# SOIL MICRONUTRIENTS: FROM B to Z

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## Introduction

Soil nutrients that are essential to plants are categorized into three broad groupings:

(1) Macronutrients: carbon (C), hydrogen (H), oxygen (O) - supplied by air and water – nitrogen (N), phosphorus (P), potassium (K).

(2) Secondary Nutrients: calcium (Ca), magnesium (Mg), sulfur (S).

(3) Micronutrients: boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), zinc (Zn).

Regardless of category, all these elements are critical to crop production. The only variance is the relative demand level of plants for the given nutrient. Macronutrient requirements of plants are relatively high; whereas, the secondary nutrients are often added to soils incidentally with lime, manure, precipitation, etc. and usually do not limit crop growth as frequently as N, P, or K deficiencies. Soil micronutrients, on the other hand, are needed by plants in small quantities. This does not diminish their importance in crop production. This paper will focus on the major micronutrients and their role in crop production.

Crop deficiencies of one or more micronutrients are most likely caused by soil conditions that render the element unavailable to the plants. Example of such soil conditions include: extreme soil pH levels, eroded soils, soil texture extremes (sands and heavy clays), soil organic matter content (too high or too low), soil moisture (too wet or too dry), and temperature (too cool).

While a deficiency of any essential element will reduce plant growth, the overuse of some micronutrients can also be detrimental and may be more difficult to correct than a deficiency. The danger of building up toxic levels is greater on coarse-textured soils such as sands, loamy sands, and sandy loams.

Micronutrients should never be applied routinely as part of an annual soil fertility regime. Parameters that should be assessed prior to the consideration of any micronutrient application include:

- Is the soil test low for the given nutrient?
- Do micronutrient deficiency symptoms appear on the plant <u>and</u> is the deficiency confirmed with plant analyses?
- Is the demand by a specific crop for the given micronutrient high (Table 1)?

A renewed interest in fertilizer micronutrients has occurred in the agricultural supply sector over the past few years due to a number of factors. These include:

(1) Perceived increase in crop need driven by more intensive grain production over the past three growing seasons which was spurred by the high commodity prices of 2007 and 2008. Additionally, new corn varieties with higher yield potential may be removing greater amounts of soil micronutrients than in the past.

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(2) Increased availability of precision nutrient application equipment that allows soil micronutrients to be applied accurately and uniformly at relatively low rates.

(3) Ease and convenience of adding micronutrients to multiple-input tank mixes of herbicides, fungicides, etc. already destined for field application.

(4) The potential for increasing retailer profit margins with the sale of micronutrient products.

(5) An increased awareness of soil nutrient deficiency occurrences by producers and their crop advisors.

Table 1. Relative micronutrient requirements of some Wisconsin crops.

| **Crop** | **Micronutrient** | | | | |
|---|---|---|---|---|---|
| | **Boron** | **Manganese** | **Zinc** | **Molybdenum** | **Copper** |
| | | | | | |
| Alfalfa | **High** | Medium | Low | Medium | Medium |
| Corn | Low | Medium | **High** | Low | Medium |
| Soybean | Low | **High** | Medium | Medium | Low |
| Wheat | Low | **High** | Low | Low | Medium |
| Oat | Low | **High** | Low | Low | Medium |
| Potato | Low | Medium | Medium | Low | Low |
| Beet | **High** | Medium | Medium | **High** | **High** |
| Cabbage | Medium | Medium | Low | Low | Low |
| Lettuce | Medium | **High** | Medium | **High** | **High** |
| Onion | Low | **High** | Low | **High** | **High** |
| Pasture (legume-grass) | **High** | Low | Low | **High** | Medium |
| Small grain silage | Low | **High** | Low | Low | Medium |
| Sorghun-sudan forage | Low | **High** | Medium | Low | Medium |

Source: Laboski et al., 2006. Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin. UW-Extn pub. A2809.

## Soil Micronutrients

### Boron (B)

**Role in plants:** B is needed by plants for cell division, cell wall synthesis, and pollen germination. B deficiencies in Wisconsin are more widespread than deficiencies of any other micronutrient. Only 0.5 to 2.5% of boron in the soil is available to plants. Soils may contain 0.5 to 2.0 parts per million (ppm) of available boron, but more than 5.0 ppm of available boron can be toxic to many agronomic crops. Plants take up less than 0.5 lb B/a.

**Susceptible crops:** Forage legumes and of some vegetable crops grown in Wisconsin are susceptible to B deficiency. Deficiency of B is the major micronutrient problem in alfalfa production. Specific crops with high requirements include alfalfa, trefoil, beet, canola, cauliflower, celery, sunflower, tomato, and forage brassicas. Those with medium requirements are apple, asparagus, broccoli, brussels sprouts, cabbage, carrot, lettuce, melons, radish, red clover, spinach, tobacco, and vetch.

**Deficiency symptoms:** In alfalfa, B deficiency is often evidenced with a yellowing or reddish color of the leaves at the top of the plant with a bunched or bushy appearance of the new growth due to shortened internode growth. If the deficiency continues, the plants' growing points can stop developing and may eventually die. Obviously, lack of B can severely reduce the yields of crops.

With forage legumes, B deficiency symptoms tend to be evident after first cutting, especially with dry weather. Because B is an immobile soil nutrient, the deficiency symptoms will occur on the new (top) growth and the lower leaves may remain green. This can be mistaken for leafhopper injury.

**Susceptible soils:** Sands and other soils low in organic matter are more likely to be deficient in boron than other soils. The storehouse for most of the boron is the soil organic matter. As a result, most of the available B is in the plow layer, where organic matter is highest. Sandy soils tend to be deficient in B more often than fine-textured silts and clays due to the fact that B is not readily held by the soil particles and moves down through coarse-textured soils, often leaching below the root zone of many plants.

Dry soils are also prone to temporary B deficiency. When the soil surface dries out, plants are unable to feed in the zone where most of the available B is present. This can lead to deficiency. When rain or irrigation moistens the soil, the plants can again feed from the surface soil and the B deficiency often disappears.

**Diagnosis:** Soil test. Optimum ranges are 0.5-1.0 ppm B for sands and 0.9-2.0 ppm B for other soils.

**Corrections:** On alfalfa and other forage legumes, the easiest way to apply B is in combination with topdressed fertilizers. If a soil tests low in available B or if a deficiency appears, apply 0.5-1.0 lb/a of B each year or 2 lb/a once in the rotation as a topdressing. For forage legumes grown on sandy soils, an annual application of 1.0 lb/a of B minimizes the leaching effect. Never use a borated fertilizer in the row for corn or soybean, or in the drill for small grains. The B concentrated in a band is toxic to germination of these crops and may cause severe injury.

## Chlorine (Cl)

**Role in plants:** Plants require chlorine for certain photo-chemical reactions in photosynthesis. Cl uptake affects the degree of hydration of plant cells and balances the charge of positive ions in cation transport. Cl deficiency has never been observed under field conditions in Wisconsin.

**Susceptible soils:** Response to Cl, expressed as reduced incidence of disease and higher yield in small grains, has been observed in a few studies in Oregon and the Dakotas. The soils in these states have high levels of potassium so potassium chloride fertilizer (0-0-60) is seldom applied. Because Wisconsin soils tend to be inherently low in potassium, application of potassium chloride fertilizer and manure has prevented any known Cl deficiency.

**Diagnosis:** Plant analysis, but this is rarely done. A soil test does exist for Cl, but research calibrating crop response to Cl has not been necessary in Wisconsin.

## Copper (Cu)

**Role in plants:** Cu serves as an activator of several enzyme systems in plants. In addition, Cu plays a role in seed and chlorophyll production and formation. It is present in soils at concentrations of 2 to 100 ppm with an average value of about 30 ppm.

**Susceptible crops:** Cu deficiency is rare in Wisconsin. Beets, lettuce, onion, spinach, sunflower, and tomato have moderate Cu requirements. Small grains (wheat, oats and barley) may respond to small additions of Cu if they are grown on susceptible soils.

**Deficiency symptoms:** Symptoms of Cu deficiency in small grains are a light green to yellowing of the crop along with leaf tips that may die back and become twisted. In severe cases, growth of small grains decreases and plants may die.

**Susceptible soils:** Occurrences of Cu deficiency are generally only seen on acid, organic soils. Organic matter binds Cu more tightly than any other micronutrient. Also, soils high in zinc may exasperate Cu deficiency. Cu is not easily leached from soils and usually remains in a plant-available form. Cu toxicity in some sandy soils has resulted from repeated use of copper-containing fungicides over many years. Cu toxicity problems are difficult to correct.

**Diagnosis:** Plant analysis. A soil test does exist for Cu, but only as part of a heavy metal screening. Soil test research calibrating crop response to Cu has not been conducted in Wisconsin.

**Corrections:** Band applications of inorganic Cu at rates of 1-2 lb/a on sands, 2-3 lb/a on other mineral soils, and 2-4 lb/a on organic soils. Broadcast applications of 4-10 lb/a on sands, 8-12 lb/a on other mineral soils, and 12-13 lb/a on organic soils. If copper chelates are used, reduce application rate to 1/6 of above.

Foliar applications of Cu can be an effective way to correct Cu deficiencies in small grains. Results from research in northwestern Minnesota indicate that applications at the tillering stage are most effective in correcting deficiencies. Copper sulfate is the most commonly used material for foliar applications.

## Iron (Fe)

**Role in plants:** Fe is required for synthesis of chlorophyll by plants and is also an enzyme activator.

**Susceptible crops:** Fe deficiency has rarely been observed on field or vegetable crops in Wisconsin, except that iron chlorosis has occasionally been observed on soybeans grown on alkaline soils (pH above 7.0). Fe deficiency in soybean is observed more often on the calcareous soils of Iowa and Minnesota. Turfgrass, pin oak trees, and some ornamentals such as yews occasionally develop Fe deficiency when grown on alkaline soils.

**Deficiency symptoms:**
Fe is very immobile in plants, so deficiency symptoms appear on new growth (youngest upper leaves). The veins of young leaves remain green, but the area between the veins becomes yellow (chlorotic). Each new leaf emerges paler than the one before. Eventually, new leaves, including the veins, are creamy white, devoid of chlorophyll.

**Susceptible soils:** Alkaline (high pH), calcareous soils.

**Diagnosis:** Plant analysis. A soil test does exist for Fe, but only as part of a heavy metal screening. Soil test research calibrating crop response to Fe has not been conducted in Wisconsin.

**Corrections:** The deficiency can be corrected by spraying the foliage several times with ferrous sulfate or an iron chelate. Soil applications are not very effective because of the rapid transformation of Fe contained in fertilizer to unavailable forms in the soil. Another option for correcting Fe deficiency is to decrease soil pH – if practical.

## Manganese (Mn)

**Role in plants:** Manganese (Mn) functions as an enzyme activator for steps in photosynthesis and is also involved in nitrogen metabolism in plants. It is an element found in plant tissue at concentrations ranging from 10 to 500 ppm or more. In most plants, it is deficient at less than 10 ppm and toxic when the concentration exceeds about 300 ppm.

**Susceptible crops:** Deficiency symptoms are most common in soybean, oats, and snap bean grown on high pH (6.8 or greater) mineral soils and neutral to alkaline organic soils. Other crops with high Mn requirements include lima beans, lettuce, onion, radish, raspberry, spinach, sorghum-sudan, and wheat. Crops with medium Mn needs are barley, beet, broccoli, brussel sprout, cabbage, carrot, cauliflower, celery, corn, cucumber, pea, potato, tobacco, and tomato.

In 2007, there was an unusual spike in the occurrence of Mn deficiency in soybeans grown on the eastern side of Wisconsin. All confirmed cases were grown on high pH and/or high organic matter soils (i.e. soils susceptible to Mn deficiency). In addition, most of these sites were planted with glyphosate-resistant soybean varieties (Conley & Laboski, 2008). Researchers from various states have identified a link between Mn deficiency and glyphosate-resistant soybean. Specifically, it is speculated that soybean root uptake and/or metabolism of Mn is reduced by either the glyphosate gene in soybean, the glyphosate application itself, or a combination of both (summarized in Lamb, 2008). At the very least, the potential for Mn deficiency on susceptible soils is amplified when glyphosate-resistant varieties of soybean are grown.

Crops susceptible to Mn toxicity include asparagus, forage legumes, mint, and pea. Mn toxicity of potato has also been identified on extremely acid soils (pH less than 5.0).

**Deficiency symptoms:** Symptoms appear as interveinal chlorosis (veins remain dark green but the tissue between turns yellow to white) of the younger leaves (new growth) because Mn is an immobile element. Severe cases can also cause cupping of broadleaf plants. In oats, the symptoms show up as specks of dead tissue, giving the deficiency the name “gray speck disease.”

**Susceptible soils:** High pH (6.8 or greater) mineral soils and neutral to alkaline organic soils or mucks (>6% OM). Cool weather during the growing season may also induce Mn deficiency in high demand crops.

Mn availability increases as soil pH decreases and Mn toxicity is common in acid soils below pH 5.5, especially when these soils are low in organic matter and/or temporarily waterlogged. Acid, sandy soils are likely to contain high Mn levels.

**Diagnosis:** Soil test for soils with organic matter contents of 6% or less. Optimum ranges for all soil textures are 11- 20 ppm Mn. For high organic matter soils, Mn soil test category is based on soil pH values: >6.9 is low; 6.0 – 6.9 is optimum; < 6.0 is high.

**Corrections:** One of the main reasons for liming acid soils, especially in legume production, is to prevent Mn toxicity. The amount of Mn in solution decreases 100-fold for each unit rise in soil pH (i.e. from 5.0 to 6.0). Where Mn deficiency exists as a result of the high pH of a soil, it is easier to correct the deficiency by adding a Mn fertilizer than by attempting to acidify the soil.

Broadcast applications of Mn fertilizer, as well as attempts to build-up soil test Mn levels over time, are not recommended due to the soil's capacity to rapidly fix (bind) Mn. Band or in-row applications of Mn reduces fixation by reducing contact with soil particles.

For crop with a medium or high Mn requirement grown on low testing soils, apply 3-5 lb Mn/a. Chelated forms of Mn are not effective when soil-applied. They are effective forms on Mn for foliar applications. To correct in-season Mn deficiencies, foliar applications at rates of 1-1.25 lb Mn/a or 0.15-0.2 lb Mn/a in the chelate form are recommended. More than one foliar application may be necessary.

## Molybdenum (Mo)

**Role in plants:** Molybdenum (Mo) is required for symbiotic nitrogen fixation and for converting nitrate ions into organic nitrogen in plants. Plants need extremely small amounts of Mo. Normal tissue concentrations are 0.03 to 1 ppm.

**Susceptible crops:** Mo deficiency (or toxicity) in Wisconsin crops is rare. Table beets, broccoli, cauliflower, lettuce, onion, spinach, and forage brassica have a high requirement for Mo. Legume crops grown on very acid soils are likely to be Mo deficient.

**Deficiency symptoms:** The first symptom of Mo deficiency is nitrogen deficiency symptoms. If the deficiency is severe, the leaf edges of some vegetable crops may become brown and curl upward. Cupped leaves also show interveinal chlorosis. Mo deficiency in cauliflower leads to a condition known as whiptail, in which leaves sometimes appear crinkled or withered.

**Susceptible soils:** Soil acidity has a major influence on the availability of Mo. As soil pH decreases, the availability of Mo decreases. Liming alone is usually enough to correct a Mo deficiency.

**Diagnosis:** Plant tissue analysis is more reliable for diagnosing Mo status in crops. Soil testing is not sufficiently calibrated for predicting the supply of Mo in Wisconsin soils.

**Corrections:** Soil applications of Mo are not recommended because of the extremely low amounts that would be required. Seed treatment or foliar sprays are the recommended application techniques. Follow Mo recommendations closely because excess Mo in feed or forage can cause animal health problems (molybdenosis).

High Mo demand crops grown on soils with a pH of 5.5 or lower should be seed-treated with 0.2 oz Mo/a as ammonium or sodium molybdate. Foliar applications at 0.8 oz Mo/a are alternative treatments.

## Nickel (Ni)

**Role in plants:** Ni is needed by plants to form the enzyme urease which breaks down urea-nitrogen for plant use. Ni is also involved in the uptake by plants of iron from soil. Concentrations of Ni in plants typically run from 0.1 to 10 ppm. Only recently, relatively speaking, has Ni been classified as an essential soil micronutrient.

**Susceptible crops:** Deficiencies of Ni are not known to exist in Wisconsin.

**Susceptible soils:** In other areas of the country Ni deficiency is associated with high soil pH levels. Generally, there is greater concern about Ni toxicity, particularly on soils where sewage sludge has been applied.

**Diagnosis:** Plant analysis, but this is rarely done. A soil test for Ni exists, but only as part of a heavy metal screening. Soil test research calibrating crop response to Ni has not been conducted in Wisconsin.

## Zinc (Zn)

**Role in plants:** Zn is required for the synthesis of a growth hormone (indoleacetic acid) by plants. It also functions as an enzyme activator in carbohydrate metabolism and protein formation. Crops generally take up less than 0.5 lb/a of Zn, yet when Zn is deficient, crop yields are reduced markedly.

**Susceptible crops:** Zn is the most common micronutrient deficiency of corn. Other crops with high Zn requirements include onion, spinach, and grain sorghum. Those with medium requirements are barley, beans, beets, cucumber, lettuce, potato, radish, sorghum-sudan forage, soybean, tobacco, and tomato. In Wisconsin, Zn deficiencies have been observed on corn, snapbean, and a few other vegetable crops.

**Deficiency symptoms:** Zn is an immobile soil nutrient; therefore deficiency symptoms usually appear first on the young leaves (at top of the plant) early in the growing season. On corn, a broad band of bleached tissue appears on either side of the midrib. The deficiency begins at the base of the leaf and usually stays in the lower half of the leaf. Zn deficiency also causes a shortening of the internodes on the corn stalk – which stunts the plant.

In broadleaf plants, Zn deficiency results in a shortening of internodes (rosetting) and a decrease in leaf size. Snapbean develops interveinal chlorosis. However, it is very difficult to distinguish between Zn and manganese deficiencies in this crop.

**Susceptible soils:** Soil acidity (pH) influences the availability of Zn more than any other factor, with lower Zn solubility as the pH increases. Zn deficiency usually is limited to soils with a pH above 6.5. Overliming of soils, especially sands, may induce Zn deficiency. Scalped or severely eroded soils are more apt to be Zn deficient. Also, sands, sandy loams, and organic soils are more likely to be Zn deficient than other soil types. Severe soil compaction can also reduce Zn availability. Also, cool weather during the growing season may also induce Zn deficiency in high demand crops. Researchers in Iowa state that high P fertilizer applications on soils that are low in Zn can cause Zn deficiencies, but high soil P levels alone do not create Zn deficiency.

**Diagnosis:** Soil test. Optimum Zn soil test ranges are 3.1–20 ppm for all soil textures. The need for supplemental Zn applications should be confirmed with plant analysis.

**Corrections:** Supplemental Zn can be applied with either band or broadcast applications. Rates of 2-4 lb Zn/a if banded or 4-8 lb Zn/a if broadcast should correct any deficiency. Rates for chelated forms of Zn should be 0.5-1.0 lb/a in a band or 1-2 lb/a broadcast. Alternatively, Zn can be foliar applied using Zn-sulfate at 1 lb Zn/a of Zn chelate at 0.15 lb Zn/a.

## Conclusion

Micronutrient deficiencies are rare in Wisconsin, but they can present themselves on occasion, particularly on sandy soils, soils extremely high or low in organic matter, soils with pH values outside of the optimum range for a specific crop, and during deviations from typical weather. Application of micronutrients should only be considered when their need is confirmed by a soil test report, plant analysis result, visual deficiency symptoms, and a crop with a proven high demand for a given micronutrient.

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