

ANALYZING THE MOBILITY IN GRANULAR FORMS OF P FERTILIZER IN BRAZILIANS SOILS UNDER LABORATORY CONDITIONS

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ABSTRACT

Phosphorus is an essential nutrient for plant growth. Million of tones of P are applied to the soils annually. However, only a small fraction of the P applied with fertilizers is taken up by crops in the year of application, and the effectiveness of any residual P fertilizer declines with time. To improve our understanding of the mechanisms underlying this response to P in the field, we have studied the mobility of P from 3 different fertilizers: monoammonium phosphate (MAP), polymer coated monoammonium phosphate (MAPp) and *Organomineral phosphate (OMP)* applied on high weathered soil samples in a Petri dish experiment. Total Reflection X-Ray Fluorescence (TXRF) was used to determine the P diffusive flux at different distances (0 - 7.5, 7.5 – 13.5, 13.5 – 25.5 and 25.5 – 43 mm) from granular fertilizer. TXRF analyses were performed at the X-Ray Fluorescence Beamline D09B at Brazilian National Synchrotron Light Laboratory (LNLS), in Campinas, São Paulo, using a polychromatic beam with maximum energy of 20 keV for the excitation and an Ultra-LEGe detector with resolution of 148 eV at 5.9 keV. Besides that, the detections were performed in a high vacuum chamber (2.5×10^{-5} mbar) to avoid air absorption. After a period of five weeks, the total P concentration increased in the soil sampled 7.5 to 13.5 mm from the fertilizer showing a diffusive flux of P. About 20% (considering MAP and MAPp) of the total P applied diffused out of the central soil ring. Different sources showed differences in diffusive flux of P. Soil pH also influenced diffusive flux of P showing higher flux on lower pH soils.

1. INTRODUCTION

The major reason that supply of phosphorus (P) to cultivated plants is a common limiting factor for crop production is the low availability of P to plant roots rather than low P content in soils. Although farmers have used large amounts of P fertilizers to improve crop growth over many decades, only a small fraction of the applied P as fertilizers are taken up by plants in the year of application (McLaughlin et al., 1988) while the residual effectiveness of P fertilizer for subsequent crops declines with time (Barrow, 1973).

The importance of phosphorus for plant survival has promoted the development of adaptation mechanisms of the plant to improve its access to stocks of P. The concentration of P in soil is usually low (Lombi et al. 2004a; 2004b) because it is readily adsorbed on the surfaces of soil

colloids and precipitated as phosphates or calcium (Ca), magnesium (Mg), iron (Fe) and aluminum (Al).

Moreover, there are studies showing decreases in crop yield due to some physical problems in the subsurface well as in the form of cultivation, preventing access to the phosphorus and other nutrients and water. Lombi et al (2004a) found that phosphorus concentrations in some treatments (using types of fertilizer: MAP granular, MAP powder and TG-MAP) decreases with increasing distance from the central point where the fertilizer was added. Thus, studying the concentration of phosphorus in radial distances from the point of application of fertilizer becomes a relevant parameter for soil cultivation and performance evaluation of the fertilizer.

In this work, we have studied the mobility of P from 3 different fertilizer in forms monoammonium phosphate (MAP), polymer coated monoammonium phosphate (MAPp) and Organomineral phosphate (OMP) applied on a High Weathered Brazilian soil samples in the laboratory. Total Reflection X-Ray Fluorescence (TXRF) was used to determine the mobility of P at different distances (0 - 7.5, 7.5 – 13.5, 13.5 – 25.5 and 25.5 – 43 mm) from granular fertilizer. TXRF analyses were performed at the X-Ray Fluorescence Beamline D09B at Brazilian National Synchrotron Light Laboratory (LNLS), in Campinas, São Paulo, using a polychromatic beam with maximum energy of 20 keV for the excitation and an Ultra-LEGe detector with resolution of 148 eV at 5.9 keV. Besides that, the experiments were performed in a high vacuum chamber (2.5×10^{-5} mbar) to avoid air absorption.

2. MATERIALS AND METHODS

In our analysis we used an agricultural surface layer (0-20 cm) of a Red Oxisol sampled in Rio Verde / Goiás. This soil was dried and sieved to 2 mm. Three doses of lime (0, 3 and 12 t/ha) were applied to the soil to obtain different pH values, identified as treatments A, B and C. The chemical characteristics of these soil samples are shown in Table 1.

Table 1: Chemical characteristic of the soils used in the experiment

Treatments	pH (water ^a)	Total P (mg/kg) ^b
A	5.2	297
B	5.7	314
C	7.0	330

- a. Results obtained by LASP/EMBRAPA SOLOS.
- b. Results obtained by LNSL/TXRF.

After incubation of soil samples for 30 days, we started the experimental setup. The experimental setup was similar to that described by Lombi et al. (2004) and Silva (2013). Plastic Petri dishes (8.7 cm in diameter, 1.1 cm high) were filled with 76 g of dry soil per dish, in the case of the three treatments, to obtain a soil density of 1.2 g cm^{-3} . The soil was then wetted to 60% of field capacity by dripping deionized water onto the soil. The Petri dishes were closed, sealed with parafilm and left to equilibrate overnight. The following day, the Petri dishes were opened and granules of fertilizer were placed in petri dishes. Table 2 shows the concentrations of phosphorus in each fertilizer.

Table 2: Concentrations of phosphorus total in the fertilisers

Fertilisers	P ₂ O ₅ (%) – total ^(a.)
MAP	56.5
MAPp	52.5
OMP	24.6

a. Analyzes were done according to MAPA (2007).

After the treatments were prepared the Petri dishes were closed, sealed with parafilm and incubated using a BOD incubator at 28°C for five weeks in the dark . A relatively short equilibration period (five weeks) was chosen because P uptake by cereal crops occurs mainly in the initial stages of plant growth (Williams, 1948). After equilibration, the Petri dishes were opened and four concentric rings of soil, centered around the granule, were removed using a series of plastic cylinders. These cylinders were driven into the soil one at a time, starting with the smallest one, and all soil inside the cylinder was removed. This procedure was adopted by Lombi et al. (2004) and it is similar to the method used by Kouboura et al. (1995) to sample soil at different distances from fertiliser bands (Figure 1). Samples of soil were collected between 0–7.5, 7.5–13.5, 13.5–25.5 and 25.5–43 mm radius from the granule.

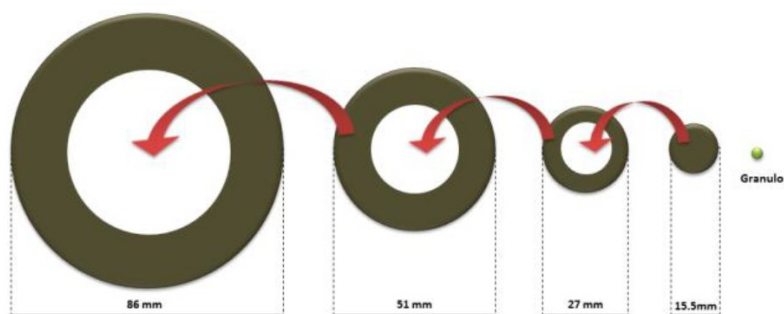


Figure 1: Four concentric rings of soil. Silva (2013)

A subsample of each soil section was digested using extractor Mehlich-1 and the total phosphorus measured. TXRF analyses were performed at the X-Ray Fluorescence Beamline D09B at Brazilian National Synchrotron Light Laboratory (LNLS), in Campinas, São Paulo, using a polychromatic beam with maximum energy of 20 keV for the excitation and an Ultra-LEGe detector with resolution of 148 eV at 5.9 keV. Besides that, the experiments were performed in a high vacuum chamber (2.5×10^{-5} mbar) to avoid air absorption.

A mass balance was calculated to determine the amount of P added to each Petri dish. The amount of P present in each section of the Petri dishes was calculated by subtracting the native P concentration from the total P concentration measured at the end of the experiment in the soil digests, and multiplying this value by the soil weight of the respective section.

The distribution of the added fertilizer P in the different sections of soil collected from the Petri dishes was calculated using the measured total P concentration and the background concentration. The percentage of P from fertilizer in each section ($\%P_f S_{1-4}$) was calculated as follows: Lombi et al (2004-b)

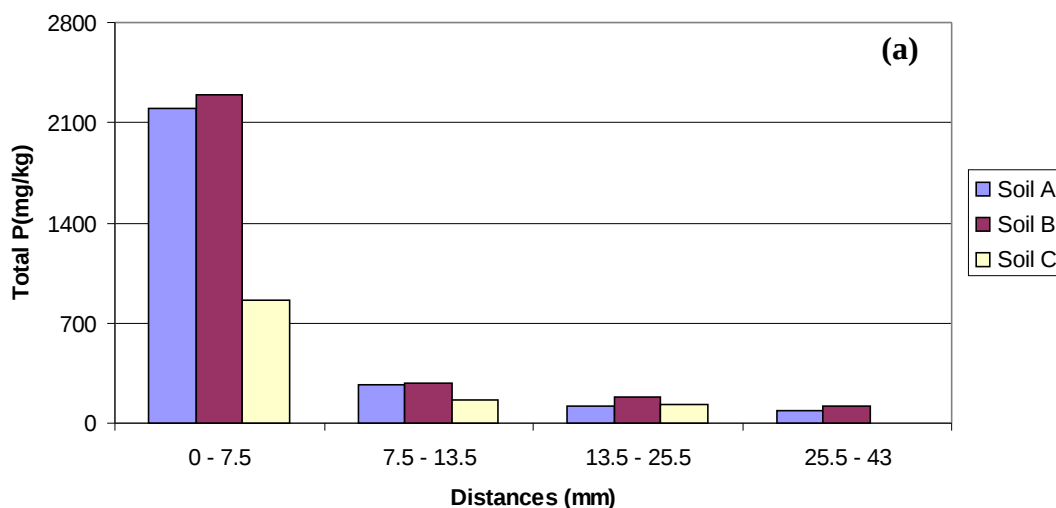
$$\%P_f S_i = \frac{([P_f]S_i \times W_i)}{\sum_{i=1-4} ([P_f]S_i \times W_i)} \quad (1)$$

where, i is the soil section (1 to 4), $[P_f]S_i$ 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.

3. PRESENTATION AND ANALYSIS OF RESULTS

Concentration of P varies with the pH of the soil, as well as the type of fertilizer (Figure 2). Figure 2 (a) we observe the mobility of P contained in the MAP can be observed a minor variation in the region close fertilizer application, the order 4.5% (0-7.5), 0.7% (7.5-13.5) when comparing the soil A and B. For soil C, we obtained a low mobility of phosphorus, it is not possible to detect in the range of 25.5-43.

In Figure 2 (b) analyzing the mobility of P fertilizer that is more efficient in the soil C. In the range (0-7.5), the concentration of P in soil C was greater than 24% in soil and 30% in soil than B. The values in the range (25.5-43) for soil A and C were below the detection limit. In Figure 2 (c), we conclude that the mobility of phosphorus in the soil B has developed more smoothly than in soil A. In all tracks, the values of C P to the soil were below the detection limit.



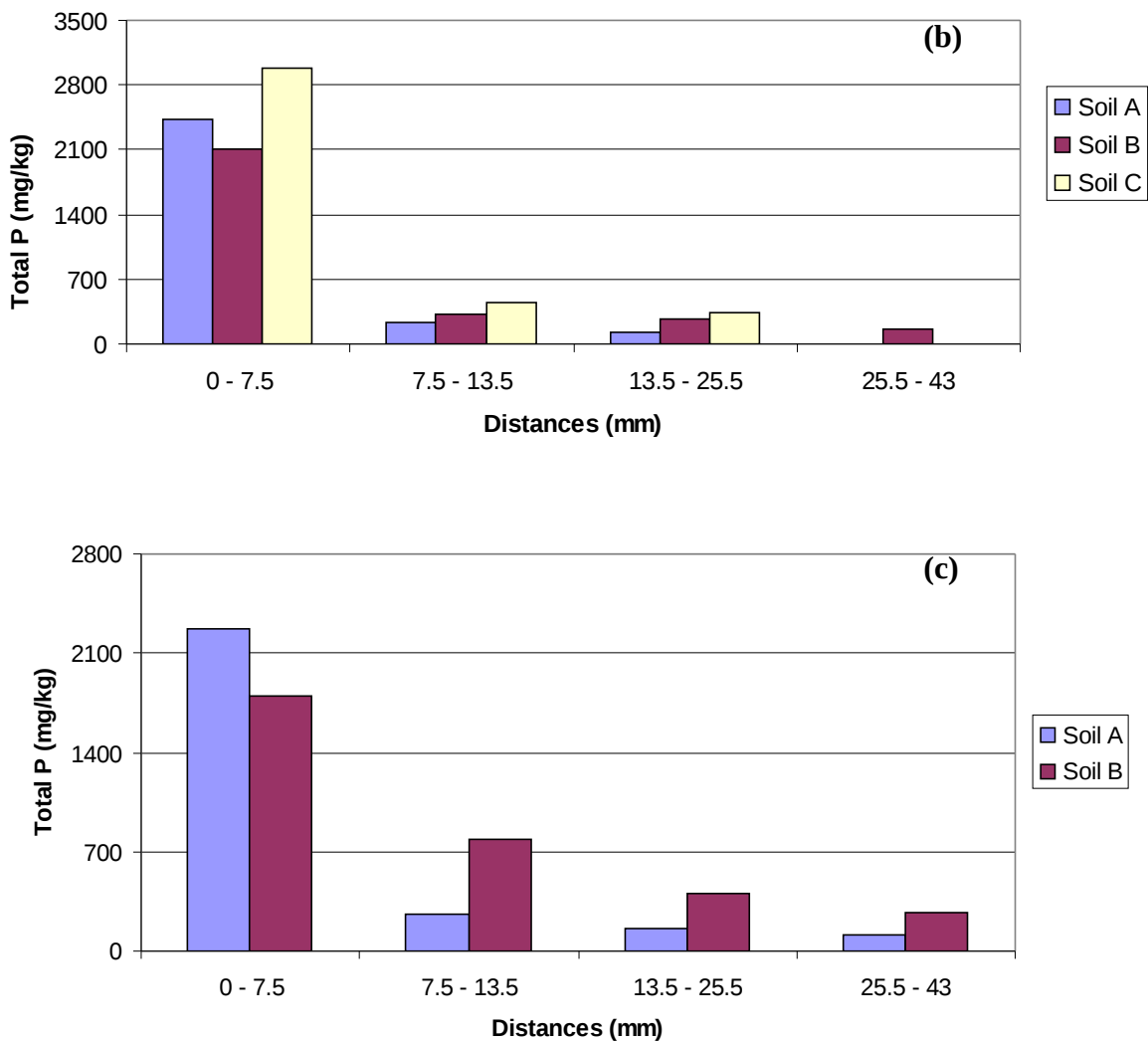


Figure 2: Concentration of P – (a) (MAP), (b) (MAPp) and (c) OMP

The results, expressed as a percentage of the P added in the fertilizers are reported in figure 3. In the MAP treatment, as expected, the distribution of P from the fertilizer closely matched the weight distribution of the soil among the different sections as reported in figure 3(a). When MAP was applied in the centre of the Petri dish, most of the P from the fertilizer (80%) remained within 0 to 7.5 mm of the point of application and only 12% diffused to the 7.5 to 13.5 mm section, analyzing the soil A. For soils B and C, have respectively 77% in the range of 0 to 7.5 mm and 11% in the range of 7.5 to 13.5 mm and 75% in the range of 0 to 7.5 mm and 14% in the range of 7.5 to 13.5 mm. This indicated that neither the initial compaction nor the coating of the granules (to suppress dust during transport) affected the diffusion of P from the fertilizer.

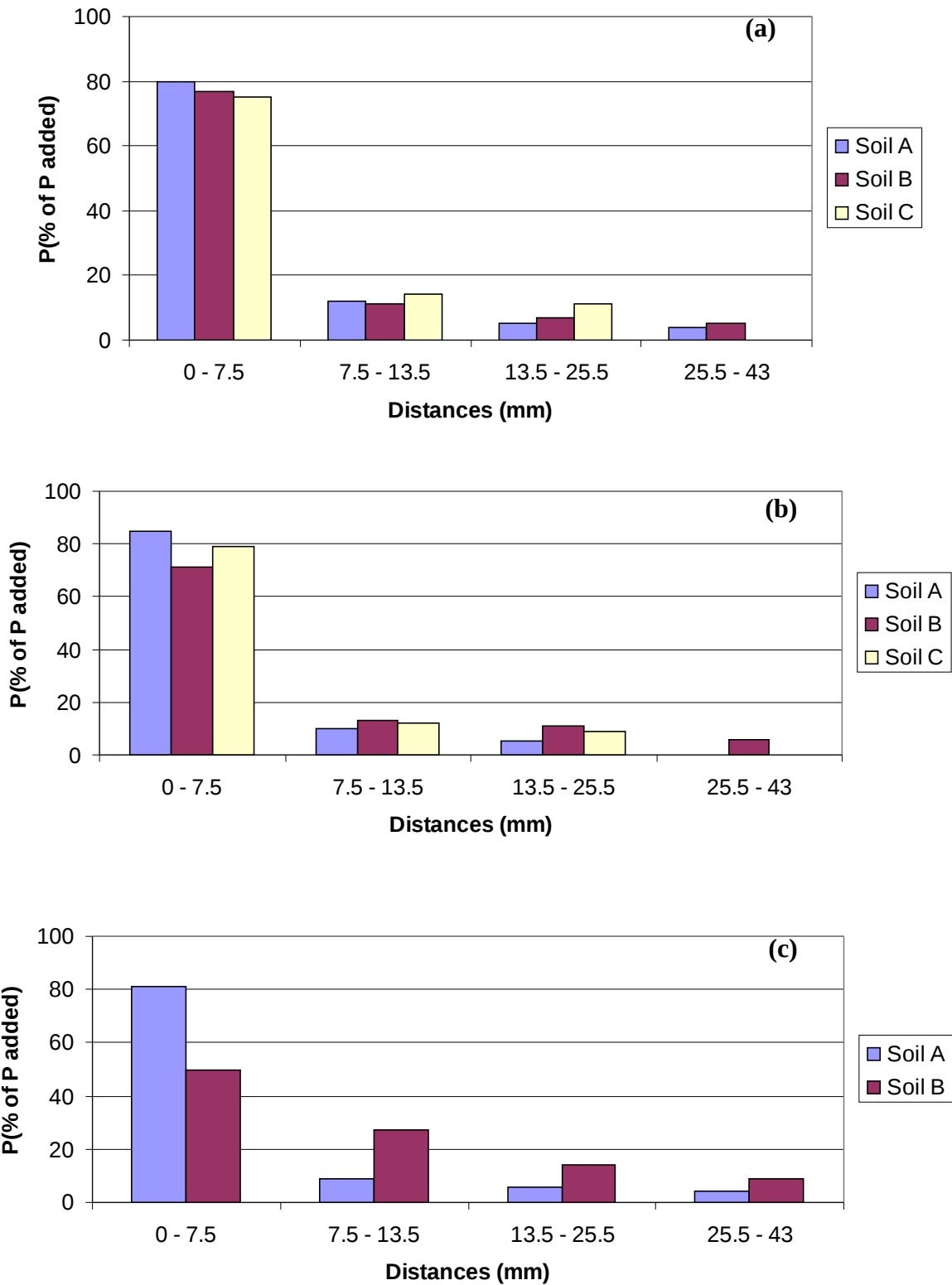


Figure 3: P migration– (a) (MAP), (b) (MAPp) and (c) OMP

The diffusion of P from MAP granules was detectable in the first three sections of the Petri dishes indicating a migration of P up to 25.5mm in 35 d with soil C. This result is comparable

with those of Blanchard and Caldwell (1966) reported diffusion of P to 20 to 30 mm from monocalcium phosphate pellets over 2 wk in a clay loam soil. Similarly, Lombi (2004-a) reported diffusion of P to 13.5 to 25.5 mm from monocalcium phosphate in a Calcareous Soil.

Even though the maximum distance to which P diffused from MAP and MAPp (Figure 3(b)) was not significantly different, the pattern of P distribution was. Most of the P from MAP and MAPp remained near the point of application whereas more P from *Organomineral phosphate* spread evenly over the soil B (Figure 3(c)).

3. CONCLUSIONS

The TXRF with synchrotron radiation (low Z and conventional) proved to be very efficient in determining concentration multielement in soil samples. The elements detected were: Mg, Al, Si, Cl, Ti, V and Mn. The results of our study provide an insight into some of the physical processes occurring when three products that contain the same form of P are applied to a Brazilian soil. In particular diffusion of P from OMP and MAPp appeared to be enhanced in comparison with conventional MAP. These differences may reflect the difference in reaction products in the zone immediately surrounding the point of fertilizer application.

ACKNOWLEDGMENTS

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REFERENCES

- McLaughlin, M.J., A.M. Alston, and J.K. Martin., "Phosphorus cycling in wheat pasture rotations. 1. The source of phosphorus taken up by wheat", *Aust. J. Soil Res.*, **26** pp.323–331. (1988).
- Barrow, N.J., "Relationship between a soils ability to absorb phosphate and the residual effectiveness of superphosphate", *Aust. J. Agric. Res.*, **11** pp.57–63. (1973).
- Lombi E, McLaughlin M J, Johnston C, Armstrong R D and Holloway R E., "Mobility and lability of phosphorus from granular and fluid monoammonium phosphate differs in a calcareous soil". *Soil Sci. Soc. Am. J.*, **68** pp.682–689. (2004-a).
- Lombi E., McLaughlin M. J., Johnston C., Armstrong R. D. and Holloway R. E., "Mobility, solubility and lability of fluid and granular forms of P fertiliser in calcareous and non-calcareous soils under laboratory conditions". *Plant and Soil*, **269** pp.25–34. (2004-b).
- Williams R. F., "The effects of phosphorus supply on the rates of intake of phosphorus and nitrogen and upon certain aspects of phosphorus metabolism in gramineous plants". *Aust. J. Sci. Res.*, **1** pp. 333–341. (1948).

Kouboura A. D., Pierzynski G. M. and Havlin J., "Phosphorus and micronutrients availability from dual application of nitrogen and phosphorus using liquid fertilizers". *Soil Sci.* **159**, pp. 49-58. (1995).

Ministério da Agricultura, Pecuária e Abastecimento (MAPA), *Manual de métodos analíticos oficiais para fertilizantes minerais, orgânicos, organominerais e corretivos*, Brasília/Brazil (2007).

Silva, Rodrigo Coqui da, *Eficiência Agronômica de fertilizantes fosfatados com solubilidade variada*, Tese de Doutorado/USP/ESAL, Piracicaba/Brazil (2013).

Blanchard, R.W., and A.C. Caldwell., "Phosphate-ammonium moisture relationships in soils: I. Ion concentration in static fertilizer zones and effects on plants". *Soil Sci. Soc. Am. Proc.* **30**, pp.39-43. (1966).