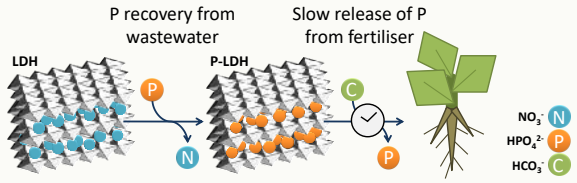
Limited phosphorus runoff losses using LDH and struvite fertilisers: A rainfall simulation study

Maarten Everaert [a], *Rodrigo C. da Silva* [b], *Fien Degryse* [b], *Mike J. McLaughlin* [b], *Erik Smolders* [a]

[a] *KU Leuven, Department of Earth and Environmental Sciences, Kasteelpark Arenberg 20 box 2459, 3001 Leuven, Belgium*
[b] *University of Adelaide, School of Agriculture, Food & Wine, Waite Campus, PMB1, Glen Osmond SA 5064, Australia*

Background

- Phosphorus (P) runoff from agricultural fields amended with fertilizers is linked to high P levels in surface waters
- This P enrichment is a major cause of **eutrophication**, which can strongly affect the quality of aquatic ecosystems
- Important role of heavy rainfall events in the runoff process
- High **P runoff losses** are linked to the use of highly soluble, commercial, rock phosphate derived fertilisers (e.g. MAP)
- Recycling P from waste streams led to the development of novel **slow-release mineral fertilisers** (**SRFs**):
  - PO_4 precipitation, obtaining **struvite**
  - PO_4 adsorption on **layered double hydroxides** (**LDH**) via anion-exchange, resulting in PO_4-exchanged LDH



- Recent studies show good agronomic effectiveness of these new SRFs, but it never exceeds that of soluble P fertilisers
- Success of P recycling products depends on their advantage in specific agronomic conditions ~ market value
- **Objective**: Illustrate the potential of struvite and LDH as SRFs for use in agricultural areas vulnerable to P runoff and surface water eutrophication

Materials

Fertilisers	LDH	Struvite	MAP
Formula	$[Mg_{0.66}Al_{0.33}(OH)_2][HPO_4^{2-}{}_{0.17}]$	$MgNH_4PO_4$	$NH_4H_2PO_4$
P (%)	3.8	12.2	22.7

Soil	pH ($CaCl_2$)	Clay (%)	OC (%)	CEC ($cmol_c/kg$)
Monarto (AUS)	5.3	41	1.8	16.9

Methods

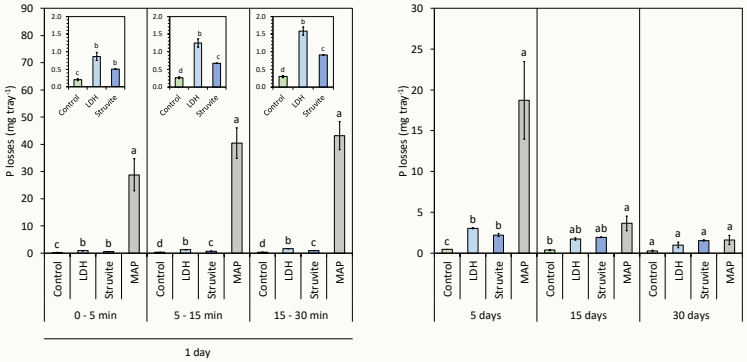
Rainfall simulation study

= rapid, efficient, controlled, and adaptable tool to simulate the effect of natural rainfall

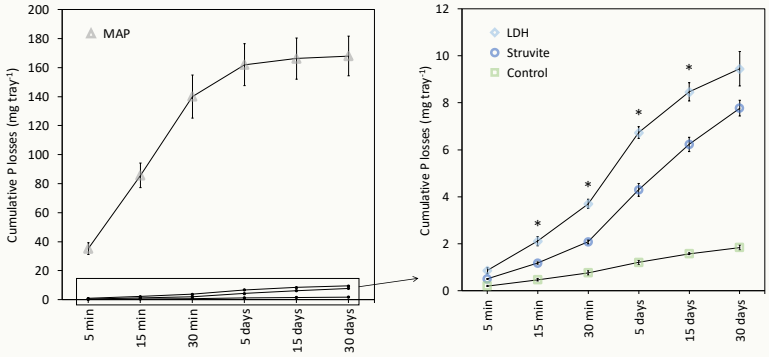
- Perennial ryegrass (*Lolium perenne*) was grown in trays filled with a poor P fixing soil
- 4 treatments: **granules** of LDH, struvite or MAP broadcasted on soil surface (40 kg P ha^{-1}) + control treatment (no added P)
- Trays placed at 5% inclination in a **calibrated rain cabin** on specific moments after P application (after day 1, 5, 15, 30), and sprayed upon for 30 min (98 mm h^{-1})
- Runoff water is collected, the amount per tray recorded
- P analysis (ICP-OES) on filtered samples from runoff water is used to quantify P runoff from the fertilisers
- Preliminary results indicated that nearly all fertiliser P runoff was present in 'dissolved' (<0.45 µm) form

Results

Runoff P losses during rain events after fertiliser application



Cumulative runoff P losses over four rain events



- **MAP**:
  - High P runoff losses in the first two rain events, and levelled off in later rain events
  - In total, **42 % of the applied P was lost** due to runoff
- **SRFs**:
  - Relative small differences in P losses between the LDH and struvite treatments during the rain events
  - Losses from SRFs are small and more **gradual over time**: less difference between different rainfall events

Conclusions

- Although MAP is a readily available P form for plant uptake, it is also an **immediate source for P runoff**
- P losses by surface runoff from a granular MAP fertiliser largely exceeded the losses from granular struvite and P-LDH fertilisers
- Areas with a **high risk of surface water eutrophication** and a **history of intensive fertilisation** might benefit from the use of granulated struvite or LDH as SRFs

Towards application

- Insights from surface chemistry and material science were used to propose this **new LDH fertiliser**, first prepared by our research group
- Agricultural effectiveness of a fertiliser is a key factor in fertiliser selection, but new SRFs can still have **other benefits** compared to soluble fertilisers:
  - This research is the first to prove that these SRFs can limit the P runoff losses; as they can also guarantee adequate P supply to crops, their use can help **avoiding stronger legislation** for fertiliser use by farmers
  - Struvite and LDH reuse P from wastewater, so their use can reduce agriculture's dependency on rock phosphate as main source for P fertilisers and help **securing the global food demand** in the future
- **Future research**: High P runoff losses from MAP can strongly influence the effective P supply to plants → determine yield of the cover grass during rainfall studies using these fertiliser treatments in P limiting conditions