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Soil organic phosphorus forms under different soil management systems and winter crops, in a long term experiment

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ABSTRACT

Organic phosphorus (P) is an important source of phosphate for plants both in natural environments and in cultivated soils. Growing plants with high P recycling capacity may increase the importance of organic forms in phosphate availability mainly in undisturbed soils. The aim of this study was to evaluate the effect of long period of cultivation of different winter species under different soil management systems in the distribution of soil organic P forms, in the P content stored into the soil microbial biomass (SMB) and in the acid phosphatase enzyme activity. The experiment was established in 1986 with six winter treatments (blue lupine, hairy vetch, oat, radish, wheat and fallow) implanted in a Rhodic Hapludox in southern Brazil, under no-tillage system (NT) and conventional tillage system (CT). The crops were cultivated with rational use of chemical phosphate fertilizer, according to plant needs and soil type maintaining high levels of soil organic carbon leading to P organic form accumulation. Growing crops during the winter period in highly weathered subtropical soil increases the importance of microbial interactions in the P cycle, especially in the NT, where a large amount of crop residues is annually added to the soil surface, increasing soil organic P level, P content stored into the SMB and acid phosphatase enzyme activity.

1. Introduction

The transformation of natural ecosystems into cultivated areas alters the distribution of the phosphorus (P) forms in the soil, mainly in organic forms. Generally, organic P declines quickly in continuous cropping systems without phosphate fertilizers application, concomitantly with the decrease of total organic carbon (TOC) and total P (Solomon and Lehmann, 2000; Solomon et al., 2002; Conte et al., 2002). There is little information about the factors that contribute to the soil organic P increase, which typically occurs on systems where the TOC and total P are enhanced or are not strongly affected (Nziguheba and Bünemann, 2005).

Organic phosphorus may represent 20–80% of total soil P (Dalal, 1997). In natural environments, after the mineralization, it is a P source for plants which occurs especially under highly weathered soils such as tropical and subtropical (Vincent et al., 2010), and in cultivated soils with very low P availability (Gatiboni et al., 2005). Nevertheless, it is less studied than the inorganic P forms mainly due to analytical limitations since there are no direct methods to quantify the organic P of soil (Turner et al., 2005).

Many studies have focused in organic P fractions extracted by the bicarbonate and sodium hydroxide. These are considered forms that can be mineralized and subsequently absorbed by plants in short and medium term. However, this relationship depends mainly of soil type and type of cultivated plant (Chen et al., 2002). Therefore, the dynamics of soil organic P, when subjected to different soil management and crops rotations, can be better understood using microbiological and biochemical parameters sensitive to these changes, such as P content stored into the soil microbial biomass (SMB) and acid phosphatase enzyme activity (Matsuoka et al., 2003, Carneiro et al., 2004; Gatiboni et al., 2008).

Soil microorganisms represent an important dynamic reservoir of nutrients potentially available to plants. According Oberson et al. (2001), they play a fundamental role in the soil organic P transformation through phosphatases excretion, solubilization of moderately labile inorganic P forms, synthesis and release of organic P. Conte et al. (2002) also reported that they worked preventing the sorption of phosphate by soil inorganic colloids through immobilization in their tissues. Later, with the death and cell lysis, P can be released more synchronized with the demand of the plant (Martinazzo et al., 2007).

Soil conservation systems, such as no-tillage (NT), in general are characterized by a higher TOC and total P content in the soil surface layers compared to CT (Bolliger et al., 2006), mainly due to the no soil disturbance, allowing the accumulation of P fertilizer applied,

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and the carbon and P of crop residues added over a period of time in this layer (Rheinheimer and Anghinoni, 2001; Redel et al., 2007; Zamuner et al., 2008). Such conditions are most suitable for the transformation of inorganic P added through fertilizer into organic forms, increasing the importance of biological P reactions in the soil surface layer under NT (Rheinheimer and Anghinoni, 2003).

According to Horst et al. (2001), the cultivation of different plant species changes the P dynamics in the soil. It occurs mainly due to P recycling mobilized by crop residues and to the colonization of microorganism's mobilizers of P in the rhizosphere of succeeding crops, in a crop rotation system. In this sense, Rheinheimer and Anghinoni (2003) reported that the lower content of organic P in soil under a succession of oat (*Avena strigosa* Schreb)/maize (*Zea mays* L.) compared to soil cultivated with oat + vetch (*Vicia* sp.)/maize + cowpea (*Vigna unguiculata* subs. *unguiculata* L. Walp) and soil cultivated with pigeon pea (*Cajanus cajan* L. Millps) + maize, was due to higher input of plant residues to the soil and/or the ability of plants, such as cowpea and pigeon pea, absorbing high amounts of P from soil solution. In addition, Kunze et al. (2011) found that cover crops have regulatory effect on enzyme activity linked to the mineralization of organic phosphorus, and this effect depends of the mycorrhizal character of the used species. These authors found that the soil cultivated with non-mycorrhizal species showed higher activity of acid and alkaline phosphatase, possibly promoting greater biochemical mineralization of organic P, and that this may have been compensated by lower P uptake in the absence of mycorrhiza.

The aim of this study was to evaluate the effect of long period with different winter species under different soil management systems in the distribution of soil organic P forms, in the P content stored into the soil microbial biomass and in the activity of acid phosphatase enzyme.

2. Materials and methods

2.1. Site description

A long-term experiment was established in 1986 at the IAPAR (Agronomic Institute) Experimental Station at Pato Branco, southwestern Paraná State, Brazil (52°41′W, 26°07′S and 700 m altitude) (Fig. 1). The soil of the experimental site is an Oxisol (Rhodic Hapludox), very acid with a high clay content. The A horizon (0–1 m) has 72% clay, 14% silt, and 14% sand. The mineralogical composition of A horizon is 68% silicate type 1:1 (kaolinite and halloysite), 13% silicate type 2:1 (vermiculite and/or montmorillonite), 14% iron oxides and 5% gibbsite, and the iron oxides composition is 51% hematite, 36% goethite and 13% maghemite (Costa, 1996). The climate is classified as subhumid tropical zone or Köppen's Cfb. The monthly average temperature and monthly average precipitation of the experimental station in the period 1979–2009 and in 2009 are presented in Fig. 2.

2.2. Historic and design of the experimental area

The experimental area was covered by subtropical forest until 1976, when it was cleared, and cultivated with maize (*Z. mays* L.) and beans (*Phaseolus vulgaris* L.) for 10 yr in a conventional system (1 disc plow + 2 disc harrowing), without terracing, before the

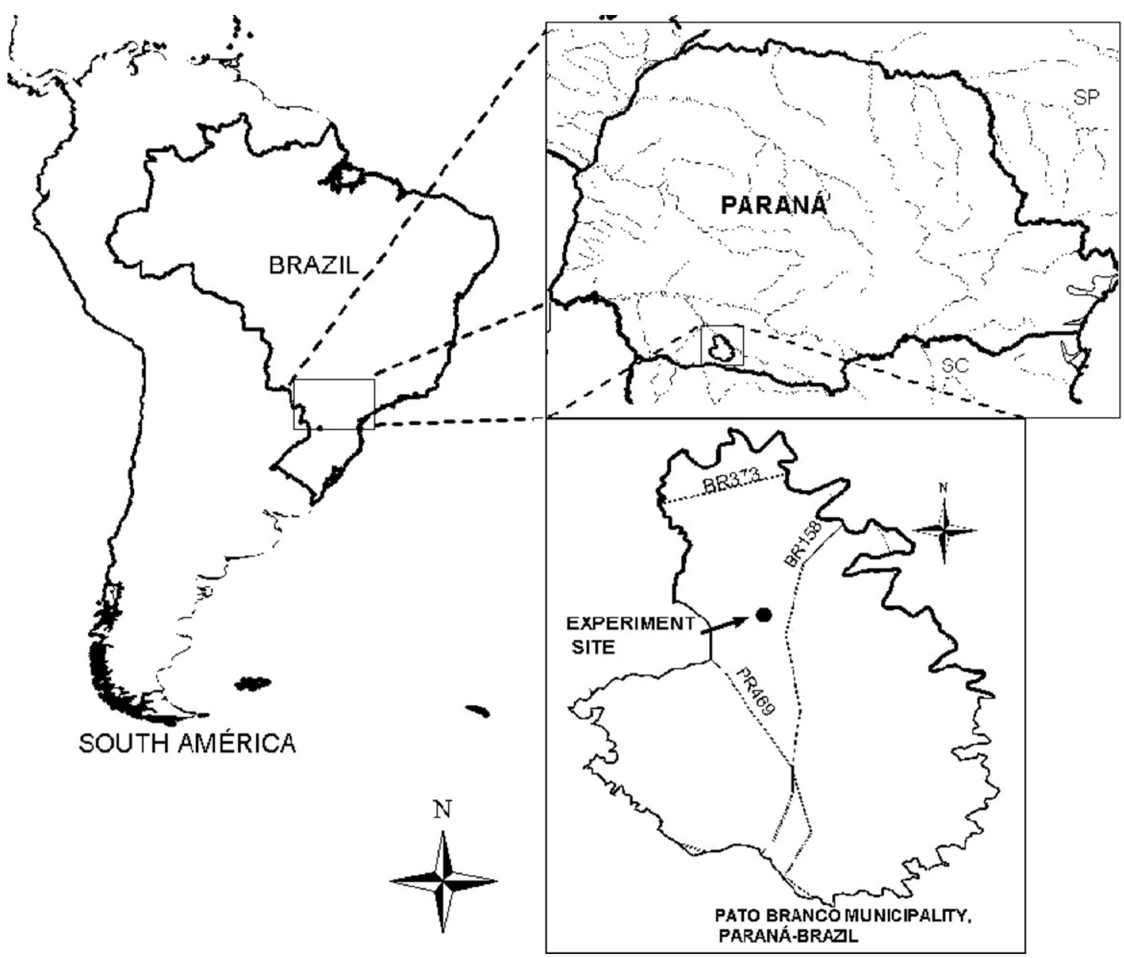

Fig. 1. Map of South America, Brazil, and Paraná State showing location of study site.