Boron in Idaho

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Boron (B)—like chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Zn)—is a micronutrient necessary for plant growth. Micronutrients are so named because plants require them in lesser amounts than nitrogen (N), phosphorus (P), potassium (K), and sulfur (S). Nevertheless, too little or too much boron will reduce plant yield the same as a lack of nitrogen.

Boron regulates transport of sugars through membranes, cell division, cell development, and auxin metabolism. Without adequate levels of boron, plants may continue to grow and add new leaves but fail to produce fruits or seeds. A continuous supply of boron is important for adequate plant growth and optimum yields.

Low soil levels of boron have been found to limit plant growth in many parts of Idaho (Fig. 1). Crops grown on northern Idaho soils have been shown to respond to boron fertilizer applications since the 1950s. Recent research has indicated that lack of boron may be a limiting factor for tree growth in northern Idaho forests. In addition, several crops north of the Snake River in southern Idaho also have been shown responsive. As land continues to be intensively cultivated in other areas of southern Idaho, responses to boron fertilizer are likely to increase.

Factors Affecting Crop Response

Soil texture, soil organic matter content, and soil moisture (annual precipitation, irrigation) are the three most important factors affecting boron availability in soils. Coarse textured soils (sands, loamy sands, sandy loams) that are low in organic matter are often low in plant-available boron. Boron deficiencies are especially pronounced in high rainfall areas (greater than 25 inches) where boron may have been leached from the soil profile. Over-irrigation may cause the same results.

The availability of boron in the soil is also influenced by pH. Maximum boron availability occurs between soil pH 5 and 7. Most soils in northern Idaho fall into this range, however, many soils of southern Idaho have pH values above the optimum range for boron availability. Soils in northern Idaho with optimum pH values are often low in available boron because of high crop usage of this element over the past several decades.

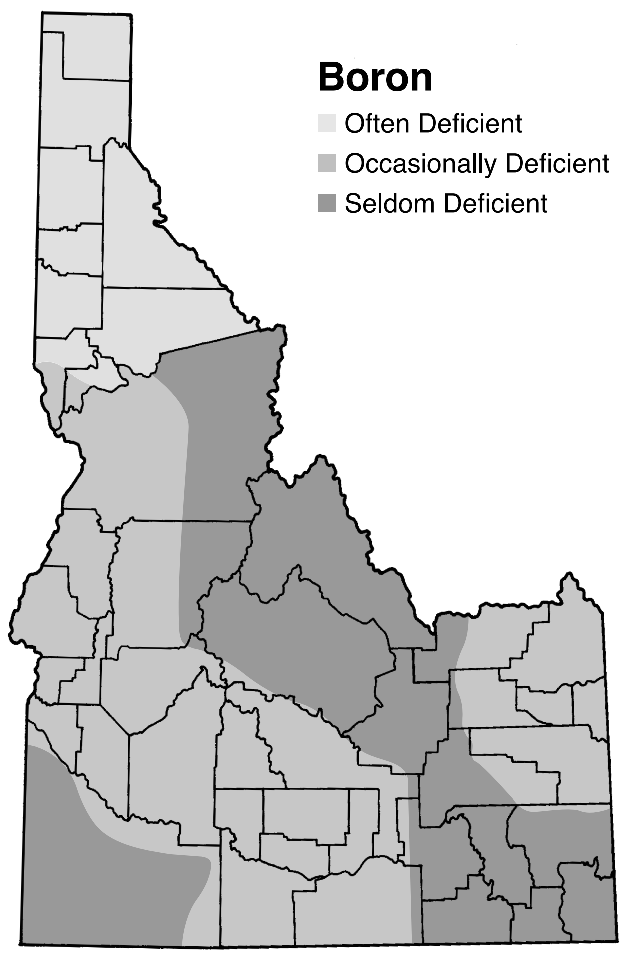

Fig. 1. Areas in Idaho with soils deficient in boron.

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Soil moisture and organic matter content are also factors that affect crop response to available soil boron. Organic matter is the major source of boron in most soils. Consequently, soils that are highly eroded or naturally low in organic matter tend to be low in boron. Boron deficiencies are also more prevalent in dry conditions (caused by lack of organic matter decomposition) and in soils with less than 2 percent organic matter.

Boron Deficiency Symptoms

Boron deficiencies first appear at the growing point of plants. Growing tips may die, and plant growth fails when no boron is present. When fruits on trees or vegetables are growing rapidly or when tuberous roots of fleshy plants are expanding rapidly, the plants develop a larger amount of meristem tissue to provide for this growth. A lack of adequate boron to the meristem at this time may result in soft or necrotic (dead) spots in the fruit or tuber. In addition to a reduction of top growth, a boron deficiency also retards root growth (Fig. 2).

- **Alfalfa**—Boron deficiency in alfalfa in its mildest form goes unrecognized because it occurs as a reduction in flowering and seed set. Such mild deficiency reflects a decrease in seed yield but is seldom detectable in hay yields from any single cutting. Reduced flowering may delay cutting and could result in poorer quality hay.

Boron deficiencies in alfalfa are commonly mistaken for drought damage. Without sufficient boron, the youngest leaves of the plant become chlorotic. The upper portion of the plant becomes yellow or red in color (often called "alfalfa yellows" which should not be mistaken with the alfalfa virus disease) while the lower, older leaves remain green and healthy. As the deficiency progresses, the internodes of the young top growth become increasingly shorter until the plant assumes a rosette appearance (circular cluster of leaves and other plant parts, see Figs. 3 and 4). At this stage, the growing tip may become dormant or die.

- **Sugarbeets**—The first symptoms occur in the crown's young, center leaves. The young leaves will appear smaller and chlorotic, and the petioles tend to be brittle. Eventually, the petioles will become se-

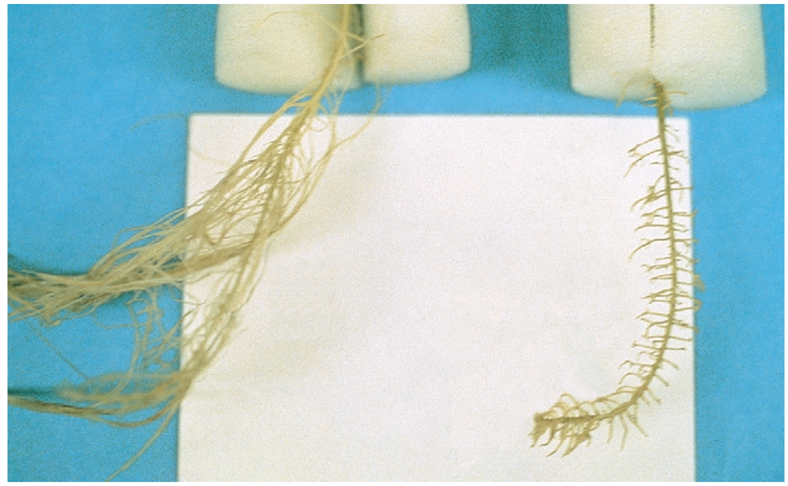

Fig. 2. Lack of boron stunts plant vegetative growth and greatly reduces root growth (right). Decreased root growth reduces the plants' ability to obtain water and nutrients from the soil.

Fig. 3. Boron deficiency in alfalfa evidenced by yellowed and stunted leaves on plants at right.

Fig. 4. Differing degrees of boron deficiency in alfalfa plants.

Fig. 5. Severe boron deficiency in young sugarbeet plants. Note that the deficiency is so severe that the leaves are difficult to identify.

Fig. 6. Boron deficiency in young clover leaves. The leaves on the right exhibit typical boron deficiency symptoms. The leaves are smaller, slightly deformed, and exhibit a bronzing on the leaf margins.

Fig. 7. Boron deficiency results in smaller, deformed, and darker potato tubers (left). During vegetative growth boron-deficient plants produced 20 percent less biomass—but the real difference becomes apparent at harvest.

Fig. 8. Boron deficiency in grapes (right) is known as "hen and chick" symptom.

verely cracked, and the young leaves will die. The growing point of the crown may die and rot. Under a severe boron deficiency plant leaves become severely deformed (Fig. 5).

- **Tree Fruits**—Variable boron deficiency symptoms occur on tree fruits. In apples, the fruit becomes corky, and the skin may die; wounds or greenish round spots occur on the fruit. Other types of fruit trees may show symptoms such as cracked fruit, blossom blast (failure of flowers to open, or failure of fruit or seeds to mature), chlorotic fruit skins, and surface pitting of the fruit.
- **Peas, Lentils, and Chickpeas**—A minor boron deficiency is usually visually unrecognizable; however, seed set will often be reduced by up to 25 percent. As the deficiency becomes more severe, deformation will occur at the growing tip of the plant.
- **Clovers**—Boron deficiency in clover often results in poor stands, reduced growth, and poor seed set. The upper leaves are frequently smaller in size and may exhibit bronzing around the margins (Fig. 6).
- **Rapeseed and Canola**—Reduced seed set is a characteristic boron deficiency in both rapeseed and canola. Plants appear stunted at the growing tip, and the new leaves are often deformed and brittle.
- **Potatoes**—Potato plants deficient in boron usually have reduced biomass. With severe deficiencies the leaves near the growing tip appear stunted. Lack of boron reduces both tuber quality and quantity (Fig. 7).
- **Grapes**—Characteristic boron deficiency symptoms in grapes include chlorosis of the terminal leaves, dieback of the shoot tips, and poor fruit set. Under severe deficiency symptoms, clusters of fruit often dry up or burn off, leaving only cluster stems with occasional berries. This condition is known as the "hen and chick" symptom (Fig. 8).

Soil Analysis and Plant Tissue Sampling

Soils should be tested for available boron three years after a soil application of boron was made and when the fourth year crop will be alfalfa, peas, lentils, chickpeas, canola, rapeseed, or a root crop. If an annual row crop was sprayed with boron (foliar application) the previous year, a boron soil test is needed for the next crop because foliar applications are intercepted by the plant canopy and boron does not reach the soil.

Deficiencies can be most easily avoided by frequently (every third year) having a soil analyzed for available boron. For testing, a soil sample should be collected from the surface 12 inches of a soil profile. A soil test level of 0.5 ppm boron is sufficient for high boron demanding crops (alfalfa, grain legumes, canola, rapeseed, root crops) while a soil test level of 0.3 ppm boron is sufficient for low boron requiring crops.

The boron status of plants can be monitored throughout the growing season through the use of plant tissue testing. Monitoring boron levels in high-value cash crops can help to prevent severe boron nutrient deficiency symptoms from developing. Table 1 lists the plant parts and stages of plant growth to sample for boron tissue analysis for major Idaho crops. Take care to sample the correct plant part at the correct stage of plant growth and to sample in a manner that is representative of the field.

Detection of Boron Problems

If you suspect a possible boron deficiency, have the soil tested for available boron. When soils test less than 0.5 ppm boron, addition of a fertilizer containing boron is recommended. Plants belonging to the grass (cereals, corn) family generally require only about 25 percent as much boron for normal growth as do dicotyledons (beans, potatoes, tomatoes, sugarbeets, etc.). Boron deficiencies are usually most pronounced on alfalfa and on certain root and cruciferous crops (sugarbeets, cabbage, cauliflower, rutabagas, and turnips). More boron fertilizer is used on alfalfa than any other crop in Idaho.

Crop Response to Boron Applications in Idaho

Field trials conducted on peas, lentils, chickpeas, alfalfa, clover, birdsfoot trefoil, rapeseed, and canola in northern Idaho between 1970 and 1995 showed these crops respond to applications of boron fertilizers when soils were initially boron deficient. Average yield increases attributable to fertilizer boron applications of one pound per acre (soils initially contained less than 0.5 ppm B) are shown in Table 2. Cereal crops have not been responsive to boron applications.

Boron Fertilizer

Several fertilizer sources of boron are available for use in Idaho (Table 3). Borax, borated gypsum, Solubor, and boric acid are the most commonly used boron fertilizers in Idaho. All four sources of boron are gener-

Table 1. Procedures for sampling Idaho crops for boron tissue levels.

Crop	Stage of growth	Plant part to sample	No. of plants to sample	CNR*
Field crops				
Alfalfa	Before or at 1/10 bloom stage	Upper 3 to 4 inches	40 to 50	20 to 30 ppm
Clovers	Before bloom	Mature leaf blades taken about 1/3 of the way down from top of the plant	40 to 50	20 to 30 ppm
Peas, lentils, chickpeas	Early to mid-season	Mature leaf blades taken about 1/3 of the way down from top of the plant	30 to 40	20 to 30 ppm
Sugarbeets	Early to mid-season	4th petiole	30 to 40	20 to 40 ppm
Potatoes	Early to mid-season	4th petiole	30 to 40	20 to 30 ppm
Fruit crops				
Apples, apricots peaches, pears, cherries	Mid-season	Leaves near base of current year's growth or from spurs	50 to 100	20 to 25 ppm
Strawberries	Mid-season	Youngest fully expanded mature leaves	50 to 75	20 to 30 ppm
Vegetable crops				
Root crops (carrots, onions, beets, etc.)	Before root or bulb enlargement	Center mature leaves	20 to 30	30 to 60 ppm
Sweet corn	1. Before tasseling	The entire fully mature leaf below the whorl	20 to 30	
	2. At tasseling	The entire leaf at the ear node	20 to 30	

*CNR—Critical Nutrient Ranges for boron in plant tissue.

ally applied to the soil. Borax and borated gypsum are used as solid forms of boron fertilizers, while boric acid and Solubor are versatile boron sources that can be used either for soil or foliar application.

Methods and Application Rates

The two principal methods of correcting boron deficiencies in the field are by (1) soil application and (2) foliar application to the plant. Boron deficiencies are most commonly corrected by applying boron fertilizer to the soil. While foliar sprays of boron compounds are often beneficial, soil applications remain effective much longer. Most boron compounds used in foliar sprays can be mixed with other liquid fertilizers for applications to the soil. Seed applications of boron should not be used as they can be toxic.

- **Soil Treatments**—A fertilizer application rate of 1 to 2 pounds of boron per acre is needed for soil treatments on certain legumes and root crops. Lower rates (0 to 1 lb per acre) are needed for other crops. Applying boron to the soil is the most efficient way of meeting the nutritional needs of most Idaho crops. Significant responses to soil-applied boron are often reported for alfalfa, peas, lentils, chickpeas, rapeseed, and canola in northern Idaho.

Table 2. Average yield increases of crops grown in northern Idaho when fertilized with 1 pound of boron per acre. (Note: Soils were initially boron deficient before fertilizer applications.)

Crop	Average yield increase, %
Legumes	
Alfalfa	13
Birdsfoot trefoil	9
Chickpeas	15
Clovers	9
Lentils	23
Peas	17
Non-legumes	
Canola	15
Rapeseed	12

If using a solid fertilizer material such as borated gypsum, borate 48, or borate 68, boron can be surface broadcast on the soil and plowed or disked in before seedbed preparation. Often boron materials such as boric acid or Solubor are first liquified then sprayed on the soil surface. Fertilizer boron should never be banded because at high concentrations it can be toxic to seeds, seedlings, and plant roots.

- **Foliar Treatments**—Foliar boron applications are commonly used on perennial tree fruits. Foliar boron is compatible and can be mixed with many pesticide sprays. Foliar boron application rates of 0.1 to 0.4 pound per acre are sufficient for most tree fruits. Foliar boron can also be used to prevent boron deficiencies in rapidly growing annual crops.

Foliar applications must be made several times during the growing season because boron is not mobile in the plant. As new growth appears, repeated spraying are required to get boron into the new growth. Five to seven foliar applications of boron over the growing season may be needed to get the same plant yield effects as 1 pound of boron broadcast and incorporated into the soil before planting.

Because of the high cost of repeated applications, foliar spraying of row crops should be used only when boron is needed to prevent yield reductions. Annual row crops generally require about one pound of boron per acre. The one pound can be divided by the number of times boron will be sprayed over the season to give the correct rate for each application.

- **Reduced Tillage Situations**—In reduced tillage situations most fertilizers are often banded. Boron cannot be banded! Potential B application strategies in such situations include: (1) apply B fertilizer as a surface broadcast in the solid or liquid forms, or (2) apply B fertilizer as a tank-mix application together with a pesticide.

- **Residual Effects**—Boron persistence in soils is largely determined by the soil type and the form of boron applied to the soil. Boron will rapidly leach from

Table 3. Boron fertilizer materials available for use on Idaho crops.

Boron material	Chemical formula	% boron	Rates per acre 0.5 lb B	1 lb B	2 lb B
		(B)	(application of material, lb)		
Borated gypsum	$CaSO_4$, $2H_2O + Na_2B_4O_7$	1	50	100	200
Borax	$Na_2B_4O_7\ 10H_2O$	11.4	4.4	8.8	17.6
Boric acid	H_3BO_3	17	2.9	5.8	11.8
Boron frits	variable	10 to 17	---------------------- depends on % B ----------------------		
Fertilizer Borate 48	$Na_2B_4O_7\ 5H_2O$	14.3	3.5	7	14
Fertilizer Borate 68	$Na_2B_4O_7$	20.2	2.5	5	9.9
Solubor	$Na_2B_4O_7\ 5H_2O$ + $Na_2B_{10}O_{16}\ 10H_2O$	20.5	2.4	4.8	9.8

sandy soils that are overirrigated or that have high rainfall but will persist for several years in soils high in silt and clay. Soil-applied boron rates of 1 to 2 pounds per acre will generally result in sufficient soil levels of boron for at least three years for all but very sandy soils. Foliar applications leave little soil residual boron since most of the applied boron is taken up by the plant and not the soil.

Boron Toxicity

Boron toxicity can result when plants have taken up too much boron; excessive levels of boron are toxic to plant growth. The best way to avoid boron toxicity problems is through proper management of fertilizer and a crop rotation program. *Boron should be applied to the soil at low rates only after a demonstrated need has been established through plant tissue and/or soil testing*.

A very narrow range exists between toxicity and deficiency. Plants differ in their sensitivity to excess boron. Beans and peas are extremely sensitive, while alfalfa is relatively tolerant to high boron levels. Amounts of boron commonly applied to alfalfa are toxic to beans. When required, boron should be applied uniformly to a field (broadcast, not banded) at rates not to exceed 4 pounds of boron per acre.

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5,000 12-81; 2,000 3-00 (formerly CIS 608) $3.00