

Over the past 80 years, hundreds of reports have documented a role for boron (B) in agricultural crops around the world. Responses to boron fertilization have been documented in almost every state and province in the U.S. and Canada. Alfalfa frequently responds, and so do a large number of fruit, vegetable and field crops.

Boron in Plants

Boron essentiality for higher plants was recognized by 1923. It has also been found essential for ferns and some algae. The primary role of B is in the cell walls, providing cross links between polysaccharides to give structure to cell walls. Boron also plays roles in formation of sugar complexes for translocation within plants, and in the formation of proteins. Cell membrane function, nodule formation, flowering, and development of seed and fruit all depend on adequate B. Deficiency can reduce both yield and quality of crops. Flower initiation and pollen development also require adequate B.

Boron in Soils

Agricultural soils range from 1 to 467 mg/kg in total B concentration. The available forms, $B(OH)_3$ and $B(OH)_4^-$, are usually mobile in the soil solution, but can be adsorbed to the common constituents of soil, including hydroxides of iron (Fe) and aluminum (Al), clay particles, and organic matter. There are several factors that influence B availability in the soil:

Organic matter is the most important soil reservoir of B. In hot, dry weather, decomposition slows down in the soil surface horizon where most of the organic matter is found. This can lead to a B deficiency. In cold weather, organic matter decomposition also slows, and low B release affects many cole crops (Brussels sprouts, radishes) and other early planted species.

Weather conditions: Dry and cold weather restricts root activity in the surface soil and can cause temporary B shortages. Deficiency symptoms may disappear as soon as the surface soil receives rainfall. Root growth resumes, but yield potential is often cut during the B shortage.

Soil pH: Plant availability of B is greatest between pH 5.0 and 7.5. At higher pH values, B uptake is reduced. Liming acid soils can lower B solubility and enhance response to B fertilizers. An experiment on an acidic soil in the southern U.S. coastal plain showed a positive yield response to applied B only when lime was also applied (**Figure 1**). The applied lime raised the soil pH in the top 2 inches from 6.0 to 6.4. Adding lime to raise soil pH may also protect against B toxicity where soil B levels are high.

Soil texture: Coarse-textured sandy soils, which are composed largely of quartz, are typically low in minerals that contain B. Plants growing on such soils commonly show B deficiencies.

Leaching: Plant-available B is mobile in the soil and is subject to leaching. Leaching of B from the root zone is of greater concern on sandy soils and/or in areas of high rainfall.

Fertilizing with Boron

It is important that B fertilizers be properly applied because of the narrow range between deficiency and toxicity. Diagnosing the need for B fertilization must consider the factors listed above controlling soil availability. Plant analysis and visual symptoms are often more useful as diagnostic tools than soil testing.

Boron fertilizer can be broadcast or band applied to soil, or applied as a liquid foliar treatment. Broadcast application requires higher rates than band or foliar. Soil application rates for responsive crops may be as high as 3 lb B/A, and for low and medium responsive crops, 0.5 to 1.0 lb/A (**Table 1**). Common forms of fertilizer are shown in **Table 2**. Soluble forms are usually preferred, except in sandy soils where less soluble forms are less susceptible to leaching.

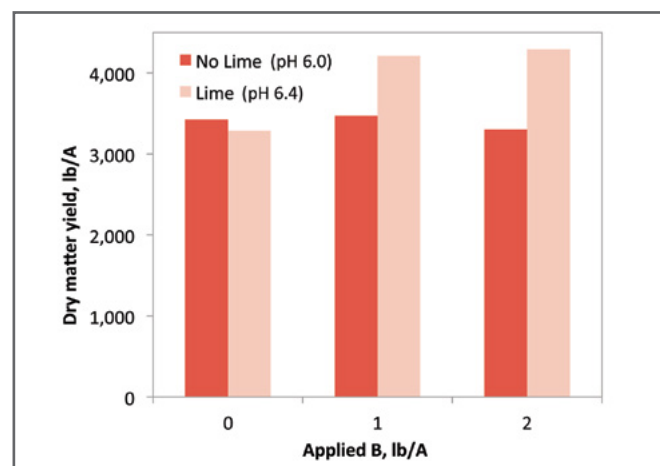


Figure 1: Rose clover response to boron depends on applying lime to raise soil pH.

Boron Deficiency Symptoms

Although B is mobile in the soil, its mobility within the plant varies among species. Nutrient deficiencies tend to appear on the youngest leaves or growing points. In certain species (such as apples and almonds), B is mobile and moves throughout the plant.

The following B deficiency symptoms occur in specific crops:

Alfalfa: short internodes and stems, younger leaves turn red or yellow, death of terminal bud.

Almond: new shoots do not develop. Brown and gummy nuts.

Apple: small, flattened or misshaped fruit, internal corking, cracking and russetting, dead terminal buds, brittle leaves, blossom blast.

Celery: crooked stem

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Boron deficiency in alfalfa is often seen

Corn: narrow white to transparent lengthwise streaks on leaves, multiple but small and abnormal ears with very short silk, small tassels with some branches emerging dead, and small, shrivelled anthers devoid of pollen.

Most Response	Medium Response	Least Response	
Alfalfa	Carrot	Asparagus	Pepper
Apple	Clover	Barley	Peppermint
Broccoli	Cotton	Bean	Potato
Brussels Sprout	Cherry	Blueberry	Raspberry
Cabbage	Lettuce	Cereals	Rye
Cauliflower	Parsnip	Citrus	Snapbean
Celery	Pear	Corn	Sorghum
Peanut	Radish	Cucumber	Soybean
Sunflower	Sinach	Flax	Spearmint
Table beet	Sugar Beat	Grass	Strawberry
Turnip	Sweet Corn	Oats	Sundangrass
	Sweet Potato	Onion	Wheat
	Tomato	Pea	

Table 3. Examples of crop yield response to application of Boron fertilizer.

Crop	Source	Rate	Time	Place	Yield Response	Reference
Soybean	$\text{Na}_2\text{B}_8\text{O}_{13}\cdot 4\text{H}_2\text{O}$	0.25 - 1.0 lb/A	V2 or R2	Foliar	0 - 130%	2
Alfalfa Seed	$\text{Na}_2\text{B}_8\text{O}_{13}\cdot 4\text{H}_2\text{O}$	0.4 - 1.1 lb/A	After 1 st cut	Foliar	37%	3
Alfalfa Forage	$\text{Na}_2\text{B}_4\text{O}_7\cdot 5\text{H}_2\text{O}$	3 - 4 lb/A	Annual	Soil	46 - 62%	4
Sour Cherry	$\text{Na}_2\text{B}_8\text{O}_{13}\cdot 4\text{H}_2\text{O}$	500 mg/L	Sept - Oct	Foliar	0 - 100%	5

Source	Formula	B, %	Water Solubility
Borax	$\text{Na}_2\text{B}_4\text{O}_7\cdot 10\text{H}_2\text{O}$	11	Soluble
Boric Acid	$\text{B}(\text{OH})_3$	17	Soluble
Sodium Pentaborate	$\text{Na}_2\text{B}_{10}\text{O}_{16}\cdot 10\text{H}_2\text{O}$	18	Soluble
Sodium Tetraborate	$\text{Na}_2\text{B}_4\text{O}_7\cdot 5\text{H}_2\text{O}$	14-15	Soluble
Solubor®	$\text{Na}_2\text{B}_8\text{O}_{13}\cdot 4\text{H}_2\text{O}$	20-21	Soluble
Boron frits	Boric oxide glass	2-11	Very Slightly Soluble

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Cotton: ringed or banded leaf petioles with dieback of terminal buds, causing rosetting effect at the top of the plant. Ruptured squares and thick, green leaves that stay green until frost and are difficult to defoliate.

Peanut: hollow heart

Sugar Beet and Table Beet: black heart (heart rot)

Boron Toxicity Symptoms

Toxic accumulation of B occurs in many arid regions. Addition of extra irrigation water will leach soluble B below the root zone. Boron toxicity symptoms appear first on the edges and tips of older leaves.

Crop Response to Boron

Crops vary significantly in their responsiveness (**Tables 1 and 3**). Most legumes, as well as several fruits and vegetables, are highly responsive to B. Other vegetables show somewhat less response. Grains and grasses are generally less responsive to B. Crops vary in sensitivity to excess B, and those with high requirements do not always have high tolerance. For example, alfalfa and cabbage are only semi tolerant to high boron levels.

References

1. Haby, V.A. et al., 1995. In Plant-Soil Interactions at Low pH: Principles and Management. Developments in Plant and Soil Sciences 64:505-510.

References

Brown, P.H. et al. 2002. Plant Biol. 4: 205-223.