PHOSPHORUS CYCLING IN SOIL UNDER WHEAT-PASTURE ROTATIONS

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by

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SUMMARY

Transformations of phosphorus (P) within the soil-plant-animal system are complex and are affected by a combination of physical, chemical and biological reactions. To date, a large proportion of the research into reactions involving soil P has focussed on the inorganic components of the P cycle, despite the knowledge that biological reactions in the soil can have overriding influences on the transformation of P from one form to another. There is a need to study the influence of the microbial biomass on P cycling in soils, and this has been aided by the development of new methods to measure P held in soil microorganisms. In Australia this need is particularly important, as P is the major nutrient applied to agricultural soils. The objectives of the research reported in this thesis were therefore

(1) to develop a suitable procedure for measurement of P held in the microbial biomass in soils under arable rotations,

(2) to assess the importance of the microbial biomass in the assimilation of fertiliser P,

(3) to determine the role of the microbial biomass in the turnover and decomposition of cereal root and pasture plant residues and,

(4) to assess the importance of pasture residues in the P nutrition of the ensuing cereal crop.

The literature pertaining to the role of microorganisms in P cycling in soil is reviewed. Factors affecting microbial activity in soil are considered in relation to the uptake of P

by microorganisms, and the turnover of P from plant roots and residues is discussed. Methods of studying P cycling are reviewed in relation to the techniques required to study P transformations in field soils.

An improved method for measuring microbial P in field soils was developed. A range of gas, liquid and vapour biocides was tested, in combination with seven extractants, for their ability to release P from soil microorganisms _in situ_. The biocides tested were chloroform ($CHCl_3$), ethanol (C_2H_5OH), propan-1-ol (C_3H_7OH), hexan-1-ol ($C_6H_{13}OH$), β-propiolactone ($C_3H_4O_2$), formaldehyde (CH_2O), glutaraldehyde ($C_5H_8O_2$), ethylene oxide (C_2H_4O) and methyl bromide (CH_3Br). The extractants tested were 0.5M $NaHCO_3$(pH8.5), 0.1M $NaHCO_3$(pH8.5), 0.05M NaOH, 0.01M $CaCl_2$, 0.05M H_2SO_4, 0.03M NH_4F + 0.1M HCl and an anion exchange resin in the bicarbonate form. An incubation technique using ^{32}P ensured only microbial P was measured.

Chloroform and hexanol were the most efficient biocides: the latter was preferred because of its less hazardous nature. The best extractant was 0.5M $NaHCO_3$ (pH 8.5). Mixed populations of soil microorganims were used for calibration purposes, and K_p factors obtained were 0.33, 0.40 and 0.57 for the three soils studied. Since microflora differ from soil to soil, as does the proportion of P released as inorganic P, calibration is necessary for each soil. Incubation is not recommended as a pretreatment for samples used to measure microbial P: soils should be treated with hexanol or extracted immediately after sampling to avoid quantitative or qualitative changes in the biomass. Errors associated with the inclusion of plant root

material in the sample can be minimised by removing the bulk of the roots before fumigating the soil.

The competition between soil microorganisms and plants for fertiliser P is likely to be greatest in the rhizosphere, where root densities are high and substrates for microbial growth are available. This poses problems for the measurement of microbial P in soil adjacent to plant roots. Accordingly, a new technique was adopted to separate the roots from soil with a porous membrane. This technique also allowed an assessment of the loss from the root of P in diffusible exudates. Wheat plants labelled with ^{33}P were grown in thin layers of soil amended with ^{32}P-labelled fertiliser. Over a 22-day growth period, net movement of ^{33}P out of healthy growing roots varied from 0.9 - 4.9% of the total ^{33}P translocated to the root. Over the same period, the plants took up 12.0% and the microbial biomass 14.1% of the fertiliser ^{32}P. On drying and rewetting of the soil after the plants were harvested, a large proportion of root P moved into soil fractions while ^{32}P appeared to accumulate in the biomass and stable forms of P.

The contribution of pasture residues and fertiliser to the P nutrition of wheat was studied in laboratory and field experiments. Wheat plants (*Triticum aestivum* cv. Warigal) were grown in a Solonised brown soil (Calcixerollic xerochrept) which had been previously cropped with medic (*Medicago truncatula* cv. Paraggio). In a laboratory experiment, ^{33}P-labelled medic residues and ^{32}P-labelled monocalcium phosphate were added to the soil in factorial combination. Amounts of ^{31}P, ^{32}P, and ^{33}P in the wheat plants and in the

soil microbial biomass were determined. Addition of residues depressed dry weight of wheat, ^{31}P, and ^{32}P uptake, while simultaneously increasing amounts of ^{31}P and ^{32}P incorporated into the microbial biomass. Addition of fertiliser had no effect on the proportion of plant P taken up from the residues, but significantly increased the proportion of microbial P derived from this source. ^{31}P held in the microbial biomass was significantly increased by addition of both residue and fertiliser P, with the former having the larger effect. Of the total P applied to the soil, medic residues contributed approximately one quarter of that supplied by the fertiliser. Of the total P in the wheat plant, medic residues supplied approximately one fifth of that supplied by the fertiliser.

In a field experiment, ^{33}P-labelled medic residues and ^{32}P-labelled fertiliser were added to open ended pots driven into the soil. Residues were mixed throughout the soil while fertiliser was banded with the seed just below the surface. Dynamics of P uptake by the wheat plants and the microbial biomass in the soil were measured over a 95 day period. ^{33}P from the residues was rapidly incorporated into the microbial biomass with more than 25% of the applied radioisotope being found in the microbial pool after only 7 days. Little of the ^{32}P from the fertiliser was taken up by the microorganisms presumably because of its location in a band, but the wheat plants were able to assimilate a significant proportion of the fertiliser ^{32}P. The microbial biomass immobilised a smaller proportion of the P released from the residues under field compared with laboratory conditions, and the residues proved to

be a less effective source of P for the plants in the field. This fact, coupled with the observation that a large proportion (50%) of the residue P was quickly converted to organic forms suggests that the turnover of the microbial population was faster in the field than in the laboratory studies. The implications of the results in terms of fertiliser management and soil P cycling are discussed.