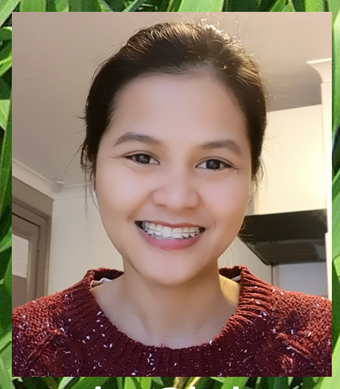
Effect of applying vivianite and P-containing Fe(III) oxides on phosphorus bioavailability and dynamics in different agricultural soil types

Saracanlao Rochelle Joie, Smolders Erik, and Everaert Maarten

Division of Soil and Water Management, KU Leuven, Leuven, Belgium

rj.saracanlao@kuleuven.be



Rationale

- Fe minerals are commonly used to trap P from P-rich waste streams yielding vivianites (Fe(II)-phosphates and Fe(III) phosphates.
- The naturally strong connection between Fe and P is a clear advantage for P recovery. However, this makes it a challenge to make P available from FePs, particularly in aerobic conditions.

Hypothesis

- Fe-based P recycling products might be suitable P fertilizers in flooded soils, e.g. in soils used in growing paddy rice, based on the increased P availability in soil after flooding following reductive dissolution of soil Fe(III) minerals.

Research Goals:

- Develop a method for the diffusion of P from TSP, a commercial fertilizer and recycled FeP products under flooded conditions using DGT gels.
- Compare agronomic effectiveness of different FeP products under contrasting water regimes.
- Determine application strategies for recycled FePs to be effective P fertilizers.

Fe(III) sludge

vivianite

Research Progress

Fig 1. P uptake of rice amended by granulated FePs in nonflooded and flooded conditions : pot experiment

A: acid **B: neutral** **C: calcareous**

- No significant increase in P uptake of rice amended by FePs compared to the control in both water treatments (except Fi)
- P uptake (FePs) << P uptake (TSP)
- Flooding did not improve P uptake of FePs probably because of the absence of reduced conditions due to low OM content of the soils, short flooding period, and presence of rice roots.

Fig 2. P release from powdered FePs with and without glutamate (C) under reduced conditions: an incubation experiment

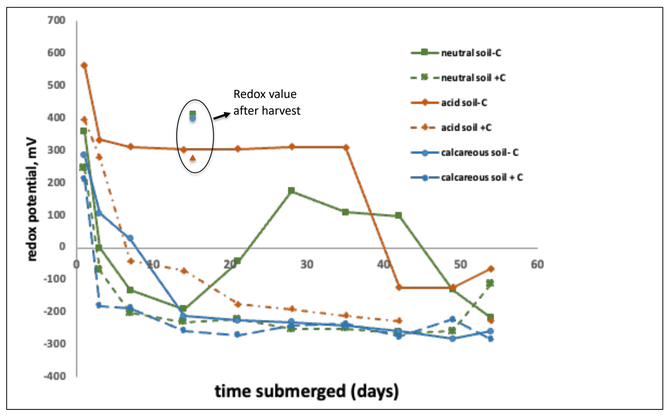


Fig 2A. Changes in soil redox potential (mV) with time after flooding in neutral (■), acid (◆), and alkaline (●) soils with (—) and without (----) OM.

- Our incubation experiment suggests that prolonged flooding (and OM addition) can promote reduced soil condition (Fig 2A) that was not observed in our pot experiment.
- Acid soil was too poor that even with glutamate addition, P concentration is not sufficient to support rice growth (0.1 mg P/L; indicated by blue line). This P concentration however was observed in neutral soil amended with Fe(III)P and glutamate but only after 60d. This P concentration was met even without glutamate in calcareous soil and only after 2 weeks for all treatments.

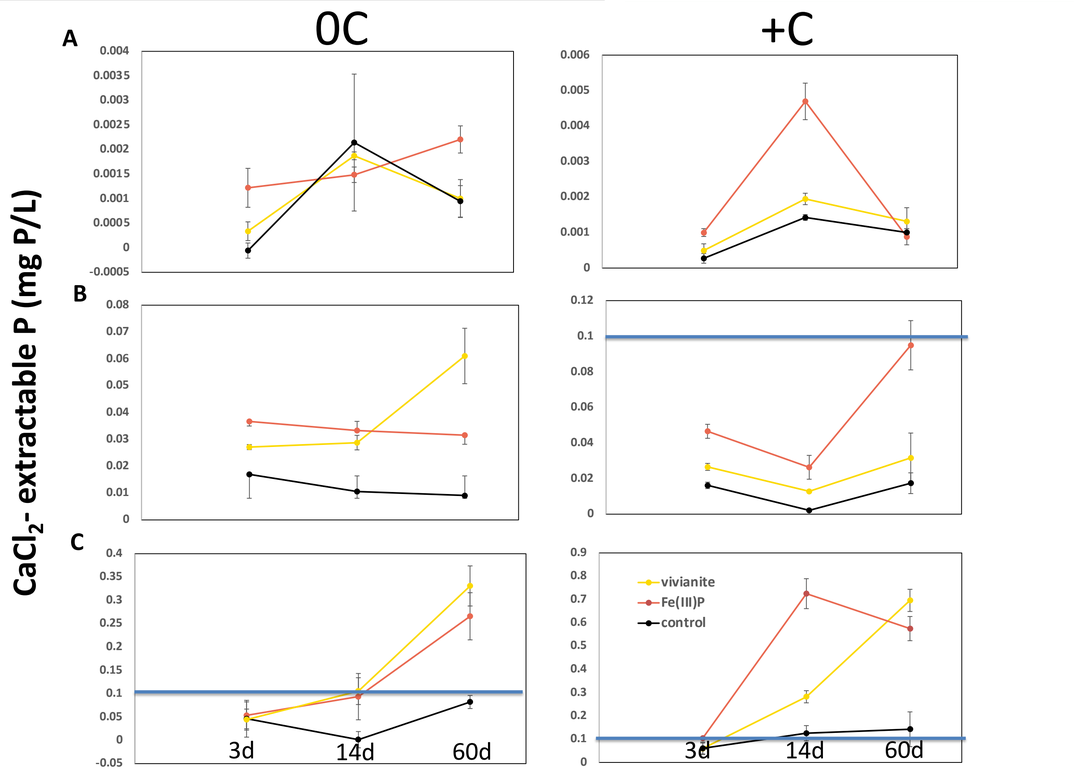


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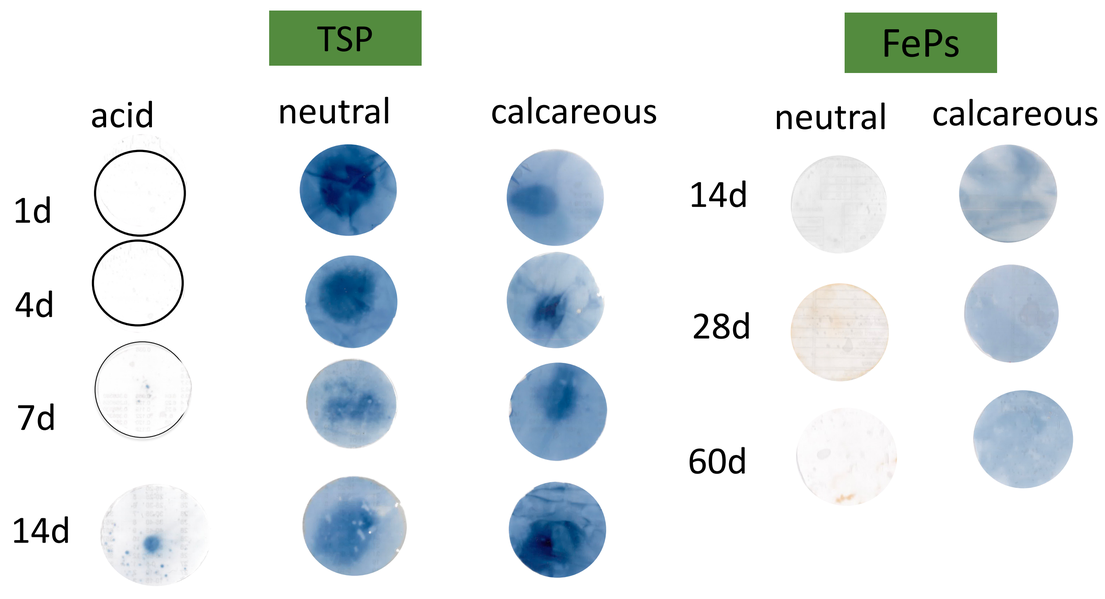
Fig 2B. Changes in mean $CaCl_2$-extractable P concentrations (mg P/L) with time in soils amended by recycled FePs (powdered) with and without glutamate.

P diffusion from P fertilizers under flooded conditions using DGT gels



- We developed a method to visualize P diffusion in flooded soils. A fertilizer granule is applied in the center of the soil-filled column, placed in between soil layers. After a given incubation time, the water and upper soil layer are removed and then, a ZrO binding gel acting as a P sink is placed on the soil surface. The P captured on the gel is visualized using a modified molybdate blue method which creates a mirror image of the diffusion zone.
- The diffusion of P from TSP (commercial P fertilizer) is highest in neutral soil and least in acid soils. This suggests that the extent of diffusion strongly depended on soil properties which influences sorption and precipitation reactions that may reduce the mobility and availability of P to plants.
- Granulated FePs did not result in any P diffusion, regardless of OM addition to treatments (not shown) and reduced conditions. The P detected in calcareous soils with FePs was from the soil and not from FePs.

Conclusions

- From these experiments, we inferred that to increase P fertilizer value of recycled FePs the following needs to be tested and further explored in the subsequent plant trial:

a. Applying FePs as powdered material and comparing its performance as P fertilizer to granulated FePs;
b. Flooding soils for a longer period (at least 6 weeks) and adding OM in soils to induce reduced conditions in soils which can promote reductive dissolution of Fe minerals and thereby release P; and
c. Incubating FePs in the soil few weeks prior to planting rice.

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