Fertilization of maize with only manure; can it be done?

Danish Crop Production Conference
MCH Herning Kongrescenter
15 January 2014

Shabtai Bittman* and Derek Hunt
Agriculture and Agri-Food Canada, Agassiz, BC
Manure Map of Canada
(Not for tourism purpose)

Study location
Lower Fraser Valley

Total manure N spread (kg ha\(^{-1}\) farmland)
> 128,000 cattle
(mostly high producing dairy)
16 million chickens
$1.6 billion farmgate revenue
> 2.5 million people
Ammonia emission contributes to poor visibility (and costs tourism income)
Ammonia emission contributes to poor visibility (and harms scenic tourism)
Concerns about fresh water

Research centre
Profile of Dairy Farms in Lower Fraser Valley

- 2.5 milking cows per ha (plus dry cows and replacements)
- 50-60% of feed is home grown
- Land area: ~50% grass silage (5 harvests) and 50% corn silage
- Crop >50% corn silage
- Imported feed and fertilizer result in nutrient surplus
Challenges in using manure to replace fertilizer:

- Knowing nutrient content
- Reliable and predictable response
- Risk of environmental contamination (esp. nutrients)
- Biosafety and odour
- Logistics (dilute/ heavy, regulations, etc.)
Challenges to using manure as fertilizer:

- Knowing nutrient content
- Reliable and predictable response
- Risk of environmental contamination (esp. nutrients)
- Biosafety and odour
- Logistics (dilute/ heavy, regulations, etc.)

**Nutrient imbalance (Low N:P ratio)**
Is starter fertilizer needed for corn on dairy farms in the Lower Fraser Valley?

Most fields, most years there is a benefit to starter fertilizer.
Challenge:
To replace starter (and season-long) fertilizer for maize with precision placed dairy slurry

Slurry source:
High-producing dairy farms using sawdust bedding
1. Injecting slurry

Slurry injected at corn-row spacing (75-cm) to a depth of ~15 cm, covered and left to soak for ~3-5 days to supply 30 kg P/ha.

2. Precision corn planting

Corn was planted a few days later at same (75-cm) spacing, <10 cm from the manure injection furrow.
Challenge:
To replace starter (and season-long) fertilizer with precision placed dairy slurry

Study 1
Precision-placed whole dairy slurry

Study 2
Precision-placed separated (settled) dairy sludge
Methods: Study 1

Properties of whole slurry

<table>
<thead>
<tr>
<th></th>
<th>Dry Matter (%)</th>
<th>TAN$^\dagger$ (g kg$^{-1}$)</th>
<th>Total-N (g kg$^{-1}$)</th>
<th>Total P (g kg$^{-1}$)</th>
<th>N:P</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole slurry</td>
<td>5.9</td>
<td>1.31</td>
<td>2.5</td>
<td>0.49</td>
<td>5.2</td>
<td>7</td>
</tr>
</tbody>
</table>

$^\dagger$Total Ammoniacal Nitrogen
Methods: Study 1

Replicated (4 reps) trial carried out in 2010-12 on Silty loam soil

<table>
<thead>
<tr>
<th></th>
<th>Application Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total N (kg ha⁻¹)</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>240</td>
</tr>
<tr>
<td>Total P (kg ha⁻¹)</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>46</td>
</tr>
<tr>
<td>Volume (m³ ha⁻¹)</td>
<td>28.8</td>
</tr>
<tr>
<td></td>
<td>57.6</td>
</tr>
<tr>
<td></td>
<td>86.4</td>
</tr>
</tbody>
</table>

Some treatments received starter synthetic fertilizer at ~ 30 kg P/ha and 20 kg N/ha
Emergence of corn precision-planted near sludge injection bands (till)
Emergence of corn precision-planted near sludge injection bands (no-till)
Early corn growth near sludge injection furrows
Slurry furrows
Dairy slurry (broadcast and injected) and N fertilizer on silage corn yield (2010-2012)
Dairy slurry (broadcast and injected) and N fertilizer on silage corn yield (2010-2012)
Dairy slurry (broadcast and injected) and N fertilizer on silage corn yield (2010-2012)
Broadcast/ incorporated slurry on whole plant N uptake by silage corn (2010-2012)
Broadcast / incorporated and injected slurry on whole plant N uptake by silage corn (2010-2012)
Broadcast / incorporated, injected slurry and fertilizer on plant N uptake by silage corn (2010-2012)
Dairy slurry (broadcast and injected) and fertilizer on P Uptake – based on total applied P
Effect of sludge injection distance on yield parameters of corn at harvest

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield</th>
<th>Grain yield</th>
<th>Dry matter</th>
<th>Plant P conc.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mg ha(^{-1})</td>
<td>Mg ha(^{-1})</td>
<td>%</td>
<td>mg g(^{-1})</td>
</tr>
<tr>
<td>Control</td>
<td>8.15 d</td>
<td>2.2 c</td>
<td>20.8 b</td>
<td>1.17 b</td>
</tr>
<tr>
<td>P fertilizer</td>
<td>15.6 bc</td>
<td>5.5 a</td>
<td>23.5 a</td>
<td>1.44 a</td>
</tr>
<tr>
<td>Sludge 0-cm</td>
<td>16.8 ab</td>
<td>5.8 a</td>
<td>23.2 a</td>
<td>1.48 a</td>
</tr>
<tr>
<td>Sludge 5-cm</td>
<td>17.0 a</td>
<td>5.9 a</td>
<td>22.9 a</td>
<td>1.44 a</td>
</tr>
<tr>
<td>Sludge 10-cm</td>
<td>15.0 c</td>
<td>4.9 b</td>
<td>21.6 b</td>
<td>1.49 a</td>
</tr>
</tbody>
</table>

Bittman et al. J. Env. Qual. 2012
Does manure band affect mycorrhizal (AMF) colonization in corn roots at critical 6-leaf stage

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure side</td>
<td>40.8 a</td>
<td>45.1 a</td>
</tr>
<tr>
<td>Non-manure side</td>
<td>42.3 a</td>
<td>46.5 a</td>
</tr>
</tbody>
</table>
Conclusions- Whole slurry

• Injected slurry produced higher silage yield, N uptake and P uptake than broadcast/ incorporated slurry even with starter at equivalent N and P rates.

• Injected slurry yielded as much as fertilizer but at somewhat higher (but reasonable?) N rates because of the non-available N fraction.

• For maximum yield with slurry, P will be in excess unless some is removed by separation.

• Long term effects of the applied organic N and C are being investigated.
Challenge:

To replace starter (and season-long) fertilizer with precision placed dairy slurry

Study 1
Precision-placed whole dairy slurry

Study 2
Precision-placed separated dairy sludge
Dual manure stream concept
- 2 products with contrasting N:P ratios

Solid liquid separation by settling

- Graph showing N:P ratios over time for low-solids supernatant and high-solids sludge.
Dual manure stream concept
- 2 products with contrasting N:P ratios

- High-solids sludge
- Low-solids supernatant

Surface banding for N on grass
Precision injection for P on corn
### Properties of high-solids fraction (sludge)

<table>
<thead>
<tr>
<th></th>
<th>Dry Matter (%)</th>
<th>TAN(^\dagger) (g kg(^{-1}))</th>
<th>Total-N (g kg(^{-1}))</th>
<th>Total P (g kg(^{-1}))</th>
<th>N:P</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole slurry</td>
<td>5.9</td>
<td>1.31</td>
<td>2.5</td>
<td>0.49</td>
<td>5.2</td>
<td>7</td>
</tr>
<tr>
<td>High-solids fraction (sludge)</td>
<td>8.4</td>
<td>1.04</td>
<td>2.4</td>
<td>0.7</td>
<td>3.5</td>
<td>7.8</td>
</tr>
</tbody>
</table>

\(^\dagger\)Total Ammoniacal Nitrogen
Methods: Study 2

Replicated (4 reps) trial carried out in 2010-12 on Silty loam soil

Application rates (based on P)

<table>
<thead>
<tr>
<th></th>
<th>Application Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total P (kg ha⁻¹)</td>
<td>16.3</td>
</tr>
<tr>
<td></td>
<td>32.5</td>
</tr>
<tr>
<td>Total N (kg ha⁻¹)</td>
<td>55.9</td>
</tr>
<tr>
<td></td>
<td>111.8</td>
</tr>
<tr>
<td>Volume (m³ ha⁻¹)</td>
<td>23.3</td>
</tr>
<tr>
<td></td>
<td>46.5</td>
</tr>
</tbody>
</table>

N rates standardized using ammonium nitrate fertilizer

Starter fertilizer used in some treatments at ~32kg P/ha and 20 kg N/ha
Apparent P recovery by corn receiving fertilizer and high-solids fraction at different N rates (2010-2012)

- Commercial fertilizer at 32 kg P ha\(^{-1}\)
- Manure sludge at 32 kg P ha\(^{-1}\) (112 kg N ha\(^{-1}\) from sludge)
- Manure sludge at 16 kg P ha\(^{-1}\) (56 kg N ha\(^{-1}\) from sludge)
Apparent P recovery by corn receiving fertilizer and high-solids fraction at different N rates (2010-2012)

- Commercial fertilizer at 32 kg P ha\(^{-1}\)
- Manure sludge at 32 kg P ha\(^{-1}\) (112 kg N ha\(^{-1}\) from sludge)
- Manure sludge at 16 kg P ha\(^{-1}\) (56 kg N ha\(^{-1}\) from sludge)
Apparent P recovery by corn receiving fertilizer and high-solids fraction at different N rates (2010-2012)

- Commercial fertilizer at 32 kg P ha$^{-1}$
- Manure sludge at 32 kg P ha$^{-1}$ (112 kg N ha$^{-1}$)
- Manure sludge at 16 kg P ha$^{-1}$ (56 kg N ha$^{-1}$)
Apparent P recovery and yield of corn receiving fertilizer and high-solids fraction at different N rates (2010-2012)

<table>
<thead>
<tr>
<th>Total N Applied (kg ha⁻¹)</th>
<th>Apparent P recovery (%)</th>
<th>Corn yield (t ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>13.4</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>15.7</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td></td>
<td>18.1</td>
</tr>
<tr>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>250</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Commercial fertilizer at 32 kg P ha⁻¹
Manure sludge at 32 kg P ha⁻¹ (112 kg N ha⁻¹)
Manure sludge at 16 kg P ha⁻¹ (56 kg N ha⁻¹)
Apparent P recovery and yield of corn receiving fertilizer and high-solids fraction at different N rates (2010-2012)
Apparent P and N recovery by corn receiving fertilizer and high-solids fraction at different N rates (2010-2012)
Apparent P and N recovery (%) by corn receiving fertilizer and high-solids fraction at different N rates (2010-2012)

- Commercial fertilizer at 32 kg P ha$^{-1}$
- Manure sludge at 32 kg P ha$^{-1}$ (112 kg N ha$^{-1}$)
- Manure sludge at 16 kg P ha$^{-1}$ (56 kg N ha$^{-1}$)

![Graph showing apparent P and N recovery](image-url)
Effect of synthetic fertiliser and dairy sludge applied by precision injection and broadcast/ incorporation on P uptake at the 6-leaf stage of maize (2010-2012)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>P uptake (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.33c</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>0.67b</td>
</tr>
<tr>
<td>Injection</td>
<td>0.84a</td>
</tr>
<tr>
<td>Inject +N fert</td>
<td>0.96a</td>
</tr>
<tr>
<td>Broadcast/inc +N fert</td>
<td>0.67b</td>
</tr>
</tbody>
</table>
Conclusions- Sludge

• P efficiency of injected sludge is equivalent to fertilizer at the same N rates.

• Injected sludge supplemented with mineral N matched fertilizer at equivalent N rates for all parameters.

• At half sludge rate with added commercial N, apparent P recovery from sludge was about 90%.

• Sludge can fully replace starter fertilizer for maize
Co-benefits of precision injection of dairy slurry and sludge

- Injection reduces ammonia loss (~15 kg N ha\(^{-1}\))
- Less risk of manure runoff
  
  \textit{but perhaps risk of leaching and N}_2\textit{O emissions}

Because sludge is more concentrated than whole manure

\begin{itemize}
  \item Sludge injection can be shallower (less power)
  \item Faster/ cheaper/ further manure hauling and application
  \item Lower risk of NH\(_3\) toxicity?
\end{itemize}
Conclusions- Final

• Our main goal of replacing starter fertilizer with whole slurry or sludge was achieved.

• Season long P can be supplied by the by slurry and sludge

• Injected slurry alone cannot fully replace N fertilizer at equivalent N rates due to the organic N fraction- but can match fertilier yields at higher N (but reasonable) N rates; soil building may occur and some of the organic N will be available in later years.
Current research (Long-term evaluation)

- What is the fate of injected organic N and C; will the N become available under no-till and in till management?
- Multi-media effects: what are the implications for nitrate leaching and nitrous oxide emissions?
Daily emissions of $\text{N}_2\text{O}$ after application of dairy slurry by injection and broadcasting or of N fertilizer over 12 months.
Thank you

PHOTO BY Heather Hirsch

Agassiz Research Centre
Toxicity? Can you plant too soon or too close to manure bands?

**Silage maize yield (t DM/ ha)**

<table>
<thead>
<tr>
<th>Planting Delay</th>
<th>Distance (cm)</th>
<th>Silage maize yield (t DM/ ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>days</td>
<td>0</td>
<td>17.6 ab</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>17.1 b</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>17.5 ab</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>16.1 b</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>16.3 b</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>19.4 a</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>16.7 b</td>
</tr>
<tr>
<td></td>
<td>16.6 b</td>
<td>16.3 b</td>
</tr>
</tbody>
</table>
Current research
(Long-term evaluation)

- What is the fate of injected organic N and C; will the N become available under no-till and in till management?
- Multi-media effects: what are the implications for nitrate leaching and nitrous oxide emissions?
**Current work: Cross media?**

**Effect of slurry injection on N₂O emission and leaching**

<table>
<thead>
<tr>
<th></th>
<th>Applied N</th>
<th>Total N₂O-N emission kg / ha</th>
<th>Emission factor (% of applied N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>0.63</td>
<td>--</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>163</td>
<td>2.77</td>
<td>1.7</td>
</tr>
<tr>
<td>Slurry broadcast</td>
<td>184</td>
<td>1.42</td>
<td>0.8</td>
</tr>
<tr>
<td>Slurry injected</td>
<td>184</td>
<td>3.42</td>
<td>1.9</td>
</tr>
<tr>
<td>Slurry injected (high dose)</td>
<td>266</td>
<td>5.43</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Summary and Conclusions

Method

• Whole dairy slurry or P-rich, high-solids sludge fraction is injected before planting corn.
• Corn seed is precision planted <10 cm from the injection furrow to help juvenile corn plants access nutrients.

Results

• Apparent P uptake efficiency and yield of corn were similar in plots receiving either high-solids sludge fraction or commercial fertilizer.
• Apparent recovery of 89% of manure sludge P was possible.

Co-benefits

• Co-benefits are reduced ammonia loss and reduced risk of runoff due to injection. Possible cross media effects (N2O emissions and leaching) are under investigation.
Overall conclusion

The dual stream approach using simple separation technique (settling) gives dairy farmers a strategic method for utilizing manure nutrients more efficiently.
Relationship between N:P ratio and dry matter content in farm dairy manures
Fraser Valley, BC, Canada

Bittman 2009 Proceedings of West Can Dairy Seminar
Dairy slurry (broadcast and injected) and N fertilizer on silage corn yield (2010-2012)
Dairy slurry (broadcast and injected) and N fertilizer on silage corn yield (2010-2012)
Dairy slurry (broadcast and injected) and N fertilizer on silage corn yield (2010-2012)
Broadcast / incorporated slurry on whole plant N Uptake by silage corn

Farm standard

N Uptake (kg N/ha)

Applied N (kg/ha)

Slurry Broadcast/ Incorporate

Farm-Slurry Brdcst/ Inc w/Starter
Broadcast / incorporated and injected slurry on whole plant N Uptake by silage corn

Farm standard

- Slurry Inject w/ Starter
- Slurry Inject
- Slurry Broadcast/ Incorporate
- Farm-Slurry Brdcst/ Inc w/Starter

N Uptake (kg N/ha)

Applied N (kg/ha)
Dairy slurry (broadcast and injected) and N fertilizer on silage corn yield – based on NH$_4$-N
Apparent P recovery by corn receiving fertilizer and high-solids fraction at different N rates (2010-2012)

- Commercial fertilizer at 32 kg P ha\(^{-1}\):
- Manure sludge at 32 kg P ha\(^{-1}\) (112 kg N ha\(^{-1}\))
- Manure sludge at 16 kg P ha\(^{-1}\) (56 kg N ha\(^{-1}\))
Soil N Budget

Leaky Pipe Model

Leaching and runoff