Micronutrients for Vegetables and Field Crops
Michigan State University
Cooperative Extension Service
Farm Science Series
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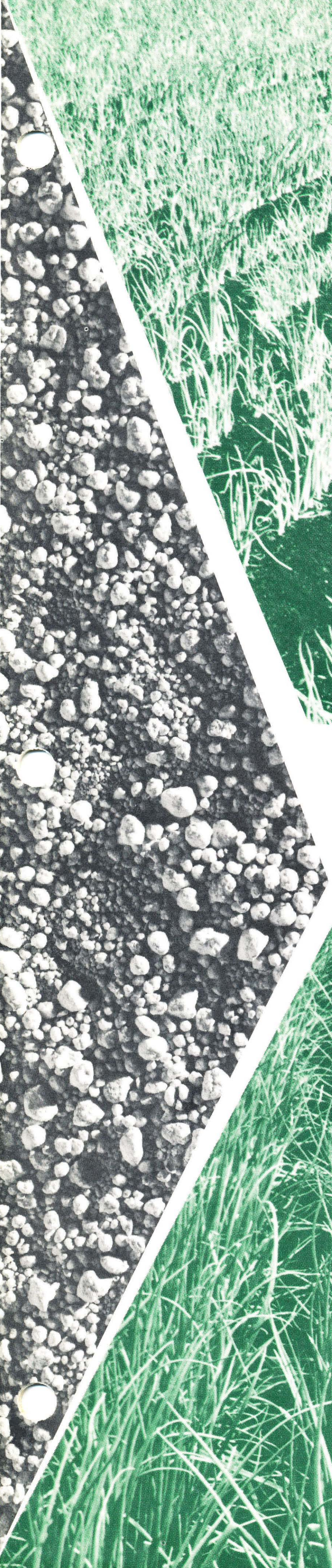
November 1964
12 pages

EXTENSION BULLETIN E-486 FARM SCIENCE SERIES NOVEMBER, 1964

COOPERATIVE EXTENSION SERVICE MICHIGAN STATE UNIVERSITY

MICRONUTRIENTS for Vegetables and Field Crops

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Robert E. Lucas
Extension Soils Specialist

Micronutrients are essential nutrient elements found in small amounts in plant tissues. These elements are sometimes called minor or trace elements. They include manganese, iron, boron, zinc, copper, molybdenum and chlorine. A serious deficiency of any one of these elements can cause a complete crop failure.

The need for micronutrients in crop production is drawing increased attention. We can expect this attention because:

1. We are better informed about crop response and availability of the nutrients in different soil types.
2. Higher crop yields require larger amounts of the elements.
3. Long-time cropping removed minerals. (This is sometimes called soil depletion.)
4. Less animal manures and more high-analysis fertilizers low in impurities are used.
5. Higher phosphorus levels in the soil can lower the availability of some micronutrients.
6. There are soils lower in organic matter, especially when top soil is removed over tile lines and spoil banks, and after fields are leveled.

Approximately 35,000 tons of fertilizer used in Michigan in 1963 contained micronutrients of sufficient quantity to be reported. Based upon present information of soil and crop needs, it is estimated that nearly 100,000 tons of fertilizer should contain micronutrients.

At present the criteria used in making micronutrient recommendations are: (1) soil type, (2) crop to be grown, (3) soil pH, and (4) plant symptoms. When greater quantities of micronutrients are used and the consumer is willing to pay for the testing expenses, soil and plant tests to determine micronutrient needs can be initiated.

Each micronutrient has a specific role in plant development. For this reason, each is reported separately.

Premium Fertilizers

Many of the fertilizer companies sell a "premium" grade fertilizer. The description "premium" means a fertilizer that has special desirable features. Some of these are better drillability, less caking, uniform-sized particles and higher water-soluble phosphorus content. Usually premium fertilizers have micronutrients added. These improved features and additions are difficult to evaluate.

The actual content of added micronutrients in premium fertilizers is usually not published. In Michigan, as of 1964, manufacturers cannot guarantee a specific micronutrient unless the fertilizer contains at least 1% manganese, ½% copper, ⅛% zinc, ⅛% boron and/or 0.08% molybdenum. Many states in the U. S. have set the minimums for claims at levels recommended by the Association of American Fertilizer Control Officials. These minimums are 0.05% manganese, 0.05% copper, 0.05% zinc, 0.02% boron, 0.0005% molybdenum and 0.10% iron. These low levels do not carry sufficient quantities to meet a problem situation. For example, one application of 300 pounds of fertilizer containing 0.05% manganese per acre will supply 0.15 pounds of manganese. In problem soils, field trials have shown a need for at least 5 pounds per acre — a 32-fold difference.

Claims may be made by the manufacturer that micronutrients in premium fertilizers are needed as a maintenance fertility program. In very sandy soils such a claim has merit for some micronutrient elements. On the other hand, for most of the agricultural soils of Michigan, the problem is not so much of maintenance level as it is keeping the nutrients in

Table 1. Suggested micronutrient mixture to be applied per acre for well limed soils* (pH above 6.0)

5.0 pounds manganese	equivalent to 20 pounds of manganese sulfate
2.0 pounds zinc	equivalent to 6 pounds of zinc sulfate
1.0 pound copper	equivalent to 4 pounds of copper sulfate
0.5 pound boron**	equivalent to 5 pounds of borax
0.2 pound molybdenum	equivalent to 8 ounces of sodium molybdate

*Double rate for peats and mucks
**Do not use boron for crops easily injured by boron, such as beans and small grain.

an available form. For example, most soils have ample **total** iron and manganese. Zinc, when needed on alkaline soils, will not remain "available." In the case of boron, since it is highly mobile and leaches rapidly, there may be little accumulation in the soil from year to year, especially in sandy soils. Charges of about $5.00 per ton for the added micronutrients may not seem great. But, for the state as a whole, such a charge for 200,000 tons of fertilizer would cost Michigan farmers a million dollars.

Although much information has been obtained about crop requirements and availability in the soil, it is physically impossible to know all situations where a micronutrient problem exists. A farmer may wish to — and should — try out an all-inclusive micronutrient mix on part of his crop. If response is obtained, further tests should be carried out to determine the source of the response. A suggested mix for a well limed soil is shown in Table 1.

The chemicals suggested in Table 1 can be obtained from most fertilizer companies.

If the mixture as suggested is used, mix thoroughly the micronutrients with a suitable N-P_2O_5-K_2O fertilizer such as 6-24-12. Special care should be taken to obtain complete mixing when micronutrients are applied with other fertilizers. Segregation, because of particle size differences, is often a problem, especially in bulk-blend mixtures. Use the mixture as soon as possible to prevent caking. Place the fertilizer in bands about two inches away from the seed so as to prevent fertilizer injury to the crop.

Micronutrients in Mixed Fertilizers

Regulations in Michigan permit the addition of micronutrients to any grade of fertilizer which has been licensed. The amount permitted is limited to one of several selections for each plant nutrient. The limitation helps to prevent endless numbers of combinations. At present, the quantities which can be used are:

Boron — ⅛, ¼, ½ or 1.0 percent (1.0 percent equals 20 pounds per ton)
Copper — ½, 1.0 or 2.0 percent
Manganese — 1.0, 2.0 or 5.0 percent
Zinc — ⅛, ¼, ½, 1.0 or 2.0 percent
Molybdenum — .04 or 0.08 percent

If micronutrients are added to a licensed fertilizer, the seller must have attached on the fertilizer sack or sales slip a label or tag bearing a legible statement showing: (1) pounds of the licensed N-P_2O_5-K_2O fertilizer grade per ton, (2) pounds of the additional plant nutrient compounds per ton and (3) guaranteed elemental percent of the added plant nutrients. A typical label would read as follows: This package contains a mixture of the following per ton:

1750 lbs. 6-24-12
nitrogen (N) .... Min. 6%
available phosphoric acid (P_2O_5) .... Min. 24%
potash (soluble K_2O) .... Min. 12%

160 pounds of manganese sulfate — equiv. 2% Mn in mixture

40 pounds of copper oxide — equiv. 1% Cu in mixture

50 pounds of borax equiv. 0.25% B in mixture

2000 pounds TOTAL

Table 2. Percentage of micronutrient suggested in mixed fertilizer as related to the amount of fertilizer applied.

Fertilizer Applications Lbs./Acre	*Pounds of micronutrient desired per acre* 0.5	1	2	4	6	10	20
				percent			
100	½	1	2	5	5	—	—
200	¼	½	1	2	2	5	—
300	¼	½	1	1	2	5	—
400	⅛	¼	½	1	2	2	5
600	—	¼	½	½	1	2	5
800	—	⅛	¼	½	1	1	2
1000	—	—	¼	½	½	1	2
1500	—	—	⅛	¼	½	½	1
2000	—	—	⅛	¼	¼	½	1

In determining the cost of the fertilizer, the billing for the N-P-K material is reduced proportionally to correct the dilution effect of the added ingredients. The charges on the additional micronutrients are then added. In price quotations, the manufacturer often shows the cost of one percent of each of the additional micronutrients in the fertilizer.

All micronutrient recommendations are given in pounds per acre. The amount required in mixed fertilizers will depend upon the application rate of the fertilizer. Values in Table 2 are suggested guides to follow.

MANGANESE

Manganese deficiency in crops is our most common micronutrient problem. The element is sometimes confused with magnesium. The role of manganese in plant nutrition is entirely different from magnesium. Thus, special care should be taken not to confuse the two elements.

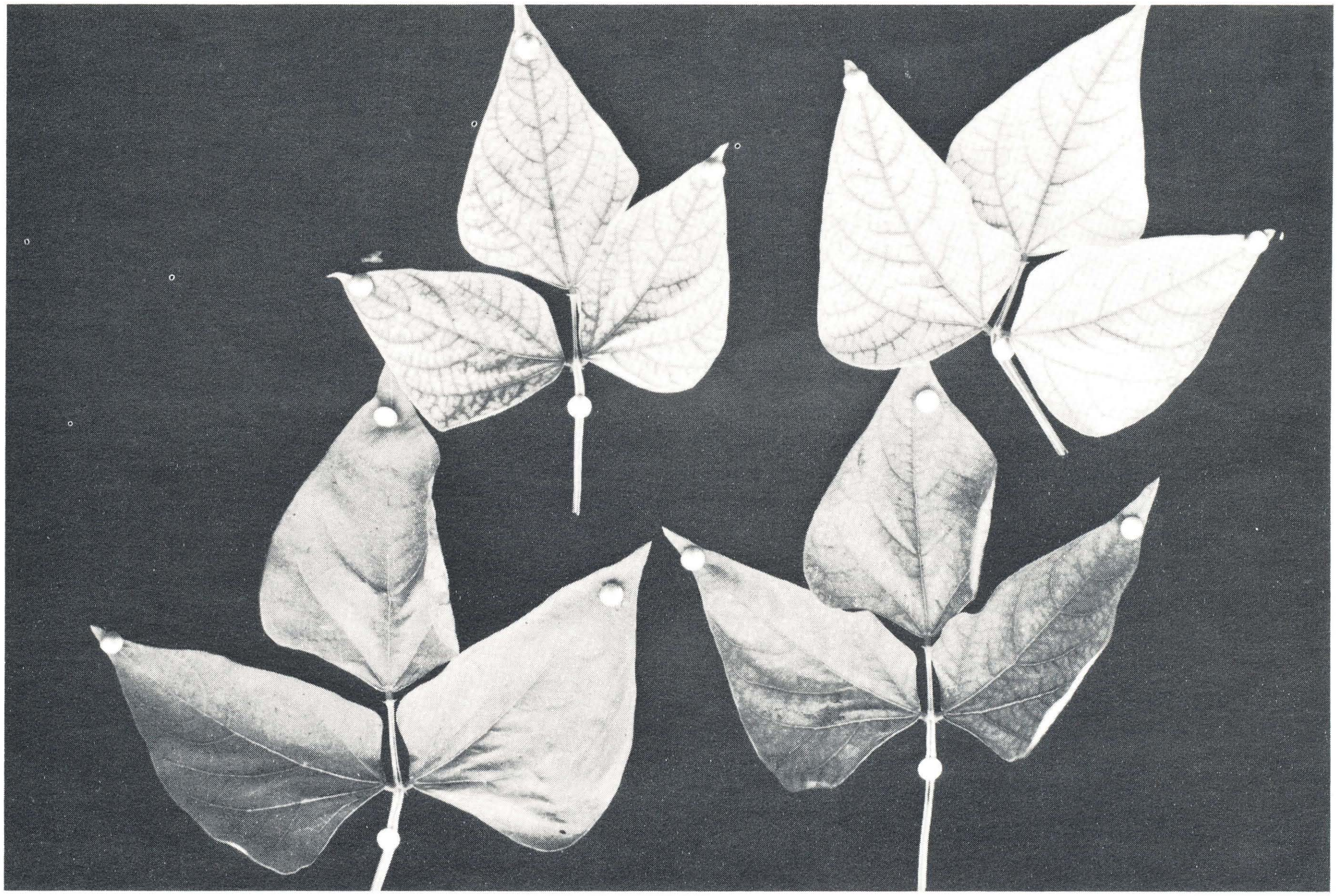

Figure 1 — Manganese deficiency pattern in beans. Lower left, normal leaf; lower right, slightly deficient; upper left, deficient; upper right, severely deficient. Note interveinal yellowing and dark veins in deficient leaves.

Manganese availability is related closely with the intensity of soil acidity. Deficient plants are found growing only on slightly acid or alkaline soils. Soil types on which the deficiency most likely is found are lake beds, glacial outwashes, peats and mucks. These deficient soils are usually dark at the surface and have a gray subsoil color. The deficiency in crops is seldom found on glacial till and moraine soils. Manganese-deficient peats, mucks and dark-colored sandy loams usually have a pH higher than 5.8; the pH of deficient mineral soils is usually about 6.5.

Manganese Deficiency Symptoms

Most crops deficient in manganese are yellowish to olive-green in color. Potatoes show noticable reduced leaf size. Grain crops have a soft, limber growth which often appears diseased. In oats, this may be described as "gray speck." Wheat and barley often show colorless spots. Corn plants do not show a marked symptom but when compared with a normal leaf blade, the deficient leaf is lighter green-colored and has parallel, yellowish stripes. In all grains the deficiency pattern is fairly uniform over the entire plant. Sometimes manganese deficiency is confused with nitrogen deficiency. To help separate the two, you should make a nitrogen tissue test. Manganese deficient plants usually test high in nitrate-nitrogen, even higher than normal.

Manganese deficiency in plants, such as soybeans, beans, sugar beets, celery, cucumbers and cabbage show marked yellowing between the leaf veins; the veins themselves are dark green. This pattern is similar to iron deficiency but is more general over the plant. Iron deficiency is most pronounced on new growths.

Crop Response to Manganese

Crops show differences in response to manganese. For many Michigan crops they are:

High Response	Low to Medium Response
Beans, lettuce, oats, onions, peas, potatoes, spinach, soybeans, Sudan grass, sugar beets, table beets, wheat	Alfalfa, asparagus, barley, cabbage, carrots, cauliflower, clover, celery, corn, cucumbers, grass, mint

Figure 2 — Onions showing severe manganese deficiency in four rows on right side. Onions on left rows received 400 pounds of 6-24-12 containing 2% manganese applied in band 3 inches below seed.

Correcting Manganese Deficiency

Manganese deficiency in crops can be prevented by applying manganese fertilizer in the soil, on the foliage, or making the soil more acid. Steam or chemical fumigation (pasteurization) will also give temporary correction. Generally when manganese is known to be deficient, manganese sulfate or manganous oxide is mixed with the fertilizer and applied in a band near the seed. Commercial manganese sulfate is 20 to 27 percent manganese (Mn) and manganous oxide is usually about 50 percent manganese. Chelated manganese materials are reported to be nearly 10 times more effective than manganese sulfate. However, little information has been obtained on these materials under Michigan conditions.

Table 3. Manganese Recommendations When Applied in a Band Near the Seed or Plant (Does not include chelated manganese)

Soil	*pH Range*	*Pounds of Manganese per acre** *High Responsive Crops*	*Low to Medium Responsive Crops*
Peats, mucks and dark-colored sandy loams	5.8 to 6.4	10	5
	6.5 to 7.2	15	8
	7.3 to 8.5	20	10
Coarse textured	6.0 to 6.4	5	—
All mineral soil	6.5 to 7.2	8	4
All mineral soil	7.3 to 8.5	10	5

*By Michigan Control Regulations, manganese can be mixed in N-P-K fertilizers to contain either 1, 2, or 5% manganese. Thus, an application of 500 pounds of fertilizer containing 2% manganese will supply 10 pounds of the element per acre.

Broadcast application of manganese is not recommended because of high fixation in the soil. Residual carry-over of available manganese fertilizer is usually low. For this reason, treatments are a yearly program for deficient soils. Suggestions for soil treatments are shown in Table 3.

When manganese is needed foliar applications are recommended where: (1) regular fungicide and insecticide sprays are practiced, (2) fertilizer is not applied in a band near the seed, or (3) deficiency symptoms appear on the foliage. The recommended rate is 1 to 2 pounds of manganese per acre (this amount is found in 4 to 8 pounds of manganese sulfate). Use the 1-pound rate if plants are small and the 2-pound

Figure 3 — Poor strip of beans growing over recently installed tile line was caused by a lack of available zinc in the calcareous soil (pH = 7.6).

rate when plants are medium to large in size. For foliar applications, use only spray grades, as certain fertilizer-grade manganese sulfate can easily plug the nozzles. Some fungicides, such as maneb, contain manganese. Such a material often contains sufficient amounts of manganese to correct a deficiency.

Some growers have experienced plant damage from certain combination pesticide - manganese sulfate sprays. Soybeans and other crops have been damaged when 8 pounds of manganese sulfate per acre were applied by air-blast sprayers. To prevent extensive damage, growers should always try out the spray program on a limited acreage. If there is injury it can be detected within 48 hours after application.

Manganese deficiency can be corrected by acidifying the soil with such materials as sulfur and aluminum sulfate. These treatments, because of high costs, are not as practical as is the use of manganese fertilizer. The use of acid-forming nitrogen and phosphorus fertilizers has a beneficial effect on releasing manganese, especially if banded near the plant. A pH reading of soil around the fertilizer band may be one unit more acid than the soil more distant from the fertilizer band. Some of the big boost accredited to band placement of fertilizer has been found to be due to the release of fixed soil manganese.

Excess manganese is a problem in extremely acid soils, especially if the soil is steamed or fumigated. Potatoes growing in acid sandy soils have shown excesses, especially when large rates of a high nitrogen fertilizer such as 12-12-12 have been banded near the seed.

Foliar composition of plant tissue is helpful in diagnosing manganese status. Values less than 25 ppm (parts per million) are usually considered deficient. Readings of 50 to 200 ppm are normal and those over 400 ppm are considered excessive or toxic.

BORON

Boron is one of the essential micronutrient elements necessary for plant growth. The need varies greatly with different crops. Rates required for the responsive crops such as alfalfa, beets and celery can cause serious damage to small grains, beans and cucumbers. Boron deficiency may occur on both alkaline and acid soils but is more prevalent on the calcareous, alkaline soils. Soil types having crop deficiencies are usually the sandy loams, dark-colored sandy loams, peats and mucks.

Boron deficiency in crops shows up as a breakdown of the growing tip tissue or as a shortening of the terminal growth. This may appear as a rosetting of the plant. Internal tisues of beets, turnips and rutabagas show breakdown and corky, dark discoloration.

Boron deficiency and leaf-hopper damage in alfalfa are often confused. The deficiency shows up as a yellowish to reddish-yellow discoloration of the upper leaves, short nodes and few flowers. It will kill grow-

Figure 4 — Plots in the four rows across the field showing immature beans without pods did not receive zinc fertilizer. (Photo courtesy of the Midland County Cooperative Extension Service)

ing tips of alfalfa, and regrowth comes after a new shoot is initiated at a lower axil. Leaf-hopper damage shows up as a "V"-shaped yellowing of the affected leaves and may appear on any or all parts of the plant; the growing tip is usually normal and the plant may support abundant flowers. Often when the soil is dry and plant growth is retarded, both boron deficiency and leaf-hopper injury occur in the same field.

Deficiency in cauliflower shows up as a darkening of the head and is associated with hollow and darkened stems. Hollow stem also can be caused by adverse weather conditions. It usually appears in small spots and may spread until the entire head is discolored.

Crop Response for Boron

Crops show a wide range of response to boron fertilizers. Those which show a response under Michigan conditions are:

High Response	Low to Medium Response
Alfalfa, cauliflower, celery, rutabagas, sugar beets, table beets, turnips	Broccoli, cabbage, carrots, clover, lettuce, parsnips, radish, spinach

The boron recommendations for soil applications are 1.5 to 3 pounds for highly responsive crops and 0.5 to 1 pound per acre for low to medium responsive crops. Corn and tomatoes may benefit from 0.5 pound of boron per acre if it can be broadcast or banded several inches away from the seed or plant. Occasionally certain deficient soils may require up to 5 pounds of boron per acre for cauliflower and red beets. The suggested rate for foliage application is 0.3 pound of boron per acre for high responsive crops and 0.1 pound for medium responsive crops.

How to Use Boron

The boron carrier most used in fertilizers is sodium borate and ranges from 10 to 20 percent boron. "Solubor" is a trade name for a sodium borate that contains 20.5 percent boron. This compound is commonly used as a foliage spray or in liquid fertilizers.

Boron may be mixed with regular N-P-K fertilizer, applied separately on the soil, top-dressed for alfalfa, side-dressed for row crops or sprayed on the plant. Special care should be taken to obtain complete mixing when boron is applied with other fertilizers. Segregation, because of particle size differences, is often a problem. Boron should never be used in combination seedings containing legumes and grass or small grain because of injury to the grass or grain. Boron for the legume should be applied as a topdressing after grass has become well established or the grain companion crop has been harvested. Care should also be taken when fertilizers containing boron are banded near the seed or plant. Spacing of the band should be about 3 inches away from the seed or plant when normal recommendations call for a 2-inch separation.

Boron can be mixed in the fertilizer by the manufacturer to ⅛, ¼, ½, or 1 percent levels. Thus, to obtain 1 pound of boron in a 200-pound-per-acre application, use a fertilizer containing ½ percent boron.

Some residual carry-over of boron into the second or third year has been observed. However, recommended rates of applications to responsive crops have not caused injury to boron-sensitive crops that followed. Exceptions have been noted where rates double the standard recommendations have been used on such crops as cauliflower growing on acid sandy soils. Sensitive crops such as beans and cucumbers which followed were partially stunted. On the other hand, low responsive crops such as corn may benefit from the residual boron applied to previous crops such as alfalfa.

ZINC

Zinc, found in small amounts in plant tissues, is one of the essential elements necessary for plant growth. Recent Michigan research shows a need for zinc on many areas where white pea beans are grown. Corn, onion and barley have shown benefits on some locations. Workers in other states report that Sudan grass, sorghum, tomatoes, potatoes and soybeans have been found responsive.

Soil types associated with the deficiency are usually neutral to alkaline in reaction. The more alkaline the soils the greater is the need for zinc. The deficiency is particularly noticeable on crops growing where calcareous subsoils are exposed by land leveling or erosion, or where subsoil is mixed with topsoil such as after tiling and spoil-bank leveling. Lake bed soils in the Saginaw valley and peats show the greatest need in Michigan. Soil series where zinc deficiency is apt to occur are listed in Table 4.

Observations and field tests show that pea beans following sugar beets often need zinc. Large quantities of phosphorus fertilizer used for sugar beets and the high zinc uptake are believed to cause the problem. Increased use of phosphorus fertilizers in a band near the bean seed also has contributed to the deficiency. Figure 4 illustrates response to zinc.

Table 4. Soil series which often have an alkaline reaction and are apt to need zinc fertilizer for responsive crops.

Series	*Management Group*	*Series*	*Management Group*
Alpena	Ga	Sanilac	2b
Bach	2c	Tappan	2c
Charity	1c	Thomas	2c
Edwards	M/mc	Tobico	5c
Essexville	4/2c	Warners	M/mc
Gagetown	2a	Whittemore	2c
Lupton	Mc	Wisner	2c
Markey	M/4c		

Zinc deficiency varies from year to year. Wet, cool, cloudy weather during the early growth enhances the deficiency. In 1960 considerable trouble in corn was noted in late June but after the soils dried out and warmed up the deficiency disappeared. Crops on poorly drained peats and mucks show a deficiency probably because of restricted root growth.

Deficiency Symptoms of Zinc

Bean plants deficient in zinc emerge light green in color. If it is not too severe, the plants usually recover in about 2 weeks and mature satisfactorily. When it is severe, the area between the veins of the leaves becomes pale green and then yellow near the tips and outer edges. The leaves in early stages are deformed, dwarfed and crumpled and in later stages look like they have been killed by sun scald. On zinc deficient plants the terminal blossoms set pods which drop off and the maturity is much delayed.

Zinc deficiency in corn appears as a yellow striping in the leaves. Areas of the leaf near the stalk may develope a general white to yellow discoloration. In severe deficiency the plants have shortened internodes and the lower leaves show a red streak about ⅓ the way from the leaf margin. Plants growing in dark sandy or organic soils usually show brown or purple nodal tissue when the stalk is split and is particularly noticeable in the lower nodes. Deficiency in onions shows up as a stunting, with marked twisting and bending of yellow stripped tops.

Zinc Fertilizer Carriers

A number of zinc compounds can be used to correct a deficiency. Zinc sulfate, zinc oxide, zinc oxysulfate and zinc carbonate are common inorganic salts. Recent trials with zinc organic compounds — often called chelates — such as zinc E.D.T.A. and zinc N.T.A. — have shown that they are about 5 times more effective than equivalent amounts of zinc found in inorganic salts. The organics, however, have a lower zinc content, which usually range from 10 to 14 percent. The content of zinc sulfate ranges from 25 to 36 percent and zinc oxide from 70 to 80 percent. In field tests granular zinc oxide was not as effective as was the dust formulation.

Figure 5 — (Top) Onion field showing severe zinc deficiency. Soil is a newly developed peat having a pH of 6.8. Photo taken July 6. (Bottom) Same onion field photographed July 28 three weeks after foliar application of zinc sulfate.

Rates and Methods of Application of Zinc Fertilizers

Zinc, to be effective, must be applied early in moist soil and near the seed. Nebraska workers report that it can either be broadcast or banded when mixed with nitrogen materials. Michigan workers prefer band application so as to reduce rates. Mixing zinc with phosphate fertilizers such as 6-24-12 or incorporation with ammonium polyphosphate has proven acceptable. The suggested rates when banded are:

Known Deficient Soils —

Inorganic salts — 3 to 4 pounds of zinc per acre
Organic salts — 0.5 to 0.8 pound of zinc per acre

Possible Deficient Soil or as a Preventive Program —

Inorganic salts — 1 pound of zinc per acre
Organic salts — 0.2 pound of zinc per acre

Because of the two types of zinc carriers available — inorganic and organic — Michigan regulations permit a number of selections for zinc that can be registered in mixed fertilizers. The amounts permitted are ⅛, ¼, ½, 1 or 2 percent zinc. An application of 600 pounds of fertilizer containing ½ percent zinc will supply 3 pounds of zinc.

Figure 6 — Cauliflower without molybdenum was a complete failure when grown on a soil high in bog iron. In early stages the deficiency symptom appears as crinkling and mottling and marginal leaf scorching. In later stages the deficiency is known as "whiptail."

Based upon present information, seed treatment with zinc oxide is not recommended. Tests have shown that 1 pound of zinc per acre from zinc oxide on bean seed showed reduced emergence and yields in most locations.

Side-dressed applications of zinc after the crop has emerged have not been too effective. If a zinc deficiency problem is diagnosed after emergence of the crop, spray the foliage with 1 to 2 pounds of zinc sulfate per acre. The solution should not exceed 5 pounds of the salt per hundred gallons of water. This is about ½ percent solution. Response to spray application is usually obvious in 10 days. It may be apparent in 5 days if the treatment is applied when the plants are in a vigorous state of growth. Plants with waxy leaves such as onions may need a wetting agent in the water to obtain good foliage cover. Figure 5 illustrates recovery of onions following a zinc spray application.

Conflicting results have been obtained with spraying some crops such as corn, onions and potatoes. It may be poor transfer of zinc down into the roots which also need the element to perform their functions. If foliage sprays are used, apply them early to obtain best results.

Some fungicides such as zineb, "M-45," and tank-mix nabam and zinc sulfate contain zinc. No doubt where these materials are used as a foliage treatment they will also help correct zinc deficiency.

Zinc Carry-Over

Residual response in calcareous (alkaline) soils is practically none. This is because of high fixation of zinc. In acid soils zinc tends to remain in an available form. At present it is not known how long the 3- to 4-pound rate of application is needed on responsive soils. Possibly after several years of treatment the rate of zinc can be dropped to 1 pound per acre.

Soil and Plant Tissue Test for Zinc

Soil tests have been developed to determine available zinc in the soil but because of limited interest and rather elaborate care necessary to make the tests, the method has not been adapted for general routine soil tests. (The University of Nebraska does make the tests for a small fee.) Plant tests can be used to help diagnose a critical or near critical level of zinc. Tissues containing less than 20 parts per million of zinc are often deficient, values of 30 to 100 parts a million are normal and values over 300 parts per million are considered excessive to toxic. Several commercial and state laboratories are available to determine the zinc content in plant materials.

Figure 7 — Molybdenum deficiency in onions. Note dead tips of leaves. Below the dead tip, the leaf shows an inch or two of wilting, flabby formation.

MOLYBDENUM

Molybdenum, an essential micronutrient for plant growth, ranges from 0.8 to 5.0 parts per million in normal tissue. Some plants have even been found to contain as high as 15 parts per million. Deficient plants usually contain less than 0.5 parts per million. Certain nonresponsive crops such as grass may contain as low as 0.1 part per million. The responsive crops are cauliflower, broccoli, lettuce, onion, spinach, soybean and clover. Very few soils in Michigan show a need for molybdenum fertilizers. Those that do are fibrous peats and acid sandy soils. The sandy soils are the type commonly used for potato production and then are used for growing cauliflower, soybean and clover. Peats and mucks that contain high amounts of bog iron often need molybdenum for normal plant growth.

Molybdenum deficiency in clover shows up as a general yellow to greenish-yellow color of the foliage, stunting and lack of vigor. The symptoms are similar to those caused by nitrogen starvation. Early stages of the deficiency in cauliflower and broccoli appear as a marginal scorching, a rolling or curling upward and a withering and crinkling of the leaves. (See Figure 6.) In later stages of growth the deficiency shows up as "whiptail" especially in the younger leaves. Older leaves show marked yellow mottling between the veins and a crinkling of the leaves. In onions it shows up as a dying of the leaf tips. Below the dead tip the leaf shows an inch or two of wilting and flabby formation. (See Figure 7.) As the deficiency progresses, the wilting and dying advances down the leaves. In severe cases the plant dies.

The usual carriers of molybdenum are sodium or ammonium molybdate. These salts contain about 40 percent of the element.

How to Control the Disorder

Molybdenum deficiency can best be corrected by seed treatment. Dissolve one-half ounce of the molybdate compound in 3 tablespoons of water and mix with sufficient seed to plant 1 acre. Do not use excess water as this can cause the solution to penetrate the seed embryo and cause injury. Mix the seed thoroughly and let dry. It may be advisable to use some suitable fungicide dust to help dry the seed. Suppliers of the molybdate compound often sell the product in 2-ounce packages. This will treat 4 acres.

Foliar sprays may be used by applying 3 to 4 ounces of the compound per acre. Use wetting agents in the spray when applying the solution to cauliflower or onions.

Soil acidity has a marked influence upon the need for molybdenum; the greater the acidity, the greater is the need for molybdenum. Research plots on a Montcalm sandy soil showed that molybdenum content of cauliflower was increased 5 fold by liming from pH 4.9 to pH 6.7. In a Houghton muck the content of molybdenum increased over 3 fold when the pH was raised from 5.4 to 7.2. Liming severely deficient soils, however, will not completely correct the deficiency.

COPPER

Copper is one of the essential micronutrients necessary for growth. Normal plants contain about 8 to 20 parts per million and deficient plants usually contain less than 6 parts per million. In each ton of dry hay there is only about 0.002 pound of copper. However, without this element all crops fail to grow. Fortunately, most of the soils of Michigan are sufficiently supplied with copper. Peaty soils low in ash are about the only ones with a deficiency. Where the problem does appear in mineral soils it will be most likely on acid sandy soils which have been cropped heavily and liberally supplied with N-P-K fertilizers. Copper applied to soil is not easily leached nor is it much used by the crop. For this reason no further copper fertilization is needed on peats and mucks if a total of 20 pounds per acre has been applied to low responsive crops and 40 pounds per acre for high responsive crops.

Copper deficiency in many plants shows up as wilting and eventual death of the leaf tips. In grain the leaves are yellowish in color and the leaf tips show a disorder similar to frost damage. Carrot roots, wheat grain and onion bulbs show poor pigmentation. Responsive crops are alfalfa, oat, barley, wheat, carrot, lettuce, onion, spinach, Sudan grass and table beets. For information on response by other crops see Extension Bulletin E-159. Rates of copper commonly used in highly responsive crops are 3 to 6 pounds per acre depending upon pH. These rates should be doubled on fields that had never received copper.

Common carriers of copper are the sulfate and the oxide. Copper sulfate has a blue color and can easily be identified in most fertilizer mixes. It has a copper content of about 25 percent. Copper oxide has a copper content of 60 to 80 percent. In field tests, copper oxide, a brown material, is as effective as copper sulfate.

Michigan control regulations permit the use of ½, 1 and 2 percent copper in mixed fertilizer.

IRON

Iron deficiency in field and vegetable crops is not common in the eastern states. It is a problem in the western states where the soils contain considerable sodium and calcium. In Michigan, woody plants such as pines, pin oaks, roses, certain ornamentals and acid-demanding plants such as blueberries, azaleas and rhododendrons may need iron. Lawns and particularly putting greens on golf courses sometimes show a lack of iron for grass because of high pH and high levels of phosphorus. Putting greens made from an excess of coarse sand and acid peat often develop iron deficiencies.

Iron deficiency in many woody plants appears when they are grown in soils low in organic matter and high in pH. Mixing in organic materials such as manure or acid peat will help increase the availability of the iron.

The use of sphagnum moss peat in mixtures with sand, perlite or vermiculite intensifies the need for iron fertilizers for the production of petunias, snapdragons, tomatoes and other bedding plants. This has been widely experienced during recent years.

Correcting Iron Deficiency

It is difficult to correct iron deficiency in plants with soil applications when soils are alkaline. Under such conditions foliage sprays are recommended. Use iron sulfate, iron chelates, iron citrate or "Nu-Iron" according to supplier's recommendations. For iron sulfate this is usually about 1 to 2 pounds of the salt in 100 gallons of water. Wet foliage thoroughly. Soil applications are effective if soils are acid or neutral in reaction. Iron chelates, though more expensive than iron sulfate, persists for longer periods of time. "Nu-Iron" is recommended for soil mixes for bedding plant production at the rate of 4 to 8 ounces per cubic yard of soil.

To help prevent an iron problem do not use excessive amounts of lime or phosphate. Apply chemicals or fertilizers to increase the soil acidity and add organic matter.

Cooperative extension work in agriculture and home economics. Michigan State University and the U. S. Department of Agriculture cooperating. N. P. Ralston, Director, Cooperative Extension Service, Michigan State University, East Lansing. Printed and distributed under Acts of Congress, May 8 and June 30, 1914.

1P—11-64—15M—JH