Agronomy Guide

Purdue University Cooperative Extension Service

SOIL/FERTILITY AY-276-W

MANGANESE DEFICIENCIES IN INDIANA SOILS

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Manganese (Mn) is one of the micronutrients all crops must have in small amounts for normal growth. In Indiana, a deficiency of this element is most likely to appear in soybeans, wheat, barley, and oats. Deficiencies have occasionally been observed in corn and alfalfa.

WHERE MANGANESE DEFICIENCIES OCCUR

Manganese deficiencies typically occur in specific areas of Indiana, and, principally, within two soil groups -- (1) the black sandy soils on the glacial outwash and lake bed material of the Kankakee River Valley in the northwest, and (2) the depressional heavy soils of Allen, Adams, Wells, and adjacent counties in the northeast (Figure 1). The problem has also been noted in Warrick and Vanderburgh counties in southern Indiana, and occasionally on light sandy soils in northern Indiana.

Although deficiencies may appear on any soil type, certain field characteristics increase the likelihood that crops will display symptoms. Typically, Mn deficiency occurs on soils with pH above 6.2 to 6.3. Within a field, symptoms do not usually appear uniformly, and symptom expression is more likely in low areas or areas of the field with more poorly-drained, dark soils. Heavy, depressional soils in any part of the state have the potential to produce deficiency symptoms in sensitive crops. In muck soils, Mn may be made unavailable by interaction with organic compounds. Some climatic conditions, such as cold, rainy weather, can enhance the problem. Management factors that reduce Mn availability in soil include operations that result in severe soil compaction or erosion and heavy liming of sandy, low organic matter soils.

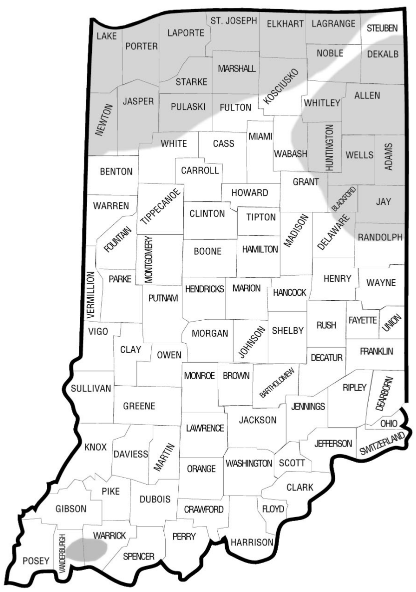


Figure 1. Areas of manganese deficiency.

SUSCEPTIBLITY OF INDIANA CROPS

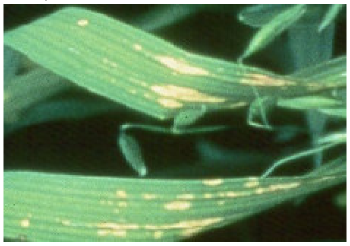
Crops have distinctly different Mn requirements. Major Indiana crops that can be expected to respond well to Mn fertilizer when grown on soils with low levels of available Mn include soybean, winter wheat and oats. Indiana crops for which a more moderate response is expected include corn and alfalfa. Mint, often grown on Indiana's muck soils, is also in the moderate response category.

HOW TO RECOGNIZE MANGANESE DEFICIENCY

Once taken up by the plant, Mn is immobile and cannot be moved from old tissue to younger tissue. Therefore, deficiency symptoms will appear first on new leaves or growth. In general, Mn deficiency symptoms on leaves are interveinal chlorosis and general chlorosis of young leaves. Crop specific symptoms are as follows:

Soybeans: Soybeans are the most common Indiana crop to display Mn deficiency, and the symptoms are easily spotted due to their unique characteristics (Figure 2a). A "yellowing" occurs in the area between the leaf veins, ranging from pale green with slight deficiency to almost white with severe deficiency. In extreme cases, this chlorosis may begin in the seedling stage. The veins remain distinctly green until chlorosis approaches the "white stage," after which the color disappears from the veins. Typically, necrotic, brown spots develop as the deficiency becomes more severe. Leaves may drop prematurely. It

2a, *M.C. Shurtleff APS Collections*



2b, *Steve Hawkins, Purdue Univ.*

2c, *G. Murray APS Collections*

2d, *Larry Bundy APS Collections*

2e, *Reggie Voss, Iowa State Univ.*

Figure 2. Manganese deficiency in a) soybeans, b) wheat , c) oats, d) corn, and e) alfalfa.

should be noted that early Mn and iron (Fe) deficiency symptoms can be easily confused. Typically, the veins of iron deficient leaves do not remain green beyond the very early deficiency stages (Figure 3).

Wheat: Symptoms may develop on wheat in the spring when plants are five to eight inches tall. Grey-white spots appearing on old and young leaves may be accompanied by chlorotic or grey-white streaking of the leaves (Figure 2b). When the spots merge together, leaves may kink or droop from the base of the blade. In comparison to healthy plants, affected plants may also appear lighter green and may mature more slowly. In cases of severe deficiency, the tops turn white, then brown. With extreme plant lodging, stands are often reduced to the point of crop failure.

Oats: Symptoms on oats appear when plants are about six inches tall. Grey specks appear near the base of the older leaf blades (Figure 2c). These specks may join to form streaks or circular patches. As the deficiency becomes more severe, the grey areas turn brown, the blade bends downward at the brown area and hangs limp, and the tip turns yellow, then brown. The heads are yellow-white in color and are shriveled.

Corn: Mild deficiency symptoms are not clear cut but leaves may turn olive green with slight streaks. More severe deficiency symptoms appear as long yellow and green stripes running the length of the leaf, a symptom very similar to a magnesium deficiency in corn (Figure 2d). Eventually the chlorotic areas may turn white and then brown as the tissue dies.

Alfalfa: Early deficiency symptoms are reduced growth coupled with strong interveinal chlorosis of only the very youngest leaves. The veins of these leaves will remain green (Figure 2e). Later, small brown necrotic areas will be visible on the upper surface of the chlorotic, young leaves.

SOIL TESTING AND PLANT ANALYSIS FOR MANGANESE

Since available Mn in soil can vary considerably across a field, soil type and pH may prove useful in predicting potential areas of Mn deficiency within a field and in directing scouting and sampling efforts. Because Mn availability in both mineral and organic soils is so highly regulated by pH, actual soil pH values are also required to interpret Mn soil test values. The Mn soil test recommended for use in Indiana is 0.1 N HCl extraction, and Figure 4 shows soil test Mn critical levels for sensitive crops increase with increasing pH. It should be noted that as a stand-alone diagnostic, soil test Mn is not a very good indicator of soil Mn availability.

If the leaves of growing soybean, wheat, oat, or corn plants develop the symptoms described above, Mn deficiency can be confirmed by laboratory analysis of plant tissue. Regular plant analysis in a monitoring program will permit the identification of existing or potential problems before visual symptoms appear. Accurate plant analysis depends on following the proper sample collecting techniques for each crop. At random, select plants from across the field that represent both the affected (Mn deficiency) and unaffected areas. Collect the following:

Figure 3. Iron deficiency in soybeans, shown here, can be confused with Mn deficiency. *Photo: David B. Mengel, Kansas State University*

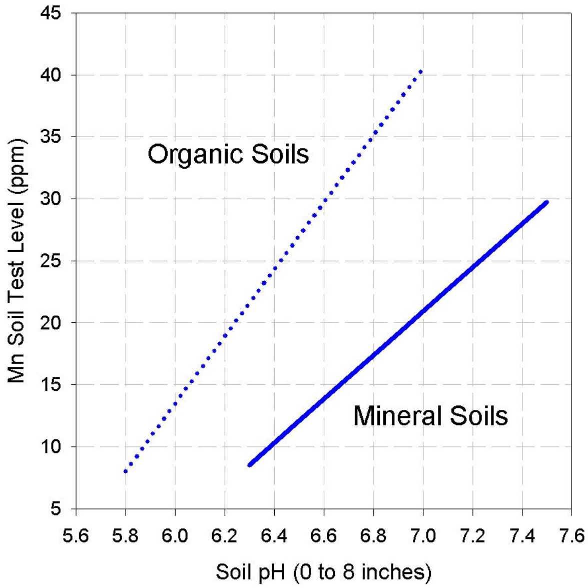


Figure 4. Critical Mn soil test levels for sensitive crops. The critical level increases with pH. For fertilizer rate recommendation tables based on soil test results, see the Tri-state Fertilizer Recommendations.

- Corn seedlings— 15 to 25 entire plants;
- Corn pre-tassel stage—15 to 25 mature leaves below the whorl;
- Corn silking— 15 to 25 ear leaf blades if in the early silking stage;
- Wheat and oats— the upper leaves from 50 to 60 plants prior to heading, or select basal leaves if deficiency symptoms develop in advance of the jointing stage;
- Soybeans— the uppermost fully expanded trifoliate leaves from 20 to 30 plants;
- Alfalfa— top 6 inches sampled prior to initial flowering, 40 to 50 plants.

Allow time for the plant tissue to air dry before placing in a paper envelope for mailing to a laboratory for analysis. Critical Mn levels for common Indiana crops can be found in Table 1.

CORRECTIVE MEASURES

Manganese deficiency is best corrected in the following ways - (1) using an acid forming row fertilizer, or (2) spraying crop foliage early in the season with a Mn carrier as soon as symptoms are observed. In fields where symptoms are known to occur on a regular basis, map the affected area and plan to routinely apply Mn when sensitive crops are grown. If available, global positioning systems (GPS) and geographic information systems (GIS) will produce accurate and reliable deficiency zone mapping that can be easily referred to in subsequent years for long-term fertility management. Common Mn fertilizers are given in Table 2. Selecting a Mn source requires consideration of cost and effectiveness of the product as well as convenience and compatibility with other aspects of fertility and crop management.

Soil Treatment: In general, applying Mn fertilizer to soil is not very effective. When Mn fertilizer is broadcast, it is rapidly fixed into an unavailable form and carryover effect is low, making frequent applications necessary. This recommendation against broadcast applications extends to chelated forms. In Indiana, soils typically have high levels of available Fe; the Fe replaces the Mn in the chelate allowing the Mn to then be fixed by soil.

A successful soil management approach to increasing low Mn availability does not necessarily use any Mn fertilizer. The use of acid forming fertilizers, such as superphosphate, placed in a band reduces the soil pH of the band sufficiently to make native soil Mn more plant available. In Indiana, use of starter fertilizers such as 3-

Table 1. Plant analysis interpretation guide for Mn concentration.

Crop	Growth Stage	Tissue to Sample	Deficient	Low	Normal	High	Excessive†
			ppm				
Corn	3 to 4 leaf	Whole plant	N.A.	N.A.	50 –160	N.A.	N.A.
	Green silk	Ear leaf	< 15	16 – 19	20 – 150	151– 350	>350
Wheat‡	Prior to boot	Top leaves	< 10	11 – 24	25 – 100	101– 350	>350
Soybean	Flower to pod set	Top fully developed trifoliate	< 14	15 – 20	21 – 100	101 – 250	>250
Alfalfa	Flowering	Upper 6”	< 20	20 – 30	31 – 100	101 – 250	> 250

N.A. Interpretive values are not available.
† Excessive concentrations are those that are toxic to the plant.
‡ Also suitable for oat and barley.

Table 2. Manganese fertilizers and suggestions for their use in banded/row starter application (Bnd) and foliar application (Fol). Broadcast applications are not recommended.

Fertilizer Material	Average Elemental Analysis (% Mn)	Preferred Application Methods	Application Notes
Manganese sulfate	23 – 28	Bnd / Fol	Effective source for soil or foliar application. Potential for strong glyphosate antagonism.
Manganese oxysulfate	28 – 40	Bnd	For effectiveness in banded treatments, at least 35 – 50% of the Mn should be in the water soluble (sulfate) form.
Manganese chelate (EDTA)	5 – 12	Fol	Mn chelate is not as effective as Mn sulfate for foliar application but Mn may be the material of choice when tank-mixed with glyphosate.
Manganese complexes: lignosulfonate	5 – 9	Bnd / Fol	Not true chelates. Equally effective to Mn sulfate when used in foliar or soil application.
Manganese oxide (finely ground)	41 – 68	Bnd	When finely ground, acceptable but less effective than Mn sulfate. Difficult to blend with granular fertilizer. Fertilizer sticker is recommended.
Manganese carbonate	31 – 35	Bnd / Fol	As effective as spray-grade Mn sulfate.

Elemental composition of some Mn fertilizer materials may vary. Read the manufacturer's label to confirm analysis and formulation.

10-10 or 10-34-0 have increased soybean yields on responsive soils (Table 3). This research found no additional benefits to adding Mn to the starter. However, when micronutrient deficiencies are more severe, starter fertilizer alone may not be sufficient to overcome the deficiency. A distinct disadvantage of Mn placement with starter or row fertilizer is that it is not easy to restrict application to only the affected area.

Row placement of Mn alone is sometimes effective because it reduces the volume of soil in contact with the fertilizer and slows fixation, although any soil applied material will eventually become unavailable over time.

For Indiana soils, the amount of fertilizer to apply ranges between 5 to 8 pounds of elemental Mn per acre for soybeans, wheat, and oats. The amount of fertilizer required can be calculated from the Mn and pH soil tests as follows:

Mineral Soils: lb. Mn = -36 + 6.2 x pH – 0.35 x ST

Organic Soils: lb. Mn = -46 + 8.38 x pH – 0.31 x ST

where lb. Mn is the lb. elemental Mn to apply per acre, pH is the soil pH measured in water, and ST is the Mn soil test level (ppm). In general, no more than 5 pounds of Mn per acre are needed for less susceptible crops, including corn. When the rate of application is ten pounds per acre or more, such as on muck or peat soils, a foliar application should be used.

Foliar Treatment: In Purdue University studies (Table 3), the foliar application of Mn sulfate was consistently the most effective means of correcting Mn deficiency of soybean on Indiana soils. While this method requires scouting and timely application of the material after the onset of the deficiency, it was more effective than any soil treatment. The recommended rate for leaf application is 1 to 2 pounds of Mn per acre, and only 1 pound if plants are small. Use sufficient water (20 to 30 gallons) to get

Table 3. Soybean yield response to Mn treatments at responsive locations in Indiana (1990, 1991). Source Eck, Mengel, and Walker, 1991.

Mn Treatment		Mn Rate per Acre	Yield (Bu. per Acre)
Control		0	44.3
Starter alone†		0	47.1*
Soil $MnSO_4$ Application	Broadcast	10 lbs.	43.4
	In-Furrow	6 lbs.	43.8
	W/ Starter†	1 qt. Mn complex	46.5
Foliar $MnSO_4$	1 application	1 lbs.	48.0*
	2 applications	2 lbs.	46.9*
Foliar EDTA	1 application	16 oz.	46.4

† Acid forming starter fertilizer source was 3-10-10 in 1990 and 10-34-0 in 1991.
* Indicates that the yield was significantly higher than the control yield.

uniform coverage of the foliage. In Indiana studies, no advantages were found for using more than one application per season. When foliar sprays of chelates are used, follow the labeled rate. Using more than the label rate can cause foliar injury and reduce uptake.

Care should be used when combining Mn sources with various pesticides and carriers. Manganese sulfate sprays combined with certain pesticides can cause plant damage, and Mn chelates mixed with some carriers can cause severe leaf burn at higher rates. If there is some concern as to possible crop damage, experiment with spray mixtures on small test areas prior to treating entire field.

Glyphosate Antagonism: Some soybean producers have observed antagonism of glyphosate efficacy when it is tank-mixed with foliar Mn fertilizers. Researchers in Michigan have been studying this antagonism and results suggest that soybean producers have reason for concern. They found significant antagonism to occur when Mn sulfate was the fertilizer source. For example, 45 days after spraying glyphosate, control of common lambsquarter was 90% or better, but when Mn sulfate was in the tank mix, only 20% control was achieved. Use of chelated Mn-EDTA minimized or eliminated this antagonism. Other factors that may be important include the specific glyphosate formulation and the use of adjuvants such as citric acid and diammonium sulfate, which can eliminate the antagonism.

At present, research results are preliminary and suggest using Mn-EDTA and diammonium sulfate when applying Mn with glyphosate. It should be noted that not all strong chelators worked equally well and some were no more effective than Mn sulfate. Furthermore, if foliar Mn and glyphosate are to be applied separately, then glyphosate should be applied first.

This preliminary research studied the impact on the weed control effectiveness of the glyphosate and not on the effectiveness of the Mn source in correcting the crop deficiency. Future studies will likely address both management objectives of this practice.

ADDITIONAL RESOURCES:

Bennett, W. F. 1994. Nutrient Deficiencies and Toxicities in Crop Plants. American Phytopathological Society Press. St. Paul, MN.

Bernards, M., Kurt Thelen, and Don Penner. "The manganese fertilizer antagonism of glyphosate story for 2002". Michigan State University. Abstract found on the Web at http://www.msu.edu/user/thelenk3/Acrobat/mngly.pdf (URL verified July 2003).

Purdue Crop Diagnostic Training and Research Center. 2003 edition. Corn & Soybean Field Guide. West Lafayette, IN.

"Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa" Extension Bulletin E-2567, Rep. August 1996, on the Web at http://www.agcom.purdue.edu/AgCom/Pubs/AY/AY-9-32.pdf (URL verified July 2003).

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