesha

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DEDICATION

To my wife, Rahel, with much love, admiration and appreciation.

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Characterizing phosphate desorption kinetics from soil: An approach to predicting plant available phosphorus

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Degree: Ph D (Soil Science)

ABSTRACT

Many agricultural fields that have received long-term applications of P often contain levels of P exceeding those required for optimal crop production. Knowledge of the effect of the P remaining in the soil (residual effect) is of great importance for fertilization management. In order to characterize P forms in soils, a wide variety of methods have been proposed. The use of dialysis membrane tubes filled with hydrous ferric oxide (DMT-HFO) has recently been reported as an effective way to characterize P desorption over a long-term in laboratoty studies. However, there is little information on the relationship between kinetics of P release using this new method and plant P uptake. This method consist of a procedure of shaking a sample for a long period of time there by exploiting the whole volume of the soil which is in contrast to the actual plant mode of uptake. This method has also practical limitations in employing it for a routine soil analysis, as it is very expensive and time consuming. The objectives of this study were (i) to study the changes in labile, non-labile and residual P using successive P desorption by DMT-HFO followed by a subsequent fractionation method (combined method) (ii) to assess how the information gained from P desorption kinetic data relates to plant growth at green house and field trials

(iii) to investigate the effect of varying shaking time on DMT-HFO extractable P and (iv) to propose a short cut approach to the combined method.

The release kinetics of the plots from long term fertilizer trials at the University of Pretoria and Ermelo were studied. P desorption kinetics were described relatively well by a two-component first-order model ($R^2 = 0.947$, 0.918, & 0.993 for NPK, MNK, & MNPK treatments respectively). The relative contributions of both the labile pool (SP_A) and the less labile pool (SP_B) to the total P extracted increased with increased P supply levels. Significant correlations were observed between the rate coefficients and maize grain yield for both soil types. The correlation between the cumulative P extracted and maize yield ($r = 0.997^{**}$) however was highly significant for Ermelo soils.

This method was also used to determine the changes in the different P pools and to relate these P fractions with maize yield. Highly significant correlations were observed between maize grain yield and the different P fractions including total P. In both soil types the contribution of both the labile and non-labile inorganic P fractions in replenishing the solution P_i was significant where as the contributions from the organic fractions were limited. The C/HCl-P_i is the fraction that decreased most in both cases as well.

Investigation was carried out to evaluate the effect of varying shaking periods on the extractable DMT-HFO-P_i for UP soils of varying P levels. Four shaking options were applied. Significant difference was observed for the treatment of high P application. Shaking option 2 seemed relatively better than the others since it showed the strongest correlation. Thus for soils with high releasing kinetics and high total P content, provided that the P release from the soil is a rate limiting step, reducing the length of shaking time could shorten the duration one needs to complete the experiment with out influencing the predicting capacity of the methodology.

The other objective of this thesis was also to present a short cut method alternative to the combined fractionation method. Comparison of the sum of DMT-HFO-P_i, $NaHCO_3$-P_i, NaOH-P_i, D/HCl-P_i and C/HCl-P_i extracted by a conventional step-by-step method with the sum of DMT-HFO-P_i and a single C/HCl-P_i extraction as a short cut approach for all extraction periods resulted in strong and significant correlations. The C/HCl-P_i fraction extracted by both methods was correlated with maize grain yield and it was found to be highly significant. This study revealed that this short cut approach could be a simplified and economically viable option to study the P dynamics of soils especially for soils where the P pool acting as a source in replenishing the labile portion of P is already identified.

The method employed here therefore could act as an analytical tool to approximate successive cropping experiments carried out under green house or field condition. However, data from a wider range of soils is needed to evaluate the universality of this method. More work is also required in relating desorption indices of this method with yield parameters especially at field level.

Key words: desorption of P, dialysis membrane tubes, phosphorus, phosphorus dynamics, phosphorus fractionation, phosphorus release rate, shaking time optimization, short cut methodology, soil test methods, successive desorption of P, two component first order model