VIBRANTZ TECHNOLOGIES™

Agriculture

Advanced Materials

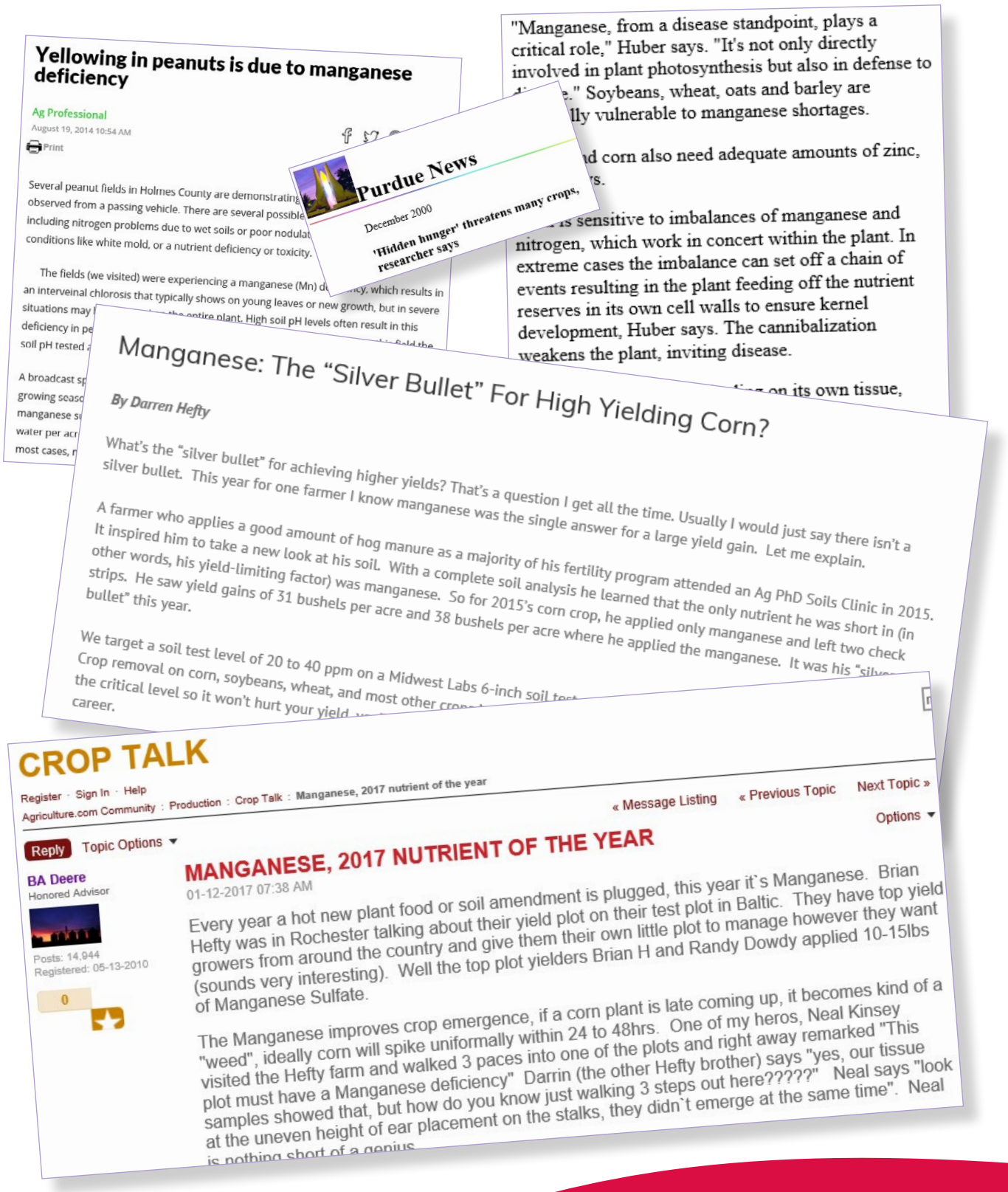
Madrid, Spain | February 14, 2018

Manganese Requirements of Crops Vibrantz

Manganese in Crops | Agenda

- What plant functions does manganese have?
- How common is manganese deficiency?
- What conditions make for a deficiency of available manganese, and why?
- What crops are most susceptible to Mn deficiency?
- What does Mn deficiency look like?
- When to apply manganese?
- How to best apply manganese – soil or foliar?
- What manganese sources are available and which is best?

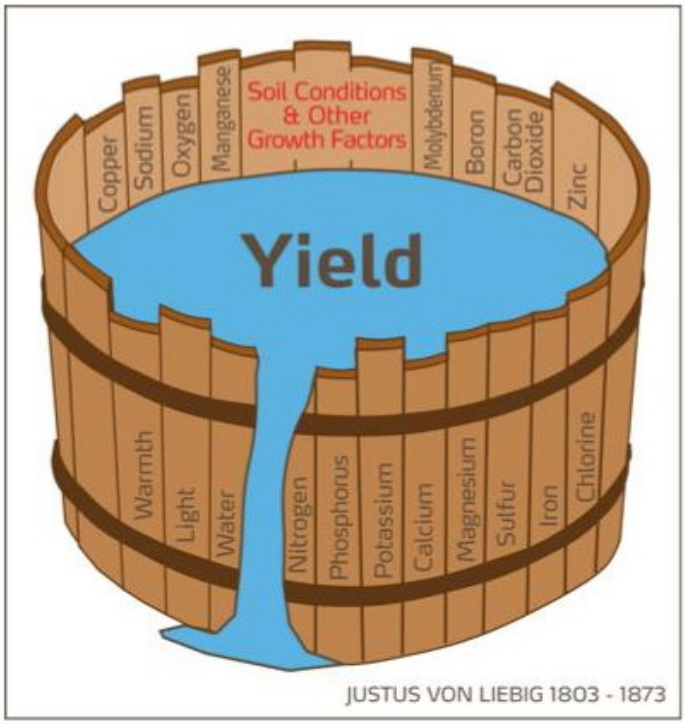
Manganese is in the News



The four R's, our guiding Principal

Liebig's Law of the Minimum

Justus von Liebig's "Law of the Minimum" published in 1873: "If one growth factor/ nutrient is deficient, plant growth is limited, even if all other vital factors/nutrients are adequate... plant growth is improved by increasing the supply of the deficient factor/nutrient"



Mulder's Graph – Nutrient Interaction

Mn Availability Antagonized By Excess:

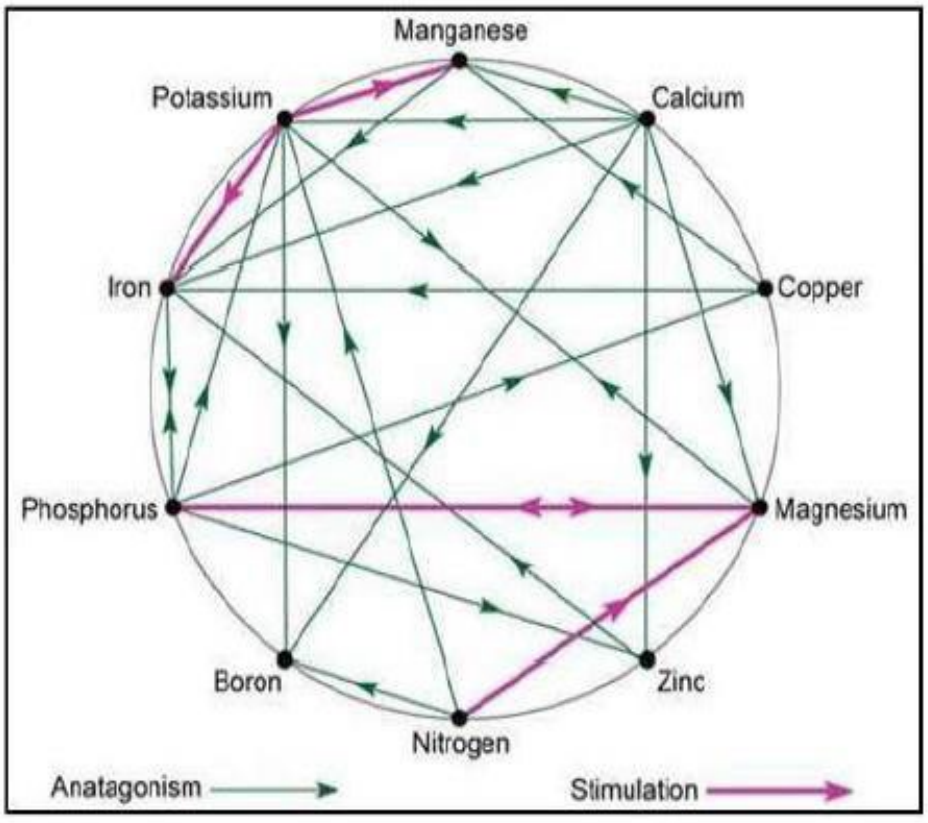
- Calcium
- Copper

Mn Surplus Antagonizes:

- Iron

Mn Demand Stimulated By:

- Excess Potassium

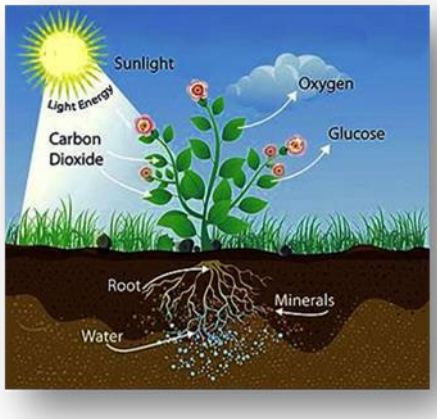


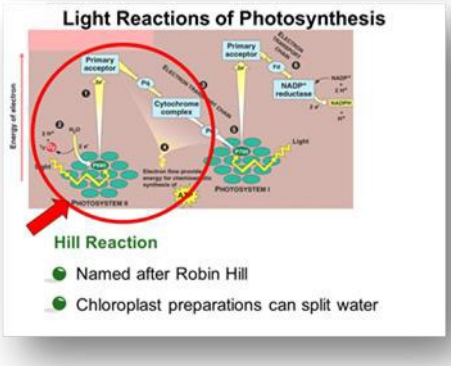
Antagonism: Decreased availability of a nutrient to a plant due to the action of another nutrient.

Stimulation: High level of a nutrient increases the demand of the plant for another nutrient.

Optimal Mn Nutrition by Fertilization can:

- Improve **photosynthetic efficiency** and dry matter production
- Provide **resistance to biotic stress** (pathogens) by optimizing the plant's ability to combat various diseases and reducing fungicide reliance
- Contribute to **abiotic stress tolerance**, particularly drought and heat
- Result in significant **crop yield improvement**.





How common is Mn Deficiency?

USA Study By the Trace Element Committee of the Council On Fertilizer Application Studied all 50 States

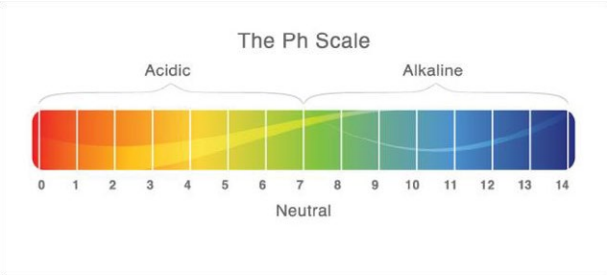
Micronutrient Deficiency	Number of States
Boron	41
Zinc	30
Manganese	**25**
Iron	25
Molybdenum	21
Copper	13

Mn Deficiency Crops	In Number of States
Bean	13
Corn	5
Fruit Trees	9
Small Grains	10
Spinach	8

http://pubs.acs.org/doi/pdf/10.1021/jf60121a005

Soil Predictors of Mn Deficiency

Soil pH:



- Ideal 5 to 6.5
- >6.5 Likely deficiency
- <5 Potential for Mn toxicity

Soil Organic Matter

- Organic (muck) soils with pH >5.8
- Soil Mn often chelated by organic molecules and often available

Soil Moisture and Temperature:

- Dry soil conditions reduce Mn availability
- Cold and wet conditions cause reduced Mn uptake

Mineral Interference:

- Excessive amounts of reduces Mn uptake:

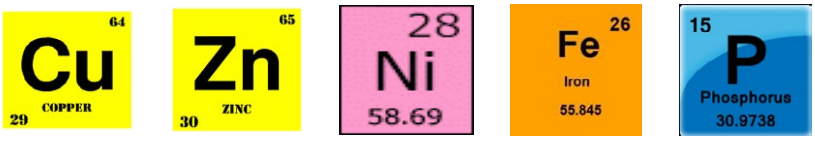
  Copper

  Iron

  Nickel

  Zinc

  Phosphorous



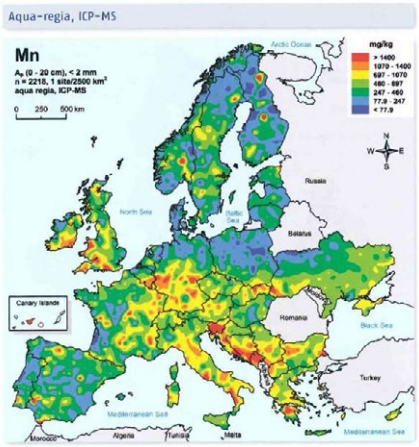
Mn Supplementation Lesser Factors

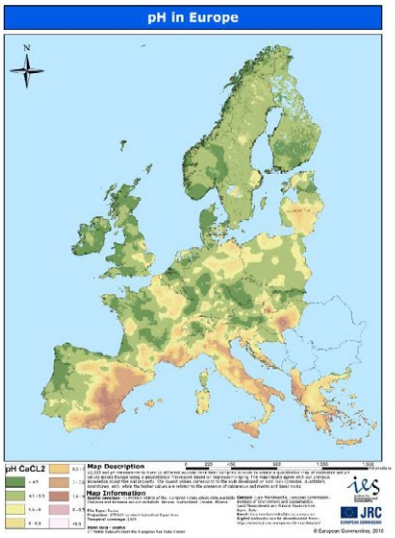
- **Mn:Mo Balance:** One researcher observed that Mn concentrations were reduced in half by molybdenum (Mo) fertilization. This limited evidence should not be used to make Mo recommendations due to the possible toxic reactions of high Mo contents that could occur in animals grazing or eating the crops grown on high Mo soils.
- **Mn:Si Balance:** Research has shown that silicon (Si) applications can alter the Mn distribution in leaf tissue in such a way as to reduce the possibility of Mn toxicity from excess Mn uptake.
- **N STRESS:** Low N availability decreases the vigor of plants to an extent that it may fail to take up adequate amounts of many other nutrients. Manganese uptake can be affected in this way.
- **Mn:S Balance:** The Sulfur interaction is primarily one-way, as the Sulfur content of the plant is diminished so also is the Manganese content.
- **Mn:Anion Balance:** Heavy fertilization with materials containing Cl-, NO3-, SO4–, can also enhance Mn uptake (termed the anion effect).

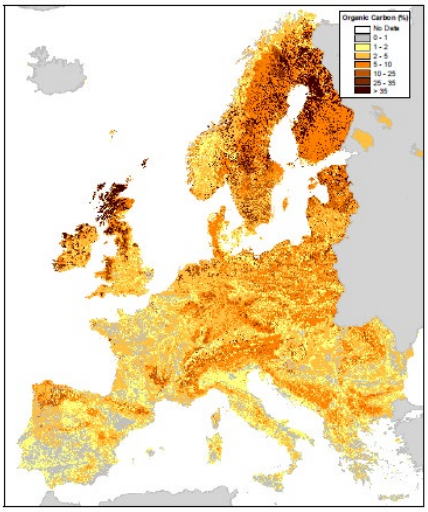
http://spectrumanalytic.com/doc/library/articles/mn_basics

Mn Supplication Predicter

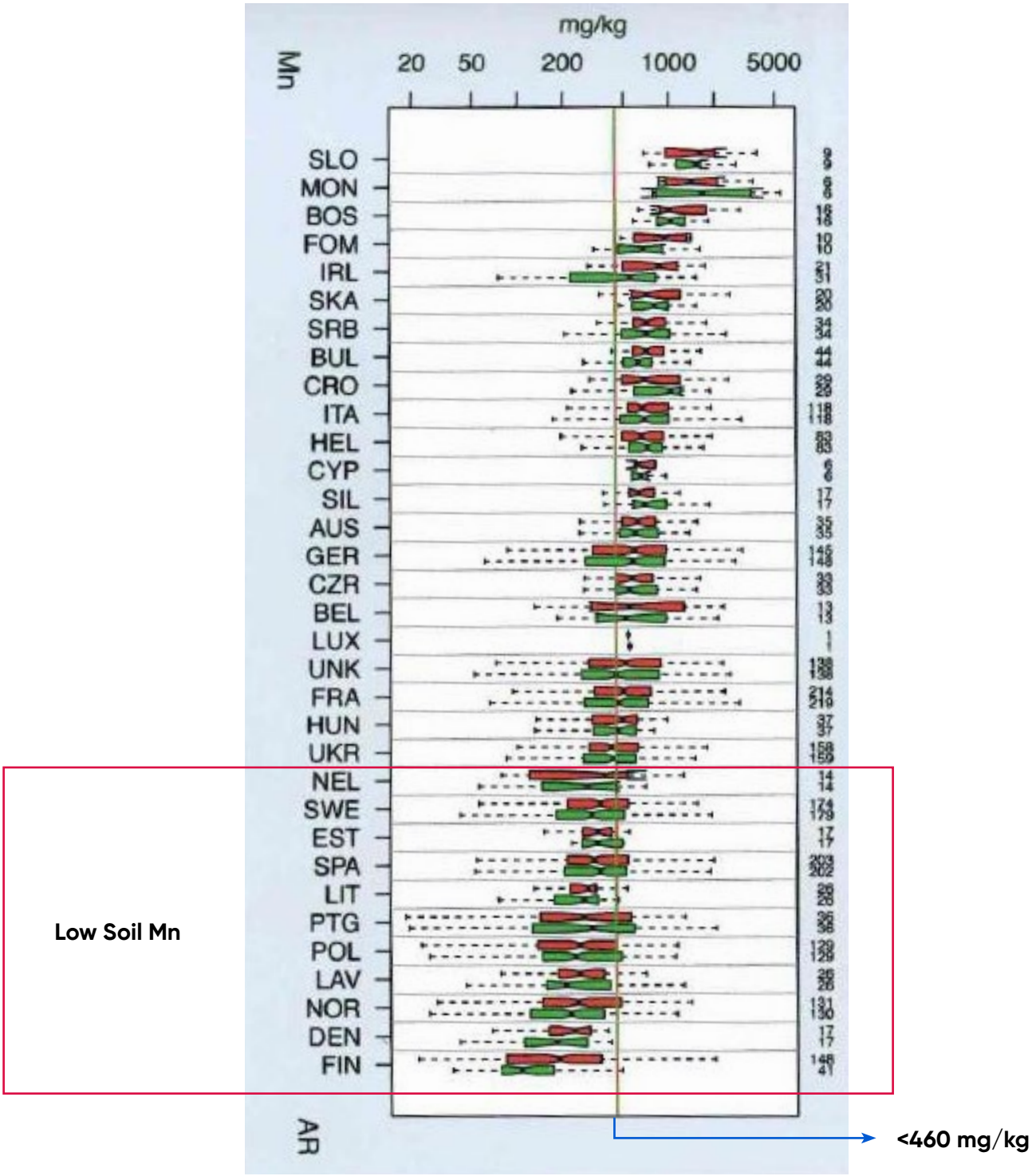
Low Soil Mn + **High pH** + **High Organic Content**



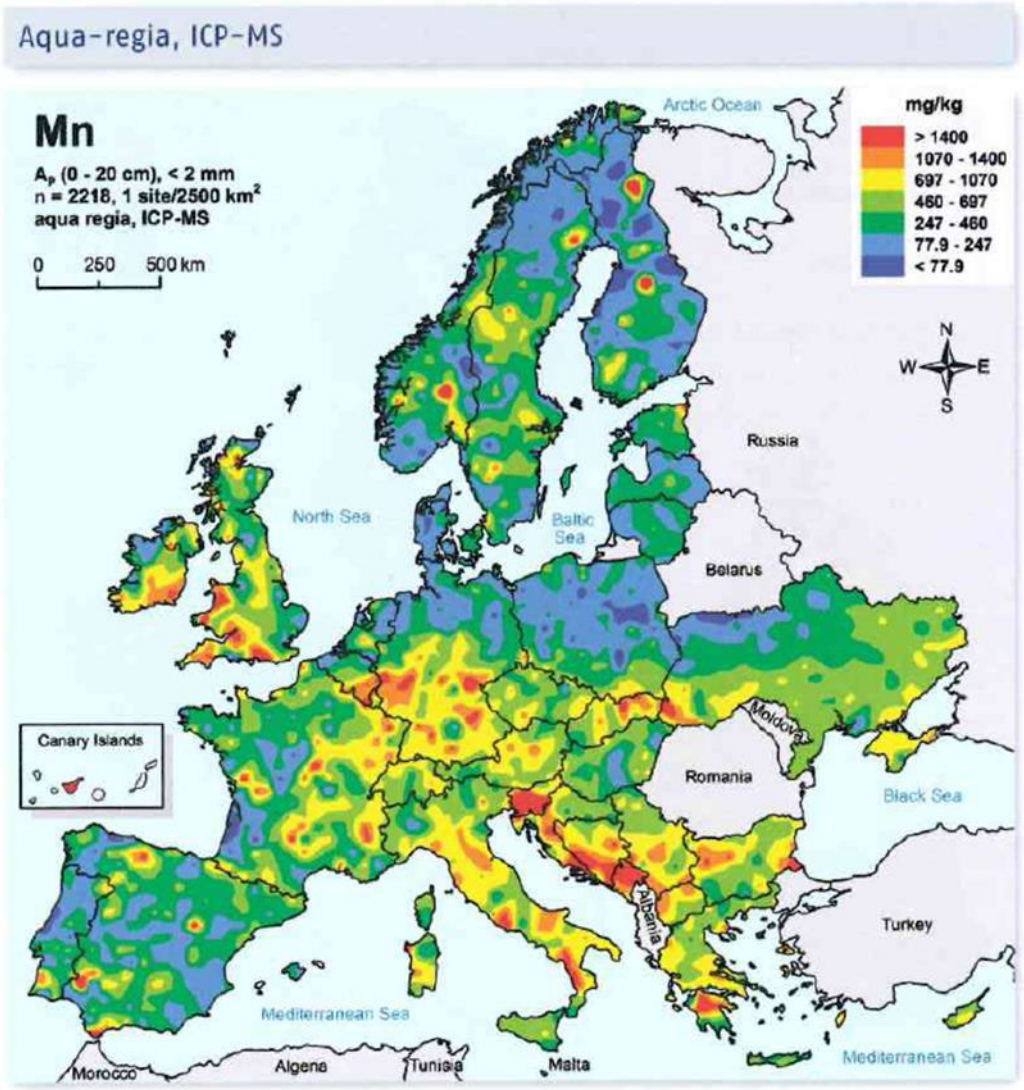




Aquia Regia Extraction of Mn From Soil



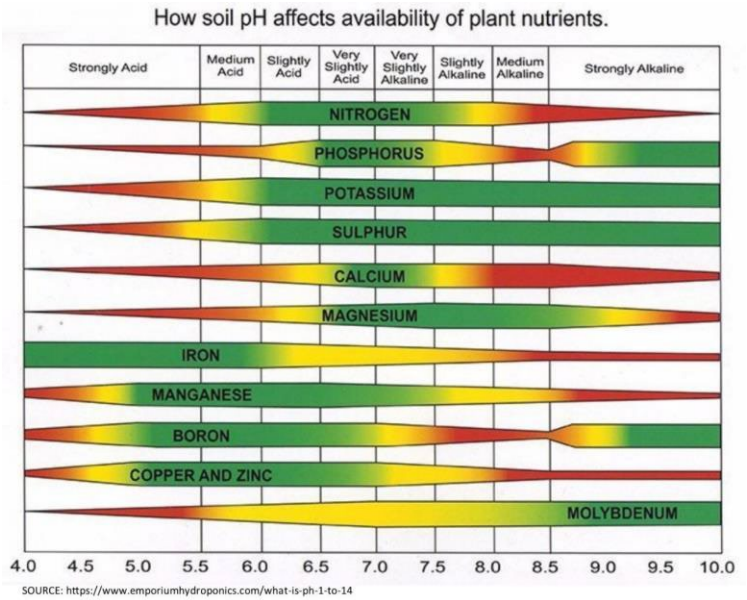
European Agricultural Production Land Mn Levels



- Manganese deficiency is the most widespread trace element problem in arable crops in the UK
- Most commonly seen in cereals, with an estimated 15-20% of the crop area being treated with Mn annually
- Increased incidence of Mn deficiency in cereal crops in the **Schleswig-Holstein area of Germany**, associated with higher yielding crops Finck (1987)
- Some deficiency also common in cereal crops grown in clay-loam soils with a soil pH of over 7.0
- Leached sand and podzolic soils especially deficient in Mn

Soil Analysis – the Baseline

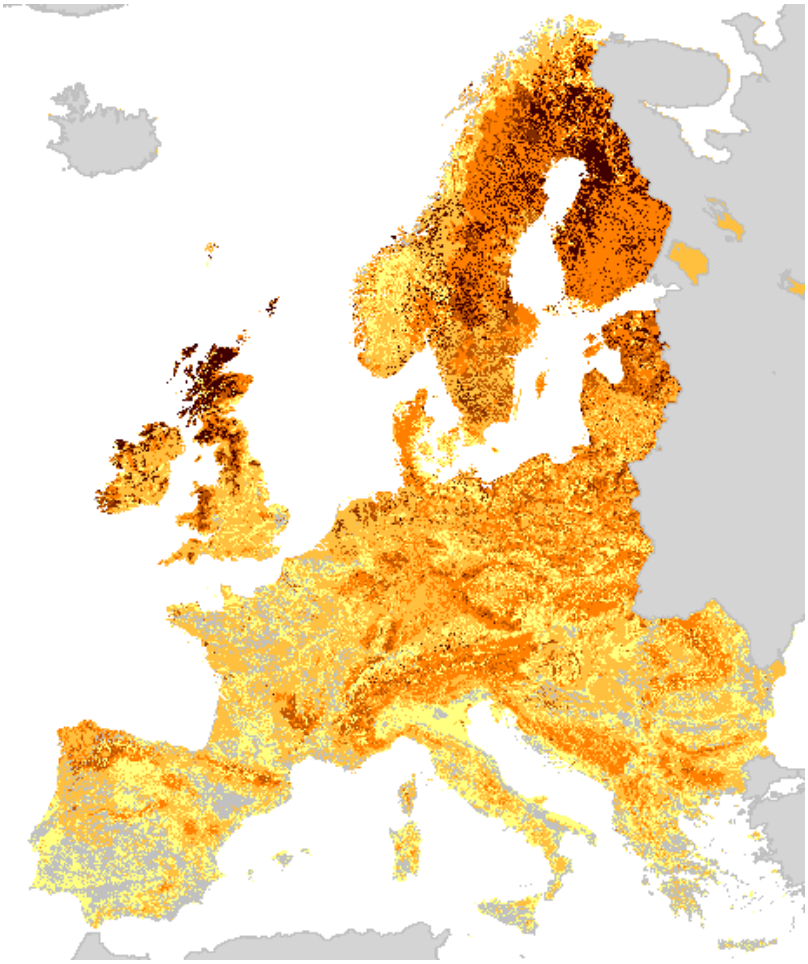
- Manganese treatment is recommended if the soil tests less than 10 PPM.
- When soil organic matter exceeds 6%, the availability of manganese is based on soil pH.
- Manganese is recommended if the pH is above 7.0



http://www.soils.wisc.edu/extension/pubs/A2526.pdf
https://richmond.ces.ncsu.edu/wp-content/uploads/2016/01/How_Soil_pH_affects_availability_of_plant_nutrients.jpg

European Soil Organic Matter

Country	Soil Organic Matter peta grams [Pg]
Sweden	13.8
Finland	12.5
United Kingdom	7.1
Germany	5.8
Norway	5.7
Poland	5.6
France	5
Spain	3.5
Romania	2.3
Italy	2
Latvia	1.8
Ireland	1.6
Estonia	1.5
Austria	1.2
Czech Republic	1.1
Lithuania	1.1
Bulgaria	1
Hungary	1
Serbia	1
Netherlands	0.8
Switzerland	0.7
Denmark	0.6
Greece	0.6
Slovakia	0.6
Portugal	0.5
Croatia	0.5
Bosnia and Herzegovina	0.5
Belgium	0.3
Slovenia	0.2
Albania	0.2
Macedonia	0.2
Cyprus	<0.1
Luxembourg	<0.1
Malta	<0.1



High Mn Response Crops

Many crop species show high susceptibility to Mn deficiency in soils, or a very positive response to Mn fertilization, including:

- Cereal crops (wheat, barley and oats)
- Legumes (common beans, peas and soybean)
- Stone fruits (apples, cherries and peaches)
- Palm crops
- Citrus
- Potatoes
- Sugar beets
- Canola

http://spectrumanalytic.com/doc/library/articles/mn_basics

Deficiency Symptoms

The key is to *know where your Mn levels are prior to having an issue.*

- Mn is not translocated in the plant
- Deficiency symptoms appear first on younger leaves.
- The most common symptoms on most plants are **interveinal chlorosis.**
- Sometimes a series of brownish-black specks appear in the affected areas.
- In small grains, grayish areas appear near the base of younger leaves.

http://spectrumanalytic.com/doc/library/articles/mn_basics

Mn Deficiency Symptoms

1. Manganese deficient corn plants (right) compared with normal corn (left)
2. Typical interveinal chlorosis caused by manganese deficiency in corn, ...
3. ...in apples
4. ...in winter wheat
5. ...in barley
6. ...in oats
7. ...on potatoes.

Tissue Analysis for Mn Levels

For timely remediation of Mn Deficiency

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

http://corn.agronomy.wisc.edu/Management/pdfs/a2526.pdf

Tissue Tested Low, Soil Tested OK

Spectrum Analytic
1087 Jamison Road NW
Washington Court House, OH 43160-8748
www.spectrumanalytic.com

Report To | **Prepared For** | **Sample Information**

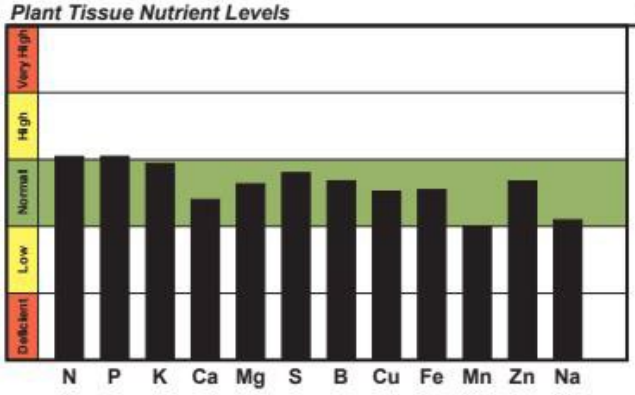
Sample ID
Lab Number
Soil Lab Number
Sampled

Plant Tissue Analysis Report Type: Soybeans *(Glycine max)* Part: Upper Most/Mature Leaves Stage: Bloom, Full

Plant Test	Result	Normal Range
Nitrogen	7.3 %	5.20 - 6.20
Phosphorus	0.57 %	0.30 - 0.50
Potassium	2.47 %	2.00 - 2.50
Calcium	1.22 %	0.70 - 2.00
Magnesium	0.49 %	0.30 - 0.60
Sulfur	0.44 %	0.20 - 0.50
Boron	53.9 ppm	20 - 70
Copper	10.7 ppm	6 - 15
Iron	187 ppm	51 - 300
Manganese	20 ppm	20 - 150
Zinc	47 ppm	20 - 60
Sodium	19 ppm	0 - 200

Soil Test	Result		Normal Range
CEC	19.7		
Soil pH	7.4	1	5.3 - 5.8
Buffer pH	0		
Organic Matter	17.2	%	
Phosphorus	99	m3-ppm	40 - 70
Potassium	211	m3-ppm	200 - 310
Calcium	5423	m3-ppm	2600 - 3700
Magnesium	584	m3-ppm	270 - 450
Sulfur	22	m3-ppm	20 - 40
Boron	2.1	m3-ppm	1.7 - 2.6
Manganese	16	m3-ppm	2 Varies

Plant Tissue Nutrient Levels



Comments from Agronomist

Analyzed by Spectrum Analytic Inc.
www.spectrumanalytic.com

HID:0010-0335-1911-0017

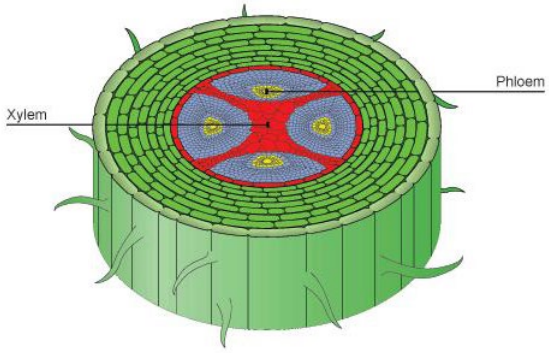
1 When soil organic matter exceeds 6.0%, the availability of Mn is based on soil pH. Mn is recommended if the pH is above 7.0

2 In general, Mn treatment is recommended if the soil tests less than 10 PPM.

When to Apply & Mn Mobility

Mobile & Non-Mobile Nutrients

MOBILE	LIMITED MOBILITY	NON-MOBILE
Nitrogen (N)	Zinc (Zn)	Calcium (Ca)
Phosphorus (P)	Boron (B)	Silicon (Si)
Potassium (K)		Iron (Fe)
Magnesium (Mg)		Manganese (Mn)
Sodium (Na)		Copper (Cu)
Chlorine (Cl)		Molybdenum (Mo)
Sulfur (S)		Nickel (Ni)



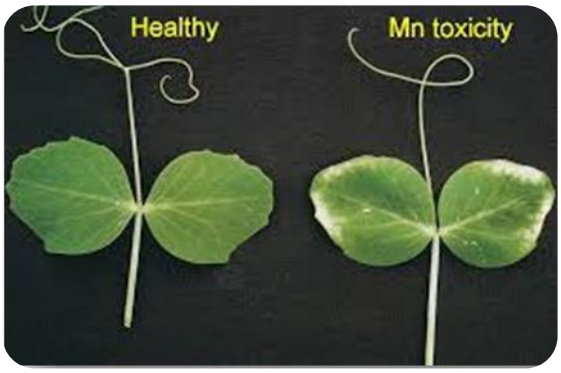
Plants have two different types of transport tissue. Xylem transports water and solutes from the roots to the leaves, phloem translocate food substances from the stems to growing tissues and storage tissues.

- Due to Mn's low phloem mobility in plants, Mn deficiency first develops in younger leaves.
- The critical concentration for Mn deficiency is generally below 20 ppm dry weight in fully expanded, young leaves.
- Feed in installments: Spoon feed the non-mobile nutrients at the right time and place. One time high rates for these nutrients is not efficient. It is best to keep feeding via the foliage or soil in small amounts on an as- needed basis.
- Apply to meet key demand periods, when these nutrients are most needed and most likely to come up short due to problems in the soil. Timely strategic fertigation or foliar feeding at critical times provides the best benefit.

http://www.fbsadvantage.com/micronutrients/#product_line_category-16084

Manganese Toxicity in Plants

- Associated with acidic and poorly drained soils of pH 5.5 or lower, but can occur whenever the soil pH is below 6.0.
- Symptoms include chlorosis and necrotic lesions on old leaves, dark-brown or red necrotic spots.
- May alleviate by using Iron chelates applied to either the soil or preferably the foliage.



Applying Mn

1. Fertigation
2. Surface Spreading
3. Foliar
4. Seed Coating
5. Banding (In Furrow)

How To Best Apply – Soil & Foliar

Applying Mn to deficient soils or crops needs to be thought out.

- Mn can be easily tied up or converted into unavailable forms when applied directly to the soil.
- Banded applications, not broadcast applications, of Mn are best when applying directly to the soil for these reasons.
- It is not recommended to add EDTA chelated forms to the soil because they can actually increase the Mn deficiency due to its affinity to iron, and substitution ensues.
- If deficiency symptoms are observed in the crop, there are several options for foliar applied Mn solutions.

http://www.lgseeds.com/blog/agronomy-blog/2017/02/03/importance-of-manganese-in-crop-production

Application Rates, Univ. of Wisconsin

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.*

http://corn.agronomy.wisc.edu/Management/pdfs/a2526.pdf

Three Main Classes of Micronutrients

1. **Inorganic**
    1. Sulfates
    2. Chlorides
    3. Nitrates
    4. Oxides
    5. Carbonates
2. **Organics** (Synthetic chelates) – protect the associated metal from reaction with other ingredients, such as herbicides, fungicides and insecticides
    1. EDTA
    2. EDDHA
    3. NTA
    4. DTPA
3. **Natural organic complexes**
    1. Glucoheptonates, sugars e.g. sugar cane by-products
    2. Lignosulfonates – Paper industry by-product
    3. Citric Acids

https://fluidfertilizer.org/wp-content/uploads/2016/09/Alan-Robinett-Micronutrient-Compatibility.pdf

Fertilizer Sources of Manganese

Mn Source	Formula	% Mn	Water Solubility	Format	Advantages	Disadvantages
Mn Sulfate	$MnSO_4$	28 to 32	Soluble	Powder or Granule	Includes sulfur, good for chelate production	Renders glyphosates ineffective if mixed together
Mn Chelate	MnEDTA	5 to 12	Soluble	Powder	Very good foliar effectiveness	Cost, and some not good for soil app.
Mn Nitrate	$Mn(NO_3)_2$	15	Soluble	Solution	Most bioavailable Mn	No dry form available
Mn Chloride	$MnCL_2$	17	Soluble	Dry prill or flake	Compatible with calcium tank mixes	Can burn plants, care in use required
Mn Carbonate	$MnCO_3$	44	Negligible	Powder	Provides slow release, and good for chelate production	Not water soluble
Mn Oxide	MnO	60	Insoluble	Powder	High Mn %	Not water soluble

Global Presence, to Serve Local Ag Customers

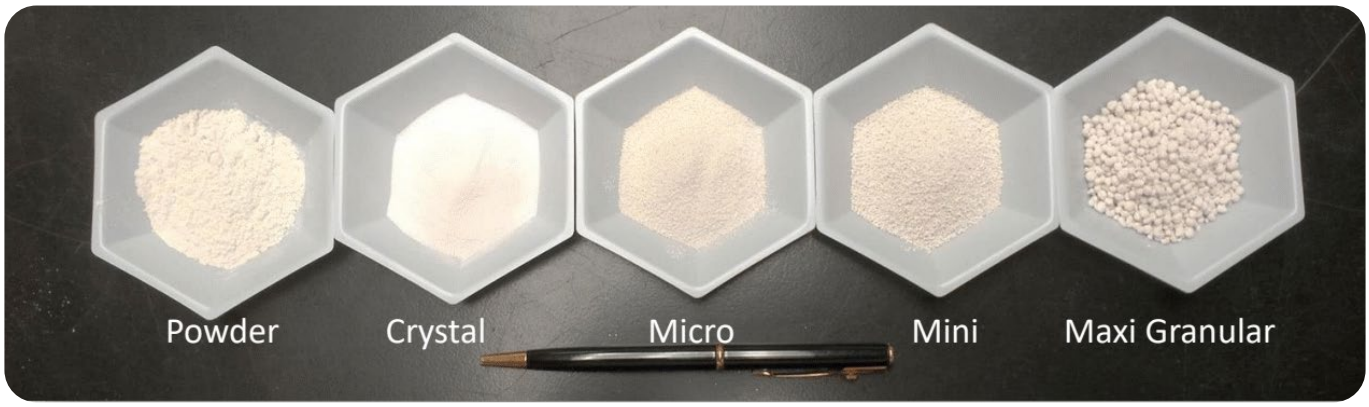
Vibrantz Mn Sources

Tecmangam® – Versatile Crop Nutrition

Fully Water Soluble Manganese Sulfate

- 31 to 32% Mn
- 19% Sulfur
- Fast & thorough dissolution
- Low calcium and Mg
- Five Particle Sizes

Powder Crystal Micro Mini Maxi Granular



MnO HP – High Purity

Popular for Producing Crop Chelates

- Highest level of Mn at 77%
- Very pure
- Fast dissolution with no residue

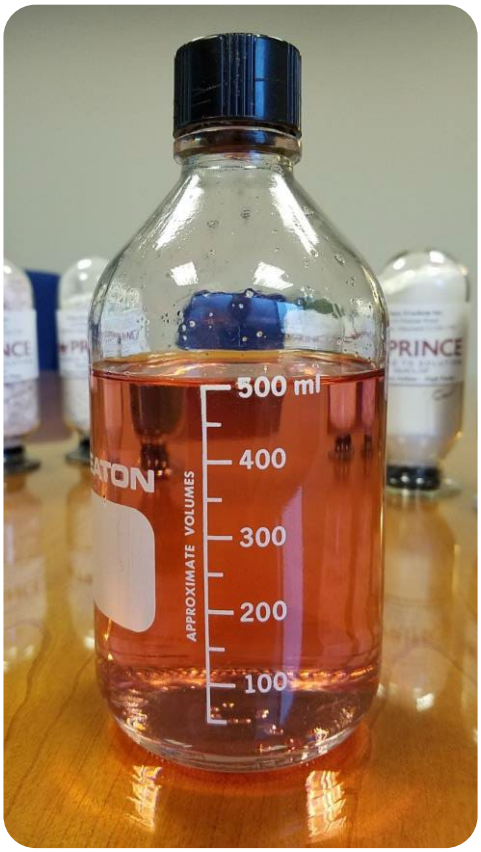
Manganese Carbonate

- Popular with Organic Trace Mineral producers for its high reactivity
- Popular addition to foliar fertilizers for a time release manganese

Guaranteed Specifications:

Mn	44% min.
H_2O (105° C)	2.5% max.
S	0.1% max.
<75 µm	90% min.

Manganese Nitrate Solution



Manganese in an extremely soluble form

- Has 15% Mn and 7% N
- Has twice the solubility on a metal basis as MnSO4

ALMA®

60% Manganese in small particle form

- No more than 2% MnO_2
- In soil, under right pH conditions, has been shown to be a slow release nutrient