Mineralization of Organic Nutrient Sources

The Traditional and the Novel

January 9, 2014

Winter Webinar #1
Agenda for Today

• why mineralization rates are needed
• methods of determining mineralization rate
• range of organic nutrient sources
• typical mineralization rates
• reasons for divergence from average rates
What the Regs Require

• all nutrient sources must be integrated into nutrient management plans
• organic sources typically contain both available and unavailable forms of nitrogen
• nutrient management planners must have a process to estimate plant available nitrogen (PAN)
Plant-Available Nitrogen (PAN)

- PAN = \( \text{Norg} \cdot (f-\text{min}) + \text{NH}_4-N \cdot (f-\text{con}) \)

- mineralization factor = f-min

- f-min = proportion of organic nitrogen that would be expected to be broken down in a particular season
organic nitrogen mineralization \( \rightarrow \) ammonium \( \rightarrow \) nitrate

production of end products

loss of starting product
How are Mineralization Rates Determined?

• *in situ*

• incubation studies

• laboratory estimates
Gold Standard – *In situ* Measurement of Net Mineralization

- measure ammonium and nitrate produced under actual field conditions
- limited in number of comparisons of organic sources
- limited in number soil and environmental conditions
* 1 core for each comparison and replicate (3-5 replicates)
* soil core is removed and analyzed for ammonium and nitrate
* cation and anion exchange resins placed in bottom to capture any ammonium and nitrate that may leach
Incubations (Aerobic)

- most common method for net mineralization
- allows the comparison of many organic sources, soils and temperature regimes at one time
- leaching columns or periodic soil sampling
- allows investigation of mineralization rate over time
Incubation Setup

- replicate 3-5 times
- sample soil periodically
- analyze soil for ammonium and nitrate
- compare amended soil to untreated soil (control)

soil

soil + A₁

soil + A₂
Leaching Column Setup

- replicate each 3-5 times
- leach periodically
- analyze leachate for ammonium and nitrate
- compare amended soil to untreated soil (control)
* Gordillo and Cabrera, UGA
* gallon zip-lock bags
* 25°C/77°F
* field capacity moisture
* 15 different litters from commercial houses
* sampled at 0, 0.25, 0.5, 1, 3, 7, 14, 28, 42, 70, 84 and 112 days
* Gordillo and Cabrera
* gallon zip-lock bags
* 9 important ag soils
* 25°C/77°F
* field capacity moisture
* sampled at 0, 0.25, 0.5, 1, 3, 7, 14, 28, 42, 70, 84 and 112 days
Let’s Summarize Their Results

- average mineralization rate of litters was 0.60
- 2 phase processes – fast ($N_f$) and slow ($N_s$)
  - on average, 50% of the total N mineralized did so in 24 hours
  - $N_f$ varies widely across litters; $N_s$ was less variable
  - $N_f$ can be predicted from the uric acid content of the litter
- soil texture impacted mineralization rate
  - a single litter on 9 soils
  - loamy sands > sandy loams > clays
(Cabrera, UGA)

Department of Environmental Science and Technology
Compost and Poultry Litter (as sampled)

- Ammonium
- Uric acid
- Other organic N

Increasing stability from left to right:

- Ammonium nitrogen
- Organic N

Available → Labile → Stable
Laboratory Estimates of Net Mineralization

• goal – a quick chemical extract that is highly related to actual net mineralization

• success story
  – poultry litter
  – practical for ag testing labs
    • 1-2 days, additional extraction
  – water-soluble organic nitrogen
    • urea & uric acid
    • likely sources of mineralizable N
$R^2 = 0.87$
RMSE = 1.72
CV = 10.2
$n = 60$

PMN = \(-0.018 + 1.293\) WSON
Gale et al., 2006 JEQ
OR & WA, 2 years
Families of Organic Sources

• animal manures
• meat and seafood processing residuals
• plant products
• yard waste composts and residuals
• commercial and on-farm composts
• bioenergy residuals
  – biodiesel and ethanol residuals
## Mineralization Rates* of Animal Manures (f-min)

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Year of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>broilers</td>
<td>0.50</td>
</tr>
<tr>
<td>layers</td>
<td>0.60</td>
</tr>
<tr>
<td>sheep and goats</td>
<td>0.30</td>
</tr>
<tr>
<td>beef and dairy cattle</td>
<td>0.35</td>
</tr>
<tr>
<td>swine</td>
<td>0.50</td>
</tr>
<tr>
<td>horse</td>
<td>0.20</td>
</tr>
</tbody>
</table>

* fraction of original organic N
Mineralization Rates* of Meat & Fish Processing Residuals (f-min)

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Year of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>blood meal</td>
<td>0.65 - 0.70</td>
</tr>
<tr>
<td>feather meal</td>
<td></td>
</tr>
<tr>
<td>hydrolyzed</td>
<td>0.60 - 0.65</td>
</tr>
<tr>
<td>fresh</td>
<td>0.10</td>
</tr>
<tr>
<td>fish powder</td>
<td>0.60 - 0.65</td>
</tr>
<tr>
<td>pelletized fish by-product</td>
<td>0.93</td>
</tr>
</tbody>
</table>

* fraction of original organic N
# Mineralization Rates* of Plant Products (f-min)

<table>
<thead>
<tr>
<th>Residual Type</th>
<th>Year of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>castor cake</td>
<td>0.45</td>
</tr>
<tr>
<td>lupine seed meal</td>
<td>0.35</td>
</tr>
<tr>
<td>Phytoperls™ (corn processing waste)</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Muller et al, 2006, J. Plant Nutrition and Soil Science

* fraction of original organic N
Mineralization Rates* of Yard Waste and Composts (f-min)

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Year of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huck’s <em>Hen Blend</em> (VA)</td>
<td>0.002</td>
</tr>
<tr>
<td>(8 parts yard waste - 1 part hen manure, C/N = 29)</td>
<td></td>
</tr>
<tr>
<td>Panorama <em>Pay Dirt</em> (VA)</td>
<td>0.05</td>
</tr>
<tr>
<td>(1 part yard waste - 2 parts poultry litter, C/N = 18)</td>
<td></td>
</tr>
<tr>
<td>leaves (fresh) (NJ)</td>
<td>-0.08 (scl) – 0.05 (sl)</td>
</tr>
<tr>
<td>grass clippings (NJ)</td>
<td>0.25 (scl)-0.40 (sl)</td>
</tr>
</tbody>
</table>

* fraction of original organic N
<table>
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<th>Material Type</th>
<th>Year of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bovung$^1$</td>
<td>-0.02</td>
</tr>
<tr>
<td>Fertilife$^1$</td>
<td>-0.02</td>
</tr>
<tr>
<td>Erth-rite-C$^1$</td>
<td>0.05</td>
</tr>
<tr>
<td>on-farm sheep manure &amp; house-hold vegetable waste compost</td>
<td>-0.05</td>
</tr>
</tbody>
</table>

$^1$ Douglas and Magdoff

* fraction of original organic N
# Mineralization Rates* of Bioenergy Residuals (f-min)

<table>
<thead>
<tr>
<th>Residual Type</th>
<th>Year of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>biodiesel residue</td>
<td></td>
</tr>
<tr>
<td>canola meal</td>
<td>0.40</td>
</tr>
<tr>
<td>mustard seed meal</td>
<td>0.60</td>
</tr>
<tr>
<td>bioethanol residue</td>
<td></td>
</tr>
<tr>
<td>wheat</td>
<td>0.30</td>
</tr>
<tr>
<td>corn</td>
<td>0.55</td>
</tr>
<tr>
<td>methane digestate (swine manure feedstock)</td>
<td>0.20</td>
</tr>
</tbody>
</table>

* fraction of original organic N
**Figure 5:** Mineral-fertilizer equivalents (% MFE) for several organic fertilizers characterizing N availability in the year of application.

*Abbildung 5:* Mineraldünger-Äquivalente (% MFE) für verschiedene organische Dünger zur Charakterisierung der N-Verfügbarkeit im Jahr der Anwendung.

Gutser et al., 2005, J. Plant Nutrition and Soil Science
Uncertainty in Utilization of Organic Nutrient Sources

• tabled mineralization rates are averages

• actual mineralization rates may vary due to composition of organic material, soil, or weather conditions

• confirming adequate N is very important for crops fertilized with organic nutrient sources!
Variability Within a Source Type

- Delaware study of 20 litters from commercial broiler houses incubated with same soil
  - average mineralization was 66%; range was 21% to 100%
- Georgia study of 15 litters in same soil
  - average mineralization was 60%; range was 41% to 85%
- USDA study of 107 dairy manures in Northeast
  - mineralization ranged from 0% to 55%
The Weather?

- mineralization is a microbial-driven process
  - cooler than usual?
  - wetter than usual?
  - drier than usual?

Slower breakdown of labile organic materials!
Curtin et al. SSSAJ, 2012
Fig. 5. Nitrite plus nitrate concentrations at six temperatures in a papermill sludge-amended soil minus those concentrations in an unamended soil related to (a) days and (b) degree days (data from Honeycutt et al., 1988).
Overall Conclusions...

- nutrients contained in organic molecules must be mineralized before they are available for plant growth
- for a specific organic material type, considerable variability may exist
- the same organic material may mineralize differently in different soils
- environmental conditions cause year-to-year variability of identical materials