Fertilization

Nutrients needed by all plants

<table>
<thead>
<tr>
<th>Primary</th>
<th>Secondary</th>
<th>Micro</th>
</tr>
</thead>
</table>

- **Phosphorus (P)**
- **Nitrogen (N)**
- **Calcium (Ca)**
- **Sulfur (S)**
- **Molybdenum (Mo)**
- **Iron (Fe)**
- **Boron (B)**
- **Chlorine (Cl)**
- **Manganese (Mn)**
- **Copper (Cu)**

Fertilization

- Practice by which essential plant nutrients are supplied
- Part of a turfgrass cultural program.

Plant Available Nutrients

Balanced Fertilizer Program

- Requires high level of expertise
- Various stresses from traffic and use
- Different needs in newly established turf
- Differences in soil types and textures
Nutrient Testing

- Soil Testing for P an K
- N application based on turfgrass growth
  - Coloration
  - Clipping Yield
  - Density
- Clipping analysis

Fertilizer Materials

- Fertilizer Grade
  - N / available P₂O₅ / water soluble K₂O

Examples of Fertilizer Analysis

- 18-5-9 “Complete” Fertilizer
- 16-0-0 Only Nitrogen (Urea)
- 11-48-0 Ammonium Phosphate
- 8-0-62 Only Potash (KCl)

Fertilizer Material

- Nutrient elements are never applied in their pure form
  - Carriers such as urea, sulfates, etc.
- Inert material for handling

Fertilizer Materials

- Salt Index
  - Compare fertilizers with sodium nitrate
  - Foliar burns at high salt index
- Impurities
  - Provide micronutrients
  - Few impurities in today’s fertilizers

Turfgrass mineral composition

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Percent dry weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>nitrogen (N)</td>
<td>3 to 5</td>
</tr>
<tr>
<td>phosphorus (P)</td>
<td>0.4 to 0.8</td>
</tr>
<tr>
<td>potassium (K)</td>
<td>2 to 4</td>
</tr>
<tr>
<td>sulfur (S)</td>
<td>0.3 to 0.7</td>
</tr>
<tr>
<td>calcium (Ca)</td>
<td>0.3 to 0.6</td>
</tr>
<tr>
<td>magnesium (Mg)</td>
<td>0.1 to 0.2</td>
</tr>
<tr>
<td>iron (Fe)</td>
<td>0.1 to 0.3</td>
</tr>
<tr>
<td>manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), boron (B), chlorine (Cl)</td>
<td>trace</td>
</tr>
</tbody>
</table>
Nitrogen

- Essential nutrient
  - Key building block of proteins, DNA, chlorophyll
- Most frequently deficient nutrient in turfgrasses
  - One of few soil nutrients lost by both leaching or volatilization

Nitrogen

- Turfgrass needs
  - 3-5% of plant tissues
  - 300 lbs/ac
- Plant Uptake as inorganic forms
  - Ammonium (NH$_4^+$)
  - Nitrate (NO$_3^-$)
  - Small amounts of soluble organic forms

Nitrogen

- Excessive N applications
  - Poor root and lateral shoot growth
  - Excessive aerial shoot growth
  - Higher disease incidence
  - Reduced carbohydrate reserves

Nitrogen

- Distribution in the soil
  - Most in organic form
    - 98% organic
      - 0.5-1.5% soluble organic
    - 1-2% inorganic
  - 5% of soil organic matter (avg.)
  - 0.15% of cultivated soil (avg.)
    - 4000-6000 kg/ha of topsoil

Nitrogen Fertilizers

- Ammonia (NH$_3$) is starting material for almost all synthetic N fertilizers
- Two basic groups of N fertilizers
  - Quickly release
  - Slowly release

Nitrogen Fertilizers

- Quick release = water soluble
  - Inorganic salts
    - Ammonium nitrate, ammonium sulfate
  - Organic compounds
    - Urea (46-0-0)
Nitrogen Fertilizers

- Slow release = water insoluble
  - Urea forms
    - Ureaformaldehyde (UF)
    - Isobutylidene diurea (IBDU)
  - Coated
    - Sulfur (SCU)
    - Plastic

Growth response

- Quick release
  - Intense growth of short duration
- Slow release
  - Less intense for longer duration

Slow Release N Fertilizers

- Release mechanisms
  - Hydrolysis
  - Microbial degradation

Slow Release N Fertilizers

- Factors determining rate of release
  - pH
  - Water availability
  - Particle size
  - Temperature

Slow Release N Fertilizers

- Influence of temperature
  - Strong response for fertilizers dependent on microbial degradation

Slow Release N Fertilizers

- Influence of moisture
Slow Release N Fertilizers

- Increased efficiency in sand and thatch
  - Low nutrient retention properties
  - Limiting the amount of N available for leaching

Nitrogen Losses

- Clipping removal
- Atmospheric loss (volatilization)
- Leaching loss (nitrates)
- Immobilization

Phosphorous

- Essential plant element
  - Cell functions
    - Phospholipids
    - DNA, RNA
    - ATP
  - Plant Growth
    - Photosynthesis
    - Seed development
    - Root growth

Soil Phosphorous

- Sources of Phosphorus
  - 200-2000 kg/ha in topsoil
  - Only 0.01% readily plant available
    - Most P compound highly insoluble
    - Soluble sources reactive with other elements (Fe, Al, Ca)

Phosphorus in Turf

- Potentially no need for P fertilizer
  - where clippings are not removed
  - Insoluble phosphorus becomes soluble as the available phosphorus pool is reduced by plant uptake
Phosphorus Fertilizers

- Commercial fertilizers;
  - Rockphosphate treated with acid
    - Super phosphate
    - Triple super phosphate
  - Various carriers

Potassium

- Essential element for photosynthesis, energy metabolism and other cellular processes
  - Activates cell enzymes
- Absorbed by plants as K⁺ ion
- Tissue concentration 0.5-6% of dry matter

Importance of Potassium

- Helps adaptation to environmental stress
  - Improving drought tolerance, winter hardiness, pest resistance

Soil Potassium Cycle

- Inputs
  - Weathering from primary minerals
  - Fertilizers, Manure
  - Plant residues
- Outputs
  - Leaching
    - Soil Solution K
    - Leaf tissues K
  - Runoff
    - Soil Solution K
  - Erosion
    - K in or on mineral particles

Leaching Losses

- Higher leaching potential in acid soils
  - more of the K⁺ ions removed from solution by cation exchange in the limed soil
- Lower leaching on soil with high CEC and SOM
Potassium Fertilizers

**POTASSIUM CARRIERS**
- KCl  Potassium Chloride
- K$_2$SO$_4$  Potassium Sulfate
- KNO$_3$  Potassium Nitrate
- KH$_2$PO$_4$  Potassium Phosphate

Secondary nutrients

- Ca, Mg, S
- Plant Functions
  - Cell walls (Ca)
  - Chlorophyll (Mg)
  - Aminoacids (S)
  - Absorption of other nutrients (Ca)
- Soil functions
  - Soil structure and pH (Ca)
  - Adsorption of other nutrients (Ca, Mg)

Secondary nutrients

- Ca turfgrass fertilization
  - Lime (CaCO$_3$)  gypsum (CaSO$_4$)
  - Superphosphate
- Mg turfgrass fertilization
  - Dolomite
    - CaCO$_3$, MgCO$_3$ mixture
  - Epsom salt
    - MgSO$_4$
- Maintain optimum pH
  - Normal liming practices will also supply required calcium and magnesium

Fertilizer Application

- Liming
  - Frequency and intensity of liming
  - pH
  - Texture
  - Type of clay
  - Fertilizer (acidifying effect)
  - Lime (texture and type) properties

Soil pH and Micronutrient Availability

<table>
<thead>
<tr>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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</thead>
<tbody>
<tr>
<td>Fe, Mn</td>
<td>Cu</td>
<td>Mg</td>
<td>Zn</td>
<td>Co</td>
<td>B</td>
</tr>
<tr>
<td>Mo</td>
<td>S</td>
<td>Cr</td>
<td>Ni</td>
<td>Cu</td>
<td></td>
</tr>
<tr>
<td>Mn</td>
<td>Zn</td>
<td>Mg</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nitrogen (N)  Calcium (Ca)  Iron (Fe)
Potassium (K)  Magnesium (Mg)  Zinc (Zn)
Phosphorus (P)  Sulfur (S)  Manganese (Mn)
Copper (Cu)
Chlorine (Cl)
Boron (B)
Molybdenum (Mo)

Nutrients needed by all plants
Micronutrients

• Management in Turf
  – Iron most likely to be deficient
    • Applied as foliar spray
    • Applied as iron sulfate or iron chelate
  – Maintaining pH in a suitable range is crucial

Fertilizer Application

• Liquid or dry
• Wide variety of equipment

Fertilizer Application

• Uniformity
• Proper rate

Fertilizer Application

• Rate too low
  – Inadequate turfgrass competition against weeds
  – Low-fertility diseases
  – Thinning of the stand
  – Chlorotic appearance

Fertilizer Application

• Rate too high
  – Excessive shoot growth
  – Reduced environmental stress tolerance
  – High-fertility diseases
  – Fertilizer-burn injury

Endophytes
Disease Resistance in Fine Fescue

Endophytic fungus growing inside cells

Endophytic fungi growing in an agar medium

Endophyte Definition

- “An endophyte is an organism that lives its lifecycle within a host plant without causing disease”
  - Gwinn et al.

Effects of Endophyte Infection

- Resistance to diseases
  - Dollar spot resistance
- Insect Resistance
  - Sod webworms
  - Billbugs
  - Chinch bugs
  - Fall army worms
  - White grubs?
- Drought Tolerance

Resistance to decline under conditions of mid-summer stress
Secondary metabolites by fungal endophytes

- Production of alkaloid poisons
  - Peramine
  - Lolitrem B
  - Ergovaline
  - Paxilline
  - many others

Endophytes

- Alkaloid poisons present problems in forage grasses

Effects of Endophyte Infection

- Endophytes may cause disease
  - Choke
- Endophytes may make the plant susceptible to disease
  - Pythium

Turfgrasses with Endophytes

- Perennial Ryegrass
- Fescues
  - Fine
  - Tall

Turfgrasses with Endophytes

- Current breeding efforts
  - Bluegrasses
  - Bentgrasses

TURFGRASS SPECIES | FUNGAL ENDOPHYTE
---|---
Perennial Ryegrass | Neotyphodium loli
Tall Fescue | Neotyphodium coenophialum
Fine Fescues | Neotyphodium typhinum
                        | Epichloe typhina
Locations of Endophytes

- Crown
- Flowering culm
- Seed

Fungal hyphae located inside the seed coat in the aleurone layer

Locations of Endophytes

- Seed
  - Initially restricted to aleurone layer
  - During germination fungus infects developing embryo

Locations of Endophytes

- Crown
  - Within stems
  - Lower portion of leaf sheaths emanating from the crown

Locations of Endophytes

- Alkaloids are translocated within the plant

Locations of Endophytes

- Endophyte will travel up with the developing inflorescence
Benefits from Endophytes

• Higher competitive ability
  – Drought tolerance
  – Root growth
  – Heat tolerance
  – Pest resistance
  – Seedling vigor

Locations of Endophytes

• Seed analysis of endophyte infected cultivars
  – Seed squash
  – Grow-out test

Endophyte-enhanced Seed

• Storage conditions for endophyte-enhanced seed
  – Moisture < 11%
  – Temperature < 41°F
• Endophyte Viability
  – 2 years in tall fescue and perennial ryegrass
  – 1 year in fine fescues