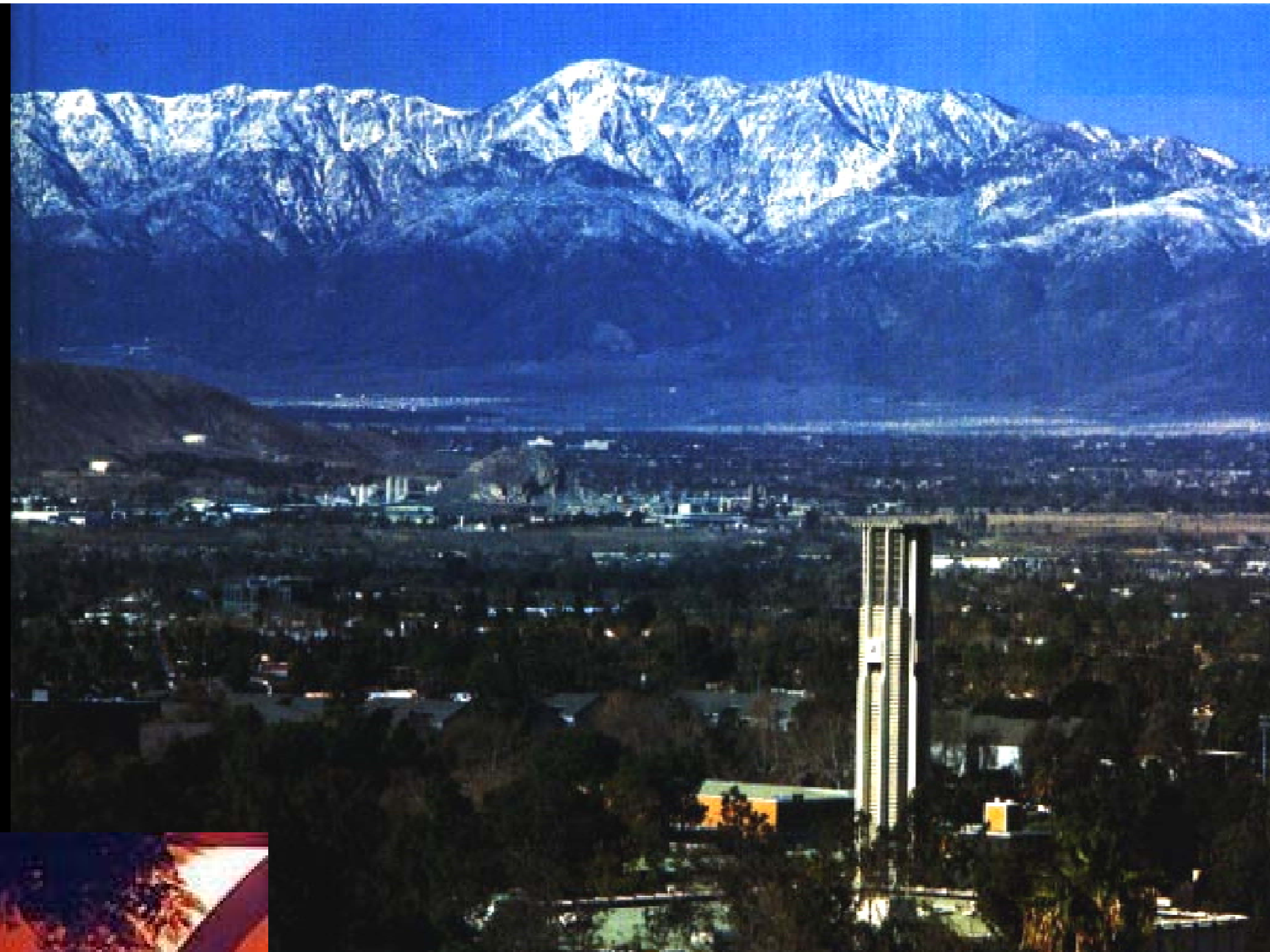

UNIVERSITY OF CALIFORNIA, RIVERSIDE

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Towards Development of
Foliar Fertilization Strategies
for Pistachio
~Proof of Concept~
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The Goal of Pistachio Growers

1) Is to increase yield, nut size, and percent split nuts per hectare, while reducing production costs.
2) Optimizing tree nutrient status is a cost-effective strategy for increasing yield, nut size and quality.
3) Foliar fertilization is a valuable tool to use in achieving this goal.

Soil Fertilization - Benefits

Essential Nutrients

Nitrogen	Zinc
Phosphorus	Manganese
Potassium	Iron
Calcium	Copper
Magnesium	Boron
Sulfur	Chloride
	Molybdenum
	Nickel

Soil fertilization is an inexpensive strategy for providing essential mineral nutrients to the tree.
Correct soil problems: soil structure, salinity, pH, water-holding capacity, pathogen-suppressive rhizosphere,unplug irrigation emitters.

Foliar Fertilization - Benefits

Many factors affect uptake of soil-applied nutrients:

Soil moisture
Transpiration
Nutrient solubility
Soil temperature
Root activity
Soil pH
Soil microflora
Salinity
Crop load

Foliar fertilization is a rapid and efficient strategy for providing an essential mineral nutrient directly to the leaves to overcome the soil's inability to release nutrients to the roots or the root's inability to take up nutrients.

Foliar Fertilization - Benefits

Foliar fertilization reduces nutrient accumulation

- soil
- run-off water
- surface waters (streams, lakes and oceans)
- groundwater (drinking water supply)

where they contribute to euthrophication, salinity, and nitrate contamination.

Foliar Fertilization - Benefits

Soil-applied fertilizers should be replaced, at least in part, with foliar-applied fertilizers in best management practices (BMPs).

Foliar Fertilization - Problems

1) Not all nutrients are taken up by leaves.

2) Even if taken up, not all nutrients are phloem mobile.

3) *A priori* knowledge derived from research is essential to develop a foliar fertilization program for a crop.

Nutrient absorption rates by leaves.

Nutrient	Time for 50% absorption
Urea	½-2 hours
Magnesium	2-5 hours
Potassium	10-24 hours
Calcium	1-2 days
Manganese	1-2 days
Zinc	1-2 days
Phosphorus	5-10 days
Iron	10-20 days
Molybdenum	10-20 days

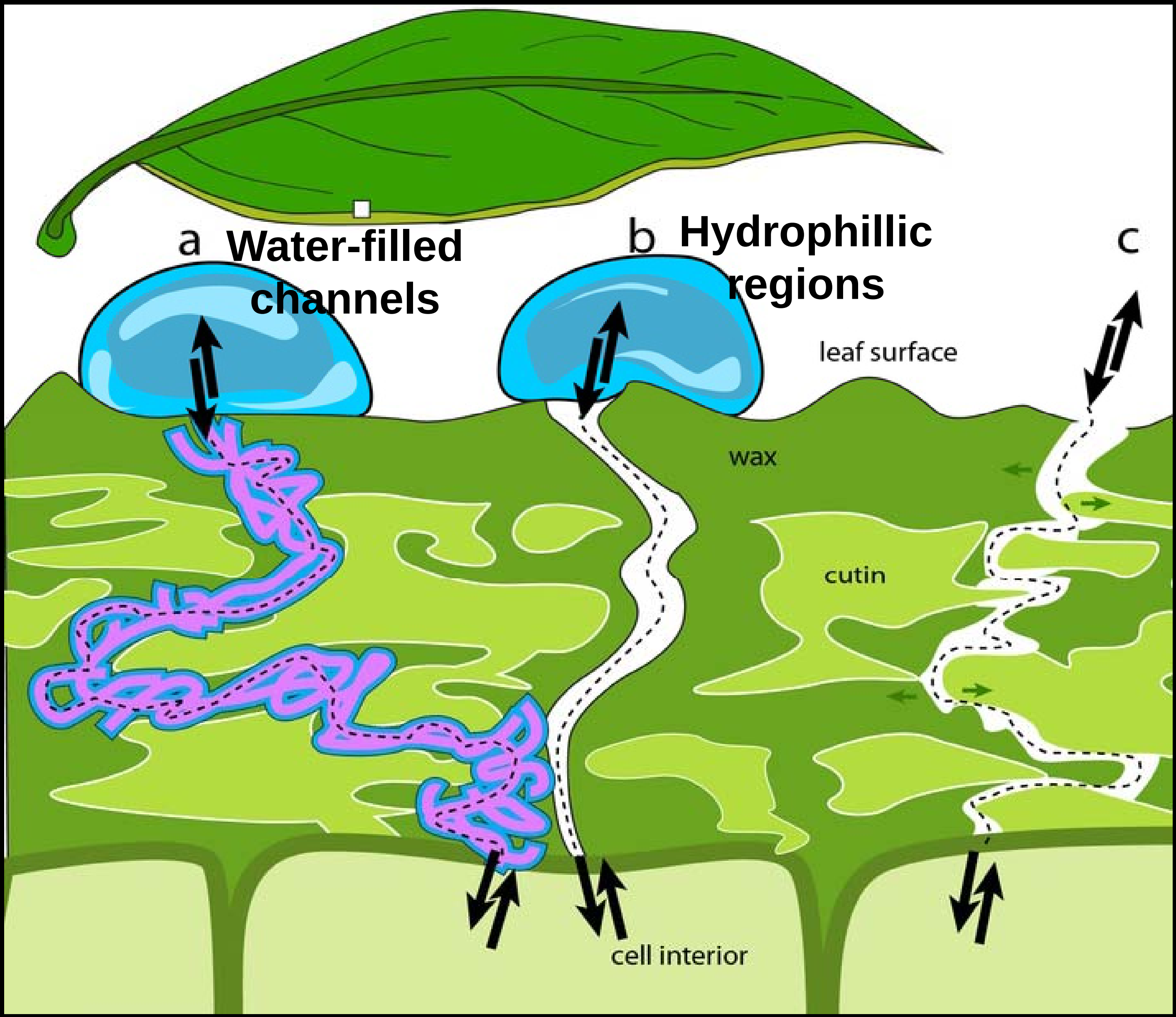
Nutrient mobility in the phloem

Mobile	Partially
Urea nitrogen	Zinc
Phosphorus	Iron
Potassium	Copper
Chlorine	Manganese
Sulfur	Molybdenum
	Boron

Immobile

Calcium

Foliar Fertilization - Problems



Lipophillic pathway

Cuticle

Cell wall

Cell interior

Foliar Fertilization - Solutions

- Select fertilizers with greater solubility.
- Use wetting agents.
- Apply foliar fertilizers when leaves are 1/2 –2/3 fully expanded.
- Target foliar-fertilizers to other organs: buds, inflorescences, or flowers.

Our Approach

Is to obtain an economic advantage

By identifying the role essential nutrients play in the physiology of the crop, and

Applying a nutrient as a foliar fertilizer at a key stage in the phenology of the tree to stimulate a metabolic process that increases yield, fruit or nut size and quality, such that the foliar-applied fertilizer results in a net increase in grower income *even when the tree is NOT deficient by standard tissue analysis*.

Our Approach

Is to target periods of high nutrient demand,

especially periods of high nutrient demand that occur when soil conditions compromise nutrient uptake by the roots.

The goal is to obtain a plant growth regulator effect from a foliar-applied fertilizer to increase fruit set, fruit or nut size and quality.

In our approach – Timing is critical!

Research Objectives

1) Strategy 1 – Foliar applications of boron, zinc urea-N at bud swell to green tip to enhance flower nutrient levels to increase fruit set.

2) Strategy 2 – Foliar applications of zinc, urea-N and zinc + urea-N at 1/2- to 2/3-leaf expansion, i.e., the cuticle is thin and surface area is large.

3) Strategy 3 – Use of low-biuret (< 0.25%) urea as a carrier to increase the uptake of boron, zinc, potassium and sulfur into buds and leaves.

4) To calculate a cost: benefit analysis.

Research Plan

Trees were 15-yr-old ‘Kerman’ pistachio scions on Pioneer Gold rootstock in an orchard owned by Paramount Farming in Kings County.

There were 12 fertilizer treatments, including an untreated control, each replicated on 15 trees in a randomized complete block design.

Fertilizers were applied in 100 gallons of water/a with a 3-point fan sprayer. Target tissues were covered prior to treatment. Tissues were sampled 7, 14 and 21 days after treatment and October for nutrient analysis by the UC Analytical Laboratory.

Results

- The experiment was well designed.
- There were no differences in tissue nutrient concentrations prior to any fertilizer application.
- Despite increased leaf levels of B, Zn, N, S, and Fe in October, elevated concentrations of these nutrients were not detected in buds or leaves the next spring.

Results

- Tissues for nutrient analysis should be collected multiple times after application.
- B applied to buds was undetectable after 8 days, but increased after 19 days.
- Zn applied to leaves was not detected after 7 or 21 days, but was elevated after 6 mos.

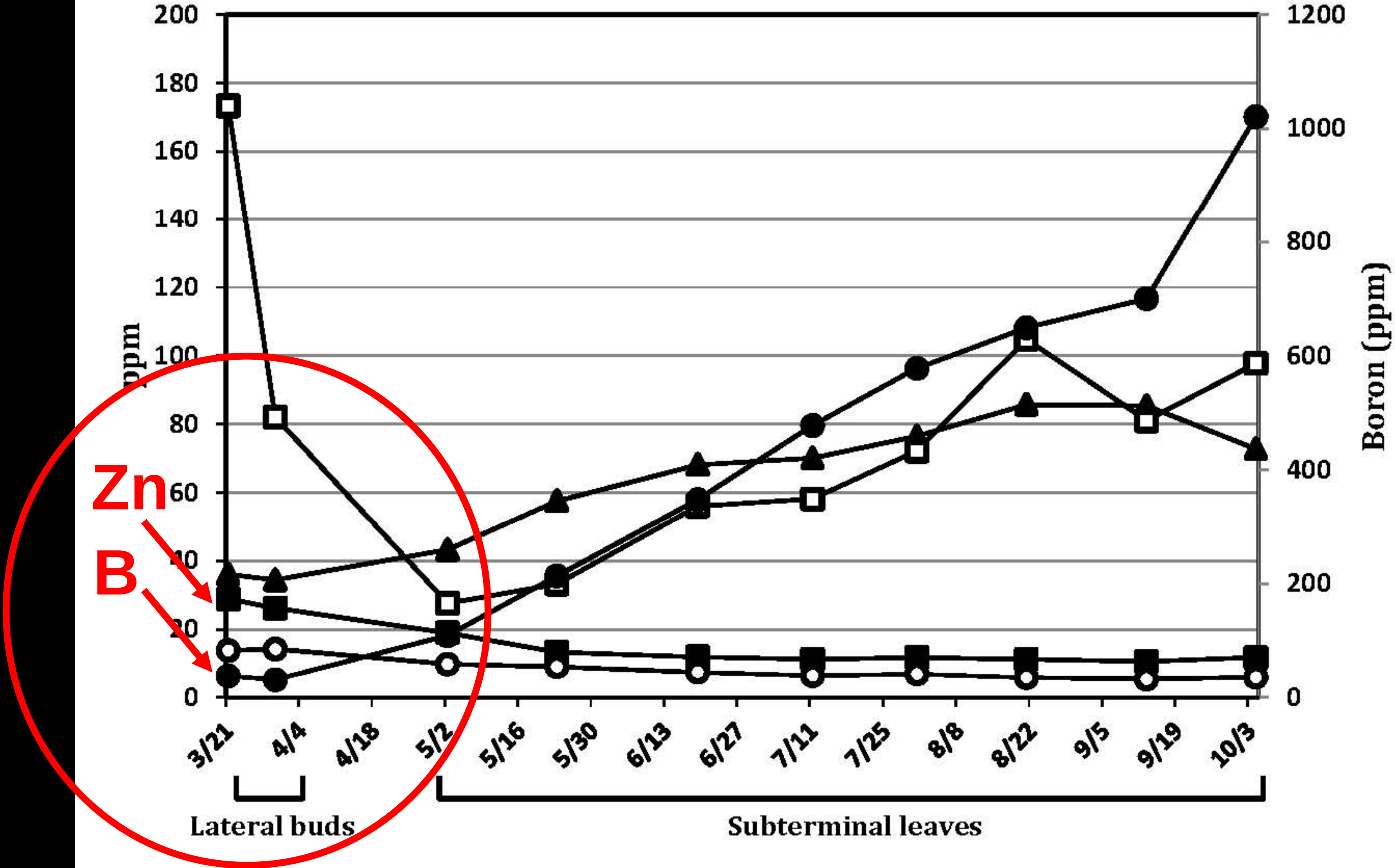
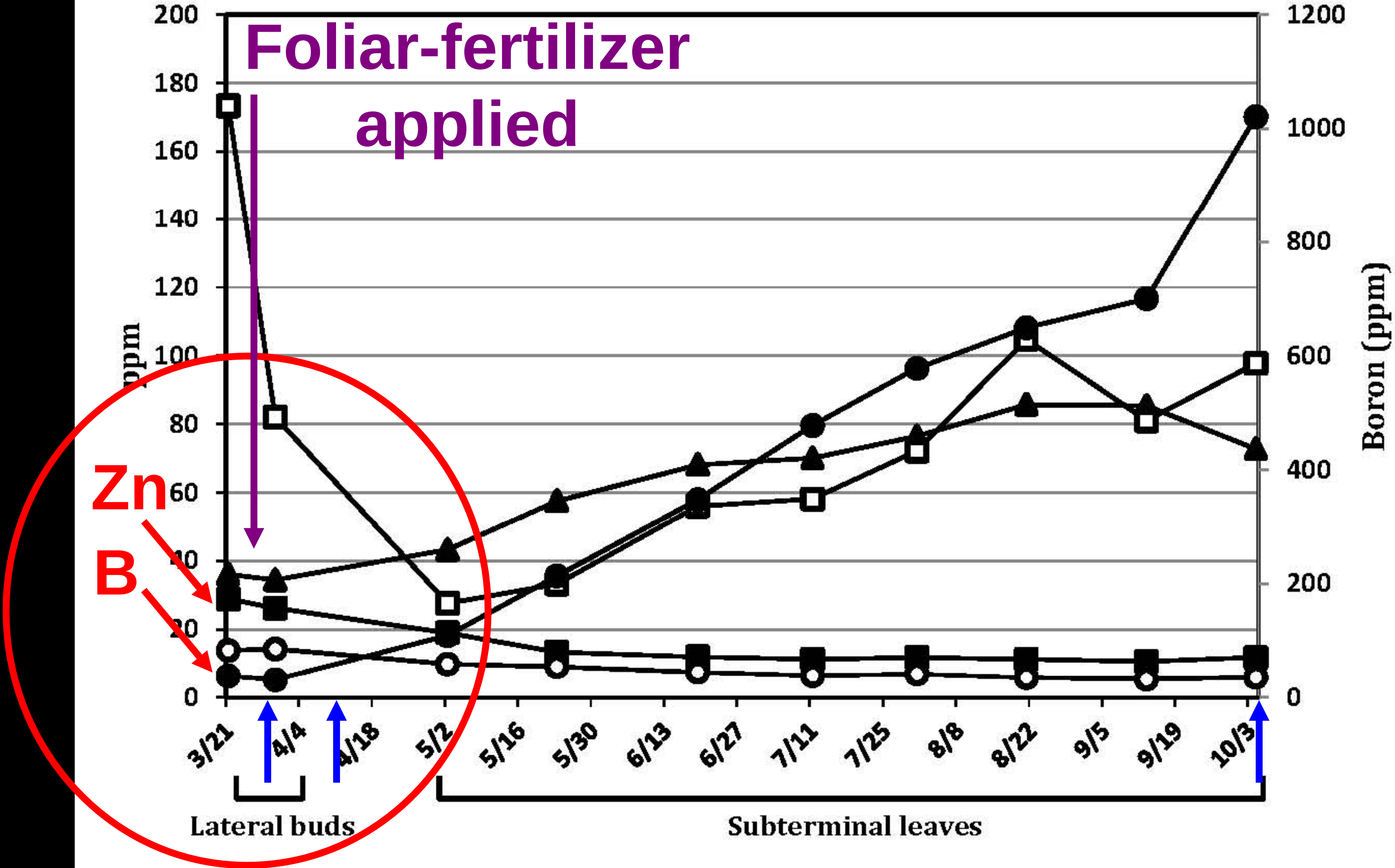


Figure 2. Comparison of the changes in bud and leaf nutrient concentrations of untreated (control) 'Kerman' pistachio trees, Lost Hills, CA, from March to October: (-●-) Boron, (-■-) Zinc, (-▲-) Manganese, (-□-) Iron, and (-○-) Copper.



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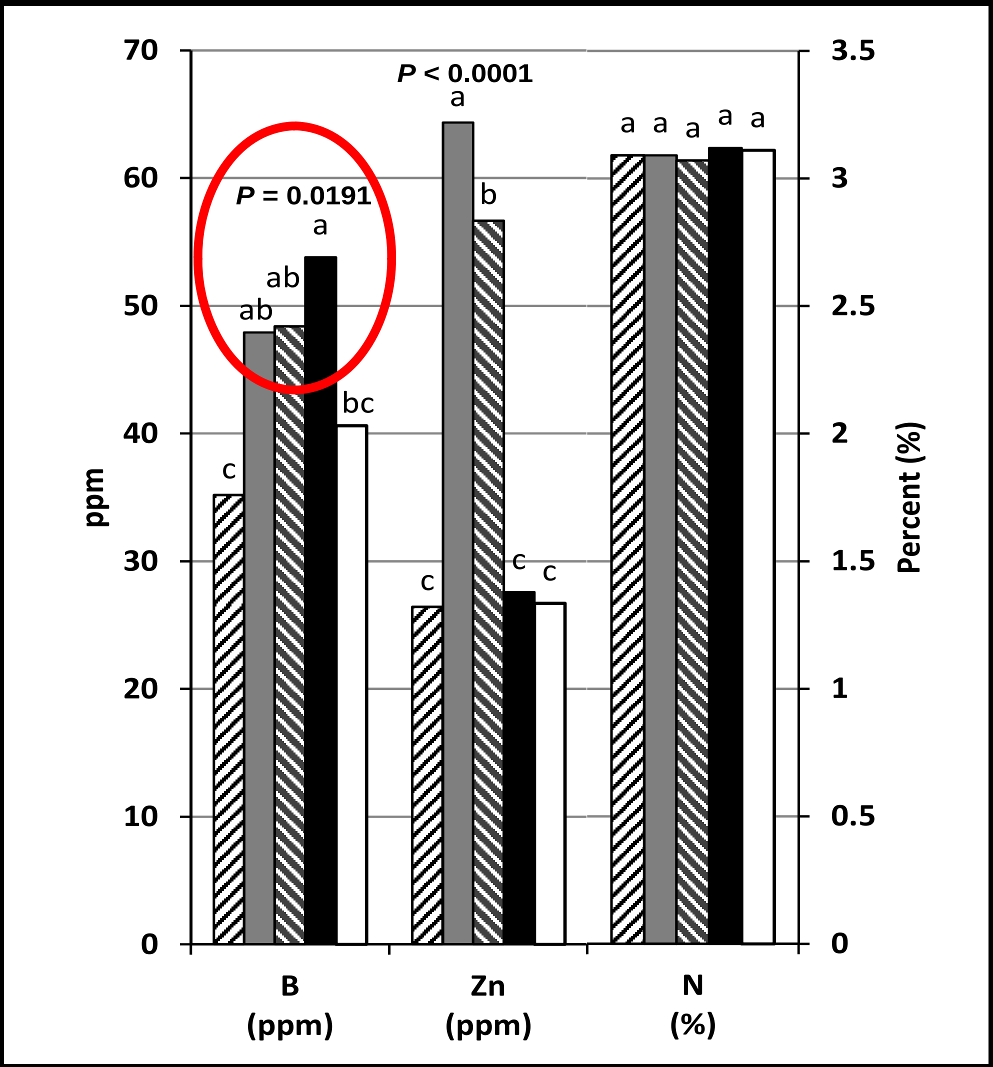
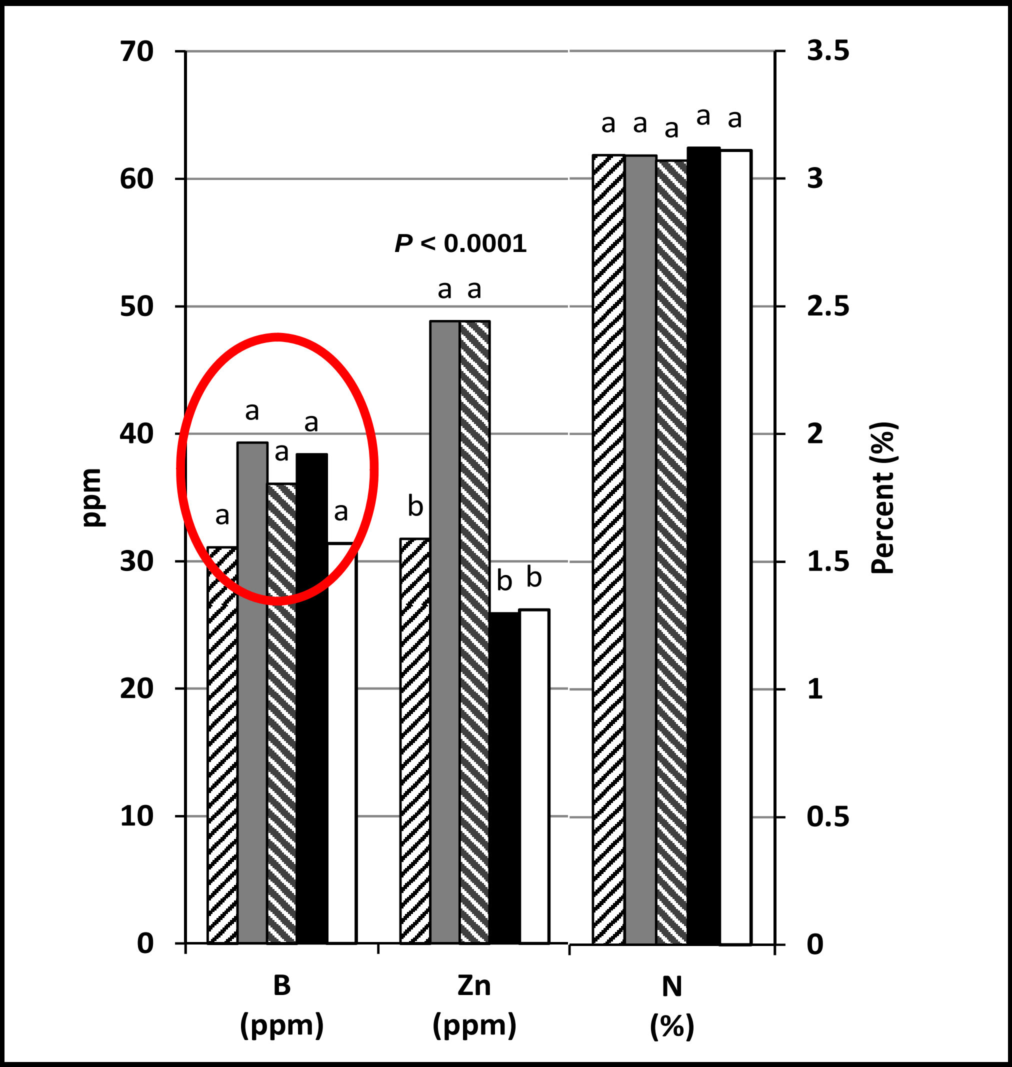
Foliar urea+B, urea+B+Zn and B applied at bud swell-green tip stage increased bud B concentration.

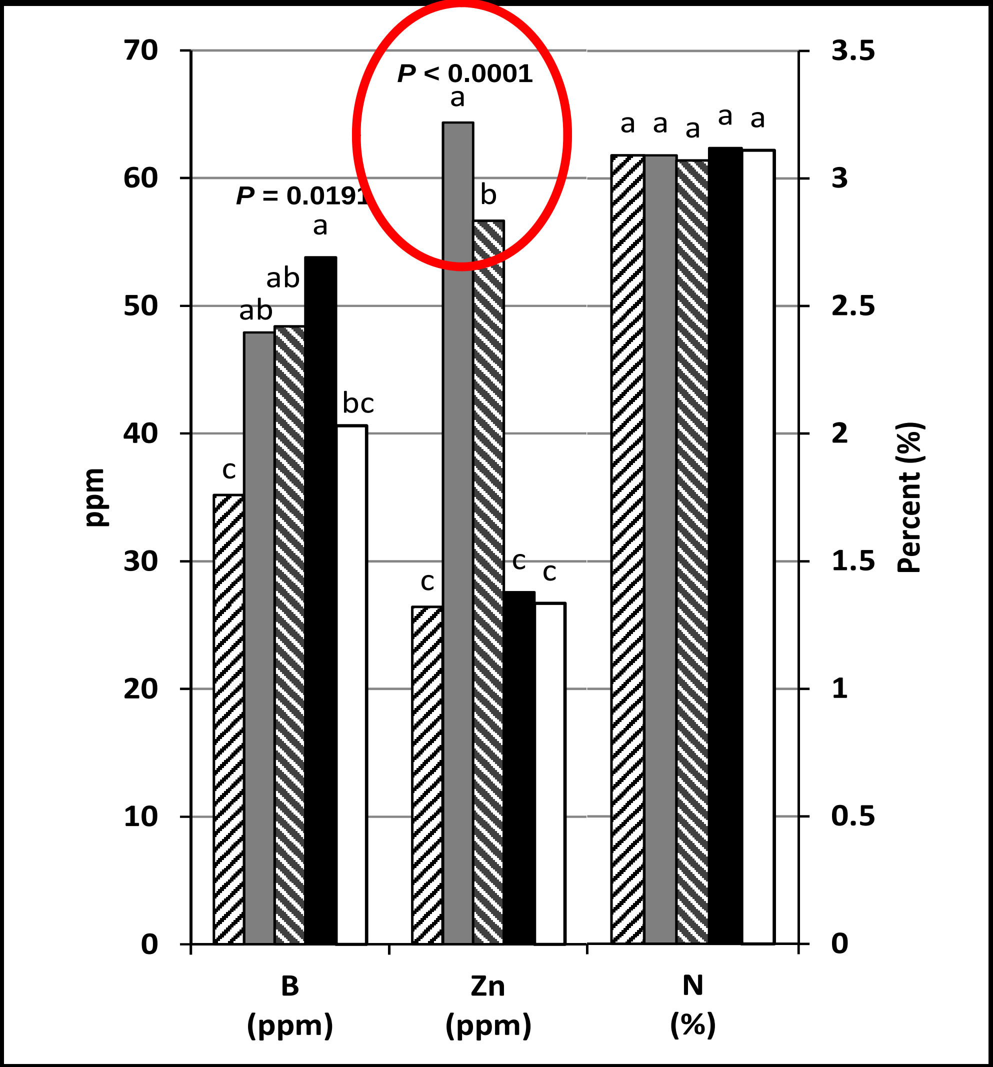




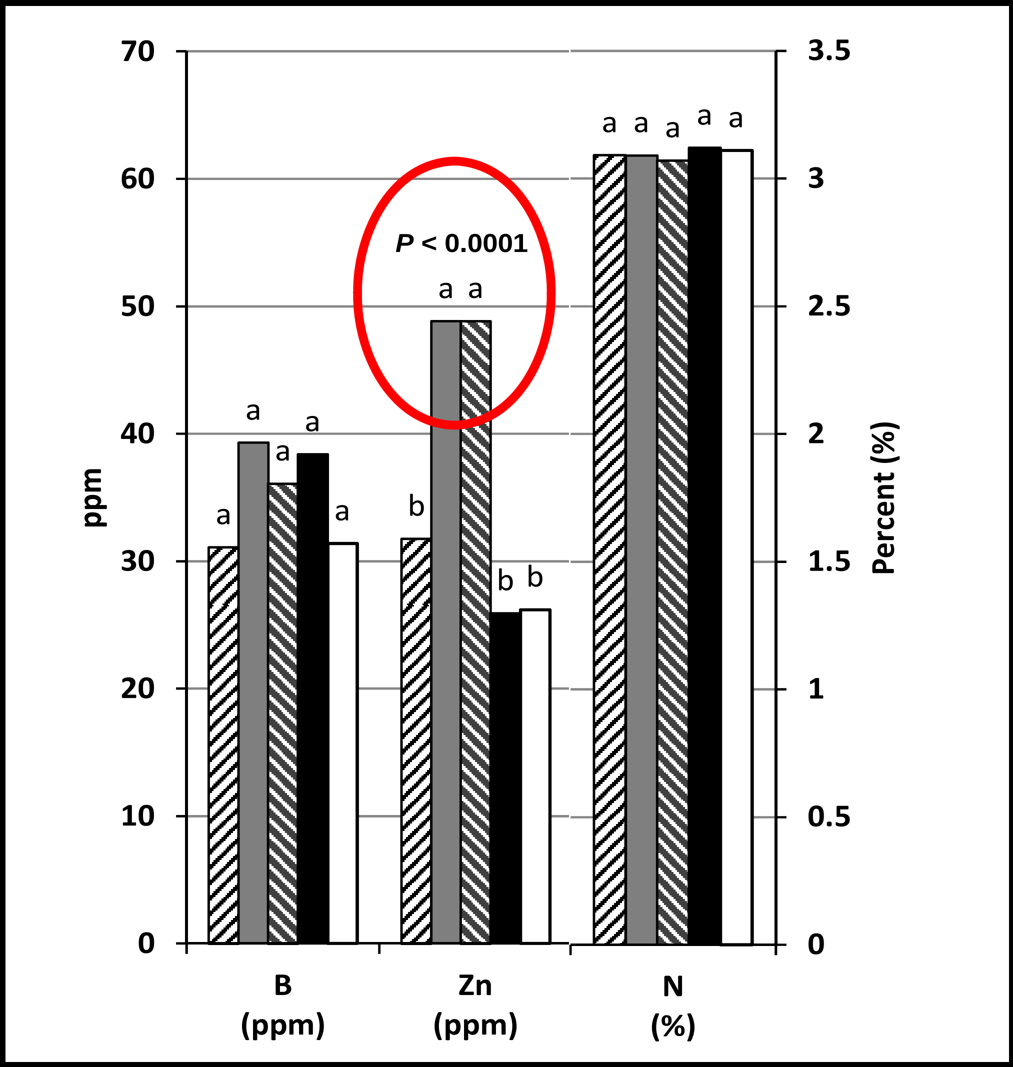
Year 1

Year 2

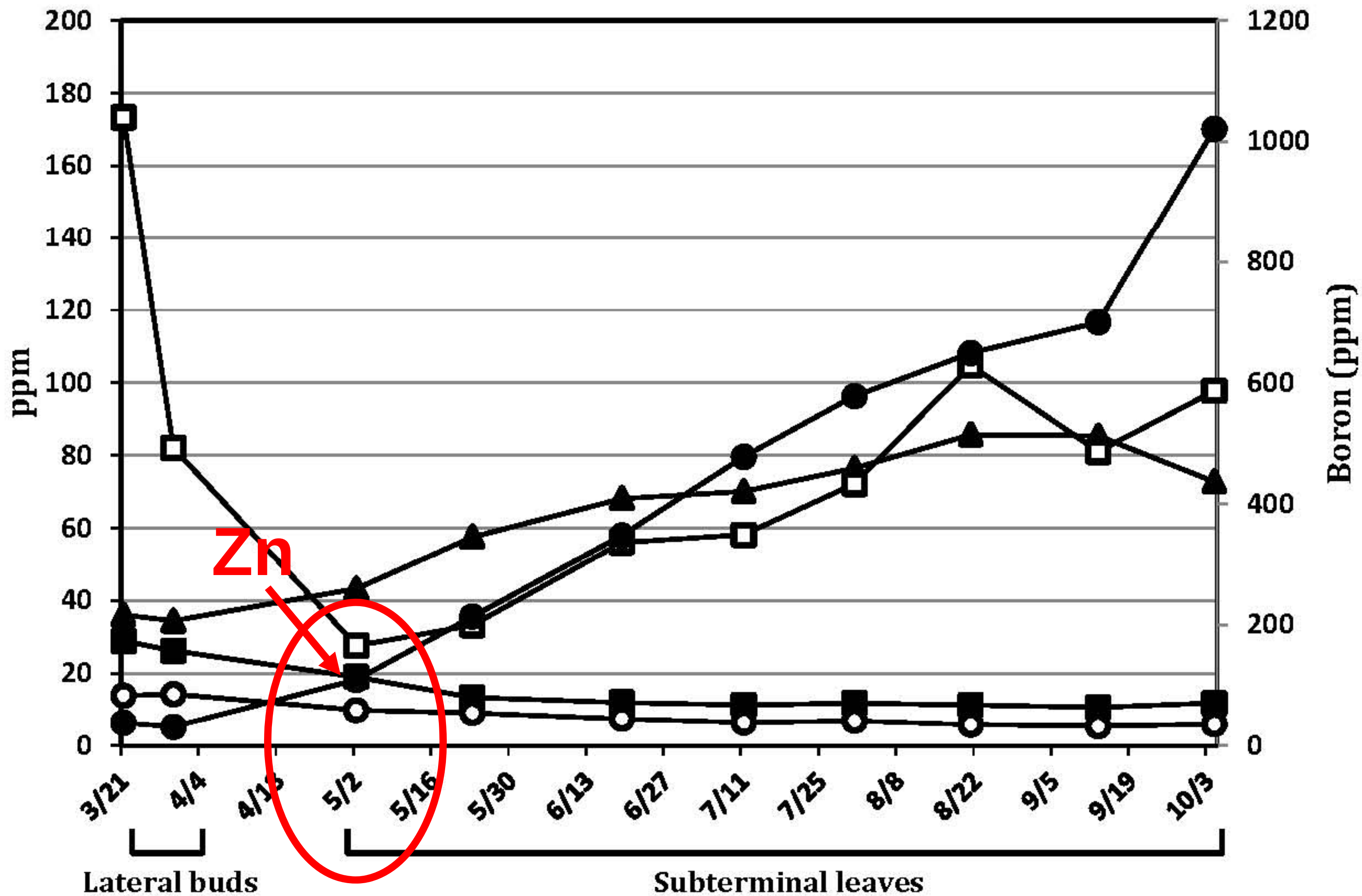
Foliar urea+B and urea+B+Zn applied at bud swell-green tip stage increased bud Zn concentration.



Year 1



Year 2



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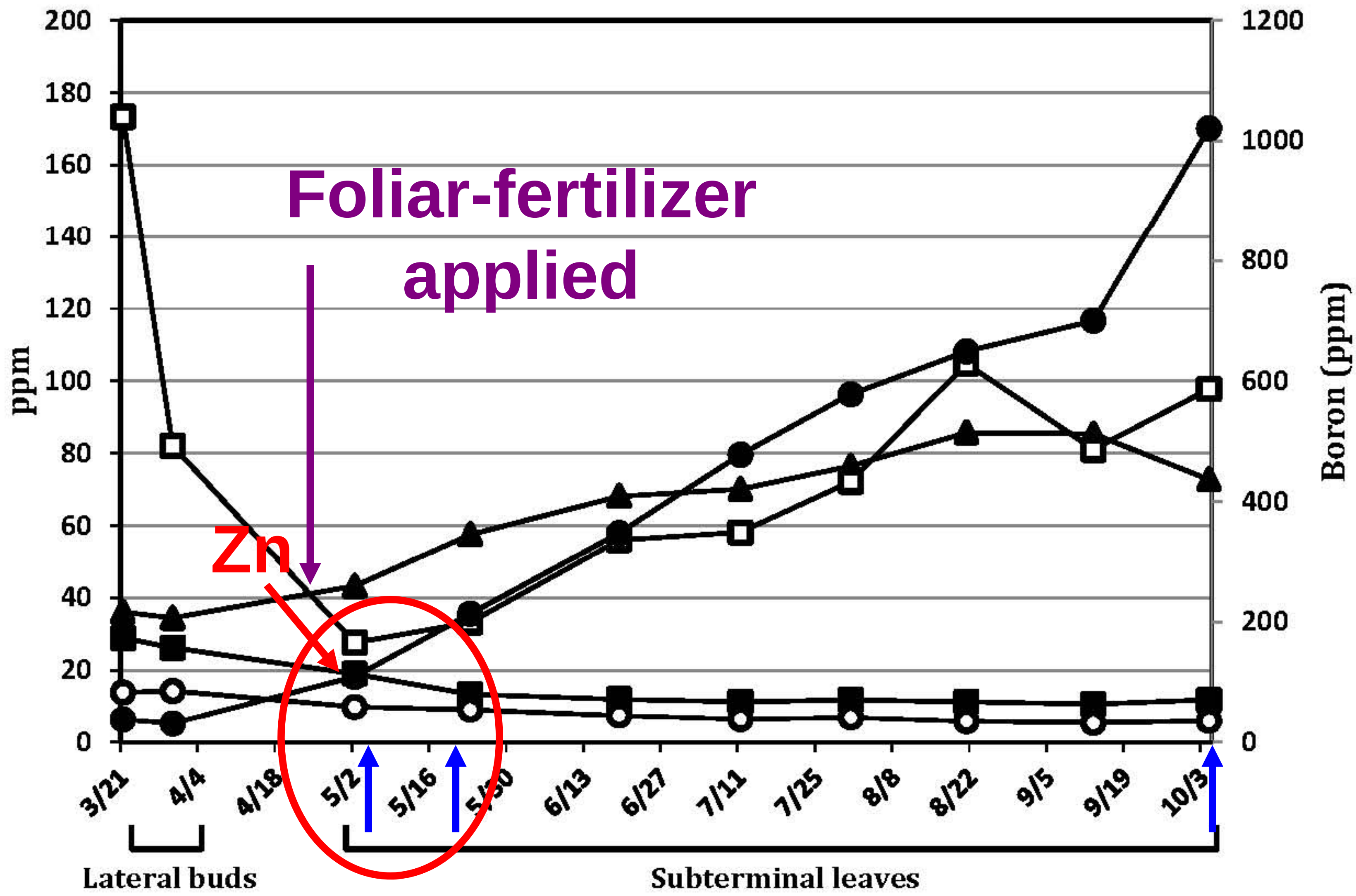

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Zinc sulfate (+/-) urea applied at 1/2-2/3 leaf expansion increased leaf Zn by October.

Treatment	Application time	Year 1	Year 2
		-------------- *ppm*	-------------
Control		10.6 c	11.8 c
Urea	Bud swell-green tip	11.2 c	12.0 c
Urea+B	Bud swell-green tip	11.1 c	12.3 c
Urea+B+Zn	Bud swell-green tip	10.4 c	12.2 c
B	Bud swell-green tip	9.9 c	12.2 c
Zn	leaf expansion	56.1 b	89.2 a
Urea	leaf expansion	10.2 c	12.7 c
Urea+Zn	leaf expansion	63.8 a	83.6 b
KTS	Jun, Jul + Aug	10.6 c	13.0 c
KNO_3	Jun, Jul + Aug	10.3 c	12.4 c
Urea	Jun, Jul + Aug	10.8 c	12.6 c
Urea+KTS	Jun, Jul + Aug	10.7 c	12.5 c
P-value		<0.0001	<0.0001

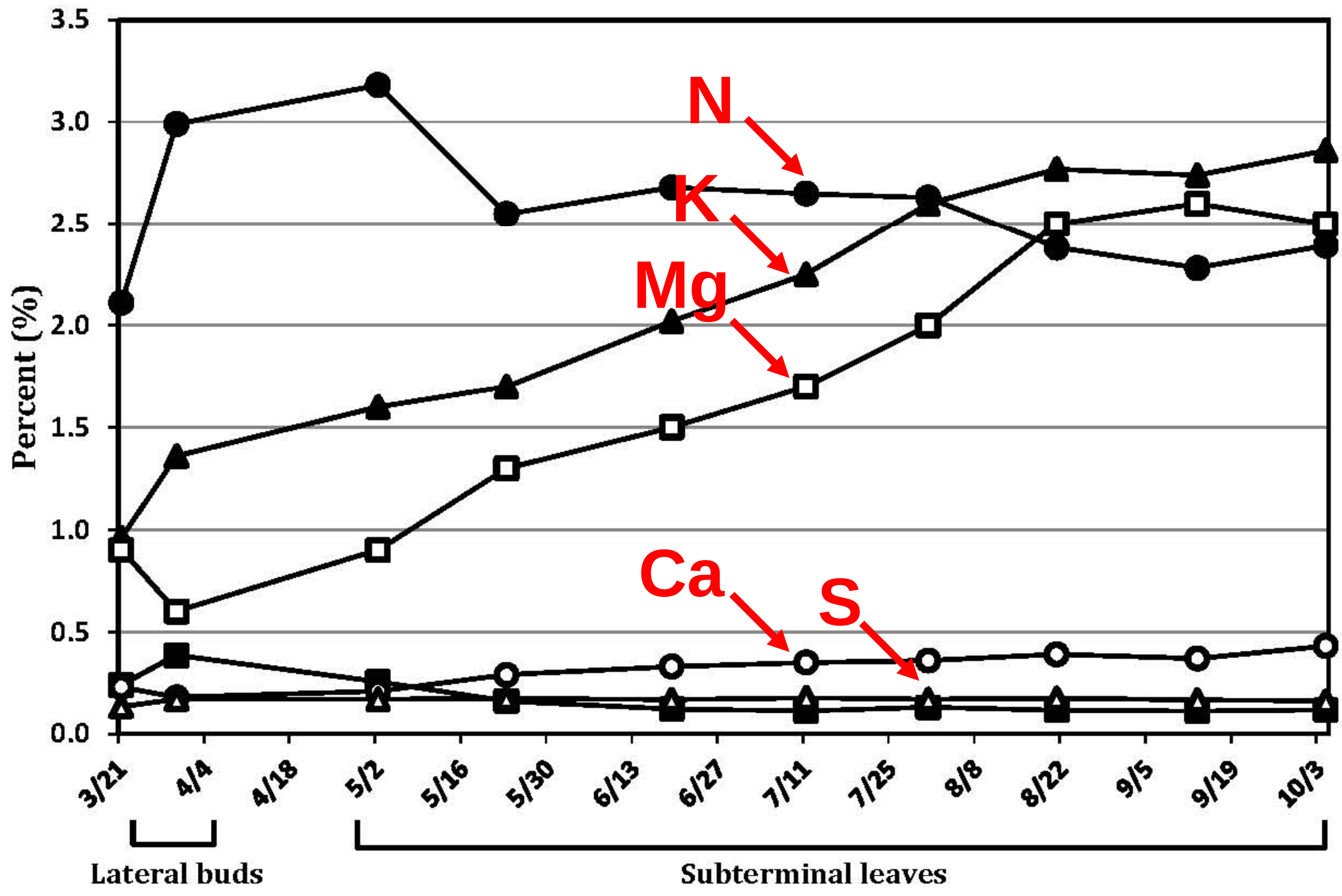

Figure 1. Comparison of the changes in bud and leaf nutrient concentrations of untreated (control) ‘Kerman’ pistachio trees, Lost Hills, CA, from March to October: (-●-) Nitrogen, (-■-) Phosphorus, (-▲-) Potassium, (-□-) Calcium, (-○-) Magnesium, and (-Δ-) Sulfur.

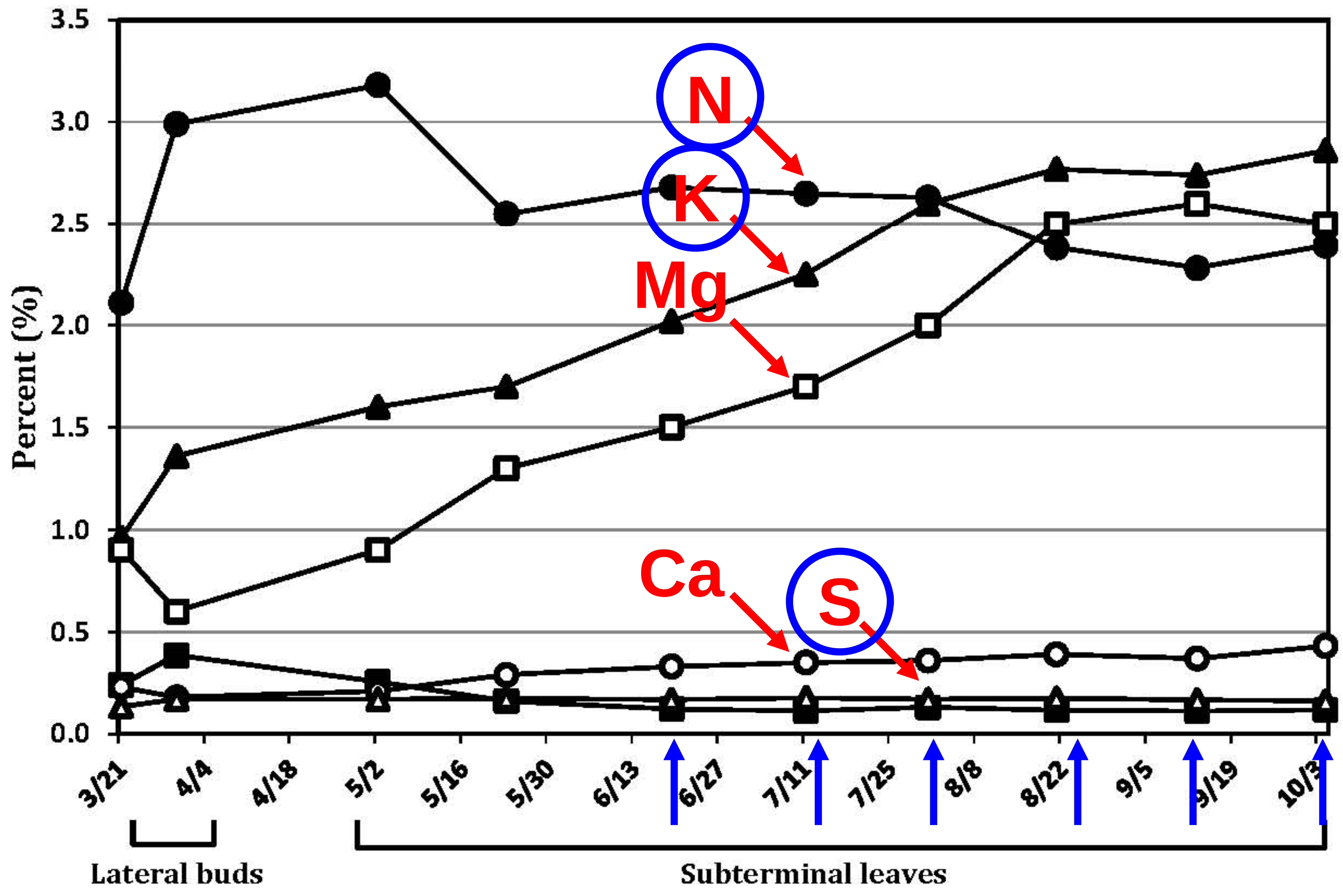

Figure 1. Comparison of the changes in bud and leaf nutrient concentrations of untreated (control) 'Kerman' pistachio trees, Lost Hills, CA, from March to October: (-●-) Nitrogen, (-■-) Phosphorus, (-▲-) Potassium, (-□-) Calcium, (-○-) Magnesium, and (-Δ-) Sulfur.

KTS (+/-) urea applied to hardened leaves (Jun, Jul + Aug) increased leaf S in July-October.

Treatment	Application time	Year 1	Year 2
		---------------- %	---------------
Control		0.14 c	0.16 b
Urea	Bud swell-green tip	0.14 cd	0.16 b
Urea+B	Bud swell-green tip	0.14 cd	0.15 b
Urea+B+Zn	Bud swell-green tip	0.14 cd	0.16 b
B	Bud swell-green tip	0.14 cd	0.16 b
Zn	leaf expansion	0.14 cd	0.16 b
Urea	leaf expansion	0.14 cd	0.16 b
Zn+Urea	leaf expansion	0.14 c	0.16 b
KTS	Jun, Jul + Aug	0.20 a	0.22 a
KNO_3	Jun, Jul + Aug	0.14 d	0.15 b
Urea	Jun, Jul + Aug	0.14 cd	0.16 b
Urea+KTS	Jun, Jul + Aug	0.18 b	0.22 a
P-value		<0.0001	<0.0001

KNO_3, urea, and urea+KTS applied to hardened leaves (Jun, Jul + Aug) increased leaf K Jul-Oct.

Treatment	Application time	Year 1	Year 2
		---------------- %	---------------
Control		2.4 a	2.9 bcd
Urea	Bud swell-green tip	2.4 a	2.8 d
Urea+B	Bud swell-green tip	2.5 a	3.0 abcd
Urea+B+Zn	Bud swell-green tip	2.5 a	2.9 cd
B	Bud swell-green tip	2.4 a	3.1 abc
Zn	leaf expansion	2.4 a	2.9 abcd
Urea	leaf expansion	2.5 a	2.9 abcd
Zn+Urea	leaf expansion	2.5 a	2.9 abcd
KTS	Jun, Jul + Aug	2.4 a	2.8 d
KNO_3	Jun, Jul + Aug	2.5 a	3.1 a
Urea	Jun, Jul + Aug	2.4 a	3.1 a
Urea+KTS	Jun, Jul + Aug	2.5 a	3.1 a
P-value		0.7306	0.0577

Urea (NOT KNO_3) applied to hardened leaves (Jun, Jul + Aug) increased leaf N in July-October.

Treatment	Application time	Year 1	Year 2
		---------------- %	---------------
Control		2.6 abc	2.4 abc
Urea	Bud swell-green tip	2.5 c	2.4 bcd
Urea+B	Bud swell-green tip	2.5 c	2.3 cde
Urea+B+Zn	Bud swell-green tip	2.5 bc	2.3 cde
B	Bud swell-green tip	2.5 c	2.4 abc
Zn	leaf expansion	2.6 abc	2.3 de
Urea	leaf expansion	2.6 ab	2.4 bcd
Zn+Urea	leaf expansion	2.6 abc	2.4 abc
KTS	Jun, Jul + Aug	2.5 c	2.2 e
KNO_3	Jun, Jul + Aug	2.5 c	2.3 bcde
Urea	Jun, Jul + Aug	2.7 a	2.5 a
Urea+KTS	Jun, Jul + Aug	2.5 c	2.4 ab
P-value		0.0113	0.0004

No foliar-applied fertilizer increased yield as kilograms split nuts (dry weight) per tree).

Treatment	Application time	Year 1	Year 2
		-- kg split nuts dw/tree --	
Control		19.6 a	8.6 a
Urea	Bud swell-green tip	17.9 a	10.3 a
Urea+B	Bud swell-green tip	19.5 a	7.5 a
Urea+B+Zn	Bud swell-green tip	19.4 a	9.2 a
B	Bud swell-green tip	20.2 a	5.7 a
Zn	leaf expansion	20.7 a	8.3 a
Urea	leaf expansion	19.8 a	6.9 a
Zn+Urea	leaf expansion	18.9 a	7.4 a
KTS	Jun, Jul + Aug	20.5 a	8.0 a
KNO_3	Jun, Jul + Aug	19.4 a	8.6 a
Urea	Jun, Jul + Aug	19.0 a	4.9 a
Urea+KTS	Jun, Jul + Aug	19.2 a	9.5 a

Conclusions

1) B as Solubor® and Zn as zinc sulfate are taken up by buds at the bud swell to green tip stage (day 19-21 for B and 7-10 for Zn).
2) Zn as zinc sulfate (+/- urea) is taken up at 1/2 to 2/3 leaf expansion (October).
3) Urea can supply N and increase the uptake of S and K in KTS by hardened leaves.
4) KNO_3 supplied K, but not N, to hardened leaves.

Conclusions

For the ‘Kerman pistachio, foliar-applied fertilizers are a valuable tool for quickly correcting nutrient deficiencies before they reduce yield, nut size or nut quality.


The power of foliar fertilizers!
Thank you

APPENDIX I - Fertilizer rates used in the research

Strategy 1: Application of foliar fertilizer at bud swell to increase flower nutrient status and thus increase fruit set.

(1) N [6 lbs/acre, urea (46% N, 0.25% biuret)];

(2) Treatment 1 combined with Zn [5 lb/acre, $ZnSO_4$ (36% Zn)] to test the capacity of urea to increase Zn uptake;

(3) Treatment 2 combined with Treatment 4 (urea + zinc + boron);

(4) B [5 lb/acre, Solubor (20.5% B)].

Strategy 2: Apply foliar fertilizer at 1/2- to 2/3-leaf expansion when cuticular leaf waxes have not developed sufficiently to limit nutrient uptake and adequate surface area exists for uptake to be great enough to impact tree physiology.

(1) Zn [2 lb/acre, $ZnSO_4$ (36% Zn)]. This strategy is currently practiced within the industry, but no data exist to support a yield benefit;

(2) N [6 lbs/acre, urea (46% N, 0.25% biuret)];

(3) Treatments 1 and 2 combined. Comparison of treatment effects will resolve whether urea increases Zn uptake and whether Zn and/or N increase fruit retention and yield.

Strategy 3: Investigate urea as a carrier to increase K and N uptake once pistachio leaves are fully mature, prior to and during kernel filling; treatments were applied in early June, early July and mid-August.

(1) K [10 lb/acre, KTS (0-0-25-17S)];

(2) K [10 lb/acre, KNO_3 (13-0-38)];

(3) N [6 lbs/acre, urea (46% N, 0.25% biuret)];

(4) Treatments 1 and 3 combined. Comparison of treatment effects on yield will determine whether urea increases K uptake and whether trees need only K or benefit from added N and/or S at this time.