THE PLACE OF MICRONUTRIENTS IN SOIL MANAGEMENT

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Although these nutrient elements are required in a lesser amount than the major nutients, they frequently are of major importance in efficient crop production. The micronutrients are required in measurable proportions rather than in true trace quantities. Therefore, the accepted term has become micronutrient, implying that the required amounts of these nutrients are generally small in comparison with crop demand for macronutrients.

The 16 nutrient elements shown to be essential for plant growth are categorized in the following table.

			Micronutrients	
	Major	Secondary	Cation	Anions
C carbon	N nitrogen	Ca calcium	Zn zinc	B boron
H hydrogen	P phosphorus	Mg magnesium	Fe iron	Mo molybdenum
O oxygen	K potassium	S sulfer	Mn manganese	Cl chlorine
			Cu copper	

The average quantities of the various essential nutrient elements generally found in plants is given in the following table on the basis of the number of molecules of each element present per each molecule of Mo present.

RELATIVE MOLECULAR RATIO OF PLANT NUTRIENTS

After Stout

Mo	1	P	30,000
Cu	100	Mg	variable
Zn	300	K	4,000,000
Mn	1,000	Ca	variable
Fe	2,000	N	1,000,000
B	2,000	H	variable
Cl	3,000	O	variable
S	30,000	C	30,000,000

RANGE IN SOILS

Element	Lbs/A	Element	Lbs/A
Mo	1-7	S	200-3,000
Cl	0-74	Mn	100-10,000
Cu	2-400	Mg	1,000-20,000
B	20-200	Ca	1,000-500,000
Zn	20-600	Fe	10,000-200,000

Many soils contain adequate amounts of the three secondary nutrients or they are added indirectly when liming and through normal fertilization practices, so that less emphasis has been placed on the addition of these plant nutrients than on the major nutrients. Adequate supplies of sulphur are brought down by rainfall in many areas.

Calcium in plants is found as a part of the middle lamella (as ca-pectate) which tends to cement the cells together. Calcium functions in plants are closely associated with the growth of apical meristems and reproduction processes.

Calcium is not very mobile from one part of the plant to another, therefore, a deficiency is first observed in the young growing tissue. The exact symptoms of a deficiency may vary from one plant species to another. As a rule, the growing point or bud fails to develop or takes on a curly top or rosetted appearance.

An excess of readily available calcium does not appear to have any harmful effect on plant growth although it may tend to reduce the uptake of potassium and magnesium. Calcium is absorbed in the uncombined form (Ca^{m}).

Magnesium is a constituent part of the chlorophyll which gives plants their green color. Small amounts of magnesium are also found in seeds and in other parts of the plant where it acts as an activator for plant enzyme systems necessary for the utilization of phosphorus.

The lack of magnesium results in a deficient amount of chlorophyll and thus a loss of green color in the plants. Since magnesium can be removed from the older leaves to the new growing leaves, deficiencies are usually observed first on the older or lower leaves. Although the appearance of magnesium deficient leaves differs some between plant species, often the leaf tissue between the veins turns reddish purple while the veins remain green. This is commonly observed on magnesium deficient cotton. If the deficiency continues, the leaves gradually turn brown and are shed.

An excess of magnesium is not normally harmful to plant tissue but may indirectly affect plant growth by reducing potassium and calcium uptake. Magnesium is absorbed in the uncombined form (Mg^{++}).

Sulphur is a part of some important amino acids, proteins, and other essential plant compounds. It is important also for nodule formation and nitrogen fixation by roots of legumes. Sulphur compounds in onions and garlic are responsible for their characteristic odor.

Sulphur deficiency is generally characterized by a loss of green color in the leaves. Sulphur has rather limited translocation, therefore, the pale green usually appears on the younger leaves of new growth.

Most of the sulphur is taken into the plants from the soil as the sulfate ion $(SO4)$. Sulphur dioxide gas from smoke in the air can be absorbed through the leaves as SO_2. Excessive amounts of SO_2 gas such as near smelters are toxic and kill plants thus denuding the landscape of vegetation. Sulphate (SO4) in excess of that needed for growth can accumulate in plants without harmful effects.

Micronutrients - zinc, iron, boron, manganese, copper, molybdenum, and chlorine are required in relatively small amounts varying from a few ounces to a few pounds per acre in available forms. In general, the functions of these elements are closely associated with enzymatic reactions in the plant metabolism, even though their roles are rather obscure. The form in which the micronutrients are absorbed and more specific plant functins are as follows:

- Zn^{++} Important in the formation of auxins.
- Fe^{++} Although not a part of chlorophyll, required for its formation and vital in respiratory systems.
- $BO_3^{\equiv}$ and others - Affects the maturation and differentiation of cells and the formation of cellular tissue.
- Mn^{++} Necessary for oxidation-reduction enzyme systems.
- Cu^{++} Necessary for oxidation-reduction enzyme systems.
- $MoO_4^{=}$ Activates nitrate reducing enzymes and affects nitrogen fixation by nodules.
- Cl^{-} Vital in chlorophyll phosphorylation.

DEFICIENCY SYMPTOMS

Zinc yellowing or chlorosis between the veins progressing to a broad bleached strip on corn and sorghum leaves with the green color lost from the veins also within the bleached strip. A general bronzing or brown spots occur on cotton and bean leaves and often a pronounced interveinal chlorosis appears. Leaves become thick and brittle with the margins cupped upward. Shortened internodes may impart a bushy appearance as is common in pecan "rosette." Symptoms generally appear on the young leaves early in the growing season.

Iron is very immobile in plants and cannot be transferred from old leaves to new growth, therefore, the new growth becomes yellow on Fe deficient plants. Iron deficiency symptoms are most always manifest as uniform yellowing or chlorosis between the veins. On plants of the grass family such as sorghum or corn, this yellowing between the green veins leaves a very conspicuous striped pattern.

Boron is not very mobile in plants, thus, the new growth is affected by deficient quantities. Buds or growing tips may have red or yellow discoloration or a bushy rosetted appearance. Internal damage in vegetable crops is common as "brown-heart."

Manganese deficiencies cause interveinal chlorosis of the younger leaves and often small dead specks appear on the leaves such as the "gray speck" disease of oats. Cotton leaves show a netted appearance with green veins and chlorotic interveinal tissue.

Copper deficiency is not often observed and has not been well defined. Symptoms generally appear on younger plants as yellowing of youngest leaves. The leaves of small grains become shriveled, twisted and broken.

Molybdenum deficiency causes the young leaves to wilt and die along the margins. It is seldom observed in the United States. "Whiptail" in cauliflower has been associated with molybdenum deficiency.

Chlorine deficiencies have not been observed under field conditions.

DEFICIENT CROPS

Zinc – beans, corn, sorghum, flax, pecan, fruit and citrus trees.
Iron - Sorghum, corn, beans, fruit-citrus-shade trees, ornamental shrubs, and grasses.
Boron – alfalfa, cotton, vegetable and root crops, clovers, and fruit trees.
Manganese - small grains, corn, cotton, citrus, and vegetable crops.
Copper - cereal crops, vegetable crops, fruit-nut-citrus trees, and sometimes on alfalfa.
Molybdenum – alfalfa, clovers, citrus, soybeans, and vegetables particularly cauliflower.

Factors affecting availability and control measures:

Zinc deficiencies often occur on alkaline soils with high pH levels. An abundance of $CaCO_3$ seems to reduce the availability of zinc in the soil. In many instances high phosphate levels in a soil or phosphate applications have induced zinc deficient conditions.

Zinc deficiencies can be corrected by foliar applications, but preferably by soil applications of 10 to 20 pounds of $ZnSO_4$ per acre or equivalent quantities from other sources.

Iron deficiencies are very common on alkaline soils throughout Texas. Chemical tests of the total Fe in soils is of no value because it tells you nothing about how much is available. The application of Fe through the soil is very inefficient in alkaline soils, however, a good response can usually be obtained from foliar sprays of 2 to 3% $FeSO_4$ in water particularly on sorghum, corn, and bean crops.

Boron is released from certain soil minerals in small quantities and its availability decreases with increase in pH. However, only a small amount of boron is usually required and there is a narrow range between deficiency for some plants and a toxicity for others. Consequently, some discrimination should be used in applying boron fertilizers.

Manganese availability increases as soils become more acid. Manganese toxicities occur on extremely acid soils and under poor aeration conditions. This situation is quite easily remedied by liming to a higher pH thus the Mn becomes less available. Deficiency conditions in neutral or alkaline soils can generally be corrected by foliar or soil applications of $MnSO_4$ or chelated Mn at rates appropriate for the specific crop.

Copper, although generally present in relatively small quantities in most soils, is seldom inadequate for plant requirements. Because of the narrow range between deficiency and toxicity, Cu toxicities have been common in areas where fungicides etc. containing Cu have been applied over several years. Copper tends to accumulate in the soil and remain longer than some other nutrient elements. Where Cu deficiencies have occurred, applications of copper sulphate have been effective.

Molybdenum availability increases as soils become more alkaline, thus Mo deficiencies have not been prevalent on such soils. Materials commonly used as sources of Mo are ammonium molybdate, sodium molybdate solubor, etc. Small quantities of Mo as a seed coating or a few ounces per acre applied to the soil have satisfactorily corrected most cases.

Good reference book is "Hunger Signs in Crops" by Howard B. Sprague, editor. Published by David McKay Company, New York, N.Y.