Nitrogen Technology for Improving N Use Efficiency in Leafy Green Vegetable Production

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Grower Reported N from Fertilizers (117 Crop Records) Compared to Specific Crop Nitrogen Uptake

Spinach Records (2015)

Nitrogen from Fertilizers & Amendments Only

*Does not include N applied in irrigation water*
Challenges to improving NUE in Leafy Green Vegetables

• Rapid growth cycle and high rate of N is taken up in the last half of the cycle
• Double cropping
• Shallow rooted
• Irrigation management is key to keeping nitrate-N in the rootzone
• Spinach grown on high-density beds which are exclusively sprinkler irrigated
• High quality demands for final product
Strategies to Improve NUE in Leafy Green Vegetable Production

- Careful irrigation management
- Accounting for residual soil nitrate and adjusting fertilizer applications accordingly
  - Crop by crop diagnostic approach (not a program approach)
- These two strategies will provide the majority of the benefits that we can realistically achieve in this cropping system
- Use of deep rooted cover crops or rotational crops to take up residual soil nitrogen
Spinach Nitrogen Uptake

N uptake range 80-130 lbs N/A

6.0 lbs N/A/day

Days After 1st Water
Rooting Depth of Spinach

88% of all roots found in top 12” of soil at harvest
Nitrogen Fertilizer Technologies

• Most mineral nitrogen during the summer production season (warm soils) rapidly converts to nitrate and is leachable

• Are there ways to manage mineralization to nitrate and gain some increase in NUE?
Shallow root system and high water use makes it difficult to keep a high percent of soil nitrate in the area of active roots.
Ammonium has a positive charge and absorbs to clay and organic matter (both rich in negative charges).
Nitrogen Fertilizer Technologies

• In the corn belt of the US and in Europe “nitrogen stabilizers” are commonly used to reduce nitrogen losses via volatilization of urea and ammonical fertilizers, as well as nitrate leaching.

• Two categories fertilizer technologies:
  - Nitrification inhibitors
  - Controlled release fertilizers
Nitrogen Fertilizer Technologies

- Initial studies on nitrapyrin in the 1980’s with nitrapyrin on cool season vegetables looked promising.
- Since then production practices have changed:
  - advent of drip irrigation and movement away from furrow irrigation
  - Use of high-density beds for spinach and other crops
Nitrification Inhibitors

\[ \text{NH}_4^+ \rightarrow \text{NO}_3^- \]

• These chemicals disrupt the activity of *Nitrosomonas* and *Nitrobacter* bacteria which are responsible for nitrification of ammonium to nitrate.

• The goal is to keep more of the applied nitrogen as ammonium which is less susceptible to leaching.
• Dicyandiamide (DCD)
  ▪ Agrotain
  ▪ Agrotain Plus
    • Contains a urease inhibitor
• Dimethylpyrazolophosphate (DMPP)
  ▪ Entec (Europe)
  ▪ NovaTec
• Nitrapyrin
  ▪ N-Serve
  ▪ Instinct
  ▪ Vindicate
• Others

DMPP

Registered in CA on corn/wheat in the registration process for tree fruit and vegetables
Controlled Release Fertilizer

one example

- The diffusion of nitrate out of the prill is controlled by the thickness of the coating and environmental conditions (temperature).
- The coating meters the released nitrate rather than allowing the release of a large quantity that would build up a nitrate pool.
Controlled Release Fertilizers

Coated urea prills (polyurethane and other coatings)

Chains or rings of urea molecules (can be foliar applied)
## Nitrogen Technology Evaluations
### 2012-2016

<table>
<thead>
<tr>
<th>Material</th>
<th>Trade name</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nitrification inhibitors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrapyrin</td>
<td>Instinct</td>
<td>Inhibitor or Nitrosomonas and Nitrobacter, commonly used in the cornbelt</td>
</tr>
<tr>
<td>DMPP</td>
<td>Novatec</td>
<td>Inhibitor or Nitrosomonas and Nitrobacter. The active ingredient is commonly used in Europe</td>
</tr>
<tr>
<td>DCD + urease inhibitor fertilizer additive</td>
<td>Agrotain Plus</td>
<td>DCD is the nitrification inhibitor and is mixed with a urease inhibitor; used as a fertilizer additive</td>
</tr>
<tr>
<td>DCD + urease inhibitor impregnated urea prill</td>
<td>Super U</td>
<td>DCD is the nitrification inhibitor and is mixed with a urease inhibitor; formulated as a dry prill</td>
</tr>
<tr>
<td><strong>Controlled release</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polymer coated urea prill</td>
<td>Duration 45</td>
<td>Polyurethane coated urea prill</td>
</tr>
<tr>
<td>Urea triazone</td>
<td>N-Sure</td>
<td>Ring of urea molecules; liquid formulation</td>
</tr>
</tbody>
</table>
Fertilizer Technology Trials

• All trials included an untreated control and with a standard fertilizer rate, as well as a moderate rate: 25-35% less than standard (produce less yield)

• All fertilizer technology treatments were applied at the moderate rate to be able to observe any boost in yield that they might provide

• We interpreted any boost in yield as a possible improvement in NUE
Lettuce trials conducted at USDA research station.

Spinach trials conducted on grower’s fields.

Lettuce trial: Drip irrigation manifold

Spinach trial: Dry or sprayed-on materials
Average Relative Yield of Spinach Treated with Fertilizer Technologies

average of 7 trials
Average Relative Yield of Lettuce Treated with Fertilizer Technologies

average of 4 trials
## Timing of Application
### 2016 Lettuce Trial

<table>
<thead>
<tr>
<th>Material</th>
<th>Nitrapyrin application timing</th>
<th>Total N/A</th>
<th>Fresh Biomass tons/A</th>
<th>Head wt lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>---</td>
<td>150</td>
<td>28.313</td>
<td>1.81</td>
</tr>
<tr>
<td>Moderate</td>
<td>---</td>
<td>80</td>
<td>23.566</td>
<td>1.50</td>
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<tr>
<td>Nitrapyrin 0.50 lb ai(^1)</td>
<td>1(^{st}) app.</td>
<td>80</td>
<td>23.832</td>
<td>1.52</td>
</tr>
<tr>
<td>Nitrapyrin 1.0 lb ai(^1)</td>
<td>1(^{st}) app.</td>
<td>80</td>
<td>24.619</td>
<td>1.57</td>
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<tr>
<td>Nitrapyrin 0.50 lb ai(^2)</td>
<td>1(^{st}) &amp; 2(^{nd}) app.</td>
<td>80</td>
<td>25.363</td>
<td>1.62</td>
</tr>
<tr>
<td>Nitrapyrin 1.0 lb ai(^2)</td>
<td>1(^{st}) &amp; 2(^{nd}) app.</td>
<td>80</td>
<td>25.727</td>
<td>1.64</td>
</tr>
</tbody>
</table>
Nitrogen Technology

• The job of the nitrogen technologies is difficult because they are highly influenced by the soil system and are subject to biological, chemical and physical influences

• But, temperature, soil type, moisture, residual mineral N make prediction of efficacy on a field by field basis difficult
Nitrogen Technology

• Nitrogen technologies show potential for improving NUE
  ▪ The effect was modest, but is real

• These technologies do not replace good agronomic and irrigation practices, but can enhance these basic practices

• The longevity of the activity of nitrification inhibitors needs more research