



Phosphorus migration analysis using synchrotron radiation in soil treated with Brazilian granular fertilizers



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HIGHLIGHTS

- Phosphorus (P) mobility in a tropical Brazilian soil.
- Total Reflection X-Ray Fluorescence was applied to determine the concentration of P.
- Fertilizers used *monoammonium phosphate* and *polymer coated monoammonium phosphate*.

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ABSTRACT

The aim of this study was to evaluate the phosphorus (P) mobility in a tropical Brazilian soil type red Oxisol treated with three different forms of granular fertilizer. Total Reflection X-Ray Fluorescence (TXRF) was applied to determine the concentration of P at different distances from granular fertilizer application point. The results showed that most of the P from fertilizers tends to concentrate in a region of up to 10 mm around the place of the fertilizer deposition.

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1. Introduction

Two important components for the development of agriculture, particularly with regard to increased agricultural productivity, other factors of production, were the researches in soil fertility and the scientific and technological innovations that allowed the efficient use of corrective and fertilizers in Brazilian agriculture.

Fertilizers are defined in Brazilian legislation (Decree 86955 of February 18, 1982) as “mineral organic, natural or synthetic substances, suppliers of one or more plant nutrients”. Its function is to restore to the ground the elements taken in each harvest, in order to maintain or even expand its production potential. Its participation is essential to increase the physical performance of agriculture, i.e. productivity.

The most common plant nutrients are nitrogen (N), phosphorus (P) and potassium (K), referred as NPK. These elements are present in the composition of ammonia, produced from atmospheric N, and phosphate and potash rock, which are extracted directly from nature.

The importance of P for plant survival has promoted the development of plant adaptation mechanisms to improve their access to P storage. According to Lombi et al. (2004a, 2004b), the concentration of P in the soil solution is generally low, because it is quickly adsorbed on the surfaces of soil particles or are precipitated as calcium, magnesium, iron and aluminum phosphates. Therefore, study the concentrations of P in radial distance from the fertilizer application point is a relevant parameter for cultivation in soil and evaluation of fertilizer performance.

The purpose of this work was to study the P mobility in Brazilian tropical soils treated with three different types of granular fertilizers. The P concentrations in soil were obtained at different distances from fertilizer application point using total reflection x-ray fluorescence technique (TXRF) at the National Synchrotron Light Laboratory (LNLS/BRAZIL). The study was developed as a

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collaboration between the Electronic Instrumentation and Analytical Techniques Laboratory (LIETA) of the Physics Institute/State University of Rio de Janeiro (UERJ) and Brazilian Agricultural Research Corporation (EMBRAPA/Soils)

2. Materials and methods

2.1. Fertilizers and soil sample preparation

Fertilizers used in this work: *monoammonium phosphate* (MAP), *polymer coated monoammonium phosphate* (MAPp) and *organomineral phosphate* (OMP). The organomineral phosphate fertilizer was produced in the Fertilizer Laboratory of Embrapa Soils mixing *monoammonium phosphate* fertilizer (MAP) with organic fertilizer (chicken manure). In order to obtain this fertilizer, 115.4 g of MAP (0.50 mm) were mixed with 184.6 g of chicken litter (< 0.85 mm) and granulated in a dish pelletizer.

This study analyzed the fertilizer MAPp to assess its efficiency in the diffusion of P, since the polymer coating is aimed at partially blocking the reactions that prevent the diffusion of P through the soil. Although much comment regarding, these products have not demonstrated efficacy in blocking/mitigating these reactions (McLaughlin et al., 2012) and this can explain the lack of agronomic benefit arising from the use of these fertilizers when compared to similar sources without any coatings or additives with this purpose.

It was used agricultural surface layers (0–20 cm; clayey Red Oxisol), sampled from Rio Verde, state of Goiás, coordinates 17°46' 01" S 51° 02' 01" W. The soil sample was dried and sieved to 2 mm. Three doses of calcareous (0, 3 and 12 t/ha) were added to the soil in order to obtain samples with different pH values, identified as treatments A, B and C. Table 1 shows the chemical characteristics of these soil samples.

An important parameter of the migration of P in soil is the maximum retention capacity, since its value regulates the amount of water to be delivered into the soil. For the quantification of the maximum water retention capacity, 50 g of the dried soil sample were weighed and subsequently placed in a funnel covered with filter paper (WhatmanR # 42). The base of the funnel was closed, 50 mL of deionized water were added and the entire system was covered to prevent water loss by evaporation, remaining at equilibrium for four hours. Next, the base of the funnel was opened and the drained water was collected for volume measurement. The same procedure was repeated without the soil sample to deduct the volume of water retained in the filter paper. Treatments A, B and C showed a retention capacity of 63.2%, 63.0% and 65.3%, respectively.

2.2. Incubation in petri dishes

An incubation experiment was conducted in petri dishes with procedures similar to those adopted by other research groups (Lombi et al. 2004a, 2004b; Lombi et al., 2006; Hettiarachchi et al., 2008; Silva et al., 2010). To obtain the desired density of 1.2 g.cm⁻³

in the petri dish, a 534.6 g sample of dry soil was placed under constant homogenization in a plastic container. Then, 62.7 mL of deionized water were added in spray form to reach an 8.5% moisture level (m m⁻¹). The procedure to ensure that the moisture is evenly distributed in the petri dish is essential to ensure that the displacement of P occurs by diffusion. Excess, erratic, or lack of water distribution in the petri dish greatly affects the assessment of the movement of nutrients (Silva et al., 2010).

Subsequently, approximately 85 g of moist soil were placed in each petri dish of 86 mm in diameter. Finally, the amount of water (20.27 mL per plate for all treatments) required to achieve 60% of the maximum water retention capacity was added dropwise with a pipette.

The petri dishes were labeled, capped, sealed with plastic film and covered with aluminum foil to avoid variations in humidity and exposure to light. They remained in a B.O.D. incubator for 24 h at 28 °C controlled temperature to ensure uniform distribution of water through the soil contained in the petri dish, which filled the entire volume.

After this pre-incubation process, the containers were opened and the granules of fertilizers under test were placed exactly in the center of the petri plates and slightly sunk so that they remained equidistant from the petri dish base and lid. Finally, the petri dishes containing soil and fertilizer were capped, sealed and coated before being subjected to incubation for five weeks (Fig. 1).

This period of time was chosen since the absorption of a sufficient amount of P should occur during this time period for most economic crops, which is a critical factor for the crop to exhibit its maximum yield potential (Williams, 1948). Furthermore, most crops' root systems are still small and relatively inefficient during this period, so that the availability of P is an even more critical factor. Finally, the adoption of five weeks of incubation allows a comparison with the results of other researchers using the same incubation time.

After a period of 5 weeks (incubation period), the petri dishes were opened and soil samples were collected in concentric rings, as shown in Fig. 2. After collection, the samples were dried at 41 °C until the mass is stabilized for a subsequent chemical analysis.

After digestion, using the Mehlich-1 (0.05 mol L⁻¹ HCl + H₂SO₄ 0.0125 mol L⁻¹), the amount of P present in each section was calculated using the TXRF at LNLS. In this study it was also calculated the percentage of P in each section (Lombi et al., 2004b) as seen in the Eq. (1).

$$\%P_f S_i = \frac{([P_f] S_i x W_i)}{\sum_{i=1-4} ([P_f] S_i x W_i)} \quad (1)$$

where *i* is the soil section (1–4 – Fig. 2), [P_f]S_i and W_i are the concentration of fertilizer P and the soil weight of each section respectively. [P_f]S_i is calculated by subtracting the P concentration of the untreated soil from the concentration of the fertilized soil.

2.3. Sample preparation and analysis in line TXRF

To perform the calibration of the detection system and

Table 1
Chemical characteristics of the soil^(a)

Treatments	pH	Al	Ca	Mg	Na	K	H+Al	P	S	T	V
	(water)	cmol _c /dm ³			mg/dm ³		cmol _c /dm ³	mg/dm ³	cmol _c /dm ³		(%)
A	5.2	0	2.7	0.5	5.3	103	5.6	3.0	3.4	8.9	59
B	5.7	0	5.7	0.3	4.0	87	2.5	3.6	6.2	8.7	72
C	7.0	0	4.0	0.4	3.7	92	2.0	4.0	4.5	6.5	78

^a Results obtained by LASP/Embrapa soils.

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