Factors affecting the water extractable phosphorus from compost

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“Phosphorus Peak” (Jasinski, 2006; EFMA, 2000)

Phosphate rock are utilized to produce P fertilizers, (Cordell et al., 2009)
Volatilità dei prezzi della roccia fosfatica e dei fertilizzanti.

Introduction

Future P lack

Together with nitrogen and potassium, phosphorus is a crucial ingredient in fertilizer. It is extracted from phosphorus-rich rock in the form of phosphate. Morocco, China, South Africa and the U.S. hold 83 percent of the world’s easily exploitable phosphate rock and contribute two thirds of the annual phosphate production (circles, below). At current rates of extraction (bars, below), known U.S. reserves are projected to last 40 years. Globally about 90 years’ worth of phosphorus remains. Once the resource starts running out, less economical supplies may have to be tapped, which could result in higher prices and market disruptions. Already production has been declining despite the incentive of increasing prices (graph, right); last year the price spiked up because of tight supply and increased demand.

Spotted production
High risk for purchasing

Phosphate Rock Reserves (thousands of metric tons)

- Australia: 82,000
- Brazil: 260,000
- Canada: 25,000
- China: 4,100,000
- Egypt: 100,000
- Israel: 180,000
- Jordan: 900,000
- Morocco: 5,700,000
- Russia: 200,000
- Senegal: 50,000
- South Africa: 1,500,000

2008 Mine Production (thousands of metric tons)

- Australia: 2,300
- Brazil: 6,000
- Canada: 800
- China: 3,000
- Egypt: 1,000
- Israel: 3,100
- Jordan: 5,500
- Morocco: 28,000
- Russia: 11,000
- Senegal: 600
- South Africa: 2,400
Introduction

P cycle in the food and non-food crop production (Cordell et al., 2009)

P total production (Mt y⁻¹)

P in Compost & Digestates 1 Mt y⁻¹
Introduction

Compost as possible P source

Amount of Selected Organic Waste for composting and # of operating composting plants in Italy (Consorzio Italiano Compostatori CIC, 2014).

≈5.500.000 ton of selected organic waste yr⁻¹

Amount of selected organic waste for anaerobic digestion and # of operating anaerobic digestion plants in Italy (CIC, 2014).

≈25.000 ton P yr⁻¹
Objectives

Assessment of the different P forms in compost for a better knowledge for rational agronomic re-utilization

- $H_2O$ extractable P is recognized to be readily available for plant nutrition;
- $NaHCO_3$ extractable P is recognized to be available in the short-term;
- $NaOH$ extractable P is recognized to be available in the long-term.

- Assess the main factors affecting the $H_2O$ extractable P in compost beside to the study of factors affecting the midle-long term releaseable P ($NaHCO_3$ and $NaOH$).
26 compost samples from the northern-center Italy:

- Selected organic fraction of municipal solid waste with tree pruning;
- Anaerobic digestate from the selected organic fraction of MSW with tree pruning (wet and dry-batch digestion);
- Green waste (tree pruning).
Materials & Method

- Assessment of the main physical chemical traits:
  - pH, TS, VS, C, N, C/N;
  - Stability: (Oxygen Uptake Rate);
  - Total P content and other elements: Ca, Fe, Al, Mn, Mg;

- Assessment of the $\text{H}_2\text{O}$ extractable P:
  - 300 mg of sample in 30 ml $\text{H}_2\text{O}$ (2h, 25°C), centrifugation, filtration;
  - Total P via ICP;
  - Inorganic P via Murphy and Riley method;
  - Organic P = Total P - Inorganic P.

- Sequential extraction (on selected stable compost):
  - $\text{H}_2\text{O}; \text{NaHCO}_3$ 0.5 M pH 8.5; NaOH 0.1 M; HCl 1M; $\text{H}_2\text{SO}_4$ 96%.

- Study of the relationships between those variable and P extractability (Principal component analysis; PCA).
Results
Results

Stability (OUR)

Compost OUR (mmol O₂ kg⁻¹ VS h⁻¹)
Results

Total P (aqua regia)

Average P content
(4.6 mg g⁻¹)
Results

Ratios between different P forms in compost

Ratio between H$_2$O extractable and total P in tested compost ($P_{H2O}/P_{tot}$)
Results

Ratio between different P forms in compost

Ratio between water soluble inorganic P and total P extractable in water ($P_i/P_{H2O}$) and between water soluble organic P and total P extractable in water ($P_o/P_{H2O}$).
Results

Factors affecting P extractability in water

PC 1 (Var. % 28.5)
-1.0 -0.5 0.0 0.5 1.0
PC 2 (Var. % 22.2)
-1.0 -0.5 0.0 0.5 1.0
PC 3 (Var. % 18.7)
-1.0 -0.5 0.0 0.5 1.0

Alcalinity
Po in H₂O

Results

Factors affecting P extractability in water

PC 1 (Var. % 28.5)
-1.0 -0.5 0.0 0.5 1.0
PC 2 (Var. % 22.2)
-1.0 -0.5 0.0 0.5 1.0
PC 3 (Var. % 18.7)
-1.0 -0.5 0.0 0.5 1.0

Stability
Po in H₂O
Sequential extraction on selected stable compost samples

\((\text{OUR} \leq 5 \text{ mmol O}_2 \text{ kg}^{-1} \text{ VS h}^{-1})\) as function of \(P_{\text{H}_2\text{O}}\)

![Graph showing the sequential extraction results for compost samples 14, 18, 9, and 12. The graph indicates increasing availability of P (percent total) across different pH conditions, with a legend for H2SO4, HCl, NaOH, NaHCO3, and H2O.]

- Increasing HCl-P – Ca bound
- Increasing H2O-P

Legend:
- Residual
- Not-available
- Available in the middle-term
- Available
- Readily available
## Results

### Sequential extraction, relationship with total CaCO<sub>3</sub> content

<table>
<thead>
<tr>
<th>Extraction</th>
<th>Relationship</th>
<th>Equation</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>H&lt;sub&gt;2&lt;/sub&gt;O-P</td>
<td>$y = -0.008x + 0.5738$</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>NaHCO&lt;sub&gt;3&lt;/sub&gt;-P</td>
<td>$y = 0.0108x + 0.0995$</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td>NaOH-P</td>
<td>$y = 0.0693x - 1.4043$</td>
<td>0.93</td>
<td></td>
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<tr>
<td>HCl-P</td>
<td>$y = 0.0018x - 0.0403$</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td>H&lt;sub&gt;2&lt;/sub&gt;SO&lt;sub&gt;4&lt;/sub&gt;-P</td>
<td>$y = 0.0018x - 0.0403$</td>
<td>0.99</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Classification</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weakly adsorbed</td>
<td>Available</td>
</tr>
<tr>
<td>Medium-available</td>
<td>Available</td>
</tr>
<tr>
<td>Strongly adsorbed</td>
<td>Not available</td>
</tr>
<tr>
<td>Not-available</td>
<td>Not available</td>
</tr>
</tbody>
</table>
Results

P apparent recovery fraction (ARF) on Ryegrass

Ryegrass in pot after 21 days of cultivation at 30 mg P kg$^{-1}$ in calcareous soil.
### Results

Relationships between $P_{\text{H}_2\text{O}}$, $P$ in $\text{P}_{\text{NaHCO}_3}$ and $P$ uptake by ryegrass

#### High P releaser

- $y = 0.8772x + 5.6742$; $R^2 = 0.73$

#### Poor P releaser

- $y = 1.0872x - 12.028$; $R^2 = 0.64$

**Relationships**

- $\text{H}_2\text{O}-P/\text{ARF}$ (3 weeks)
- $\text{H}_2\text{O}+\text{NaHCO}_3-P/\text{ARF}$ (6 weeks)
The 26 composts showed high variability of many traits:

- samples representative of compost production in Italy;

Total P content ($P_{tot}$) : variable but very interesting.

Good relationship with CaCO$_3$ and P extractable in:

- $\text{H}_2\text{O}$ (readily available);
- $\text{NaHCO}_3$ (available);
- $\text{HCl}$ (not available).

P availability resulted mainly CaCO$_3$ driven in tested stable compost.
Conclusion

- During the composting process the mineralized P-org precipitate with Ca, thus reducing plant available P;
- The study of (free) water soluble P beside to the labile Ca-bound (NaHCO$_3$) can reliably predict plant-available P from compost.
- (Stable) Compost utilization can ensure interesting amount of plant-available P this beside to the organic matter restoration, especially in mediterranean region (calcaceous soils).
- Longer pot trial are now running to assess the role of metal-bound P (NaOH-P).
Thank you for your attention

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Fattori influenti la estraibilità del P in H₂O

Factor loadings (PCA)

Results
PO$_4$(NH$_4$)$_2$ (150 kg ha$^{-1}$)  
30.1 kg P ha$^{-1}$

Compost (20 ton ha$^{-1}$)

Substitution hypothesis (20 ton ha$^{-1}$)
Discussione

Fosforo apportato con i diversi compost in un’ipotesi di distribuzione alla dose di 20 ton ha\(^{-1}\)

Fosfato biammonico (150 kg ha\(^{-1}\))
30,1 kg P ha\(^{-1}\)

Compost (20 ton ha\(^{-1}\))
25÷30 kg P prontamente e mediamente disponibile ha\(^{-1}\)

![Substitution hypotesis (20 ton ha-1)](image)
<table>
<thead>
<tr>
<th>Variable</th>
<th>PC 1</th>
<th>PC 2</th>
<th>PC 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUR</td>
<td>-0.42</td>
<td></td>
<td>-0.56</td>
</tr>
<tr>
<td>$P_i$, H$_2$SO$_4$</td>
<td>-0.60</td>
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<td>0.58</td>
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<tr>
<td>Ca</td>
<td></td>
<td>0.81</td>
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<td>Fe</td>
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<tr>
<td>Al</td>
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<tr>
<td>pH</td>
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<td>0.45</td>
<td>0.47</td>
</tr>
<tr>
<td>$P_i$</td>
<td></td>
<td>-0.85</td>
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</tr>
<tr>
<td>$P_o$</td>
<td></td>
<td></td>
<td>0.66</td>
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<tr>
<td>Variance (%)</td>
<td>28.5</td>
<td>22.3</td>
<td>18.7</td>
</tr>
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