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**MICRONUTRIENT SHORTAGES**

# Micronutrient Deficiencies in the United States

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**The Trace Element Committee of the Council on Fertilizer Application has listed the known micronutrient deficiencies, by crop, as reported by research workers in each of the 50 states. The results show these deficiencies to be widespread with boron being reported as deficient in one or more crops in 41 states, copper in 13, manganese in 25, molybdenum in 21, iron in 25, and zinc in 30. Boron-deficient alfalfa was reported in 38 states, and zinc-deficient corn in 20. Crop needs for micronutrient elements are expected to continue to increase in the future. The areas of micronutrient deficiencies within the state are generally quite limited and are not nearly as extensive as are the areas of deficiencies of nitrogen, phosphorus, and potassium. Promiscuous use of micronutrient elements as a soil application should not be encouraged because of the dangers of building up toxic quantities of these elements.**

THE RECOGNITION of the need of micronutrient applications to crops becomes greater each year because more research is being done on micronutrients, soils are becoming more depleted in them, and crop yields are increasing throughout the U. S. For example, in Wisconsin, copper and zinc were sufficient at a 100-bushel level of corn. Increasing major nutrient element fertilization increased the yield about 25 bushels per acre. The addition of 2 pounds of copper oxide and 10 pounds of zinc sulfate further increased the yield by 16 bushels.

The Trace Element Committee of the Council on Fertilizer Application surveyed the micronutrient needs by crops in the U. S. The results obtained for boron, copper, iron, manganese, molybdenum, and zinc are presented here. All 50 states reported in answer to a questionnaire. The results of the survey listing the micronutrient deficiencies by crop for each state are given in Figures 1 to 6.

For the most part, areas of micronutrient deficiencies within the state are too widely scattered to be delineated. However, in some instances, deficiencies are relatively isolated to a few soil types and are well defined. In some states, peat and muck soils are deficient in one or more of the micronutrient elements for all crops grown. A general recommendation is usually given for all vegetable crops on these soils.

### Boron

Boron deficiencies, reported in 41 states, are the most widespread of all micronutrient deficiencies (Table I). States having boron deficiency are shown in Figure 1. Alfalfa, reported boron deficient in 38 states, leads all crops for all micronutrient deficiencies reported (Table II). Boron deficiencies occur largely in more humid regions of the country and are not reported in arid regions of low rainfall where boron contents of soils and waters are high.

**Table I. States Reporting Micronutrient Deficiencies in One or More Crops**

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

**Table II. Extent of Micronutrient Deficiencies in United States**[a]

| *Crop* | *States* | *Crop* | *States* |
|---|---|---|---|
| BORON | | COPPER | |
| Alfalfa | 38 | Corn | 3 |
| Beet | 12 | Fruit trees | 3 |
| Celery | 10 | Grasses | 3 |
| Clover | 13 | Onion | 7 |
| Cruciferae | 25 | Small grains | 4 |
| Fruit trees | 21 | MANGANESE | |
| IRON | | Bean | 13 |
| Bean | 5 | Corn | 5 |
| Corn | 3 | Fruit trees | 9 |
| Fruit trees | 11 | Small grains | 10 |
| Grasses | 7 | Spinach | 8 |
| Shade trees | 7 | ZINC | |
| Shrubs | 11 | | |
| | | Bean | 7 |
| MOLYBDENUM | | Corn | 20 |
| Alfalfa | 13 | Fruit trees | 12 |
| Clover | 6 | Nut trees | 10 |
| Cruciferae | 9 | Onion | 4 |
| Soybean | 3 | Potato | 3 |

[a] Deficiencies also observed on many other crops but with less frequency.

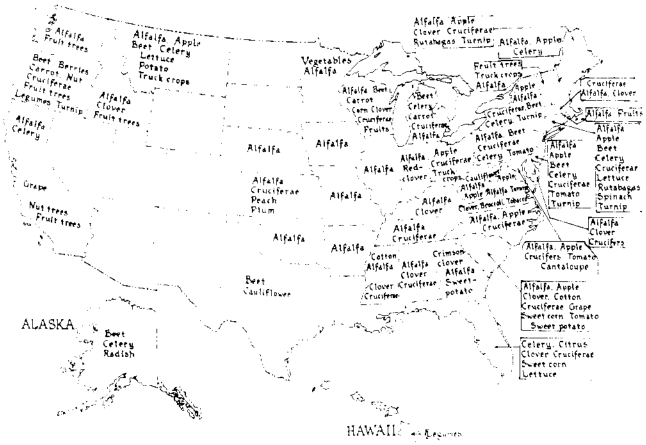


Figure 1

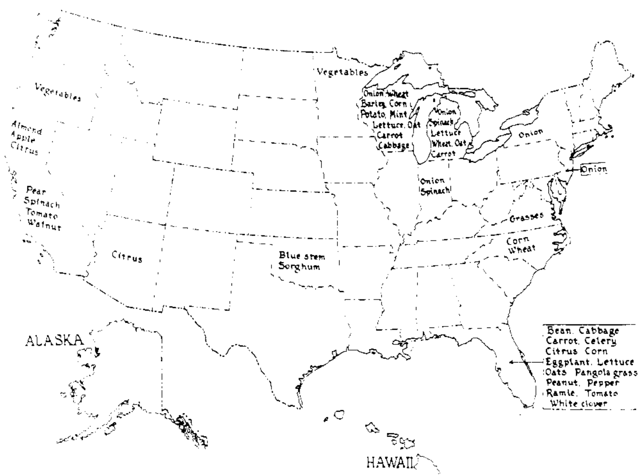


Figure 2

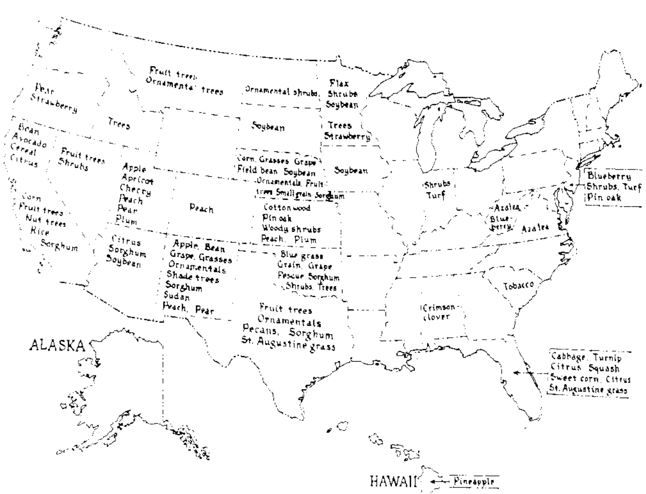


Figure 3

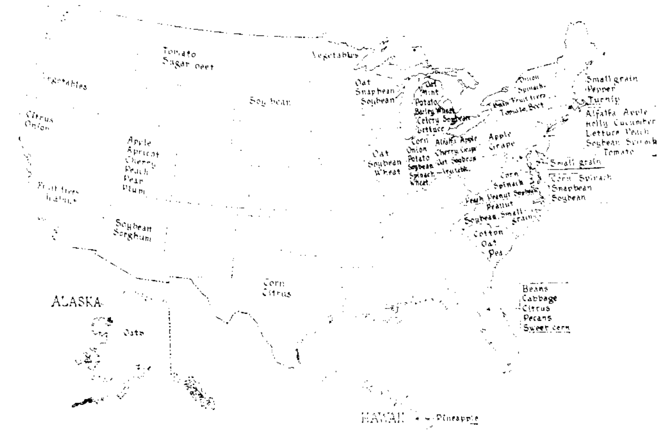


Figure 4

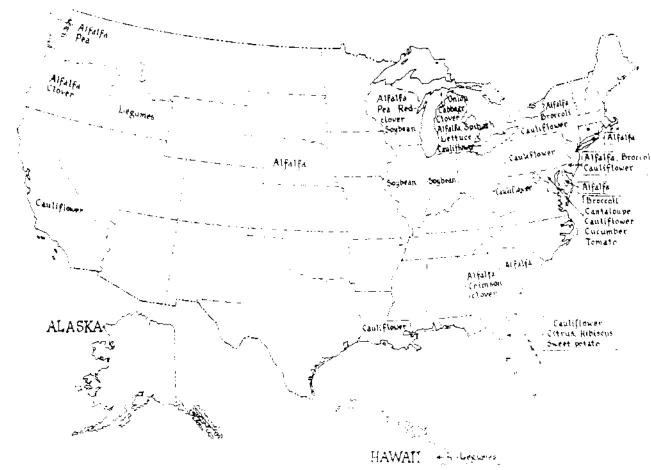


Figure 5


Figure 6

Available boron is easily leached from the soil. In the humid region, boron deficiencies frequently occur on highly leached soils and on most alkaline soils. While tourmaline is the main boron mineral in soils, a large part of the total boron in soils is held in the organic matter. The available boron is largely released from the organic matter by microbial action. Thus, intermittent boron deficiencies frequently appear in many soils. In periods of drought, boron deficiencies appear because of a lack of microbial action to release boron from the organic matter, largely contained in the plow layer. While in times of adequate moisture on the same soil, enough boron will come available so that the same crop does not show the deficiency.

Boron-deficiency symptoms are frequently quite striking. Because boron is immobile in plants, the youngest growing part of the plant is influenced first.

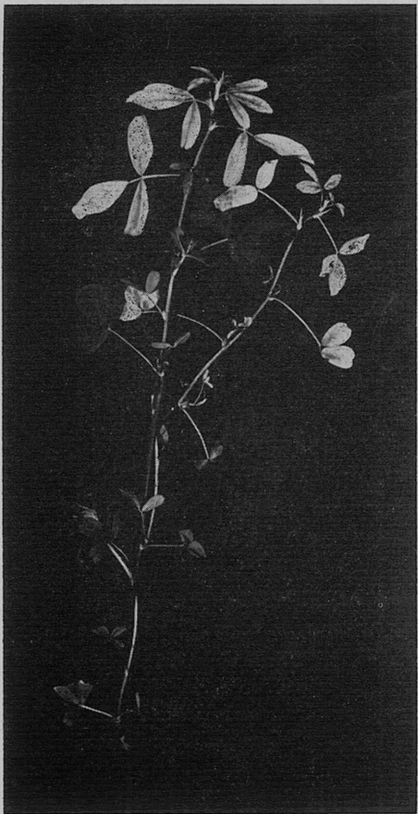

Figure 7. Boron-deficient alfalfa

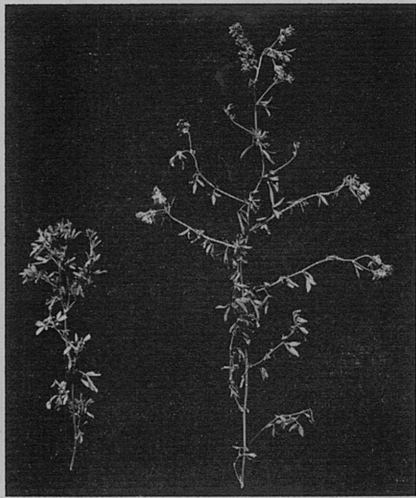

Figure 8. Boron-deficient alfalfa (left) and healthy (right)

Same number of internodes in both plants

Figure 9. Zinc-deficient corn plant

Figure 10. Corn response to zinc

Left row received 10 pounds of zinc sulfate per acre plus 400 pounds of 4–16–16. Center row, short corn, 400 pounds of 4–16–16 without zinc.

In alfalfa, internodes are greatly shortened by lack of boron, blossoms drop or do not form, and stems are short. Upper leaves turn yellow or red in color. The lower part of the plant that may have received an adequate amount of boron will frequently contain twice as much boron as does the upper part of the plant. Boron-deficient alfalfa as compared to healthy is shown in Figures 7 and 8. Boron deficiency often results in death of cells in the merismatic region resulting in necrotic areas in the roots of beets, turnips, and rutabagas, or in die back and little leaf of fruit trees.

Boron deficiencies are corrected by soil application of borax, fertilizer borate, and ground, borated glasses. Boron deficiencies in trees are frequently corrected by spray applications of borax. Boron deficiencies probably cover the greatest acreage of any micronutrient deficiency. In Wisconsin, nearly two million acres of alfalfa show boron deficiency at one time or another during the growing season.

### Copper

Copper deficiency is apparently the least widespread and is reported in 13 states (Figure 2). In a number of states, it is found mainly on peat and muck soils. Copper deficiencies are reported in seven states for onions, in four states for small grains, and in three states for corn, fruit trees, and grasses (Table II). A number of other vegetable crops also show copper deficiency. With corn and small grains, severe deficiency first appears in the youngest leaves at any early stage of growth. Upper leaves of corn show a light, yellow-green color, with the tip of the leaf becoming necrotic and dying. This area finally breaks and hangs down as a dry, twisted portion. With slight deficiency, the upper leaves dry at the margins near the base of the leaf. Copper deficiencies are usually corrected by applications of copper sulfate or copper oxide.

### Iron

While many micronutrient deficient areas are found in more humid regions of the country, iron deficiency is found to a larger extent in more arid regions because of the decrease in availability of iron in alkaline soils (Figure 3). Iron deficiencies are reported in 25 states, most frequently with fruit trees, shrubs, and shade trees (Table II). Iron deficiencies are commonly alleviated by spray applications of iron sulfate or iron chelate materials.

### Manganese

While soil manganese also becomes less available in alkaline soils, many states in more humid regions of the country report manganese deficiencies often on peat and muck soils and on local areas on alkaline soils. Twenty-five states report manganese deficiency (Figure 4). Manganese deficiencies are frequently corrected by spray applications of manganese sulfate, usually 5 to 10 pounds per acre. Manganese sulfate is also applied to the soil at rates of from 20 to 150 pounds per acre. Manganous oxide is also used to correct manganese deficiencies. In alkaline soils, an acid-forming material, usually fertilizer, is applied to prevent fixation of the applied manganese.

### Molybdenum

Of the six micronutrient elements reported here, molybdenum was the last to be considered essential for crop growth, but deficiencies are now reported in 21 states (Table I). The number of crops reported to be deficient in molybdenum is less, however, than for any other micronutrient element (Table II and Figure 5).

In highly acid soils, molybdenum is sometimes fixed in an unavailable form thus causing deficiencies, particularly for legumes. The amount of molybdenum in soils and the amount required by plants is very small. In addition to sodium molybdate soil application of 0.5 to 2 pounds per acre, a commercial seed coating preparation (Molygro) for some legumes applied at about 2 ounces per acre, is used to correct deficiencies. Broadcast applications are best mixed with limestone on very acid soils to prevent fixation.

### Zinc

The 30 states reporting zinc deficiency are shown in Figure 6: Recognition of zinc deficiency in corn, in many states, is recent and again shows the influence of higher yields on the greater need for micronutrient elements.

Deficiency in corn causes a shortening of the internodes of corn and a severe stunting. A typical zinc-deficient plant is shown in Figure 9. When the deficiency is severe, many corn plants will die in the seedling stage, with those recovering exhibiting several different colorations and symptoms ranging from a lack of green color in the upper leaves to interveinal striping in the upper leaves. Severe zinc deficiency in corn is known as "white bud."

Zinc deficiencies are corrected by soil applications of zinc sulfate and zinc chelates in the case of row crops, and by spray as well as soil applications for trees. Responses to zinc application are often marked (Figure 10). Yield increases as large as 30% have been obtained with the application of zinc, without deficiency symptoms being present.


### *Acknowledgment*

This report was prepared in cooperation with Leon Chesnin, John G. A. Fiskell, F. H. Gilbert, S. W. Melsted, W. F. Mierke, and R. P. Thomas, members, Trace Element Committee, Council on Fertilizer Application.

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## Correction

### Phosphine Residues from Phostoxin-Treated Grain

In this article by R. B. Bruce, A. J. Robbins, and T. O. Tuft [J. Agr. Food Chem. **10,** 18 (1962)], the following corrections should be made on page 20:

Column 1, line 7: (Table IV) should read (Table III). Column 3, line 4: maximum of 0.023 p.p.m. in one sample should read maximum of 0.029 p.p.m. in one sample. Column 3, line 6: (Table V) should read (Table IV). Column 3, fourth full paragraph, line 2: in Table II should read in Table V.

**MICRONUTRIENT SOURCES**

# Metal Ammonium Phosphates as Fertilizers


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A number of divalent metals including magnesium, iron, zinc, copper, and manganese form ammonium phosphates having the general formula $MeNH_4PO_4.xH_2O$. These compounds are very slightly soluble in water and soil solutions. They are effective sources of nitrogen, phosphorus, and metals for plants through both foliar and soil application. When properly granulated they can be applied to soil at rates greatly exceeding those of conventional fertilizers without danger of burning plant roots, and they continue to furnish nutrients over long periods of time. In pulverized form, they may be applied to leaves of plants at high rates without burning.


Several divalent metals form ammonium phosphates having the general formula $MeNH_4PO_4.xH_2O$ (*3*). The most familiar of these compounds is magnesium ammonium phosphate. Others are the iron, zinc, manganese, copper, and cobalt ammonium phosphates. The most common form is the monohydrate. All are only slightly soluble in water.

The slight solubility of these compounds suggested their use as nonburning and long-lasting sources of nitrogen, phosphorus, and metals. Magnesium ammonium phosphate has been mentioned as a possible fertilizer material (*2, 10–12*), but has never been commercially available or widely used for fertilizer purposes. Magnesium ammonium phosphate is present in certain natural fertilizers such as guano (*12*). The other metal ammonium phosphates have not been used as fertilizers.

The present work has shown that metal ammonium phosphates when properly granulated are nonburning to plants even when applied at extremely high rates, and they can be used to supply plant nutrients over predetermined periods of time by control of their particle size. They can be used effectively for either soil or foliar application.

These special properties of the metal ammonium phosphates make them particularly suitable in uses where conventional fertilizers are inefficient, burning is a problem, and long residual effects are desired. Applications include fertilization of ornamentals, orchards, nurseries, forest outplantings, turf, highway plantings, certain other crops, and seed coating.

### *Chemical and Physical Properties*

**Composition of Pure and Fertilizer Grade Compounds.** The metal ammonium phosphates of interest as fertilizers are listed in Table I. All (except the molybdenum compound) exist as

**Table I. Theoretical Composition of Metal Ammonium Phosphates**

| Compound | Color | Mol. Wt. | % N | % $P_2O_5$ | % Metal | % Ignition Loss |
|---|---|---|---|---|---|---|
| $MgNH_4PO_4.6H_2O$ | White | 245.43 | 5.71 | 28.92 | 9.91[a] | 54.65 |
| $MgNH_4PO_4.H_2O$ | White | 155.35 | 9.02 | 45.69 | 15.65[b] | 28.36 |
| $FeNH_4PO_4.H_2O$ | Green | 186.881 | 7.50 | 37.98 | 29.89 | 19.29 |
| $ZnNH_4PO_4$ | White | 178.395 | 7.85 | 39.79 | 36.65 | 14.60 |
| $MnNH_4PO_4.H_2O$ | Pink | 186.023 | 7.53 | 38.16 | 29.53 | 23.68 |
| $CuNH_4PO_4.H_2O$ | Blue | 194.571 | 7.20 | 36.48 | 32.66 | 22.64 |
| $CoNH_4PO_4.H_2O$ | Purple | 189.971 | 7.37 | 37.36 | 31.03 | 23.25 |
| $(NH_4)_3[P(Mo_3O_{10})_4]$ | Yellow | 1876.50 | 2.24 | 3.78 | 61.36 | 4.16 |

[a] 16.43% MgO. [b] 25.95% MgO.