EFFECTS CF MLCRO-NUTRIENT ELEMENTS ON FOREST NURSERY SEEDLINGS

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INTRODUCTION

Green plants, when growing in soil, absorb all minerals which are present in an available form. A majority of today's known elements have been found in plant tissue. However, it was not until the middle of the last century that plant physiologists began to formulate and understand the essential element concept. During this period, basic concepts wore established which indicated that plant dry matter was mainly made up of carbon, oxygen, and hydrogen. The remaining dry matter, constituting about 10%, was composed of minerals absorbed from the soil.

To date some thirteen elements supplied by the soil are considered essential for plant growth. Of the thirteen elements, six are used in relatively large quantities and aro termed macro-nutrients or primary elements. They are nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. The other nutrient elements are used by higher plants in very small amounts and are called micro-nutrients, trace elements, minor elements, or secondary elements. They are iron, manganese, copper, zinc, boron, molybdenum, and chlorine.

Except for iron, trace elements are found sparingly in most soils and their availability to plants is often very low (Table 1). Consequently even though the removal by plants is small for any given year, the cumulative effects of crop production over a period of years may rapidly reduce the limited stores originally present. The three general soil situations where micro-nutrients are most apt to be a problem are: (1) sandy soils; (2) organic soils; (3) very alkaline soils. This is due to the relatively small amounts of micro-nutrients in sands and organic soils and to the low availability of most of the trace elements under very alkaline conditions.

FUNCTIONS AND DEFICIENTY SYMPTOMS OF T1 VARIOUS TRACE ELEMENTS

Most of the research on the roles of the various trace elements has been done with herbaceous plants because of their short life cycle. Very little work has been done with forest tree seedlings, but assuming that various elements perform the same function in both herbaceous and woody plants, we can define a few specific functions of each of the trace elements as follows:

Iron. Iron probably plays some role in the synthesis of chloroplast proteins, and much of the iron in leaves occurs in the chloroplast.

The deficiency of iron shows up first in the young leaves of plants. It does not appear to be translocated from older tissues to the tip meristem, and as a result, growth stops. The young leaves develop an interveinal chlorosis

TABLE 1

TIE APPROXIMATE NONTOXIC LEVELS OF TRACE ELEMENTS FOUND IN WHOLE PLANTS AND THE RANGE COMMONLY F OUND IN S OILS

ELEMENT	NORMAL RANGE IN SOILS	APPROXIMATE AMOUNT IN WHOLE PLANT
Chlorine	10 - 1,000 ppm 1/	100 - 300 ppm
Iron	5,000 - 50,000 ppm	10 - 1500 ppm
Manganese	200 - 10,000 ppm	5 - 1500 ppm
Zinc	10 - 250 ppm	3 - 150 ppm
Copper	5 - 150 ppm	2 - 75 ppm
Boron	5 - 150 ppm	2 - 75 ppm
Molybdenum	0.2 - 5 ppm	Very minute

1/ ppm = parts per million

which progresses rapidly over the entire leaf. In severe cases the loaves turn completely white.

Boron. Boron is said to function in carbohydrate metabolism and to facilitate the movement of sugars by forming a permeable boron-sugar complex or by joining the cell membrane in such a way that it is made more permeable to sugars.

Boron is not readily translocated from older to meristormatic regions. When a deficiency occurs, the first visual symptom is the cessation of growth of the terminal bud, followed shortly thereafter by death of the young leaves. The youngest leaves become pale green, losing more color at the base than at the tip. The basal tissues break down, and if growth continues, the leaves have a one-sided or twisted appearance. Usually the leaves die and terminal growth ceases. Deficiency symptoms for boron have boon found in western red cedar foliage by Walker, et al (7) at 45 ppm. Stone, et al (6) also showed the deficient level in the foliage of red pine and white pine growing on acid sandy soils was 21 and 3L ppm respectively.

Manganese. Like iron, manganese is essential for the synthesis of chlorophyll. Its principal function probably is the activation of enzyme systems, and it probably also affects the availability of iron.

Manganese is a relatively immobile element. The symptoms of deficiency usually show up first in the younger leaves. This deficiency often causes a malformation of leaves known as "frenching" and the development of chlorotic or dead areas. Ingested (4) has found chlorosis duo to manganese deficiency in spruce and birch growing on calcareous soil. Deficiency symptoms were controlled by foliar sprays of 2-10r, solutions of MnC12 applied at the rate of 150 mi/tree, or by 50% MnC12 injected in the stems at the rate of 5 ml. Soil application of 100 kg/ha MnC12 were slower and loss effective.

Luau. Copper is a constituent of certain enzymes, including ascorbic acid oxidase and tyrosinase. It has also been suggested that it may be one of the metals concerned with the light reaction in plants.

Copper deficiency has been reported in numerous plants. Symptoms of the deficiency vary with the crop. In general, however, the symptoms progress from a yellowing of the younger leaves to dieback in the older leaves. In advanced stages dead tissue appears along the tips and edges of the older leaves giving rise to the term "tip burn." Benzian and Warren (3) found needle "tip burn" on Sitka spruce seedlings growing on a highly leached acid sandy nursery soil. Sprays of CuSO4 solution supplying 0.5% Cu prevented "tip burn." The spray increased seedling height by 50;:? and Cu content by 40;%.

Zinc. Zinc functions in plants largely as a metal activator of enzymes. It is also thought to be concerned in the formation of some growth hormones and in the reproduction process of certain plants.

Zinc deficiencies make their appearance first on the younger leaves, starting with an interveinal chlorosis and followed by a great reduction in the rate of shoot growth. A deficiency of zinc also produces leaf malformations in several species of trees resembling virus diseases, often called "little leaf." Wilson (8) found that both loblolly and short leaf pine require approximately 0.1 ppm of zinc for normal growth. Loblolly seedlings appeared to be less susceptible to zinc deficiency than were short leaf seedlings, and deficiency symptoms in both closely resembled those described for "little loaf" disease.

Molybdenum. This element is required in the lowest concentration of any essential element, only 1 ppm sufficing for most plants. Molybdenum is thought to be essential for the process of nitrogen fixation, both symbiotic and non-symbiotic. It must be present in plants if nitrates arc to be metabolized into amino acids and proteins. In any case molybdenum apparently is an essential part of the respective enzyme system which facilitates the nitrogen change.

Symptoms of molybdenum deficiency differ with various crops, but as a rule they are first observed as an interveinal chlorosis, followed by complete yellowing of the loaves and stunted growth symptoms characteristic of nitrogen deficiency. Booking (2) corrected chlorosis and marginal scorch in the lower leaves of alder plants growing in molybdenum deficient soil by the application of 0.15 grams he as sodium molybdate. Total nitrogen in the tops was increased by 370 percent.

Chlorine. Chlorine has only recently boon found to be essential for plant growth, in spite of the fact that it is used in larger quantities by most plants than any of the micro-nutrients except iron. Two reasons account for man's failure to recognize the essentiality of this nutrient earlier:

1. The wide occurrence of chlorine as an impurity in salts used for research work.

2. The annual additions to soil of significant quantities of chlorine through precipitation.

Little or nothing is known of the role of chlorine in nutrition other than that it is required for the growth and development of the plant.

The symptoms of chlorine deficiency arc not easily identified. Plants so affected are said to wilt, to become chlorotic and necrotic in some areas, and to exhibit leaf bronzing. In nutrient cultures it has been shown that chlorine deficiency is associated with reduced root growth.

FERTILIZER SOURCES CF MICRO-NUTRIENTS

Micro-nutrient additions as fertilizers must be much more carefully controlled than is the case for the macro-nutrients. The difference between the amount of a given micro-nutrient present when a deficiency occurs and when a toxic level is reached is very small. Consequently, micro-nutrients should be added only when one is certain they are needed and when the amount required is known.

When a trace element deficiency is to be corrected, especially if the case is urgent, a salt of the lacking element is often added separately to the soil (Table 2). Copper, manganese, iron, and zinc generally are supplied as the sulfate, while boron is applied as borax. Molybdenum is added as sodium molybdate. Iron and zinc may also be added as a chelate. Iron, manganese, copper, and zinc are sometimes sprayed in small quantities on the leaves rather than being applied directly to the soil.

The rate of application of trace elements should be carefully regulated as an overdose can cause severe injury. For instance Anderson (1) has found that in greenhouse pot tests, zinc added to Webster Nursery soil caused mortality of 1-0 Douglas-fir seedlings at 20 to 200 lbs. per acre depending on the source of

TABLE 2

Salts of Micro-Nutrients Commonly Used in Fertilizers

ELEMENT	COMPOUND	FORMULA	NUTRIENT CONTENT
Copper	Copper sulfate	$CuSO_4$	25-35% Cu
	Copper carbonate	$CuCO_3$	57% Cu
Zinc	Zinc sulfate	$ZnSO_4$	23-35% Zn
Manganese	Manganes sulfate	$MnSO_4$	23% Mn
Boron	Sodium borate	$Na_2B_4O_7$	34-44% B_2O_3
Iron	Ferrous sulfate	$FeSO_4$	20% Fe
	Ferric sulfate	$Fe(SO_4)_3$	17% Fe
Molybdenum	Sodium molybdate	Na_2MoO_4	37-39% Mo

zinc. The addition of 50 lbs. per acre of borax is nearing the maximum for the average soil when its pH is near 7. Molybdenum may be beneficial if added at rates as little as to 1 ounce per acre, while applications of 3-4 lbs. per acre may be toxic to most plants.

MICRO-NUTRIENTS IN NORTHWEST FOREST NURSERIES

There is little published literature to show that the supply of micro-nutrients in any Northwest nursery has been deficient enough to show typical symptoms. However, a recent study by Krueger (5) has shown that several Northwest forest nurseries have low Douglas-fir foliar concentrations for several micro-nutrients when compared to seedlings growing in high-site forest areas in Washington and Oregon. Seedlings from the Webster Nursery and Wind River Nursery had boron levels of 2-3 ppm compared to levels in forest-grown seedlings of 4-14 ppm. Levels of iron, manganese, zinc, copper and chlorine in the nurseries sampled appear to be satisfactory, though the manganese concentration in seedlings from the Industrial Forest Nursery at Canby, Oregon approaches the low end of the range found in forest-grown seedlings i.e. 250 ppm vs. 233-870 ppm.

Anderson (1) has also found a growth response to zinc in a greenhouse pot test using 1-0 Douglas-fir seedlings grown in Webster Nursery soil. When zinc was applied as $ZnSO4$, ovendry weight of seedling roots increased to a maximum at 80 lbs. Zn/acre. Top growth showed a general increase in dry weight with increasing zinc concentrations, but the response was not as dramatic as the root response.

Trials of this nature indicate that although no apparent visual symptoms of deficiency exist for micro-nutrients in Northwest nurseries, greenhouse pot tests and field fertilizer experiments with some elements merit investigation to obtain high quality seedlings.

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Question: On field trials, did the lack of nutrients show up?

Answer: None reported.

Question: What is the relative cost of applying micro'-nutrients to the soil as compared to nitrogen?

Answer: The amount required is low and it would be inexpensive.