Boron: Function and Recent Research Results



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Definition of Boron

Nonmetallic chemical element occurring only in combination
- with sodium and oxygen in borax, $Na_2B_4O_5(OH)_4 \cdot 8H_2O$

- boric acid: H_3BO_3

Boron is an essential plant micronutrient:

- Micronutrients:
  - trace, ppm, amounts in tissue
  - essential growth and development

- Katherine Warington: 1923
  - determined boron essential micronutrient
    - black fly
  - Research after1990 established functions

n-history.org.uk/harpenden-history/people-2/scientists/katherine_warington_5_september_1897_3_july_1993

Katherine Warington - 1897 to 1993

Distinguished Botanist - first to note importance of boron to plant growth

Early life and education

Katherine Warington was born in Harpenden on 5 September 1897, a twin and one of the five daughters of Helen Louisa Makins and the agricultural chemist Robert Warington FRS (Jnr). Her mother died when the twins were a year old, so they were sent to to live with their mother's sister Gertrude and her husband the Revd Charles Longland, vicar of Radley near Oxford. When their father married one of Dr Spackman's daughters, Rosa Jane, in 1902, the twins returned to the family home, High Bank (14) Milton Road. However in 1907 Robert Warington died of cancer, and the five sisters kept Rosa Jane company until her death in 1923.

Family Photograph (1903), with Rosa Jane Warington

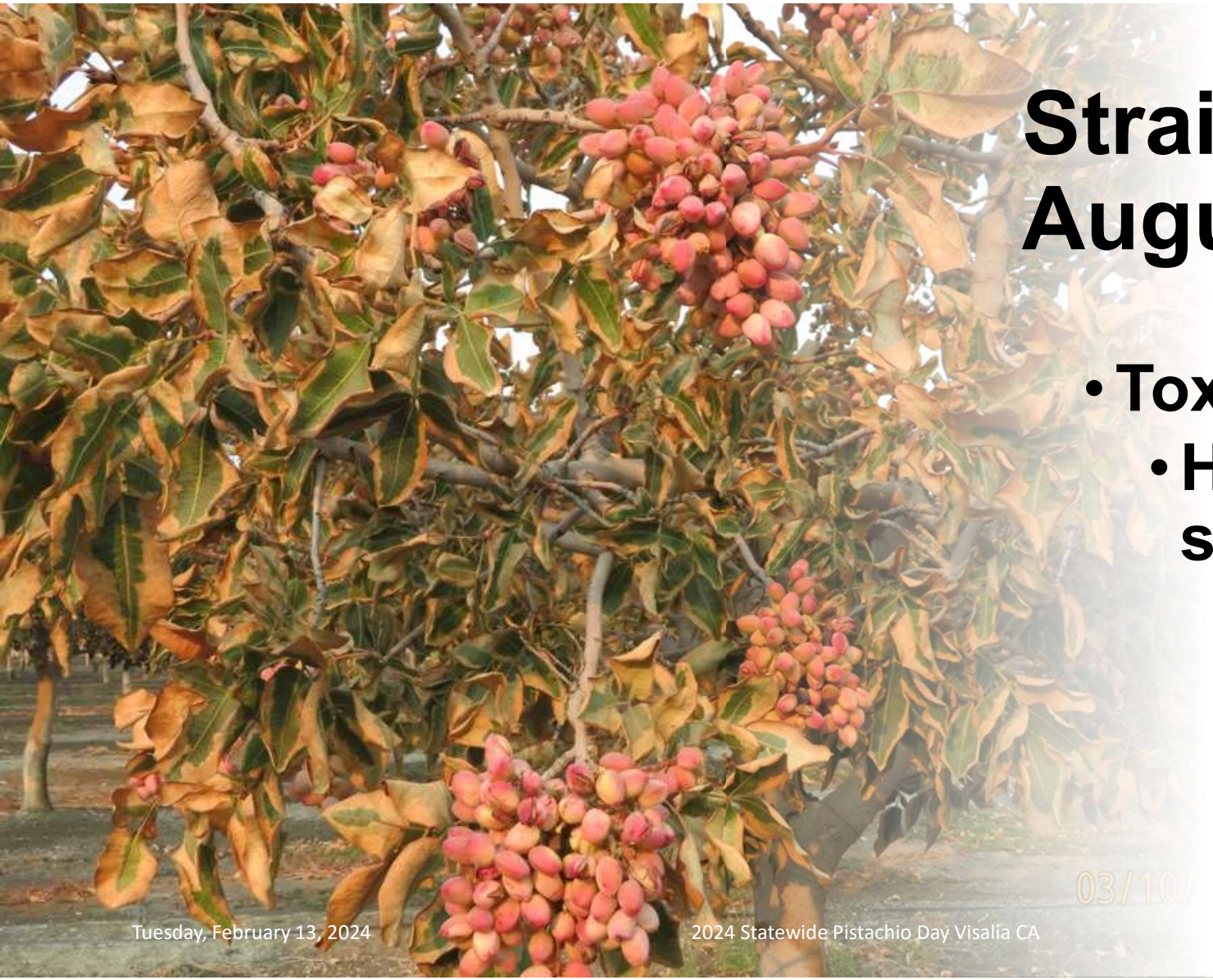
The Warington family in 1903 – the five girls with their father and step-mother. * – Credit: Warington-Wickham family archives

Boron: functions

- Essential for cell wall and membrane construction in multiple tissues:
- Deficiencies appear in meristems first:
  - Reproductive > Roots > Leaves

Boron in pistachio:

- Initially deficiency:
  - Strain Ranch in Colusa county…late 1980s
  - Atlantica and Integerrima (PGI)



Strain Ranch: August 1989

- Toxicity
  - Heavy fruit set
    - Pollen tube growth

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Boron Boosts Pistachio Yields

California researchers find foliar applications are most effective after three-year trials. Timing of application is critical.

***Summary**: Boron supplementation applied on pistachio trees in the late dormant stage increases germination, reduces blanking as well as non-splits, and, consequently, increases yield.*

Soil applications of boron are effective in raising leaf boron levels, but are not as effective as foliar sprays at increasing yield.

Recommended rates of boron application most effective in raising yields are between 2 and 5 lbs Solubor/100 gals.

Timing of foliar applications of boron is critical. Late dormant sprays (just prior to bud swell through to 20 percent bud break) are the most effective. Enhanced yield response to boron sprays may decrease yield in the following off-year effectively enhancing alternate bearing. At the site used here, boron sprays produced a net yield increase of approximately 20 percent over two veers.

Based on the results of this work, it is suggested that pistachio growers provide supplemental boron sprays at the rate of 2 to 5 lbs Solubor/100 gals during the late dormant or early bud break stage. These recommendations are based on research in two soil types in plants with average tissue summer boron levels of 150 to 190 ppm. The validity of these recommendations in different soils and environmental conditions is being assessed.

Boron deficiency occurs widely in the fruit growing regions of California. It is a limiting element in many pistachio growing regions of the central valleys. Boron deficiency results in characteristic leaf symptoms that can be alleviated with the additions of boron fertilizer.

Boron long has been recognized as an essential element for plant growth.

However, its role and mode of action are unknown. Boron has been reported to be involved in such diverse processes as nucleic acid metabolism, cell division, sugar biosynthesis and translocation. and membrane functions. The role boron plays in the flowering and fruiting process, however, is unclear.

There is an immediate need, therefore, to understand how boron moves through the soil and plant, and

Table 1. Effect of application date of foliar boron (5 pounds of Solubor/100 gals) on pistachio yield and leaf boron, Brown et al., University of California.

Application Date	Growth Stage	Yield lbs	Leaf Boron (July) micro-g
February 28	Late dormant	64	188
March 19	Early bud break	52	188
April 3	Flowering	54	187
April 17	Leafing out	51	256
May 8	Fully leafed out	52	468

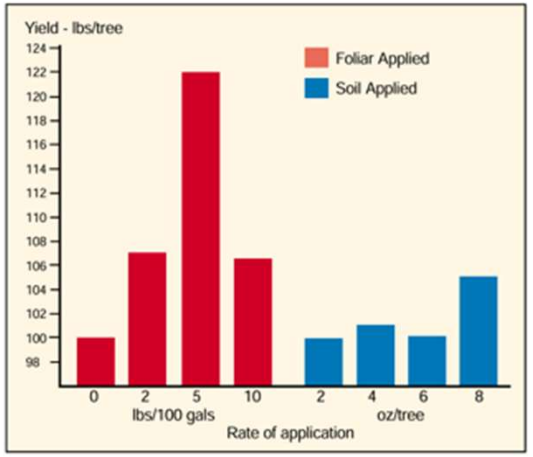

Figure 1. Influence of boron (soil or foliar) on pistachio yield, three-year average, Brown, et al., University of California.

Boron Rate, Timing and Application Method:

Late dormant:

Solubor: (20.5% B as borate)

- Foliar:

5 lbs/acre product

Soil:

8 oz/tree

August leaf level:

- critical: < 90 ppm

- 150-250 ppm

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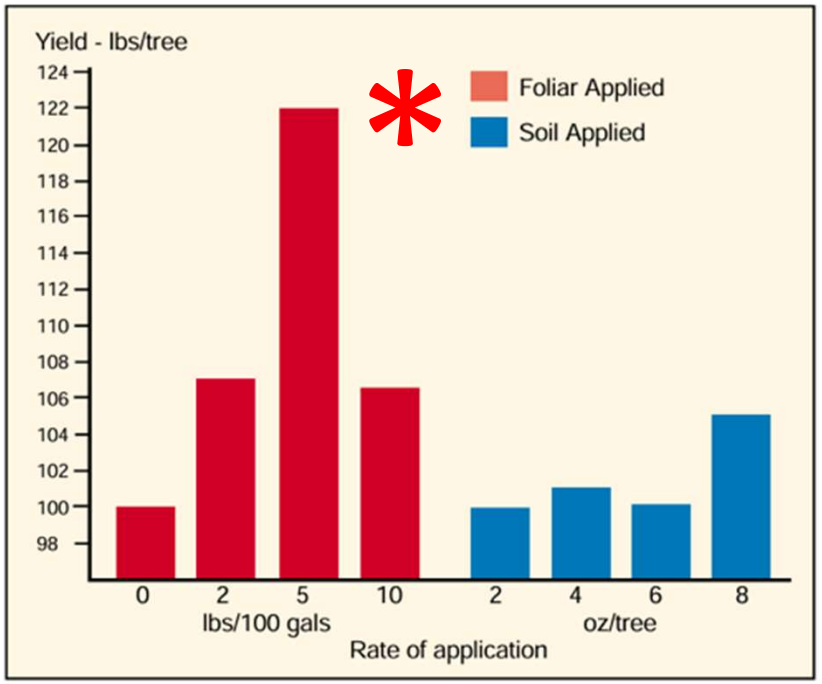

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Why was late dormant foliar so effective?

- **Pollination and fruit set:**
  - **Short, rapid, critical growth stage with high boron demand**
  - **Low soil temperatures decrease root uptake**
  - **Low transpiration rate of buds decreases transport to buds**
  - **Boron is immobile in pistachio**

How boron improves yield:

- Enhanced:
  - Pollen germination
  - Pollen tube growth
    - high boron demand*
  - Fruit set
- Decreased
  - Embryo (nut) abortion

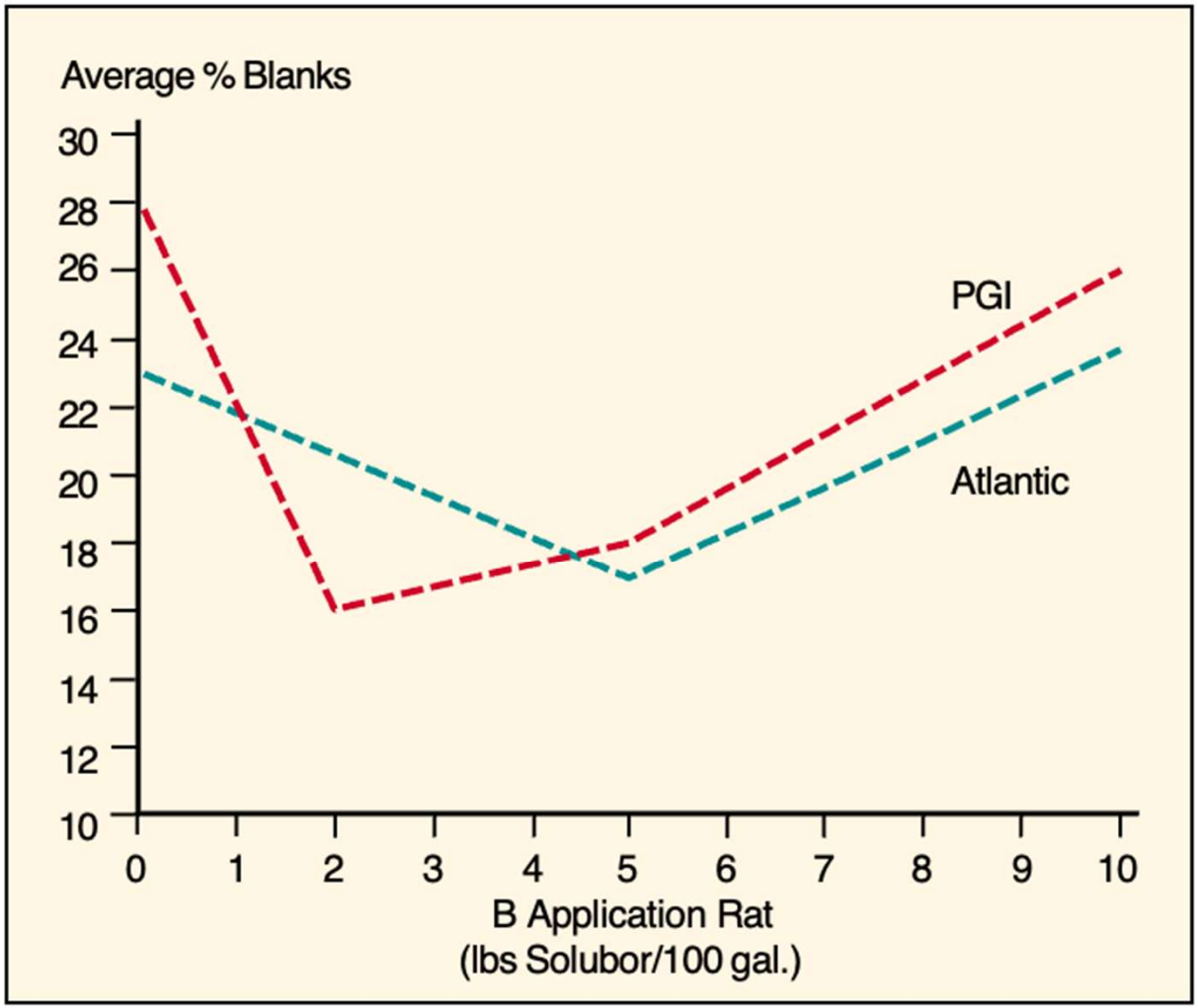

Figure 2. Effect of boron foliar treatment on percent of blanks in pistachio, Brown, et al., University of California.

*
Title:
The gene responsible for borate cross-linking of pectin RG-II is required for plant reproductive tissue development and fertilization

Authors and affiliations:
Hiroaki Iwai*, Akiko Hokura†, Masahiro Oishi§, Hiroshi Chida*, Tadashi Ishii‡, Shingo Sakai* & Shinobu Satoh*

Boron: function in roots, leaves

- **Deficiency limits cell enlargement and cell division in the root meristem limiting root growth**
- **Deficiency affects cell wall synthesis, carbohydrate metabolism and reduces nitrate reductase activity, N and K levels**

>

Managing vegetative boron deficiency is easy:

- Boron is generally not fixed in the soil, therefore available
- In low boron soils, make available prior to key growth stages
- Soluble boron fertilizers are best
- Foliar application is effective
  - effect is short term
  - localized due to immobility

>

Narrow deficiency to toxicity range:

Very quickly moves from deficiency to toxicity:

- narrow range is a function of boron solubility

- in soil boron exists primarily in the solution phase; at lower pH is boric acid

- ~ 15% boron adsorbed as a fixed soil fraction*

- easily taken up if soil boron levels are high

- uptake uncontrolled at very high levels

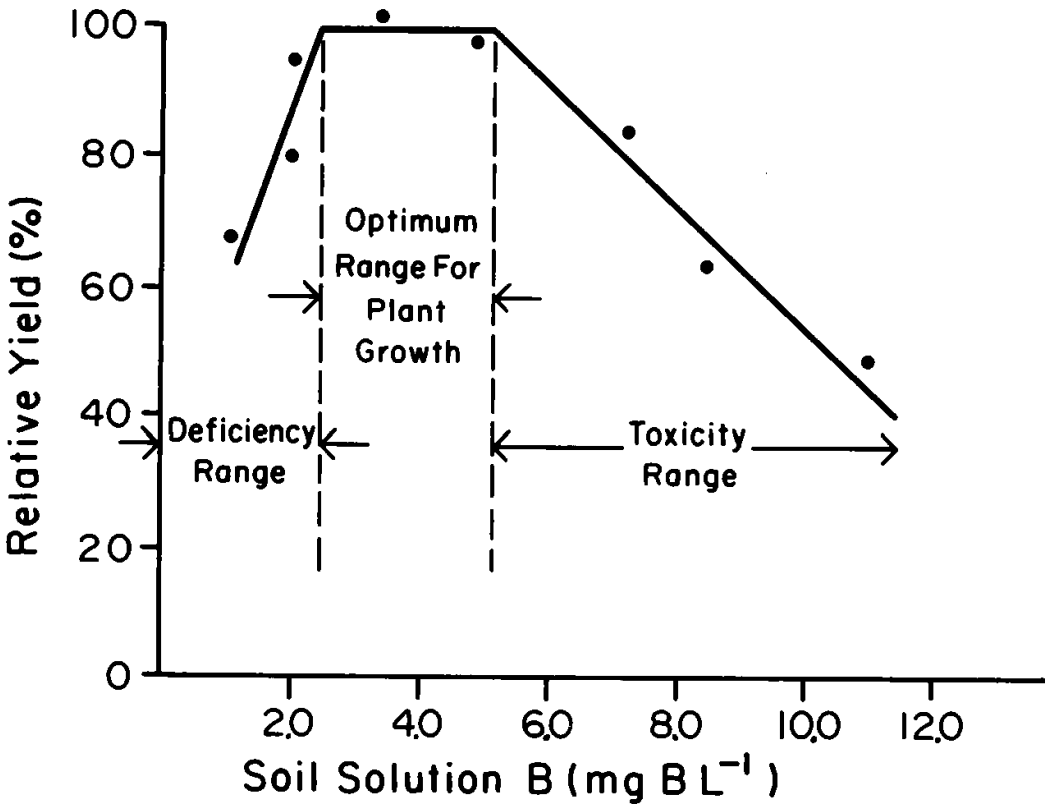

Fig. 2. Relative yield as influenced by soil solution boron (idealized).

*Van Eynde et al., (2020) Boron speciation and extractability in temperate and tropical soils: A multi-surface modeling approach. Applied Geochemistry 123(3)

Gupta,` U. C., et al. (1985). "Boron toxicity and deficiency: A review." Canadian Journal of Soil Science 65(3): 381-409.

pH, EC and soil texture affect boron availability:

- @ pH 8.5 uncharged easily assimilated H_3BO_3 becomes anion HBO_4^- , cannot pass membranes
- Clay vs sandy soils have higher adsorption capacity
- Boron uptake decreases as soil EC increases

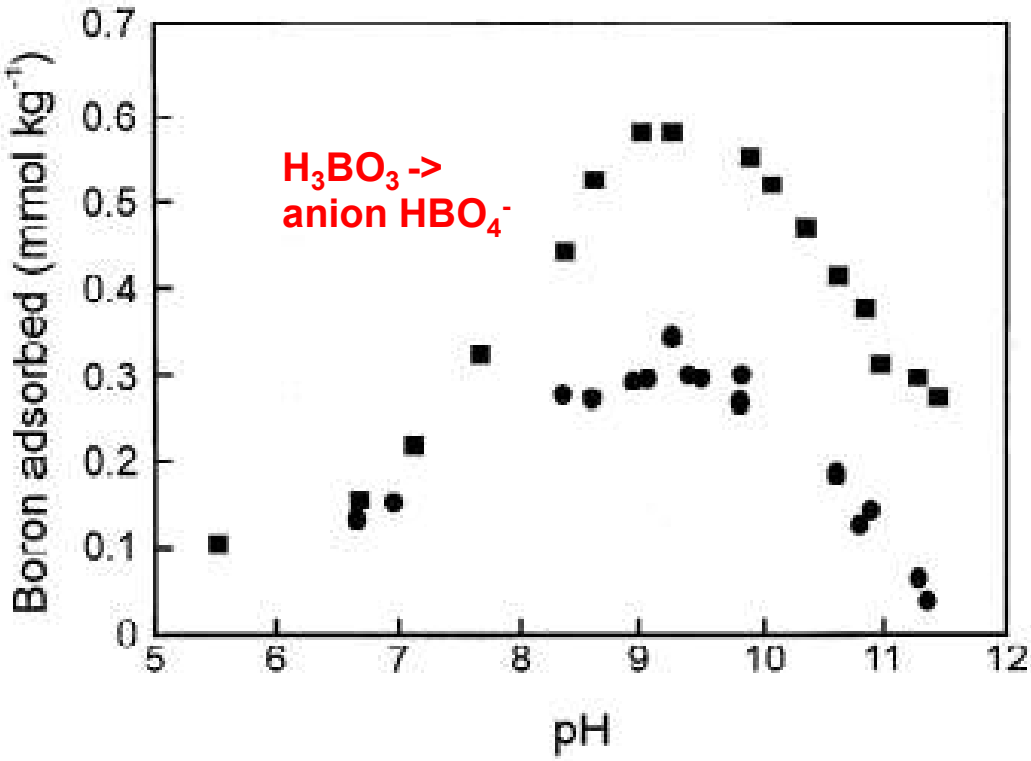

Figure 2. Boron adsorption on a surface (■) and a subsurface (●) sample of an arid zone soil as a function of pH.

Species differences in uptake:

Uptake varies among Pistacia species

Sensitivity to boron among *Pistacia* rootstock species ?

Roots are generally more sensitive that shoots

- compromises root growth

- compromises N fixation

- secondary N and K deficiency

- often goes undetected

HortScience 57(1):65–71. 2022. https://doi.org/10.21273/HORTSCI16191-21

Leaflet Boron Concentration Reduced with Hybrid *Pistacia vera* Rootstocks

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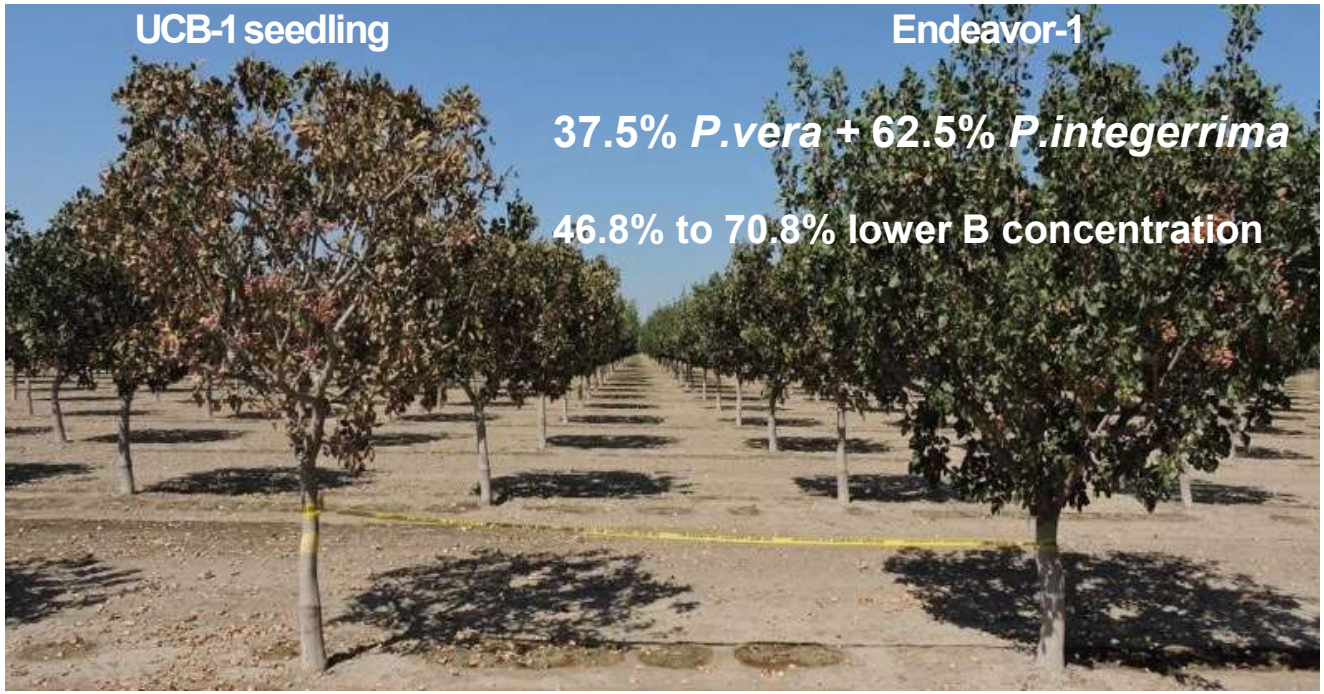
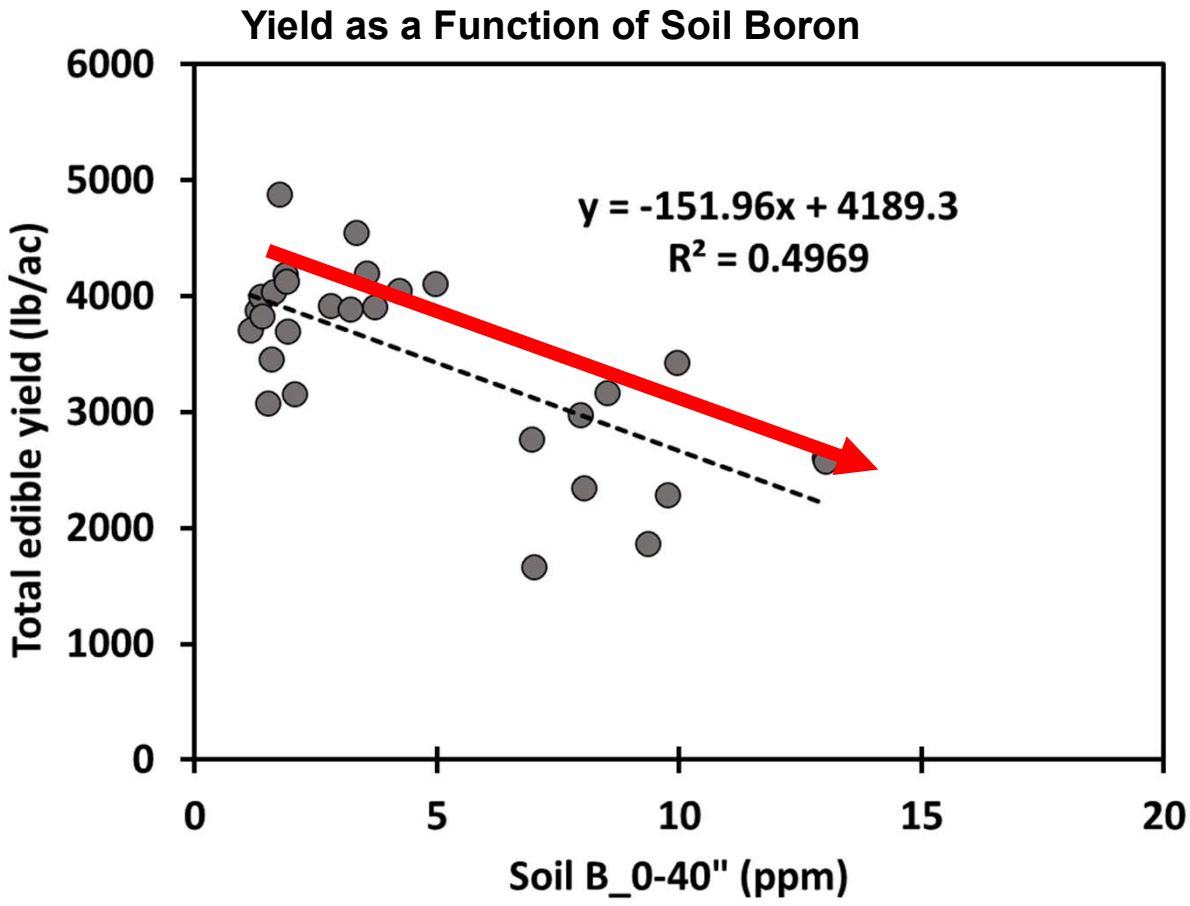


Boron “toxicity”?

- Coexists with sodium and chloride in arid regions
  - Does not contribute to salinity
- Visible leaf damage: multiple explanations in literature
  - membranes, metabolism, N,K
- **Questions:**
- **how harmful is boron toxicity?**
- **how does boron produce its harmful effects?**

As soil boron levels increased yield declined:

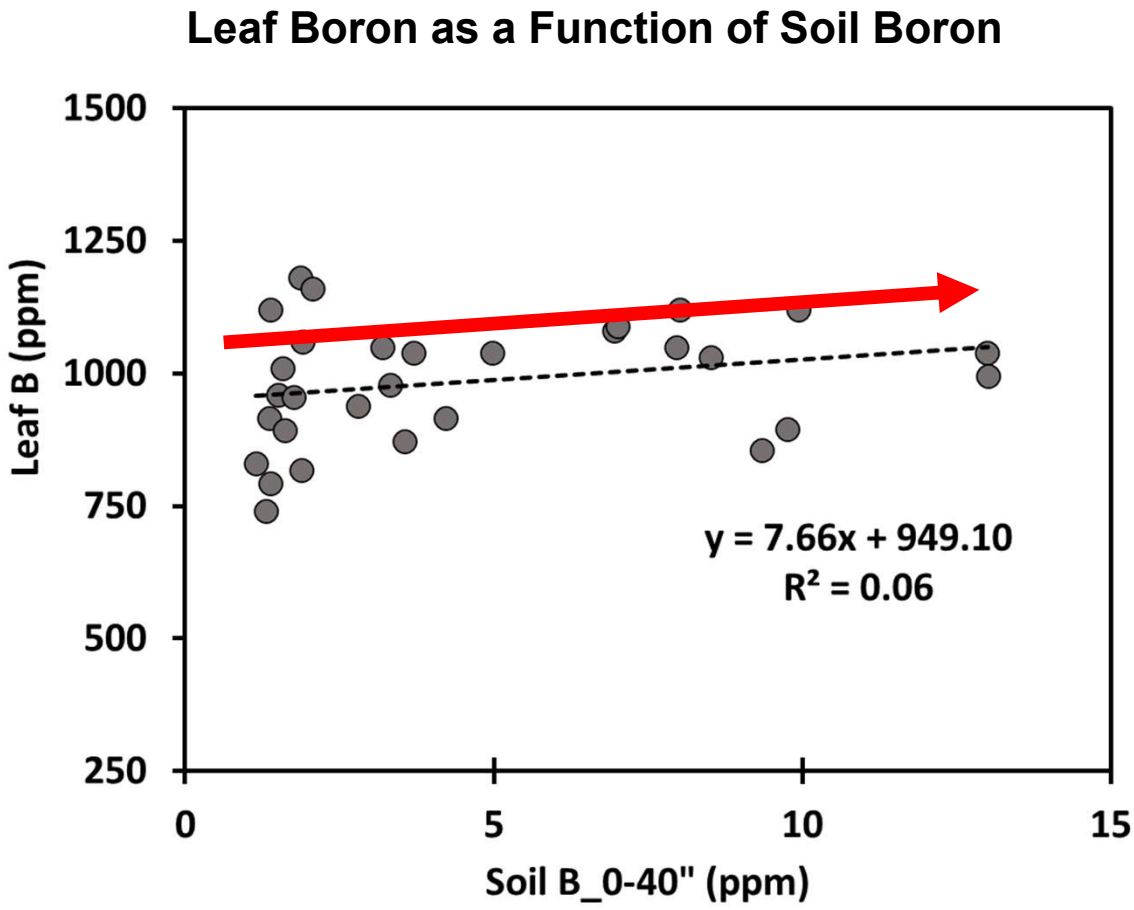
(r = - 0.705, p < 0.001)



As soil boron levels increased leaf levels did not:

No significant correlation between leaf boron and soil boron:

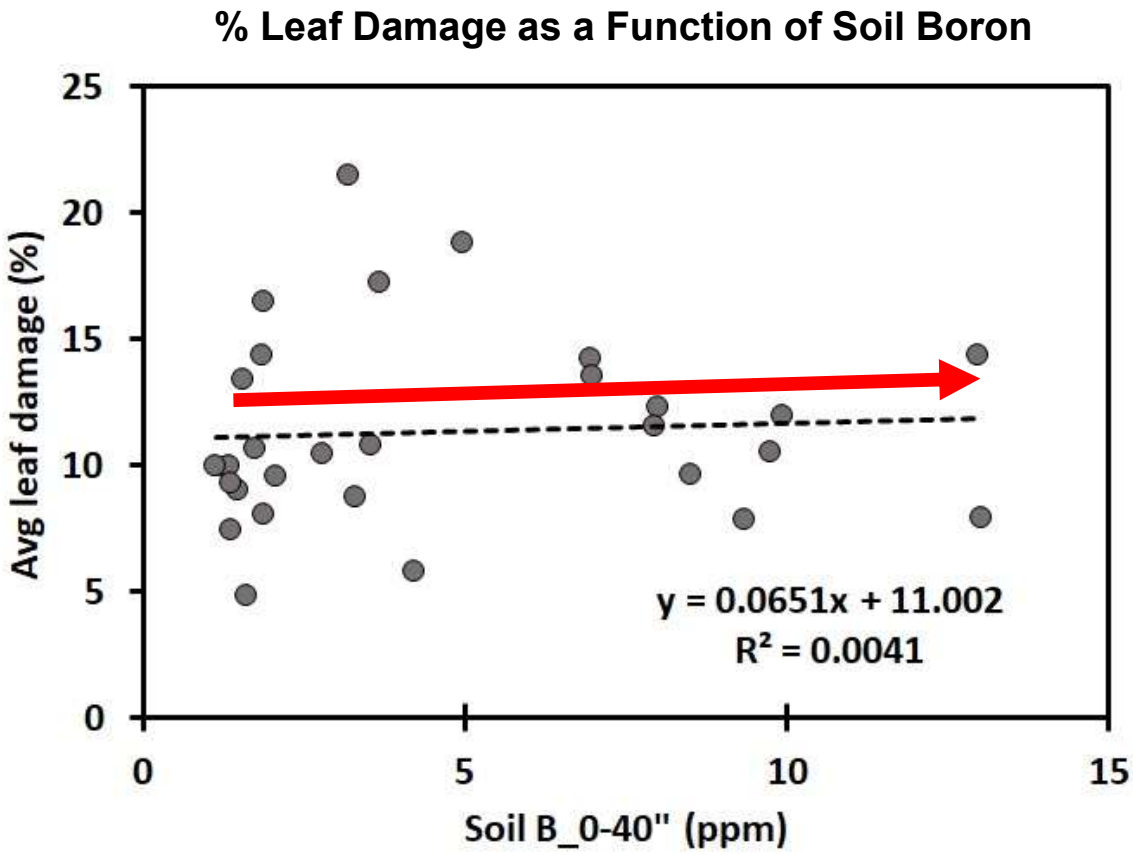
(r = 0.25)



As soil boron levels increased % leaf damage did not:

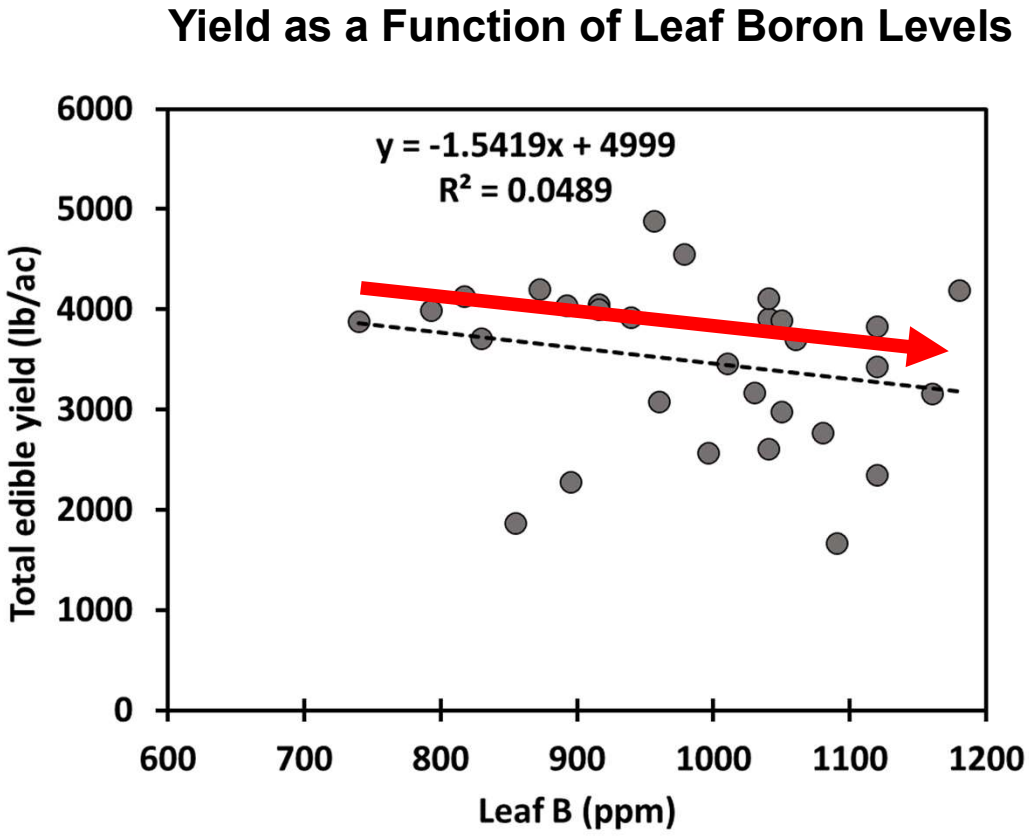
No significant correlation between leaf boron and % leaf damage:

(r = 0.0064)



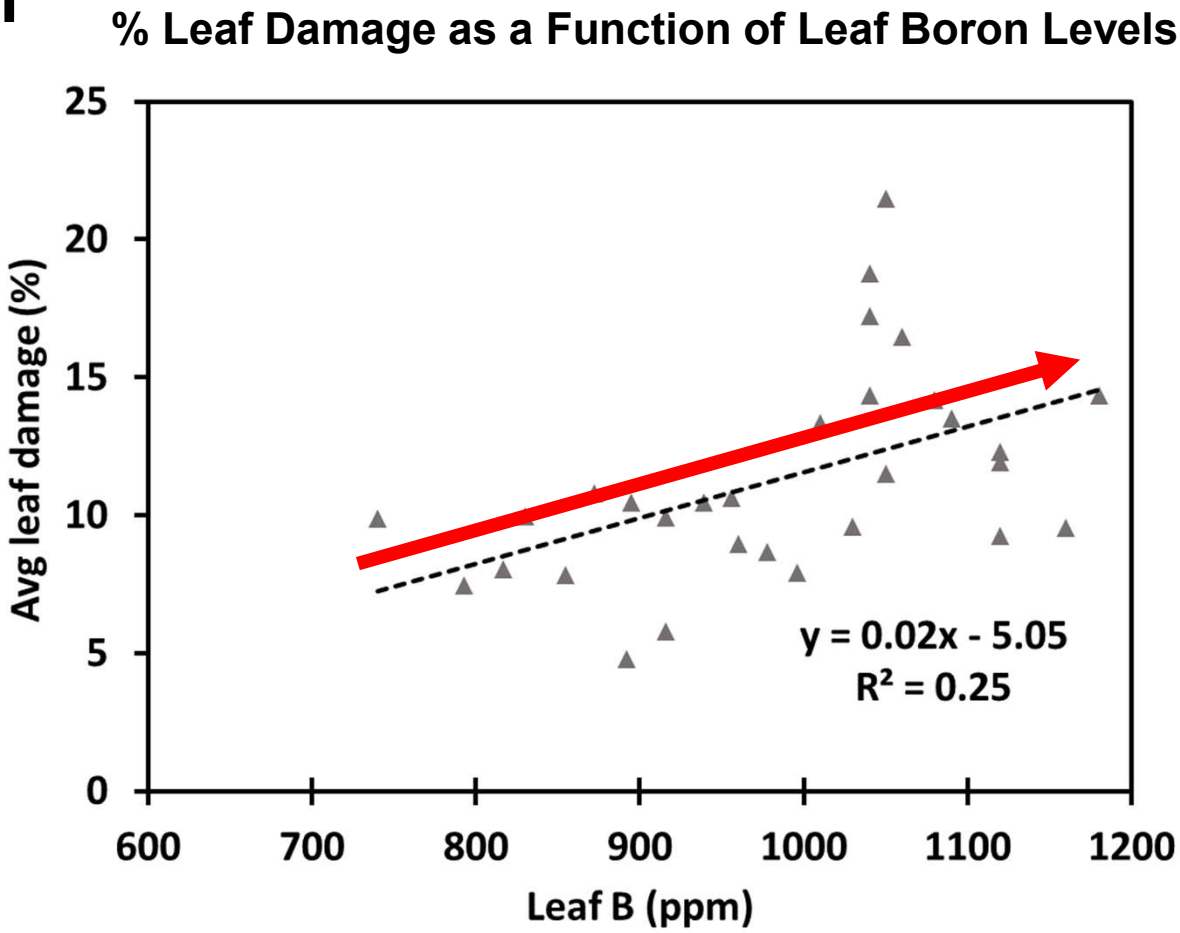
Increases in leaf boron levels did not decrease yield significantly:

(r = 0.22)



Increases in leaf boron levels moderately increased % leaf damage:

(r = 0.50, P<0.01)

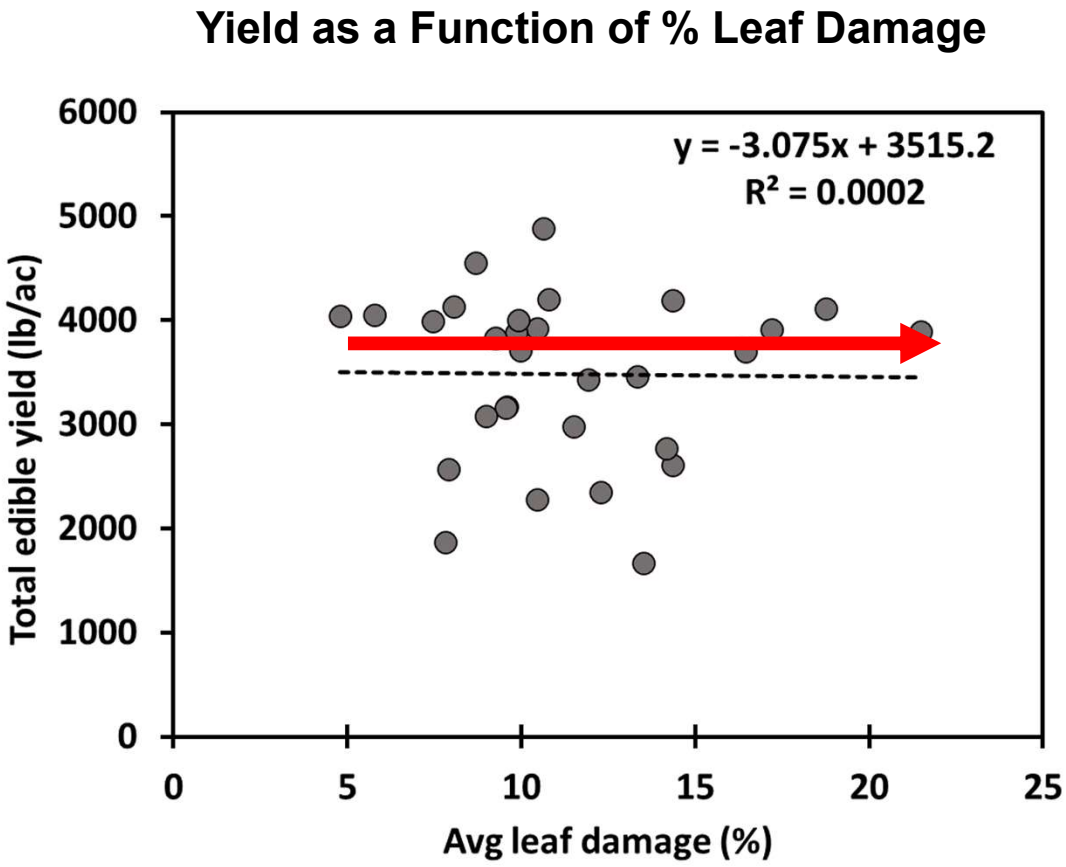


Increases in % leaf damage had no effect on on yield:

No significant relationship between % leaf damage and yield

(r = 0.014)

Summary:
While soil boron levels affect yield:
- not correlated with leaf boron
- not correlated with % leaf damage
"Boron Toxicity"
Suggesting:
- should be monitoring/controlling soil boron to decrease yield loss.



Boron Summary:

Boron deficiency manifests in meristems first:
- **flowers > roots ? > vegetative parts**
- **flowering easily corrected with foliar, and vegetative growth, with soil applications**

Best deficiency management is assessing soil boron levels, fertilize/fertigate to maintain 150 ppm leaf level, supplement with late dormant and spring micronutrient foliar sprays

Boron can quickly move from deficiency to "toxicity":
- **soil texture, pH, EC and rootstock uptake**

Evidence thus far suggests monitoring/decreasing soil boron levels is best approach to decreasing yield losses due to boron "toxicity"