Essential Micronutrients: Manganese
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# MANGANESE:
# *An Essential Plant Micronutrient*

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PLANTS AND ANIMALS do not grow well without ample manganese (Mn). This element is classed as a trace element or a micronutrient because such small quantities are required for the production of economical yields.

## Manganese in Animals

Food of plant origin is the major source of Mn for animals. Because Mn levels in plants vary greatly between species and parts of the plant, deficiencies in animals are most likely when rations contain limited sources of feed. Chickens, for example, on occasion are subject to a deficiency, especially when the ration contains large amounts of corn. Because rations for poultry usually are high in corn, supplemental Mn is nearly always used on commercial poultry farms.

Sheep, cattle and hogs appear to be less subject to deficiencies than chickens. Even so, some instances of deformities or reproductive failures have been attributed to low levels of Mn in feed.

Manganese is not considered to be very toxic to animals. Because of this, the most practical method of preventing deficiencies is the addition of Mn salts to feed or mineral supplements.

## Manganese in Plants

Manganese levels in plants vary greatly, and in Michigan the levels range from deficiency to toxicity. In either extreme, crop yields are greatly reduced.

The total Mn content of select crops is reported in Table 1. In general, Mn is concentrated in leaves and stems. Seeds usually contain very small amounts. As with other essential elements, crop requirements are closely related to the yield produced. Manganese is essential for the activity of many enzyme systems within a plant. Chlorophyll production, carbohydrate and nitrogen metabolism depend upon this essential micronutrient.

Michigan crops can be divided into three groups on the basis of their response to Mn fertilizer as reported in Table 2.

The highly responsive group nearly always responds to Mn fertilizer when grown on high pH soil. The crops in the medium group may respond to fer-

**Table 1. Manganese Levels of Select Crops.**

| *Crop* | *Plant part* | *Yield* | *Lbs./A* |
|---|---|---|---|
| Alfalfa | Hay | 6 T | 0.66 |
| Barley | Grain | 60 Bu | 0.05 |
| | Straw | 1.5 T | 0.45 |
| Bean | Seed | 40 Bu | 0.07 |
| Corn | Grain | 150 Bu | 0.09 |
| | Stover | 4.5 T | 1.50 |
| Oat | Grain | 100 Bu | 0.15 |
| | Straw | 2 T | 0.45 |
| Potato | Tuber | 800 Bu | 0.18 |
| Red clover | Hay | 3 T | 0.62 |
| Rye | Grain | 60 Bu | 0.44 |
| | Straw | 2 T | 0.28 |
| Sorghum | Grain | 100 Bu | 0.07 |
| | Stover | 4 T | 1.10 |
| Soybean | Seed | 40 Bu | 0.06 |
| Sugarbeet | Plant | 20 T | 0.74 |
| Tomato | Fruit | 20 T | 0.13 |
| Wheat | Seed | 60 Bu | 0.14 |
| | Straw | 2 T | 0.25 |

**Table 2. Relative Response of Select Crops to Fertilizer Manganese.**

| | | |
|---|---|---|
| | *Highly Responsive Crops* | |
| Bean | Pea | Spinach |
| Lettuce | Potato | Sudangrass |
| Oat | Radish | Table beet |
| Onion | Sorghum | Wheat |
| | Soybean | |
| | *Medium Responsive Crops* | |
| Alfalfa | Celery | Peppermint |
| Barley | Clover | Spearmint |
| Broccoli | Cucumber | Sugarbeet |
| Cabbage | Corn | Sweetclover |
| Carrot | Grass | Tomato |
| Cauliflower | Parsnip | Turnip |
| | *Low Responsive Crops* | |
| Asparagus | Blueberry | Rye |

**Table 3. Manganese Sufficiency Range.**

| *Crop* | *Sampling notes* | *Sufficiency range* |
|---|---|---|
| | | *(ppm)* |
| Corn | Ear Leaf just before silking | 20-150 |
| Soybean | Upper mature leaf just before flowering | 20-100 |
| Alfalfa | Top growth–6 inches to flowering | 30-100 |
| Wheat | Upper leaves prior to first bloom | 15-200 |
| Sugarbeet | Center mature leaf–midseason | 20-150 |
| Navy bean | Upper mature leaf just before flowering | 20-150 |
| Vegetables | Top fully developed leaf–midseason | 30-200 |
| Potato | Petioles from newly matured leaf at midseason | 30-200 |

tilizer Mn. Crops in the low group do not generally respond to fertilizer Mn. In fact, they have the ability to tolerate exceptionally high levels of soluble Mn.

The Mn status of crops can be evaluated by chemical analyses of plant tissue. Such analyses are available through several laboratories. The Mn values in Table 3 represent the "sufficiency range" concept which defines the level necessary for high crop yields. Values which are outside of the range represent yield-limiting production problems. Lower values obviously represent a Mn deficiency, while higher values represent a nutrient imbalance or toxicity. When levels of Mn are very high, iron (Fe) levels are low. Thus, it is difficult to determine if the problem is an Fe deficiency or a Mn toxicity. This condition represents the nutrient imbalance concept.

The sufficiency range concept is most easily used when tissue samples are collected at the indicated stage of plant development and when the tissue represents the specified plant part.

Visual Mn deficiency symptoms frequently are seen in Michigan. However, they sometimes are difficult to interpret correctly because they are very similar to iron (Fe) and on some crops are somewhat similar to magnesium (Mg). Soil testing is an aid in interpreting Mn deficiency symptoms.

Symptoms on soybeans, field beans and sugarbeets are similar in that leaves are mottled. Leaf veins are much darker green than the interveinal tissue. On small grains and corn, the leaves are likely to be striped. Oats are an excellent indicator crop because frequently a short distance back from the leaf tip gray specks appear. With time a zone across the entire leaf eventually develops which causes the end of the leaf to hang rather than to be in a natural upright position. The foliage of most grains is light yellow and has soft, limber stems.

Excessive Mn is a problem on acid soil or may develop in plants if excess soil and/or foliar treatments are used. The first symptoms of toxic levels may be similar to those for Mn deficiency—interveinal chlorosis on navy beans and soybeans is distinctive. The mottling is followed by a slight folding or cupping of the leaves and by scorching along the margins. The symptom is often described as "crinkle leaf." Potatoes and tomatoes have brittle leaves, stem streak necrosis, and also crinkly leaves.

## Manganese in Soil

Manganese occurs in the soil in several forms, some of which are not available to crops. Only exchangeable and water-soluble Mn are used by plants. In testing soils, several extractants are commonly used. The MSU Soil Testing Laboratory is currently using 0.1 normal hydrochloric acid (0.1 N HCl). As with all levels for Mn, the results are sometimes not closely correlated with responses to Mn fertilizers because the degree of oxidation can and does change rapidly. The ability of the soil to oxidize Mn controls the degree of availability to plants.

While poor drainage may actually increase the solubility of some forms of soil Mn, the condition also limits root proliferation and extension; thus deficiencies develop for Mn as well as other nutrients.

After naturally wet soils are drained, Mn soil test levels frequently are similar to those of the naturally well drained soil as is shown in Table 4. These data represent the average Mn level in the profiles of 135 sample locations in southern Michigan. The data in

**Table 4. Average Extractable Manganese Levels in Southern Michigan Soil as Related to Texture and Natural Drainage.**

| | | *Natural drainage* | | | |
|---|---|---|---|---|---|
| *Dominant profile texture* | *Soil management group* | *Well drained* | *Somewhat poorly drained* | *Poorly drained* | *Mean* |
| | *Symbol* | *a* | *b* *(ppm)* | *c* | |
| Clay and clay loam | 1 and 1.5 | 35 | 35 | 34 | 35 |
| Loam and sandy loam | 2.5 and 3 | 27 | 31 | 36 | 31 |
| Loamy sand and sand | 4 and 5 | 9 | 16 | 14 | 13 |
| | Mean | 24 | 27 | 28 | |

this table also demonstrate that extractable Mn levels in fine-textured soil are more than double those of coarse-textured soils.

There is little correlation between extractable levels of Mn in different kinds of soil and sites where deficiencies have been confirmed. There are at least three explanations to this situation.

**The first** is related to the solubility of Mn as regulated by the degree of oxidation of the element. Oxidized forms are relatively insoluble and reduced forms relatively soluble. Thus, soils developed under poor drainage conditions are likely to contain less total Mn than those developed under good drainage. Manganese would leach at water-logged sites, which is where deficiencies are observed most frequently.

**The second** is related to the degree of acidity or alkalinity of the soil. Solubility or availability of Mn decreases with an increase in pH level. If pH levels of all the soils reported in Table 4 were similar, test levels undoubtedly would be different. Average pH levels in the well drained "a" soils were 0.6 units lower than the "c" soils.

This situation is also illustrated in Table 5 where average tests of subsoil and parent materials were lower than in the plow layer. Average pH levels in the A, B, and C horizons were respectively 7.1, 7.2, and 7.8.

**The third** explanation is related to how the samples were handled in the laboratory. Many observations show that extractable Mn levels decrease when samples are air dried. The state of oxidation of Mn increases in the drying process, thereby decreasing the solubility.

This partially explains why the term "extractable" Mn rather than "available" is used in this discussion. This situation helps to explain why soil tests for Mn are difficult to closely correlate with responses to Mn fertilizer and why some chemists recommend testing for Mn only on freshly collected moist samples.

As previously implied, the availability of Mn increases with an increase in acidity. Manganese can be leached from strongly acid soil, but leachates from alkaline soils show only traces. Since water moves easily through the more sandy soils, such soils are more likely than others to be acid and have Mn in a soluble form which is most easily leached. Thus, sandy soils contain less total Mn as well as available Mn.

The soluble Mn levels in very acid soils is likely to be very high. In fact it can be so high that toxicity develops. Obviously, the solution to this problem is to lime.

**Table 5. Average Extractable Manganse Levels in Southern Michigan Soil as Related to Profile Depth and Natural Drainage.**

| | | *Natural drainage* | | | |
|---|---|---|---|---|---|
| *Horizon* | *Symbol* | *Well drained* | *Somewhat poorly drained* | *Poorly drained* | *Mean* |
| | | | *(ppm)* | | |
| Plow layer | Ap | 36 | 41 | 34 | 37 |
| Subsoil | B | 16 | 22 | 17 | 18 |
| Parent material | C | 20 | 20 | 32 | 24 |
| | Mean | 24 | 27 | 28 | |

### Manganese Levels in Livestock Manure

Livestock manure generally contains very small amounts of Mn as is shown in Table 6. While Mn levels vary greatly, they are seldom high enough to be significant. This is true even for poultry manure where birds are fed supplemental Mn.

### Manganese Levels in Irrigation Water

River water in Michigan varies from undetectable amounts up to 80 ppb (parts per billion) depending upon time of year and the river sampled. The most frequent test levels are less than 2 ppb. This is also the situation for lake, pond and well water. Thus, irrigation water is not a good source of Mn.

### Manganese Levels in Municipal Sludges and Wastewater

Manganese levels are not reported in the analyses of most sludges and wastewater because it is usually present in such small amounts. Manganese is so reactive that it is strongly adsorbed by colloidal material or is oxidized into an insoluble or unavailable form. Therefore, sludges and wastewater are not good sources of Mn for field crop production.

**Table 6. Average Manganese Levels in Livestock Manure.**

| | *Tons of manure* | | |
|---|---|---|---|
| *Kind of manure* | *1* | *5* | *20* |
| | | *(Lbs.)* | |
| Chicken[1]—no floor litter | 0.2 | 1.0 | 4.0 |
| Chicken—floor litter | 0.1 | 0.5 | 2.0 |
| Dairy cow | 0.02 | 0.1 | 0.4 |
| Fattening cattle | 0.01 | 0.05 | 0.2 |
| Hog | 0.04 | 0.2 | 0.8 |
| Horse | 0.02 | 0.1 | 0.4 |
| Sheep | 0.02 | 0.1 | 0.4 |

[1]*May contain up to 0.8 pound per ton depending on feed content.*

**Table 7. Carriers of Manganese.**

| *Carrier* | *Formula* | *Percent manganese* |
|---|---|---|
| Manganese chelate | MnEDTA | 12 |
| Reax manganese | MnMPP | 10-12 |
| THIS manganese | MnPP | 5 |
| Manganese silviplex | MnMPPP | 7 |
| Manganese sulfate | $MnSO_4 \cdot 3H_2O$ | 26-28 |
| Manganese frit | Frit | 35 |
| Manganous oxide | MnO | 41-68 |
| Rayplex Mn | MnPF | 8-8.5 |

### Manganese Carriers

Examples of both organic and inorganic carriers of Mn are reported in Table 7. Manganous oxide (MnO) and frit materials are only slightly soluble and are generally less suitable than other materials unless they are very finely ground. Chelated Mn materials in general have not been satisfactory on organic soils but are effective on mineral soils. The material that has been most effective on all soils is manganese sulfate ($MnSO_4$). Manganic oxides ($MnO_2$) are not recommended as a source of fertilizer.

### Recommendations

Where Mn deficiency is suspected, soil should be tested especially for pH. Plant tissue analyses are of great value in this situation.

Where needed, Mn should *not* be broadcast because most soils have a great capacity to fix Mn into an unavailable form. This greatly increases costs to correct the problem. The most effective use of Mn occurs when it is mixed with commercial fertilizer and is band-placed at planting time.

Recommended rates of Mn are reported in Table 8. The "response" shown in this table refers to the crops listed in Table 2.

Manganese can also be used as a foliar spray. Such application is recommended where (1) fungicides and insecticide sprays are used, (2) fertilizer is broadcast or is not used, (3) deficiency symptoms for Mn appear early in the season.

For sprays, use one pound per acre on small plants and two pounds for larger plants. Most fertilizer dealers carry spray grades of Mn.

### Summary

Manganese is an essential element for both plants and animals. Deficiencies are not common in well-managed livestock but may be a problem on soils with relatively high pH levels. Plant toxicities are observed on very acid soils.

Manganese levels in soil decrease with depth. The deficiency in plants is more common when grown on organic soils or soils that are naturally poorly drained.

To determine Mn fertilizer requirements, both soil testing and plant analysis is advised.

Foliar spraying and banding of Mn at planting time are recommended where deficiencies occur. Broadcast applications are not recommended because of poor recovery and high costs.

Livestock manure, irrigation water, and municipal sludges and wastewater contain very low levels of soluble Mn and are not good sources of this essential micronutrient.

**Table 8. Manganese Recommendations for Band Application on Mineral and Organic Soils.[1]**

| | *Mineral soils* | | | | *Organic soils* | | | |
|---|---|---|---|---|---|---|---|---|
| *Soil test[2] ppm Mn* | *Above pH 6.5* | | *pH 6.0 - 6.5* | | *Above pH 6.4* | | *pH 5.8 - 6.4* | |
| | Response | Mn - lbs/A | Response | Mn - lbs/A | Response | Mn - lbs/A | Response | Mn - lbs/A |
| Below 5 | Probable | 8 | Probable | 6 | Certain | 16 | Certain | 12 |
| 5-10 | Probable | 6 | Possible | 4 | Certain | 12 | Probable | 8 |
| 11-20 | Possible | 4 | None | 0 | Probable | 8 | Possible | 4 |
| 21-40 | None | 0 | None | 0 | Possible | 4 | None | 0 |
| Above 40 | None | 0 | None | 0 | None | 0 | None | 0 |

*[1]Manganese fertilizers are not recommended when tests are below pH 6.0 for mineral soils and 5.8 for organic soils.*
*[2]Soil extracted with 0.1 N HCl.*

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