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

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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):
  - PO₄ precipitation, obtaining struvite
  - PO₄ adsorption on layered double hydroxides (LDH) via anion-exchange, resulting in PO₄-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

<table>
<thead>
<tr>
<th>Fertilisers</th>
<th>LDH</th>
<th>Struvite</th>
<th>MAP</th>
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</thead>
<tbody>
<tr>
<td><strong>Formula</strong></td>
<td>(Mg₆(Al₂O₃)(PO₄)₂(OH)₂)</td>
<td>MgNH₄PO₄</td>
<td>NH₄H₂PO₄</td>
</tr>
<tr>
<td>P (%)</td>
<td>3.8</td>
<td>12.2</td>
<td>22.7</td>
</tr>
<tr>
<td><strong>Soil</strong></td>
<td>pH (CaCl₂)</td>
<td>Clay (%)</td>
<td>OC (%)</td>
</tr>
<tr>
<td>Monoarto (AUS)</td>
<td>5.3</td>
<td>41</td>
<td>1.8</td>
</tr>
</tbody>
</table>

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**

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