CROP INSIGHTS
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Micronutrients for Crop Production

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Summary

- Due to higher yields, commodity prices and crop input costs, growers are reviewing all potential barriers to top grain production, including micronutrient deficiencies.
- In the major crops and production areas of North America, the micronutrients most often supplied by fertilization include zinc, manganese, boron and iron.
- Micronutrient deficiencies can be detected by visual symptoms on crops and by testing soils and plant tissues.
- The most reliable micronutrient soil tests are for zinc, boron, copper, and manganese. Though adequate, these tests are not as precise as those for soil pH, potassium and phosphorus.
- Plant tissue analysis is more reliable than soil testing for identifying many micronutrient problems, and can also supplement soil test information.
- Most often, micronutrients are soil-applied in a band at planting, or foliar-applied, as these methods allow lower use rates of sometimes expensive materials.

Micronutrients are essential elements that are used by plants in small quantities. For most micronutrients, crop uptake is less than one pound per acre. In spite of this low requirement, critical plant functions are limited if micronutrients are unavailable, resulting in plant abnormalities, reduced growth and lower yield. In such cases, expensive, high requirement crop inputs such as nitrogen and water may be wasted. Because of higher yields, higher commodity prices and higher costs of crop inputs, growers are reviewing all potential barriers to top grain production, including micronutrient deficiencies. This *Crop Insights* will discuss general micronutrient requirements, deficiency symptoms, soil and plant sampling, and fertilization practices. Future *Crop Insights* articles will discuss specific crops, their micronutrient or secondary nutrient requirements and management considerations.

Plant Requirements and Soil Availability

There are 16 elements essential to growth of crop plants:

Supplied by air and water: carbon, hydrogen, oxygen

Macronutrients: nitrogen, phosphorous, potassium

Boron deficiency in alfalfa.

Secondary Nutrients: calcium, magnesium, sulfur

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

The seven micronutrients are sufficient in most soils to meet crop needs. However, some sandy soils and other low-organic matter soils are naturally deficient in micronutrients, and high pH soils may make some micronutrients less available and therefore deficient. In the major crops and production areas of North America, the micronutrients most often supplied by fertilization include zinc, manganese, boron and iron. Basic chemical properties of micronutrients help determine their availability in soils (Table 1).

Table 1. Chemical properties of micronutrients.

Cations	Positively charged - bind to soil particles Solubility is greatest under acid conditions Most likely deficient on calcareous soils or soils extremely high in organic matter where strong chelation decreases availability
Copper	
Iron	
Manganese	
Zinc	
Anions	Negatively charged – subject to leaching In short supply in areas where they are readily leached and not being replenished by organic matter decomposition
Boron	
Chlorine	
Molybdenum	

Because of complex chemical reactions within the soil, micronutrient availability is ultimately controlled by the equilibrium between the soil solution, soil organic matter, cation exchange sites, and insoluble compounds of micro-nutrients. Soil acidity or alkalinity has a large effect on the tie-up of micronutrients or their availability to plants. Micronutrients are most available in acid soils and often unavailable at high pH (Figure 1).

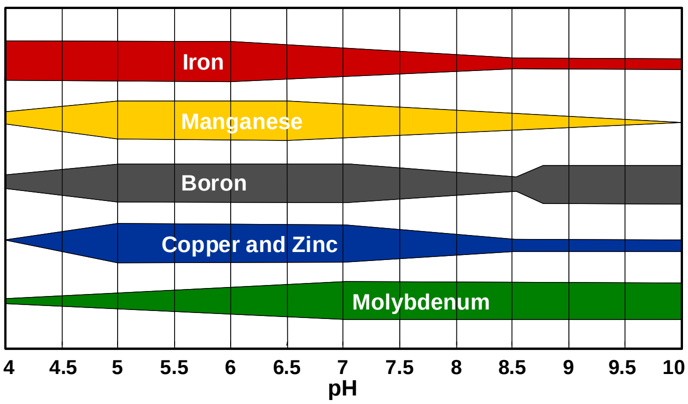

Figure 1. Relative availability of micronutrients by soil pH[1].

Organic Matter

Organic matter is a reservoir for essential plant nutrients, continuously supplying these nutrients to the crop as it decomposes over time. This reservoir is especially important for anions such as boron, which do not bind to soil particles and are therefore subject to losses. Soils that receive regular additions of organic residues such as manures rarely show micronutrient deficiencies. An exception is deficiencies caused by nutrient imbalances, such as a deficiency of manganese caused by an excess of phosphorus in overly manured soils. Another exception is soils of extremely high organic matter such as muck or peat soils. In these soils, strong, natural chelation (the combination of a micronutrient with an organic molecule) can make some micronutrients unavailable, particularly copper, manganese and zinc.

Micronutrient Removal by Crops

Crop yields are continually increasing due to genetic improvements in stress tolerance and disease resistance, incorporation of insect resistance traits, and use of seed treatments and other crop protection products. This means that more micronutrients are removed from the soil by each harvest. An example of nutrient removal by two major crops is shown in Table 2.

By comparison, corn and soybeans remove about 50 to 100 lbs/acre of P and K in the grain, so it is apparent that micro-nutrient needs are only about 0.1% to 1% of macronutrient needs (except for iron, which is higher.)

Table 2: Micronutrient uptake by corn and soybeans[2].

	Nutrient uptake (lbs/acre) by:	
Micronutrient	**200 Bu. Corn**	**75 Bu. Soybeans**
Iron (Fe)	2.53	2.12
Manganese (Mn)	0.40	0.75
Zinc (Zn)	0.36	0.25
Boron (B)	0.21	0.12
Copper (Cu)	0.13	0.12
Molybdenum (Mo)	0.01	0.01

Detecting Micronutrient Deficiencies

Micronutrient deficiencies can be detected by visual symptoms on crops and by testing soils and plant tissues. To understand visual symptoms, it is useful to know the role each micronutrient plays in plant growth and development.

Functions of Micronutrients

Micronutrients differ in the form they are absorbed by the plant, their functions and mobility in the plant, and their characteristic deficiency or toxicity symptoms (Tables 3 and 4).

Table 3. Functions of micronutrients in plants[3].

Element	Function in plant
B	Important in sugar transport, cell division, and amino acid production
Cl	Used in turgor regulation, resisting diseases and photosynthesis reactions
Cu	Component of enzymes, involved with photosynthesis
Fe	Component of enzymes, essential for chlorophyll synthesis, photosynthesis
Mo	Involved in nitrogen metabolism, essential in nitrogen fixation by legumes
Mn	Chloroplast production, cofactor in many plant reactions, activates enzymes
Zn	Component of many enzymes, essential for plant hormone balance and auxin activity

Micronutrient Deficiency Symptoms

Except for Mo, the micronutrients are considered weakly mobile or immobile in plants. This means that deficiency symptoms appear first or most severely on newest plant tissues

Iron or zinc deficiency symptoms in corn. Soil and tissue testing can help determine which of these nutrients is deficient.

(assumes plants started with some supply of the nutrient but ran out as plants developed.) For molybdenum, deficiency symptoms appear first on oldest plant tissues. Symptoms vary according to crop, but generalized symptoms are shown in Table 4.

Table 4. General micronutrient deficiency symptoms[3].

Element	General Micronutrient Deficiency Symptoms
B	Light general chlorosis, death of growing point, deformed leaves with areas of discoloration
Cl	Chlorosis and wilting of young leaves. Deficiency rarely seen on crop plants in field
Cu	Light overall chlorosis, leaf tips die back and tips are twisted, loss of turgor in young leaves
Fe	Chlorosis or yellowing between the veins of new leaves
Mo	Similar to those of ordinary nitrogen deficiency – general chlorosis (yellowing) of young plants, chlorosis of oldest leaves
Mn	Chlorosis or yellowing between the veins of new leaves (much like Fe deficiency)
Zn	Stunted growth, reduced internode length, young leaves are smaller than normal

Micronutrient deficiencies usually have a patchy distribution in fields due to variation in soil properties that affect availability (e.g., pH, drainage, and salinity) and management history such as manure applications. Learning to identify deficiencies visually is important in recognizing problem areas and planning remediation for future crops. However, it is often too late for corrective action in the current crop by the time visual symptoms appear.

Common Micronutrient Deficiencies

The probability of a micronutrient deficiency is greatly increased on specific soils types and in certain crops (Table 5).

Table 5. Soil conditions which may lead to micronutrient deficiencies for various crops[4].

Micro-nutrient	Soil Characteristics	Crop
B	Sandy soils or highly weathered soils low in organic matter	Alfalfa, clover
Cl	Occasionally on sandy soils in areas, high rainfall very rare	
Cu	Acid peats or mucks with pH < 5.3 and black sands	Wheat, corn
Fe	Soils with high soil pH, soluble salts and/or calcium carbonate levels	Corn, soybean
Mn	Peats and mucks with pH > 5.8, black sands and lakebed/low-lying soils with pH > 6.2	Soybean, wheat, sugar beets, corn
Mo	Acid prairie soils	Soybean
Zn	Peats, mucks and mineral soils with pH > 6.5	Corn, soybean

Soil Tests to Detect Micronutrient Deficiencies

Many plant symptoms associated with micronutrient deficiencies, including stunting and chlorosis, may have a variety of causes, including disease, insect or herbicide damage, or environmental conditions. Soil and plant analysis are both useful in determining if the cause is truly nutritional. Though adequate for this purpose, micronutrient soil tests are not as precise as soil pH, phosphorus, and potassium tests.

The most reliable micronutrient soil tests are for zinc, boron, copper, and manganese. Because interpretations are soil specific, it is best to use locally calibrated recommendations. Soil tests for iron and molybdenum are considered to be of little value in predicting the supply of these nutrients in soils. When sampling for micronutrients, sample the root zone from 0 to 8 inches deep.

Plant Analysis to Detect Micronutrient Deficiencies

Plant tissue analysis is more reliable than soil testing for identifying many micronutrient problems, and can also supplement soil test information. Tissue testing is especially valuable in cases where reliable soil tests are unavailable. However, molybdenum and chlorine levels cannot be determined by this method.

Plant analysis can be used in two ways; one is to monitor the crop's micronutrient status, and the other is to diagnose a problem situation. By quantifying the nutrient content of tissues, plant analysis can point out an existing or potential problem before visual symptoms develop.

If in-season micronutrient deficiencies are suspected, plant samples should be taken as early as practical; treatments, when needed, should be made in a timely manner. Research has shown that once a micronutrient deficiency is detected, the plant has already suffered irreversible yield loss.

Because plant nutrient composition varies with the crop, age of the plant, part of the plant sampled and other factors, it is important to follow the standard sampling procedures provided by your plant diagnostic laboratory. In order to obtain a **representative sample**, take multiple plants from areas randomly distributed throughout the affected field area. Avoid border plants and those contaminated with dust, soil or foliar sprays. Taking samples of non-symptomatic plants to compare with apparent nutrient-deficient plants can increase the usefulness of plant analysis. Be aware that interpreting results is complex and may require expert advice.

Managing Micronutrient Deficiencies

Selecting Micronutrient Sources

There are three main classes of micronutrient fertilizers: inorganic, synthetic chelates and natural organic complexes.

Inorganic sources consist of oxides, carbonates and metallic salts such as sulfates, chlorides and nitrates. Sulfates are the most common metallic salts used in the fertilizer industry because of their high water solubility and plant availability. Less soluble oxides must be finely ground or partially acidulated with sulfuric acid to form oxysulfates in order to increase their effectiveness. Metal-ammonia complexes such as ammoniated Zn sulfate decompose readily in soils and provide good agronomic effectiveness.

Chelates are fertilizers in which the micronutrient is combined with an organic molecule to increase its stability and effectiveness in the soil. Chelates such as Zn-EDTA are more stable and more effective in correcting Zn deficiency than other forms of applied Zn. These synthetic chelates are more effective and less variable than natural organic complexes such as lignosulfates, phenols and polyflavonoids.

Method of Application

The best method of micronutrient application depends on the element and when the deficiency is being addressed.

Soil application. For deficiencies known at the start of the season, soil application is preferred to foliar application for most nutrients. Micronutrients **banded** with starter fertilizers at planting time are usually more effective over a longer period than foliar-applied micronutrients. This method also gets the nutrient to the plant at the earliest opportunity.

Soil-applied micronutrients may also be **broadcast,** but a concentrated band near the plant allows lower use rates of sometimes expensive materials. Manganese should only be banded, because of the ability of most soils to strongly “fix” this element. However, boron should not be banded, as high concentrations near the seed can be toxic.

Foliar application is especially useful for some elements that are not efficiently used when applied to the soil, such as iron. This method is also useful for quick uptake in emergency situations when deficiencies are noted or in cases where other materials are being sprayed. Like banding, foliar applications generally have lower use rates, but more than one application may be needed. However, because the crop partially develops prior to foliar application, irreversible damage may have already occurred before the needed nutrient is supplied.

Broad-spectrum micronutrient applications are **not** recommended to treat a single micronutrient deficiency, as this approach is expensive and potentially harmful to the crop. The harm can occur because of potential toxicities, or because the presence of additional nutrients may interfere with the uptake of the needed nutrient.

Achieving a **uniform spread pattern** is important to correct deficiencies, regardless of whether the material is liquid or solid, banded or broadcast, or preplant or foliar applied.

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