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Essential Micronutrients: ZINC

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by L. S. ROBERTSON and R. E. LUCAS

Extension Specialists in Crop and Soil Sciences

ZINC (Zn) was one of the first micronutrients known to be essential for both plants and animals. Without ample Zn, deficiencies limit yields and cause reproduction problems. Along with iron (Fe), boron (B), manganese (Mn), copper (Cu), molybdenum (Mo) and chlorine (Cl), Zn is classed as a micronutrient because it is required and used in such small quantities.

Zinc in Animals

Feed of plant origin is the primary source of Zn for animals, although soluble salts are frequently used to insure adequate levels in the ration. While the free use of salt containing Zn causes some concern about possible toxicities, there apparently is a substantial margin of safety when using dietary Zn supplements. Toxic levels are almost unknown.

Some Zn in feed is not completely utilized by animals. This partially explains the higher Zn levels in the manure of animals fed dietary Zn supplements. High calcium (Ca) and phosphorus (P) in feed have been associated with poor digestibility of dietary Zn.

In human diets, meat is an important source of Zn. Research has shown that those who consume very little meat frequently display typical symptoms of Zn deficiency which include loss of appetite and taste ability and slow healing of burns and wounds.

In pigs, a dry, cracked skin condition—is referred to as parakeratosis—may be a symptom of Zn deficiency.

Limited research suggests that Zn fertilizers may increase levels in some crops enough to significantly affect needs for supplemental Zn. Because so little is known about Zn levels in both livestock and human food, no one should experiment with supplemental sources unless under the supervision of a specialist.

Zinc in Plants

All plants need Zn for normal growth and reproduction. The quantity utilized is small. Even the highest yielding crop takes up less than 0.6 pound per acre, which means that the need of a crop can be met by an amount equaling only one one-thousandth of its nitrogen (N) requirement.

Zinc is an essential part of certain enzyme systems related to plant growth. Plants that do not get enough Zn are stunted and have thickened leaves. Internodes on stems are shorter than normal. Chlorotic zones on leaves usually develop between veins. Also, smaller leaves are produced. Deficiency symptoms of Zn may resemble those of magnesium (Mg), manganese (Mn) or iron (Fe). Zinc deficiency occurs together with that of Mn on several crops. Under such circumstances, the tissue in nodes may be off color.

In Michigan, Zn deficiencies have been identified on navy beans, especially the Sanilac variety. On occasion, other crops respond to Zn-containing fertilizer, invariably when they are grown on soils with very high pH levels, above 7.2.

Intensities of Zn deficiencies vary from year to year. They are likely to be most pronounced early in the season when the soil is wet or compacted and when the weather is cool and cloudy. Symptoms of deficiencies on some crops, corn for example, may disappear after the soil

Table 1. Pounds per Acre of Zinc in Selected Crops[1].

Crop		Yield	Pounds per acre
Alfalfa	Hay	6 T.	0.55
Barley	Grain	60 Bu.	0.09
	Straw	1.5 T.	0.07
Beans	Seed	40 Bu.	0.06
Corn	Grain	150 Bu.	0.15
	Stover	4.5 T.	0.30
Oats	Grain	100 Bu.	0.07
	Straw	2 T.	0.30
Potatoes	Tubers	800 Bu.	0.10
Red clover	Hay	3.0 T.	0.42
Rye	Grain	60 Bu.	0.06
	Straw	2.0 T.	0.10
Sorghum	Grain	100 Bu.	0.07
	Straw	4 T.	0.14
Soybean	Grain	40 Bu.	0.04
Sugarbeet	Root	20 T.	0.52
Tomato	Fruit	20 T.	0.03
Wheat	Grain	60 Bu.	0.19
	Straw	2.0 T.	0.07

[1] *Calculated from several sources.*

Table 2. Relative Responses of Selected Crops to Zinc.[1]

	High response	
Beans		Onions
Corn		Sorghum
	Sweet corn	
	Medium response	
Barley		Sudangrass
Potatoes		Sugarbeets
Soybeans		Table beets
	Tomatoes	
	Low response	
Alfalfa		Oats
Asparagus		Peas
Carrots		Peppermint
Clover		Rye
Grass		Spearmint
	Wheat	

[1] *From MSU Extension Bulletin E-468 (1973).*

dries and warms. Restricted root growth is believed to cause deficiencies at some locations where they would not normally be expected.

Zinc requirements vary considerably, as reported in Table 1. Uptake is not necessarily related to opportunities for deficiencies. For example, of those crops shown in Table 1, alfalfa utilizes more Zn than any other crop. Despite this, deficiencies on alfalfa are unknown in Michigan and elsewhere occur only very rarely.

Field crops common to Michigan can be divided into groups on the basis of relative response to Zn fertilization. This has been done in Table 2. The crops in the highly responsive group have all responded frequently and significantly to Zn fertilization when grown on high-pH soils. The crops listed in the other two groups have not responded or have responded only infrequently to fertilizer Zn.

The Zn status of plants can be evaluated by analyzing the tissue for Zn. Tissue analyses are available at several laboratories. The Zn values in Table 3 represent the "sufficiency range" which defines a level essential for high crop yields. Levels outside of the range suggest the possibility of yield-limiting problems. Low levels imply good opportunities for deficiency. Chemical analyses are easiest to interpret when tissue samples are collected at the indicated time. Interpretation is more difficult when other plant parts are analyzed.

While the sufficiency range concept is a valuable tool for diagnosing plant nutrition problems, care should be exercised in using such data. Soil test results for both Zn and pH aid considerably in estimating the potentials of a Zn deficiency limiting crop yields.

Zinc in Soil

Extractable Zn levels (0.1 *N* HCl extraction) in soil vary greatly as reported in Table 4, which represents an analysis of 405 samples from 135 locations in southern Michigan. All averages represent relatively low levels of availability. If all samples had pH levels above 7.5, Zn would be recommended for highly responsive crops on all soils.

In general, extractable Zn levels increased with organic matter (the naturally poorly drained soils have the highest organic matter levels). Also, extractable Zn levels tend to decrease with depth in the profile. The plow layer contained approximately four times that of the parent material.

The availability of Zn is closely associated with the pH level of the soil. In general, the higher the pH in Michigan soils the greater the opportunity for a deficiency. Some soils in the state have naturally high pH levels. Such soil series with average pH levels above 7 and those where Zn deficiencies have been diagnosed at lower pH levels are reported in Table 5.

Table 3. Zinc Sufficiency Ranges for Selected Field Crops.[1]

Crop	Sampling notes	Sufficiency range ppm[2]
Corn	Ear leaf just before silking	20-70
Soybean	Upper mature leaf just before flowering	21-50
Alfalfa	Top growth — 6 inches to flowering	21-70
Wheat	Upper leaves prior to initial bloom	21-70
Sugarbeet	Center mature leaf at midseason	19-60
Navybean	Upper mature leaf prior to flowering	20-70
Vegetables	Top fully developed leaf	30-100
Potatoes	Petioles from newly matured leaf at midseason	30-100

[1] *From MSU Extension Bulletin E-486 (1973).*
[2] *ppm - parts per million.*

Table 4. Extractable zinc levels in the profiles of soil in southern Michigan.[1]

Dominant profile texture	Soil group symbol	Soil[2] profile symbol	Natural drainage class: Well drained (a)	Somewhat poorly drained (b)	Poorly drained (c)
			ppm[3]		
Clay and Clay Loam	1 & 1.5	Ap	3.6	3.4	5.1
		B	2.5	3.4	5.0
		C	0.5	0.3	1.8
Loam and Sandy Loam	2.5 & 3	Ap	3.0	4.7	5.7
		B	2.0	3.3	4.5
		C	1.0	1.2	1.3
Loamy Sand and Sand	4 & 5	Ap	3.0	3.4	4.0
		B	0.7	1.3	0.7
		C	1.0	0.7	1.2

[1] *Robertson, L. S., B. D. Knezek and D. L. Mokma — unpublished data.*

[2] *Ap—Plow layer, B—Subsoil, C—Parent material*

[3] *0.10 N HCl extractant.*

Deficiencies of Zn have been observed on many other soil series, but the symptoms were less well defined unless the location represented a site where the surface soil had been partially or entirely removed by erosion. On occasion, those fields that have been leveled may show deficiencies where part of the surface soil was moved to another section of the field. Ditch-spoil banks and areas over tile lines frequently produce Zn deficiency symptoms in plants.

Toxic levels in Michigan are unknown although they may be present in extremely acid soils, those with pH levels below 5.0. This condition is difficult to diagnose because high Zn levels are likely to induce Fe deficiencies. Thus, care is needed in evaluating such circumstances. The use of lime should eliminate any potential problems of Zn toxicity.

Table 5.
Michigan soil series with high pH levels where responsive crops need zinc fertilizer.[1]

Soil series	Management group	Soil series	Management group
Alpena	Ga	Markey	M/4c
Bach	2.5c-c	Sanilac	2.5b-c
Carlisle[2]	Mc	Tappan	2.5c-c
Charity	lc-c	Thomas	1.5c-c
Edwards	M-mc	Tobico	5c-c
Essexville	4/2c-c	Warners	M-mc
Gagetown	2.5a-c	Whittemore	1.5c-c
Houghton[2]	Mc	Wisner	1.5c-c
Lupton	Mc		

[1] *From MSU Extension Bulletin E-486 (1973).*

[2] *These soils are not alkaline but have shown a need for Zn fertilizer.*

Zinc in Irrigation Water

Irrigation water is not a good source of Zn. Levels of Zn in the natural waters of Michigan are extremely variable with source of water and time of year, as well as location on a stream. All levels are too low to be a significant consideration.

Average levels in river water would supply between 0.01 and 0.11 pound of Zn per acre-foot of water used. Lake, pond and well water are assumed to have similar levels.

Zinc in Livestock Manure

Zinc levels in manure are exceptionally variable and are rapidly increasing from those levels of only a short time ago. For example, in 1961, the average Zn level in poultry manure was less than 0.2 pound per ton of manure. Today, when Zn is an important part of the feed, levels may be as high as 3 pounds per ton. With the use of 20 tons per acre, this amounts to 60 pounds of Zn which, over a period of time, would be excessive. Therefore, care should be exercised when using manure at very high rates. Under such circumstances, chemical analyses of both soil and manure is advised.

Table 6. Carriers of Zinc.[1]

Carrier	Formula	Percent Zinc
Zinc carbonate	$ZnCO_3$	52-56
Zinc chelate	$Na_2ZnEDTA$	14
Zinc chelate	NaZnHEDTA	9
Zinc oxide	ZnO	78-80
Reax zinc	ZnMPP	10-12
THIS zinc	ZnMPP	7
Zinc Silviplex	ZnMPPP	7
Zinc sulfate...........	$ZnSO_4 \cdot H_2O$	36
Raplex Zn	ZnPF	10

[1] *From Fertilizer Handbook — The Fertilizer Institute.*

Zinc in Municipal Sludges and Wastewater

Zinc levels in municipal wastes are also variable. Recent analyses of 57 Michigan sludges showed a range from 72 to 16,400 ppm Zn. Because some sources are high in Zn, use sludges with extreme caution. Recognize that they can contain relatively large amounts of other metals. A complete analysis for copper, nickel, cadmium and zinc is desirable. Lead, chromium and mercury may be problems in specific materials; therefore, analysis for these elements is recommended where problems are anticipated. With this information, recommendations on the appropriate use of such materials can be made.

Zinc levels in municipal wastewaters are usually so low as to be insignificant.

Zinc Carriers

The most common carriers of Zn in Michigan are shown in Table 6. Such materials vary in cost and in ease of application. Zinc recommendations are made on the basis of the element and not on the basis of a carrier.

Recommendations for Zinc

When Zn deficiencies are suspected early in the growing season, it is possible to spray a solution of Zn on the leaves. Within ten days the leaves should return to normal color if ideal growing conditions exist. For a spray test, dissolve one teaspoonful of zinc sulfate ($ZnSO_4$) in a gallon of water and wet all of the foliage on abnormal plants in several parts of the field.

If a Zn deficiency is diagnosed early in the season, spray the foliage with 0.5 to 1.0 pound of Zn per acre. This is equivalent to 1.5 to 3.0 pounds of Zinc sulfate ($ZnSO_4$), which has proven to be a reliable material for this kind of treatment. While a wetting agent is not essential for all crops, it is good insurance, especially on those plants with waxy leaves.

Some fungicides contain Zn, but the concentration is too low to totally correct a severe deficiency. Some Zn fertilizers are compatible with certain insecticides and fungicides. If compatible, the Zn can be added to such materials, thus saving time and expense.

For a treatment of deficient soil, a band application at planting time of 3 to 4 pounds of inorganic Zn or 0.5 to 0.8 pound of organic Zn (chelate) per acre is recommended. Where Zn is broadcast, rates should be increased. On highly responsive crops, 25 pounds per acre of Zn showed good availability for seven years. Also, after several years of banding Zn where a total of 25 pounds were used, rates can be greatly reduced and, in some instances, even eliminated.

Some cash crop farmers, as a part of a preventive program, are using small quantities of Zn each year when beans or corn are grown. Under such circumstances, normal recommendations should be reduced 50 percent. Granular forms of zinc oxide (ZnO) have not been effective in either preventive or corrective programs.

Summary

Zinc is an essential element for both plants and animals. Deficiencies seldom occur in well-managed livestock and crops. Toxicities are almost unknown.

The need to use Zn fertilizer in Michigan can be determined with both soil tests and plant analysis methods. Zinc requirements are determined by evaluating soil test levels, kinds of soil, and species of crops.

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