PAST

- organic fertilizers
- nutrients returned to soil with crop residues and manure
- challenge: yields limited by nutrient deficiency, non-optimal timing of availability and nutrient imbalance
Justus von Liebig’s “Law of the Minimum” published in 1873

“If one growth factor/nutrient is deficient, plant growth is limited, even if all other vital factors/nutrients are adequate... plant growth is improved by increasing the supply of the deficient factor/nutrient”
Methylene urea as a slow-release nitrogen source for processing tomatoes

Marja E. Koivunen* and William R. Horwath

2-year field trial on processing tomato fb wheat at UC Davis

Main question:
• Can N use efficiency of processing tomato be improved with a slow-release N fertilizer (methylene urea/urea formaldehyde)

**Variables:**
- Urea vs. methylene urea
- Fallow vs. Cover crop
- Seeded vs. transplanted tomato

**Parameters:**
- Yield quantity and quality
- N uptake by crop
- Fertilizer N use efficiency using $^{15}$N technique
- Soil $^{15}$N (nitrate and biomass N) fall/spring
- Residual N effect on wheat grown w/o fertilizer
RESULTS (Koivunen and Horwath 2005)

- No difference in tomato yield quantity and quality
- Deep soil core samples taken to 200-cm (6.5 feet) depth after the first transplanted tomato crop in fall 1999 showed high contents of fertilizer-derived NO$_3$-N in the urea-fertilized soil. The following spring, soil $^{15}$NO$_3$-N content was significantly lower in these plots (note: all $^{15}$N plots were left fallow during the winter)

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Seeded block, $^{15}$NO$_3$-N</th>
<th>Transplanted block, $^{15}$NO$_3$-N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fall 2000 (%)</td>
<td>Spring 2001 (%)</td>
</tr>
<tr>
<td>Furea</td>
<td>4.1a</td>
<td>0.1</td>
</tr>
<tr>
<td>FuMU</td>
<td>1.8b</td>
<td>0.3</td>
</tr>
<tr>
<td>CCurea</td>
<td>4.2a</td>
<td>0.1</td>
</tr>
<tr>
<td>CCuMU</td>
<td>5.7a</td>
<td>0.4</td>
</tr>
</tbody>
</table>

NS $P > 0.05$; *$0.05 \geq P > 0.01$; **$0.01 \geq P > 0.001$; ***$0.001 \geq P$.

F – fallow
CC – cover crop
uMU – 50:50 mixture of urea and methylene urea
RESULTS (Koivunen and Horwath 2005)

Fertilizer N use efficiency

Table 3. $^{15}$N recovery (%) in the plant biomass and soil.

<table>
<thead>
<tr>
<th></th>
<th>Seeded block</th>
<th>Transplanted block</th>
<th>Transplanted block</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tomato 00 (%)</td>
<td>Wheat 00/01 (%)</td>
<td>Soil 01 (%)</td>
</tr>
<tr>
<td></td>
<td>Tomato 99 (%)</td>
<td>Tomato 00 (%)</td>
<td>Wheat 00/01 (%)</td>
</tr>
<tr>
<td></td>
<td>Soil 01 (%)</td>
<td>Total (%)</td>
<td>Soil 01 (%)</td>
</tr>
<tr>
<td></td>
<td>Total (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Furea</td>
<td>40.0ab</td>
<td>17.5</td>
<td>17.4</td>
</tr>
<tr>
<td>FuMU</td>
<td>42.7ab</td>
<td>22.4</td>
<td>31.8</td>
</tr>
<tr>
<td>CCurea</td>
<td>44.6a</td>
<td>9.0</td>
<td>21.8</td>
</tr>
<tr>
<td>CCuMU</td>
<td>32.4b</td>
<td>16.8</td>
<td>28.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Tomato 99 (%)</th>
<th>Tomato 00 (%)</th>
<th>Wheat 00/01 (%)</th>
<th>Soil 01 (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer (FE)</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS*</td>
</tr>
<tr>
<td>Management (M)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS*</td>
</tr>
<tr>
<td>FE × M</td>
<td>***</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS***</td>
</tr>
</tbody>
</table>

For plant recovery, the total $^{15}$N in aboveground plant biomass was included. For determination of the $^{15}$N in soil at the end of the 2-year study, soil samples (0–30 cm) were analyzed for total $^{15}$N content. Letters in columns indicate differences between treatment means according to Tukey’s protected LSD test at $P \leq 0.05$. Letters are indicating differences only in cases where the interaction (F × M) is statistically significant.

NS $P > 0.05$; *$0.05 \geq P > 0.01$; **$0.01 \geq P > 0.001$; ***$0.001 \geq P$.

N use efficiency was not significantly improved with slow-release N.
Lesson learned #1. Nitrogen uptake curve for tomato

N content in the above-ground biomass was generally higher in the transplanted than seeded tomato plants.

The plant N content did not significantly change between the last sampling (16 weeks after seeding or 12 weeks after transplanting) and harvest.

F – fallow
CC – cover crop
uMU – 50:50 mixture of urea and methylene urea

Time 0 sampling: 7 weeks after seeding or 3 weeks after transplanting.

*Figure 1.* N uptake (g plant⁻¹) measured during the growing season in 1999 for (a) a seeded and (b) a transplanted tomato variety (Heinz 8892).
Hypothetical nutrient uptake curve for processing tomato based on field data and fertigation programs designed for greenhouse tomatoes.
Lesson learned #2. Effect of cover crop on soil properties and nitrogen management

- Increased organic matter content
- Increased soil microbial activity
- Increased storage of N in the microbial biomass
- Decreased bulk density
- Increased infiltration rate

Improved Soil Health

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Improving Soil Health

- Long-term Thinking and Strategy

*Basic Methods (Toolbox)*

- Tillage Management (Reducing tillage)
- Cover Cropping
- Crop Rotation
- Organic Matter Addition & Management

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2015 International Year of Soils

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Soil Health Indicators

**Physical**
- Bulk density
- Penetration resistance
- Aggregate stability
- Water infiltration rate
- Water holding capacity
- Pore size distribution

**Chemical**
- Cation exchange capacity
- N, P, K
- Salinity
- Micronutrients
- [Toxins, pollutants]

**Biological**
- Soil disease suppressive capacity
- Beneficial and pathogenic nematodes, [other pathogens]
- N mineralization rate (PMN)
- Decomposition rate
- Respiration rate
- Earthworm counts
- % OM
- “Active” C, N in OM
• mineral fertilizers, specialty fertilizers, improved application techniques and timing (4R principle)
• plant nutrition/fertilizer use based on crop requirements and soil nutrient content
• focus on improved nutrient efficiency and decreased losses in the environment
• new appreciation of soil organic matter and soil health
**BIOSTIMULANTS – WHAT ARE THEY?**

- **CROP PROTECTION**
  - Pesticides
  - Plant Growth Regulators (PGR)

- **BIOSTIMULANTS**
  - Pesticides, PGRs or Fertilizers ??

- **FERTILIZATION**
  - Plant nutrients
  - Soil amendments
Beneficial Substance: Means any substance or compound other than primary, secondary, and micro plant nutrients that can be demonstrated by scientific research to be beneficial to one or more species of plants, when applied exogenously. (AAPFCO 2007)

**BIOSTIMULANT**

Plant Biostimulant means a material which contains substance(s) and/or microorganisms whose function when applied to plants or the rhizosphere is to stimulate natural processes to benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, and/or crop quality, independently of its nutrient content.

EXAMPLES:
- Seaweed extracts
- Microbial inoculants
- Protein hydrolysates
- Humic and Fulvic acids
- Amino acids

European Biostimulant Industry Consortium (EBIC)
Unclear regulatory environment is slowing down the market growth in the US.
Site-specific prescription application of fertilizers, pesticides and biostimulants

Multi-Product Application

- Micronutrients
- Biologicals
- Nematicides
- Fungicides
- Insecticides

- iPad®
- Wireless
- Works with all brands of equipment
FUTURE

- combination of inorganic and organic nutrient sources
- site-specific and variable-rate application techniques
- focus is shifted from the quantity and quality of plant nutrients to enhanced nutrient uptake by the plant
PAST
- organic fertilizers
- nutrients returned to soil with crop residues and manure
- challenge: yields limited by nutrient deficiency, non-optimal timing of availability and nutrient imbalance

PRESENT
- mineral fertilizers, specialty fertilizers, improved application techniques and timing (4R principle)
- plant nutrition/fertilizer use based on crop requirements and soil nutrient content
- focus on improved nutrient efficiency and decreased losses in the environment
- new appreciation of soil organic matter and soil health

FUTURE
- combination of inorganic and organic nutrient sources
- site-specific and variable-rate application techniques
- focus shifted from the quantity and quality of plant nutrients to enhanced nutrient uptake by the plant
Organic fertilizers: decrease → increase → ??
Inorganic fertilizers: increase → ??
Nutrient use efficiency: increase
Application technology: improvement
Biostimulants: increase
Environmental regulations: increase
Thank You

Questions?