

Manganese

Manganese (Mn) is one of the 17 elements essential for plant growth and reproduction. It is needed in only small quantities by plants, but like other micronutrients, Mn is ultimately as critical to plant growth as are the major nutrients.

Manganese in Plants

The normal concentration range of Mn in plants is typically from 20 to 300 ppm. When the Mn concentration falls below 15 to 20 ppm, deficiency often occurs (**Table 1**).

Table 1. Manganese sufficiency ranges for some crops and crop responsiveness to applied Mn fertilizer.

Crop	Mn sufficiency range, ppm	Responsiveness
Corn	30-150	Medium
Soybeans	20-100	High
Alfalfa	30-100	Medium
Wheat	20-200	High
Sugar beets	30-150	High
Sorghum	18-190	High
Cotton	25-350	Low
Potatoes	30-200	Medium

Manganese is taken up by plants in the Mn^{2+} form, and in organically complexed forms. Plant roots release exudates such as low molecular weight organic acids that aid in Mn uptake from the soil. Within plants Mn functions mostly as an activator in enzyme systems, but it is also a constituent of certain enzymes. It is essential to photosynthesis reactions and is involved in the evolution of oxygen in photosynthesis. The synthesis of lignin, which adds strength and stiffness to cell walls, is dependent on Mn. Manganese is also essential for root growth.

Manganese in Soils

The Earth's crust is about 0.11 percent Mn. Total Mn in soils generally ranges from about 20 to 3,000 ppm (0.002 to 0.30 percent), but only a fraction of this total is plant available. The most common form of Mn in soil solution is Mn^{2+} , which is often complexed by organic compounds.

The concentration of Mn^{2+} in soil solution is highly pH dependent, with levels decreasing by about 100x with each unit of pH increase. Thus, plant-available Mn increases as soil pH decreases, so deficiencies are more likely to occur in alkaline soils. On the

other extreme, if soil pH is too low (<5) Mn can be toxic to sensitive crops.

Crop deficiencies of Mn occur most often on high pH (alkaline) soils, and on soils that are simply naturally low in Mn. Deficiencies may also be problematic in high organic matter soils such as peats and mucks that favor the formation of unavailable Mn chelates. It should be noted too that high levels of copper (Cu), iron (Fe), or zinc (Zn) may reduce Mn^{2+} uptake. The most common extractant used in soil analysis for Mn is the chelating agent DTPA. The critical level for DTPA-extracted Mn is usually set at 1 ppm, but this varies depending on local calibration research.

Manganese Deficiency Symptoms

Manganese, like many other micronutrients, is immobile in plants. This is an important point because it means that deficiency symptoms will first appear on younger leaves since the plant cannot easily scavenge Mn from older tissue. Some crops are more susceptible than others to Mn deficiency. Sensitive crops include soybeans, small grains, peanuts, cucurbits, onions, peas, radishes, and beans. Symptom descriptions for selected crops are given below.

Soybeans: Upper leaves first become chlorotic between the veins while veins remain green. Newer leaves become pale green first and then pale yellow. As the deficiency becomes more severe, brown, dead areas appear. Some, but not all research has indicated that glyphosate-ready soybeans may be more responsive to Mn addition than conventional varieties.

Corn: Deficient plants appear stunted with short, thin stems and pale green to yellow leaves. If deficiency becomes severe, leaves turn pale yellow, and white flecks appear in interveinal chlorotic areas. Symptoms appear on younger leaves first.

Cotton: The younger leaves are affected first. They become cupped and yellowish-grey or reddish-grey in color with green veins. Excessive soil Mn can be toxic at low soil pH. This condition is referred to as crinkle leaf.

Small grains: Oats are the most susceptible among this class. A Mn deficiency in oats is sometimes called "gray speck" and usually starts as a gray oval-shaped spot on the edge of the new leaf at the three to four leaf stage. The speck may gradually spread across the entire leaf, or many spots may develop. In wheat and barley, plants develop yellow parallel streaks on the younger

IPNI PHOTO-
SHARMA/KUMAR)



Mn-deficient corn.

leaves that run the length of the leaf. It is always a good idea where possible to confirm field symptoms with plant tissue analysis.

Onion: One of the vegetable crops most susceptible to Mn deficiency is onion. Outer leaves show striped interveinal chlorosis and develop tip burn with progressive necrosis. Stunted plants and delayed bulbing are also symptoms.

Fertilizing with Manganese

IPNI PHOTO-SADANA



Nitrogen deficient corn leaf.

Manganese sulfate (MnSO_4) is the most common of the Mn fertilizer sources. It is highly water soluble and suited for soil or foliar application. There are several other Mn fertilizer sources including chelates, chlorides, oxides, and oxysulfates (**Table 2**).

Table 2. Manganese fertilizer sources, formulas and Mn content.

Source	Chemical Formula	Mn content, %
Manganese Sulfate	$\text{MnSO}_4 \cdot 3\text{H}_2\text{O}$	26-28
Manganese Chloride	MnCl_2	17
Manganese Carbonate	MnCO_3	31
Manganese Oxide	MnO_2	63
Manganous Oxide	MnO	41-68
Manganese Chelate	MnEDTA	12
Manganese Frits	-	10-25

Manganese fertilizer can be broadcast, banded in soil, or applied as a foliar spray. Rates of Mn application are highly dependent on method of application. Soil-applied broadcast rates generally range from about 10 to 15 lb Mn/A, banded near the crop row ranges from about 3 to 5 lb Mn/A, and foliar application usually ranges from about 1 to 2 lb Mn/A.

Banded or foliar applications are preferable over broadcast in high pH soils since Mn is rather quickly rendered insoluble in alkaline conditions. In these soils, band application minimizes soil-to-Mn contact and thus delays soil-Mn reactions. Also, applying

Mn in a band with acid-forming fertilizers (e.g., elemental S and ammonium-N) may help prolong availability in alkaline soil conditions.

Water-soluble Mn fertilizers are good sources of Mn when applied to either soil or foliage, but limited solubility Mn sources (like oxides or oxysulfates) should only be used for soil applications and when finely ground to particle sizes less than 0.1 to 0.15 mm. With application of Mn chelates to soil, it should be noted that the chelation feature may be short-lived since the chelating agent may quickly form more stable iron (Fe^{3+}) chelates in the soil. It is for this reason that some suggest the use of MnSO_4 for soil application.

Foliar applications should be made immediately if deficiency symptoms appear and again if symptoms reappear. Mixing of Mn fertilizers with glyphosate should be avoided since the two will form undesirable complexes.

Crop Response to Manganese

A soybean trial in Indiana compared a zero Mn control to foliar applications of chelated Mn and MnSO_4 , as well as various soil applications. Soil applications of Mn included broadcast, in-furrow, and placement with an acid-forming starter fertilizer. A treatment with starter only (no Mn) was also included. Foliar application of MnSO_4 was consistently the most effective means of correcting Mn deficiency in soybeans in this experiment.

Table 3. Soybean yield response to Mn treatments in Indiana¹.

Mn Treatment	Mn Rate/A	Yield, bu/A
Control	0	44.3
Starter alone	0	47.1*
Soil MnSO_4		
Broadcast	10 lb	43.4
In-furrow	6 lb	43.8
W/ Starter	1 qt. Mn complex	46.5
Foliar MnSO_4		
1 application	1 lb	48.0*
2 applications	2 lb	46.0*
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.

References

1. Brouder, S. et al. 2003. Purdue University Cooperative Extension Service. Agronomy Guide AY-276-W.