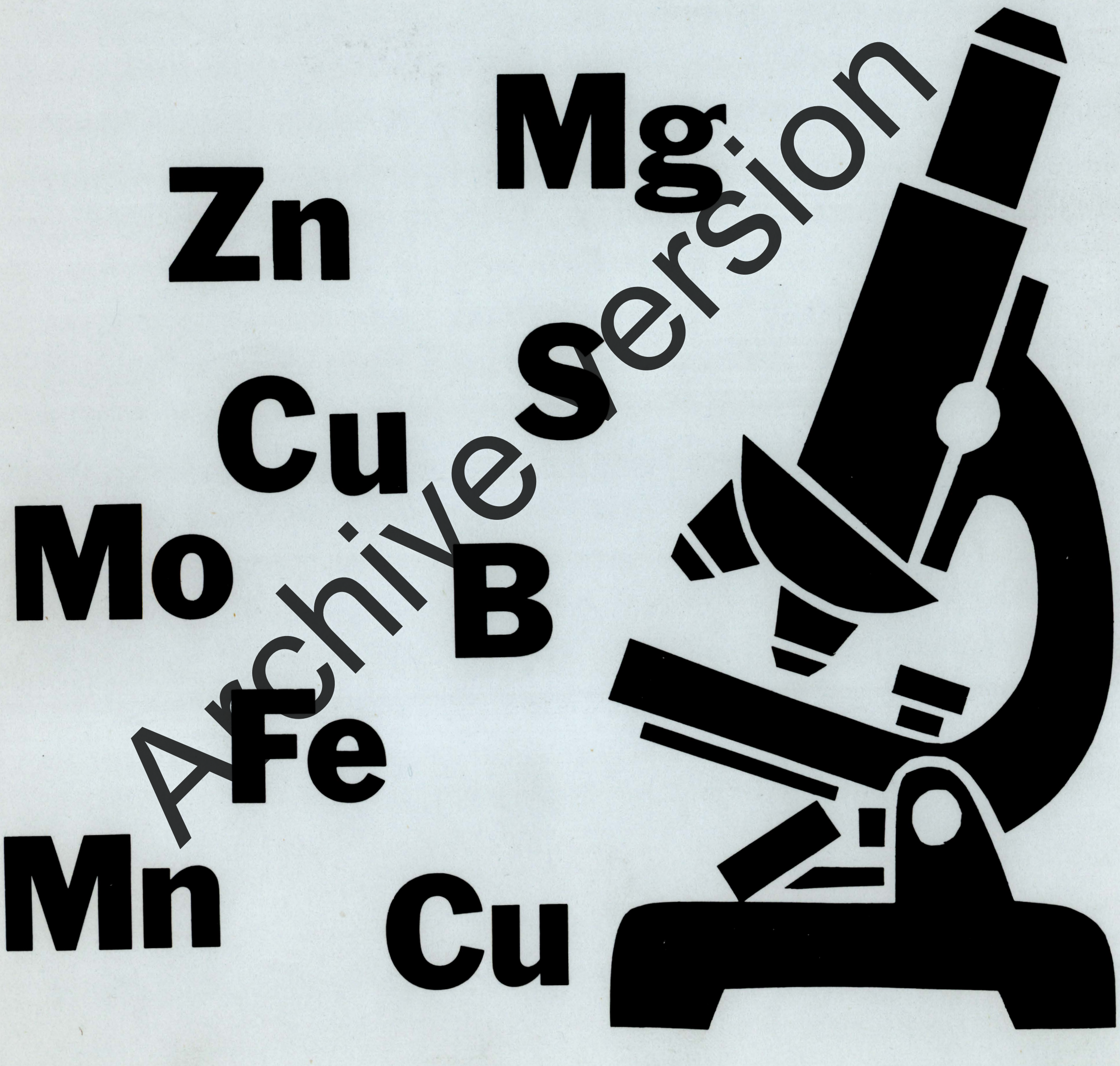
MICRO and SECONDARY NUTRIENTS in MISSOURI



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Micro- and Secondary Nutrients in Missouri

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Introduction

This publication follows closely the format of a mimeographed publication written by A. L. Preston and Marshall Christy entitled "Function, Need, Use for Missouri Soils of Zinc, Iron, Boron, Manganese, Magnesium and Molybdenum" and distributed in 1969. The current authors revised, edited and added to the Preston-Christy report. The work of these two former state extension specialists is acknowledged.

This publication was written to provide agronomists in Missouri with an inexpensive guide to the status of micro- and secondary nutrients as the authors perceive it in 1977. A list of references at the end of this publication should be consulted for greater detail.

The UMC Agronomy Department has conducted many field and greenhouse studies on micro- and secondary nutrients in the past decade. While all soil series and crop combinations were not studied, the statements made in this publication are justified.

The order in which the elements are discussed reflects the authors' judgment on their potential for influencing crop yields. That is, an economic response to zinc can be obtained in several areas of Missouri, but an economic response to copper fertilization has not been documented.

Many laboratories in the country offer micronutrient tests, and some imply that laboratories not offering such tests are inadequate. However, any lab can offer a test and make a recommendation based on that test. But the value of that recommendation depends on the calibration of test levels with fertilizer applications and crop responses under conditions approximating those of the farmer using the test.

Because of lack of plant response, the authors have been unable to calibrate tests for B, Mo, S, Mn, Fe and Cu under Missouri conditions. One must get consistent responses before offering a test. A plant analysis monitoring program is offered to farmers in Missouri through all county University of Missouri extension centers. Use University of Missouri Guide Sheet No. 9131 "Sampling Plant Tissue and Soil for Analysis" as a guide to collect good plant samples.

ZINC - Zn

Function in Plant

Zinc in the plant is bound by several enzymes into metallo-enzymes. The majority of the enzymes with which zinc is bound are dehydrogenases, reductases and anhydrases. Zinc deficiency limits the activity of these enzymes. The deficiency symptoms of zinc in plants and knowledge of the associated enzyme functions have shown that zinc is required for chlorophyll synthesis, carbohydrate transformations and auxin (growth promoting substances) formation.

Requirements

The total amount of zinc required by plants is small. Analysis of plant tissue has enabled research workers to establish the following ranges for corn, grain sorghum, and soybean leaf tissue.

ppm Zn

$<$21 - low, deficiency symptoms may occur
21 to 70 - adequate
71 to 150 - high
$>$150 - excess, toxicities may develop

A 150 bushel corn crop may take up only ½ to ¾ of a pound of zinc per acre, yet this quantity is essential.

Deficiency Symptoms

Corn: The half portion of leaves nearest the stalk appear "whitish" or "bleached" between midrib and leaf margins. Lack of color is noticeable as leaf comes out of whorl. Midrib, leaf margins and tip retain green color. Internodes shorten, causing rosette appearance. Silking and tasseling are delayed. Severe deficiency results in noticeable stunting of plants.

Sorghums: Similar to corn.

Soybeans: New leaves are small and become yellow or chlorotic. Lower leaves may turn brown and drop. Plants are stunted and flowering is greatly reduced.

When Deficiencies May Occur

In mineral soils, the surface layer is normally much higher in available zinc than the subsoil. As soils develop, growing plants assimilate available zinc for incorporation in plant tissue. Upon the death of the plant, this tissue is deposited on the soil surface. Zinc is not subject to leaching. Consequently, as the soil profile develops, zinc is closely related to organic matter content of the surface soil. Because of this relationship, zinc deficiencies may occur in the following situations:

- Subsoils exposed due to grading, land leveling, terracing or erosion.
- Sandy soils low in organic matter.
- Growing seasons featured by cold, wet weather—breakdown of organic matter is delayed and when the supply of zinc in the soil is marginal, deficiencies develop.
- Peat soils where the parent material was low in zinc with no mineral material available.
- Alkaline soils.
- High levels of soil phosphorus.

In some areas high phosphate levels have induced zinc deficiencies. This usually occurs where heavy applications of phosphate fertilizer are made in a band near the row. The high concentration of phosphate in the root zone apparently reduces the translocation of zinc. As a safeguard, row or band applications of phosphate should be no greater than 40-50 pounds of P_2O_5 per acre.

Zinc deficiencies are common on calcareous or high pH soils. In most cases this is a natural soil condition and not the result of applying agricultural limestone. *To date, applications of recommended levels of lime to soils have not resulted in zinc shortages.* Restrict lime applications to the amounts suggested by soil tests because overliming is unprofitable and may lead to zinc deficiencies.

In Missouri, the largest area of potential zinc deficiency is in the Delta (Bootheel) on sandy soils. In addition, newly terraced fields in the state have in some cases responded to zinc fertilizer. Monitor soil under irrigation because of the consistent high demand on soil zinc. The University of Missouri offers a zinc soil test and interpretation for corrective application for corn and soybeans.

Sources of Zinc

Source	*Formula*	*Approx. % Zn*
zinc sulfate monohydrate	$ZnSO_4 \cdot H_2O$	35
zinc sulfate heptahydrate	$ZnSO_4 \cdot 7H_2O$	23
basic zinc sulfate	$ZnSO_4 \cdot 4Zn(OH)_2$	55
zinc oxide	ZnO	78
zinc carbonate	$ZnCO_3$	52
zinc sulfide	ZnS	67
zinc frits	(silicates)	variable
zinc phosphate	$Zn_3(PO_4)_2$	51
zinc chelates	$Na_2ZnEDTA$	14
	NaZnNTA	13
	NaZnHEDTA	9
Zn polyflavonoids	—	10
Zn ligninsulfonate	—	5

Corrective Treatments

Inorganic zinc applied to soil is the most effective way to correct deficiencies. Foliar applications normally will correct deficiency symptoms but must be repeated. Comparison of costs between carriers should be made using prevailing prices.

Soil treatments are based upon the zinc soil test. Research to date has calibrated the test for corn and grain sorghum. Soybeans and cotton have failed to respond to zinc fertilizer.

Test Rating and Corrective Treatments (corn grain, corn silage, sorghum grain, sorghum silage - crop codes on Missouri soil tests are 17, 18, 26, 17) follow:

Soil Test lbs Zn/A	*Rating*	*Corrective* Treatment lbs Zn/A*
$<$2.0	low	20
2.0 - 4.0	medium	10
$>$4.0	high	0

*Inorganic sources, broadcast; use 25 percent of the rate if banded and repeat annually. The corrective treatment should last four years. Foliar treatments with chelates should follow the manufacturer's recommendations.

How to Confirm Deficiency

- Take a tissue sample for spectrographic analysis and a soil sample for zinc test from the suspect area and from a normal area in the same field.
- Dissolve one ounce of zinc sulphate in one gallon of water. Using a sprayer or sprinkler, apply to foliage in 25-30 feet of row.

- Observe treated areas. Response should appear within a few days. Plant analysis should confirm field response and degree of deficiency.

BORON - B

Function in Plant

The role of boron in plant growth is not completely understood. It is essential for proper cell development and normal growth, flowering and quality. It is immobile in plants and is not translocated from one part of the plant to another. Thus, the lower or older portions may contain adequate supplies of boron and be normal in appearance, but the newer or growing portions may exhibit deficiency symptoms.

Requirements

Alfalfa tissue with less than 30 parts per million is considered low in boron, and deficiency symptoms may occur when the concentration falls below 20 ppm. Thirty-one to 80 parts per million is considered adequate. Levels above 125 parts per million may indicate toxicity, and plants may exhibit burning or dying of leaf margins. A 5 ton per acre alfalfa crop with a modest level of 40 ppm B would remove .4 of a pound per acre from the soil.

Sensitive Crops

Alfalfa is the most sensitive crop grown in Missouri, and boron deficiencies are rather common unless it is applied. Red and white clovers sometimes exhibit deficiency symptoms, but the problem is not general.

Boron should not be used on cereal crops and soybeans. They are very sensitive to the element and may exhibit toxicity symptoms. They are tolerant of low levels of available boron and seldom suffer from deficiencies.

Occasional boron responses by cotton have been observed, but research at the Delta Center has failed to provide any methods of predicting deficiency.

Deficiency Symptoms

In alfalfa, upper leaves become yellow, and internodes shorten, giving a rosette appearance. Affected plants produce few blossoms. Leaves on lower one-third of deficient plants will typically retain normal color and appearance. Deficiency symptoms are most likely to appear during dry periods. Appearance of affected leaves may be confused with potash deficiency or leaf hopper damage. However, in the case of potash, lower, not upper, leaves show symptoms. Leaf hopper damage causes V-shaped yellowing of the outer end of the leaflets.

Red and white clovers exhibit symptoms similar to alfalfa. Terminal internodes shorten, and plants fail to bloom. Upper leaves may become reddish in color, rather than the yellow characteristic in alfalfa.

Terminal growth of cotton is reduced by boron deficiency resulting in a rosette condition. Fruits abort resulting in nearly barren plants.

When Deficiencies May Occur

Boron deficiencies in alfalfa are common on most soils of the state. While the problem is more severe on the low organic matter, unglaciated soils of South Missouri, applications of boron are needed for alfalfa production throughout the state. Deficiency symptoms are most likely to appear during periods of dry weather.

Boron leaches, and available boron may be removed by excessive rainfall from open soils with good or excessive internal drainage. Thus, deficiencies may be more severe in years following wet periods.

Sources of Boron

borax	11%B
borate 65	20%B
solubor	20%B

Corrective Treatments

Apply 2-3 pounds of boron per acre every other year to established stands of alfalfa. Because of the small amount of material required, mix the boron carrier with a phosphate and/or potash fertilizer, and apply as top dressing.

One half to one pound of boron per acre banded on cotton will normally correct most deficiency problems in that crop.

MAGNESIUM - Mg

Function in Plant

Magnesium, while not a micronutrient, is sometimes associated with micronutrient deficiencies. Extractable soil magnesium is routinely determined in the Missouri Soil Testing Program.

Magnesium plays a complex role in the plant. It is a part of the chlorophyll molecule necessary for photosynthesis. Magnesium is mobile within the plant and can be translocated from one portion to another. As plants develop under a magnesium deficient situation, magnesium is translocated from older to the new or rapidly growing leaves. Therefore, deficiency symptoms appear first in the older tissue.

Requirements

The following percentages of magnesium on a dry matter basis represent those levels below which deficiencies may occur:

Crop	*%Mg*
corn	.21
grass (forage)	.21
soybeans	.26
alfalfa	.31

Sensitive Crops

Corn is the crop in Missouri in which magnesium deficiency symptoms most often are observed. This may be due to the distinct symptoms shown by corn, compared to the other crops.

Forage grasses and small grains used for pasture fall into a special category. While these grass crops seldom show magnesium deficiency, low levels of magnesium in the forage may induce grass tetany in ruminants.

Deficiency Symptoms

In corn, the older leaves develop yellowish streaks between veins. These develop into "bleached" or "white" streaks running parallel to the veins, giving a distinct "stripe" appearance. In cotton and legumes, lower leaves may become yellowish or reddish, with veins remaining green. This yellowing may sometimes be confused with maturity in cotton or soybeans. Soil tests and plant analysis are suggested to confirm a suspected shortage.

When Deficiencies May Occur

While magnesium deficiency symptoms have not been confirmed, residual soils developed from almost pure calcitic limestone are soils where magnesium imbalances associated with grass tetany are likely to occur. This includes the Baxter-Nixa Soils in Southwest Missouri; grass tetany is prevalent in this area. Soils of the Ozark Plateau and Ozark Border were derived entirely, or in part, from dolomitic limestone and are normally high in magnesium. Soils of North Missouri, which are derived from loess or glacial till, usually contain adequate supplies in the surface, and available magnesium increases with depth.

Magnesium deficiencies in crops confirmed to date have for the most part been confined to sandy or light textured alluvial soils of the state. In such situations, both parent material and leaching probably contributed to low levels of available magnesium. Corn, especially when heavily fertilized with potash, may develop magnesium deficiencies on these sandy soils. While not completely understood, a relationship, or magnesium-potassium interaction, occurs and results in symptoms most common with high potassium levels.

Sources of Magnesium

dolomitic limestone	variable
magnesium sulfate	9% Mg
potassium magnesium sulfate	11% Mg
magnesium oxide	55% Mg

Corrective Treatments

Magnesium problems can be avoided by soil testing and the use of magnesium carrying materials when needed. Dolomitic limestone is readily available over most of the state. When limestone is not needed or magnesium limestones are not available, other magnesium carriers are suggested.

MOLYBDENUM - Mo

Function in Plant

Molybdenum is required in quite small amounts but is essential for proper nitrogen metabolism. The molybdate ion is required for the fixation of atmospheric nitrogen by the nitrogen fixing bacteria in soils and legume nodules. Legumes grown in soils without adequate molybdenum develop nitrogen deficiencies.

The enzymatic reduction of nitrate nitrogen in plant cells also depends on adequate molybdenum. This reduction is necessary before the plant can form amino acids, the building blocks of protein.

Requirements

A fraction of an ounce of available molybdenum is adequate for sensitive legume crops such as soybeans. The amount of the element in forages which is toxic to livestock is also extremely small. Tissue analysis of legumes showing 1-5 ppm of molybdenum should indicate adequacy. The range in concentration between molybdenum deficiency and toxicity is the smallest of any essential element.

Sensitive Crops

Legumes are most responsive to treatment if a molybdenum deficiency exists. Soybeans are the only crop which has given a response to treatment in Missouri, and this response has been inconsistent from year to year. Some states, especially in the eastern and southern United States, report response with alfalfa and clovers as well as with soybeans.

Cauliflower is subject to molybdenum deficiency resulting in "whiptail." Young leaves develop abnormally. The edges curl and the heads fail to develop. Broccoli, lettuce, tomatoes and citrus have been affected by limited molybdenum in some areas.

Mo Concentration in Plant Tissue (ppm)

	Low to Deficient	Normal	Excess
Soybeans	<1.0	1.0-5.0	>10.0
Alfalfa	<1.0	1.0-5.0	>10.0
Grasses	<0.1	0.1-1.0	>10.0

Deficiency Symptoms

The major deficiency symptom in legumes is simply a nitrogen deficiency. Plants lack vigor; foliage is pale green in color. The nodule bacteria are unable to fix atmospheric nitrogen regardless of nodule formation. Insufficient nitrogen nutrition results in stunted growth. This may explain the reason some perennial legumes respond temporarily when chemical nitrogen is applied.

Toxicity

Problems of excess molybdenum occur in ruminant livestock rather than in plants. "Teart" disease in cattle is reported in various places in the world from steady consumption of forage containing 10 ppm molybdenum or more. Reports indicate weird changes in hair color, such as mouse-gray for Holsteins, rusty-orange for Herefords and rusty for Angus. Digestive disturbances prevail, and fatalities occur with severe poisoning.

When Deficiencies May Occur

Solubility of molybdenum in soils and therefore availability to plants is determined largely by the amount of soluble iron and aluminum present. Molybdenum reacts with these soluble metallic elements forming insoluble iron and aluminum molybdates. Amounts of soluble iron and aluminum increase as soils become more acid (low pH), thus immobilizing molybdenum.

Sandy soils are more likely to be deficient in available molybdenum than heavier textured soils. Soils with high organic matter generally contain more molybdenum than soils with limited organic matter. If legumes, especially soybeans, are being produced on acid sandy soils, the molybdenum-lime need should be investigated.

Soil reactions with molybdenum differ from other micronutrients. Molybdenum becomes less available with increasing soil acidity; it resembles phosphorus in this respect. Crop response to molybdenum has seldom been observed and is not likely when soil pH_s is 6 or above.

Dramatic responses to molybdenum added to soils *unable* to supply *adequate available* amounts have occurred. Seed or foliar application of trace amounts per acre result in a dark green color and healthier, more vigorous growth.

Sources of Mo

sodium molybdate	39% Mo
ammonium molybdate	54% Mo
seed treatment material	variable

Corrective Treatments

Use of adequate limestone on acid soils usually will correct the deficiency in Missouri. This will provide the most permanent and effective method of alleviating several problems associated with extreme soil acidity.

Uniformly mixing 1 to 4 ounces of molybdenum with dry fertilizers for broadcast application is difficult. Further, the fixation with iron and aluminum is rapid when the material is incorporated into the soil.

Most satisfactory application is made by dissolving the required amount of one of the soluble salts such as sodium or ammonium molybdate in just enough water to moisten seeds for a given acreage. Dry dust treatment has been less effective. Commercially available seed treatments have proven effective.

The seed treatment suggested is 6 grams or .2 of an ounce of the element per acre, uniformly applied to the seed.

Foliar applications may be used, especially for observation purposes, where a deficiency is suspected. Two ounces of sodium or ammonium molybdate per 100 gallons of water is suggested. Approximately 30-40 gallons per acre should wet the foliage.

SULFUR - S

Function in Plant

Sulfur is an element contained in three amino acids, methionine, cystine and cysteine, as well as in many large molecules in the plant, including enzymes, vitamins and other essential organic compounds. Sulfur may increase the oil content of soybeans, but the mechanism is not understood.

Requirements

In spite of the ill-gotten name of "secondary nutrient," the sulfur content of most crops is equal to that of phosphorus, a "primary nutrient." The ear leaf of corn for example may contain .3 percent sulfur.

Deficiency Symptoms

The requirement for sulfur in amino acid and protein formation provides the clue that sulfur deficiency symptoms would be similar to those of nitrogen, as is the case. A general loss of dark green color is observed with sulfur deficiency in contrast to the chloric corn midrib observed with nitrogen deficiency. Another difference is that sulfur deficiency usually affects the younger leaves first, whereas nitrogen deficiency symptoms are first observed on the older leaves, especially in grasses. Sulfur is not readily transferred from older to younger growth.

When Deficiencies May Occur

Soils with low organic matter or sandy soils would be likely to demonstrate sulfur deficiency, especially if acid. Greenhouse work on selected Delta soils has induced sulfur response, but this response has not been found in the field. Continued use of processed phosphate fertilizers coupled with low atmospheric sulfur may result in sulfur deficiencies in the future in the Delta and other areas of sandy or low organic matter soils.

Sources of Sulfur

ammonium sulfate	24% S
hydrated gypsum	18% S
Epsom salts (magnesium sulfate)	23% S
potassium magnesium sulfate	18% S
ordinary superphosphate	14% S
"Agrisul"	90% S

Corrective Treatments

An application of 40-60 pounds of sulfur per acre in any of the above carriers would be adequate in most cases. Soil tests are offered by some laboratories, but calibration data are lacking in Missouri because of lack of consistent responses in the research work done to date.

MANGANESE - Mn

Function in Plant

Manganese is associated with chlorophyll synthesis, nitrogen metabolism and carbohydrate breakdown. The element is known to be an activator of some primary enzyme systems and serves as a regulator of certain cell metabolic functions, especially oxidation-reduction phenomena.

Manganese within the plant cells serves as an oxidizing agent. However, an excess may create an iron deficiency by converting available ferrous iron into a physiologically inactive ferric state.

Requirements

Small amounts of this element are required, but large quantities of manganese are toxic to plants. Concentrations of approximately 20-150 ppm in plant tissue of common agronomic crops in the vegetative stage are considered adequate. Below 20 ppm indicates a potential deficiency. Two hundred ppm and above is a high level approaching a toxic concentration for most crops.

Sensitive Crops

Crops vary in uptake and utilization of manganese. For example, oats may have 700 ppm in its tissue, but tobacco may have 3,000 ppm when grown on the same soil. Oats may tolerate high soil manganese with a built in mechanism for excluding it from the root; but the high level may be toxic to tobacco.

Soybeans and small grains are most responsive to manganese treatment when available soil levels are inadequate. Less response can be expected from corn and grasses, and alfalfa shows very little response except where soil levels are extremely low.

Toxicity

Manganese toxicity is more prevalent than deficiency in Missouri. Acid soils contain a relatively large amount of manganese and give rise to a problem most easily solved with adequate liming. Cotton, soybeans, potatoes and tobacco are crops which may exhibit stunted growth and cupped leaves from excessive availability and uptake of manganese when soil pH_s falls below 5.

"Crinkle leaf" in cotton starts with cupping of the leaves followed by necrosis (death of tissue) and a brittle or crinkle appearance and feel. Toxicity in tobacco plants is manifested by stunted growth and chlorotic leaves followed by necrosis.

Alfalfa leaves develop white spotting of tips and margins followed by scorching. Clover leaves are small and cupped with the margins scorched. Interveinal brown spots appear on leaves of small grains.

Deficiency Symptoms

This element is rather immobile and not translocated in the plant. Younger leaves are first to exhibit visual deficiencies. The most common symptoms are: (1) chlorosis between veins; (2) dark green veins which become lighter with severity; (3) stunted growth; (4) reduced flower formation; and (5) leaf drop in severe cases. A foliar spray of manganese to a few test plants will restore dark green color within a few days if a manganese deficiency exists.

Diagnosis of crop problems by visual symptoms only is risky. Several elements when limited result in similar symptoms. Proper use of soil and plant analysis as well as observation can detect possible difficulties at an early stage. No soil test for manganese has been developed in Missouri due to lack of deficient sites on which to calibrate the test.

Concentration of Mn in Plant Tissue (ppm)

	Low to Def.	Normal	Excess
Corn	<19	20-150	>200
Cotton	<30	31-300	
Soybeans	<20	21-100	>250
Alfalfa	<30	30-100	>250
Grasses	<30	30-150	
Small Grains	<10	10-100	

When Deficiencies May Occur

Poorly drained, calcareous soils high in organic matter with a pH of 7 or above may result in varying degrees of manganese deficiency. Certain kinds of organic matter form insoluble, unavailable manganese complexes.

Manganese deficiency may occur in high pH soils where alternate water logging and drying occurs. Wet, anaerobic conditions and percolation removes soluble manganous manganese. A deficiency may then occur upon drying and rapid oxidation.

Good soil aeration causes the oxidation of soluble manganese, rendering it less available. In most Missouri soils, this reduces potential toxicities. Liming acid soils is the cheapest means of eliminating manganese toxicity. Organic matter decay products complexes manganese.

Sources of Manganese

manganese sulfate	26-28% Mn
manganese EDTA (Chelate)	12% Mn
manganous oxide	41-68% Mn
manganese carbonate	31% Mn

Corrective Treatments

Toxicities are more probable than deficiencies in Missouri. Observation, conventional soil testing and plant analysis are useful in determining the situation. Adequate liming when needed, return of crop residues and animal manure, and drainage of low, wet areas will help correct the problem of excess manganese in a readily available state.

When deficiencies are encountered, soil or foliar applications may be used. Materials include manganese sulfate, manganous oxide and chelates. One or two annual applications probably will be needed where serious deficiencies are encountered. Little carry-over of soil applied manganese occurs in the available form.

Foliar spraying affected plants with a water solution of 1-2 pounds of elemental manganese using approximately 20 gallons per acre should correct the problem.

Applications of manganese-fertilizer mixtures may be drilled in for small grains and alfalfa. Banded application is most efficient. Manganous oxide should be used only in a band, because oxidation will result in its becoming unavailable when broadcast.

The amount of the element needed for soil application will depend on severity of the problem and the crop. This may range from 4-20 pounds per acre of the actual element, although 6-10 pounds may be adequate in most cases.

Iron - Fe

Function in Plant

Iron is indispensible for chlorophyll synthesis, although it is not a part of the chlorophyll molecule. Absence of sufficient iron causes chlorosis or yellowing of leaves because of impaired production of green chlorophyll.

Some of the enzymes and carriers which operate in the respiratory system of living cells are iron compounds. These compounds are synthesized as needed to serve as catalysts for cell division and cell growth.

Requirements

Although iron is as vital to adequate plant nutrition as any other essential element, the amount needed is relatively small. An estimated 3 pounds per acre of elemental iron in an available form is adequate for a 150 bushel corn crop, while approximately 300 pounds of nitrogen is needed.

Iron is one of the most common metallic elements in the earth's crust. It occurs as oxides, hydroxides and phosphates and is associated with clay minerals. Weathering usually provides adequate available iron for crops in Missouri.

Total iron content of soils is of little value in diagnosing the supply for plant nutrition. Some areas of the world with high total iron have serious plant nutritional problems because of limited availability. Likewise soil tests for available iron are not very useful in acid soils (pH <7.0).

Sensitive Crops

Serious iron deficiencies and consequently reduced yields are reported in sorghum, corn, soybeans and alfalfa in some alkaline soils (pH in excess of 7). Horticultural crops in some areas of western states are afflicted with iron deficiency.

Frequently, fertilized grasses of lawns and golf greens on soils with a pH above 7 may respond in color and growth with addition of available iron, as may some shade trees. Iron is simply immobilized and unavailable in such situations.

Blueberries, pin oaks, azalea and some ornamentals require a high level of iron nutrition. These crops may suffer from a severe iron deficiency on very acid, cold and wet natured soils.

An imbalance of iron, copper, manganese and zinc ions is known to result in iron chlorosis. An accumulation of copper or zinc in orchard soils from sprays has created difficulties with iron availability. Extremely acid soils creating high manganese availability has resulted in iron problems in plants. Certain varieties of some crops seem to better tolerate a narrower iron to copper, manganese and zinc ratios than others.

Concentration of Iron in Plant Tissue (ppm)

	Def	Low	Normal	High	Excess
Corn	<10	10-20	21-250	251-350	>350
Soybeans	<30	31-50	51-250	350-500	>500
Alfalfa	<20	21-30	31-250	251-400	>400
Grasses	—	<50	50-150	—	>300
Sm Grains	—	<20	21-250	—	>500

Deficiency Symptoms

Chlorosis or general yellowing over the entire leaf appears first in the youngest leaves. Iron is relatively immobile in the plant and is not translocated from old to new leaves if a deficiency develops. A constant supply is needed through the growth period.

Leaf tissue between the veins turns yellow while veins may remain green. Eventually the leaf may turn almost white in severe cases. Growth is usually retarded and yields reduced.

When Deficiencies May Occur

Most difficulty has been encountered in alkali and free carbonate soils, in very acid sands and in soils with imbalances of metallic ions and especially with excessive manganese and copper.

Removal of organic matter through erosion and land leveling may result in iron deficiencies. The organic matter soil fraction is the storehouse of available organic iron and several other essential elements. Most iron in soils exists in the unavailable oxidized form. The chemically reduced iron ion is most available to plants.

Iron deficiencies of agronomic crops are practically unknown in Missouri. Difficulties are most likely a result of excessive manganese uptake with very acid conditions. Some deficiency may possibly arise with severe cuts in land leveling in some soils. Soil compaction, especially on acid sandy soils with low organic matter, may induce some problems with iron.

Sources of Iron

chelates	variable
ferrous sulfate	19% Fe
ferric sulfate	23% Fe
ferrous ammonium phosphate	29% Fe

Field Diagnosis

If iron deficiency is suspected, one of the surest tests is to apply a foliar spray of an iron carrier to a test area of the field. Observe the plant growth; compare the test area to the untreated area. If the chlorosis in new growth does not develop on the treated plants in a week or so after application, but does on the untreated area, iron deficiency is almost surely present.

It is quite difficult to distinguish between marginal nitrogen, iron and sulfur deficiency based only on visual symptoms.

Corrective Treatments

Visual observation, plant analysis and conventional Missouri soil tests will provide the best clues to an iron problem and possible imbalances. Adequate liming of acid soils is suggested as needed. Return of crop residues and animal manure will be helpful. Drainage and improved aeration to encourage microbial activity will help with cold, wet soils. Soil tests for iron have not been developed for Missouri due to failure to find responsive areas on which to calibrate a test.

Crop deficiencies may be best corrected with foliar sprays where 0.5 to 3 pounds elemental iron per acre is considered adequate for row crops. Chelates are more effective as a soil amendment than ferrous sulfate, which oxidizes to the less available ferric form. Chelates should be used according to manufacturers' instructions.

Solutions of 4 to 5 percent iron sulfate ($FeSO_4 \cdot 7\ H_2O$) may be used as foliar application at the rate of 40-50 gallons per acre. Repeated, frequent applications are necessary to adequately provide for needs of young tissue.

COPPER - Cu

Function in Plant

Copper is found in combination with selected proteins in the plant. These proteins are involved in many of the oxidase enzyme systems in the plant. Therefore, copper has a role in the respiratory activities within the plant.

Requirements

Crop	*Sufficiency Range (leaf tissue)*
corn, grain sorghum	6-25 ppm
soybeans	10-30 ppm
alfalfa	11-30 ppm
forage grasses	10-50 ppm
small grains	6-25 ppm

Deficiency Symptoms

Copper is immobile in the plant; therefore, young tissue will be the first to develop deficiency symptoms.

Corn: In mild deficiency, the young leaves yellow; as the deficiency progresses, some dieback of older leaves occurs.

Legumes: Copper deficient legume leaves turn a faded green with a grayish cast. Necrotic areas may develop on the margins of leaves.

When Deficiencies May Occur

Organic soils (peats and mucks) often have a history of copper deficiency. High levels of nitrogen or phosphorus may cause a deficiency where copper levels in soil are marginal.

There are no known areas of copper deficiency in the state at this time. Recent studies in northern and southeastern Missouri with several species and varieties resulted in no yield increases due to copper fertilization.

Sources of Copper

chelates	variable
copper (ic) sulfate pentahydrate	25% Cu
cupric oxide	89% Cu

Plant Analyses Summary Data

Plant samples (corn and soybeans) submitted by farmers are used in an annual summary which includes totals of past years. The results of analyses are grouped by soil regions. The number of samples from some regions are too small to obtain a meaningful summary.

Figure 1 presents the 12 soil regions in Missouri. The summary of 1,714 corn samples submitted during 1970-76 is presented in Table 1. More samples were deficient in nitrogen than in any other element analyzed for. Among the secondary and micronutrients, boron, iron and copper would appear to be much in need. Time of plant sampling can influence some deficiency indications as many samples were collected late. In the past, there has been a failure to obtain responses to these elements under field conditions; thus deficiency indications may actually be nutrient imbalances.

The results of 366 soybean leaf samples are summarized in Table 2. There are a sufficient number of samples deficient in nitrogen, phosphorus and potassium to cause concern. Copper appears to be a micronutrient of concern, but late sampling of soybeans under high phosphorus suggests low copper by plant analysis. Failure to obtain a response to copper in the past would indicate no great concern for copper in Missouri soils.

References

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Table 1. 1970-1976 Percent Corn Tissue Samples "Deficient" by Soil Regions - 1714 Samples

Conc. % (Less Than)	Soil Region 1	2	3	4	Other	State
	Percent					
N 2.45	25.3	27.7	28.4	41.4	28.6	28.1
P 0.15	2.4	1.6	1.6	9.5	5.9	2.8
K 1.25	9.8	9.9	21.2	13.8	14.3	13.8
Ca 0.10	14.5	3.0	13.4	5.7	1.2	9.8
Mg 0.10	1.0	.3	.6	4.3	2.4	1.1
ppm						
Cu 2	19.4	21.7	8.7	6.9	10.1	15.1
Fe 10	21.2	19.0	12.8	4.3	7.1	15.8
Zn 15	1.9	1.3	1.6	3.4	11.9	6.5
B 2	12.2	10.7	9.3	1.7	12.5	20.3
Mn 15	29.8	23.0	21.0	11.2	14.9	2.3

Table 2. 1970-1976 Percent Soybean Tissue Samples "Deficient" by Soil Region - 366 Samples

Conc. % (Less Than)	Soil Region 1	2	3	4	Other	State
	Percent					
N 4.00	20.2	10.2	14.4	40.0	21.9	17.21
P 0.15	7.9	13.6	16.4	26.7	12.5	13.38
K 1.25	20.2	13.6	24.7	6.7	12.5	19.67
Ca 0.20	0.9	-	-	-	-	0.27
Mg 0.10	3.5	3.4	0.7	-	6.2	2.45
ppm						
Cu 4	21.0	15.2	19.2	26.7	34.4	20.76
Fe 30	0.9	1.7	0.7	-	-	0.82
Zn 15	-	-	-	-	-	-
B 10	-	1.7	1.4	6.7	-	1.10
Mn 14	3.5	-	0.7	-	3.1	1.64
Mo 0.4	-	-	-	-	-	-

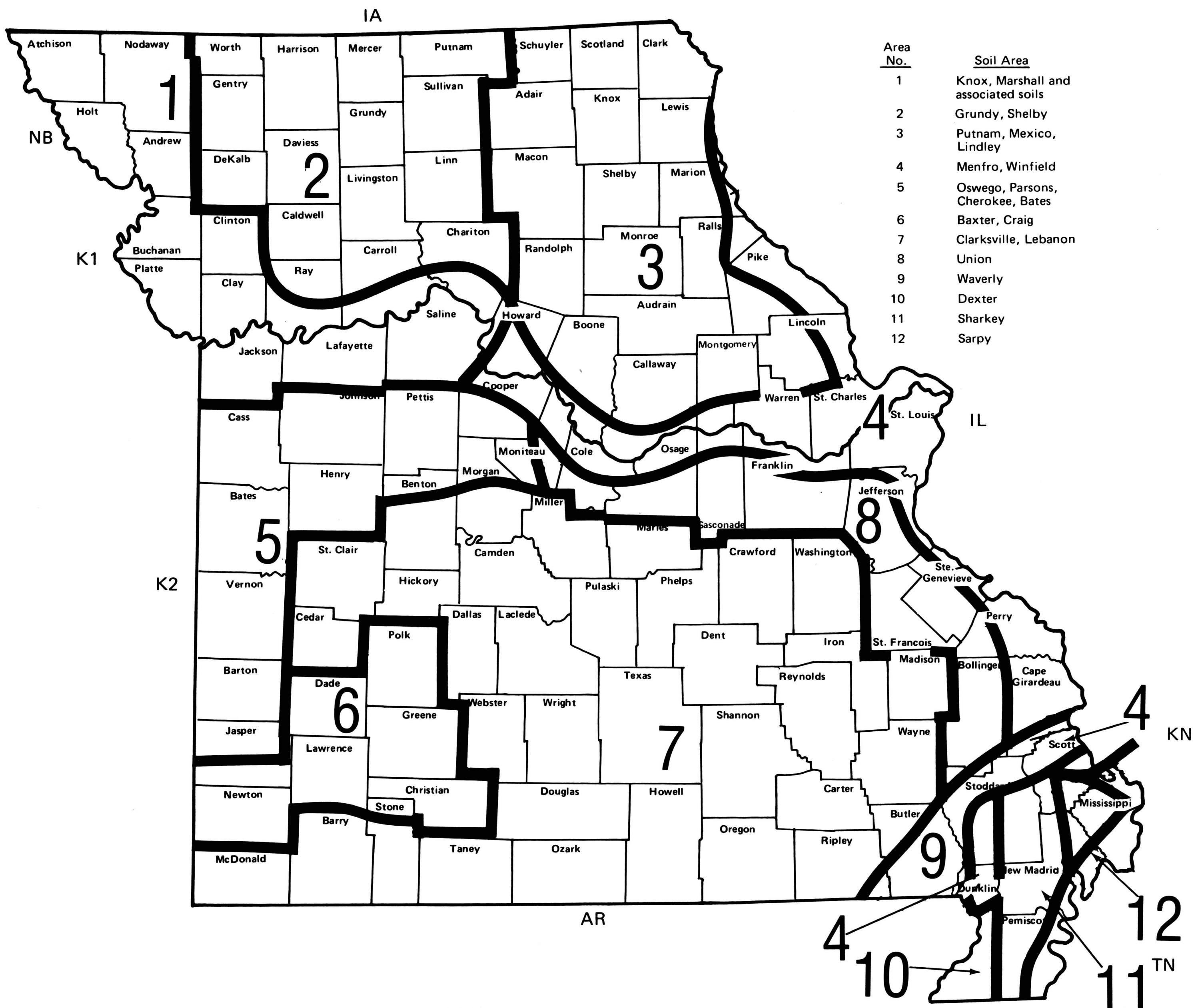

Figure 1. Soil Regions of Missouri

Issued in furtherance of Cooperative Extension Work Acts of May 8 and June 30, 1914 in cooperation with the United States Department of Agriculture. Carl N. Scheneman, Vice President for Extension, Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, Missouri 65201.