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SALINITY AND BORON EFFECTS ON ALMOND

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Abstract:

Reduction in availability of good quality irrigation water as a result of water shortage and competition from urban use will likely lead to increasing use of groundwater for almond irrigation. Much of the available groundwater contains significant quantities of dissolved salts. Irrigation with these waters will result in accumulation of salts in the root-zone and may lead to growth and yield reductions. The potential for salt damage is particularly relevant to agriculture on the west side of the San Joquin Valley where large areas of saline/boric soils and groundwater occur.

In this study we are examining the importance of root-zone B, Na and Cl on the growth and productivity of almond. In 1990 and 1991 we established a collection of clonally propagated almond, peach, plum and almond X peach hybrid rootstocks and have commenced differential B X Salinity treatments. In April 1991 we established a factorial salinity X B experiment to a 3.4 Ha field plot of mature almond. Application of the stable isotope ^{10}B in pot studies and in the field has been used to trace B movement into plants under differential saline treatments and to monitor the movement of B through the soil profile. Interactions between B, Ca and salinity in almond as well as other plant species are being investigated.

Objectives:

A. Determine the relationships between the annual irrigation volumes applied with a single-line source trickle system and the resulting concentration and distribution of B and EC_e in almond irrigated with a moderately sodium-sulfate saline (about 1.6 dS m^{-1}) ground water containing 0.8 mg l^{-1}.

B. Develop relationships for the assimilation of B in almond leaves as a function of soil B concentration and distribution.

C. Compare rootstock effects on the uptake, distribution and toxicity of B under saline and non-saline conditions. investigate the mechanism of excess B injury.

Research Plans and Procedures:

The research described here addresses the problems of irrigation management of salinized soils, B/salinity interactions and selection of saline/B resistant rootstocks. Research is being performed at two sites, field studies are being conducted on the established UC/USDA research site at the West Side Field Station and pot studies are being conducted at U.C.Davis. An experimental site of almond (Butte/Ruby 7 acres, 678 trees) was established in 1980 at the West Side Field Station. Trees were irrigated by drip (single in-line) in a design that allowed control of irrigation volume and salinity delivered to each tree. In 1984 irrigation levels of 0.6, 0.8, 1.0, 1.2, and 1.4 of estimated ET were established. In 1989 investigation of salinity effects on growth were initiated with the addition of a separate non-saline water source to supply half of the trees. Each of these 12 treatments were randomized within six blocks. Samples of almond leaf, kernel and root samples were collected over the past 4 years and will be analyzed for Na,Cl, B, Ca, S and other nutrients. Thus, with minimal effort we will be able to address some pertinent questions on B/salinity effects in low volume systems.

To further investigate the effects of B excess and differential responses of plant species to B applications a population of seedlings of peach (cv Nemaguard, Lovell), plum (cv Marrianna), almond (Titan) and peach almond hybrid (Titan x Nemaguard) is being grown in sand culture to control the activity of boron under a range of saline conditions. Two levels of B (0.5 and 5.0 ppm) and three levels of salinity (2, 4, 8 dS/m^{-2} as sodium sulfate) were applied to each of the five rootstocks, ten replicates of each treatment were used for a total of 300 pots. Additions of a stable boron isotope (^{10}B) will be made at various stages of growth and the assimilation of B, Na, Ca, K and Cl by the plant monitored. Analysis of growth, ion partitioning and carbon allocation will be used to asses the effects of B excess on tree growth and metabolism. This procedure aims to identify screening methods and potentially useful rootstocks for use in areas where B and salinity is a problem.

In a separate study three almond rootstocks (Lovell, Titan, Nemaguard) were exposed to B (0.5 and 1.5 ppm) and Ca (20, 100, 400 ppm) in a sand culture system to investigate the effect of Ca on B accumulation. This study was initiated since high levels of soil and irrigation water Ca occur in the field plots used. Calcium has been shown to alleviate salinity stress by protecting membranes from Na induced damage, since B has also been shown to bind with cell membranes the possible interaction between these elements was investigated.

Discussion and summary:

The results presented here represent the first year of a muli-year experiment and as such are prelimiminary. Detailed assesment of treatment effects and plant responses will not be made until the experiment has been duplicated for a second year.

Influence of salinity on the uptake and distribution of B in Almond:

Tissue enrichment with ^{10}B in the leaves of a 12-year-old almond was detectable within 20 days of application of the label to the soil (fig 1). This rapid movement of B into the tree is surprising given the heavy texture of this soil (>65% clay) and indicates that the form of label applied remains readily available for plant growth. The uptake of B as indicated by the change in isotopic ratios continued in a more or less linear fashion with time and was proportional to the amount of applied label. The use of a saline irrigation source apparently impairs B uptake at both the 30 and 60g B rates. It is unclear whether this represents a competition between B and some element present in the saline irrigation water or is the result of salinity effects on root growth or membrane characteristics that in turn influence B uptake.

The movement of soil applied ^{10}B through the soil profile was followed by monitoring ^{10}B concentration in the soil at different depths with time (fig 2). At day 0 (before ^{10}B application) the level of B in the soil saturation extract was between 0.2 and 0.23 ppm B throughout the soil profile. The ratio of 10:11 B was constant throughout the profile at 0.245 which is slightly less than the accepted 'natural' abundance. Forty-two days after the addition of the label (30g $H_3{}^{10}BO_3$) there was a marked enrichment of the ^{10}B fraction at all soil depths. The greatest enrichment was evident in the 0-10 and 10-20 cm fractions where the 10:11 B ratio had increased to 1.3. At greater depth (20-30 and 30-40 cm), enrichment by ^{10}B was less marked, though it was still significantly increased (0.72 and 0.54, respectively). At 63 days, the concentration of ^{10}B

decreased in the upper layers and increased in the lower two layers. At this time the surface soil had a reduced 10:11 B ratio of 0.5 (roughly double natural abundance), at 10-20cm the ratio was 0.35, at 20-30cm it was 0.58, and at 30-40cm it was 0.89. Apparently a proportion of the applied label had passed through the profile or had been accumulated by the tree. The occurrence of higher ^{10}B in the 0-10 cm layer than in the 10-20 cm layer at day 63 may reflect a small fixation of B at the surface.

Influence of Ca on B uptake and distribution in almond rootstocks.

As the results for each variety and for each sampling date were essentially the same only one species will be discussed. Data presented are for B uptake 10 days after label application. Application of ^{10}B to 'Nemaguard' peach growing in sand culture resulted in a rapid uptake of the label into vegetative portions of the plant (Figure 3). The concentration of ^{10}B in plant tissues was influenced by tissue age and by the B:Ca ratio in the growth medium. In general the presence of Ca in the growth medium restricted ^{10}B movement to the shoot, this was apparent at both low and high B levels. At the low B application the youngest plant tissue had the highest level of enrichment followed by the YEB, with the smallest amount of ^{10}B being found in the older tissues. At higher B levels YEB's tended to have the highest B content followed by young leaves and old leaves. The apparent reduction in ^{10}B uptake by trees in the highest B treatment is probably the result of isotope dilution by the large pool of un-enriched B in this treatment. High B applications also lead to an inhibition of apical growth which may have influenced B distribution into youngest tissues.

The observation that high levels of Ca can influence B uptake has not been made previously, though numerous reports exist of a physiological interaction between Ca and B.The mechanism of this interaction is being investigate further.

Influence of rootstock on the uptake of B under saline conditions:

Differences in B uptake and salinity tolerance between rootstocks grown in the pot study have yet to be observed. Initial tissue elemental analysis suggest a significant interaction between soil B and saline levels as well as rootstock is evident though it is too early to determine how this may effect plant growth and tolerance.

Summary:

Preliminary results suggest that interactions between salinity, rootstock and B occur and may influence the distribution of B in plants and soil. Insufficient data has been accumulated to predict the interactions between these factors and plant growth, rootstock response or elemental composition. Yield data have not yet been assessed from this years experiments.

The data provide evidence of the importance of B in consideration of salinity problems for perrrenial agriculture in California.

Publications:

The following manuscript utilized some of the results obtained by this project

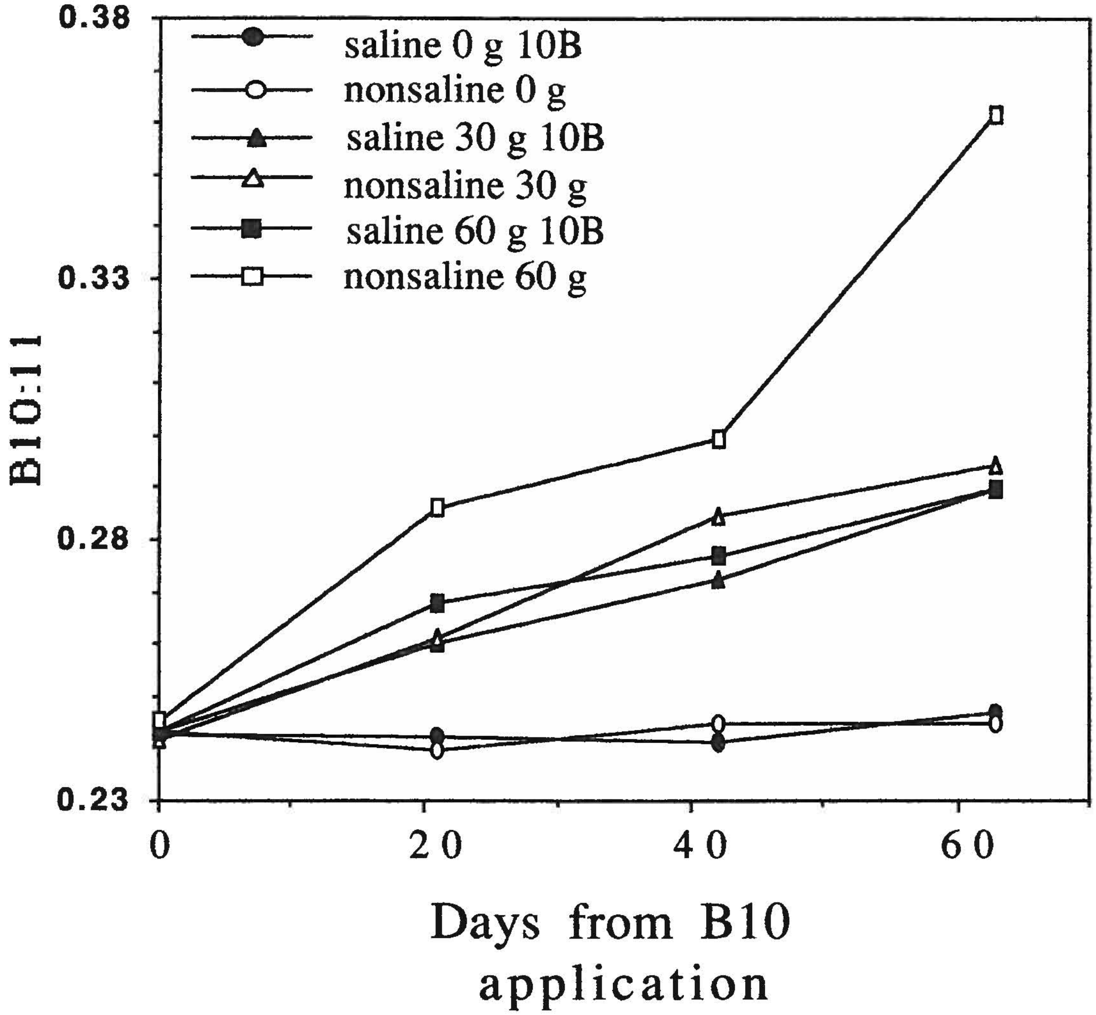
Brown, P.H., G. Picchioni, M. Jenkin and H.Hu. 1991. The use of ICP-MS and ^{10}B to trace the movement of boron in plants and soils. Comm.Soil Sci. Plant Anal. (In Press).

Figure 1. Accumulation of ^{10}B into mature almond trees drip irrigated with saline or non-saline water. Treatments were established in April, 1990 and three levels of labelled B (0, 5, 10 g ^{10}B) were applied in April, 1991. ^{10}B accumulation was determined at 21 day intervals.

Figure 2. Movement of soil applied ^{10}B through the soil profile in a mature almond orchard. Five grams of ^{10}B (95.91% enriched) was added to the soil surface and ^{10}B concentration determined in saturation extract at three week intervals.

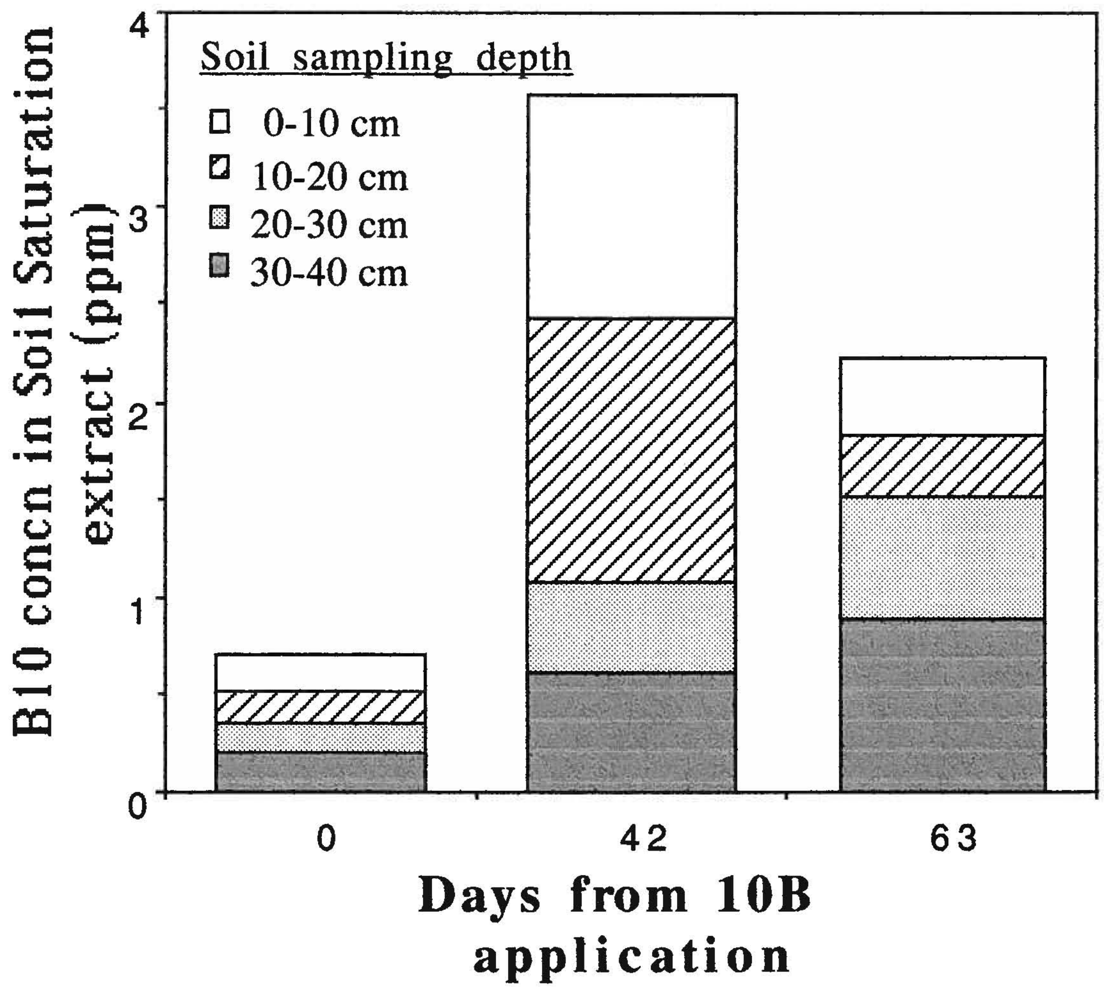
Figure 3. B accumulation in youngest expanding leaves (young), youngest fully expanded leaves (YEB) and old leaves (old) 10 days after application of 0.16g ^{10}B. Plants were grown in sand culture and supplied with 1/2 strength Hoaglands. Boron and Ca were supplied as follows; Low B (0 ppm, low levels of residual B present), high B (1.5 ppm), low Ca (16 ppm) or high Ca (400 ppm). A control pot was maintained with B and Ca at normal 1/2 strength Hoagland concentrations of 0.13 ppm B, 80 ppm Ca. SE bar shown represents largest SE of the data (n=3).

Fig 1:



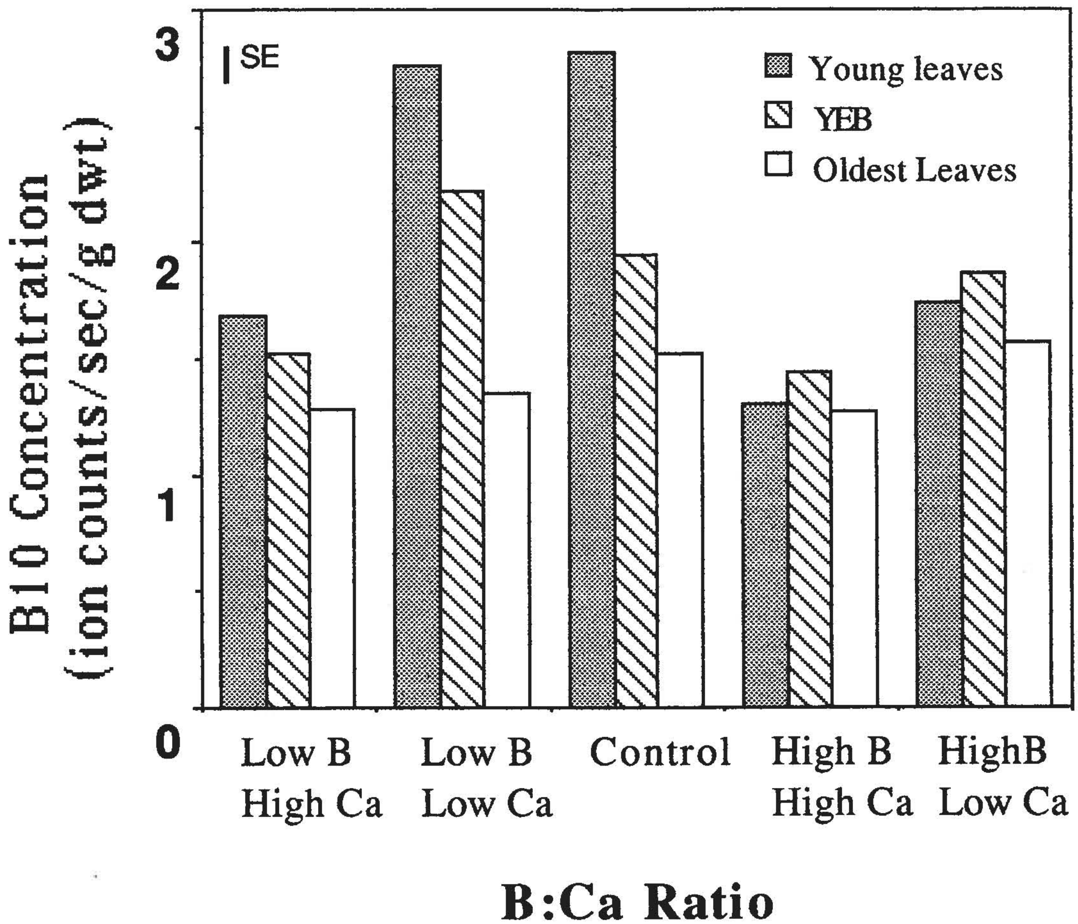
0.38
0.33
0.28
0.23
B10:11
saline 0 g 10B
nonsaline 0 g
saline 30 g 10B
nonsaline 30 g
saline 60 g 10B
nonsaline 60 g
0
20
40
60
Days from B10 application

Fig 2



B10 concn in Soil Saturation extract (ppm)
4
3
2
1
0
Soil sampling depth
0-10 cm
10-20 cm
20-30 cm
30-40 cm
0
42
63
Days from 10B application

Fig 3


3
2
1
0
SE
Young leaves
YEB
Oldest Leaves
B10 Concentration
(ion counts/sec/g dwt)
Low B
High Ca
Low B
Low Ca
Control
High B
High Ca
HighB
Low Ca
B:Ca Ratio