

Time-based evaluation of bioavailable phosphorus in a calcareous soil after the application of anaerobically digested sewage sludge



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Introduction



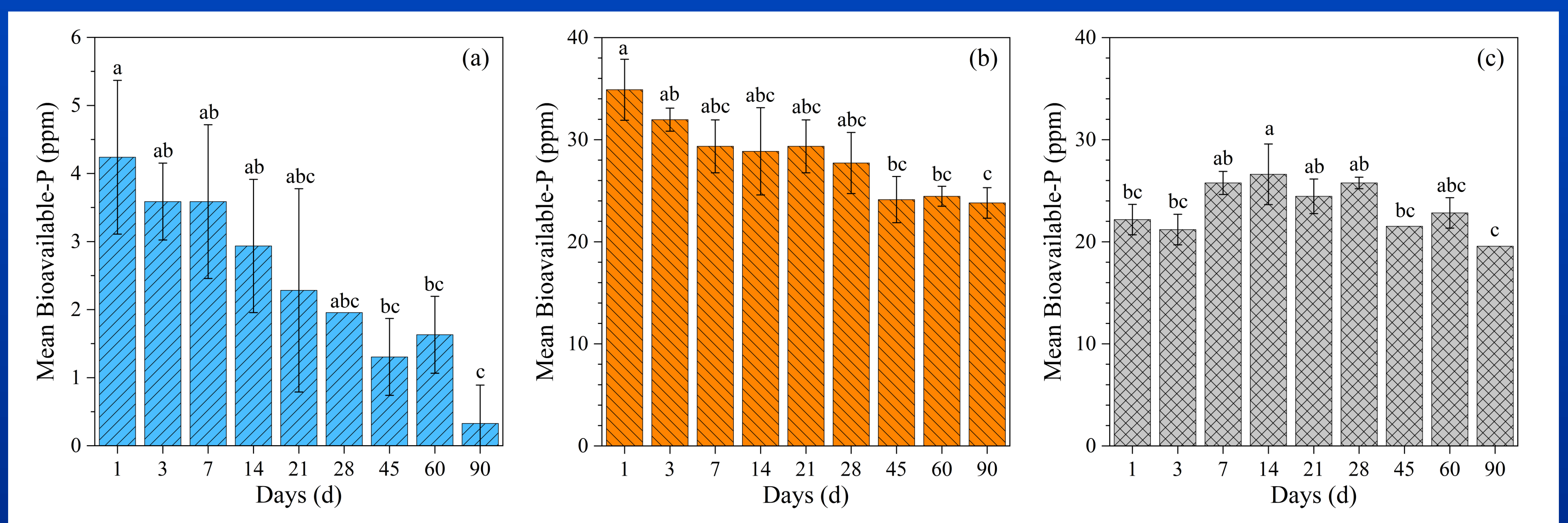
Figure 1: Falcon tubes in the climatic chamber

- Phosphorus (P) natural reserves are being depleted.
- P fertilizers demand is increasing;
- Phosphorus is well contained in waste materials such as sewage sludge (the main byproduct obtained from wastewaters treatment).
- Only a small amount (1-3%) of the soil total phosphorus P-Tot is bioavailable for plant nutrition.
- The present study focuses on the determination of the kinetics of bioavailable phosphorus concentrations in a sandy calcareous soil after the application of anaerobically digested sewage sludge (SSAD).
- Centrifuged (C) and dried (D) SSAD were tested for fertilizing calcareous sandy soil.
- 50 mL falcon tubes containing negative control (T) and soil treated with C and D were incubated from 1 to 90 days at 25 °C in a climatic chamber.
- Soil phosphorous fractionation was performed with the SMT method and bioavailable-P was extracted through the Olsen method. Phosphorous was spectrophotometrically quantified by the molybdovanadate method.
- Kinetics of bioavailable-P on soils were evaluated using four kinetic models: first order, second order, simple Elovich and power function equations.

Results & Discussion

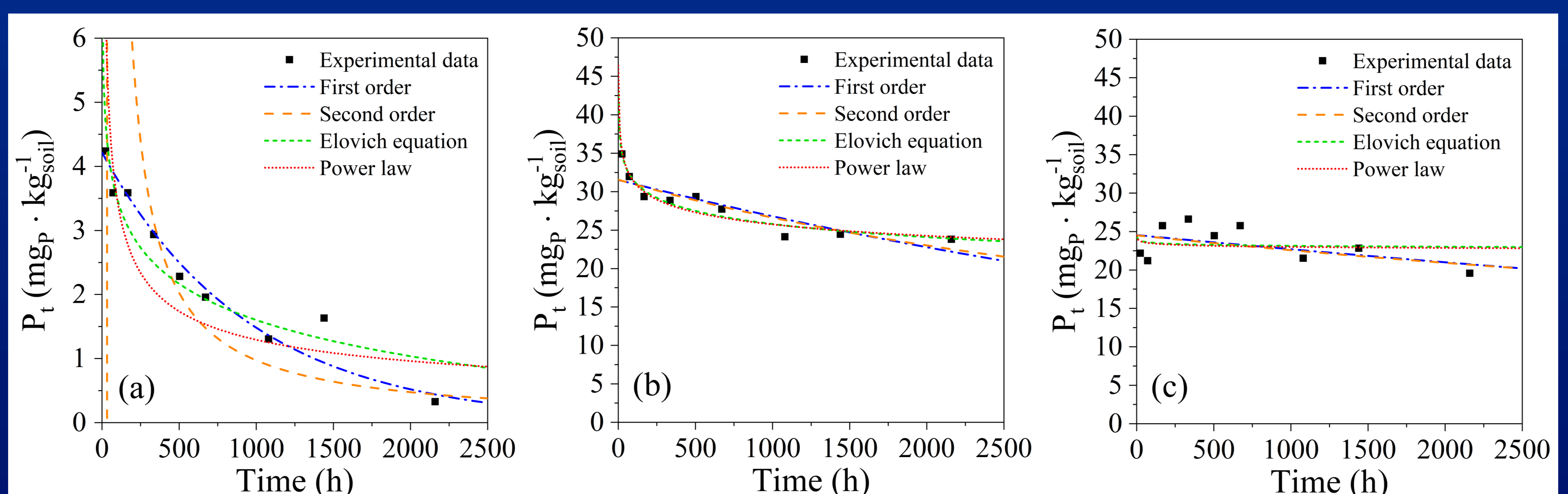
- Total phosphorus in sandy soil was around 478 ppm. Addition of SSAD increases this content of almost 100 ppm. No significant changes of P-Tot.
- SMT method allows to measure 4 fractions of P: organic P, inorganic P, apatite P (form associated with calcium) and non-apatite P (form associated with oxides and hydroxides of Al, Fe and Mn. No significant changings on SMT P fractions over time.
- The bioavailable-P significantly decreased over time in T (Figure 2.a) and C (Figure 3.b) treatment. Decrease due to precipitation and adsorption of P with calcium: at alkaline pH and with great presence of Ca^{2+} ions, formation of sequential calcium phosphates. HPO_4^{2-} reacted with Ca^{2+} forming firstly dicalcium phosphate and secondly tricalcium phosphate.
- $$\text{HPO}_4^{2-} \xrightarrow{\text{CaCO}_3} 2(\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}) + \text{CO}_2 \uparrow \xrightarrow{\text{CaCO}_3} \text{Ca}_3(\text{PO}_4)_2 + \text{CO}_2 \uparrow + 5\text{H}_2\text{O}$$
- D treatment showed a peak of bioavailable-P concentration on day 14 (Figure 2.c). Trend due to organic carbon compounds, competitive sorption and metal bridging.

Figure 2: Mean bioavailable-P (PPM) among three months in soil of: control (a), centrifuged (b) and dried (c). Different letters indicate differences between PPM levels that are significant at $P < 0.05$ (Tukey HSD). Each error bar represents one standard deviation



- Elovich model best described the adsorptive-precipitate process of bioavailable-P in T (Figure 3.a) and C (Figure 3.b). Conversely, none of the models satisfactorily described the behavior of bioavailable-P in D samples (Figure 3.c).

Figure 3: Kinetic of bioavailable-P in soils over 2160 hours (90 days) in: (a) not treated soil, (b) treated with centrifuged SSAD soil and (c) treated with dried SSAD soil. Black points represent the mean values of experimental bioavailable-P, while colored lines represent the fitted kinetic models of bioavailable-P



Conclusions

Thanks to this work it was possible to assess the trend of bioavailable-P in a calcareous sandy soil fertilized with SSAD. Furthermore, the study increases the knowledge on P-related phenomena for designing and optimizing fertilizers and reducing their drawbacks such as eutrophication.