Deficiency to Toxicity:

The Role of Boron in California Crop Production

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Overview

- Nutrient Functions of Boron
- Boron in CA Soils and Waters
- Boron & Major CA Crops
- Managing Boron Deficiency
- Managing Boron Excess

Nutrient Functions of Boron

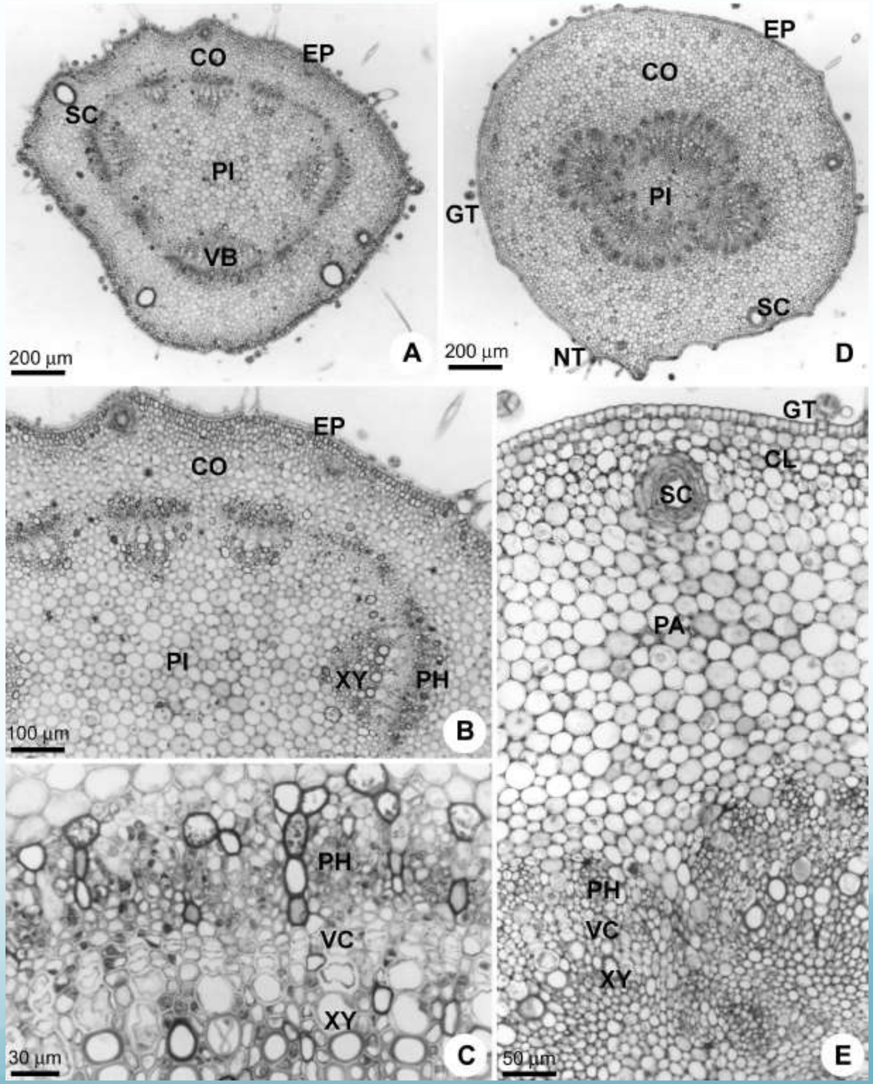
- Boron is a crucial component of properly formed cell walls. Without it, cell walls are unable to attain the strength and properties necessary for normal function.
  - Boron cross-links pectin-type molecules.
  - Cell wall extension without sufficient B leads to cell death.
  - Flower fertility, pollen tube growth
  - Root elongation
  - Shoot elongation

Nutrient Functions of Boron

- Boron deficiency affects cell metabolism in several ways:
  - Strong reduction of the synthesis of ascorbate and glutathione.
  - Reduction of photosynthetic efficiency.
- Boron excess **and** deficiency can decrease nitrate reductase activity.

Nutrient Functions of Boron

- Boron **does not** have a direct role in sugar translocation.
  - Poor sugar movement is again a function of tissue defects, namely poor phloem development.



Source: *Boron Deficiency Inhibits Petiole and Peduncle Cell Development and Reduces Growth of Cotton*

Nutrient Functions of Boron

- In legumes, the beneficial interaction between plant and the symbiont bacteria requires boron.
- Boron plays an important role in cell membrane stability and function, and in the interaction between cell wall and plasmalemma (outer membrane around the cell).
- B is probably still the least understood plant nutrient.

Boron Behavior in Soils

- B occurs in soils as boric acid $B(OH)_3$ or as the borate anion $B(OH)_4^-$.
  - Even in soils with a pH well above 7, boric acid is the dominant species.
- Boron in soils is adsorbed to clay minerals, oxides of iron and aluminum, lime, and SOM.
  - The finer the texture and/or the higher the OM and lime content, the more B can be adsorbed.
- B availability decreases with increasing soil pH and dryness.
- B availability increases with soil temperature and moisture.

Boron Sources in CA

- Parent material: Many soils derived from sediments originating in the Coastal Range contain elevated levels of B.
  - This is due to the marine origin of many rock formations in the Coastal Range.
- Surface water: Streams draining the eastern slopes of the Coastal Range have boron levels of up to 25 mg/L.
- Ground water: According to the USGS, boron is present in high concentrations in all Central Valley and Southern CA groundwater basins.
  - High concentration means above 1000 µg/L (=1 mg/L)

Boron Uptake by Roots

- With sufficient to excessive supply of B in the soil solution, B uptake is a passive diffusive process.
  - Since this mechanism is only dependent on the external B concentration in the soil solution, it cannot be downregulated by the plant.
- There is evidence of an active, energy-dependent uptake mechanism, induced when availability of boron is low.

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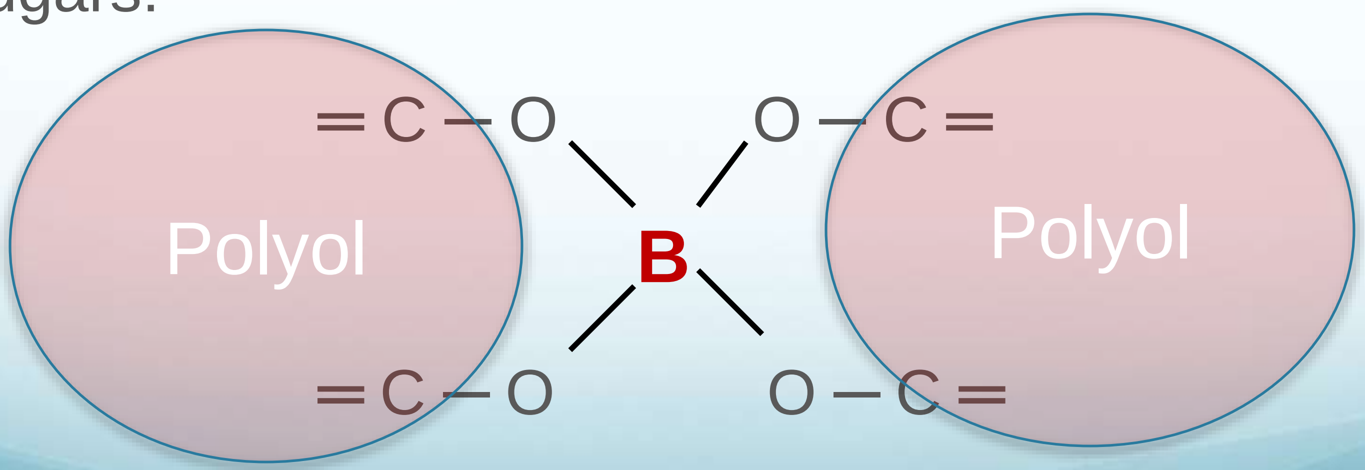
Boron Mobility in the Plant

- Boron is mobile in plants that use complex sugar alcohols (polyols) as the primary photosynthetic metabolite.

- Boron that moved up from the roots to the leaf in the transpiration stream (xylem) complexes with these sugars:



Boron Mobility in the Plant

- The polyol – B – polyol complexes can enter the phloem for transport to actively growing tissues (meristems).

- Tree crops in which boron is **mobile**:
  - Prunus ssp.: Almond, peach, apricot, plum, cherry
  - Malus ssp.: Apples
  - Pyrus ssp.: Pears
  - Vitis ssp.: Grapes
  - Pomegranate
  - Olive

Boron Mobility in the Plant

- Boron is immobile in plants that do not generate significant amounts of polyols.
  - Boron moves only in the xylem, accumulating in transpiring organs (mainly leaves).
- Tree crops in which boron is **immobile**:
  - Walnut
  - Pecan
  - Pistachio
- Field crops in which B is immobile:
  - Tomato
  - Strawberry

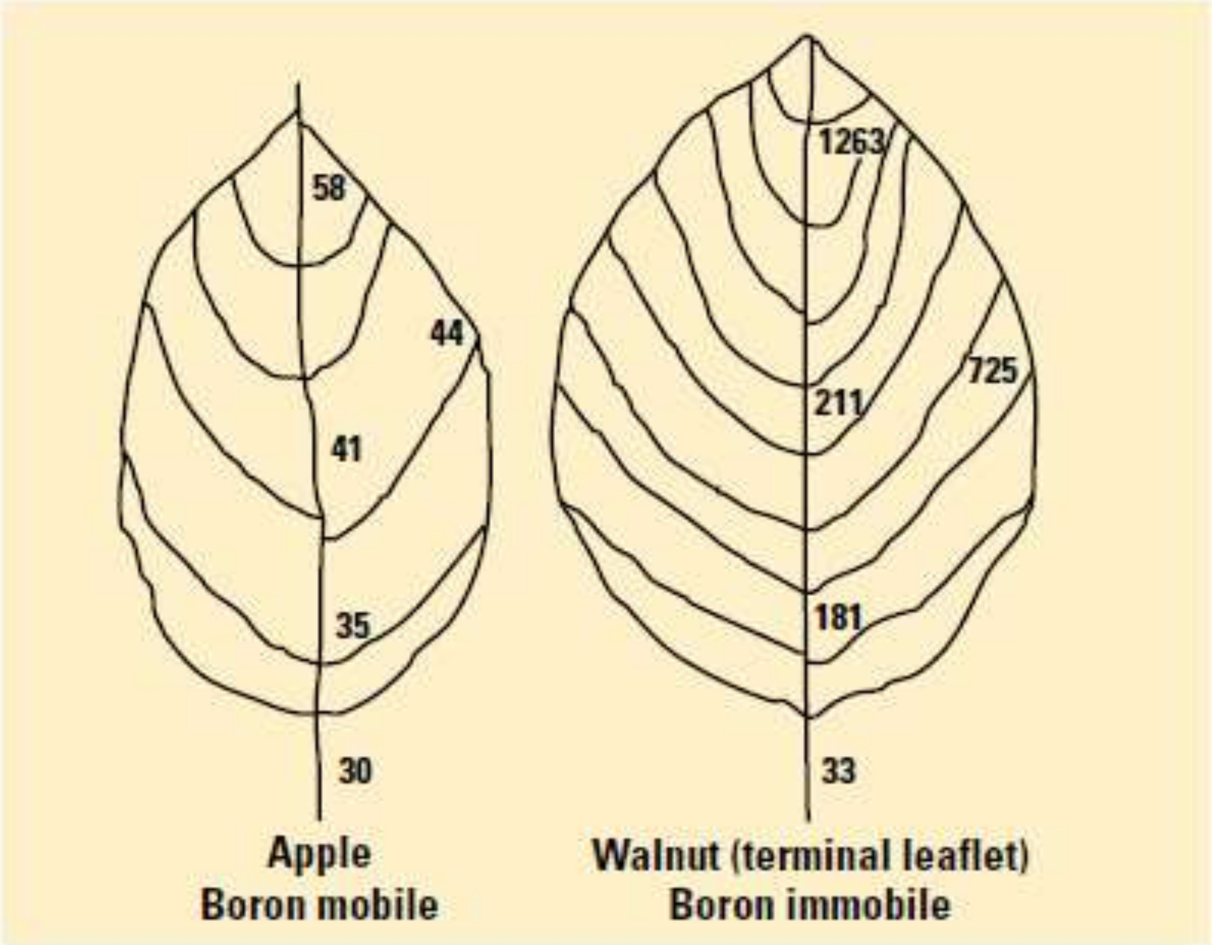


Figure 1. Leaf B concentration (ppm) in field grown apple and walnut. Leaves were collected at the end of the growing season. The two species were grown in close proximity and received the same irrigation.

B-Mobile vs B-Immobile

Source: *Boron Mobility and Consequent Management in Different Crops.*

Boron Tissue Ranges for Some CA Tree Crops

Deficient	Crop	Excessive
< 70 ppm	Almond (hull)	> 150 ppm
< 20 ppm	Avocado (leaf)	> 100 ppm
< 20 ppm	Citrus (leaf)	> 250 ppm
< 25 ppm	Grape (petiole)	> 100 ppm
< 25 ppm	Peach (leaf)	> 100 ppm
< 90 ppm	Pistachio (leaf)	> 250 ppm
< 20 ppm	Walnut (leaf)	> 300 ppm

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Boron Tissue Ranges for Some CA Row Crops

Deficient	Crop	Excess
< 15 ppm	Alfalfa	> 200 ppm
< 20 ppm	Cotton	> 80 ppm
< 20 ppm	Melon	> 80 ppm
< 6 ppm	Onion	> 30 ppm
< 20 ppm	Pepper	> 80 ppm
< 6 ppm	Rice	
< 20 ppm	Tomato	> 150

Boron Deficiency

- Lack of boron inhibits growing tissues, especially those forming flowers and fruits/seeds.
- Visible deficiency symptoms are
  - Inhibition of apical growth and necrosis of terminal buds
  - Inhibition of extension growth – stunted internodes
  - Tissue defects – cracking, breaking, lesions
  - Abortion of flowers and fruit drop
- Necrosis (heart/crown rot, corkiness) is often due to the accumulation of toxic levels of phenolic compounds.

Managing Boron Deficiency

- In B-mobile crops, boron fertilization is possible through the soil as well as foliar. Unless an acute deficiency has been identified, timing is not crucial as long as sufficient amounts are applied.
- In B-immobile crops, foliar fertilization is most effective. Applications should be made when reproductive tissues become active. An example is foliar boron in walnut at the catkin stage to ensure nut set.

Boron Excess

- Beyond a crop-specific threshold, boron is toxic.
- Visible symptoms of B toxicity are similar to those of deficiency:
  - Reduction of shoot growth
  - Reduced tissue extension
  - Chlorosis
  - Eventually necrosis of tissues accumulating excessive B
- The mechanism of boron toxicity is yet unknown.

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Boron Excess

- Excess boron in soils used for crop production is primarily a problem of arid climate and irrigation.
  - Lack of precipitation passing through the soil profile means boron is not leached.
  - Irrigation increases soil moisture, making B more available.
  - Irrigation waters containing B exacerbate the problem.

Managing Boron Excess

- Soil sample: Take samples in 6 inch depth intervals down to the bottom of the crop's active root zone.
  - Soils can have "clean" topsoil but high-B subsoil.
- Analyze your irrigation water.
  - Wells should be sampled every year after the first irrigation.
  - Delivered water originating as snowmelt is "clean".

Managing Boron Excess

- Leach high-B soils with low-B water.
  - The more sorption capacity, the more water is needed.
  - "Boron regeneration" will occur on high sorption soils -> leaching must be repeated for several cycles.
- Ensure proper drainage. Soils with a high water table require artificial lateral drainage to remove leached B.

Managing Boron Excess

- Select boron-tolerant row crops.
- Plant boron tolerant tree crops.
- Select adapted rootstocks for boron-sensitive tree crops.
  - Hybrid rootstocks for almond and stone fruit.
  - Take other soil factors into account (pH, salts, drainage, texture, pest pressure…).
- Remove residues that accumulate B (Almond hulls, leaves of B-immobile tree crops).

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