Dynamics of soil organic phosphorus

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Abstract. The transformations of soil organic phosphorus are described and organized in a conceptual model. Microbial uptake of P and its subsequent release and redistribution play a central role in the soil organic P cycle. Interactions with soil minerals and stabilization of organic matter and associated P in organo-mineral complexes determine the persistence and buildup of organic P through soil development, in different ecosystems and under varying management. An understanding of organic P turnover in soils will greatly aid assessment of P fertility in many agricultural and native systems.

Compartments of the soil phosphorus cycle

The dynamic nature of soil organic phosphorus (P$_o$) is masked by the fact that only a small portion of the total soil organic matter may be biologically active. Although this active portion can turn over rapidly and seasonal changes in certain P$_o$ fractions have been demonstrated (Halm et al., 1972; Dormaar, 1972; Chater and Mattingly, 1980; Sharpley, 1985), little net change will be noticed in the total P$_o$ since both immobilization and mineralization occur simultaneously in the soil (Halstead and Mckercher, 1975; Dalal, 1977). Thus, for an adequate description of the dynamics of P$_o$ in soils, it is important to understand the interactions of microbes, fauna and plants upon which the processes involved in the rapid cycling of P-compounds depend (Cosgrove, 1977; Coleman et al., 1983; Tate, 1984).

Any discussion of P$_o$ dynamics must also consider the complete P cycle because the immobilization, mineralization and redistribution of P in soil depends on physical-chemical properties, such as P sorption by colloidal surfaces, as much as it depends on microbial, mycorrhizal or plant uptake of P. This is illustrated in a conceptual P cycle (Figure 1) in which the following processes are described.

Primary P minerals are slowly dissolved providing phosphate ions that enter into the labile or solution P$_o$ pool. A portion of the solution P$_o$ will be precipitated as secondary P minerals and eventually converted to
occluded (unavailable) forms in more weathered soils (Smeck, 1985). The
central component of the active soil $P_o$ cycle is biomass $P$. Biomass $P$ can
be taken up directly by predators or by saprophytes and incorporated into
new consumer biomass (Coleman et al., 1983). This process constitutes the
most rapid cycling of $P_o$ and is accompanied by rapid rates of C and N
transformations. Organic $P$ released by secretion or cell lysis into the soil
environment can be taken up by soil organisms or, after hydrolysis, by
plants. Alternatively, it can be stabilized as part of the soil organic matter
through its organic moiety, or by interactions of the phosphate group with
mineral components. The presence of highly charged phosphate groups
will prevent most $P_o$ from entering into strongly humified materials, and
soil $P_o$ is usually found in reactive sidechain parts of the soil organic matter
(Jaquín and Fares, 1974; Batsula and Krivonosova, 1973). Phosphodiesters
in particular may enter into associations mediated by their organic
moiety whereas monoesters are more likely to bind through the reactive
$-OPO_3^-$ to positively charged sites on organic matter, clays, ses-
quioxides, or to free cations present in the soil solution. Stable $P_o$ accu-
mulates in both chemically resistant and aggregate protected forms (Hed-
ley et al., 1982a). The long-term accumulation of $P_o$ in soils has been well
documented but only a few attempts have been made to measure the
dynamics of short-term processes that cause the long-term changes in soil
$P$ (Cole et al., 1978; Chauhan et al., 1979, 1981).

Complete identification of individual $P$ compounds and their modes of
association with soil organic and mineral components has so far not been
accomplished. Several specific phosphate esters such as phospholipids
(Kowalenko and Mckercher, 1970), glycerol phosphates, phosphatidyl
choline (Hance and Anderson, 1963) and nucleic acids (Anderson, 1970),
have been identified, though usually in quantities amounting to less than