Nitrogen Management of Lettuce: Field Scale Studies

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Nitrogen Fertilization

• In the recent past, nitrogen fertilizers have been relatively inexpensive and constituted a small proportion of the production budget – 5%
• In 2008 there was a spike in fertilizer prices that increased interest in fertilizer use efficiency
Figure 2. Indexes of prices paid by US farmers 1990-1992 = 100

Source: USDA, National Agricultural Statistical Service.

Fertilizer prices follow fuel prices
Fertilizer Prices
(FOB, bulk)
Monthly Averages
January 2000 - Mid-December 2008

World fertilizer prices doubled in 2007 and reached all-time highs in April 2008. But prices began dropping dramatically in October and November.

FOB = free on board (average price, with buyer paying freight and insurance, to destination port).
DAP = diammonium phosphate. MOP = muriate of potash.

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Nitrogen Fertilization of Lettuce

- Nitrogen uptake by lettuce is modest:
  - 120 - 140 lbs N/A
- However:
- Lettuce is shallow rooted
- It requires frequent irrigation
- This scenario opens the door to losses of nitrogen in crop production
Nitrogen Cycle

Soil Organic Matter
Most soil N is in this form
(1000 – 3000 lbs N/A)

Mineralization*

Death

CEC

Plants

Nitrification

NH₄⁺

NO₃⁻

Microbes

Death

* Mineralization is a key step in making N available for plant growth. It is dependent upon adequate soil temperatures (i.e. > 50 F)
Nitrogen Cycle

Soil Organic Matter
Most soil N is in this form
(1000 – 3000 lbs N/A)

Mineralization*

CEC

Plants

NH$_4^+$

Nitrification

NO$_3^-$

Microbes

Death

Fertilizers
(AN20, CAN17)
Nitrogen Cycle

Soil Organic Matter
Most soil N is in this form (1000 – 3000 lbs N/A)

Mineralization*

NH$_4^+$

NO$_3^-$

Plants

Death

Microbes

Death

Denitrification

CEC

Leaching & Losses in Runoff
Importance of Nitrate

• Nitrogen from all sources tends to transform to nitrate in warm soils
• As a result, nitrate is the dominant form of available nitrogen in the soil
• It accumulates in quantities that can be easily measured
• Nitrate is beneficial in agricultural soils
• However, large pools of soil nitrate are susceptible to leaching past the root zone of the crop
Nitrogen Losses

- However, losses to ground or surface waters is a pollutant
- Causes eutrophication of surface waters
- Reduces the use of groundwater for municipal water (drinking water standard is <45 ppm NO₃)
- Nitrate losses are of great concern to many groups (Regional Water Board, Marine Sanctuary, Municipalities, etc)
Average Nitrate-Nitrogen Levels Measured in Soil Over Growing Season (two crops of lettuce)

Smith and Schulbach, 1996
Average Nitrate-Nitrogen Levels Measured in Soil Over Growing Season (two crops of lettuce)

20 ppm threshold

Beginning of winter fallow period

Smith and Schulbach, 1996
Techniques to Increase Nitrate Utilization by Crops

- Fertilizer management
  - Split applications, etc...
- Irrigation management
- Drip irrigation
  - spoon feed N
  - manage water carefully
- Slow release fertilizers
- Nitrification inhibitors
- Soil/plant tissue testing
• The residual soil nitrate acts just like fertilizer nitrogen and can be used for crop growth
• The nitrate quick test measures the pool of nitrate in the soil
• It gives a rapid measurement of nitrate that is available for crop growth
• 20 ppm is considered adequate for lettuce growth
Nitrogen Uptake Characteristics of Lettuce
• Lettuce takes up nitrogen in a predictable way:
  – 30 days after the first water lettuce takes up no more than 5-7 lbs of N
  – Between 30 to 60 days lettuce grows exponentially and requires careful fertilization
  – In total, it takes up about 120 - 140 lbs of N in the tops
Daily Nitrogen/A Uptake by Head Lettuce in Summer

\[ y = 3.306x - 98.36 \]
\[ R^2 = 0.931 \]
N Uptake of Lettuce

• In the northern Salinas Valley with a summer temperature regime that averages 21 GDD per day

• On average lettuce take up 3.3 lbs of N/A/day

• Lettuce grown in areas with higher GDD would have higher daily N uptake. For instance in King City, with warmer temperatures mean daily lettuce N uptake would average > 4 lbs of N/A.
Interest in Increasing Nitrogen Use Efficiency

Pressure for improving nitrogen use efficiency grew in 2008 due to:

• Spike in fertilizer prices
• Increased pressure to reduce nitrate losses from agricultural fields by the Regional Water Quality Control Board (renewal of the conditional waiver in 2009)
Farm-Scale Nitrogen Management Evaluations

Three trials conducted:

- Each field 20 – 27 acres
- Two treatments: Standard and BMP
- All conducted on the 2\textsuperscript{nd} crop of the season (more residual N available in the soil)
- Nitrogen in BMP plots managed based on use of the nitrate quick test
### Trial No. 1 – Head Lettuce

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Preplant 400 lbs 3.5-16.9-25</th>
<th>At planting 40 gals 6-16-0</th>
<th>Pre thinning 30 gals 21-0-0-8*</th>
<th>Thinning 30 gals 21-0-0-8</th>
<th>Post thinning 15 gals 21-0-0-8</th>
<th>Post thinning 30 gals 21-0-0-8</th>
<th>Total Nitrogen Per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>0 DAP 14.0</td>
<td>0 DAP 26.4</td>
<td>20 DAP 69.3</td>
<td>25 DAP 69.3</td>
<td>35 DAP 0.0</td>
<td>41 DAP 69.3</td>
<td>248.3</td>
</tr>
<tr>
<td>BMP</td>
<td>14.0</td>
<td>26.4</td>
<td>0.0</td>
<td>0.0</td>
<td>34.6</td>
<td>34.6</td>
<td>109.7</td>
</tr>
</tbody>
</table>

Planted June 26
Harvested Sept 3
Prior crop = lettuce
Trial No. 1 – Head Lettuce

Nitrate nitrogen in soil over season

mg N/kg dry soil

Days After Planting

0 5 10 15 20 25 30 35 40 45 50 55 60 65

0 20.0 40.0 60.0 80.0 100.0 120.0

Standard

BMP
Lettuce Nitrogen uptake lbs/A

Days after planting
Amount of Nitrogen in Top Three Feet of Soil on July 25 (30 DAP)

Standard = 425 lbs N/A
BMP = 538 lbs N/A in top 3 feet of soil

- 0 to 1 Feet: Standard = 250 lbs, BMP = 250 lbs
- 1 to 2 Feet: Standard = 150 lbs, BMP = 150 lbs
- 2 to 3 Feet: Standard = 50 lbs, BMP = 50 lbs
Cored Head Lettuce Yield
Ibs/A

- Standard: 54,649 lbs/A
- BMP: 55,506 lbs/A
- Untreated: 58,826 lbs/A
Lysimeters were installed and maintained at suctions that approximated the flow of gravitational water. Samples of this water were analyzed for nitrate content. From the concentration of nitrate in this water and estimations of movement of water through the soil we could estimate nitrate loss.
Nitrate Leaching

• The lysimeters were used to estimate nitrate leaching to two feet in irrigation events

• In one irrigation event from July 24 to July 29 we estimated the following movement of nitrate:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Lbs of N</th>
<th>Value of N*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>37.3</td>
<td>$15.67</td>
</tr>
<tr>
<td>BMP</td>
<td>11.2</td>
<td>$4.70</td>
</tr>
</tbody>
</table>

* at $0.42/lb N
## Trial No. 2 - Romaine

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Preplant</th>
<th>Planting</th>
<th>Fertigation</th>
<th>Fertigation</th>
<th>Fertigation</th>
<th>Fertigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>100 lbs</td>
<td>0 DAP</td>
<td>7 gals</td>
<td>7 gals</td>
<td>7 gals</td>
<td>7 gals</td>
</tr>
<tr>
<td></td>
<td>0-0-50</td>
<td>0 DAP</td>
<td>0-20-0</td>
<td>28-0-0-5'</td>
<td>NpHuric</td>
<td>28-0-0-5'</td>
</tr>
<tr>
<td></td>
<td>0 DAP</td>
<td></td>
<td>32 DAP</td>
<td>37 DAP</td>
<td>41 DAP</td>
<td>45 DAP</td>
</tr>
<tr>
<td>BMP</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>12.4</td>
<td>21.5</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>12.4</td>
<td>21.5</td>
<td>30.8</td>
</tr>
</tbody>
</table>

**Total** | **Know** | **Know** | **Know** | **Know** | **Know** | **Know** |

| Total     | N/A      | 12.4     | 21.5      | 21.5      | 21.5      | 76.9       |
|           | 12.4     | 21.5     | 30.8      | 64.7      |           | 76.9       |

**Planted July 12**
**Harvested Sept 12&16**
**Prior Crop - rapini**
Trial No. 2 – Romaine

Nitrate Nitrogen in Soil Over Season

Days After Planting

mg N/kg dry soil

Standard
BMP
Trial No. 2 - Romaine

Total N Applied to the crop:

- Standard = 77 lbs
- BMP = 65 lbs
- If an average lettuce crop contains 120 lbs N/A the remainder of the N that was supplied to this crop was from residual N (prior crop residues and nitrogen mineralization from organic matter)
Trial No. 2 - Romaine Commercial Yield – Cored

![Bar chart showing yield comparison between 9/12/2008 Platinum and 9/16/2008 Sun Valley for Romaine with and without BMP.]
## Trial No. 3 - Romaine

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Planting</th>
<th>Post thinning</th>
<th>Rosette</th>
<th>Mid growth</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40 gals 6-16-0 0 DAP</td>
<td>21-0-0-8* 27 days</td>
<td>21-0-0-8 34 days</td>
<td>21-0-0-8 42 days</td>
<td>N/A to date</td>
</tr>
<tr>
<td>Standard</td>
<td>26.4</td>
<td>57.8</td>
<td>57.8</td>
<td>57.8</td>
<td>199.7</td>
</tr>
<tr>
<td>BMP</td>
<td>26.4</td>
<td>34.7</td>
<td>57.8</td>
<td>34.7</td>
<td>153.6</td>
</tr>
</tbody>
</table>

Planted August 22
Harvested October 31
May be necessary to collect samples by angling towards the row middles.
Trial No. 3 - Romaine Trimmed Yield/A

- Standard: 24,289
- GAIN: 21,045
- Untreated: 18,923
## Summary

<table>
<thead>
<tr>
<th>Site</th>
<th>Standard N/A</th>
<th>BMP N/A</th>
<th>Nitrogen Reduction</th>
<th>Cost Reduction*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site No. 1</td>
<td>248</td>
<td>110</td>
<td>139</td>
<td>58.42</td>
</tr>
<tr>
<td>Site No. 2</td>
<td>77</td>
<td>65</td>
<td>12</td>
<td>5.04</td>
</tr>
<tr>
<td>Site No. 3</td>
<td>200</td>
<td>154</td>
<td>46</td>
<td>19.32</td>
</tr>
<tr>
<td>Average</td>
<td>175</td>
<td>109</td>
<td>66</td>
<td>27.59</td>
</tr>
</tbody>
</table>

* Based on $0.42/lb of nitrogen
### Summary

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Impact on Yield</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site No. 1</td>
<td>No difference</td>
<td>Clearly able to reduce N use in this type of scenario</td>
</tr>
<tr>
<td>Site No. 2</td>
<td>No difference</td>
<td>Grower practice was optimal</td>
</tr>
<tr>
<td>Site No. 3</td>
<td>Reduced Yield</td>
<td>Site was variable and soil unusual</td>
</tr>
</tbody>
</table>
• These trials showed that it is possible to reduce nitrogen fertilizer and irrigation inputs.
• Irrigation is key to nitrogen (nitrate) fertilizer management.
• Leaching of nitrate can be an unseen cost.
• In spite of the down swing in fertilizer prices, the need for improved nitrogen management is not reduced.