MEASURE AND MANAGE

Zinc

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The zinc content of the earths crust ranges from 10 to 300 ppm, however only small amounts are available to the plant. The primary soil minerals that contain zinc are Franklinite, Smithsonite and Willemite. Zinc deficiencies can be widespread and are usually associated with high pH, calcareous, fine textured soils, coarse textured low organic matter soils.
Landscapes that are highly eroded by tillage or wind and water erosion also exhibit zinc deficiencies in crops.

Available Soil Zinc

There are many forms of zinc in the soil and many impact on plant availability. The main forms are solution zinc, adsorbed zinc on clay surfaces, organic matter and calcium carbonates, oxide minerals and zinc in organic complexes. These various forms do cycle back and forth amongst the different phases. Solution zinc is the plant available form and exits as Zn^{+2} however half of this maybe complexed with organic matter compounds. These interactions limit the mobility of zinc in the soils as a consequence leaching loss is negligible.

F**actors Affecting Plant Available Zinc**

Many factors impact on Zinc availability including pH, adsorption on clay, organic matter, calcium and magnesium carbonates, and surfaces of oxide minerals, weather and other nutrient interactions.

Soil pH has the biggest influence with a 30 fold reduction in availability with each unit rise in pH in the range of 5-7.

Most pH induced zinc deficiencies occur on calcareous soils. However not all high pH soils exhibit a zinc deficiency due to natural chelation from organic acids that breakdown products from soil organic matter. As pH increases though there is more adsorption onto clay mineral and carbonate surfaces.

Adsorption on illitic clays of Ontario is responsible for reduction in available solution zinc. The amount of adsorption is related to the CEC. Higher CEC more adsorption

however it is reversible and can be desorbed to soil solution. At soil pH above 7.7 Zinc Carbonate is formed which is highly soluble and can supply zinc even at high pH.
Soils that are dominated by magnesium carbonates hold zinc more strongly. Zinc can substitute for magnesium on the clay lattice binding the zinc and reducing the rate of desorption.

Organic matter forms stable complexes with Zn^{+2}. Organic Matter reactions with zinc form highly immobile compounds with lignin. This is what happens in some of the muck soils. Freshly added crop residues in their initial breakdown into soluble short chain acids and bases act as chelators to increase zinc availability and mobility. The form or age of organic matter impacts on Zinc availability. A good crop rotation with variety of crop residues and range of maturity and different manures and compost will act on zinc availabilities differently. .

Interactions with other Nutrients

Phosphorus

The most popular and highly over rated interaction is zinc and phosphorus. High soil P and P fertilizer applications on deficient zinc soils will induce a zinc deficiency. So the solution is to address the zinc deficiency or lower the P application rate. Livestock operations with land application of manure often times have high soil test P and high zinc soil tests and no apparent zinc deficiencies. Soils that are deficient in zinc will have plants that take up excessive amounts of P and cause P toxicity which is the classic zinc deficiency symptoms of yellow striping, white bud or shortened internodes.
The impact of high soil P on reduced mycorrhizal infections maybe more responsible for reducing zinc uptake. Mycorrizal infection in most plants enhances micronutrient uptake. The notion that P precipitates zinc is highly improbable. As this compound is very soluble and indeed we tend to apply zinc in starter bands with P as a way to deliver and enhance availability by impacting on pH in the band and increasing zinc availabilities.

Nitrogen

Application of nitrogen especially high rates in marginal zinc soils will stimulate growth rates and yield potential and increase the demand for zinc. Use of ammonical N sources lowers pH in the rhizosphere and increases micro nutrient availability. The use of neutral pH or nitrate N may raise pH and reduce uptake.

Sulphur

Applications of gypsum on slightly acidic soils may increase the amount of zinc sulfate and increase zinc uptake.

Climate Factors

Zinc deficiencies are more pronounced in cold wet weather and often disappear when warm weather returns. Excessive moisture and cold soils, slow growth rates and decease zinc in soil solution.

Plant Factors

Zinc uptake is by diffusion, mass flow and root interception. Mass flow depends on rapid growth and transpiration to move nutrients to the roots. Rapid expanding roots are required for root interception and diffusion. Weather that slows growth reduces these activities which are all dependent on root growth. If plants lose leaves due to herbicide burn the loss of leaf area stops transpiration. Leaves feed roots and therefore root growth slows. With no root growth 2/3 of the zinc uptake mechanism is paralyzed. These will most likely show zinc deficiency on subsequent new growth until enough photosynthetic capacity is restored in the canopy to feed the roots and aid in recovery.

Saturated Soil Conditions

Soils that are submerged for extended time periods often have an increase in nutrient concentrations except for zinc. In calcareous soils the pH often declines during flooding, this should increase zinc availability however, poor aeration increases zinc deficiency. In acid soils pH may increase under flooding causing a precipitation of primary zinc minerals such as franklinite.

Zinc Soil Testing

Agri-Food Laboratories is an OMAF Accredited Laboratory and uses the DTPA Method of Zinc Extraction. Ontario soils are predominately neutral with pH around 7 to 7.5. Samples do ranges in the 5 to 8 pH in some areas.

On our AgTest Soil Reports we report the extracted Zinc in ppm as well as the OMAF Zinc Index as required by Accreditation.

We provide interpretation for both. The following tables maybe used to determine zinc recommendations using Agri-Food Laboratories DTPA Extracted Zinc. Do not use these tables with any other extraction method.

Soils with pH < 6.5

Zinc DTPA Extraction (ppm)	**Zinc Lbs Actual per acre**
<0.59 Deficient	5
0.59-0.9 Low	3
0.9-1.2 Low Medium	2
1.2-1.4 Medium	1
1.4-2.0 Medium High	0
2 - <25 Very High	0
>25 Excessive	0

Soils with pH >6.5

Zinc DTPA Extraction (ppm)	**Zinc Lbs Actual per acre**
<0.59 Deficient	6
0.59-0.9 Low	4
0.9-1.2 Low Medium	3
1.2-1.4 Medium	2
1.4-2.0 Medium High	1
2 - <25 Very High	0
>25 Excessive	0

To convert to foliar rates divide by 8.

Crops Demand Rating for Zinc

High	Medium	Low
Corn	Alfalfa	Carrots
Soybeans	Barley	Oats
Onions	Potato	Rye
Grapes	Tomato	Peas
White beans	Wheat	Forage grasses
Fruit trees	Sugar beets	Asparagus
	Canola	

OMAF Zinc Index
The zinc index incorporates the extracted zinc and soil pH in the following formula to calculate a unit-less index value

Zinc Index = 203 + 4.5(DTPA extracted zinc in ppm) – 50.7 x soil pH+ 3.33 $(soilpH)^2$

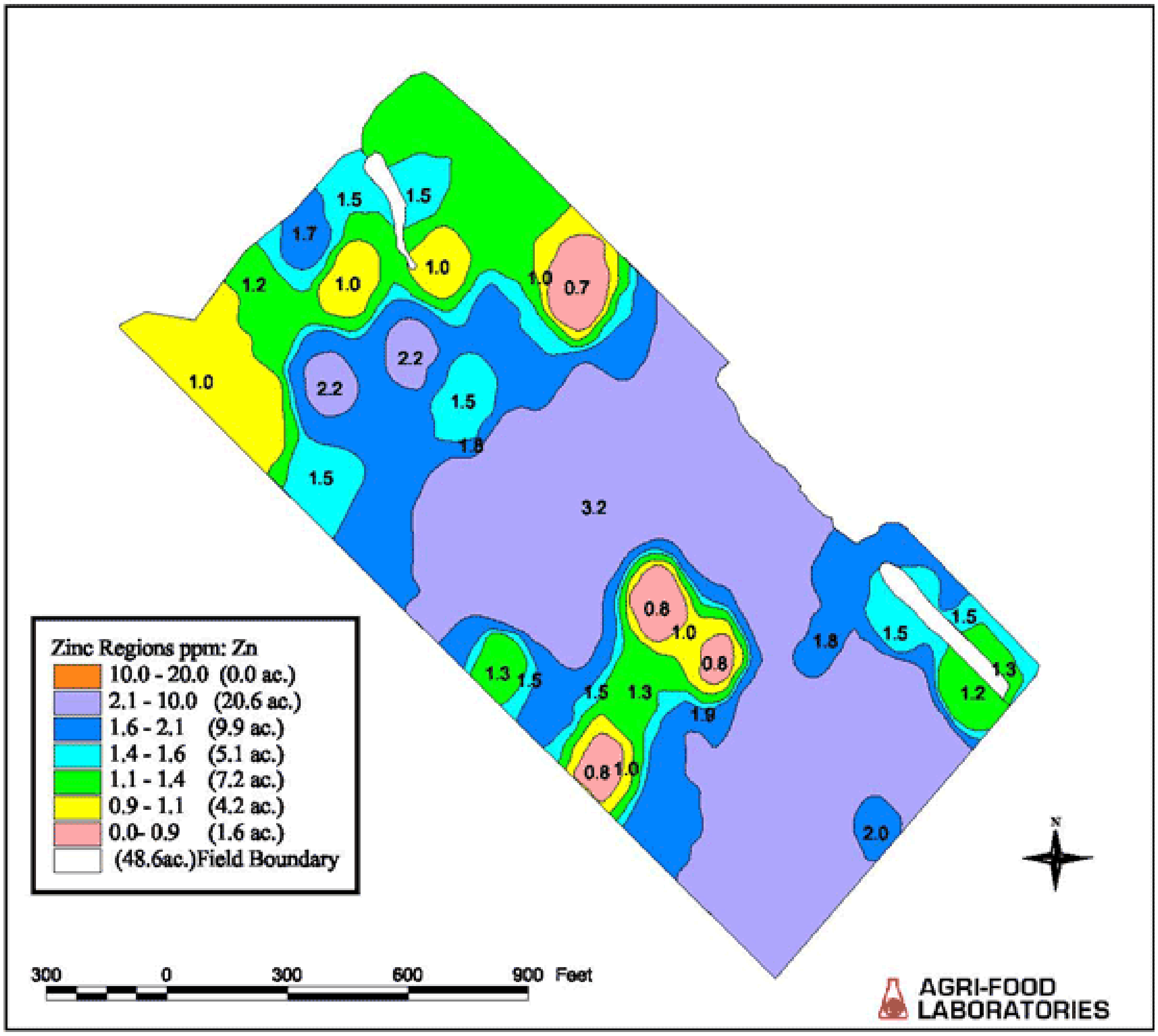
Zinc Requirement for OMAF values in kg/ha

Zinc Index	Crop	Other crops
	Corn, onion	
0-7	4	1
8-14	4	0
15-100	0	0
100+	0	0

Zinc Application Methods

Zinc can be broadcasted or banded, the choice is rate dependant. Unlike manganese, zinc is not subject to strong reducing/oxidation reactions. Low rates can be band applied in starter fertilizers. Higher rates can be broadcast at rates of 10 to 15 pounds every 10 years to build and maintain soil tests. Precision Agriculture site specific soil sampling has certainly revealed the high spatial variability for zinc in the field landscape. Fields may average sufficient levels yet have 150% Coefficient of variation. A field that averages 2 ppm Zinc may have a range of 0.2 to 5 ppm. Broadcast applications on a variable rate basis can address this large spatial variation by applying zinc only where it is needed based on the soil test. The low mobility of Zinc in the soil requires thorough incorporation of broad cast applications. If this is not possible then banding may be more appropriate which places zinc into the root zone.

Test Plot (48.63 ac.) - Zinc Regions (ppm)



Foliar Zinc Applications

Foliar application is appropriate for perennial tree crops. Applying foliar zinc to annual field crops requires early application. Waiting for symptoms to develop may already have impacted yield. There are a host of organic and inorganic chelated compounds available for application. Foliar application on seedlings allows for rapid response and correction of deficient situations.

Plant Tissue Analysis

Collection of the appropriate plant part at critical growth stages for submission to Agri-Food Laboratories for analysis can determine the nutritional status of the plant in question. The diagnostic approach can be used to identify or confirm symptoms. It can be done at any time and it is often useful to submit a “good” as well as a “bad” plant tissue sample for comparison. Submitting a soil sample at the same time enhances the learning opportunity.

Crop monitoring is also possible on high value crops. Submitting samples as the season develops to track and maintain tissue levels above threshold or critical levels assures that no shortages develop. This is often popular with drip irrigated crops where spoon feeding of nutrients throughout the season in the drip lines allows for adjustments in nutrient feeding. (See Plant Tissue Section)

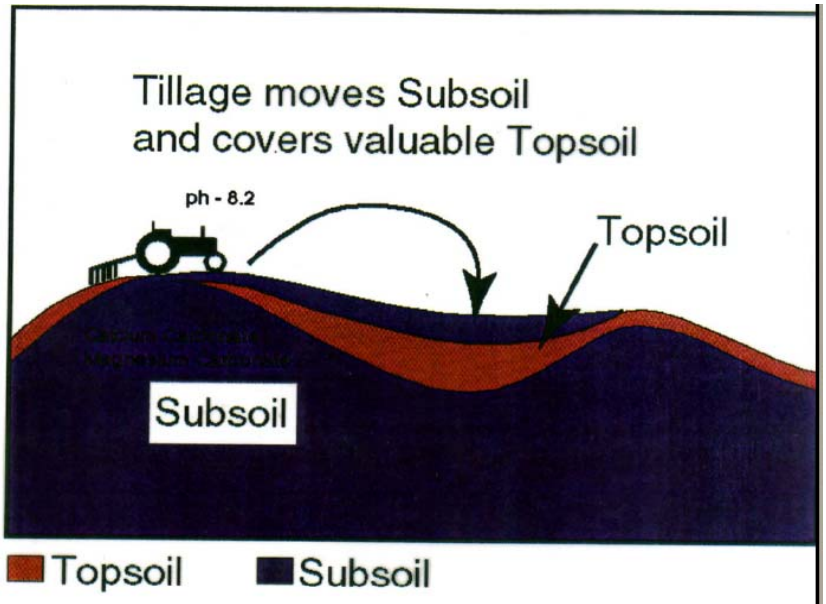
Zinc Deficiency in Plants

Zinc content in plants ranges from 20 to 60 ppm. It is difficult to increase Zinc content of plants. Deficient plants respond to applied zinc by growing and elongating their stems this results in a slight dilution of zinc content. Observation of growth pattern and character of growth is an important in determining zinc deficiency symptoms. Additional application of zinc to these plants will increase tissue concentration but may not increase yield.

Zinc is concentrated in the active growing meristematic regions of plants. Zinc is needed for the formation of plant hormone auxin which determines leaf surface area.
Zinc symptoms show a reduction in internodal length causing a dwarfed or rossetted appearance in plant stems. Roots are also affected; tomato roots can have swellings and absence of root hairs except at the root tips.

Generally, zinc deficiency occurs in the new growth as zinc is not very mobile in the plant. However in corn it is not unusual to see zinc deficiency symptoms on the lower leaves and the new leaves are sufficient. This maybe related to temporary unavailability due to dry surface soils early on, inducing a deficiency. Then sufficient moisture later on restores availability and the new growth is no longer deficient, but the lower older leaves appear to stay deficient throughout the season.

In mid slope positions on a rolling landscape where topsoil was moved down slope and is now covered by subsoil from those upper slopes. These areas may show the lower leaves deficient in zinc. In the early season the zinc level is too low in the surface soil and later on as the roots explore the deeper depths they encounter the higher organic matter and higher zinc in the displaced topsoil now buried by upslope subsoil. The subsequent new growth may not show zinc deficiency.



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Deficiency Symptoms

Corn
Severe symptoms - stunted growth shortened internodes
Mild symptoms – general pale color, in new growth a blotchy yellow patch in the emerge whorl of corn
Delayed maturity, higher harvest moisture

Soybeans Brown spots on cotyledons at Emergence
White beans Slight chlorosis of leaves
Small seeds, incomplete pod fill

Alfalfa Thin short stems, yellow mottled foliage,

Fruit trees Chlorosis of young leaves," little leaf" and rossetting on lateral shoots of new growth

Zinc Fertilizers

There are a variety of zinc sources and they are listed here with Zinc availability in descending order:

- Zinc chelates/lignosulfonates
- zinc sulphate
- zinc oxy-sulphates

- zinc oxides.

Zinc chelates/lignosulfanates, are for spray applications and fertilizer solutions. The remaining products are for dry applications either broadcasted or banded with dry starter fertilizers. The single most important factor in dry products is the percentage that is water soluble, these products should contain a minimum of 40% water soluble zinc.
Zinc chelates are the most expensive on a pound for pound basis compared to dry formulations. Zinc sulphates have greater plant availability compared to oxide forms and therefore sulfates cost more because of greater manufacturing costs to acidulate the zinc. While zinc oxide is cheaper it has lower availabilities and may take several pounds to equal the availability of a pound of more soluble zinc sulfate.

Manure
Testing manure for zinc is a worthwhile exercise. Some high dry matter manures can contain up to 2 lbs of zinc in each 5000 gallon application.

Zinc Needs Check List

Soil pH > 7.0. presence of free lime
Low organic matter < 2%
High Nitrogen rates or high levels of soil nitrates
High yield potential
Soil test <1.5 ppm
Crop with high zinc need
Plant tissue confirmation of deficiency or observed deficiency
High clay soils
High magnesium soils > 600 ppm

The determination of zinc needs should be established by the soil test, field observation and the factors that are present in the fields that alter plant and soil interface reactions.