Opportunities and challenges of meeting crop and soil nutrient requirements using bio-based fertilisers

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Thomae Kakouli-Duarte & team Carlow Institute of Technology, Ireland
Soil & Plant Nutrition team

My team on

- conventional & new mineral fertilisers
- New bio-based recycled fertilisers from the bio-economy
- Organic manures
- On-going N,P,K,S & inhibitor work
- National, EU & industry funded projects

Agronomy – Water & Air losses – Soil Health integrated

e.g.
Lysimeters
Gaseous emissions
Running down soil fertility

Maize Nitrogen (N) trial, Maryland, USA P.J. Forrestal

Wheat Phosphorus (P) trial, Wexford, Ireland P.J. Forrestal

Barley Potassium (K) trial, Wicklow, Ireland P.J. Forrestal

Grass Sulphur (S) trial, Wexford, Ireland P.J. Forrestal
Nutrient recycling role bio-based fertilisers
Opportunities and Challenges

- EIP-Agri Focus Group Work
- In 2016 selected along with 20 experts (Scientists, Farmers, Advisors & Industry) from 16 countries to assess and report on:
  - How to improve the agronomic use of recycled nutrients (N and P) from livestock manure and other organic sources?

https://ec.europa.eu/eip/agriculture/en/focus-groups/nutrient-recycling

Results

- Starting paper
- Final report
- Factsheet

Other information

- Agenda 1st meeting, 31 May - 1 June 2016, Svartsjö - Stockholm, Sweden
- Agenda 2nd meeting, 15-18 November 2016, Leuven, Belgium
- Mini-paper 1: Available technologies for nutrients recovery from animal manure and digestates
- Mini-paper 2: On Farm Tools for accurate fertilisation
- Mini-paper 3: On Farm Practices
- Mini-paper 4: Towards increasing the mineral fertiliser replacement value of biobased fertilisers
- Mini-paper 5: The value of recycling organic matter to soils: Classification as organic fertiliser or organic soil improver
- Mini-paper 6: End-user requirements for recycled and biobased fertiliser products
- Mini-paper 7: Regulatory environment affecting nutrient recycling
- Mini-paper 8: Assessing the environmental effects of nutrient recycling from organic materials used as fertilisers

Figure 1. Agro-processing of residues could serve to reconnect nutrient cycles between plant and animal production.
Where does conventional mineral P fertiliser come from?

Mosaic Phosphate mine, Florida, USA
Is there a need for recycling and reuse of P in Ireland?

An overview on deficit and requirements of the Irish national soil phosphorus balance

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c Teagasc, Environment Research Centre, Johnstown Castle, Co. Wexford, Ireland

HIGHLIGHTS

- 62.8% of Irish agricultural land has agronomically suboptimal P levels.
- 43,000 t of imported P fertilisers are annually applied to Irish agricultural land.
- 95,500 t of P are required annually to sustain crop production and build soil P.
- Cattle produce the largest quantity of indigenous P annually at 19,300 t.
- Ireland produces 30% of its P requirements from indigenous sources.

GRAPHICAL ABSTRACT

Nutrients: bio-based and mineral – what opportunities do the National (Ireland) and EU Strategy Statements indicate?

National Policy Statement on the Bioeconomy 2018

- Emphasizes the importance of the bioeconomy and using an increasing list of renewable biological resources and in some cases those that would have hitherto been discarded as residues or waste and putting them to more productive uses. It extends across sectors including farming and the agri-food businesses.

European Union Farm to Fork Strategy 2020

- The circular bio-based economy is still a largely untapped potential for farmers and their cooperatives. For example, advanced bio-refineries that produce bio-fertilisers.
- This will reduce the use of fertilisers by at least 20% by 2030.
- Notably in hotspot areas of intensive livestock farming and of recycling of organic waste into renewable fertilisers.
- The Commission will act to reduce nutrient losses by at least 50%, while ensuring that there is no deterioration in soil fertility.
Nutrients and Soil Fertility Explaining the Irish Systems of expressing fertiliser nutrient content & soil P & K index system

In Ireland we express & label nutrient content on an Elemental basis i.e. N,P,K,S

Multiply P by 2.29 to convert to $P_2O_5$

Multiply K by 1.21 to convert to $K_2O$

Multiply S by 2.5 to convert to $SO_3$

Soil Index System
Morgan’s extract used

<table>
<thead>
<tr>
<th>Soil Index</th>
<th>Index description</th>
<th>Response to fertilizers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Very low</td>
<td>Definite</td>
</tr>
<tr>
<td>2</td>
<td>Low</td>
<td>Likely</td>
</tr>
<tr>
<td>3</td>
<td>Medium / Adequate</td>
<td>Unlikely / Tenuous</td>
</tr>
<tr>
<td>4</td>
<td>Sufficient / High</td>
<td>None</td>
</tr>
</tbody>
</table>

Table 4-4: The P Index system

<table>
<thead>
<tr>
<th>Soil P Index</th>
<th>Grassland crops</th>
<th>Other crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0 – 3.0</td>
<td>0.0 – 3.0</td>
</tr>
<tr>
<td>2</td>
<td>3.1 – 5.0</td>
<td>3.1 – 6.0</td>
</tr>
<tr>
<td>3</td>
<td>5.1 – 8.0</td>
<td>6.1 – 10.0</td>
</tr>
<tr>
<td>4</td>
<td>Above 8.0</td>
<td>Above 10.0</td>
</tr>
</tbody>
</table>

Table 4-5: The K Index system

<table>
<thead>
<tr>
<th>Soil K Index</th>
<th>Soil K ranges (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 – 50</td>
</tr>
<tr>
<td>2</td>
<td>51 – 100</td>
</tr>
<tr>
<td>3</td>
<td>101 – 150</td>
</tr>
<tr>
<td>4</td>
<td>Above 150</td>
</tr>
</tbody>
</table>
Irish Grassland soils 2019 - P

Soil test P Grassland (27,213 samples)
Percentage of samples in each index

P needed to match crop P off-take (19,865 or 73%)

- Index 1: 24%
- Index 2: 25%
- Index 3: 24%
- Index 4: 26%

“Build-up” P, lift index 13,334 or 49%

[Agriculture and Food Development Authority logo]
The bio-based recycled fertilisers examined

<table>
<thead>
<tr>
<th>Source</th>
<th>Slurry</th>
<th>Struvite 1</th>
<th>Struvite 2</th>
<th>Ash 1</th>
<th>Ash 2</th>
<th>Dairy residue 1</th>
<th>Dairy residue 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source</td>
<td>Cattle</td>
<td>Potato processing</td>
<td>Sewage sludge</td>
<td>Sewage sludge</td>
<td>Poultry litter</td>
<td>Dairy processing</td>
<td>Dairy processing</td>
</tr>
<tr>
<td>Dry matter %</td>
<td>9</td>
<td>58</td>
<td>51</td>
<td>100</td>
<td>100</td>
<td>25</td>
<td>12</td>
</tr>
<tr>
<td>Organic C</td>
<td>3.5</td>
<td>0.06</td>
<td>0.08</td>
<td>0.07</td>
<td>0.05</td>
<td>3.3</td>
<td>3.6</td>
</tr>
<tr>
<td>N</td>
<td>0.28</td>
<td>3.0</td>
<td>2.6</td>
<td>0.03</td>
<td>0.02</td>
<td>0.64</td>
<td>0.73</td>
</tr>
<tr>
<td>P</td>
<td>0.054</td>
<td>6.2</td>
<td>5.1</td>
<td>8.4</td>
<td>5.5</td>
<td>2.025</td>
<td>0.552</td>
</tr>
<tr>
<td>K</td>
<td>0.39</td>
<td>0.69</td>
<td>0.03</td>
<td>10.7</td>
<td>1.3</td>
<td>0.14</td>
<td>0.21</td>
</tr>
<tr>
<td>S</td>
<td>0.04</td>
<td>0</td>
<td>0</td>
<td>3.0</td>
<td>3.1</td>
<td>0.07</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Comparative P Concentration (of fresh material)

- Mineral P 16%
- Cattle Slurry
- Struvite 1
- Struvite 2
- Ash 1
- Ash 2
- Dairy residue 1
- Dairy Residue 2

Total P content fresh material (%)
Bio-based fertiliser research and demo is on-going
Supported by EU H2020 and INTEREG

Grassland:
Mineral P fertiliser replacement value of bio-based fertilisers
Demonstrate & evaluate their multi-year integration into a fertiliser programme

Arable:
Demonstrate & evaluate their multi-year integration into a cropping rotation, on-farm collaboration

Watch on YouTube
Grassland Field Site

- Low fertility site selected
- Starting soil test P 2.9 mg/l Index 1 deficient
- Starting pH 5.6 – lime added at the start to bring pH to 6.1
- Randomised complete block with five replications
- 3 silage cuts and one residual cut
- A single application of 40 kg P/ha at the beginning in 2019
- N,K,S applied in accordance with recommendations
Differing Phosphorus Crop Availability of Aluminium and Calcium Precipitated Dairy Processing Sludge Potential Recycled Alternatives to Mineral Phosphorus Fertiliser

S.M. Ashkuzzaman 1,*, Owen Fenton 1, Erik Meers 2 and Patrick J. Forrestal 1

Relative P effectiveness of 2 Dairy Processing Waste Precipitated Sludges compared to superphosphate (first year)

Adapted from Ashkuzzaman et al., 2021 Agronomy: 11, 427 Table 4
Grassland Phosphorus and Nitrogen Fertiliser Replacement value of Dairy Processing Dewatered Sludge

S.M. Ashokuzzaman*, Patrick Forrestal, Karl G. Richards, Karen Daly, Owen Fenton

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Nitrogen Fertiliser Replacement Value (N FRV) of 4 Dairy Processing Waste Precipitated Sludges compared to CAN

Adapted from Ashokuzzaman et al., 2021. J. Sust. Prod & Cons. 25: 363-373
• Bacteria diversity was maintained or enriched by use of struvite and ash RDFs

• Sewage sludge ash unfavorably affected nematode diversity

• Neither struvite impacted nematode communities

Karpinska et al. (2021) https://doi.org/10.3390/su132212342
Conclusions

Opportunity

- Clear continued need for nutrients
- Several bio-fertilisers performing as well or better than mineral P
- Policy driver
- Potential soil health/nutrient mineralisation opportunities
- Role in soil health
- Cost - security
- Right thing to do

Challenge

- Cost and transport
- Field validation needed, e.g. can’t assume nutrient content = performance
- Field environmental performance testing needed
- Granulation
- Concentration of nutrients
- Matching crop/soil requirements
- Regulation & certification
Thank you for your attention

Questions?