Nitrogen Dynamics in High Density Vegetable Production Systems

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Nitrogen Management of High-Density Leafy Vegetables

• Nitrogen use in vegetable production in the coastal production district is now being monitored by the Central Coast Regional Water Quality Control Board

• Growers are looking for practices to bring N application rates closer to crop N uptake
Acreage and Value of High-Density Vegetables in California

• Acreage of high density crops
  ▪ 27,976 acres – spinach
  ▪ 21,884 acres - spring mix
  ▪ 4,317 acres - cilantro
  ▪ 21,400 acres - baby lettuce

• Combined value* of $453,757,000

* Baby lettuce value not available
High-Density Vegetable Crops

- Eighty-inch wide beds present a particular challenge for managing nitrogen and water
- Crops are planted densely with 24 - 32 seedlines across the wide bed top using 2 to 4 million seed per acre
- The crops are typically fast maturing, shallow rooted and exclusively sprinkler irrigated
- These characteristics create difficulties for achieving high N-use efficiency
- Growers are under pressure to meet strict quality standards from buyers for these leafy vegetables
Objectives of this Study

- Document the rate of N uptake and total N uptake of spinach, baby lettuce, mizuna and cilantro
- Evaluate quantities of irrigation water applied to these crops over the course of the growth cycle
- Evaluate the rooting depth over the growing season
- Evaluate fertilizer additives such as urease and nitrification inhibitors with pre/at-planting fertilizer applications to improve N use efficiency
- Utilize the information gained on nitrogen uptake, water needs and rooting depth to refine the algorithms in the CropManage
Days to Harvest

- Cilantro: 41-53 days
- Baby Lettuce: 24-35 days
- Mizuna: 19-29 days
- Spinach: 26-37 days
Nitrogen Uptake

Spinach

- 6.0 lbs N/A/day

Cilantro

- 3.5 lbs N/A/day

Baby Lettuce

- 4.1 lbs N/A/day

Mizuna

- 5.9 lbs N/A/day
# Biomass and Nitrogen Uptake

<table>
<thead>
<tr>
<th>Crop</th>
<th>Dry Biomass lbs/A</th>
<th>N total uptake lbs/A</th>
<th>N fertilizer lbs/A</th>
<th>N applied/uptake ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cilantro</td>
<td>2,054</td>
<td>104</td>
<td>208</td>
<td>2.0</td>
</tr>
<tr>
<td>B. lettuce</td>
<td>1,210</td>
<td>64</td>
<td>184</td>
<td>2.9</td>
</tr>
<tr>
<td>Mizuna</td>
<td>1,722</td>
<td>99</td>
<td>179</td>
<td>1.8</td>
</tr>
<tr>
<td>Spinach</td>
<td>2,197</td>
<td>128</td>
<td>180</td>
<td>1.4</td>
</tr>
</tbody>
</table>
# Nitrogen Uptake and N in Crop Residue after Harvest

<table>
<thead>
<tr>
<th>Crop</th>
<th>N total uptake lbs/A</th>
<th>N in residue lbs/A</th>
<th>% N uptake in residue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cilantro</td>
<td>104</td>
<td>47</td>
<td>45</td>
</tr>
<tr>
<td>Baby lettuce</td>
<td>64</td>
<td>24</td>
<td>38</td>
</tr>
<tr>
<td>Mizuna</td>
<td>99</td>
<td>41</td>
<td>41</td>
</tr>
<tr>
<td>Spinach</td>
<td>128</td>
<td>40</td>
<td>31</td>
</tr>
</tbody>
</table>
Baby lettuce residue
Mineralization of Crop Residue
most breakdown is complete in 4-6 weeks

Hartz, 2013
Available N from Vegetable Crop Residue after 8 Weeks

<table>
<thead>
<tr>
<th>Crop Residue</th>
<th>N content</th>
<th>N in crop residue</th>
<th>Net N mineralization after 8 weeks</th>
<th>Net N mineralization after 8 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent</td>
<td>lbs N/A</td>
<td>Percent</td>
<td>lbs N/A</td>
</tr>
<tr>
<td>Spinach</td>
<td>6.2</td>
<td>40</td>
<td>82</td>
<td>33</td>
</tr>
<tr>
<td>Romaine</td>
<td>3.4</td>
<td>70</td>
<td>57</td>
<td>40</td>
</tr>
</tbody>
</table>

These crops residues mineralize so quickly that the quantity of N that they provide can best be assessed with a soil test.
# Phosphorus and Potassium Uptake

<table>
<thead>
<tr>
<th>Crop</th>
<th>Percent P at harvest</th>
<th>P uptake lbs/A</th>
<th>Percent K at harvest</th>
<th>K uptake lbs/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cilantro</td>
<td>0.3</td>
<td>6.7</td>
<td>6.9</td>
<td>141</td>
</tr>
<tr>
<td>Baby lettuce</td>
<td>0.5</td>
<td>7.1</td>
<td>7.8</td>
<td>105</td>
</tr>
<tr>
<td>Mizuna</td>
<td>0.6</td>
<td>9.5</td>
<td>5.3</td>
<td>97</td>
</tr>
<tr>
<td>Spinach</td>
<td>0.7</td>
<td>15.0</td>
<td>9.3</td>
<td>203</td>
</tr>
</tbody>
</table>
Rooting Depth of Spinach

In the first 15 days of the crop cycle, the roots only reached to 10 inches.
Rooting Depth of Spinach

88% of all roots found in top 12” of soil at harvest
Nitrate Distribution in Spinach Beds After Harvest

Most Active Roots

zone of efficient crop N removal

nitrate leached past root zone

NO3-N (mg/kg soil) vs. Depth (in)
Cilantro roots grow at the same rate as spinach but reached deeper into the soil presumably because of the longer crop cycle (47 vs 33 days).
## Water Use by High-Density Crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Applied water inches</th>
<th>Crop ET inches</th>
<th>Applied water/ETc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cilantro</td>
<td>5.8</td>
<td>3.7</td>
<td>156</td>
</tr>
<tr>
<td>Baby lettuce</td>
<td>12.5</td>
<td>4.3</td>
<td>283</td>
</tr>
<tr>
<td>Mizuna</td>
<td>4.1</td>
<td>3.1</td>
<td>148</td>
</tr>
<tr>
<td>Spinach</td>
<td>7.7</td>
<td>3.1</td>
<td>245</td>
</tr>
</tbody>
</table>
High-density 80-inch wide beds are exclusively sprinkler irrigated.

Uniformity of size and quality is critical for these machine-harvested crops.

Growers are careful to avoid sprinkler patterns.

This may increase water use on these crops.
Improving Nitrogen Use Efficiency

• Accounting for residual soil nitrogen
• Managing water to keep nitrate where most of the active roots occur
• Use of nitrogen technology
Effect of Residual Soil Nitrate on Spinach Yield

Initial Soil Nitrate-N = 5.8 ppm

Initial Soil Nitrate-N = 28.0 ppm
Shallow root system and high water use makes it difficult to keep a high percent of soil nitrate in the area of active roots.
Nitrification inhibitor:
Keeps ammonium from converting to nitrate for a brief period of time

4-12 inches area of active root system
Controlled Release: Urea encapsulated in a plastic prill. Urea is released to the area of active root system, 4-12 inches below the surface.
Nitrogen Technology Trial Update

• A total of 7 trials have been conducted over the past two years on spinach and baby lettuce

• All trials were conducted on commercial production fields using standard practices

• These trials are difficult on grower’s fields due to high levels of residual N in the soil and the common practice of applying N through the sprinkler irrigation system
Materials Tested

• Controlled release materials:
  ▪ Coated Urea – Duration
  ▪ Triazone - NSure

• Nitrification inhibitors:
  ▪ Nitrapyrin - Instinct
  ▪ DMPP - Novatec
  ▪ DCD – Super U
* Material sprayed over spread ammonium sulfate and then mulched into bed
2014 Soil Ammonium Levels

Ammonium-N ppm

AS + Nitrpyrin 120
UN232 + Nitrpyrin 120
Novatec 120
Duration ST 120
Super U 120
Amm Sulf 120
Amm Sulf 200
Untreated

5-May
13-May
19-May
27-May
3-Jun
9-Jun

Soil Ammonium Levels
Yield of Romaine
Drip Applied UN32 with Fertilizer Additives
Spence, 2014

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (lbs N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>0</td>
</tr>
<tr>
<td>Standard 155</td>
<td>155</td>
</tr>
<tr>
<td>Moderate 105</td>
<td>105</td>
</tr>
<tr>
<td>Nitrapyrin 105</td>
<td>105</td>
</tr>
<tr>
<td>Nsure 105</td>
<td>105</td>
</tr>
<tr>
<td>Novatec 105 lbs N</td>
<td>105</td>
</tr>
</tbody>
</table>
Fertilizer Trials Summary

• These trials have provided an opportunity to test established products and new materials that are not presently used commercially

• We have also had a chance to test methods of application of some of the materials

• It has been difficult to get significant differences in small plot trials in commercial conditions

• Under certain conditions, fertilizer technologies have shown to be useful in giving a boost to a low amount of nitrogen equal to the standard amount
Algorithms Developed for CropManage

- Nitrogen uptake curves
  - Used to make nitrogen fertilizer recommendations
- Crop canopy development
  - Used to calculate crop coefficient at all stages of the crop cycle
  - Used to estimate irrigation requirements
- Root development
Thank You for Your Attention