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**DISSOLUTION AND PLANT-AVAILABILITY OF PHOSPHATE ROCKS
IN SELECTED NEW ZEALAND AND INDONESIAN SOILS**

A thesis presented in partial fulfilment of
the requirements for the degree of
Doctor of Philosophy in Soil Science
at Massey University

Donald Tambunan
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ABSTRACT

Use of phosphate rocks (PRs) as direct-application fertilizers has received considerable attention in countries that have large areas of acidic soils. Properties of acidic soils generally favour dissolution of PRs and increase their effectiveness as direct-application fertilizers. In this study, the dissolution and effectiveness of several PRs, North Carolina (NCPR), Moroccan (MPR) and Pati (PPR) phosphate rocks, was investigated in a range of New Zealand and Indonesian soils. The main objective of the thesis was to provide information that could assist in improving recommendations on their use in field situations.

Laboratory studies showed that the extent of PR dissolution could be estimated using sequential P fractionation techniques to measure amounts of residual (undissolved) PR in soils. In New Zealand soils, residual PR was accurately estimated from the increase in HCl-extractable P ($\Delta\text{HCl-P}$) between NCPR-fertilized and unfertilized soils following sequential extraction of soil and soil/NCPR mixtures with 0.5 M NaCl/TEA (30 min), 1 M NaOH (16 h) and 1 M HCl (16 h). The $\Delta\text{HCl-P}$ method, however, was not suitable for use on strongly weathered Indonesian soils because of low recovery P in the HCl extractant following NaOH extraction. Tri-acid ($\text{HNO}_3\text{:HCl:HClO}_4$) digestion or H_2SO_4 (0.5-1 M) extraction overcame this problem. A $\Delta\text{H}_2\text{SO}_4\text{-P}$ method involving 0.5 M NaCl/TEA, 1 M NaOH and 0.5 M H_2SO_4 extractions was subsequently tested and shown to be suitable for measuring residual PR in acidic New Zealand and Indonesian soils. Measurement of ^{32}P -labelled synthetic francolite dissolution in these soils confirmed the accuracy of the new $\Delta\text{H}_2\text{SO}_4\text{-P}$ method.

Considerable evidence exists from this study to indicate that the capacity of soil to supply acid and remove Ca from the site of PR dissolution are most important in determining the extent of PR dissolution. The extent of NCPR dissolution in New Zealand soils was found to decrease with increasing additions of CaCO_3 or NaHCO_3 due to increases in soil pH (for NaHCO_3 and CaCO_3 -amended soils) and exchangeable Ca (for CaCO_3 -amended soils). The maximum extent of PR dissolution occurring in the range of acidic New Zealand and Indonesian soils incubated with NCPR and MPR was found to be negatively correlated with initial amounts of exchangeable soil Ca ($r=0.83$ -

0.92) and the percentage Ca saturation of the cation exchange capacity ($r=0.78-0.92$). Also, increases in soil pH, and possibly solution concentration of Ca, were the main reasons for decreases in synthetic francolite dissolution in soils amended with increasing rates of plant residue. And finally, field trials conducted in Indonesia showed that the extent of PR (NCPR, MPR and PPR) dissolution was greater in the more acidic Ultisol ($pH_{H_2O}=4.8$) than in the Entisol ($pH_{H_2O}=5.3$).

Laboratory incubation studies showed that the key factors determining the chemical-availability (i.e. extractable with Olsen, Bray 1 and resin tests) of P derived from soluble P fertilizer or PRs in New Zealand and Indonesian soils were rate of addition, soil pH and P sorption characteristics and the nature of soil test. A short-term (30 days) glasshouse study using a range of New Zealand soils showed that the plant-P uptake from soil fertilized with NCPR was low, relative to monocalcium phosphate (MCP), indicating the low extent of NCPR dissolution. The plant-availability of soluble P and dissolved P from PR, however, was more dependent on soil P adsorption characteristics than on other soil properties.

Field trials in Indonesia showed that PRs were more effective agronomically than triple superphosphate (TSP) for maize in a P deficient Ultisol only when the PRs were applied to *Calopogonium caeruleum* cover crop 6 to 18 months prior to sowing maize. In an Entisol, PRs were less effective than TSP irrespective of application time. In the Ultisol, PR effectiveness was not affected by liming, provided that the PRs were applied 6 to 18 months prior to the addition of lime.

Results of the Indonesian field trials showed that Bray 1 test was a better predictor of plant growth responses than either Olsen or resin tests in PR-fertilized Ultisol, where high effectiveness of PRs was observed.

Three PR dissolution models of increasing complexity (Mitscherlich, Cubic, Kirk and Nye) were tested using NCPR and MPR dissolution data generated from a laboratory incubation study. Only Mitscherlich and Kirk and Nye models adequately described PR dissolution in the soils studied. A sensitivity analysis showed that any differences between observed and simulated PR dissolution by the Kirk and Nye model could be

attributed to problems in obtaining a representative measure of soil solution pH.

The Kirk and Nye model was modified to simulate PR dissolution in the field and tested using data from the Ultisol field site. The model adequately predicted NCPR and MPR dissolution over 545 days. In this case the accuracy of predictions was found to be dependent on the value of the initial soil pH and the accuracy of simulating daily soil water contents. The model showed potential for use in a wider range of soil-plant-climate conditions in order to assist with the selection of soils suitable for the use of direct-application PR fertilizers.

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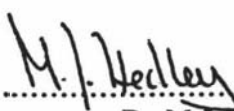
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This is to state the research carried out for the Ph.D. thesis entitled "Dissolution and Plant-availability of Phosphate Rocks in Selected New Zealand and Indonesian Soils" was done by D Tambunan in the Soil Science Department, Massey University, Palmerston North, New Zealand. The thesis material has not been used for any other degree.


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(Chief Supervisor)

18th November 1992
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Date