

Use and Management of Micronutrient Fertilizers in Nebraska

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

Of the 16 elements known to be essential for plant growth, seven are used in very small amounts and, with the exception of iron, have an uptake of less than one pound per acre per year (*Table I*). These are classified as micronutrients and include zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo), and chlorine (Cl). Interest in micronutrients has increased with increasing yield levels, increasing rates of nutrient removal in harvests, and availability of alternative micronutrient products.

Table I. Estimates of micronutrient uptake by crops.

Micronutrient	200 Bu Corn	60 Bu Soybean	6 Ton Alfalfa
	lbs/acre	lbs/acre	lbs/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

Adapted from: *Role of Micronutrients in Efficient Crop Production*, D.B. Mengel, Purdue University AY-239.

Micronutrient Availability

Some micronutrients are supplied to plants when weathering breaks down soil minerals over time, but the greatest supply usually derives from the breakdown (mineralization) of soil organic matter. Soils with low clay and organic matter content may 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. Soluble manganese concentrations can be toxic in soil with less than 5.0 pH. Copper, zinc, and boron availability increase with decreased pH until pH measures 5.0 to 5.5;

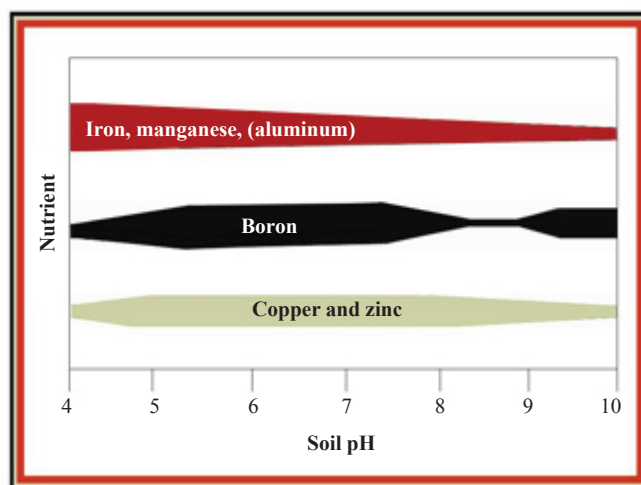


Figure 1. Nutrient availability as affected by soil pH.

below this level availability decreases. With the exception of molybdenum, micronutrient availability decreases as pH increases above 7.5.

Soil organic matter and applied organic matter 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. That's why micronutrient fertilizer products often contain the nutrient in chelated form. Excessive chelation can occur in soil with greater than 10 percent organic matter, resulting in deficiencies of some micronutrients. Most Nebraska soils contain one to four percent organic matter.

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.

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



Figure 2. Iron chlorosis commonly appears as patches in fields.

Diagnosis of Micronutrient Problems

Research has demonstrated that Nebraska soils can supply all the micronutrients needed for plant growth with the exception of zinc and iron on some soils. Wheat response to chlorine 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 has been observed elsewhere but not 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 can be useful in identifying problem areas in the field for future action.

Soil tests of the 0- to 8-inch soil depth are diagnostic for some micronutrients, including zinc and boron, but not for all. If chloride deficiency problems develop in Nebraska, the chloride soil test may be useful. A soil test for iron deficiency is meaningful for calcareous soils. 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 needs to be considered in diagnosis of nutritional disorders. For example, corn may respond to zinc fertilizer at a low soil test zinc level, but alfalfa will not. The sensitivities of various crops to low soil zinc availability and to iron chlorosis are shown in Tables II and III, respectively. Alfalfa has a relatively high boron requirement (Table I) and is more likely than other Nebraska agronomic crops to show deficiency symptoms.

Zinc and Zinc Fertilizers

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

- 1) the soil is calcareous (pH greater than 7.3 because of excess free lime);
- 2) the topsoil has been removed by erosion;

Table II. Probability of crop response to applied zinc in case of low soil zinc availability.

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

Table III. Probability of reduced crop performance 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
		Sugar beet

- 3) land has been leveled or terraced; or
- 4) 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. (For more information see UNL NebGuides addressing fertilizer use for individual crops.)

Corn is sensitive to low soil zinc levels (Table I). 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. Zinc deficiency symptoms appear first on newer leaves



Figure 3. Symptoms of zinc deficiency expressed in corn leaves from most affected (left) to least affected. (Source: Gary Hergert, UNL)

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 3*). 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/or plant analyses.

Zinc fertilizer products can be grouped as:

- 1) organic chelate (ZnEDTA, ZnHEDTA);
- 2) organic non-chelate (natural organic complexes);
- 3) soluble inorganic (zinc sulfate, zinc ammonium complex); and
- 4) insoluble inorganic (zinc oxide, zinc carbonate).

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. The 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 the plant roots will come in contact with the zinc fertilizer. Organic non-chelated zinc carriers and some inorganic carriers are soluble but not very mobile in the soil and 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 fertilizer are usually applied at rates sufficient to meet the requirements of the current crop. With zinc, 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 non-calcareous soils, five 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 uniformly applied 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. The effectiveness of chelates depends on the

application method, however. For broadcast 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.

Iron Chlorosis

Most Nebraska soils contain adequate amounts of iron for optimal crop performance. In some soils, however, conditions



Figure 4 a-c. Iron chlorosis is commonly associated with calcareous soils and is expressed as interveinal chlorosis, beginning with the younger leaves.

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 occur on soils which have excess salts and high or excess sodium or which are poorly drained. It may occur even on soils testing high in iron. Soil test iron is considered to be very low when DTPA-Fe is less than 2.5 ppm and marginal when DTPA-Fe is between 2.5 and 4.5 ppm. Values above 4.5 ppm indicate low probability of iron deficiency.

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 4 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 chlorosis can be managed by planting tolerant varieties, planting at a density of 12 viable seeds per foot, applying iron fertilizers with the seed, and using 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 (Fe-EDDHA), mixed in 20-25 gallons of water per acre, directly with the seed is often an effective fertilizer treatment for soybean. Soybean yield response to foliar application of iron fertilizer has been inconsistent and generally less effective than applying chelated iron with the seed.

For corn, research suggests that applying iron sulfate ($\text{FeSO}_4 \bullet 7\text{H}_2\text{O}$) in the seed furrow at rates of 50 to 100 lbs of product per acre prevents chlorosis. Iron sulfate (50 or 100 lbs per acre depending on chlorosis severity) applied in the seed row was less expensive but of similar effectiveness when compared to chelated iron, especially on non-tolerant hybrids. Corn hybrid selection is important for iron chlorosis management. Avoid over-irrigating high sodium and calcareous soils.

Foliar applications of iron can be used for corn, sorghum, soybeans, and field beans, and have been more effective on hybrids/varieties relatively tolerant of iron chlorosis. By the time most 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 or a 1.0 percent 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 has been confirmed in one case of alfalfa in central Nebraska on sandy soil under severe drought stress and in another case of sugar beets 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 leached in the soil. Boron deficiency is most likely 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 deficiency. If both soil and irrigation water are low in boron, borate and borax fertilizer can be soil-applied. Application rates should not exceed one pound per acre. Excessive application rates can cause toxicity. The application rate for one crop can be a toxic level for another crop. Broadcast application is preferred. Boron is toxic to seed and should not be applied in the seed furrow.

Micronutrient Toxicities

Application of excessive amounts of a micronutrient can cause reduced yield, especially with boron. Excessive boron rates can produce barren corn stalks. Response to applied boron is rare in Nebraska and including boron in fertilizer is not advised. Irrigation water contains boron, and harmful effects of over-application are more likely under irrigated conditions.

Excessive rates of copper, a heavy metal known to accumulate in the soil, are of concern. 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, as 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 aluminum can indicate the severity of crop damage expected.

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**Index: Soil Management
Fertility**

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