

MEASURE AND MANAGE

Manganese

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Manganese is a unique micronutrient. The levels found in Ontario soils by extraction chemistry are wide ranging, values from 2 ppm to 80 ppm are found routinely. Manganese can have a valence from 2 to 7 (Mn^{2+} to Mn^{7+}). The most common forms are Mn^{2+} and Mn^{4+} . The total amount of manganese in soil can range from 200 to 20,000 ppm plus, however there is no relationship between extractable and total. The question then becomes what determines available Mn?

Factors Affecting Available Manganese

- **Soil pH**
- **Microrganisms**
- **Soil Conditions- organic matter, aeration, moisture**
- **Weather**
- **Soil Test Level**

Soil pH

Availability of Mn increases as soil pH decreases. As soil pH dips below 5.5 Mn toxicity may be evident as pH increases above 6.5 deficiencies are more likely. At lower pH the manganous Mn^{2+} is more dominant and is more readily plant available. At higher pH the manganic form $Mn^{3,4,7+}$ dominates and is less plant available. Liming acid soils changes the availability of Mn by changing soil solution pH and the form of Manganese. When liming, care needs to be exercised so that deficiencies are not induced by over-liming with low soil test Mn levels. Over-liming can be avoided by paying attention to BpH.

Microrganisms

There is a class of microbes that change the form of Mn in the soil to less available forms and compete directly with the crop for uptake. (Don Huber Purdue) It has been documented by some researchers that the same bacteria that converts ammonium to nitrates also oxidizes Mn to unavailable forms. Where you notice high levels of naturally occurring Nitrate there is a chance you will observe low levels of extractable Mn. It has been suggested that corn deficient in Mn and grown in an environment of excessive Nitrate N will be predisposed to stalk rot. When a nitrification inhibitor was used to

protect the Ammonia N source there was a higher level of Mn in the plant and better stalk quality.

Soil Conditions

Organic matter plays a role in determining the fate of Mn. Soils with a high organic matter and neutral pH will be low in Mn. As the organic matter increases the complexing of Mn with organic matter also increases. Combine this with high soil pH and the Mn availability decreases further. Soils high in organic matter will usually be low in available Mn. Higher organic matter also encourages more microbiological activity which can further decrease the availability of Mn.

These conversions are also influenced by soil aeration and moisture levels. Poor soil oxygen level caused by high moisture conditions coupled with a high rate of microbe activity fuelled by organic matter, consume oxygen and convert less available forms of Mn to more reduced or available forms. Under prolonged wet conditions available Mn can leach out of the root zone. Under continued waterlogged conditions these forms of Mn can plug the tile when exposed to the air in the tile runs.

Weather

Weather conditions affect the cycling of Mn as well. Obviously excess rain can increase availability (reduction) as described previously and drought can increase the deficiency (oxidation) symptoms. In 2002 there was more widespread deficiency caused by an early warm spell then cooler weather this encouraged top growth then slowed root growth. Most of the Mn is taken up by diffusion and root interception. Actively growing roots are necessary to take up sufficient Mn. Cool weather slows root development. In 2003 we have a slower start only 60% of the GDD of 2002 resulting in a steadier shoot to root expansion. There is less widespread Mn deficiency of wheat however there seems to be smaller more intense areas of deficiency. These would be areas that are either high in organic matter or sandy soils naturally low in organic matter and extractable Mn. In one field near Sarnia which was recently tilled the tile runs are showing Mn deficiency in the wheat. These areas have major soil upheaval resulting in increased aeration and oxidation of Mn to less available forms.

Soil Test Level

The OMAF accredited test is an extraction done with Phosphoric Acid. The means of reporting is by the Mn Index. The Mn index incorporates the soil test and soil pH. An index greater than 15 indicates no need for an application; less than 15 suggests an application usually a foliar recommendation.

The index is calculated by this formula:

$$\text{Mn Index} = 498 + 0.248 (\text{soil test level by Phos Acid}) - 137 (\text{pH}) + 9.64(\text{pH})^2$$

OMAF Manganese Requirement Table for Oats, wheat, triticale, soybeans, onions, lettuce, beets. October 2002 OMAF Update to Soil Testing Services.

Manganese Index	Oats, Wheat, Barley, Triticale, Soybeans, Onions Lettuce Beets Kg/ha	Other Crops Kg/ha
0-7	2	0
8-15	2	0
16-50	0	0

Manganese should be applied as foliar spray of Manganese Sulphate at 2 kg/ ha in 200 liters of water with a **spreader sticker**. When deficiencies are severe 2 or more sprays are necessary. Soil applications are inefficient and not recommended according to OMAF.

Spreader Stickers

The application rate of spreader stickers varies with product. The literature and numerous web-sites has sited 6 to 16 ounces per 100 gallons of spray material.(0.18 liters to 0.5 liters per 375 liters of spray volume.) **Follow label Directions.**

The following Table shows the relationship of pH to Soil Test Mn in ppm to result in an index of 14.

Soil pH	Soil test Mn ppm
6.6	1.1
6.8	7.4
7.0	10

Agri-Food Laboratories Recommendations

We use the same extraction method and report both the ppm and the index. We use the pH above and below 7.0 as a break point as well as responsiveness of crops to Mn for our recommendations.

General Guidelines for Mn Application based on Phosphoric Acid Extraction pH < 7.0

Rating	ppm manganese	lbs actual Mn banded
Deficient	0- 1.5	4-5
Low deficient	1.6- 2.5	3-4
Low	2.6 3.5	2-3
Low Adequate	3.6- 4.5	1-2
Adequate	4.6- 12	1-1.5
High	12 to 20	0
Very High	20 +	0

ph > 7.0

Rating	ppm manganese	lbs actual Mn banded
Deficient	0- 1.5	5-6
Low deficient	1.6- 2.5	4-5
Low	2.6-4	2-4
Low Adequate	4.1- 5.0	1- 1.5
Adequate	5.1- 15	1
High	15 to 50	0
Very High	50 +	0

Soil Applications

If soil applying, Mn should be **banded** with acid forming fertilizer blends that contain MAP or Ammonium Sulphate. Broadcast applications are ineffective.

Work at Clemson University cited soil applications of 10 pounds actual Mn(broadcast) from MnSO₄ provided some relief of symptoms of Mn deficiency on soybeans at pH of 6.5 in the first and second year. It took 30 pounds to have an effect in year 3. At \$2.00 per pound this is \$60.00 per acre cost where as foliar materials for 3 years cost < \$15.00 per acre. They also cited that the critical soil test level at pH of 5.6 it was 2.5 ppm, pH of 6.5 was 6 ppm and at a pH of 7.0 it was 9 ppm.

Crops with a High Manganese Requirement

Soybeans	Lettuce	Spinach
Wheat	Onion	Potato
Barley	Pea	Beans
Oats	Radish /Beets	

Crops with a Medium Requirement

Corn	Carrot	Tomato
	Cauliflower	Rutabaga
	Celery	
	Cucumber	

Foliar Applications

To convert soil application recommendations to foliar rates divide by 8. A 2 pound MnSO₄ recommendation becomes 0.25 pounds of an inorganic chelate. The literature states a 2 pound per acre rate of Mn from Manganese sulphate as a blanket recommendation along with a spreader sticker. This is economical and supplies a full 2 pounds of Mn, however some users find this inconvenient.

There are several inorganic and chelated sources available for purchase. $MnSO_4$, $MnCl_2$, $Mn(NO_3)_2$, chelates of MnEDTA, MnDTPA, and Mn lignosulfonates. All are equally effective in correcting deficiencies. The optimum rate for these chelates is in the 0.1 – 0.2 lb Mn/ acre range. Chelates are more costly on a pound for pound basis compared to salts but their low foliar rates make them economical on a per acre applied basis. Manganese Chelates are however ineffective as a soil applied treatments. (Always read and follow manufacturer's labels to avoid crop damage and poor product performance.)

Timing of foliar sprays is critical in order to achieve maximum yield response. James Camberato of Clemson reports that the sprays must go on at the first signs of deficiency, by delaying 2 weeks only 90% is realized, and after 6 weeks only 70%.

Manganese Deficiency in Plants

The role of Mn in plants was discovered in 1922. It is essential for photosynthesis, production of chlorophyll and nitrate reduction. Plants which are deficient in Mn exhibit a slower rate of photosynthesis by as much as half of a normal plant. Plants which are low in Mn cause other metals such as Iron to exist in an oxidized and unavailable form the reduced form of metals are available for metabolism.

Mn is nonmobile in the plant therefore deficiencies are exhibited in the new growth.

Deficiency Symptoms

Soybeans and edibles show an interveinal chlorosis with the veins remaining green.

Cereals show stunting, pale green, faint stripping, oats show grey specks.

Lettuce, celery, onions delayed maturity, stunting and yellowing. .

Plant tissue Sampling

Most consultants are very good at diagnosing Mn deficiency visually. This is good skill to have as timing of foliar treatments is critical. However to determine an actual deficiency or to sort out multiple symptoms gathering plant tissue samples is a viable tool. Visit our website www.agtest.com click on Laboratory Services then Plant Tissue Analysis then Plant Sampling and finally Sampling Guidelines to find the appropriate plant part to collect, and how many leaves to make a sample.

Summary

The soil test level and pH will give an initial indication of possible deficiency. The crop grown and growing conditions including soil type, organic matter, and past history will help give a more complete picture of the Mn status of a cropping system. Soil applications are at best short term and expensive. A band application with acid forming materials in starter fertilizers is one solution on a season by season basis. If no starter is used then foliar is the only solution, and more than one spray maybe necessary under extremely deficient conditions. The longer term solution is to monitor pH, manage soil moisture with tillage and drainage, and limit major compaction that inhibits root growth.

Scout your fields and appreciate the influence of weather on crop growth and Mn availability. Plan to include foliar Mn in the spray schedule.

Manganese Management Check List

Soil test level <5 ppm

pH > 6.5

Plants with medium to high requirement

Soil with high iron content > 100 ppm

Sandy soil CEC < 10

High Organic matter > 5 % (food for oxidizing bacteria.)

Muck soil

High yields

High rates of Nitrate N or history of high Nitrate soil tests.

Observed deficiency history

Plant tissue results < 20- 25 ppm most crops.

If you can answer yes to 7 of the 11 factors controlling Mn availability you are in a situation that requires *consistent* management of Mn in the cropping system.