Cultural Perspectives

Micronutrients - Boron

Boron (B) is the fifth of the micronutrients that we have discussed in this series (Table 1). Boron is unusual because it is the only trace element that is not a metal. It is not found free in nature because, like carbon, it has the capacity to form stable covalent bonds. Boron occurs in very low concentrations in most soil parent materials but is the micronutrient that most commonly limits yields of agricultural crops. Deficiencies have occurred in over 132 crops around the world, including forest trees grown in plantations. Boron is also unique because it first received attention due to its toxic effects. Because boron is often carried in irrigation water, toxicities are relatively common in arid and semiarid regions.

Table 1 - The seven essential micronutrients and their typical concentrations in seedling tissue

Element	Symbol	Average Concentration in Plant Tissue (%)	Adequate Range in Seedling Tissue (ppm)		Where and When Published
			Bareroot	Container	
Iron	Fe	0.01	50 to 100	40 to 200	Forest Nursery Notes: July, 1997
Manganese	Mn	0.005	100 to 5,000	100 to 250	Forest Nursery Notes: January, 1998
Zinc	Zn	0.002	10 to 125	30 to 150	Forest Nursery Notes: July, 1998
Copper	Cu	0.0006	4 to 12	4 to 20	Tree Planters' Notes: 49 (3)
Molybdenum	Mo	0.00001	0.05 to 0.25	0.25 to 5.00	To Do: Winter, 2002
Boron	**B**	**0.002**	**10 to 100**	**20 to 100**	**This issue**
Chloride	Cl	0.01	10 to 3,000	NA	To Do: Summer, 2002

Role in Plant Nutrition

More research has been done on boron nutrition than on any other micronutrient. Early trials showed significant growth-promoting effects when boron was supplied in low concentrations but severe toxicity when present in higher amounts. To further complicate matters, the range between deficient and toxic levels of boron is very narrow.

Although boron is not a structural component of plant tissues, it is essential for numerous metabolic reactions. Boron is involved in cell division and elongation; lignification of cell walls; translocation of nitrogen, phosphorus, sugars, and starches; synthesis of amino acids and proteins; and carbohydrate metabolism. Pollination and fruit set is affected as well as nodule formation in legumes. One of boron's most critical functions involves the development and growth of new cells and therefore one of the first visual symptoms of boron deficiency is cessation of meristem activity, followed by death of new leaves. Boron deficiency also reduces the stability of cell membranes, causing them to leak amino acids and sugars. This effect, and the fact that boron helps produce phenolic compounds toxic to fungal parasites, explain why deficiencies weaken the plant's physical and chemical defenses.

Availability and Uptake

Boron typically exists in four major locations in soil and is readily cycled between both organic matter and soil minerals (Figure 1). In the soil solution, orthoboric acid (H_3BO_3) behaves much like an anion and therefore boron is not tightly held to soil particles. This causes it

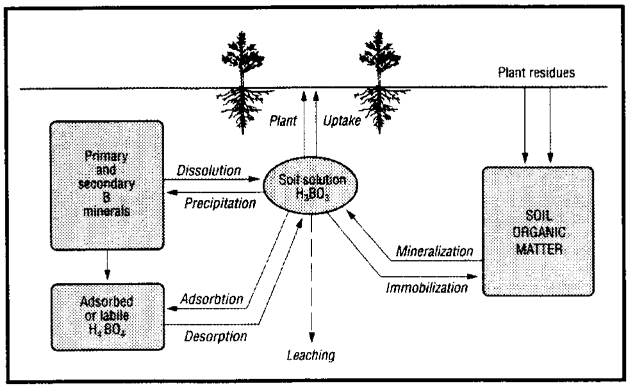

Figure 1

to be readily leached under high rainfall or irrigation conditions, similar to other anions such as phosphate and nitrate. Course textured soils that are low in organic matter content are even more vulnerable because they possess fewer exchange sites for boron retention. In addition, boron availability decreases with increasing pH, particularly on calcareous and clay soils. Young plants with small root systems, and species that have shallow root systems are most likely to suffer unless there is constant replacement. Deficiency can also occur under drought conditions because mass flow of water to plant root systems is impaired. Boron, like calcium, is immobile once it is assimilated and so cannot be translocated from older tissues to seedling meristems. Thus, new tissue growth is dependent on a continuous supply of boron from the soil or growing media. Passive uptake of boron relies on mass flow of soil solution to newly formed root tips, which have the greatest absorptive capacity. After uptake, xylem water flow delivers boron throughout the plant. Because root pressure is a relatively minor factor, the ability of a tissue to obtain boron is mainly a function of its transpiration demand. Unfortunately, meristems, buds and fruit, which are the very tissues that need boron the most, often loose out to young leaves, which transpire water at the highest rates. Non-transpiring organs must rely on root pressure, which is relatively weak and sometimes only available at night. High transpiration rates (very dry conditions) may carry boron to places where it is less needed while low transpiration rates (high humidity) reduce boron uptake in general. Thus, minimizing plant moisture stress is critically important to prevent boron deficiency.

Diagnosis of Deficiencies and Toxicities

Deficiency symptoms - Visible boron deficiency symptoms manifest themselves at the growing points. Below ground, root elongation is reduced and will cease altogether within 24 hours of complete boron removal. Above ground, terminal buds and young leaves become distorted and/or discolored and may die. Internodes are generally shorter, giving seedlings a bushy or rosette appearance (Figure 2A). At low foliar concentrations, conifer seedlings will appear stunted with terminal buds small or absent (Figure 2B). Dropping buds, flowers and immature fruit is also a typical symptom of boron

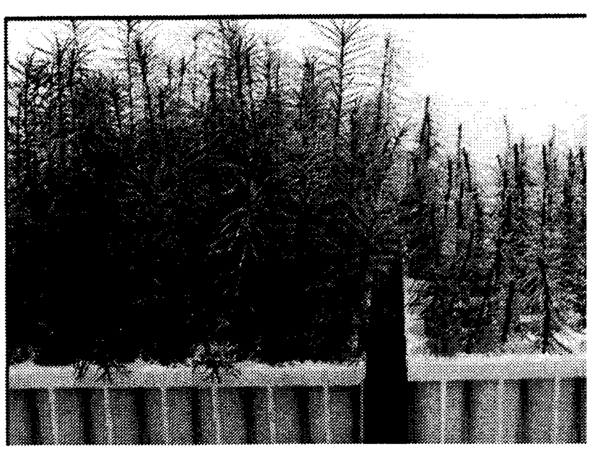

Figure 2A

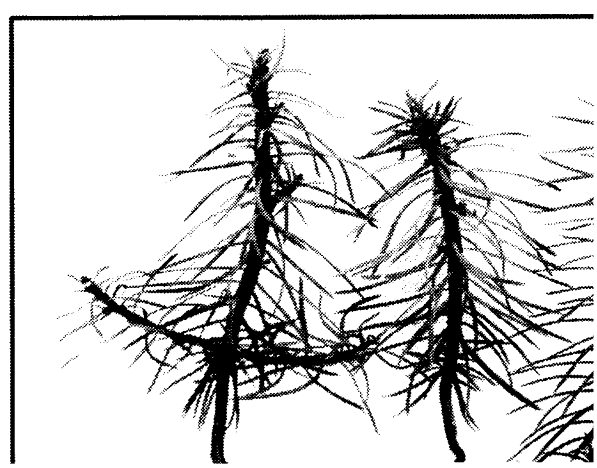

Figure 2B

deficiency. Often subsequent infections by disease causing organisms are inevitable, and can also lead to misdiagnosis of the real problem.

Sufficient boron levels vary with plant species, life stage, and climate. The main differences in boron requirements are thought to be related to differences in cell wall composition. Species with greatest lignification tend to have the highest requirement for boron. For this reason boron deficiency in monocots is less common than dicots and can be especially severe in woody plants. Sensitivity to low boron levels is increased under bright weather conditions. This is thought to be due to its involvement in phenol synthesis, a group of compounds that are elevated in plants growing under high light intensity.

Toxicity symptoms - Boron toxicity symptoms include chlorosis and necrosis of the terminal bud and on margins or tips of mature leaves. Stunting is also common although not symptomatic. Whereas toxicity is rare under natural conditions, it is increasing being encountered on sites that have been treated with boron-containing wastes, such as domestic laundry wastewater, sewage effluent, fly ash from coal, fiber glass insulation, tunnel or mine spoils. Misapplication of boron fertilizers through inconsistent fertilizer distribution and soil incorporation. Boron is commonly carried in water and toxicity can occur when using irrigation water with concentrations as low as 0.5 to 1.0 ppm.

Monitoring

The boron status of nursery soils or growing media can be monitored with seedling nutrient analysis and tests of irrigation water. Soil testing is of dubious value in determining boron availability because it is physically or chemically immobilized in most soils (Figure 1). Nevertheless, soil tests can reveal areas where boron deficiency will *not* occur. Analysis of seedling tissue has resulted in an ideal range of 10 to 100 ppm boron (Table 1). The considerable variation between individual samples makes diagnosis of boron deficiency or toxicity difficult but foliar analysis can at least indicate the potential of boron deficiency. In actual practice, however, the occurrence of symptoms (Figure 2A and 2B) and the prompt correction with boron fertilizers has proven more useful in determining a boron deficiency problem than chemical analysis. Because boron toxicity is often related to water deposition, irrigation water analysis can be diagnostic.

Boron Management

As with all the micronutrients, soil management and fertilization are the two main ways to manage boron in forest and conservation nurseries.

Soil Management - Good soil management practices can play a role in avoiding deficiency and toxicity problems. Since boron retention is greatest in soils high in organic matter, maintaining adequate soil organic matter levels can reduce the likelihood of boron deficiencies. Soils high in calcium will restrict boron availability. Therefore crops growing on recently limed soils have a higher probability of showing boron deficiencies. The reverse of this is also true - high concentrations of calcium can protect crops from boron toxicity. Low soil water can depress boron uptake and mobility in the plant. Maintaining adequate plant moisture and reducing vapor pressure during the growing season will further reduce the chances of boron deficiencies.

Although high pH is frequently mentioned as an important factor is determining boron availability, overliming is the only situation that has practical significance. It appears the reason that excess lime causes problems is that aluminum hydroxide immobilizes boron rather than a simple high pH reaction. Therefore, care in applying lime is warranted to avoid boron deficiency.

Boron toxicity should not be a problem if all soil amendments are tested before use.

Fertilization - Boron is one of the most widely applied micronutrients. Boron deficiency is entirely preventable through the use of soil and foliar products coupled with good soil management practices. Boron fertilizers can be separated into those that are an immediate source of boron *(e.g.* Solubor®) and those that are longer acting *(e.g.* colemanite) (Table 2). Use completely soluble materials that can be applied as a foliar spray or banded in the soil for a quick response to boron deficiency symptoms. Foliar sprays have proven safe and effective on a variety of plants. Longer acting boron fertilizers are incorporated into the soil and attention to achieving even distribution is critical in avoiding patterns of boron toxicity and deficiency. Blending boron with large volume fertilizers such as superphoshate or ammonium nitrate is recommended to avoid distribution problems.

Table 2 - Some common fertilizers containing boron (B)

	Chemical Notation	B (%)	Use in **Nurseries**
Single Nutrient Fertilizers			
Boric acid	H_3BO_4	17	Foliar or soil applications
Borax	$Na_2B_4O_7 \bullet 10\ H_2O$	11	Soil applications
Solubar®	$Na_2B_4O_7 \bullet 5\ H_2O$+ Na2$B_{10}$O16 • 10 H_2O	20	Foliar or soil applications
Sodium tetraborate - Dehydbor	$Na_2B_4O_7$	22	Foliar or soil applications
Colemanite	$Ca_2B_6O_{11} \bullet 5\ H_2O$	10 to 16	Soil applications
Multinutrient Fertilizers			
Soluble Trace Element Mix-STEM®	B as Boric acid	1.4	Foliar or soil applications
Micromax®	B as Sodium borate	0.1	Incorporation in growing media
B frits	B as Boric acid	0.03 to 1.50	Only for soil applications
Plant-Prod® Chelated Micronutrient Mix	B as Boric acid	1.3	Foliar or soil applications
Compound 111®	B as Boric acid	0.2	Incorporation in growing media
Osmocote Plus®	B as Boric acid	0.02	Incorporation in growing media

Conclusions and Recommendations

In conclusion, boron is critical for the formation of new cells at growing points of root tips, ends of stems and flower buds. Deficiencies in forest and conservation nurseries can be prevented through soil and fertility management, which includes the use of boron fertilizers, maintaining soil organic matter levels and attention to soil moisture during growing season. Overliming should also be avoided. Toxicities can be avoided by correctly applying boron fertilizers and avoiding the use of any soil amendments containing elevated levels of boron.

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