The perfect match – P fertilizer demand and fertilizer rates

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Worldwide P reserves are finite so that a sustainable use of P is imperative on a global scale!
Decree on the admission of additives to foodstuff for technological purposes (Anlage 4 Teil B zur ZZulV, 2012).

<table>
<thead>
<tr>
<th>Additive</th>
<th>Foodstuff</th>
<th>Maximum permitted amount (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium phosphates (E 339)</td>
<td>Energy drinks, table water</td>
<td>500</td>
</tr>
<tr>
<td>Potassium phosphates (E 340)</td>
<td>Beverage whitener</td>
<td>30,000</td>
</tr>
<tr>
<td>Calcium phosphates (E 341)</td>
<td>Beverage whitener for slot machines</td>
<td>50,000</td>
</tr>
<tr>
<td>Salts of ortho-phosphoric acid Diphosphate (E 450)</td>
<td>Ice cream</td>
<td>1,000</td>
</tr>
<tr>
<td>Triphosphate (E 451)</td>
<td>Desserts</td>
<td>3,000</td>
</tr>
<tr>
<td>Polyphosphate (E 452)</td>
<td>Powdered dry desserts</td>
<td>7,000</td>
</tr>
<tr>
<td>Fine pastries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flour</td>
<td>Fine pastries</td>
<td>20,000</td>
</tr>
<tr>
<td>Flour, baking quality</td>
<td>Flour, baking quality</td>
<td></td>
</tr>
<tr>
<td>Soda bread</td>
<td>Soda bread</td>
<td>20,000</td>
</tr>
<tr>
<td>Liquid eggs</td>
<td>Liquid eggs</td>
<td>10,000</td>
</tr>
<tr>
<td>Gravies</td>
<td>Gravies</td>
<td>5,000</td>
</tr>
<tr>
<td>Soups, broths</td>
<td>Soups, broths</td>
<td>3,000</td>
</tr>
<tr>
<td>Breakfast cereals, snacks</td>
<td>Breakfast cereals, snacks</td>
<td>5,000</td>
</tr>
</tbody>
</table>

The P intake with food products doubled since the 1990s (Rindlisbacher 2012).
The Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) estimates that in relation to the produce 20-75% of the food or 20 million tonnes of groceries are disposed each year in Germany.

FAO valued the dumping of foodstuff to one third of the total production worldwide.
The P dilemma

withering crops or withering waterbodies?

Severe P deficiency in maize

Severe eutrophication of a lake
Agriculture is the largest consumer and non-point emitter of P.
Manure application is restricted to 170 kg/ha*yr N, but additional mineral fertilizer input is not regulated.

As a consequence increasing soil P levels go along with escalating mineral and organic fertilizer rates.

P content of plants is not related to soil P status and P surplus in the nutrient balance.

(Schumann et al. 1997- Landbauforschung Völkenrode, special issue 180)
Options for improving P efficiency in agriculture

- Targeted P nutrition of livestock
- P-efficient crop plants
- Site-specific P management
- Safe recycled & new P fertilizer materials

Ultimate target is a closed P cycle on farms!
Site-specific nutrient management

Local knowledge  Variable rate fertilisation

(Haneklaus and Schnug 2006. Handbook of Precision Agriculture - A Global Perspective, pp. 91-151)
The small-scale variability of soil and plant parameters may be within a paddock as high as in the whole surrounding landscape.

(Haneklaus and Schnug 2006. Handbook of Precision Agriculture – A Global Perspective, pp. 91-151)
Mismatch of P demand and uniform P fertilizer rates
P fertiliser rates may equal off-take by harvest products on soils where the soil P status is sufficiently high for obtaining the potential yield.

Origin of nutrients in harvest products of cultivated plants

Annotation: off-take with target yield
D = fertiliser; B = nutrients from previous fertiliser applications; C = native soil nutrients; b = Utilisation efficiency of accumulated nutrients; c = utilisation efficiency of native nutrients in soil; d = utilisation efficiency of fertiliser-derived nutrients in the year of application


P-rates based on off-take are economically viable and ecologically sound!
Assessing and addressing the small-scale spatial variation of P in soils

- Directed sampling
- Identification of monitor pedocells for soil sampling
- Optimizing supply with essential nutrients, organic matter and biological activity
- Using exclusively water or citric acid soluble P forms
- Accounting for P in farmyard manure to 100%
- P fertilizer rates:

\[ P_{\text{CAL}} < 75 \text{ mg kg}^{-1} \text{ P}, \text{ then rates} > \text{ off-take} \]
\[ P_{\text{CAL}} > 75 \text{ mg kg}^{-1} - 100 \text{ mg kg}^{-1} \text{ P}, \text{ then rates} = \text{ off-take} \]
\[ P_{\text{CAL}} > 100 \text{ mg kg}^{-1} \text{ P}, \text{ then no P until} P_{\text{CAL}} < 100 \text{ mg kg}^{-1} \text{ P} \]

(rule of thumb: soil P content halves within 8-10 years)
Algorithms for a balanced variable rate input of N, P and K within a three year crop rotation employing a NPK fertilizer with tailor-made nutrient ratio

(Haneklaus and Schnug 2006. Handbook of Precision Agriculture - A Global Perspective, pp. 91-151)
Balanced P use of manure = rates compensate P demand

Mean off-take of 22 kg/ha P = 139, 87 and 72 kg/ha N
(dairy cows, pigs and broiler)

Maximum manure rate of 170 kg/ha N = 27, 43 and 52 kg/ha P
(dairy cows, pigs and broiler)

Algorithms for manure application

If P demand ≥ off-take, then variable manure rate.
If P demand = off-take, then uniform manure rate.
If P demand < off-take, then no manure.

Variation of P content in manure

<table>
<thead>
<tr>
<th>Source</th>
<th>Cattle</th>
<th>Pigs</th>
<th>Poultry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnett 1994</td>
<td>25.0 - 57.6</td>
<td>5.8 - 47.0</td>
<td>16.2 - 23.0</td>
</tr>
<tr>
<td>Derikx et al. 1997</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sharpley and Moyer 2000</td>
<td></td>
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</tr>
</tbody>
</table>

Limitations

- Suitable for direct use of poultry manure
- Cattle and pig manure require conditioning

Sources:
Norms for recycled fertilizer products

Declaration of P speciation including guideline values for minimum quantities
Contamination with xenobiotics and heavy metals
Hygiene
Mineral composition of manure and digestate samples

<table>
<thead>
<tr>
<th>Product</th>
<th>d.m (%)</th>
<th>P (% d.m.)</th>
<th>Zn (mg/kg d.m.)</th>
<th>Cu</th>
<th>Pb</th>
<th>Cd</th>
<th>Cr</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original substrate 1</td>
<td>9.9</td>
<td>0.5</td>
<td>188</td>
<td>54</td>
<td>1.4</td>
<td>0.1</td>
<td>25</td>
<td>11</td>
</tr>
<tr>
<td>Digestate 1</td>
<td>7.9</td>
<td>0.6</td>
<td>301</td>
<td>81</td>
<td>2.2</td>
<td>0.2</td>
<td>23</td>
<td>10</td>
</tr>
<tr>
<td>Original substrate 2</td>
<td>6.6</td>
<td>1.1</td>
<td>1110</td>
<td>81</td>
<td>1.2</td>
<td>0.2</td>
<td>8.5</td>
<td>7.8</td>
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<tr>
<td>Digestate 2</td>
<td>3.8</td>
<td>1.9</td>
<td>2115</td>
<td>145</td>
<td>1.2</td>
<td>0.4</td>
<td>8.9</td>
<td>10</td>
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<tr>
<td>Original substrate 3</td>
<td>5.3</td>
<td>0.6</td>
<td>334</td>
<td>41</td>
<td>0.7</td>
<td>0.2</td>
<td>12</td>
<td>6.9</td>
</tr>
<tr>
<td>Digestate 3</td>
<td>8.3</td>
<td>1.1</td>
<td>628</td>
<td>85</td>
<td>1.2</td>
<td>0.3</td>
<td>11</td>
<td>7.8</td>
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<tr>
<td>Gasified pig manure</td>
<td>3.9</td>
<td>1605</td>
<td>241</td>
<td>3.1</td>
<td>0.1</td>
<td>61</td>
<td>28</td>
<td></td>
</tr>
</tbody>
</table>

% of total P

- Water: <0.01
- Alkaline ammonium citrate (AAC): 19
- Neutral ammonium citrate (NAC<sub>EU</sub>): 37
- Water + NAC: 40
- Citric acid: 54
- Formic acid: 66

(Schick et al. 2013. Report on the chemical quality of different types of manure (processed and unprocessed) including P solubility. www.balticmanure.eu)
Recommendations for farmers

1. Set-up your own on-farm experimentation
2. Postulate full declaration of fertilizer materials
3. Treat your soils as an unique heritage

Recommendations for policy makers

1. Mandatory recording of whereabouts of manure
2. Adopt full declaration of fertilizer materials (EU)
3. Balanced fertilisation is soil and marine protection
We destine agriculture-to-be!