How Does Row Placed Fertilizer Fit in Today’s Agriculture

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University of Wisconsin
Why Starter Fertilizer

- Precision placement
  - Higher nutrient use efficiency
  - Avoid skips and lapping
- Limits fixation of P and K by the soil
- Soils slow to warm in the spring
- Environmental incentives?
Historically Starter “Was a Good Thing”

- Lower soil test levels
- Smaller planters
- Limited corn acreage per farm
- Lower availability of custom application
- Response often linked to P
Early Season Growth Response Not a Guarantee of Economic Response

- Starter fertilizers stimulate early plant growth and development
- Early season growth response is not always a predictor of yield response
- Yield response potential lower on high testing soils
- Grain moisture reductions observed with starter
Effect of Starter Fertilizer on Corn Growth Rate

Bullock et al., 1993
# Starter Fertilizer Effects on Corn Yield and Moisture, Urbana, IL

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield</th>
<th>Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>--- bu/a-a- ---</td>
<td>--- bu/a-a- ---</td>
<td>-------- % -----</td>
</tr>
<tr>
<td>Starter</td>
<td>181</td>
<td>140</td>
</tr>
<tr>
<td>Control</td>
<td>186</td>
<td>138</td>
</tr>
</tbody>
</table>

Soil test P = 68 ppm, K = 346 ppm. 10-34-0 starter, 13 lb N and 47 lb $P_2O_5$/acre

*Bullock et al., 1993*
Starter Fertilizer Use Has Changed

- Loss of time-use efficiency at planting
- Practicality of mounting and carrying attachments and fertilizer on very large planters
- Cost of attachments
- Lower potential for response on high testing soils
Many Attachment Options When Purchasing a Planter

Source: Kinze Mfg. website
## Economics of Starter Fertilizer Attachments in Illinois No-Till Corn

<table>
<thead>
<tr>
<th>Attachments on 8-row Planter</th>
<th>Total Planter List Price</th>
<th>Field Capacity</th>
<th>Avg. cost of 8-row planter with starter since purchase</th>
</tr>
</thead>
<tbody>
<tr>
<td>No attachments</td>
<td>$26,400</td>
<td>9.3</td>
<td></td>
</tr>
<tr>
<td>2 x 2-banded fertilizer attachments</td>
<td>$34,700</td>
<td>8.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Years after purchase</th>
<th>Seed-placed</th>
<th>2 x 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.05</td>
<td>4.10</td>
</tr>
<tr>
<td>4</td>
<td>1.35</td>
<td>2.70</td>
</tr>
<tr>
<td>6</td>
<td>1.10</td>
<td>2.20</td>
</tr>
<tr>
<td>8</td>
<td>1.00</td>
<td>2.00</td>
</tr>
<tr>
<td>10</td>
<td>0.90</td>
<td>1.80</td>
</tr>
</tbody>
</table>

Starter attachments increased planter price 31% and slowed planting 14%

Hibbard et al., 1996

Cost of starter attachments decreases with time and use (500 acres per year)
What Factors Affect the Probability of Response to Starter?

- Soil test P and K
- pH
- Organic matter
- Manure use
- Soil texture
- Hybrid maturity
- Planting date
- Previous crop
- Soil type
- Latitude
- Fertilizer grade
- Soil yield potential
- Weather
- Placement
- Tillage
Soil Test Levels Continue to Increase

Average soil test P levels of Wisconsin cropland fields over time

Non-responsive range
Regional Trend for More Conservation Tillage

- Eight Midwestern states:
  - 106 million acres of cropland
  - 37 percent of all U.S. cropland
- 46% of no-till acres in U.S. in the Midwest
- 2002 Midwest data
  - 17 million acres of no-till soybeans
  - 7 million acres of no-till corn
  - Forty-five million acres (42.5 %) used conservation tillage

CTIC Website (2002 data)
Soil Test Stratification Following Five Years of Tillage Management, Arlington, Wis.

Wolkowski, 2003 (corn/soybean rotation)
Fertilizer Placement Affects Corn Root Distribution (0-15 In.)

<table>
<thead>
<tr>
<th>Tillage</th>
<th>Fert. placement</th>
<th>Row</th>
<th>Untracked Inter-row</th>
<th>Tracked Inter-row</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH</td>
<td>ROW</td>
<td>17.1</td>
<td>3.0</td>
<td>0.8</td>
</tr>
<tr>
<td>CH</td>
<td>INTER-ROW</td>
<td>12.0</td>
<td>4.4</td>
<td>1.4</td>
</tr>
<tr>
<td>NT</td>
<td>ROW</td>
<td>19.8</td>
<td>2.5</td>
<td>0.8</td>
</tr>
<tr>
<td>NT</td>
<td>INTER-ROW</td>
<td>10.8</td>
<td>6.1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Kaspar et al., 1991
Conservation Tillage is More Responsive to Banding

- **Positional availability**
  - Lack of mixing by tillage
  - Immobilization

- **Wheel track vs. non-wheel track effects on root distribution**

- **Cooler soil conditions**

- **Reduced K uptake from zones of poor aeration**
## No-till Corn Yield Response to Starter Fertilizer in Selected Experiments

<table>
<thead>
<tr>
<th>Location</th>
<th>Starter Treatment</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missouri</td>
<td>N,P,K; 2 x 2</td>
<td>6 of 6 expts.</td>
</tr>
<tr>
<td>Iowa</td>
<td>N,P,K; 2 x 2</td>
<td>7 of 9 expts.</td>
</tr>
<tr>
<td>Buha et al. (1999)</td>
<td></td>
<td>4-18 bu/a incr.</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>N,P,K; 2 x 2</td>
<td>8 of 12 expts.</td>
</tr>
<tr>
<td>Illinois</td>
<td>N,P,K; 2 x 2</td>
<td>8 of 9 expts.</td>
</tr>
<tr>
<td>Ritchie et al. (1996)</td>
<td></td>
<td>14 bu/a incr.</td>
</tr>
</tbody>
</table>
Soil Temperature Affected by Tillage and Crop Residue

Effect on crop residue, Arlington, 1994

Effect on in-row soil temperature, Arlington, 1994

Wolkowski, 2000
Interactive Effect of Tillage and Row Fertilizer, Arlington, 1994-1996 (3 yr. avg.)

Wolkowski, 2000
Interaction Between Starter Fertilizer and Row Cleaners

Vetsch and Randall, 2000
Where Do We Put Starter

- Trend toward lower rates and N or N-P composition using fluids
- More interest in seed-placement
- Is 10-34-0 or similar N-P fertilizer adequate as a starter?
- Is a complete (N-P-K) fertilizer necessary?
- 2 x 2 versus seed
What About Seed-placement

- Some suggest higher availability for seed-placed materials
- Difficult to include K
- Avoid high salt carriers and use on salt-sensitive crops
- No urea, UAN, ATS
- Limit to 10 lb N + K₂O/a
- Use with caution on sandy or dry soils
Comparisons of Liquid and Dry Starter Fertilizers Applied to Corn, Arlington, Wis.

<table>
<thead>
<tr>
<th>Starter N+P₂O₅+K₂O</th>
<th>Placement</th>
<th>Corn yield 3 yr. avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0+0+0</td>
<td>----</td>
<td>125</td>
</tr>
<tr>
<td>3.2+6.5+3.2 “cold”</td>
<td>seed</td>
<td>133</td>
</tr>
<tr>
<td>3.2+6.5+3.2 “hot”</td>
<td>seed</td>
<td>128</td>
</tr>
<tr>
<td>6+24+24 liquid</td>
<td>2x2</td>
<td>139</td>
</tr>
<tr>
<td>6+24+24 dry</td>
<td>2x2</td>
<td>137</td>
</tr>
<tr>
<td>LSD (0.10)</td>
<td></td>
<td>11</td>
</tr>
</tbody>
</table>

Wolkowski and Kelling, 1985
Influence of Rate and Type of Seed-placed Fertilizer

Gelderman et al., 1995
Response Potential is Complicated
(Tillage, Planting Date, and Composition)

- **Tillage**
  - No-till
  - Moldboard plow

- **Planting Dates (four)**
  - Late April – Late May

- **Composition (lb/a, all received 10 lb N/a)**
  - Control (0 + 0)
  - $P_2O_5$ (25 + 0)
  - $K_2O$ (0 + 25)
  - $P_2O_5 + K_2O$ (25 + 25)

*Bundy and Widen, 1992*
<table>
<thead>
<tr>
<th>Starter N-P₂O₅-K₂O</th>
<th>Moldboard plow</th>
<th>No-till</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-0-0</td>
<td>153 b</td>
<td>143 b</td>
<td>148 c</td>
</tr>
<tr>
<td>10-25-0</td>
<td>157 b</td>
<td>149 ab</td>
<td>153 b</td>
</tr>
<tr>
<td>10-0-25</td>
<td>152 b</td>
<td>147 ab</td>
<td>150 bc</td>
</tr>
<tr>
<td>10-25-25</td>
<td>164 a</td>
<td>152 a</td>
<td>158 a</td>
</tr>
</tbody>
</table>

Average of four planting dates

(Bundy & Widen, 1992)
### Effect of Starter Fertilizer & Tillage on Grain Moisture

<table>
<thead>
<tr>
<th>Starter N-P$_2$O$_5$-K$_2$O (lb/acre)</th>
<th>Moldboard plow</th>
<th>No-till</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-0-0</td>
<td>24.5 NS</td>
<td>32.7 a</td>
</tr>
<tr>
<td>10-25-0</td>
<td>25.8</td>
<td>28.7 b</td>
</tr>
<tr>
<td>10-0-25</td>
<td>25.5</td>
<td>27.3 b</td>
</tr>
<tr>
<td>10-25-25</td>
<td>24.7</td>
<td>29.0 b</td>
</tr>
</tbody>
</table>

*Data from late May planting date (Bundy & Widen, 1992)*
## Planting Date and Tillage Effects on Starter Response

<table>
<thead>
<tr>
<th>Planting Date</th>
<th>Yield Response</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MP</td>
<td>NT</td>
<td></td>
</tr>
<tr>
<td>Apr. 23-26</td>
<td>+16</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>May 2-3</td>
<td>+3</td>
<td>+6</td>
<td></td>
</tr>
<tr>
<td>May 11-14</td>
<td>+15</td>
<td>+11</td>
<td></td>
</tr>
<tr>
<td>May 23-24</td>
<td>+9</td>
<td>+21</td>
<td></td>
</tr>
</tbody>
</table>

*Average of 3 years*
On-farm Validation

- 100 On-farm sites (total over 3 years)
- Major corn growing areas
- With/without starter
- Field scale strips, 3 reps.
- Production practices, site histories
- Plant height, 8 weeks
- Grain yield w/, w/o starter

Bundy and Andraski, Wis.
Overall Results

- Average starter rate = 15+26+32
- Most soil tests excessively high
  - P = 93% EH
  - K = 73% EH
- Average yield response: 4 bu/acre
- Economic return (4.5 bu/a) positive at 40% of sites
Relationship Between Selected Site Factors and Response to Starter (pr>F)

- Soil pH 0.99
- Manure use 0.93
- P in starter 0.91
- Soil OM 0.91
- Crop residue 0.87
- Texture 0.77
- Previous crop 0.64
- Soil test P 0.63
- N in starter 0.62
- K in starter 0.36
- Yield potential 0.31
- Planting date 0.29
- Soil test K 0.05
- Rel. maturity 0.05
Importance of Potassium in Starter Fertilizers
Research Shows the Value of K in Starter Compared with Broadcast

<table>
<thead>
<tr>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trmt</td>
<td>Yield</td>
<td>Trmt</td>
</tr>
<tr>
<td>K₂O (lb/a)</td>
<td>bu/a</td>
<td>K₂O (lb/a)</td>
</tr>
<tr>
<td>0</td>
<td>114</td>
<td>0</td>
</tr>
<tr>
<td>40 (2 x 2)</td>
<td>143</td>
<td>45 (2 x 2)</td>
</tr>
<tr>
<td>100 (bdct)</td>
<td>136</td>
<td>105 (bdct)</td>
</tr>
<tr>
<td>200 (bdct)</td>
<td>140</td>
<td>--</td>
</tr>
</tbody>
</table>

Wagar and Rehm, 2004
**Effect of Rotation, Tillage, and Fertilizer on Corn K Concentration 45 DAP, Arlington, Wis., 2001**

<table>
<thead>
<tr>
<th></th>
<th>CC</th>
<th>SbC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CH</td>
<td>ST</td>
</tr>
<tr>
<td><strong>NONE</strong></td>
<td>2.23</td>
<td>2.37</td>
</tr>
<tr>
<td><strong>BDCT</strong></td>
<td>2.35</td>
<td>2.19</td>
</tr>
<tr>
<td><strong>2 x 2</strong></td>
<td>2.85</td>
<td>3.26</td>
</tr>
</tbody>
</table>

*Wolkowski, 2003*
Response Of Corn To Tillage And Fertilizer Placement, Arlington, Wis. 2001-2003

Wolkowski, 2004
200 lb 9-23-30/a
Evaluaton of Response to K in Long-term Calibration Plots

- Long-term plots with wide range of soil test K (VL to EH, 60 to 265 ppm).
- Response to NPK starter (100 lb/a 9-23-30) across range of soil test K levels.
- Corn yield responses measured over 4 yr. (1993 to 1996)

Bundy and Andraski, Wis.
# Growing Season Characteristics

<table>
<thead>
<tr>
<th>Year</th>
<th>PDRM*</th>
<th>F.F. days</th>
<th>GDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>225</td>
<td>154</td>
<td>2055</td>
</tr>
<tr>
<td>1994</td>
<td>228</td>
<td>189</td>
<td>2293</td>
</tr>
<tr>
<td>1995</td>
<td>227</td>
<td>145</td>
<td>2413</td>
</tr>
<tr>
<td>1996</td>
<td>228</td>
<td>170</td>
<td>2043</td>
</tr>
</tbody>
</table>

*Planting dates: Apr. 30 to May 3; RM=105
Soil K Response Relationship Relative to Current Soil Test Interpretation Ranges at Arlington, 1993 To 1996
Relationship Between Soil Test K Level and Yield Response to Starter Fertilizer at Arlington, 1995

QRP

\[ y = 343 - 6.82x + 0.034x^2 \]

if \( x < 100 \)

\( y = 0 \) if \( x > 100 \)

\( R^2 = 0.52 \)  n=54
Relationship Between Soil Test K Level and Yield Response to Starter Fertilizer at Arlington, 1996

Yield response, bu/acre

Soil test K, ppm

VL      L       O       H                             EH
(34)   (34)   (12)      (7)                             (7)

QRP

\[ y = 145 - 2.04x + 0.0075x^2 \]
if \( x < 136 \)
\[ y = 6 \]
if \( x > 136 \)

\[ R^2 = 0.32 \quad n = 111 \]
Relationship Between Soil Test K Level and Yield Response to Starter Fertilizer at Arlington, 1993-1996

QRP

\[ y = 153 - 2.35x + 0.0092x^2 \]

if \( x < 128 \)

\[ y = 0 \] if \( x > 128 \)

\( R^2 = 0.34 \)  \( n=309 \)
Relationship Between Temperature (GDD And Departure – May to September) and Maximum Soil Test K Level Where Yield Response Occurred to Starter Fertilizer

\[ y = 1119 - 0.84x + 0.00017x^2 \]
\[ R^2 = 0.97 \]
Soil compaction destroys structure, reduces porosity, increases resistance to root growth, and limits aeration needed for root respiration.
Poorly Developed Root Systems Cannot Explore the Entire Soil Volume (Which Side Received Starter?)
Compaction Affects Nutrient Uptake

**Potassium Affected Most**

- Compaction reduces porosity and limits root growth
- Lowers soil $O_2$ and slower replenishment from the atmosphere
- $O_2$ needed for root respiration and active uptake of K
- Compacted soils are often responsive to K fertilization
Row K Effects on Corn Yield with Increasing Soil Compaction

Initial K Soil test = 102 ppm

Wolkowski, 1989
Summary

- Are we finished with starter?
  - Research shows it is worth the time and expense in many situations

- N or N-P starters may not maximize response
  - Complete (NPK) starters give a more consistent response

- Research shows K in starter is important
  - Reduced tillage
  - Low K soils
  - Compacted soils
Summary

- Frequency and size of response to starter is influenced by GDD accumulation
  - Response to starter occurred at higher soil test K levels in cooler growing seasons
- Use a complete starter
  - Use fluids containing K
  - Risks with seed placement
  - Recommend 10+20+20 (N+P$_2$O$_5$+K$_2$O) for soils slow to warm in the spring