Turfgrass Nutrition

An average plant is 15 - 40% dry matter and 60 - 85% water

Dry matter is composed of C, H, O and mineral matter

Essential Mineral Nutrients

- Carbon (C)
- Hydrogen (H)
- Oxygen (O)
- Nitrogen (N)
- Iron (Fe)
- Manganese (Mn)
- Molybdenum (Mo)
- Zinc (Zn)
- Copper (Cu)
- Nickel (Ni)
- Calcium (Ca)
- Magnesium (Mg)

Make up over 90% of plant's weight

Come from the atmosphere and water
Essential Mineral Nutrients

- Macronutrients
- Must be > 0.1% of plant's weight
  - Carbon (C)
  - Hydrogen (H)
  - Oxygen (O)
  - Nitrogen (N)
  - Phosphorus (P)
  - Potassium (K)
  - Sulfur (S)
  - Calcium (Ca)
  - Magnesium (Mg)

Macronutrients
- Divided into Primary and Secondary
  - Primary
  - Secondary
  - Oxygen (O)
  - Nitrogen (N)
  - Phosphorus (P)
  - Potassium (K)
  - Sulfur (S)
  - Calcium (Ca)
  - Magnesium (Mg)

- Micronutrients
- Typically < 0.01% of plant's weight
  - Iron (Fe)
  - Manganese (Mn)
  - Molybdenum (Mo)
  - Zinc (Zn)
  - Boron (B)
  - Chlorine (Cl)
  - Copper (Cu)
  - Nickel (Ni)

17 elements
- Carbon (C)

Iron (Fe)
- Manganese (Mn)
- Molybdenum (Mo)
- Zinc (Zn)
- Boron (B)
- Chlorine (Cl)
- Copper (Cu)
- Nickel (Ni)
Turgrass tissue sufficiency ranges

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Creeping Bentgrass</th>
<th>Perennial Ryegrass</th>
<th>General</th>
</tr>
</thead>
<tbody>
<tr>
<td>N, %</td>
<td>4.50 – 6.00</td>
<td>3.34 – 5.10</td>
<td>2.75 – 3.50</td>
</tr>
<tr>
<td>P, %</td>
<td>0.30 – 0.60</td>
<td>0.35 – 0.55</td>
<td>0.30 – 0.55</td>
</tr>
<tr>
<td>K, %</td>
<td>2.20 – 2.60</td>
<td>2.00 – 3.42</td>
<td>1.00 – 2.50</td>
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<tr>
<td>Ca, %</td>
<td>0.50 – 0.75</td>
<td>0.25 – 0.51</td>
<td>0.50 – 1.25</td>
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<tr>
<td>Mg, %</td>
<td>0.13 – 0.40</td>
<td>0.16 – 0.32</td>
<td>0.20 – 0.60</td>
</tr>
<tr>
<td>S, %</td>
<td>0.20 – 0.50</td>
<td>0.27 – 0.56</td>
<td>0.20 – 0.45</td>
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<tr>
<td>Fe, ppm</td>
<td>50 – 500</td>
<td>97 – 934</td>
<td>35 – 100</td>
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<tr>
<td>Mn, ppm</td>
<td>25 – 300</td>
<td>30 – 73</td>
<td>25 – 100</td>
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<td>Cu, ppm</td>
<td>5 – 50</td>
<td>6 – 38</td>
<td>5 – 20</td>
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<td>Zn, ppm</td>
<td>20 – 250</td>
<td>14 – 64</td>
<td>20 – 55</td>
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<tr>
<td>B, ppm</td>
<td>6 – 30</td>
<td>5 – 17</td>
<td>10 – 60</td>
</tr>
<tr>
<td>Mo, ppm</td>
<td>0.10 – 1.20</td>
<td>0.5 – 1.00</td>
<td>no data</td>
</tr>
</tbody>
</table>

Adapted from Jones, 1980 and Mills and Jones, 1996

**Why must nutrients be applied?**

- Nutrient fate
- Plants remove nutrients – leave the system
- Nutrients become unavailable
- Nutrients leach or runoff – leave the system
- Plant demand > plant availability

---

**Nutrient fate**

Nutrients are lost from the system through:

1. **Nutrient removal by plants**
2. **Nutrient leaching and runoff**
3. **Nutrient immobilization**
4. **Nutrient volatilization**

**Nutrient removal by plants**

- Nutrients are absorbed by plants for growth.
- Nutrients not absorbed are lost from the system.

**Nutrient leaching and runoff**

- Nutrients are carried out of the system by water.

**Nutrient immobilization**

- Nutrients are stored in organic matter.

**Nutrient volatilization**

- Nutrients are lost to the atmosphere.

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**Nutrient cycles**

**Atmospheric N**

- **Ammonification**
- **Nitrogen-fixing bacteria**
- **Nitrogenase**
- **Ammonium (NH₄⁺)**
- **Nitrites (NO₂⁻)**
- **Nitrate (NO₃⁻)**
- **Denitrifying bacteria**
- **Assimilation**

**Nutrient cycling**

- Nutrients are cycled between the soil, plants, and atmosphere.

---

**Nutrient management**

- Nutrient application is necessary to maintain soil nutrient levels.
- Nutrient application helps to prevent nutrient deficiencies and excesses.

---

**Nutrient application**

- Nutrients are added to the system to replace those removed by plants.
- Nutrients are added to prevent nutrient deficiencies and excesses.

---

**Nutrient monitoring**

- Nutrient levels are monitored to ensure adequate nutrient supply.
- Nutrient levels are monitored to prevent nutrient deficiencies and excesses.

---

**Nutrient efficiency**

- Nutrient efficiency is evaluated to determine the effectiveness of nutrient application.
- Nutrient efficiency is evaluated to ensure adequate nutrient supply.

---

**Nutrient recycling**

- Nutrients are recycled within the soil-plant-atmosphere system.
- Nutrients are recycled to ensure adequate nutrient supply.

---

**Nitrogen cycle**

- Nitrogen is cycled between the soil, plants, and atmosphere.
- Nitrogen is recycled to ensure adequate nutrient supply.

---

**Nutrient balance**

- Nutrient balance is maintained through nutrient application and nutrient recycling.
- Nutrient balance is maintained to ensure adequate nutrient supply.

---

**Nutrient cycling and management**

- Nutrient cycling and management is necessary to maintain soil nutrient levels.
- Nutrient cycling and management helps to prevent nutrient deficiencies and excesses.

---

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- Nutrient cycling and management helps to prevent nutrient deficiencies and excesses.
Turf's perpetual hunger for N

The Primary Macros: Nitrogen

- Functions
  - Proteins
  - Chlorophyll molecule
  - DNA
- Deficiency symptoms
  - Reduced growth
  - Off-color
  - Low density, invasion of weeds (esp. clover)
The Primary Macros: Nitrogen

- Management
  - Tricky because we are always growing N “deficient” turfgrass
  - The “Goldilocks” nutrient
The Primary Macros: Nitrogen

- Too much
  - N reduces root system
  - Decreases stress tolerance - esp. water
  - Causes excessive thatch development
  - Greatly increases mowing requirement
  - Increases incidence of certain diseases
    - Leaf spot, necrotic ring spot, snow mold

- Not enough
  - Reduced shoot density
  - Increased weed invasion
  - Increased reliance on pesticides
  - Poor playing conditions
  - Increases incidence of certain diseases
    - Rust, red thread, dollar spot

- Just right
  - Good green color
  - Moderate growth rate
  - Optimum tolerance to environmental stresses
  - High shoot density and vigorous root system
  - Good recuperative potential
The Primary Macros: Phosphorus

- Functions
  - ATP energy currency of the cell
  - Membrane components
  - DNA components
- Deficiency symptoms
  - Reduced growth
  - Dark, purple color

Phosphorus deficient turf

The Primary Macros: Phosphorus

- Management
  - P very insoluble in soil
  - Availability is a function of root surface area
- Establishment
  - Root system is not extensive
- Post establishment
  - Responses to P rarely seen and deficiencies (purple color) are even more rare
The Primary Macros: Phosphorus

- Management
  - P availability is also sensitive to pH
  - Maximum P availability in soil is at pH 6.5
  - Calcareous soils?

- High P favors Annual Bluegrass
  - Improves drought tolerance
  - Germination
The Primary Macros: Potassium

- Functions
  - Water regulation
  - Cell growth
  - Opening and closing of stomata
  - Activates enzymes
  - Regulates cell pH
  - Deficiency symptoms
    - Reduced growth
    - Yellow leaf margins

Potassium deficiency in corn
The Primary Macros: Potassium

- **Management**
  - $K^+$ held on cation exchange sites in soil

Recent research suggests turfgrass requires less potassium than previously thought.

What has been said of $K$:
- Improves drought tolerance
- Improves cold hardiness
- Increases rooting
- Resistance to dollar spot
- Wear tolerance

Summary of the big 3

- Nitrogen management is extremely important
- Phosphorus is important at establishment
- Potassium is of less importance than we thought – although continue to maintain soil test levels
### Calcium Carbonate Equivalent

<table>
<thead>
<tr>
<th>Fertilizer Source</th>
<th>Per 100 lb Material</th>
<th>Per 1 lb nutrient</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N Sources</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium sulfate</td>
<td>110</td>
<td>5.4</td>
</tr>
<tr>
<td>Monopotassium phosphate</td>
<td>46</td>
<td>3.1</td>
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<tr>
<td>Diammonium phosphate</td>
<td>64</td>
<td>3.6</td>
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<tr>
<td>Sulfur coated urea</td>
<td>119</td>
<td>3.2</td>
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<tr>
<td>Urea</td>
<td>80</td>
<td>1.8</td>
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<tr>
<td>Ammonium nitrate</td>
<td>84</td>
<td>1.8</td>
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<tr>
<td>Urea</td>
<td>76</td>
<td>1.8</td>
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<tr>
<td>Nitric organic</td>
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<td>1.7</td>
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<tr>
<td><strong>P Sources</strong></td>
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<td></td>
</tr>
<tr>
<td>Superphosphate</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Triple superphosphate</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>K Sources</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium magnesium sulfate</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Potassium chloride</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Potassium sulfate</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Potassium nitrate</td>
<td>-26</td>
<td>-0.6</td>
</tr>
</tbody>
</table>

### Salt Index

<table>
<thead>
<tr>
<th>Fertilizer Source</th>
<th>Equal Material Basis</th>
<th>Equal Nutrient Basis</th>
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</thead>
<tbody>
<tr>
<td><strong>N Sources</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium nitrate</td>
<td>100</td>
<td>0.06</td>
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<tr>
<td>Potassium nitrate</td>
<td>74</td>
<td>0.34</td>
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<tr>
<td>Ammonium sulfate</td>
<td>69</td>
<td>0.35</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td>105</td>
<td>2.96</td>
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<tr>
<td>Monopotassium phosphate</td>
<td>30</td>
<td>2.45</td>
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<tr>
<td>Urea</td>
<td>75</td>
<td>1.62</td>
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<td>Diammonium phosphate</td>
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<tr>
<td>Ammonia</td>
<td>47</td>
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<td>Nitric organic</td>
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<td>0.70</td>
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<td><strong>P Sources</strong></td>
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<td></td>
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<td>0.39</td>
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<td>Triple superphosphate</td>
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<td>0.22</td>
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<tr>
<td><strong>K Sources</strong></td>
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<tr>
<td>Potassium magnesium sulfate</td>
<td>43</td>
<td>1.97</td>
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<tr>
<td>Potassium chloride</td>
<td>116</td>
<td>1.94</td>
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<tr>
<td>Potassium sulfate</td>
<td>74</td>
<td>1.58</td>
</tr>
<tr>
<td>Monopotassium phosphate</td>
<td>8</td>
<td>0.58</td>
</tr>
</tbody>
</table>

Adapted from Carrow et al., 2001
Things to consider when choosing a fertilizer source:

- Acidifying Effects
- Salt Index
- Cost
- Release Rate and Mechanism

Release Rate

“The highest priority in developing a fertilization program is for one to fully understand the expected response from the nitrogen sources he intends to use.”

- Powell and Shoulders, 1976, USGA Green Section Record

Sources of Nitrogen

- Fast Release
  - Inorganic salts
  - Synthetic organic
Sources of Nitrogen

- **Fast Release**
  - Inorganic salts
  - Synthetic organic

- **Slow Release**
  - Synthetic organic
  - Coated materials
  - Uncoated materials
  - Natural Organic

---

**Fast Release**

- Inorganic = ammonium and nitrate salts
  - NH$_4$NO$_3$, (NH$_4$)$_2$SO$_4$, KNO$_3$, MAP, DAP, etc.

- Synthetic organic = urea

![Urea Structure](image)

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**Fast Release: Advantages**

- Nitrogen is immediately available for uptake.
- Can be liquid or granular
  - Granular form will dissolve quickly
- Release not dependent on soil temperature or pH
Quick-release: Disadvantages

- Highest burn potential (salt index)
- Require small, frequent applications
- Prone to leaching losses
- Can produce unwanted growth surge
- Release last < 4 weeks

Slow-release Fertilizers

- Natural/Organic fertilizers
- Coated fertilizers
- Uncoated fertilizers
Slow-release: General information

- SRN accounts for over 2/3 of all N applied on golf courses (Sartain, 2002)
- Releases N gradually
  - Longer lasting response
  - Larger applications
  - Leaching losses decrease

- Release rates vary
  - Weeks to months
- Release mechanisms dependent on
  - Temperature
  - Soil Moisture
  - pH

Slow-Release Fertilizers

Natural/Organics
Natural/Organic Fertilizers

- Sewage Sludge
- Milorganite™
- Poultry and Dairy Compost
- Sustane, Nature Safe
- Dried blood, Bone meal, Fish meal, Feather meal, Corn gluten meal etc.

Release dependent on:
- Microbial decomposition
- Temperature
- Moisture
- pH
- C:N content of fertilizer

Release ~ 1-3 months

Natural/Organic Fertilizers: Advantages

- Slow-release
- Low Burn Potential
- Often lacking essential nutrients
Natural/Organic Fertilizers: Disadvantages

- No release at low temps
- N content < 6%
  - Need lots of bags (shipping cost)
- Expensive – if not then probably poor quality

Slow-release fertilizers: Coated products

- Sulfur Coats
- Polymer Coats
- Sulfur + Polymer Coats

Synthetic Slow-release: Coated fertilizers

- Release dependent on type of coating:
  - Sulfur coat
    - Thickness of coat
    - Brittleness of coat
  - Polymer coat
    - Thickness, type of polymer
    - Temperature
Synthetic Slow-release: Coated fertilizers – Advantages

- Controlled release (esp. Polymers)
- Low burn potential
- Sulfur coated urea is relatively inexpensive

Synthetic Slow-release: Coated fertilizers – Disadvantages

- Polymer coated materials can be expensive
- Sulfur coats can be inconsistent
  - Some are almost quick-release

Synthetic Slow-release: Uncoated fertilizers

Uncoated fertilizers
Urea-Formaldehyde (UF) or Methylene Urea (MU)
Isobutylidene diurea (IBDU)
Synthetic Slow-release: Uncoated fertilizers – UF and MU

- Produced by reacting urea with formaldehyde
- Results in polymer chains of various lengths and ratios of urea: formaldehyde

Release is dependant on:
- Temperature
- Moisture
- pH

Very similar to natural organics but...
- Length of chain determines release

<table>
<thead>
<tr>
<th>Fertilizer Source</th>
<th>What happens to the release when...</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temp is low</td>
</tr>
<tr>
<td>Fertilizer Source</td>
<td>What happens to the release when...</td>
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<td>-----------------------</td>
<td>------------------------------------</td>
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<td></td>
<td>Temp is low</td>
</tr>
<tr>
<td>Inorganics and urea</td>
<td>Same</td>
</tr>
<tr>
<td>Natural organic</td>
<td>↓↓</td>
</tr>
<tr>
<td>Synthetic organic (UF, MU)</td>
<td>↓↓</td>
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<td>Fertilizer Source</td>
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<td>Natural organic</td>
<td>▼</td>
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<td>Polymer coated N</td>
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</tr>
<tr>
<td>Polymer coated N</td>
<td>▼</td>
</tr>
<tr>
<td>Fertilizer Source</td>
<td>Release rate under optimal conditions</td>
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<td>------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Inorganics and urea</td>
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</tr>
<tr>
<td>Natural organic</td>
<td>1 – 3 months</td>
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<tr>
<td>Sulfur coated N</td>
<td>1 – 2 months</td>
</tr>
<tr>
<td>Polymer coated N</td>
<td>Variable (weeks to all year)</td>
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<tr>
<td>Ureaform</td>
<td>1 – 2 years</td>
</tr>
<tr>
<td>Methylene Ureas</td>
<td>2 – 4 months</td>
</tr>
<tr>
<td>MDU/DMTU</td>
<td>1 – 2 months</td>
</tr>
<tr>
<td>IBDU</td>
<td>1 – 4 months</td>
</tr>
</tbody>
</table>

Turf color response to SRN and Quick-release

General Guideline: ½ SRN + ½ quick-release provides most consistent color

Spreader and Sprayer Calibration
Fertilizer Calculation

- Analysis: N-P-K
  - % Nitrogen (N), Phosphorus (P), Potassium (K)

- Ratio:
  - 10-10-10 (1-1-1)
  - 20-5-10 (4-1-2)

- Nitrogen expressed on an elemental basis
- P expressed as P₂O₅ (44% P)
- K expressed as K₂O (83% K)
Calculating P & K

- \( P_2O_5 \) contains 44% P
- \( K_2O \) contains 83% K

\[
(50 \text{ lb})(.10) = 5 \text{ lb. } P_2O_5 \\
(5 \text{ lbs. } P_2O_5)(.44) = 2.2 \text{ lbs.}
\]

\[
(50 \text{ lb})(.10) = 5 \text{ lb. } K_2O \\
(5 \text{ lbs. } K_2O)(.83) = 4.15 \text{ lbs.}
\]

Example

1. How many pounds of 28-3-10 needs to be applied for a recommended rate of 1 pound of Nitrogen per 1,000 ft²?

2. How many pounds of 28-3-10 must be ordered for 65,500 ft² area?

Calculations

\[
\frac{1 \text{ lb N}}{1000 \text{ ft}^2}
\]
Calculations

\[
\frac{1 \text{ lb N}}{1000 \text{ ft}^2} \times \frac{1 \text{ lb Fertilizer}}{0.28 \text{ lbs N}} = \frac{3.6 \text{ lbs of Fertilizer}}{1000 \text{ ft}^2}
\]

OR

\[
\frac{\text{Desired rate}}{\% \text{ Nitrogen}} \times \frac{1 \text{ lb N}}{0.28} = 3.6
\]
Calculations

How much fertilizer for 65,500 ft²

\[
\frac{3.6 \text{ lbs fertilizer}}{1000 \text{ ft}^2} \times \frac{X}{65,500 \text{ ft}^2}
\]

\[
65,500 (3.6) = 1000 (X)
\]
Calculations

- How much fertilizer for 65,500 ft²

\[
\frac{3.6 \text{ lbs fert}}{1000 \text{ ft}^2} \times \frac{X}{65,500 \text{ ft}^2} = \frac{65,500 (3.6)}{1000} \rightarrow X = \frac{235,800}{1000} \\
X = 236 \text{ lbs of Fertilizer}
\]

Calculations

- How much P and K would we apply?

Calibrating Spreaders

- Application rate depends upon:
  - Pace of travel:
  - Spreader type: drop vs. cyclone
  - Particle size: Fine vs. coarse
Drop Type Spreaders

- Accurate
- Easy to calibrate
- Less drift
- Good for designated area
- Over-lap
- Time (labor)

Steps to Calibration

- Measure Hopper Width
- Measure distance of

1) Hopper Width = 3 feet.
2) Area = 1000 ft²

1000 ft² / 3 = 333.3 ft

3) 3.6 lbs. of 28-3-10 must be applied/1,000 ft².
4) Therefore 3.6 lbs. must be in the catch tray after traveling 333 ft.

Cyclone Spreaders

- Less time to apply materials
- Difficult to calibrate
- Difficult in limited designated areas
- Must determine effective spreading width.
Determining Effective Width

- Each box represents one square foot.
- Boxes are emptied in vials to determine effective application width

Calibration Method

- Same approach as drop spreader
- 1.) Effective application width is 6 ft.
- 2.) 3.6 lbs. of 28-3-10/1,000 ft² must be applied.
- 3.) 3.6 lbs. should be in the hopper after traveling 167 feet.

Sprayer Calibration

- Similar Methods as spreader calibration
- Things that affect output:
  - Type & size of nozzle
  - Operating speed
  - Operating Pressure
Steps
1. Determine Operating Speed RPM
2. Determine Operating Pressure PSI
3. Measure Boom width & Determine Test area size.
4. Operate & Time Sprayer over known area.
5. Collect water under each nozzle for recorded operating time.

Example
Boom width=17 ft.
Operating speed=1,500 rpm in first gear
Operating pressure=30 psi

Time Travel Distance
-Boom width = 17 ft
-Calibrating for 1,000 ft²
  1,000 ft² = 59 ft.
  17 ft.
-Speed = 1,500 rpm
-Time = 14 seconds
Measure Sprayer Output

- Hold containers under every nozzle for 14 seconds at operating psi.

Measure Sprayer Output

- Record every nozzle output
- Take average output for the nozzles
  - Ex. 14 oz
  - Replace or repair any nozzle that puts out more or less than 5% of average
    - 14 x 0.95 = 13.3 oz
    - 14 x 1.05 = 14.7 oz

Measure Sprayer Output

- Average output =
  - 14 oz x 16 nozzles = 224 oz

\[
\frac{224 \text{ oz}}{128 \text{ oz/gallon}} = 1.75 \text{ gallons/1000 sq ft}
\]
Tank Mix/Application Example

- **Given Information:**
  - Liquid fertilizer (Brand X) label states a rate of 3 fl. oz/1,000 ft².
  - Sprayer output is 1.75 gal./1,000 ft².
  - Tank size is 300 gallons.

- How much fertilizer must be added to 300 gallon tank?

**Solution**

\[
\frac{3 \text{ oz. fertilizer}}{1.75 \text{ gallon}} = \frac{X}{300 \text{ gal}}
\]

\[1.75(X) = 3(300); \quad 900 = 514 \text{ oz.}
\]

\[X = \frac{514 \text{ oz.}}{1.75} \text{ or 4 gallons of fertilizer added to the 300 gallon tank}
\]

Another Example

- **Given the same facts, how much water and fertilizer X needs to be mixed to control an area of 65,500 ft²?**
Solution

How much water must be added to the tank?

\[ \frac{1.75 \text{ gal. output}}{1,000 \text{ ft}^2} = \frac{\text{water needed} \ (X)}{65,500 \text{ ft}^2}. \]

\[ 1,000(X) = 1.75(65,500); \]

\[ 114,625 = \frac{114.6 \text{ gallons of water}}{1,000} \]

Solution

How much fertilizer X must be added to the tank?

\[ \frac{3 \text{ oz. fertilizer}}{1.75 \text{ gal. output}} = \frac{X}{114.6 \text{ gal. water}} \]

\[ 1.75(X) = 3(114.6); \]

\[ 343.8 = \frac{196 \text{ oz.}}{1.75} \]

Summary

196 oz. of fertilizer X
114.6 gallons of water
65,500 ft² area
Fertilizer label rate of 3 oz. per 1,000 ft².
<table>
<thead>
<tr>
<th>Phosphorus Fertilizer Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock Phosphate</td>
</tr>
<tr>
<td>Superphosphate (0-20-0)</td>
</tr>
<tr>
<td>Triple superphosphate (0-46-0)</td>
</tr>
<tr>
<td>Ammoniated phosphates</td>
</tr>
<tr>
<td>Monoammonium phosphate (MAP) 11-48-0</td>
</tr>
<tr>
<td>Diammonium phosphate (DAP) 18-46-0</td>
</tr>
</tbody>
</table>
Potassium Fertilizer Sources
- Potash – burn wood, leach ashes with water and evaporate water to get K salts, mostly K₂CO₃
- Most K fertilizers are taken from salt mines
  - KCl – potassium chloride – muriate of potash (0–0–60)
    - Inexpensive
    - High Salt Index
- K₂SO₄ – potassium sulfate – sulfate of potash (0–0–50)
  - Lower salt index
  - For establishment look for this source
- KNO₃ – potassium nitrate (13–0–44)
  - Very high salt index!

Calcium and Magnesium Sources
- Seldom required when pH is above 5
- In cases where we want to increase Ca without increasing pH we can use gypsum
- Ca and Mg are usually present as impurities in N, P, and K fertilizers
Sulfur Sources

- Component of many N, P, and K fertilizers
- Superphosphate
- Sulfur-coated urea
- Sulfate of potash
- Atmospheric deposition is a main source

Micronutrient or Trace Element Sources

- Micronutrients: Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Boron (B), Molybdenum (Mo), Chlorine (Cl), and Nickel (Ni)
- Normally sufficient in most soils – soil testing is unreliable at this point
- Dangerous to apply: over-application is easy and can result in toxicity (although Fe is pretty safe)

Micronutrients

- Iron (Fe)
  - Cofactor for chlorophyll formation
  - Chlorosis at high pH
- Magnesium
  - Deficiencies at low pH
  - Center of chlorophyll molecule
  - Enzyme activity
  - Test for deficiency with Epsom salt
    - 1 teaspoon / 1 pint of water
How do you measure a fertilizer response in a turf setting?

- Aesthetics characteristics:
  - color: dark green
  - shoot density: dense
  - uniformity: consistent
How do you measure a fertilizer response in a turf setting?

- Aesthetics characteristics:
- Functional characteristics:
  - * withstand traffic stress
    (wear, compaction)
  - * recuperate from damage
    (insects, diseases, traffic, heat/drought/cold)
  - * remains dense to prevent erosion and runoff

---

How do you measure a fertilizer response in a turf setting?

- Aesthetics characteristics:
- Functional characteristics:
- Growth or yield:
  Not directly!
  - Unless you are in seed or sod production

---

Nitrogen Requirements

- Things to know:
  * grasses
GUIDELINES: SPECIES
Annual Nitrogen Rates

<table>
<thead>
<tr>
<th>Species</th>
<th>Nitrogen Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kentucky bluegrass</td>
<td>3-4 lbs./1000 ft²/year</td>
</tr>
<tr>
<td>Perennial ryegrass</td>
<td>3-4</td>
</tr>
<tr>
<td>Tall fescue</td>
<td>2-5</td>
</tr>
<tr>
<td>Fine fescue</td>
<td>1-2</td>
</tr>
</tbody>
</table>

Nitrogen Requirements

- Things to know:
  - soils
  - irrigation
  - degree of sunlight (sun vs. shade)

Seasonality of cool season shoot and root growth
Nitrogen Requirements

Things to Know:
* expectation of site
* compaction/traffic
* environmental concerns

How to determine amounts

- Color & density
- Growth rate
- Indicator pests
- Soil tests?
- Foliar test (2 to 6 % N)

Standard Nitrogen Fertilization Rates

<table>
<thead>
<tr>
<th>Site</th>
<th>lbs. N/1000 ft²/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golf-greens</td>
<td></td>
</tr>
<tr>
<td>sand</td>
<td>2.5-4.0</td>
</tr>
<tr>
<td>soil</td>
<td>2.0-3.0</td>
</tr>
<tr>
<td>tees</td>
<td>3.0-5.0</td>
</tr>
<tr>
<td>fairways</td>
<td>2.0-4.0</td>
</tr>
<tr>
<td>roughs</td>
<td>0-2.0</td>
</tr>
</tbody>
</table>
### Standard Nitrogen Fertilization Rates

<table>
<thead>
<tr>
<th>Site</th>
<th>lbs. N/1000 sq.ft./year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athletic fields</td>
<td></td>
</tr>
<tr>
<td>low budget/expectations</td>
<td>1.0-2.0</td>
</tr>
<tr>
<td>med. to high budget/exp.</td>
<td></td>
</tr>
<tr>
<td>soil</td>
<td>3.0-5.0</td>
</tr>
<tr>
<td>sand</td>
<td>4.0-6.0</td>
</tr>
</tbody>
</table>

### Timing of application (season)

- Periods of high demand
  - Early fall
  - Mid-late spring
  - Late fall
Cool-Season Grass Fertilization

- As a general rule use a ratio of 4:1:2 or 3:1:3 (N-P-K)
- Exceptions
  - Establishment
  - Late fall fertilization
  - If soil tests give sufficient levels

Cool Season Fertilization
Fall (Aug 15-Sept 15)

- Most important time for fertilization
- Improves density
- Recovers from summer stress
- Accumulates carbohydrates
- Cool temperatures for optimum growing.

Late Fall: November 1st

- Apply when above ground growth has stopped, but plant is still green.
- Carbohydrate accumulation
- Good response in Spring
- Increased density
Objective of late fall fertilization
- Supply N after growth has stopped, but photosynthesis is still occurring.
- Nutrients are stored
- Reduces need for early spring fertilization.
- Use fast release nitrogen for benefit.

Cool Season Fertilizer
Late Spring
- High nutrient demand
- Reduced flush of growth

Cool Season Fertilizer
Early Spring
- Quick color response
- Rapid plant growth
- Damage recovery from winter
Cool Season Fertilizer
Early Spring

- Depletes carbohydrate reserves
  (decreases summer stress tolerance)
- Average consumer puts too much fertilizer in Spring

Summer

- Use moderate to low rates
- Improves recovery from wear
- Tolerance to some diseases
- Excessive fertilization can reduce stress tolerance
- Use slow release forms of nitrogen

Total Fertilizer by Year

<table>
<thead>
<tr>
<th></th>
<th>Early Spring</th>
<th>Late Spring</th>
<th>Summer</th>
<th>Early Fall</th>
<th>Late Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5 lb N/M</td>
<td>0.5-1.0 lbs N/M</td>
<td>Maybe a little slow release</td>
<td>1-2 lb N/M</td>
<td>1-1.5 lbs N/M Fast Release</td>
</tr>
</tbody>
</table>

- Amounts depend on turf use and needs.
Warm season Fertilization

- Apply throughout growing season at regular intervals
- 1 lb Nitrogen / 1000 / growing month

Phosphorus and Potassium

- Determining amounts:
  - Environmental considerations
    - Water quality and Phosphorus
  - Dense turf reduces runoff
  - Avoid treating impervious surfaces
  - Soil testing for P level may not be an effective tool in reducing P runoff

Phosphorus and Potassium

- Determining amounts:
  - Soil Testing
  - Foliar testing
    - Phosphorus (0.3 to 0.55 %, dry weight)
    - Potassium (1 to 2.5 %, dry weight)
Other macronutrients and micronutrients

- Calcium: often no response, can suppress K uptake
- Magnesium: can have chlorotic leaves when excessively high levels of Ca present
- Sulfur: limited response in very acid soils or in areas with limited air pollution
- Of the micronutrients, only iron gives a consistent response (dark green color), other could be deficient on sandy higher pH sites low in organic matter.

Nutrient sufficiency level

Table 11-2. Elemental tissue content sufficiency ranges and common turfgrass deficiency symptoms.

<table>
<thead>
<tr>
<th>Element</th>
<th>Tissue content sufficiency range (wt%, 1000)</th>
<th>Deficiency symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>27.3-35.8 g kg⁻¹</td>
<td>General yellow-green or chlorotic color. Other leaves usually healthy and chlorotic from top. Growth density and lateral development reduced.</td>
</tr>
<tr>
<td>P</td>
<td>3.0-5.5 g kg⁻¹</td>
<td>Leaves turn from light green to yellowish inволuntary color. Leaves may appear shoot and seed development was suppressed. New leaflets may be brittle.</td>
</tr>
<tr>
<td>K</td>
<td>13.3-25.0 g kg⁻¹</td>
<td>Older leaves exhibit following first, followed by discolor or tips then along leaf margins. Early spring deficiency symptoms.</td>
</tr>
<tr>
<td>Ca</td>
<td>4.0-12.0 g kg⁻¹</td>
<td>Yellow leaf tips and veins on grass.</td>
</tr>
<tr>
<td>Mg</td>
<td>2.0-6.0 g kg⁻¹</td>
<td>Older leaves turn red to cherry red along margins.</td>
</tr>
<tr>
<td>S</td>
<td>2.0-8.0 g kg⁻¹</td>
<td>Similar to N deficiency although roots may be unhealthy.</td>
</tr>
<tr>
<td>Fe</td>
<td>35-100 mg kg⁻¹</td>
<td>Young leaf exhibit symptoms first, typically an interveinal chlorosis, leaves are not yellow between veins. Speckled leaf margins.</td>
</tr>
<tr>
<td>Mo</td>
<td>25-510 mg kg⁻¹</td>
<td>Interveinal chlorosis of purple leaves. Leaflet margins may become brown.</td>
</tr>
<tr>
<td>Zn</td>
<td>09-55 mg kg⁻¹</td>
<td>Stunted leaves. Some (Mosses). Puckered leaf margins.</td>
</tr>
<tr>
<td>Cu</td>
<td>0-30 mg kg⁻¹</td>
<td>Younger leaf exhibit discolor. May get white-tip. Growth may be stunted.</td>
</tr>
<tr>
<td>B</td>
<td>10-60 mg kg⁻¹</td>
<td>Floral growth and setting.</td>
</tr>
<tr>
<td>Mo</td>
<td>Not known</td>
<td>Similar to Zn deficiency. May get some interveinal yellowing.</td>
</tr>
<tr>
<td>Cl</td>
<td>Not known</td>
<td>N/A (rarely observed in turf.</td>
</tr>
</tbody>
</table>

Building Your fertilizer Program

- Things to consider:
  - grasses
  - expectation of site
- soil conditions:
  - initial fertility (soil test)
  - pH
  - drainage
Building Your fertilizer Program

• Things to consider:
  • site conditions: sun/shade
  • environmental factors

• Things to consider:
  • fertilizers sources
    • release rate, costs
  • burn potential
  • application rate

• Things to consider:
  What are you going to apply?
  How much are you going to apply?
  When are you going to apply?
Final Thoughts