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Micronutrient Management in Nebraska

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This NebGuide addresses issues of micronutrient fertilizer use with a focus on zinc and iron.

Of the 17 elements known to be essential for plant growth, eight are used in very small amounts and, with the exception of iron, have an uptake of less than 1 pound per acre per year (*Table 1*). These elements are classified as micronutrients and include zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo), chlorine (Cl), and nickel (Ni). Interest in micronutrients has increased because of accelerated rates of nutrient removal due to greater yields and the availability of alternative micronutrient products.

Table 1. Estimates of micronutrient uptake (whole plant) by crops.

Micronutrient	200 Bu Corn	60 Bu Soybean	6 Ton Alfalfa
	lb/acre	lb/acre	lb/acre
Iron	2.4	1.7	1.8
Manganese	0.4	0.6	0.6
Zinc	0.4	0.2	0.2
Boron	0.2	0.1	0.3
Copper	0.1	0.1	0.06
Molybdenum	0.01	0.01	0.02
Nickel	0.01	0.01	0.01

Adapted from: *Role of Micronutrients in Efficient Crop Production*, D.B. Mengel, Purdue University AY-239. https://www.extension.purdue.edu/extmedia/AY/AY-239.html

Micronutrient Availability

Some micronutrients are supplied to plants when weathering breaks down soil minerals over time. However, the greatest supply usually derives from the breakdown (mineralization) of soil organic matter. Soils with low clay and organic matter content are more likely to be deficient in one or more micronutrients. Soils that receive regular manure applications seldom have micronutrient deficiencies.

Nutrient availability is affected by soil pH (*Figure 1*). The availability of iron and manganese increases with increased acidity (lower pH). Soluble manganese concentrations can be toxic in soil with less than 5.0 pH. Copper, zinc, and boron availability increases with decreased pH until 5.0 to 5.5; below this level availability also decreases. With the exception of molybdenum, micronutrient availability decreases as pH increases above 7.5.

Soil organic matter and applied organic materials

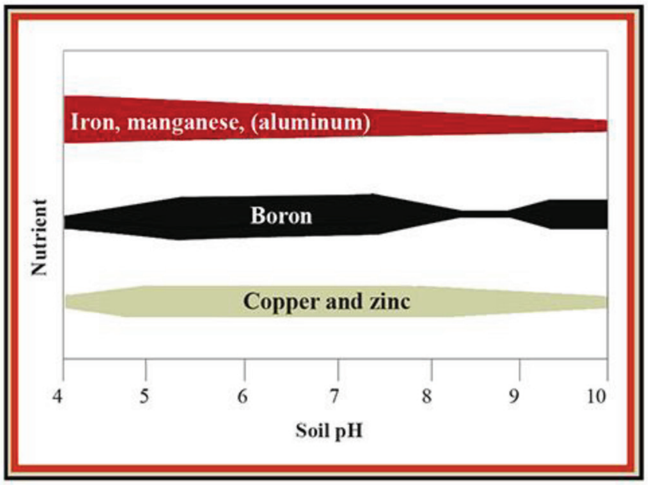

Figure 1. Nutrient availability as affected by soil pH. Molybdenum is similar to copper and zinc at low pH but does not decrease at higher pH levels.

Figure 2. Iron chlorosis commonly appears as patches in fields that can guide future site-specific management. (Photo: Rodrigo Werle, UNL)

affect the availability of positively charged micronutrients through chelation. Chelation is the formation of bonds of varying strength between a metallic ion and an organic molecule. Chelation often increases the solubility and availability of a nutrient and delays reaction and tie-up of the nutrient with soil minerals. This is why micronutrient fertilizer products often contain nutrients in a chelated form. Excessive chelation can occur in soils with greater than 10 percent organic matter, resulting in deficiencies of some micronutrients. However, most Nebraska soils contain 1 to 4 percent organic matter, so this is rarely an issue.

High levels of one nutrient can affect the availability of some micronutrients. High rates of phosphorus application to calcareous soils or soils with low zinc levels can induce zinc deficiency. Iron uptake can be reduced by high bicarbonate concentration in the soil.

Weather conditions also can affect plant use of micronutrients. Under cool, wet conditions, uptake of iron, zinc, and manganese may be reduced due to slow root growth. Boron deficiency is more likely to occur with dry weather conditions.

Diagnosis of Micronutrient Problems

The only micronutrient deficiencies that have been confirmed in Nebraska through crop response to applied nutrients are zinc and iron on certain soils. Wheat response to chloride application has been observed in Kansas and South Dakota but not in Nebraska. Response of glyphosate-resistant, high-yielding soybean (greater than 80 bushels per acre) to manganese application has been observed in some states but has not been verified in Nebraska.

Micronutrient deficiencies generally have a patchy distribution in fields due to variation in soils and management history (*Figure 2*). Symptoms of micronutrient disorders often appear too late for corrective action but such symptoms can be useful in identifying problem areas in the field for future action.

Soil tests at a 0- to 8-inch soil depth are diagnostic for some micronutrients, including zinc and boron, but not for all. Recently, in a survey of 65 producer fields in Nebraska, soils were sampled at the 0–4 and 4–8 inch depths separately with a simultaneously collected foliar sample. Overwhelmingly, for most micronutrients, foliar micronutrient concentrations did not correlate to soil micronutrient concentrations, with the exception of manganese (Figure 3). There was significant stratification identified for zinc, with the 0–4 inch depth having a greater average concentration than the 4–8 inch depth. Available calibrations for micronutrient response in Nebraska are based on a 0–8 inch sampling depth and interpretations based on samples of less or greater depth are likely to be misleading.

For each graph in *Figure 3*, the data points in the lower left quadrant mean that both the soil and the plant samples tested below established critical levels. Points below the horizontal lines tested below plant critical levels and points to the left of the vertical lines tested below soil critical levels. For B, Fe, and Mn, no sites were low in both the soil and the corn foliar samples. For B, there were low plant samples. Low soil and low plant samples occurred

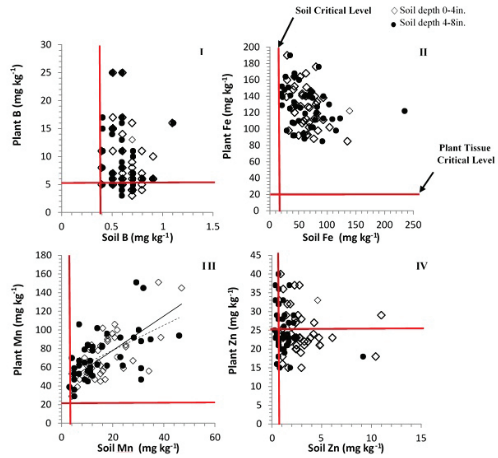

Figure 3. Example relationships between soil and corn leaf micronutrient concentrations. Corn critical values are presented as red lines for leaf samples collected at VT-R5 (horizontal line) and soil samples (vertical line). Samples were collected on the same date (Source: Stewart Dissertation, 2016 http://digitalcommons.unl.edu/agronhortdiss/102/). For soil B (III), the correlation R2 is 0.48 and 0.30 for the 0–4 and 4–8 depths, respectively. Units in mg kg^{-1} are equivalent to ppm.

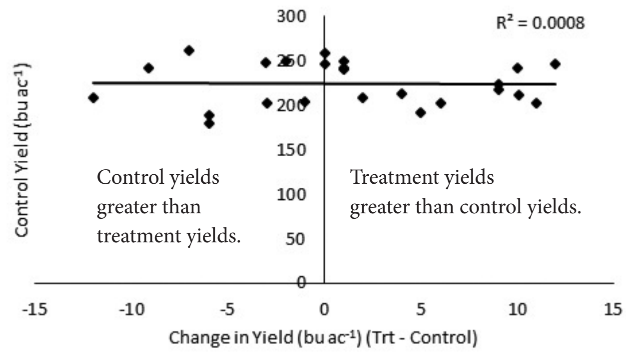

Figure 4. Relationship between control corn grain yield and the change in grain yield (treatment–control yield) due to foliar micronutrient treatments for 26 on-farm trials receiving foliar micronutrient application. Foliar micronutrients consisted of either Zn, Mn, B, or Fe alone or in combination selected to match plant tissue recommendations (Source: Stewart Dissertation, 2016 http://digitalcommons.unl.edu/agronhortdiss/102/).

Table 2. Probability of crop response to applied zinc in cases of low soil zinc availability (<0.4 ppm DPTA Zn or <0.7 ppm Mehlich 3 Zn).

High	Moderate	Low
Corn	Grain sorghum	Alfalfa
Dry bean	Clover	Barley
Sweet corn	Potato	Oats
	Forage sorghum	Millet
	Soybean	Rye
	Sugarbeet	Wheat
	Sudan grass	Grasses

Table 3. Probability of yield loss where iron chlorosis commonly occurs.

High	Moderate	Low
Dry bean	Corn	Barley
Forage sorghum	Alfalfa	Grasses
Grain sorghum	Clover	Millet
Soybean	Sweet corn	Potato
Sudan grass		Oat
		Rye
		Wheat
		Sugarbeet

only with Zn. These results are consistent with earlier work that shows Nebraska soils are unlikely to have B and Mn deficiencies, but could have Zn deficiency under specific conditions. Iron deficiencies are found in Nebraska but are not addressed in *Figure 3*. Soil tests are useful to confirm visual symptoms.

If chlorine deficiency problems develop in Nebraska, the chloride soil test may be useful. While wheat yield response to applied chloride has been calibrated for Kansas, https://www.bookstore.ksre.ksu.edu/pubs/MF2570.pdf, yield responses have not been verified by research conducted in Nebraska.

Diagnosing iron deficiency from a soil or tissue test alone may at times be misleading. Iron deficiencies can occur when soil and tissue tests indicate adequate iron. In higher pH soils, soil tests may fail to truly represent iron availability to the plant. When considering tissue testing, iron in the plant and soil may actually be adequate, but it is in the form that is not accessible for the plant to utilize. Iron deficiency can occur more frequently with iron inefficient varieties of soybean or sunflower when soil nitrate level is high.

Uptake of nitrate into the plant results in bicarbonate release from roots to soil causing a soil pH gradient that prevents the conversion of unavailable iron to a plant available form. There are no guidelines as to soil nitrate levels that are likely to induce an iron deficiency. The deficiency is situational and may not occur every year. Typical iron deficiencies not associated with elevated soil nitrate are generally reoccurring in the same location of a field.

Low soil pH, coupled with plant analysis, is the most reliable indicator of potential problems with manganese toxicity. Plant analysis is most useful when samples of moderately stressed and unstressed plants are compared.

Crop Sensitivity to Soil Test Levels

Crop sensitivity needs to be considered in diagnosis of nutritional disorders. The assessment of a soil level is a start, but not all plants have the same efficiency of use. For example, corn may respond to zinc fertilizer when a soil test reveals a low zinc level, but alfalfa will not. The sensitivities of various crops to low soil zinc availability and to iron chlorosis are shown in *Tables 2 and 3*, respectively. Alfalfa has a relatively high boron requirement (*Table 1*) and is more likely than other Nebraska agronomic crops to show deficiency symptoms.

Foliar tissue test concentrations and the interpretive critical values vary with growth stage. Laboratories also differ in their interpretation of soil and plant tissue test results. Therefore, use soil and tissue test results for micronutrients, other than zinc, with caution and obtain verification from additional soil and plant samples, and/or on-farm trials, before investing in micronutrient applications. Interpretation is complicated by the soil test method. Generally, interpretations are based on DTPA extraction while some labs use Mehlich 3 extraction. The relationship between results of DTPA and Mehlich 3 extraction generally do not correlate well. The exception is zinc where the Mehlich 3 results in about 60 percent more extraction of zinc compared with DTPA. Temporary deficiencies are common when weather/soil conditions stress a plant early in its growth, and time is often the best remedy. Additionally, some hypothesize that higher yielding locations having higher micronutrient demand would have a greater probability of increased yield response to micronutrient applications. If there was a greater likelihood of micronutrients increasing yield at greater yield levels then the line in Figure 4 would have a positive upward slope. However, results of 26 on-farm trials in Nebraska do not support this hypothesis, but do show that yield increases are possible. (*Figure 4*).

Plant Sampling

The best strategy for plant sampling, regardless of plant growth stage or plant part, is to sample several plants from the "good" area of the field (vigorous growth, normal color), then sample plants from the transition area where the deficiency has just started but is evident. Harvesting plant samples from severely deficient areas will often show greater concentration levels of micronutrients than the good areas. This is because of reduced plant growth in deficient areas compared with the normal growth in good areas. If one also sampled the plant dry matter and calculated micronutrient uptake, it would probably be greater in the good areas. Micronutrients largely do not remobilize within plant tissues. Thus, when collecting foliar samples to diagnose micronutrient deficiency, leaves should be collected from the uppermost, new growth that has fully developed (e.g., fully collared leaves for corn or fully developed trifoliate leaves for soybeans). A video on how and when to sample soybeans is available at: https://www.youtube.com/watch?v=UkoK4vRtU3k

Figure 5. Symptoms of zinc deficiency expressed in corn leaves from most affected (left) to least affected. (Photo: Gary Hergert, UNL.

Zinc and Zinc Fertilizers

Most Nebraska soils have adequate zinc, but deficiencies can occur. In general, the application of zinc may be needed for sensitive crops where:

- the soil is calcareous (pH greater than 7.3 because of excess free lime).
- the topsoil has been removed by erosion.
- land has been leveled or terraced.
- soils are very sandy with low organic matter content.

Zinc deficiency is most likely to occur under cool, wet conditions in the spring when root growth is slow. In some cases, applying high rates of phosphorus without zinc on calcareous soils with a low or moderately low zinc level can induce zinc deficiency and reduce corn yields.

A soil test is the best guide for determining the need for a zinc fertilizer. In Nebraska, soil test zinc levels, using DTPA extraction, of 0.8 ppm or greater are adequate. Soils testing 0.4 to 0.8 ppm DTPA-Zn are medium and require zinc application for some crops. Zinc application is needed for several crops when DTPA-Zn is less than 0.4 ppm. (See *Table 2* above and [EC155, *Nutrient Management for Agronomic Crops in Nebraska*] for comprehensive fertilizer recommendations for individual crops.)

Corn is sensitive to low soil zinc levels (*Table 2*). If corn does not exhibit a need for added zinc, other crops are not likely to need zinc fertilizer. Zinc is relatively immobile in plants. Deficiency symptoms appear first on newer leaves with interveinal striping beginning at the base of the leaf and extending to the tip, often appearing as broad, whitish bands on either side of the midrib (*Figure 5*). The midrib, leaf margin, and leaf tip remain green. Plants tend to be stunted due to a shortening of the internodes.

Pinto beans exhibit a general stunting of the young plants. Leaves show a general yellowing of the upper foliage with a browning or bronzing of the older or lower leaves. The leaves of zinc-deficient beans typically have a crinkled appearance. A general downward curl of the leaves also will occur and pod set will be poor. Confirm visual observations with soil tests and plant analyses.

Zinc fertilizer products can be grouped as:

- Inorganics (dry or liquid)
- Soluble (chlorides, sulfates, nitrates, Zn-NH_3 complexes)
- Insoluble (oxides, carbonates, silicates, oxysulfates)
- Synthetic chelates (dry or liquid)
- Strong versus weak chelation (EDTA versus other)
- Natural organic complexes
- Lignosulfonates from paper industry, sucrates from sugar industry

Zinc sources should be compared on the basis of solubility, cost per pound of zinc, ease of application, and residual effects.

Soluble sources of zinc will provide the most consistent correction, especially on higher pH soils. Insoluble sources are best used on soils with pH less than 6.5. Proper placement depends on the mobility of the zinc products. Zinc chelates move with soil water, and the chelate delays zinc tie-up with soil minerals. The insoluble inorganic zinc carriers are not mobile, and must be broadcast as small, finely divided particles and thoroughly incorporated so plant roots will come in contact with the zinc fertilizer. Organic complex zinc carriers and some inorganic carriers are soluble but not very mobile in the soil. They need to be placed in the root zone to ensure root-zinc contact. All sources of zinc have been shown to be equally effective where the zinc carrier is dissolved or suspended in a fluid fertilizer. Manure is an excellent source of zinc.

Plant nutrients supplied in fertilizers are usually applied at rates sufficient to meet the requirements of the current crop. With zinc fertilization, however, it may be more practical to raise the zinc level of the soil, thus assuring an adequate supply for several years. On low zinc noncalcareous soils, 5 pounds of zinc per acre can be applied as granular zinc sulfate. This rate can be increased to 10 pounds per acre on calcareous soils. If soil pH is less than 7.4, finely ground zinc oxide is also a good choice when it's applied uniformly and incorporated into the soil.

Zinc sulfate or zinc oxide is effective when applied in a band with nitrogen and/or phosphorus fertilizer as a starter. Band application of fluid fertilizer containing a compatible zinc source provides good zinc distribution for root accessibility. A zinc-ammonium complex is often used in starter fertilizer solutions. If a producer uses a dry bulk blend (a zinc source blended with other dry fertilizers), segregation of the materials is minimized when the fertilizers are of similar particle size. Dry fertilizer blends that incorporate all nutrients in each prill also lead to better crop response due to improved fertilizer distribution.

A primary consideration with zinc materials is the cost per pound of nutrient. Research shows that mobile (chelated) forms are more plant-available than inorganic sources. However, the effectiveness of chelates depends on the application method. For broadcast application of zinc sources, one-third as much chelated zinc can be applied compared with a soluble inorganic source. For row-applied zinc, half as much chelated zinc can be used as compared with a soluble inorganic source. Claims of greater effectiveness of 10 to 1 or 5 to 1 for chelated versus inorganic sources of zinc are not supported by research. If soil test zinc is above 0.8 ppm and the application is to build or maintain a high level of availability, use a soluble (> 40 to 50 percent water solubility) inorganic form.

Iron Chlorosis

Most Nebraska soils contain adequate amounts of iron for optimal crop performance. Recent research indicates that iron chlorosis can be lessened by avoiding high soil

Figure 6 a–c. Iron chlorosis is commonly associated with calcareous soils and is expressed as interveinal chlorosis, beginning with the younger leaves. (Photos: Gary Hergert, UNL)

nitrate levels. In some soils, however, conditions restrict a plant's use of iron. As a result, iron chlorosis occurs. Iron chlorosis is commonly, but not always, associated with high lime (calcareous) soils. Iron chlorosis can also occur on soils that have excess salts, high or excess sodium, or that are poorly drained. Plant symptoms may occur even on soils testing high in iron, but Table 4 gives some indication of what is considered low soil test levels.

However, iron deficiency in Nebraska occurs with DTPA-Fe values well above 4.5 ppm. The best indicator of potential response to applied iron is a history of iron chlorosis occurrence.

Iron is relatively immobile in plant tissue, and chlorosis conditions are more likely on younger tissue. Iron chlorosis causes the interveinal areas of young leaves to become pale green to yellow or white (*Figure 6 a–c*). The interveinal striping on corn and sorghum leaves occurs along the full length of the leaf.

Correcting iron chlorosis is difficult. Manure application is effective when iron chlorosis is due to low soil iron availability, but it may not be effective when soil iron availability is adequate and metabolic use of plant iron is restricted. Mapping of chlorotic areas is recommended for site-specific application of fertilizer iron. Broadcast application of non-chelated iron is generally ineffective as iron rapidly becomes unavailable.

Soybean and Iron

Soybean chlorosis can be managed by planting tolerant varieties, planting at a density of 12 viable seeds per foot, applying iron-chelate fertilizers with the seed, and using

Table 4. Interpretation of soil test for iron (DTPA-Fe).

Rating	Concentration
Very low	<2.5 ppm
Marginal	>2.5 < 4.5 ppm
Likely sufficient	>4.5 ppm

a foliar treatment. If chlorosis is a problem, do not plant soybean in narrow rows as it is important to have a high plant density within rows. Applying chelated iron (FeEDDHA, 1–1.5 lb; 6% AI) mixed into 5 to 8 gallons of water per acre directly with the seed is often an effective fertilizer treatment for soybean. Seed dressing with iron EDDHA at 0.2 lb/ac iron has been as effective as applying 50 lb/ac iron as iron sulfate. Soybean yield response to foliar application of iron fertilizer has been inconsistent and generally less effective than applying chelated iron with the seed.

Corn and Iron

For corn, research suggests that applying iron sulfate ($FeSO_4$•7H2O) in the seed furrow at rates of 50 to 100 lb of product per acre prevents chlorosis as effectively but at less cost than chelated iron applied in the seed row, especially on non-tolerant hybrids. Research in western Nebraska in high pH soils suggests that foliar Fe applications to locations with visual, but not severe, signs of deficiency (i.e., interveinal chlorosis, stunting, and yellowing) can increase grain yield (*Figure 4*). On-farm research conducted in 2015 indicated that precision foliar application of as little as 0.2 lb Fe ac^{-1} to corn, regardless of application time, from V6 to R2 to areas with visual signs of Fe deficiency, can have significant effect on increasing grain yield by an average of 9.6 percent. Other management practices, such as selection of corn hybrids known to be tolerant to chlorosis conditions and avoiding over-irrigation of high sodium and calcareous soils, is important for iron chlorosis management.

Dry beans and Iron

For dry beans, research shows that 1 to 1.5 pounds of FeEDDHA/ac can increase yields in chlorotic areas. The FeEDDHA can be seed applied and diluted in 5 to 7 gallons of water with the seed, banded (due to mobility) or the FeEDDHA can be included in 10–34–0 and banded at the same 1 to 1.5 lb/ac rate and applied beside the seed. The FeEDDHA is usually dissolved in 3 to 4 gallons of water, which is then added to the 10–34–0 to facilitate mixing.

Foliar applications

Foliar applications of iron can be used for corn (as described above), sorghum, soybeans, and dry beans, and have been more effective on hybrids/varieties relatively tolerant of iron chlorosis. By the time most non-chronic iron chlorosis occurs and is treated with foliar application, significant growth reduction and loss of yield potential has already occurred. To avoid serious yield reductions, make the first foliar application of iron chelate (1 pound of FeEDDHA in 20 gallons of water) or a 1.0 to 1.5 percent solution of ferrous sulfate as soon as chlorosis appears. Because so little plant area is covered when the plants are small, repeated spraying every 7 to 14 days is necessary. Spray in early morning or early evening to avoid leaf burning.

Boron

Boron deficiency is rarely seen, but it was confirmed on alfalfa in central Nebraska. This occurred on sandy soil under conditions of severe drought stress. It also was found on sugarbeets grown on very sandy soil in north central Nebraska. Soil organic matter is an important source of boron, and deficiency is most likely on low organic matter soils. Boron is a negatively charged ion and easily leaches into the soil. Boron deficiency is most likely to occur during drought stress.

Irrigation water typically contains enough boron to meet crop needs. Soil test levels for boron (hot water extraction) of less than 0.25 ppm indicate potential for deficiency. If both soil and irrigation water are low in boron, borate and borax fertilizer can be soil-applied. Yield response to applied boron has not been confirmed in Nebraska. Low soil test values indicating deficiency should be verified by additional sampling and/or on-farm trials. Application rates should not exceed 1 pound per acre. Excessive application rates can cause toxicity, with broadcast applications preferred. Care is needed as the application rate for one crop can be a toxic level for another crop. Irrigation water contains boron, and harmful effects of over-application are more likely under irrigated conditions. Boron is toxic to seed and should not be applied in the seed furrow.

Micronutrient Toxicities

Applying excessive amounts of a micronutrients can cause reduced yield, especially with boron. Excessive boron can produce barren corn stalks. Response to applied boron is rare in Nebraska, and including boron in fertilizer is not advised.

Excessive rates of copper, a heavy metal known to accumulate in the soil, could cause plant damage if soil levels become too great, but there is no Nebraska data. Manganese toxicity occurs with acid soil conditions and may be a problem when soil is less than 5.0 pH.

Aluminum is not a nutrient, but can become toxic when soil pH is below 5.0. Aluminum toxicity has been observed on irrigated sands in north central Nebraska. If soil pH is below 5.0, lime should be applied, based on soil tests. Soil tests for exchangeable aluminum can indicate the severity of crop damage expected.

Summary

Micronutrient availability and likelihood of occurrence in Nebraska was discussed. The most likely micronutrient issues are for zinc and iron under specific conditions, usually related to soil pH. Use of soil and tissue testing, and experience with specific fields will help diagnose micronutrient issues.

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