A2526

Understanding Plant Nutrients

Soil and Applied Manganese

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Manganese (Mn) deficiency and toxicity have been noted in Wisconsin on various soils. The amount of manganese in rocks and soils varies greatly. Some soils may have as much as 3,000 parts per million (ppm) manganese, yet most of this is unavailable for plant use. Manganese in rocks and minerals is unavailable to plants and becomes available very slowly as the minerals undergo chemical weathering. Most available manganese occurs as exchangeable manganese, manganese associated with organic matter, or various manganese oxides. Table 1 gives the manganese content of some soil-forming rocks.

MANGANESE REACTIONS IN SOILS

In soil, manganese occurs as exchangeable manganese, manganese oxide, organic manganese, and a component of ferro-magnesian silicate minerals. The manganese ion (Mn^{++}) is similar in size to magnesium (Mg^{++}) and ferrous iron (Fe^{++}) and can substitute for these elements in silicate minerals and iron oxides.

Manganese reactions in soils are quite complex. The amount of available manganese is influenced by soil pH, organic matter content, moisture, and soil aeration.

Soil pH

Manganese availability increases as soil pH decreases. Manganese toxicity is common in acid soils below pH 5.5. On the other hand, manganese deficiency is most common in soils with a pH above 6.5.

One of the main reasons for liming acid soils, especially for legumes, is to prevent manganese toxicity. The amount of manganese in solution decreases 100-fold for each unit rise in soil pH (as from 5.0 to 6.0). Where manganese deficiency exists as a result of high pH, it is easier to correct the deficiency by adding a manganese fertilizer than by attempting to acidify the soil.

Organic Matter

Soils high in organic matter (more than 6.0%) and near neutral in pH (above pH 6.5) may be deficient in manganese. As the organic matter content increases, the amount of exchangeable manganese decreases due to the increased formation of organic matter and manganese complexes.

Soil microorganisms also appear to reduce the availability of manganese by oxidizing manganese to less-available forms and competing with crops for available manganese.

Moisture and Aeration

Poor soil aeration, or reduced oxygen level, usually is caused by excess moisture along with high microbial activity. High microbial activity consumes oxygen when soil temperatures and supplies of organic carbon are favorable. As a result, manganese oxide is transformed to soluble manganese (Mn^{++}). Under prolonged waterlogged conditions, soluble manganese leaches out of the soil. Manganese and iron deposits may plug tile lines as drainage water carrying these elements contacts air in the tile. Temporary waterlogged conditions are conducive to manganese toxicity; prolonged wet conditions, as in a marsh, can result in manganese deficiency.

FERTILIZER SOURCES OF MANGANESE

Broadcast applications of manganese fertilizer or attempts to build soil test manganese levels are not recommended, particularly on high pH, high organic matter soils because of their capacity to rapidly fix manganese. Band or foliar applications of manganese reduce chemical fixation by reducing contact with soil particles. Mixing manganese with ammonium nitrogen in a fertilizer band further

Table 1. Occurrence of manganese in rocks and soil.[a]

IGNEOUS ROCKS		SEDIMENTARY ROCKS			
GRANITE	BASALT	LIMESTONE	SANDSTONE	SHALE	SOILS
ppm		ppm			ppm
400	1,500	1,100	10–100	850	20–3,000

[a]*Source: Krauskopf, K.B. 1972. Geochemistry of micronutrients. In* Micronutrients in agriculture, *ed. J.J. Mortvedt et al., pp. 7–40. Madison, WI: Soil Science Society of America.*

improves its availability as a result of the acidity produced as ammonium converts to nitrate.

Manganese sulfate ($MnSO_4 \cdot 3H_2O$) and chelated manganese (MnEDTA) are the most common fertilizer sources of manganese (Table 2). Both are very soluble and are effective as foliar treatments. However, chelated forms of manganese are not as effective as manganese sulfate for soil application. Research with soybean on a manganese-deficient Sebewa loam showed that applying manganese chelate to the soil actually increased the deficiency. Apparently, the manganese chelate converted to the more stable iron chelate. As a result, the soybean took in more iron, accentuating the iron-manganese imbalance.

Before applying a manganese fertilizer, sample soils or plants to determine whether they need this element. With foliar applications, two or three applications are sometimes necessary for optimum response. When soils test low in manganese, apply the amount of manganese indicated in Table 3.

Table 2. Fertilizer sources of manganese.

SOURCE	FORMULA	PERCENT MANGANESE
Manganese carbonate	$MnCO_3$	31
Manganese chelate	MnEDTA	12
Manganese chloride	$MnCl_2$	17
Manganese dioxide	MnO_2	63
Manganese oxide	MnO	41–68
Manganese sulfate	$MnSO_4 \cdot 3H_2O$	26–28

Table 3. Manganese fertilizer recommendations.

	— MnO or $MnSO_4$ —		— Mn CHELATE —	
CROP	SOIL	FOLIAR	SOIL	FOLIAR
	lb/a of elemental manganese			
Beans (dry, lima, snap), lettuce, oat, onion, radish, raspberry, soybean, spinach, sorghum-sudan, wheat	5.0	1.0	0.8	0.15[a]
Barley, beet, broccoli, brussels sprout, cabbage, canola, carrot, cauliflower, celery, corn, cucumber, pea, potato, tobacco, tomato, triticale	3.0	0.75	0.5	0.10
Other crops (not listed above)	0	0	0	0

[a]*Phytotoxicity may occur if Mn chelate is applied at a rate greater than 0.25 lb/a of Mn.*

MANGANESE DEFICIENCY AND TOXICITY

Manganese deficiency is most likely to occur in neutral- to high-pH soils that are also high in organic matter. It is common on the red soils of eastern Wisconsin especially in low-lying areas and on burned-over organic soils. Soils high in organic matter with a calcareous subsoil (marl) may exhibit manganese deficiency when drained. Crops with high manganese requirements include beans (lima, snap), lettuce, oat, onion, radish, raspberry, soybean, spinach, sorghum-sudan, and wheat. Those with medium relative manganese needs are barley, beet, broccoli, brussels sprout, cabbage, carrot, cauliflower, celery, corn, cucumber, pea, potato, tobacco, and tomato.

Excess manganese is found in acid soils (pH less than 5.5), especially when these soils are low in organic matter and temporarily waterlogged. Acid, sandy soils are likely to contain high manganese levels. Crops susceptible to manganese toxicity include asparagus, forage legumes, mint, and pea. Manganese toxicity of potato has also been identified on extremely acid soils (pH less than 5.0)

DIAGNOSTIC TECHNIQUES

Deficiency Symptoms

Manganese functions as an enzyme activator for steps in photosynthesis. Manganese deficiency in oat is known as gray speck. This is not a pathogenic disease but a breakdown of leaf tissue. Gray speck usually starts as a gray oval-shaped spot on the edge of a new leaf when the oat plant is in the three- to four-leaf stage. The speck appears away from the tip and may gradually spread across the entire leaf, or many such spots may appear.

In wheat and barley, manganese-deficient plants develop yellow parallel streaks on upper leaves that run the length of the leaf. The tip does not remain green as in oat, and the yellowing does not start at the tip of wheat or barley plants as it does with nitrogen or potassium deficiencies.

In beans and most non-grain crops, manganese deficiency appears as interveinal chlorosis. The top leaves of deficient plants turn yellow in the area between the veins while the veins remain green.

Manganese deficiency symptoms, like those of most other micronutrients, often appear in random patterns across fields. Rarely is an entire field affected.

Toxicity Symptoms

Excess manganese distorts leaves and produces dark specks on leaves. In severe cases, leaf tissue begins to die at the leaf margins and continues back from the margins as toxic conditions increase.

Soil Analysis

Manganese treatment is recommended if the soil tests less than 10 ppm. When soil organic matter exceeds 6.0%, the availability of manganese is based on soil pH. Manganese is recommended if the pH is above 7.0.

Plant Analysis

Analyzing plant tissue provides an accurate assessment of available manganese in soil. It measures how much manganese the plant itself gets from the soil. Plant analysis can also determine how much applied manganese plants are able to use. Table 4 interprets manganese levels for common Wisconsin crops.

Table 4. Manganese plant-analysis interpretations for common Wisconsin crops.

			INTERPRETATION				
CROP	PLANT PART SAMPLED	TIME OF SAMPLING	DEFICIENT	LOW	SUFFICIENT	HIGH	EXCESSIVE
			ppm				
Alfalfa	Top 6 inches	Bud	<15	15–25	26–150	151–300	>300
Corn	Earleaf	Silking	<15	15–25	26–150	151–200	>200
Oat, wheat	Top leaves	Boot	<10	10–25	26–150	151–250	>250
Onion	Tops	Midseason	<10	10–20	21–150	151–300	>300
Potato	Top leaves	Flowering	<10	10–20	21–200	201–400	>400
Soybean	First Trifoliate	Early flower	<15	15–20	21–100	101–250	>250

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A2526 Soil and Applied Manganese RP-08-2004-(SR 07/99)