AG-FO-3344
1988

MANAGEMENT OF SOILS
IN **SOUTH-CENTRAL** MINNESOTA

A Correspondence Course

Unit 4: Micro-nutrients

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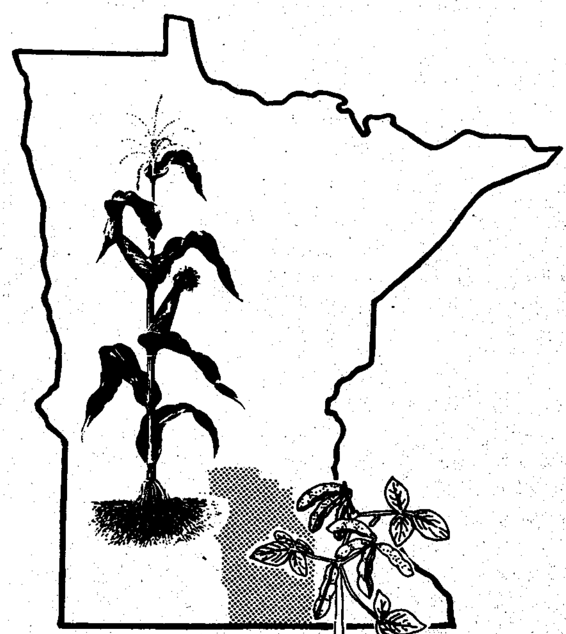
Objectives

- Characterize the soil conditions that contribute to specific micronutrient deficiencies.
- Delineate the extent of micronutrient deficiencies in south-central Minnesota.
- Learn about plant micronutrient requirements and how to identify deficiency symptoms.
- Become familiar with general recommendations for diagnosing and correcting micronutrient deficiencies.



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WHAT ARE MICRONUTRIENTS?

Sixteen nutrients are known to be essential for the complete growth cycle of plants. Of these, seven—boron, chlorine, copper, iron, manganese, molybdenum, and zinc—are considered micronutrients. Micronutrients are required in lower amounts than the other essential plant nutrients. Generally, soils contain sufficient levels of micronutrients to supply crop demands; however, in some areas, micronutrient shortages may result in serious limitations to yields.

EVALUATING CROP NEEDS

Several factors should be considered in determining whether a micronutrient fertilizer is needed.

A loss in yield may indicate that a micronutrient deficiency exists. Visual symptoms (described below for each micronutrient) should be evaluated. Tissue analysis can be used to confirm whether visual symptoms are due to a micronutrient deficiency. Table 1 lists concentrations of micronutrients for healthy plant tissue of selected crops. The crop's response to micronutrients (Table 2) also should be considered.

Soil factors such as pH, texture, and organic matter can affect micronutrient soil levels and availability. Soil tests can help determine whether soil levels of many micronutrients are adequate for crop production. These tests and interpretations will be discussed below.

Because micronutrients are needed in small amounts, indiscriminate use can lead to over-application and a consequent yield loss. In many cases, it may be desirable to put in a test plot where a micronutrient application is compared to a check strip. Cost of application and material (Table 3) should be taken into account.

BORON

Boron deficiency is most likely on coarse-textured, sandy soils low in organic matter. In alfalfa, deficiencies become noticeable after periods of drought. Excessive rainfall or irrigation may leach boron from sandy soils, leading to boron shortages.

Characteristic boron deficiency symptoms are death of the growing points and stunting of growth. In corn, boron shortage causes small, twisted unfilled ears and white spots on the youngest leaves. In many of the vegetable crops (cauliflower, broccoli), boron deficiency causes hollow and blackened stems and dark, discolored heads.

The total quantity of boron used by plants is very low. For example, a good crop of alfalfa will remove from 0.1 to 0.3 lb/A of boron.

A suspected boron deficiency should be confirmed by soil and plant analyses before a boron fertilizer is applied, since excessive boron can be toxic to plants. Boron soil tests can be used to determine boron fertilizer needs (Table 4). Broadcast boron fertilizer one to two weeks before planting. See AG-FO- 0723, *Boron for Minnesota Soils,* for further information on boron.

CHLORINE

Adequate levels of chlorine to meet plant requirements are believed to be present in most Minnesota soils. Chlorine is available to plants as the chloride anion (Cl^-) and is a major component of potash fertilizer, 0-0-60. Recent re-

Table 1. Micronutrient concentrations in tissues of healthy plants.

Crop	Plant Part	Time of Sampling	Micronutrient Concentration[a]					
			B	Cu	Fe	Mn	Mo	Zn
Alfalfa	Top 15 cm	1/10 bloom	30-80	10-30	30-400	30-250	1-10	20-100
Corn	Ear leaf	Initial silk	6-40	5-30	20-350	20-200	—	16-70
Potato	Young mature leaf	Tubers half grown	30-40	—	70-150	30-100	—	20-40
Small Grains	Flag leaves	During heading	8-20	8-20	40-200	30-200	—	20-70
Soybean	Recently mature leaf	Early pod set	20-100	10-30	50-200	20-250	1-10	20-75

[a]Values denote sufficiency range. Levels below this range are considered low or deficient; levels above this range are considered excessive or toxic. B = boron; Cu = copper; Fe = iron; Mn = manganese; Mo = molybdenum; Zn = zinc.

Table 2. Response of different crops to micronutrients under soil or environmental conditions favorable to a deficiency.

Crop	Relative Response[a]					
	Zinc	Iron	Manganese	Molybdenum	Copper	Boron
Alfalfa	Low	Med.	Med.	Med.	High	High
Barley	Med.	High	Med.	Low	High	Low
Cauliflower	—	High	Med.	High	Med.	High
Clover	Med.	—	Med.	High	Med.	Med.
Corn	High	Med.	Low	Low	Med.	Low
Dry beans	High	High	High	Low	Low	Low
Oats	Low	Med.	High	Med.	High	Low
Pea	Low	—	High	Med.	Low	Low
Potato	Med.	—	Med.	Low	Low	Low
Soybean	Med.	High	High	Med.	Low	Low
Wheat	Low	Low	High	Low	High	Low

[a]"High" indicates that a response is likely under favorable soils and environmental conditions; "low" indicates that little if any response is expected.

Table 3. Prices of selected micronutrient fertilizers.[a]

Fertilizer Material	% Element	Price/lb element[b]
Granular Boron	10	$ 2.35
Solubor	28	3.50
Liquid Boron	10	9.65
Copper Sulfate	25	2.60
Copper Chelate	5	19.50
Ferrous Sulfate	40	0.63
Iron Chelate	5	14.40
Manganese Sulfate	28	0.95
Manganese Chelate	5	14.25
Liquid Molybdenum	4	65.50
Zinc Sulfate	36	0.80
Zinc Chelate	7	10.50

[a]Based on 1987 prices, prices subject to change.

[b]To determine price per acre, multiply the recommended rate of element in lb/A by the price per pound. Examples for zinc and boron:

10.0 lb/A zinc broadcast as zinc sulfate is recommended:
10.0 lb/A x $0.80/lb = $8.00/A.

2.0 lb/A zinc row-applied as zinc sulfate is recommended:
2.0 lb/A x $0.80/lb = $1.60/A.

2 lb/A boron broadcast as granular boron is recommended:
2.0 lb/A x $2.35/lb = $4.70/A.

search in some states has shown that wheat and barley may respond to chloride-containing fertilizer. This response was highly correlated with soil chloride content. Because response to chloride has not been reported in south-central Minnesota, supplemental fertilizer applications to supply chloride are not recommended for this area.

COPPER

Copper deficiency is most likely on organic soils. Copper deficiency symptoms include general yellowing of the plant, leaf-tip or shoot dieback, and twisting of the leaf tips. Wheat and certain vegetable crops grown on peat soils have been reported to respond to copper applications. Yield responses to copper by crops on mineral soils (loams, clay loams) in Minnesota have not been demonstrated.

Relatively low amounts of copper are removed from the soil by crop production. Crops such as wheat and oats would take over 30 years to remove one lb/A of copper from the soil when the grain only is harvested.

Copper fertilizer applications (broadcast or foliar) are recommended for organic soils only (Table 5). See AG-FO-0648, *Copper for Organic Soils,* for further information.

IRON

In alkaline soils (pH greater than 7.0), iron is in a form not readily available to plant roots. Crops grown in these soils may develop symptoms of iron chlorosis, characterized by interveinal yellowing of the newer leaves with the vein remaining green. These symptoms are usually more severe in cold, wet soils. Soybeans, flax, sorghum, and many ornamental trees and shrubs are commonly affected. Corn is not as seriously affected. Soybean varieties differ in their susceptibility to iron chlorosis. Chlorosis is most common in western and south-central Minnesota.

Iron chlorosis may be corrected by soil applications of iron chelate, but the amounts required are large, making the practice uneconomical. Iron chelate applied as a foliar

Table 4. Relative boron levels and recommendations for boron for Minnesota soils.

Boron Soil Test (ppm)	Relative Level	Boron to Apply: Vegetables[a] Group I[b]	Group II[b]	Group III[b]	Alfalfa	Other Crops
		lb/A				
0-1.0	Low	2-4	0.5-1	0	2-4	0
1.0-5.0	Adequate	0	0	0	0	0
5.0+	Excessive	0	0	0	0	0

[a]Group I: Table beets, broccoli, brussels sprouts, cabbage, cauliflower, rutabaga, turnip.
Group II: Carrot, celery, lettuce, onion, radish, tomato.
Group III: Asparagus, snap beans, peas, potato, sweet corn.
[b]Rates suggested are for broadcast applications. Use 1/8 of listed rate for banded applications.

Table 5. Copper soil test interpretation and recommendations.[a]

Method	Copper Soil Test (ppm): 0-2.5 (low) Actual Copper	0-2.5 (low) Copper Sulfate[b]	2.6-5.0 (marginal)	5.0+ (adequate)
	lb/A	lb/A		
Spray broadcast on soil	6-12	24-48	Trial only[c]	None
Foliar treatment for small grain[d]	0.3	1.2	0.3 lb/A actual copper	None

[a]Recommendations are for organic soils for wheat, oats, barley, flax, alfalfa, lettuce, onions, spinach, and table beets. No copper is recommended for other crops.
[b]Apply as copper sulfate and mix thoroughly to top six inches of soil before planting. Retest in three years. Copper chelates also can be used. Less copper is required when chelates are used.
[c]Recommended rate for trial is 6 lb/A of copper (24 lb/A of copper sulfate).
[d]Apply copper sulfate solution at late tillering stage for wheat, oats, barley, and flax. It is effective only during the year in which it is applied.

spray offers the best method to alleviate the problem. For soybeans, iron chelate 138 applied to leaves at 0.1 to 0.15 lb/A of actual iron will often correct the chlorosis if the material is applied when beans are putting out the second trifoliate leaves. Cultivation also may help to reduce the chlorosis problem. Iron chlorosis in soybeans can be minimized by selected iron-efficient varieties. For further information see AG-FS-1212, *Correcting Iron Chlorosis.*

MANGANESE

Manganese deficiency may occur on alkaline soils and on organic soils with a pH above 5.8. Symptoms of manganese deficiency include yellowing of the younger plant tissue, often similar to iron chlorosis. The extent of deficiency is not known in south-central Minnesota. A few suspected deficiencies have been reported on vegetable crops grown on organic soils. Soil tests and plant tissue tests can be used to determine whether a deficiency exists. Banded applications of manganese sulfate fertilizers (10 to 20 lb/A of actual manganese) are recommended if manganese deficiency is suspected. Foliar applications of manganese chelate at the rates of 0.2 lb/A of actual manganese are recommended if deficiency symptoms are observed in standing crops.

MOLYBDENUM

Molybdenum deficiency is not common in Minnesota. Typically, deficiencies will occur only on acid, coarse-textured soils and acid peats. Alfalfa did respond to molybdenum on an unlimed area at the Rosemount Experiment Station, but no response has been reported on other soils. Certain vegetable crops such as cauliflower and broccoli are susceptible to molybdenum deficiency.

Symptoms of molybdenum deficiency usually appear first in the middle and older leaves and are characterized by yellow leaves and a rolling-in of the leaf margins. In cauliflower, new growth is spindly and leaves are misshapen (often referred to as whiptail).

Liming soils to a pH of 6.0 to 6.5 is recommended to correct molybdenum deficiency. If molybdenum is applied to the soil, 0.25 to 0.5 lb/A of actual molybdenum is recommended. This may be applied as ammonium molybdate $[(NH_4)_2MoO_4]$. Foliar application of 0.12 lb/A of actual molybdenum is recommended for cole crops where molybdenum deficiency is known or suspected. Caution should be taken when using molybdenum fertilizer as high levels of molybdenum in forage are toxic to animals.

ZINC

Zinc deficiency is most likely to occur on alkaline soils under conditions similar to those for iron deficiency. High levels of soil phosphorus coupled with low levels of soil zinc may induce zinc deficiency. Response to zinc may also occur on coarse-textured sandy soils low in organic matter. Zinc deficiency is most common in western and south-central Minnesota.

In corn, zinc deficiency causes shortened internodes resulting in a shortened plant. Younger leaves also may appear striped on either side of the mid-rib. Dry edible beans are likely to respond to zinc if soil zinc levels are low. The probability of a response to zinc increases if corn or dry edible bean follows a crop of sugarbeets. For normal growth, plants seldom absorb more than 3 ounces of zinc per acre.

Zinc soil tests should be used to determine whether a zinc fertilizer is needed (Table 6). If zinc deficiency is known or suspected, zinc sulfate can be blended with a dry bulk fertilizer. Broadcast or row applications may be used. Zinc applied in the row should not come in contact with the seed. For growing crops showing zinc deficiency, foliar applications of zinc as zinc sulfate (0.5 to 1.0 lb/A of zinc) or zinc chelate (0.15 lb/A of zinc) are recommended. These materials should be applied with a minimum of 20 gallons of water per acre. More than one application may be necessary to correct the problem. For further information refer to AG-FS-0720, *Zinc for Minnesota Soils.*

Table 6. Zinc recommendations for field corn, sweet corn, grain sorghum, edible beans, and onions in Minnesota.

		Zinc to Apply	
Zinc Soil Test (ppm)	Relative Level	Broadcast Applied	Row Applied[a]
		------- lb/A	-------
0-0.5	Low	10-12	2
0.5-1.0	Marginal	5-10	1
1.0 +	Adequate	0	0

[a]The rates suggested for row application probably will not increase the soil test level for Zn and are therefore intended to be an annual application.

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