4R Nutrient Stewardship†:
New Mexico Specifics

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† An Educational Program Initiated by the
International Plant Nutrition Institute (IPNI)
Remember what an agronomist is

• **Agronomist /ə-’grän-ə-məst/ noun:**
  – One who studies the science of soil management and crop production
  – One who applies the various soil and plant sciences to soil management and crop production; scientific agriculture
Or…

• from Greek: *Agros* (field) and *nomos* (to manage)

• The branch of agriculture that treats of the principles and practices of crop production and field management.

• First started, perhaps, in 1843 in Rothamsted, England to study fertilizer use.
And Continues in the U.S.

Ag Science Center - Artesia
General Goals for Both Horticultural and Field Crops

- **Turf**
  - Attractive
  - Healthy
  - Withstand Rigors of Intended Use

- **Row Crops**
  - Chile, Corn, Sorghum, Wheat, others
    - Yield
    - Quality
    - Profitability

- **Pecans**
  - Yield
  - Quality

- **Forages & Grains**
  - Alfalfa
  - Small grains for silage
  - Small grains for grain
Fertilization Contributes to

**Turf**
- Color
- Density
- Uniformity
- Growth Rate

**Agronomic Crops**
- Growth Rate
- Yield
- Crop Quality
- End User Nutrition
- Flour Quality
Properly Fertilized Crops Are

- Better able to compete with weedy species
- Recover better from stress
  - Environmental
  - Biotic
So, I could tell you that you need

- 200 – 250 lb N/A
- 80 lb P$_2$O$_5$/A
- 120 lb K$_2$O/A
- Plus other nutrients

- However, ....
But it is NOT all about rate!

• THE 4 R’s
  – Right Source
  – Right Time
  – Right Place
  – Right Rate
Liebig’s Law of the Minimum
Liebig’s Law of the Minimum

Yield & Performance is Limited by the Nutrient in Least Supply

(all other factors – water, salinity, pests, environment -held constant)
Water is a BIG “other” factor
Alfalfa Yield and Water Production

Fig. 1. Water-production function for alfalfa New Mexico.
Chile Yield and Water

The graph shows the relationship between yield (ton/ha) and water applied (cm) for Chile over several years:
- **1977**: Black dots
- **1978**: Green plus signs
- **1979**: Blue circles
- **1980**: Crosses
- **1981**: Triangles

As water applied increases, yield also tends to increase, indicating a positive correlation.
Corn for Grain Yield and Water

\[
Y(\text{kg/ha}) = -7309 + 238.9(ET)
\]

\[\text{SEE} = 961 \text{ kg/ha} \]
\[r^2 = 0.90\]

Figure 13. The water-production function of the high-N corn SLS plot, 1982.
Soil Type Impacts
Crop Response to Irrigation
So is Soil Salinity
Increasing Salinity

Measured by electrical conductivity (e.c.)

- RO Reject Water
- Soft Water
- Tap Water
- Spring Water
- RO Water
- Distilled Water
  - 0 mmhos/cm
Yield/Performance as a function of EC

\[ Y = 840.7 - 87.92 \text{EC}_e \]

\[ R^2 = 0.93 \]

Threshold

Slope
Yield/Performance as a function of EC

\[ Y = 840.7 - 87.92 \text{ EC}_e \]

\[ R^2 = 0.93 \]

Threshold

Slope

EC (mmhos cm\(^{-1}\))

Yield/Performance as a function of EC\(_e\)
Yield/Performance as a function of EC

\[ Y = 640.7 - 87.92 \times EC \]

\[ R^2 = 0.93 \]
Yield/Performance as a function of EC

\[ Y = 840.7 - 87.92 \text{EC}_e \]

\[ R^2 = 0.93 \]

Threshold
Saturated Paste is Best & Preferred when EC > 0.5 mmhos/cm
Predicted Soil E Ce vs Measured E Ce

NH₄OAc extractable Ca, Mg, Na in mg/kg used in model development

Model 1: $E_Ce = 0.793 + 2.09(E_{C1}) - 2.49 \times 10^{-4}(Ca) + 0.00207(Na)$  adjusted $R^2 = 0.8692$

Model 2: $E_Ce = 2.14(E_{C1}) + 0.00187(Na)$  adjusted $R^2 = 0.9373$
Salinity & Sodium
Sodium Promotes Dispersion

No or Reduced Aggregates
Sodium Adsorption Ratio

\[
\text{SAR} = \frac{[\text{Na}^+]}{\sqrt{([\text{Ca}^{2+}] + [\text{Mg}^{2+}])/2}}
\]

(concentrations are in mmol/L)

• High SAR = Unstable Soil
• Low SAR = Stable Soil
Manage Sodium in Soil with Calcium (Gypsum (CaSO₄))

Excess water must be applied!!

Must also be good drainage!
TIME = 0

WATER

WATER + GYPSUM
TIME = 24 hours

Gypsum rate determined from soil Exchangeable Sodium Percentage (ESP) and sodium concentration in the soil.
Liebig’s Law of the Minimum

Need to know what you need in order to determine a Source
Determined by Soil Sampling
Past History
Appropriate Tests for NM Soils
(Guide A146)

- Saturated paste pH
- Saturated paste EC
- Sodium Adsorption Ratio (SAR) SP
- Organic Matter
- Nitrate-N or Total Inorganic-N
- Phosphorus (Olsen)
- Potassium (Water or Ammonium Acetate)

- DTPA Extractable
  - Fe
  - Zn
  - Mn
  - Cu

- Optional (if already known)
  - Texture
  - Soil Lime %
Sampling is KEY to the 4R program
Be Representative
Be Representative!

- Good production on a productive soil
- Soil Related Poor Production
- Moderate production on fairly productive soil.
Plant Nutrition

- Soil testing identifies nutrients needed for productivity
  - Low
  - Moderate
  - Sufficient
  - Excessive
### Soil Test Results

<table>
<thead>
<tr>
<th>Sample ID (#)</th>
<th>pH (mmhos/cm)</th>
<th>E.C. (#)</th>
<th>Soil Texture (class)</th>
<th>O.M. (%)</th>
<th>NO$_3$-N (ppm)</th>
<th>P (ppm)</th>
<th>K (ppm)</th>
<th>Mg (meq/l)</th>
<th>Ca (meq/l)</th>
<th>Na (meq/l)</th>
<th>Cu (ppm)</th>
<th>Zn (ppm)</th>
<th>Mn (ppm)</th>
<th>Fe (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.5</td>
<td>3.1</td>
<td>Loam</td>
<td>0.50</td>
<td>25</td>
<td>60</td>
<td>80</td>
<td>2.67</td>
<td>8.59</td>
<td>9.7</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** E.C. = Electrical Conductivity or Saltness, O.M. = Organic Matter, ESP = Exchangeable Sodium %.

**Crop to grow:** Pasture, grass, G stand, L. season

**Yield Goal:** 15 t/ac

<table>
<thead>
<tr>
<th>Nitrate-N</th>
<th>Phosphorus-P</th>
<th>Potassium-K</th>
<th>Magnesium-Mg</th>
<th>Calcium-Ca</th>
<th>Iron-Fe</th>
<th>Copper-Cu</th>
<th>Zinc-Zn</th>
<th>Manganese-Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>140</td>
<td>V High</td>
<td>V High</td>
<td>V High</td>
<td>V High</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
Minerals Required for Plant Growth

Turfgrass

- Nitrogen: 8%
- Phosphorus: 0.8%
- Potassium: 0.7%
- Sulfur: 0.6%
- Calcium: 0.5%
- Magnesium: 0.4%
- Iron: 0.2%
- Others: 0.1%
PLAN FOR “FULL-FEED”

FULL-FEED
HIDDEN HUNGER

HUNGRY

STARVED

Low Soil Nutrient
Moderate Soil Nutrient
Sufficient Soil Nutrient
# Nutrient Recommendation

<table>
<thead>
<tr>
<th>Nutrient Recommendation:</th>
<th>N lbs/ac</th>
<th>P$_2$O$_5$ lbs/ac</th>
<th>K$_2$O lbs/ac</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recommended Nutrient Rate:</strong></td>
<td>180</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Organic Nutrient Source (Liquid or Solid Manure):</strong></td>
<td>72</td>
<td>240</td>
<td>544</td>
</tr>
<tr>
<td><strong>Irrigation Water Credits (ppm NO$_3$-N):</strong></td>
<td>5</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td><strong>Other Nutrient Sources (Standing Legume Crop):</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Supplemental Nutrient Rate:</strong></td>
<td>88</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Available Nutrients &gt; Crop Requirements:</strong></td>
<td>NO</td>
<td>Caution P</td>
<td>Caution K</td>
</tr>
</tbody>
</table>

**General Note:**
Apply P and K in the spring. Split N into 2-4 applications with the first in early spring.

**N – P$_2$O$_5$ – K$_2$O, others**
N Credits = Soil Organic Matter
SOM also improves micronutrient availability & water holding capacity
Legume N Credit
Manure Nutrient Credit

• Average 35 lb Total N/dry ton (8-12 lb available N).

• NMSU Soil Test Interpretation Workbook will subtract out
  – potential volatilization losses of the NH$_4$ content
  – De-nitrification (N$_2$) losses depending on soil organic matter levels and soil drainage class
  – Mineralized N from the organic N pool in manure is estimated based on literature or C:N ratio
### Other Manure Nutrient Credits per Dry Ton

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Pounds per Dry Ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus</td>
<td>24</td>
</tr>
<tr>
<td>Potash</td>
<td>50</td>
</tr>
<tr>
<td>Calcium</td>
<td>63</td>
</tr>
<tr>
<td>Magnesium</td>
<td>15</td>
</tr>
<tr>
<td>Iron Credit</td>
<td>7.2</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.3</td>
</tr>
<tr>
<td>Total Salt</td>
<td>51</td>
</tr>
</tbody>
</table>
Effluent Characteristics

- **Cl**: 80 lbs per acre inch
- **P2O5**: 20 lbs per acre inch
- **K2O**: 140 lbs per acre inch
- **Na**: 40 lbs per acre inch
- **Org. N**: 50 lbs per acre inch
- **NH4-N**: 60 lbs per acre inch

706 lb total salt per acre inch

Fall 2003, n = 48 sampled dairies
But, much of NM’s productive land has >3% lime.

Soil pH as related to soil calcium carbonate.
Soil pH = 7.3
Iron = 12 ppm (VH)
Free lime = medium (~2%)

**Choices:**
- Elemental S
- Ironite
- Sequestar
- Fe-EDDHA
- Fertilome’s Chelated (EDTA) Liquid Iron Product
Client results

- Fertilome & Ironite is a very rich green color. Most successful products.
- EDDHA had not greened up much
Soil pH > 7.5

% Lime = 20%
EDDHA Chelate

- Miller’s Ferriplus
- Some additional N may help the chelate do a better job.
The Chelates

- Organic Molecules that “hold” metals like Iron, Zinc, Nickel, etc.
- Hampene
  - (Fe)EDTA
- Sequestrene 138
  - (Fe)DTPA
- Miller’s Ferriplus
- (Fe)EDDHA
Stability and Availability

% Chelate with Fe

Soil pH

EDDHA  EDTA  DTPA
Chelate Effectiveness

FeEDDHA  FeDTPA  FeEDTA
Remember

• Using problems like iron deficiency is an opportunity to test different sources of iron. Not only for effectiveness but for cost.

Milorganite?
Composted WWTP solids?
Nutrient Sources

- Incomplete
  11-52-0
- Complete
  10-10-10
- Solids
- Liquids
- Quick Release
- Slow Release
  - Includes organics
# Quick Release N Fertilizers

<table>
<thead>
<tr>
<th>Carrier</th>
<th>Grade</th>
<th>% N</th>
<th>Residual Response</th>
<th>Burn Potential</th>
<th>Leaching Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>UREA</td>
<td>46-0-0</td>
<td>45-46</td>
<td>short</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Ammonium sulfate</td>
<td>21-0-0</td>
<td>20.5 - 21</td>
<td>short</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Potassium nitrate</td>
<td>13-0-44</td>
<td>13</td>
<td>short</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>
# Slow Release N Fertilizers

<table>
<thead>
<tr>
<th>Carrier</th>
<th>Grade</th>
<th>% N</th>
<th>Residual Response</th>
<th>Burn Potential</th>
<th>Leaching Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBDU</td>
<td>Variable 24-4-12</td>
<td>Variable 24</td>
<td>Moderate</td>
<td>Moderate Low</td>
<td>Low</td>
</tr>
<tr>
<td>Sulfur Coated Urea</td>
<td>21-0-0</td>
<td>20.5 – 21</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Resin-coated</td>
<td>24-0-0 to 35-0-0</td>
<td>13</td>
<td>Mod to Long</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Methylene coated and ureaformaldehyde</td>
<td>38-0-0</td>
<td>38</td>
<td>Mod to Long</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

IBDU = isobutylidene diurea
Nitrogen can be volatilized
Especially in high pH soils

• Some products have been demonstrated to lower volatilization rate
  – Agrotain® on urea if not able to irrigate in
  – Or be sure to irrigate in with at least 3/10” to ½” of water immediately after application.
Nitrogen Carriers

- Ammonium Sulfate (NH$_4^+$)
- Urea (CH$_4$N$_2$O)
- UAN (Urea Ammonium Nitrate)
- Calcium Nitrate (Ca(NO$_3$)$_2$)
- Ammonium Nitrate (NH$_4$NO$_3$)
- Organic Sources through Mineralization
Beware of Volatilization / Leaching

• Ammonium containing fertilizers subject to volatilization losses.
  – Additives may reduce volatility (e.g., Agrotain)

• Nitrate containing fertilizers subject to leaching with too much applied water.
The 4 R’s

- Right Source
- Right Time
- Right Place
- Right Rate
TIMING OF N APPLICATION
Example: Apples

- N uptake by apple roots begins about 3 weeks after bud-break.
- BUT – Soil Temperature also affects uptake
  - Soil Temps 54°F to 68°F enable tree to take up more N
    - 1/3 N remains in roots
    - 2/3 N moved to shank, stem, and new growth
Timing Important for Irrigated Fields
Flood/Furrow Irrigated Fields

No Effluent or Manure

With Effluent or Manure
Pivot Irrigated Fields

No Effluent or Manure

With Effluent or Manure
Leaching

The graph illustrates the leaching of soil nitrate-N (mg/kg) at various soil depths for different areas labeled as Area 1 and Area 2. The graph is divided into three sections: "Top", "Middle", and "Bottom". Each section shows the nitrate-N concentration at different soil depths, ranging from 0-12 inches to 96-108 inches. The data is represented using green and orange bars, with green indicating Area 1 and orange indicating Area 2.
Timing Applications – small grains example

45 bu/ac, 2.5% N in the grain

50 lb N/ac

days with GDD>0?

100 lb N/ac

75 lb N/ac

October 0

February 120

June 240 days
Timing Applications

45 bu/ac, 2.5% N in the grain

50 lb N/ac

100 lb N/ac

75 lb N/ac

days with GDD>0?

October
0

February
120

June
240 days

N uptake, lb/ac
Proportion of Above-ground DM & Nutrients in Irrigated Spring Wheat

% accumulated by anthesis

Dry Matter (DM) or Nutrient:
- DM
- N
- P
- K
- Ca
- Mg
- S
- Zn
- Fe
- Mn
- Cu
The 4 R’s

• Right Source
• Right Time
• Right Place
• Right Rate
Definitions

Band, single side

Band, double side

Broadcast and incorporate

Topdress

Seed

Fertilizer

Seed

Fertilizer

Broadcast and incorporate

Topdress
Starter Fertilizer Configurations

2x2 Starter
Seed
Fertilizer

Pop-up or Drill row Direct seed contact
Seed
Fertilizer

Dribble Surface Band
Seed
Fertilizer
The 4 R’s

- Right Source
- Right Time
- Right Place
- Right Rate
## Nutrient Rate Recommendation

<table>
<thead>
<tr>
<th>Nutrient Recommendation</th>
<th>N</th>
<th>P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt;</th>
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**General Note:**
Apply P and K in the spring. Split N into 2-4 applications with the first in early spring.

N – P<sub>2</sub>O<sub>5</sub> – K<sub>2</sub>O, others
Green Manures
## Determining Organic Source Rate

- **Verify C:N Ratio**
- **Season = 125 days**
  - 2200 GDD (0°C base)
- **§: Chicken Composts similar to uncomposted 4% N material**

### Table: Uncomposted Materials

<table>
<thead>
<tr>
<th>% of DW</th>
<th>Total N</th>
<th>C:N</th>
<th>PAN† (% of Total N)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>28 d</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Season</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Uncomposted Materials</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>35</td>
<td>&lt;0</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>9</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>7</td>
<td>45</td>
</tr>
<tr>
<td>6</td>
<td>&lt;6</td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>7</td>
<td>&lt;6</td>
<td></td>
<td>75</td>
</tr>
<tr>
<td>8+</td>
<td>&lt;6</td>
<td></td>
<td>75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Composts§</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>2-3</td>
<td></td>
<td>10-15</td>
<td>5</td>
</tr>
</tbody>
</table>

†Dan Sullivan, OSU
Measured Data

%PAN & Total %N

-20 0 10 20 30 40 50 60 70 80 90 100 110 120

0 5 10 15 20

28-day PAN
Full-season PAN

Total %N

Measured Data
Smoothed data

Potentially Available N

Percent Total N (Dry Weight Basis)
When low soil nutrients

Cool Season Grasses

<table>
<thead>
<tr>
<th>Grass</th>
<th>lb N/1000 sq ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tall fescue</td>
<td>2-4</td>
</tr>
<tr>
<td>Perennial ryegrass</td>
<td>2-4</td>
</tr>
<tr>
<td>Creeping bentgrass</td>
<td>3-8</td>
</tr>
</tbody>
</table>
When low soil nutrients

Warm Season Turf

<table>
<thead>
<tr>
<th>Grass</th>
<th>lb N/1000 sq ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved bermudagrass</td>
<td>4-8</td>
</tr>
<tr>
<td>Buffalograss</td>
<td>0-2</td>
</tr>
<tr>
<td>St. Augustinegrass</td>
<td>2-4</td>
</tr>
<tr>
<td>zoysiaagrass</td>
<td>2-4</td>
</tr>
</tbody>
</table>
4R Nutrient Stewardship

**ENVIRONMENTAL**
- Soil erosion
- Nutrient balance
- Yield
- Net profit
- Productivity
- Profitability
- Return on investment
- Quality
- Yield stability
- Durability
- Working conditions
- Adoption
- Soil productivity
- Ecosystems services
- Farm income
- Healthy environment
- Nutrient loss
- Nutrient, Water
- Water & air quality
- Energy, Labor, Nutrient, Water
- Biodiversity

**ECONOMIC**

**SOCIAL**