Nothing minor about **micronutrients**

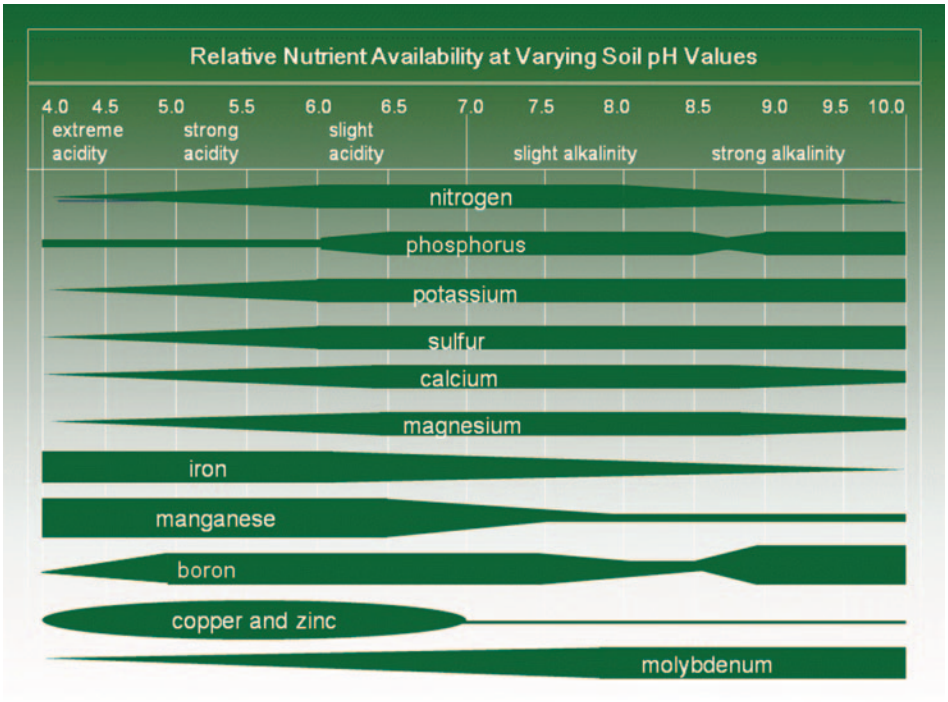
ALTHOUGH TURFGRASSES CONTAIN ONLY TRACE AMOUNTS OF BORON (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn), these eight micronutrients are essential for plant growth and survival. When it comes to turfgrass nutrition, essential micronutrients deserve attention and should not be overlooked.

In order for a nutrient to be considered 'essential', it must 1) be required for a turfgrass plant to complete its growth cycle; 2) perform a plant function that cannot take place without it; or 3) be directly involved in photosynthesis, respiration, or the production or breakdown of organic materials within the plant, or necessary for a critical chemical reaction.

Of the essential nutrients, carbon, hydrogen and oxygen are supplied to turfgrasses by carbon dioxide and water. The majority of carbon dioxide is taken up through minute pores, or stomates, on the surface of leaves and stems. In addition to moving nutrients from one plant part to another, water also provides turfgrasses with hydrogen and oxygen.

Turfgrasses primarily absorb the remaining essential nutrients from soil. The fibrous nature of the root system and the massive number of root hairs contribute to a turfgrass plants ability to extract these mineral nutrients from a soil solution. Due to the amount turfgrasses require, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) are categorized as macronutrients. The macronutrients are often further sub-divided according to the amount required by turfgrasses. Nitrogen, P and K are primary macronutrients, while Ca, Mg and S are secondary macronutrients. Results of analyses of macronutrients in tissue are often reported as percent on a dry-weight-basis. For example, bermudagrass turf is often considered nutrient deficient if shoot tissue contains less than 2% N, 0.3% P, 1% K, 0.5% Ca, 0.3% Mg and 0.2 % S on a dry-weight-basis.

Figure 1. Soil pH chart.



EFFECT OF SOIL PH ON UPTAKE OF MICRONUTRIENTS

Micronutrients, also referred to as trace or minor nutrients, are usually found in dry turfgrass shoot tissue at levels less than 1,000 ppm. Micronutrient applications are seldom beneficial to turfgrasses growing in fertile, mineral soils with a slightly acid pH (for example, 6.0 to 6.9). However, when turfgrasses are managed in high-sand-content soils, organic soils or soils with high- or low pH, the application of a micronutrient may be very beneficial. The availability of micronutrients in soil for uptake by turfgrasses is influenced by the level of soil acidity or alkalinity. Plant availability of Fe, Mn, Cu and Zn decreases as the soil pH rises above neutral (7.0), while that of Mo increases with increasing soil pH (Figure 1).

ROLE OF MICRONUTRIENTS IN TURFGRASSES

Boron affects the formation of plant cell walls and the transport of sugars. Chlorine influences photosynthesis, the division and length of plant cells, and the opening and closing of stomates. Copper is necessary for photosynthesis and influences the lignin content and strength of cell walls. Iron is involved in the production of chlorophyll. Several enzymes associated with the transfer of energy, N fixation and the production of lignin contain Fe. Manganese is necessary for photosynthesis and is involved in the formation and breakdown of N-containing compounds. Plants deficient in Mn for an extended period of time are, most often, very low in chlorophyll. Molybdenum is involved in the formation of proteins and the use of N and S by turfgrasses. Molybdenum also affects the production of pollen. Nickel, recently classified as an essential micronutrient, is a component of an enzyme.

Table 1.
Copper recommendations for both new and established turfgrass areas (for organic soils only).[a,b]

	Application method	
Copper, Cu	Soil broadcast	Foliar Spray[c]
Soil test level	Amount of Cu to apply/1000 sq. ft.[d]	
ppm	Pound Cu	Ounce Cu
0 to 2.5	0.1 to 0.3	0.4
> 2.5	0.0	0.0

[a] From: Rosen, C.J., P.M. Bierman and R.D. Eliason. 2008. Soil test interpretations and fertilizer management for lawns, turf, gardens, and landscape plants. Department of Soil, Water, and Climate. Regents of the University of Minnesota (http://www.extension.umn.edu/distribution/horticulture/components/1731-complete.pdf)
[b] Applications are suggested on a trial basis only.
[c] Apply foliar sprays at the recommended rate 2 to 3 times per year.
[d] Multiply by 44 to convert the rate from lb./1000 sq. ft. to lb./acre; multiply by 2.7 to convert from oz./1000 sq. ft. to lb./acre.

Table 2.
The chemical symbol, plant available form and general sufficiency range in shoot tissue of eigh essential micronutrients.[a]

Micronutrient, chemical symbol	Form absorbed by plants	General sufficiency range, ppm- dry weight basis
Boron, B	H_3BO_3, BO_3^{-3}	5 - 60
Chlorine, Cl	Cl^-	200 - 400
Copper, Cu	Cu^{+2}, $Cu(OH)^+$, Cu-chelates	5 - 20
Iron, Fe	Fe^{+2}, Fe^{+3}, Fe-chelates	50 - 100
Manganese, Mn	Mn^{+2}, Mn-chelates	20 - 100
Molybdenum, Mo	MoO_4^{-2}, $HMoO_4^-$	1 - 4
Nickel, Ni	Ni^{2+}	< 1
Zinc, Zn	Zn^{2+}, $ZnOH^+$	20 - 55

[a] Summarized from: Carrow, R.N., D.V. Waddington and P.E. Rieke, 2001. *Turfgrass soil fertility and chemical problems: assessment and management.* Hoboken, NJ: John Wiley and Sons, Inc.

Several enzymes active in the production of carbohydrates and proteins contain Zn.

Many soil testing laboratories test for available B, Cu, Fe, Mn, Mo and Zn. More than one method (Mehlich II and III, DTPA) can be used to extract micronutrients from soil and results often vary from one method to the next. After testing soil, very specific recommendations may be made regarding the application of individual micronutrients (Table 1). Interestingly, it is not uncommon for turfgrasses to respond favorably to an application of Fe even though a soil test report indicates that the concentration of the micronutrient is in the High range. An analysis of plant tissue is recommended as a supplement to soil testing. Micronutrient levels in turfgrass tissue are usually reported as ppm on a dry-weight basis. For example, bermudagrass turf is often considered nutrient deficient if shoot tissue contains less than 100 ppm Fe, 30 ppm Zn, 25 ppm Mn and 10 ppm Cu on a dry-weight-basis. Information regarding specific micronutrient sufficiency ranges for individual turfgrass species or varieties is limited, however general or common sufficiency ranges have been published (Table 2).

POSSIBILITY OF A MICRONUTRIENT DEFICIENCY

Some micronutrients are more apt to be at low or deficient levels than others. A deficiency of Fe in turfgrasses maintained out of doors is much more common than a deficiency of the other micronutrients. Iron deficiencies are most likely to occur in poorly rooted and thatchy turfs maintained in calcium-rich soils with high P and pH (> 7.5) levels, and very little organic matter. Turfgrasses irrigated with water high in bicarbonates, P, Ca, Cu, Mn or Zn may also be deficient in Fe.

Although less commonly observed than a Fe deficiency, a Mn deficiency in turfgrasses is not unusual. A Mn deficiency, like that of Fe, may occur in plants maintained in soil with a high pH and Ca level. Extended periods of dry, warm weather reduce Mn availability in soil. Boron, Cu, Mo and Zn deficiencies are rare. High levels of Ca in soils can reduce the availability of B. Boron deficiencies are also more likely to occur in turfgrasses growing in porous, sandy soils with a high pH and high level of K. Since Cu can tightly bond with soil organic matter, deficiencies of Cu have been observed in turfgrasses growing in organic soils. Copper deficiencies have also occurred in turfgrasses maintained in sandy and alkaline soils, and soils with high N, P, Fe, Mn, Zn or pH levels. Molybdenum deficiencies are more prevalent in turfgrasses growing in acidic and sandy soils.

High levels of S, Cu, Fe and Mn may limit the amount of Mo turfgrasses absorb from soil. Zinc deficiencies have occurred more often in turfgrasses in shade, in alkaline or acidic soils, and during cool, wet weather. At present, no Cl or Ni deficiencies have been documented in turfgrasses.

Once inside a turfgrass plant, some micronutrients are much more mobile than others. Iron and Mn are immobile and Cl is mobile in turfgrass plants. Boron, Cu, Mo and Zn are somewhat mobile. The location of a deficiency symptom on a turfgrass plant is influenced by nutrient mobility. For example, due to the inability of a turfgrass plant to move the micronutrient from older to younger leaves, symptoms of a Fe and a Mn deficiency occur first on young leaves. Leaf tissue between veins of young leaves of a plant deficient in Fe often turns yellow then white. This condition is commonly referred to as interveinal chlorosis. The youngest leaves of a plant deficient in Mn usually develop small grayish-green spots before the leaf tips and the tissue between veins turn yellow. Turfs deficient in

Several factors deserve consideration when applying micronutrients in water to turfs. They include: the weather; the type, nutrient status and growth rate of turfgrass; leaf wetness; the form of the micronutrient; the product application rate, frequency and interval; the spray volume; and the spray tip.

Mn often appear mottled. Young leaves of a turfgrass plant deficient in B may have yellow or white leaf tips and exhibit interveinal chlorosis long before older leaves. The margins of young and middle-aged leaves of plants deficient in Cu often turn yellow, and leaf tips may have a bluish cast. Symptoms of a Mo deficiency are much like that of an N deficiency. The older leaves of plants deficient in Mo 'fire' when the micronutrient is mobilized and moves to young leaves. Leaves of Zn deficient plants are often mottled and stunted, and may roll or appear 'crinkled'. The symptoms of Zn deficiency may be more apparent on younger leaves.

SELECTING AND APPLYING A PRODUCT

A micronutrient deficiency can be corrected by either a foliar or soil application. Micronutrient-containing fertilizer formulations may be in solid or liquid form (Figure 2), and a micronutrient may be mixed with other nutrients (Figure 3, on page 13).

>> **Figure 2.** An example of a liquid fertilizer formulated with macronutrients and micronutrients.

Whether in liquid or solid, organic or inorganic form, a fertilizer must be applied uniformly according to label directions.

Several factors deserve consideration when applying micronutrients in water to turfs. They include: the weather; the type, nutrient status and growth rate of turfgrass; leaf wetness; the form of the micronutrient; the product application rate, frequency and interval; the spray volume; and the spray tip. The rate at which cells of leaves divide and expand is influenced by light, temperature, moisture and fertility level. The length of time between micronutrient applications can be adjusted according to the rate of growth of the aerial shoots. The recommended product application interval may decrease with increasing plant growth rate.

Several sources of an individual micronutrient may be available for use in turf (Table 3, on page 12). For example, iron (ferrous) sulfate and iron chelates are common sources of iron. Iron chelates are most often more effective as soil applications than ferrous sulfate, which can be highly effective when applied as a foliar treatment. In soil, a ferrous ion (Fe+2) from iron sulfate may quickly be converted to a ferric ion (Fe3+), which is much less available for plant uptake.

Chelates are produced by combining a positively (cation) or

negatively (anion) charged micronutrient with an organic compound or chelating agent. The reaction results in a 'protected' micronutrient cation or anion bound in a chemical ring structure. The length of time during which a chelated micronutrient remains in plant available form in soil is influenced by the soil pH, the ion that is in protected form, and the chelating agent. Citric (CIT), acetic [DTPA, diethylene triamine pentaacetic acid; EDTA, ethylene diamine tetraacetic acid; EDDHA, ethylene diamine di (o-hydroxyphenylacetic acid); and HEDTA, hydroxyethyl ethylene diamine triacetic acid] and oxalic (OX) acids are examples of chelating agents used to produce chelated micronutrients.

When foliar feeding, no more than one-half gallon of a micronutrient-containing solution is usually applied per 1,000 sq. ft. The intent of a soil-drench (one gallon of water or more per 1,000 sq. ft.) treatment is to carry the micronutrient through thatch and into the soil. Turfgrasses most often respond more quickly to a foliar feeding than a granular or soil drench application. The addition of a surfactant may, or may not, be recommended.

Thorough and uniform coverage is essential when applying a micronutrient to turf in water. The diameter of spray droplets varies depending on the spraying pressure and the spray tip installed in the nozzle body on the sprayer boom. The diameter of spray droplets may range from very coarse (> 550 microns) to very fine (< 150 microns).

Table 3.
Several fertilizer sources of essential micronutrients and their approximate nutrient content.[a]

Source	Formula	Approximate micronutrient content (%)[b]
Boron, B		
Borax	$Na_2B_4O_7{\cdot}2H_2O$	11
boric acid	H_3BO_3	17
Chlorine, Cl		
Potassium chloride	KCl	45
Copper, Cu		
Copper oxide	CuO, Cu_2O	75, 89
Copper sulfate	$CuSO_4{\cdot}H_2O$, $CuSO_4{\cdot}5H_2O$	25, 35
Copper chelate	Na_2Cu EDTA	13
Iron, Fe		
Ferric oxide	Fe_2O_3	69
Ferrous oxide	FeO	77
Ferric sulfate	$Fe_2(SO_4)_3{\cdot}4H_2O$	23
Ferrous sulfate	$FeSO_4{\cdot}7H_2O$	20
Ferrous ammonium phosphate	$Fe(NH_4)PO_4{\cdot}H_2O$	29
Ferrous ammonium sulfate	$(NH_4)_2SO_4{\cdot}FeSO_4{\cdot}6H_2O$	14
Iron chelates	NaFeDTPA, NaFeEDTA	10, 6
Manganese, Mn		
Manganese oxide	MnO	41 - 68
Manganese sulfate	$MnSO_4{\cdot}4H_2O$	27
Manganese chelate	Na_2Mn EDTA	12
Molybdenum, Mo		
Ammonium molybdate	$(NH4)_6Mo_7O_{24}$	54
Molybdenum trioxide	MoO_3	66
Sodium molybdate	$Na_2MoO_4{\cdot}2H_2O$	40
Zinc, Zn		
Zinc oxide	ZnO	78
Zinc sulfate	$ZnSO_4{\cdot}H_2O$, $ZnSO_4{\cdot}7H_2O$	35, 23
Zinc chelate	Na_2Zn EDTA	14

[a] From: Carrow, R.N., D.V. Waddington and P.E. Rieke. 2001. *Turfgrass soil fertility and chemical problems: assessment and nanagement.* Hoboken, NJ: John Wiley & Sons, Inc.
[b] The actual percentage of the micronutrient may vary depending on the purity and source of the product.

GUARANTEED ANALYSIS

Magnesium (Mg) 1.00%
1.00% Soluble Magnesium
Sulfur (S) 3.50%
3.50% Combined Sulfur
Boron (B) 0.02%
Copper (Cu) 0.25%
0.25% Chelated Copper
Iron (Fe) 4.00%
4.00% Chelated Iron
Manganese (Mn) 1.00%
1.00% Chelated Manganese
Molybdenum (Mo) 0.0005%
Zinc (Zn) 0.60%
0.60% Chelated Zinc (Zn)

Derived from: Magnesium Sulfate, Sodium Borate, Copper Glucoheptonate, Iron Glucoheptonate, Manganese Glucoheptonate, Zinc Glucoheptonate, and Sodium Molybdate

- ***Optimal liquid foliar formulation of essential plant nutrients***
- ***Aids in the prevention and correction of micronutrient deficiencies***

RECOMMENDED RATES

Turf (Fairways, Greens & Tees): Apply 2-6 oz. per 1,000 sq. ft. or 3-6 quarts per acre in enough water to cover.

Trees & Ornamentals: Apply 4-6 quarts per 100 gallons of water as a drench or foliar spray. Repeat as needed.

PRODUCT INFORMATION

Harrell's MAX Minors (complete minors package) is a liquid foliar formulation of essential nutrients and micronutrients to aid in the prevention and correction of deficiencies. The ratio of minors in Harrell's MAX Minors micronutrient package has been optimized for higher pH soils where trace elements often become unavailable to the plant. In alkaline soils, Harrell's MAX Minors will remain available longer than many other products. Harrell's MAX Minors can be applied with most pesticides and fertilizers except high phosphate materials. The addition of a non-ionic surfactant will aid surface coverage which will help leaf absorption.

DIRECTIONS FOR USE

Harrell's MAX Minors may be tank mixed with most liquid fertilizer and pesticides; however a jar compatibility test should be performed on unknown combinations.

PRECAUTIONS

Shake well before each use. Avoid getting in eyes, mucous membranes or on skin. Use of side-shielded safety glasses is recommended. Use with adequate ventilation. Keep container capped when not in use. Do not contaminate feed, seed, or water supplies. Avoid spraying on concrete or painted surfaces as staining may occur.

Keep away from Children.

FIRST AID

Skin: Remove contaminated clothing. Wash with plenty of clean water and soap. Consult a physician.
Eyes: Rinse with clean water for a minimum of 15 minutes. Seek medical attention.
Internal: Drink 2 glasses of water. DO NOT INDUCE VOMITING. Seek medical attention at once.

STORAGE AND CONTAINER DISPOSAL

Store this product in a dry place, in original container only. Keep lid tightly closed. Keep away from open flame or intense heat. Triple rinse container and offer for recycling or dispose of in accordance with federal, state and local authorities.

CONDITIONS OF SALE

Seller warrants that products will be labeled as required under state and federal laws and that they conform to the label description. Any non-conformance must be reported in writing to Seller within Thirty(30) days after purchase as a prerequisite to maintaining any claim against Seller. Buyer agrees to inspect all products purchased immediately upon delivery. The seller's liability under this warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability and fitness for a particular purpose. There are no warranties which extend beyond this statement.

Figure 3. An example product label identifying the micronutrient sources and application rates.

Manufacturers often rate the effectiveness of each type of spray tip as good, very good, excellent or not recommended, for specific applications (e.g., broadcast liquid fertilizer; contact and systemic fungicides, herbicides and insecticides; …).

Since an application may, or may not result in a visual improvement in foliage color or turfgrass health even though test results indicate that one or more micronutrients are in the low or deficient ranges, it may be advantageous to treat a limited amount of turf with a product of interest before making a broadcast application over the entire sports field. ■

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