High Yield Systems: Role of Placement and Timing

T. Scott Murrell
U.S. Northcentral Director

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Outline

• How close are yields to those that are possible?
• Concepts to carry with you when working in high-yield systems
  – Short-term efficiency vs. long-term soil fertility management
  – Characteristics of young root systems
  – Root-nutrient interactions in bands
  – Spatial variability introduced by bands
  – Redistribution of nutrients in the soil caused by crop growth
  – Using banding to address economic constraints
Yields:
Determining the potential
Yield goal vs. potential yield

• Farmers want to know how close their yields are to what is possible

• Yield goal:
  – Average of historical yields + _____%
  – “What has been done plus a little more”
  – Estimates for the coming season are used to determine “maintenance rates”

• Potential yield:
  – “…the maximum yield that could be reached by a crop in given environments” (Evans and Fischer. 1999. Crop Sci. 39:1544)
  – Estimated through crop growth models
Estimating potential yield

*Hybrid-Maize* plant growth simulation software
Yield attained vs. potential yield

<table>
<thead>
<tr>
<th>Year</th>
<th>S/C</th>
<th>S/C/C</th>
<th>S/C/C/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>203</td>
<td>204</td>
<td>202</td>
</tr>
<tr>
<td>2006</td>
<td>192</td>
<td>228</td>
<td>226</td>
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<tr>
<td>2007</td>
<td>185</td>
<td>268</td>
<td>226</td>
</tr>
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- **Yield attained**: 203, 192, 185
- **Potential yield with current practices**: 204, 228, 226
- **Potential yield with improved practices**: 268, 226

Corn grain yield (bu/acre)
Banded applications:

*Efficiency and soil tests*
Nutrient placement considerations

• Banding:
  – Less soil volume fertilized
  – Smaller portion of fertilizer is “tied up”
  – Roots proliferate where N and P are found
  – Rate may be too low to maximize yield
    • Fewer roots exposed to supply
    • Increase in influx rate by roots may not compensate for fewer total number of roots near P supplies

![Conceptual model](nutrient deficient soil)

Dry matter yield

0 20 40 60 80 100

Fertilized soil fraction, percent

Anghinoni and Barber, 1980
Mississippi River Basin (MRB) states recommending rate reductions with banded applications

Highlighted MRB states: MT, ND, MN, SD, NE, KY, WV

7 states

- MRB states
- Highlighted MRB states
- No data

Map showing states recommended for rate reductions and highlighted states.
A K recommendation that does consider yield goal: Example: MN – broadcast application

2000 – 2010 average yield = 157 bu/acre (NASS)
A K recommendation that does consider yield goal: 
Example: MN – banded application (40% reduction)

2000 – 2010 average yield = 157 bu/acre (NASS)

Neutral ammonium acetate extractable K (ppm)

V. Low  Low  Medium  High  Excessively High

Pounds above (+) or below (-) nutrient removal (lb K2O/acre)
Monitoring nutrient removal

- Short-term improvements in efficiency must be weighed against long-term impacts on soil fertility
- Consider creating a local database of crop removal rates for crops in your area
Banded applications near the seed at planting

Theoretical principles
Environmental effects: soil temperature

- Air temperature held constant at 77°F
- 23 day old corn seedlings measured

Dry weight, g/pot

Soil temperature, °F

Walker, 1969
Rate of K uptake by roots differs with plant age

Barber, 1978; Mengel and Barber, 1974
Rate of P uptake by roots differs with plant age

Barber, 1978; Mengel and Barber, 1974
Flux rate affects the rate of nutrient depletion

Lower P/K concentration

Higher P/K concentration

Diffusion
Early growth response does not necessarily translate to increased yield

- Larger plant dry weight from 500 to 1200 GDD
- Final plant dry weight not affected by starter
- Starter hastened:
  - Development
  - Maturation
- No yield increase

Bullock et al., 1993 (Illinois)
Banding nutrients together

Theoretical principles
N and P cause roots to “proliferate”

- Split-root experiment
- Percent of the total root system on the side with P was greater than that on the side without P

Anghinoni and Barber, 1980
Ammonium and nitrate: rhizosphere pH differences

\[ \text{NH}_4^+ + \text{H}^+ \]

Acid

Basic

\[ \text{NO}_3^- + \text{OH}^- \text{ or } \text{HCO}_3^- \]

Marschner, 2002
Rhizosphere pH affects P uptake by corn

- 11 day old corn
- Ammonium source reduced rhizosphere pH and increased P uptake

![Graph showing the relationship between rhizosphere pH and total P uptake. The graph includes data points for Wendigo SL, Oneida L, and Buford SiL, with different symbols representing different treatments: MCP + CaCl₂, MCP + Ca(NO₃)₂, and MCP + (NH₄)₂SO₄.](image-url)

Soon and Miller, 1977
Starter fertilizer: $\text{NH}_4^+$ and P should be placed together

Miller and Ohlrogge, 1958

Percent of the plant P coming from the band

Phosphate added to bulk soil, lb P$_2$O$_5$/A

Occurs regardless of P soil test level
Impact of banded applications on spatial variability

Theoretical principles
Months after initial application in the spring

6 mo. | 12 mo. | 18 mo.
--- | --- | ---
20 lb P₂O₅/A

Multiple of background concentration

1.5 | 3.0 | 4.5 | 6.0 | 7.5 | 9.0 | 10.5

2 in.

Stecker et al., 2001
Impact of successive banding

- Mexico silty clay loam soil
- Single 20 lb/A band fertilizes 2.6% of soil volume
- Volume assumed to be additive
- Annual applications stay ahead of volumetric reductions of specific bands over time

Stecker et al., 2001
Successive banding in different places creates concentrated zone that decay over time

- Placing bands in different places over time can lead to a greater volume of fertilized soil over time
Impact of crop uptake and on spatial variability

Theoretical principles
Transport of banded K

Nutrient uptake

Deposition and leaching

Diffusion
K uptake and leaching by a corn crop: Estimated quantities

K removal in 200 bu/A grain
(54 lb K₂O/A)

Total above-ground K uptake
(274 lb K₂O/A)

K leached from stover
(220 lb K₂O/A)

K leached from roots
(39 lb K₂O/A)

Murrell and Vyn, 2010
The role of starter fertilizer under economic constraints

Theoretical principles
Combination for maximum profit:
Wheat response to N and P

- **98 lb N/acre**
- **61 lb P₂O₅/acre**
- **Cost: $60/acre**

- **74 lb N/acre**
- **25 lb P₂O₅/acre**
- **Cost: $31/acre**

N = $0.18/lb
P₂O₅ = $0.70/lb
Wheat = $4.50/bu