Supporting Information

Engineered phosphate fertilizers with dual-release properties

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Table S1. Elemental analysis of tap water used in the runoff experiment, as determined by ICP-OES. The numbers in brackets refer to the standard deviation (n=3).

<table>
<thead>
<tr>
<th>Element</th>
<th>Na</th>
<th>K</th>
<th>Mg</th>
<th>Ca</th>
<th>S</th>
<th>Zn</th>
<th>Cu</th>
<th>P</th>
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<tr>
<td>Concentration (mg L⁻¹)</td>
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<td></td>
<td>1.33  (0.02)</td>
<td>4.96 (0.38)</td>
<td>8.85 (0.50)</td>
<td>17.82 (0.65)</td>
<td>18.64 (0.31)</td>
<td>0.15  (0.06)</td>
<td>0.35  (0.10)</td>
<td>&lt;0.004</td>
</tr>
</tbody>
</table>

Figure S1. XRD spectra of the a) GO-3Fe, GO-4Fe, and GO-5Fe and b) GO-3Fe-P, GO-4Fe-P, and GO-5Fe-P composites.
Figure S2. FTIR spectra of the a) GO-3Fe, GO-4Fe, and GO-5Fe and b) GO-3Fe-P, GO-4Fe-P, and GO-5Fe-P composites.

Figure S3. FTIR spectra of the a) GO-3Fe, GO-4Fe, and GO-5Fe and b) GO-3Fe-P, GO-4Fe-P, and GO-5Fe-P composites.

Figure S4. Kinetics of P, K and S release from GO-3Fe-P composite (prepared at pH 3) in column; a) cumulative release, b) solution concentrations of P, K and S released over time. Error bars represent standard deviations (n=2).
Figure S5. SEM images of a and b) Str granules and, c and d) MAP-GO-3Fe-P granules.

**Granule Crushing Strength**

To measure crushing strength of the dual-release fertilizers, an Imada force gauge connected to a stand was used. Individual granules were placed on a mounted flat surface and pressure was applied by a flat-end rod attached to the force gauge. The load at which the granule fractured was considered as the crushing strength and a total of 15 parallel measurements were carried out for each formulation. The average of those measurements determined the crushing strength of the granules.

Figure S6. The crushing strength of granules measured in Newton (N). The average of weight of granules was 54.5 and 54.7 mg for MAP-GO-3Fe-P and MAP-Str, respectively. Error bars represent the standard errors (n=15).
Figure S7. Photos of a) GO-3Fe-P, b) MAP-GO-3Fe-P, SEM images of c) GO-3Fe-P and d) MAP-GO-3Fe-P at the end of the runoff experiment showing the granules from the GO-3Fe-P and MAP-GO-3Fe-P treatments preserved their initial structure.

Figure S8. AFM image (contact mode) of typical structure of GO showing a thickness of 1-2 GO layers.