BIOL 695

BORON

Chapter 18
MENGEL et al, 5th Ed

SOIL BORON

- Occurs in soil as H_3BO_3
- Fluorine borosilicate - B containing soil mineral
- B level in soils ~ 7- 80 ppm
- Adsorption decreases as soil pH lowered
  - Thus Borate availability lowest in alkaline soils. Lowest - pH 7- 9

GENERAL

- B is a metalloid (intermediate properties between metals & nonmetals.
- Has 3 valences
- Best idea of role of B is
  - cell wall biosynthesis & structure
  - plasma membrane integrity

B COMPLEXES

- Forms stable with cis-diols
- Polyhydroxil compds with adjacent cis-diol config required for formation
  - of mannitol, mannan, &
  - polymannuronic acid
  - const of hemicellulose fraction of cell walls

MORE B IN DICOTS THAN MONOCOTS

- o-phenolics (caffeic acid)
  - precursor to lignin synthesis in diocots (has cis-diol config)
- Large portion of B complexed in cell walls as cis-borate esters.
- Dicots have higher B requirements than monocots because more cis-diol compds in cell walls of dicots.

DICOTS and MONOCOTS, con't

- Complexed B in wheat roots: 3-5 μg
- Complexed B in sunflower roots 30 μg g^{-1} dw
- Assumed that B similar to Ca in stabilizing cell wall constituents including plasma membrane

CELL ELONGATION

- B deficient plants have stubby roots
  - Inhibition of root growth within 3 hrs of B cut off.
  - Complete stop in 24 hrs
  - Growth begins 12 hrs after B resupply
- B cut off $\Rightarrow$ 6-12 hrs later - IAA increases

CELL WALL SYNTHESIS

- B def plants exhibit:
  - cracked stems
  - stem corkiness
  - hollow stem disorder
  - Thicker cell walls, greater dry wt
  - Celery cell walls 1μm - B sufficient
  - Celery cell walls 4 μm - B deficient

CALLOSE

- Large portion of B-1,3-glucan (the main component of callose
  - Accumulates in sieve tubes of B deficient plants
  - Impairs phloem transport

B IS IMMOBILE

- Historically
  - Plants with adequate B supply
    - B conc higher in old leaves compared to young leaves
  - B defic sym typically in meristems
  - B tox sym in margins of oldest lvs at end of transpiration stream
  - Conclusion: B is immobile

MORE EVIDENCE

- **Squash & tomato developed B def sym:**
  - **When transferred from B sufficient to B deficient conditions**
  - **B established in leaves did not decrease even when apical tissues were completely inhibited.**
  - **Conclusion: B almost completely immobile**

B IS MOBILE

- ***Prunus, Pyrus, Malus* are exceptions**
  - **1944 work noted no B toxicity sym in stone fruit trees**
  - **These spp do not accumulate high B levels in leaves**
    - **But develop twig die back & gum exudation as result of B toxicity**
    - **No marginal leaf burn of old leaves**

MORE EVIDENCE

- ***Prunus*** **exposed to high B**
  - **B accumulation in fruit, young stems, apical areas; also as ^{10}B**
  - **NOT in mature leaves**
- **Not consistent with view that distrib of B related to B transl in xylem to areas of greatest water loss.**

WHY *Prunus*?

- **Sorbitol is a major CHO in** ***Prunus, Pyrus,*** **and** ***Malus***
- **Sorbitol forms complexes with B resulting in stoichiometric shift in pH and conductivity.**
- **Sorbitol-borate ester formation (fact)**

HYPOTHESIS

- **B is mobile in species that transport significant amts of sorbitol in phloem and that movement of B in these plants will be determined by the movement of sorbitol. "Pat Brown, UC Davis"**

THOSE ON THE OUTSIDE

- ***Ficus, Pisticia, Juglans* are sorbitol poor .**
  - **B is not mobile in these genera.**

IAA & PHENOL METABOLISM

- **Confused situation**
  - **High IAA only in species that in response to B def accum phenolics (caffeic acid) which inhibits IAA oxidase act.**
  - **Phenols dependent on light**
  - **Accumulation of phenols typical in B deficient plants**

SHIFT TO PENTOSE-P CYCLE

- **Under B defic substrate flux shifted**
  - **Toward pentose-P cycle**
  - **Enhancing phenol biosynthesis**
  - **Formation of borate complexes**
  - **That regulate phenols in lignin synthesis**

SHIFT TO PENTOSE-P CYCLE

- **Under B def -**
  - **Phenols accumulate**
  - **Polyphenol oxidase act. increased**
  - **Leads to highly reactive intermediates (caffeic quinone) in cell walls ⇒ superoxide radicals**
    - **Can damage membranes by lipid peroxidation**

MEMBRANE FUNCTION

- **B has role in plasma membrane integrity**
- **B influences the turgor-regulated**
  - **Nyctinastic movement of *Albizzia* leaflets**
- **B enhances both ^{86}Rb influx & stomatal opening**

B-ENHANCED UPTAKE OF P

- P lower in root tips of B defic plants
  - Uptake increased only 1 hr after B treatment
  - Membrane-bound ATPase restored same level as that in B sufficient tr
- Effect of B on uptake mediated by direct effect on plasma membrane-bound H^+ pumping of ATPase

EFFECT OF B ON H^+ATPASE

- Effect of B on H^+ATPase requires presence of IAA & vice versa.
- Supported by evidence of K efflux in expanding sunflower leaves
  - Leaves immersed in B-def or distilled water
- Conclusion: B exerts primary infl in cell wall at PM-Cell wall interface

POLLEN GERMINATION & TUBE GROWTH

- Close relation between B supply &
  - Pollen producing cap of anthers
  - Viability of pollen grains
- B stimulates pollen tube growth
- Sugar leakage from pollen decreases with increasing B

POLLEN TUBE GROWTH

- High B in stigma & style req for inactivation of callose from pollen tube walls
  - By formation of borate-callose complexes
  - When B low, callose syn inc & induces phytoalexins in stigma & style as defense similar to resp to microbial infection

LIGNIN SYNTHESIS

- **Polyphenol oxidases involved in biosynthesis of lignins**
  - **Formation of brown melanotic substances when tissues wounded**
  - **Active as phytoalexins (PLX)**
    - **Inhibit spore germination & fungal growth**

ISOFALVONES

- ***Phytophthora megasperma* elicits**
  - **Synthesis of isoflavones which is a phytoalexins (PLX)**
    - **Leads to accumulation of phenolic polymers at the infection site**

DISEASE RESISTANCE

- **Within few hrs post infection:**
  - **Signal transmitted to non-infected leaves which increase their phenol synthesis**
    - **Cu & B profound influence on synthesis & binding of phenols**
- **Neg corr between inc N & phytolexin & Downy Mildew on grapes**

B DEFICIENCY

- **Sym noticeable at apex - become discolored & may die**
- **Internode shorter - rosette**
- **Increase diameter of petiole & stem**
- **Bud, flowers, dev fruit drop common**
- **Lettuce may have black heart**
- **Failure of seed & fruit to set**
- **Fruit malformed - internal cork**

B TOXICITY

- May be problem in semiarid areas where high B in irrigation water
- B conc 1 - 10 ppm for sensitive to tolerant crops
- Symptoms
  - Marginal or tip chlorosis - necrosis
  - Symptoms reflect dist of B following transpiration stream

SUSCEPTIBILITY TO B

- Sensitive - peaches, pecans, grapes, kidney beans, figs
- Semi-tolerant - peas, potato, Lucerne, tomato, pistachio
- Tolerant - Turnips

B TREATMENT

- Deficiency in:
  - Acid sandy soils low in B may ` need regular treatment
  - Treat when lime applied
  - High clay inc Borate adsorption
  - 1 ppm too low, 5 ppm too high in water soluble B soil solution

MORE TREATMENT

- More noticeable in dry soil following wet spring
- Apply $Na_2B_4O_7 \cdot 10H_2O$ to soil
- Apply H_3BO_3 as foliar spray
- Foliar Solubor at 15 - 60 mg B/tree
- Slow release Boro-silicate to maintain narrow range