Foliar Crop Nutrition: What Can We Learn From Turf?

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Fluid Technology Round Up - 2013

Fluid Fertilizer Foundation
Turfgrass Science University of Nebraska
Welcome To Foliar Feeding
What the heck is a turf specialist doing talking to a roomful of producers?
Talking Points for Foliar Applications

- “can’t justify the cost”
- “no better than granular applications”
- “plants can not efficiently take nutrients thru their leaves”
- Granulars/solubles have always been ok, why change?
Plant Nutrient Application

- Solid fertilizers
- Liquid fertilizers
- Organic fertilizers
- Inorganic fertilizers
- Foliar feeding
- Root feeding
Nutrient absorption

Granular fertilizers
- root absorption

Liquid fertilizers
- root and foliar absorption

“True” foliar feeding
- foliar (total or partial?)
Foliar Nutrition Research: A historical perspective
Foliar uptake is well documented
UPTAKE OF NUTRIENTS VIA CUTICULAR NANOPORES

MONOVALENT GREATER THAN DIVALENT IONS

- SMALL UNCHARGED MOLECULES MOVE READILY.
- HIGH CONCENTRATION MAY OVERCOME REPULSION
- PERMEATION GREATER WHEN NUTRIENTS ARE IN SOLUTION THAN WHEN DRIED ON SURFACE.
DIAMETER OF HYDRATED CATIONS &
CUTICULAR PENETRATION RATES

PERMEABILITY COEFFICIENTS OF CATIONS \((k/k_{(Li^+)0.5\text{ M}})\)

\[
K^+ > Na^+ > Mg^{2+} > Ca^{2+} >> Fe^{3+}
\]

\[
1.67 \quad 1.48 \quad 0.64 \quad 0.36 \quad 0.17
\]

DIAMETER OF HYDRATED CATIONS (nm)

\[
0.62 \quad 0.53 \quad 0.76 \quad 1.00 \quad 0.64
\]

The rate of cuticular permeation decreases as hydration diameter of monovalent cations (size) increases.

For divalent cations, increased hydration weakens charge strength and promotes greater permeation.

\[
\text{NH}_4^+ > K^+ > Na^+ > Ca^{2+} > Mg^{2+}
\]
Ectodesmata - pores with a diameter of less than 1 nm. These pores are readily permeable to solutes such as urea (radii 0.44 nm), but not larger molecules such as synthetic chelates.
Grass Leaf Surface
The first reports on foliar application of mineral nutrients in plant production date back to the second half of the 18th century.

Most studies on the uptake of mineral nutrients and their translocation within a plant were carried out after the Second World War (advent of radio isotopes).
The most studied foliar nutrient is nitrogen - 30 to 99% foliar absorbed
48 hour nutrient recovery in crops - Nitrogen

- % Soil Applied
  - 10 to 40%
    - sorghum & cotton

- % Foliar Applied
  - 31 to 99%
    - tomato, corn & turfgrasses
Basic Concept

✓ “Non-Root” parts of plants will take up nutrients.

✓ Some types of fertilizers applied to the leaves of plants can be absorbed quickly and plentifully.

✓ Foliar absorbed nutrients are quickly available to the plant.
Why Foliar Feed?

✓ More control with less risk
✓ Lower overall nutrient inputs
✓ Less nutrient leaching past the root system resulting in less potential for groundwater contamination
Foliar Fertilization

✓ “Spoon Feeding”
✓ Allows for continuous adjustment of rates.
✓ Tank Mixing
Complexing and Chelating Agents

✓ Process removes the positive charge from the metals, allowing the neutral or slightly negatively charged, chelated molecule to slide through the pores on the leaf and root surface more rapidly.

✓ These pores are negatively charged, so there is a problem with fixation of positively charged minerals at the pore entrance.

✓ No barrier for the neutral mineral.
Complexing and Chelating Agents

✓ “Organic Facilitators” have the capacity of binding substantial amounts of metals and other cations.
Liquid Products

✓ Synthetic/inorganic forms
✓ Complexes
✓ Chelates
Synthetic Chelating Agents

Synthetic chelates used in fertilizer products:

*EDTA
*HEDTA
*EGTA

✓ They are very popular and very effective when used in the soil, less effective for foliar applications

✓ They only chelate the metals.
Complex

When a metal ion combines with an electron donor, the resulting substance is said to be a complex or a coordination compound.

(CH₃)-N-COO-metal
The main difference between a metal complex and a chelate is the donor atoms are attached to the metal and each other.
Amino Acid Chelate

Form a very strong bond
Organic products used as complexing and chelating agents:

- humic acids
- fulvic acids
- ligno sulfonates
- glucoheptanates
- derivatives from the wood pulp industry
- hydrolyzed protein mixes
- citric acid
- amino acids

Some have low stability constants; tank mixing can be problematic (precipitate)
Organic Agents

* Advantage over non-organic

✓ degradable in the plant or soil

✓ provide an energy source to soil microorganisms, which in turn helps make soil nutrients available to the plant.

✓ less phytotoxic
Why Use Properly Formulated Products?

✓ Compatibility and stability mixing with other nutrients and products

✓ They are better absorbed because they are non-ionic

✓ Protects nutrient from falling out (precipitating) and assists in plant uptake and translocation
Many products are not 100% chelated and although classified by law as a chelate may not be effective

Some chelating agents are far superior to others
Uptake of Foliar Nutrients on a Putting Green

- Conducted in 2005 in Nebraska (L-93)
- Conducted in 2006 in Nebraska, Michigan (Poa & Bent) & South Carolina in 2006/07 (Champion Bermudagrass) Florida 2007 on Paspalum.
- Univ of Nebraska, Michigan State Univ (Kevin Frank), Clemson University (Haibo Liu) & Univ of Florida (John Cisar)
- 3 Treatments
- 2 times of year (cool vs. hot)
- Not with radio-isotopes
  - “uptake by subtraction”

Funded by.............
California green, L-93, 3 years old, 0.11 mowing height
101

START TIME =

6:50:14
- amount applied per unit area (from food saver)
- amount in untreated (from wash)
- amount in wash
= (amount absorbed)
Creeping Bentgrass (L-93) University of Nebraska

Minutes After Treatment

Percent Uptake

N
P
K
Creeping Bentgrass (L-93) University of Nebraska

Minutes after Treatment

Percent Uptake

B
Ca
Cu
Fe
Mg
Mn
Zn

Minutes after Treatment
Annual Bluegrass Michigan State University

Minutes after Treatment vs. Percent Uptake

- B
- Ca
- Cu
- Fe
- Mg
- Mn
- Zn
Florida Test 2 Seashore Paspalum (Macronutrients)

- N
- P
- K

Minutes after Application

Percent Uptake

0 20 40 60 80 100 120 140 160 180 200

0 10 20 30 40 50 60 70 80 90 100

N
P
K
Increase in absorption for foliar vs soluble for nutrients statistically different

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Fe</th>
<th>Mn</th>
<th>Cu</th>
<th>B</th>
<th>Ca*</th>
<th>Mg*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bent UNL</td>
<td>4.4X</td>
<td>1.3X</td>
<td>2.8X</td>
<td>1.4X</td>
<td>19.2X</td>
<td>72%</td>
<td>61%</td>
</tr>
<tr>
<td>Bent MSU</td>
<td>1.3X</td>
<td>5.3X</td>
<td>3.5X</td>
<td>NS</td>
<td>4.0X</td>
<td>62%</td>
<td>NA</td>
</tr>
<tr>
<td>Poa MSU</td>
<td>1.4X</td>
<td>8.0X</td>
<td>7.9X</td>
<td>NS</td>
<td>4.0X</td>
<td>61%</td>
<td>NA</td>
</tr>
<tr>
<td>Bermuda</td>
<td>1.1X</td>
<td>1.6X</td>
<td>9.8X</td>
<td>NS</td>
<td>3.0X</td>
<td>97%</td>
<td>92%</td>
</tr>
</tbody>
</table>

*Not in soluble product; data indicates maximum absorption.
NA = not applied

In all elements the increase in efficiency was always attributed to the foliar product (of the products tested)
Does spraying time affect absorption?

AM Spray vs. PM Spray

% Absorbed

Elements

AM Spray = 52° F, PM Spray = 71° F
Creeping Bentgrass (L-93) University of Nebraska

![Graph showing the effect of temperature on percent uptake of various nutrients.](image-url)
Work was also done in greenhouse under controlled conditions.
How quickly can the nutrient get into the leaf?
Foliar Initial Uptake

Minutes after Application vs. Percent Uptake

- N
- P
- K
- Cu
- Fe
- Mn
- Zn
Foliar Initial Uptake

Minimum after Application

Percent Uptake

N  K  Fe  Mg  Mn  Si
Foliar Uptake N source differences

Minutes after Application

Percent Uptake

N
P
K
Cu
Fe
Mn
Zn

Nitrate N

Urea N
How quickly does the nutrient get into the leaf?

- Intake is rapid, often within 15 minutes
- Carrier will influence speed
Summary of our turf work:

- Temperature
- Summer/Fall
- Time of day
- Element
- Source
- Spray Volume
- Shade
- cultivar

Nutrients applied to turf can be foliar absorbed
Agronomic Law of Minimum

- 13 essential elements besides C, H, O₂ are required-
- Growth and health will be limited by the lowest optimum level present
- No element may substitute for any other
- Roots at times and under certain conditions are limited in their uptake of nutrients
General information about foliar fertilization

- In general our cultured plants take up necessary nutrients from the soil.
- The basis for plant nutrition is dependent on location, cultural practices and fertilization of the soil.
- A healthy rootzone comes first. Foliar nutrition is a supplement to soil nutrition, not a substitute for it.
General information about foliar fertilization

- But even if there is optimum fertilization of the soil there is not always a continuous supply of nutrients to the plant.

- Circumstances exist where foliar fertilization is a necessary addition to soil fertilization
Foliar fertilization is by far the most effective way to apply secondary and trace elements. The readily-available nutrients are more easily utilized, because foliar absorption is a physical and chemical process and not a biological process as is the case with most granular fertilizers.
Nutritional Foliar Sprays
H.B. Tukey, Jr., PhD / S.H. Wittwer, PhD

“Produce quick, visible results and can increase the effectiveness of fertilizer applications to the soil, reducing total amounts of fertilizer applied.”

Work With Radioactive Isotopes: 1952-56
For Ph D degree at Michigan State University
Water exits plant through stomata.

Water moves up plant through xylem.

Water enters plant through roots.

Upper epidermis
Palisade mesophyll
Vascular bundle
Spongy mesophyll
Intercellular space (100% humidity)
Epidermis
Stoma
Summary of Tukey’s Work:

- Foliar fertilizer, among other things, increases chlorophyll production and photosynthesis in the leaves, which in turn increases the uptake of soil applied fertilizer - in response to increased need for water by the leaf - bringing more nutrients to the plant via the vascular system.
Foliar Feed When....

- Poor root structure
- Plant is under stress
- You need to push growth quickly
- You have pH problems in the soil
When Micronutrients Such as Mn, Fe or Zn are Locked in the Soil

- Alkaline conditions cause some micro-nutrients, particularly iron, manganese and zinc, to form insoluble compounds and become unavailable to plants. You can correct this condition by adjusting the soil pH to make it more acid, but this adjustment may take weeks, months or years to release the nutrients and if the water is also high in pH it may never happen.

- A foliar feeding of micronutrients will feed the plants until the soil nutrients become available again.

- This is the most common use of foliar feeding.
Why Foliar Feed?

- Better response if your optimum soil pH is out of balance
  - Fe, Mn, Zn and other minors in high pH soils
Soil pH Effects

The % Availability of Phosphate at Different Soil pH

- AVAILABLE PHOSPHORUS
- FIXED AS Fe, Al & Mn OXIDES
- REACTION WITH MINERAL SILICATES
- FIXED CHEMICALLY to SOLUBLE Fe, Al and Mn
- pH

% Availability

- 0%
- 20%
- 40%
- 60%
- 80%
- 100%
Early spring and late fall growth is limited by cold soil, even when the air is warm.

Under such conditions, soil microorganisms are not active to convert nutrients into forms available for roots to absorb. Yet, if the nutrients were available, the plant could grow.

A nutrient spray to the foliage will provide the needed nutrients immediately to the plants, allowing the plant to begin growth before the roots are able to absorb nutrients from the soil.
Soil Temperature Effects

The % Availability of Phosphate at Different Soil Temperatures

Soil Temperature 'F

% Availability

70 66 60 55 50
As turf is grown in cooler soils the need for starter nutrients such as zinc increases.
Temperature Influence on Potassium Uptake

Cold wet spring and fall soils restrict the uptake of Potassium
Spray Solution Effects

- **Surfactants/Adjuvants**
  - Beneficial to critical
- **pH**
  - Slightly acidic to neutral
Liquid fertilizer effects on spray solution pH

Water pH

- pH 7.0
- pH 8.0
- pH 10.0

- Ultraplex
- Urea
- AmSO₄
- FeSO₄
- Urea + FeSO₄
- AmSO₄ + FeSO₄

- Control
SECONDARY UTILITY ADJUVANTS

Acidifying Agent. An acidifying agent is defined as “a material that can be added to spray mixtures to lower the pH” (ASTM 1995). Typically, acidifying agents are dilute solutions of strong acids. They will rapidly lower the pH of the spray solution. However, because they are strong acids, the pH of the spray solution will rise if alkaline-based products are added to the spray solution.

Buffering Agent. A buffering agent is defined as “a compound or mixture that, when contained in solution, causes the solution to resist change in pH, with a characteristic limited range of pH over which it is effective” (ASTM 1995). Both buffering agents and acidifying agents will reduce spray solution pH. A buffering agent will maintain a pH range of the spray solution when other acid- or alkaline-based materials are added to the spray solution, whereas an acidifying agent will not maintain the spray solution pH. Buffering agents have a characteristic pH range that they will maintain, and they vary in buffering capacity.
Compendium of Herbicide Adjuvants, 9th Edition

Get the pocket-sized booklet
Just $3.00

Use our order form
## Buffering Agent or Acidifier

This information was provided by the adjuvant manufacturers/distributors.

There were **62** products that matched your request.

<table>
<thead>
<tr>
<th>PRODUCT NAME</th>
<th>MANUFACTURER/DISTRIBUTOR</th>
<th>ADJUVANT CATEGORY</th>
<th>PRINCIPAL FUNCTIONING AGENTS</th>
<th>USE RANGE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADURO</td>
<td>Estes, Inc.</td>
<td>Water Conditioning Agent and Nonionic Surfactant and Buffering Agent or Acidifier</td>
<td>Ethoxylated fatty amino-glycerol acid complex, polyoxyethylene ether blend, pH adjusting agents and deposition agents</td>
<td>1 - 4 pints / 100 typical</td>
<td>All in 1 glyphosate additive</td>
</tr>
<tr>
<td>AERO DYNEMIC</td>
<td>Helena Chemical Co.</td>
<td>Methylated or Ethylated Vegetable Oil and Nonionic Surfactant and Buffering Agent or Acidifier</td>
<td>Proprietary blend of ethoxylated alkyl phosphate esters, polyethylene modified polydimethylsiloxane, nonionic emulsifiers and methylated vegetable oils</td>
<td>For aerial use only at 2-8 qt/100 gal; provides pH reduction and buffering, NTS and oil blend. See label for rates.</td>
<td></td>
</tr>
<tr>
<td>AMS-XTRA Label/MSDS</td>
<td>Drexel Chemical Co.</td>
<td>Buffering Agent or Acidifier and Nitrogen Source</td>
<td>Ammonium sulfate solution, dimethylpolysiloxane</td>
<td>1-2.5 gal/100 gal</td>
<td>Contains defoaming agents</td>
</tr>
<tr>
<td>AQUA-KING MAX</td>
<td>Estes, Inc.</td>
<td>Nonionic Surfactant and Buffering Agent or Acidifier</td>
<td>Nonylphenol polyethylene glycol ether, glycol and free fatty acids, organic phosphatic acids, dimethylpolysiloxane</td>
<td>1-4 pt/100 gal</td>
<td>Aquatic Labeled, pH Buffering</td>
</tr>
<tr>
<td>BALLAST</td>
<td>Winfield Solutions, LLC</td>
<td>Buffering Agent or Acidifier</td>
<td>Alkylarylpolyethoxylethanol phosphates and organic phosphatic acids</td>
<td>1-12 oz/100 gal</td>
<td></td>
</tr>
<tr>
<td>BRANDT PROLEC Label/MSDS</td>
<td>Brandt Consolidated, Inc.</td>
<td>Buffering Agent or Acidifier and Water Conditioning Agent and Nonionic Surfactant and Deposition (Drift Control) and/or Retention Agent</td>
<td>Phospholipids, ethylenimine acid and fatty acid ethoxylated</td>
<td>4-16oz/100 gal for acidification; 0.5-2 pts/100 gal for surfactant; 1-2 qts/100 gallon for drift reduction</td>
<td></td>
</tr>
<tr>
<td>BRONC MAX</td>
<td>Wilbur-Ellis Company</td>
<td>Water Conditioning Agent and Surfactant</td>
<td>AMS/ammonium alkyl aryl sulfonates, polycarboxylic acid</td>
<td>1-8 pt/100 gal</td>
<td>AMS replacement</td>
</tr>
</tbody>
</table>
Precipitate Formation

- $\text{FeSO}_4 = \text{precipitate at pH} = 8 \& 10$
- Foliar (buffered) solution no precipitate
- Weight equaled ca. 60% of what was initially dissolved
- In 100 gallons = ca. 0.25 lbs
How do you know if you need a buffering agent?

- Recommended on label
- pH >7.5
- Tank mixing multiple products
How do you know your spray solution pH?

• Measure it, but how?
  – How accurate do you need to be?
  – When should you test?

• For some water sources, pH fluctuates with season, test frequently
A science class favorite, this package of 100 pH test papers lets you learn about acids and bases. Chemical reactions cause the paper's color to change when exposed to varying levels of acid and base. This color change can be matched against the 1-14 scale color chart provided to determine the pH of the solution at hand.

More than just a lab experiment, recent studies have shown the pH of the body is important to one's overall health and well being. This pH test paper can also be used on collected samples of your own bodily fluids (saliva, urine) to determine your pH.
Putting it all together............
6 CO₂(g) + 6 H₂O(l) → C₆H₁₂O₆(aq) + 6 O₂(g) + water + light energy → glucose + oxygen

6 CO₂ + 6 H₂O + light energy → C₆H₁₂O₆ + 6 O₂
Photosynthesis
- Growth
- Carbohydrate accumulation

Respiration
- Maintenance
- Carbohydrate depletion
Annual Bluegrass / Bentgrass Greens

- Winter
  - 1/2 to 1 lb Granular N/1000 ft²
  - Foliar N & Fe mixed with Growth Regulators & elicitors

- Spring
  - Weekly Foliars with 1/20 to 1/10 lb N / 1000 ft² & PO3 and Si and elicitors

- Summer
  - 1/2 lb N&K/1000 sq/ft with aerification

- Fall
  - 1 lb N/1000 sq/ft
Seasonal Shoot Root Growth
Warm - Season Turfgrass
Delay granular N fertilization until spring growth has initiated. Foliar feed with N, PO4 and minors.

Avoid high N fertilization during hardening off period. Begin foliar feeding with a complete program in winter.

Higher N with High Foliar Phosphites
High foliar Mn
Soybean Growth Stages

and threats to maximize yield potential

April
- Wireworm, seedcorn maggot

May
- White Grub

June
- Bean Leaf Beetle
- Soybean Cyst Nematode
- Spider Mite
- Soybean Aphid
- White Mold

July
- Bean Leaf Beetle

August
- Fusarium Root Rot
- Rhizoctonia Root Rot
- Phytophthora Root Rot

September
- Pythium Root Rot
- Brown Stem Rot

October
- Sudden Death Syndrome
Take Home

- Embrace new technologies while staying true to basic agronomic principles
- There are agronomic benefits of low dose, foliar fertilizer application - specifically as a supplement to an already existing, sound, granular program.
Take Home

- There are inherent nutrient uptake inefficiencies from the soil based on limitations of the environment (soil - physical, chemical, biological).
- Foliar nutrition makes sense when root growth is compromised or plants are under stress.
Bottom Line for Foliar Nutrition

• The work in agronomic crops is not as far along as the work in turf systems
• Most University specialists are skeptical, as they should be, concerning recommendations
• Be open minded about the possibilities.
http://turf.unl.edu

Thanks and have a great holiday season!!