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Project No. 92-AC2 - Salinity and Boron in Almond

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Objectives: 1) To determine the effect of boron and salinity on root-growth and tree productivity in irrigated almond. 2) To follow the accumulation of B, Na, Cl and other elements in plant and soil as influenced by irrigation volume, salinity (EC_c) and B concentration. 3) To identify the symptoms of B toxicity in almond and to identify the soil and plant B levels at which yield will be reduced. 4) Determine the relative susceptibility of various almond, peach, plum and hybrid rootstocks for use with almond in salinity and B sensitive areas.

Results: 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 x irrigation 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.

a) Field Studies Table 1 summarizes the main treatment effects of the experiment, specific points of interest will be highlighted and reference made to the accompanying figures. In figure 1 average nut yield is presented for the 5 irrigation rates, two water qualities (largely a carryover from previous years) and two irrigation types. At all irrigation levels, saline water resulted in a 20-30% reduction in yield. There was a slight, though not significant, increase in yield with increasing irrigation rate in the non-saline treatment but not the saline treatment, indicating that irrigation quantity did not significantly alleviate saline induced yield reduction. Significantly, these responses were not the result of a measurable change in tree size (fig 2), and there was no significant effect of treatment on shelling fraction or average kernel weight. The use of microspray irrigation resulted in the lowest yield of any treatment, with a significant negative impact of prior treatment with saline water (fig 1). This yield reduction cannot be explained by simple loss of irrigation volume by evaporation, though it may have been associated with a marked increase in tissue salt levels (see table 2, discussed later). There was also a significant reduction in trunk size as a result of the use of microspray irrigation (Table 1). The lack of effect of water quantity on plant response to salinity suggests that yield reduction in almond is not the result of salinity induced water stress but is likely a specific ion response induced by the enhanced uptake of a toxic levels of either B or Na.

Analysis of tissue nutrient levels indicates a significant accumulation of Na and B (though not Cl) in response to use of saline irrigation water (Fig 3 and 4). Sodium accumulation was reduced significantly be water volume in both saline and non-saline conditions whereas B concentration was increased slightly. The leaf concentrations of both B and N observed in this experiment would be considered marginally high according to currently accepted standards, and while irrigation volume did reduce leaf Na levels to below the 'toxic' concentration there was no subsequent increase in yield. This may have been due to the continued increase in tissue B with increasing irrigation levels. The use of microspray (as apposed to drip irrigation) significantly influenced tissue elemental concentrations at the 1.0 ET level (Table 2). Microspray irrigation resulted in significant accumulation of both Cl and Na though not B, this accumulation and the consequent reduction in tree yield may have been due to the evaporation and subsequent concentration of both Na and B in the irrigation water.

Distribution of elements within the tree differed markedly between the elements. Whereas tissue concentrations of Na and Cl were fairly uniform throughout the tree, the concentration of B was markedly higher in fruiting (particularly hull) tissues (Table 3). The localized accumulation of B in fruit tissue and the lack of a marked B accumulation in leaf tissue indicates that in Almond B distribution is not primarily transpiration driven as is widely believed. The localization of B in non-leaf tissue was also observed in pot studies (see below) and has significant implications for the validity of using leaf B levels to whole plant B status.

b) Rootstock Comparisons: Significant differences in tolerance to high B and salinity were expressed within the six rootstocks tested. This is best illustrated by the % shoot death at the highest combination of B and Salinity (fig. 5). At these extreme treatment levels the widely used peach rootstocks 'Nemaguard' and 'Nemared' were far more susceptible than either plum or peach x almond hybrids, this same ranking of susceptibility was observed at all salinity levels. Tolerance of high B/salinity levels expressed by peach x almond hybrids was also expressed in grafted trees in which 'Titan' almond was grafted onto either the sensitive 'Nemared' or the tolerant 'Hybrid' rootstock (fig 9). The tolerance of a particular rootstock to high B and salinity was most closely correlated with the level of B in stem tissue indicating that tolerance is associated with restriction of movement of B to the scion (fig 10).

Boron and Na act synergistically to reduce plant growth, this is illustrated in the effect of increasing shoot death in response to a simultaneous increase in treatment B and salinity (fig 7). With increasing Na levels there is an increasing toxicity of B as indicated both by symptomology and shoot death. This increase in shoot death is associated with increasing concentrations of stem B as a result of increasing treatment B and Na (fig 8). It is clear that increasing Na results in an increase of B concentration in the stem, which in turn results in stem death and growth reduction. There was no effect of increasing B levels on tissue Na concentrations. It was also observed that increasing treatment B resulted in a marked decrease in the concentration of SO_4-S in all tissues (fig 6), the significance of this is unknown.

The symptoms of B toxicity in Prunus species have not been previously described. Surprisingly, B toxicity in Prunus is not expressed in leaf tissue as it is in other species. The first symptom of B toxicity is the formation of gummy deposits on the surface of the stem, followed by necrosis of the stem and petiole and finally complete girdling of the shoot. Coincident with the appearance of gum deposits there is a breakdown of internal vascular systems that initiates with the death of phloem cambial tissue (microphotographs are available on request).

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Summary:

The choice of rootstock, level of soil B and salinity all interact to influence the productivity of Almond. This effect is cumulative with time and can lead to yield reduction even when tissue Na and B levels are below those commonly regarded as limiting. Significantly, evidence is now appearing to suggest that B and salinity act in a more than additive fashion to reduce almond growth and productivity. Previous results (1991) also indicate that Ca supplementation may partially alleviate the effects of high soil B.

The distribution of B within almond tissues and the symptoms of B toxicity have not been previously described. In contrast to most other annual and perennial crops, prunus species do not appear to accumulate B in leaf tissue. Further, the symptoms of B toxicity in these species

do not resemble the marginal leaf scorch or leaf deformation commonly described for other tree crops. Localized concentration of B in stem and fruit tissue of almond results in the development of gummy deposits coincident with the disruption of vascular cambial activity, necrosis of stem tissue and ultimate stem girdling. We hypothesize that the resultant disruption of stem water flow acts to exacerbate salinity induced water stress, this would explain the additive effects of B and salinity on tree yield depression. Significant differences in rootstock tolerance of high B and salinity were also observed. This tolerance appears to be associated with a restriction of B movement to above ground portion of the plant.

Conclusions and Recomendations: Preliminary conclusions from this work suggests: a) choice of rootstock can greatly influence susceptibility to high B and salinity, b) damage from moderate levels of salinity and B may take several years to appear and are cumulative with time, c) B and salinity act additively and high B can greatly exacerbate the impact of salinity, d) B accumulates in stem and fruit tissue in almond. Significant removal of B from the orchard can occur through removal of harvested fruit and prunings. New methods of tissue testing for excess B and salinity are required.

In the coming year we will refine the critical tissue B and Na values for almond, develop new tissue sampling methodology and further define the role of rootstock selection in long term resistance to salinity and B stress. The ultimate goal is the development of management practices to minimize the potentially damaging effects of excess salinity and boron in almond. Continuation of this research for an additional year is indicated.

Publications:

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. (1992) 17-19: 210-220.

Hutmacher.R.B., Nightingale H.I., Rolston, D.E., Biggar, J.W., Dale F, Vail, S.S., Peters, P. (SUBMITTED) Growth response of almonds (Prunus amygdalus) to six levels of trickle irrigation.

Table 1 Statistical analysis of yield and fruit for Almond field trials 1991. All significant comparisons are shown. Treatment code: First number is Et; 1=0.6, 2=0.8, 3-1.0, 4=1.2, 5=1.4 Et. Second letter is water source; S=saline, N= Non-saline. Third Letter is cultivar, B=Butte, R=Ruby. Fourth letter = irrigation method; T=trickle, M=microsprinkler.

Contrasting Treatments	Nut Meat Yield		Kernel Weight		Tree Trunk Diameter	
	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F
1SBT - 1NBT	11.87	.0137	8.98	.0401	17.01	.0001
2SBT - 2NBT	89.86	.0001	11.11	.0290	26.81	.0000
3SBT - 3NBT	41.46	.0007	.17	.6997	.25	.6197
4SBT - 4NBT	22.32	.0032	2.07	.2238	.20	.6581
5SBT - 5NBT	6.74	.0409	8.21	.0457	5.01	.0295
3SRT - 3NRT	1.55	.2684	1.61	.2935	.79	.3776
3SBM - 3SBT	30.51	.0015	.002	.9695	9.88	.0028
3NBM - 3NBT	21.40	.0036	10.09	.0336	18.45	.0001
3SBM - 3NBM	29.73	.0016	15.18	.0176	.004	.9489
3NRM - 3NRT	5.26	.0703	10.40	.0484	8.59	.0053

Table 2 Elemental concentration in Almond irrigated with either trickle (drip) or microsprinkler. Values expressed as ppm in leaf dry matter.

Element	Irrigation Method#			Na^^	
	Microsprinkler	Drip			
P	1278	1288	Microsprinkler	1780	(saline)
K	16100	15880		773	(non-saline)
Ca**	24190	28560			
Mg**	7520	8353	Drip	665	(saline)
Mn**	27	70		510	(non-saline)
B**	35	45			
Zn	13	13			
Cl**	3540	2430			
Na**	1204	633			

#values are average of all irrigation levels and sources

**Significant effect of irrigation method

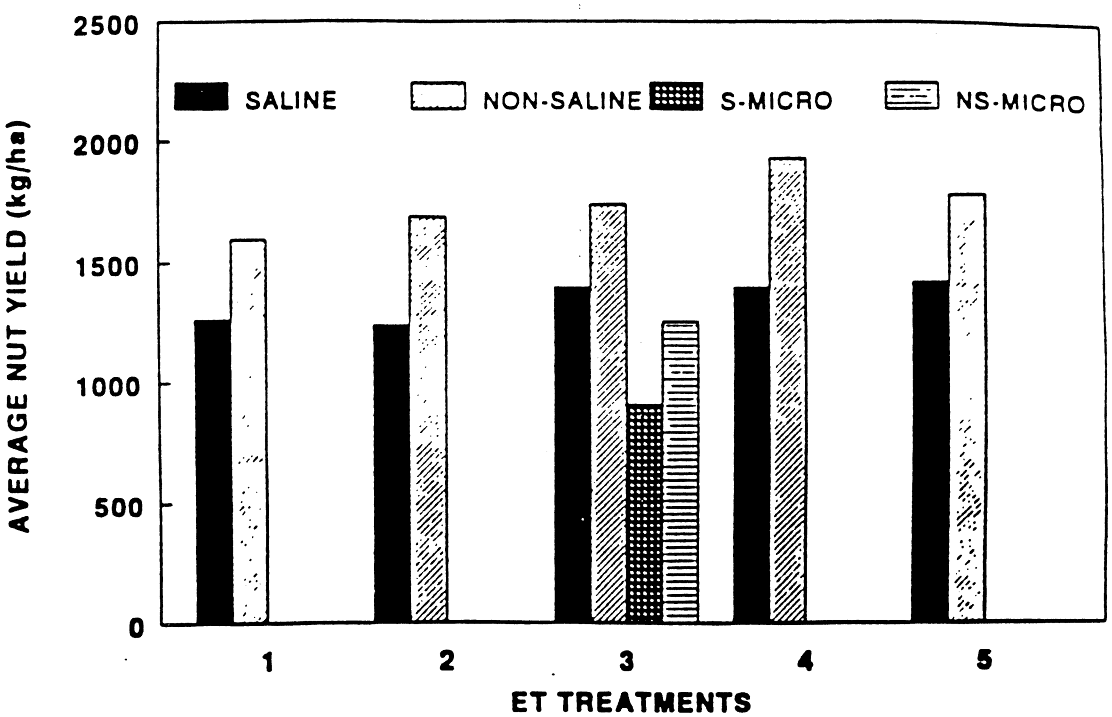
^^all treatment effects significant at 1%

Table 3 Boron concentration in various tissue of almond. All values are ppm (dry weight basis). Values have been averaged over all treatment groups in Butte cultivar.

	TISSUE TYPE*				
TREATMENT	Mesocarp (hull) (ppm)	Endocarp (shell) (ppm)	Kernel (ppm)	Whole Fruit (ppm)	Leaf (ppm)
Saline	406	73	91	254	54
Non-Saline	279	43	75	229	45

*means of all irrigation treatments

All treatment and tissue effects are significant (5%)



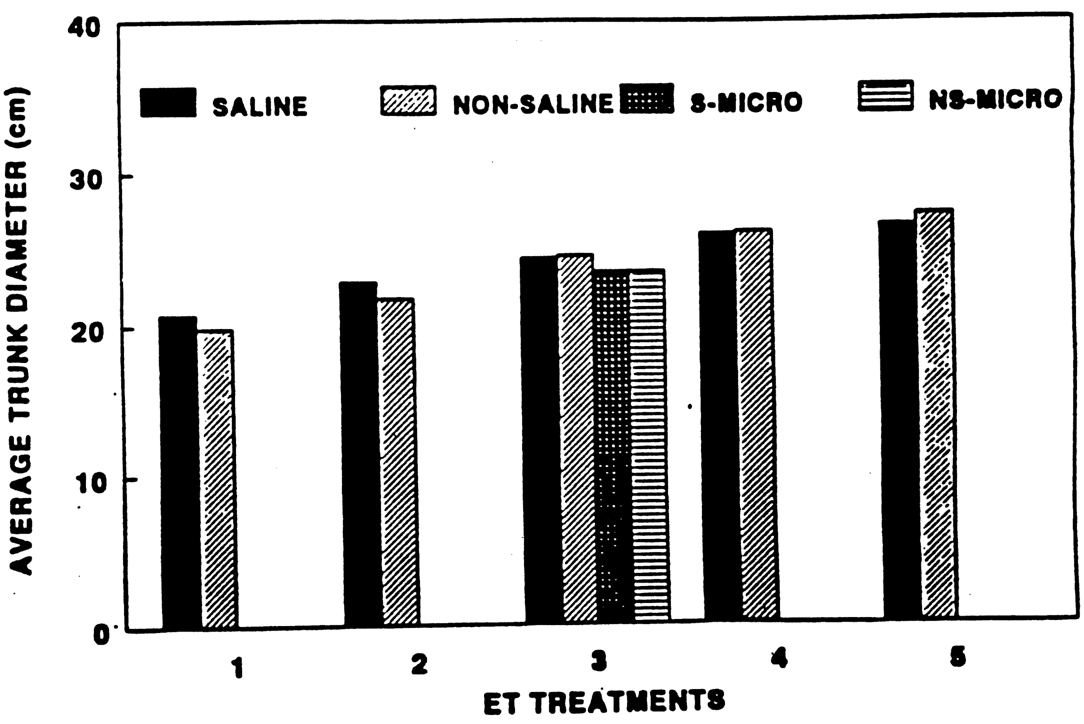
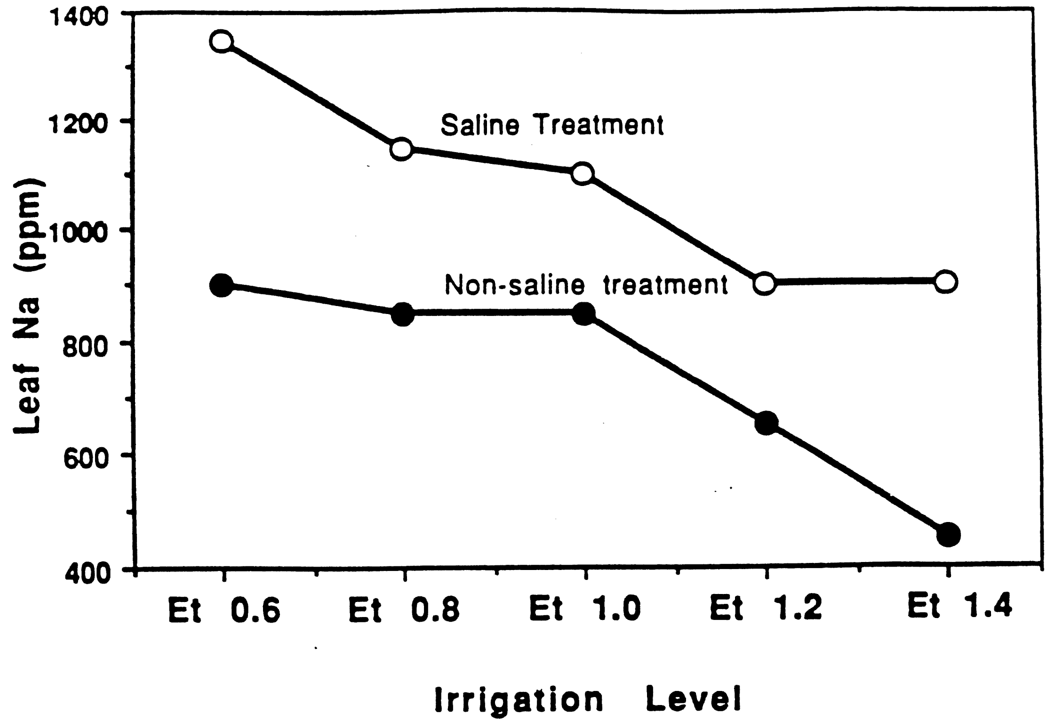


Figure 1 (upper). Average nut yield for 1991 in response to irrigation level in Butte cultivar. Et treatments are 1 = 0.6 Et, 2 = 0.8 Et, 3 = 1.0 Et, 4 = 1.2 Et, 5 = 1.4 Et. Statistical analysis presented in table 1.

Figure 2 (lower). Average trunk diameter for 1991 in response to irrigation level in Butte cultivar. Et treatments are 1 = 0.6 Et, 2 = 0.8 Et, 3 = 1.0 Et, 4 = 1.2 Et, 5 = 1.4 Et. Statistical analysis presented in table 1.



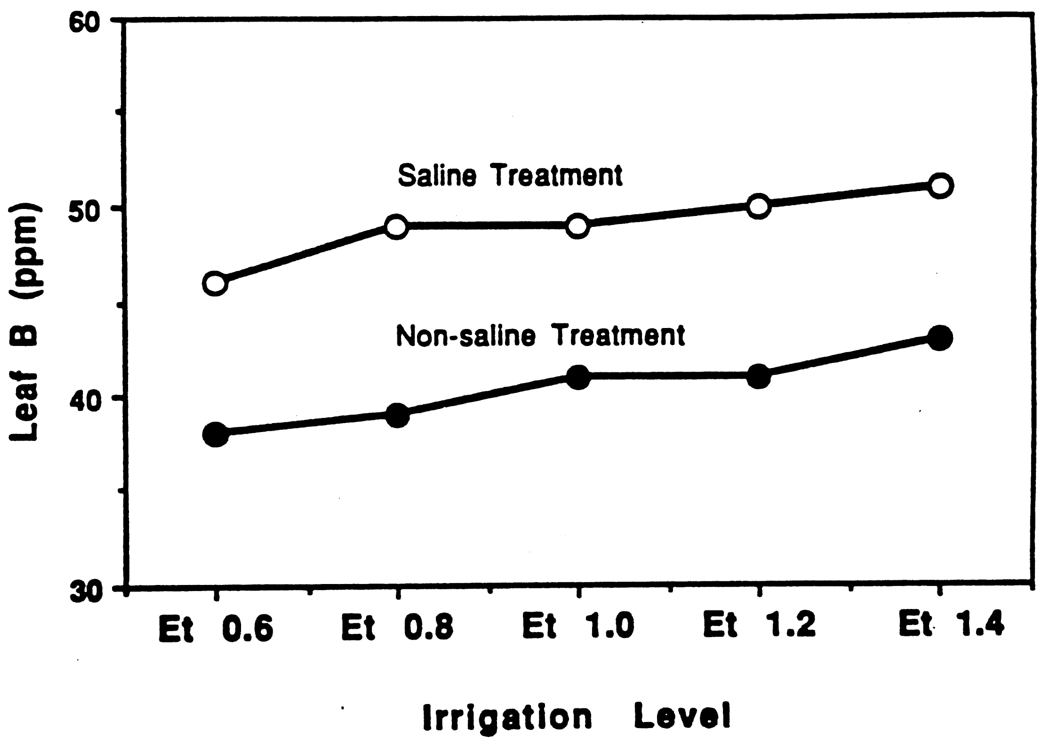


Figure 3 (upper). Leaf Na levels in Butte almond, July 1991. Sodium concentrations in saline treatments are significantly higher (P< 1%) at all irrigation levels.

Figure 4 (lower). Leaf B levels in Butte almond, July 1991. Boron concentrations in saline treatments are significantly higher (P< 5%) at all irrigation levels.

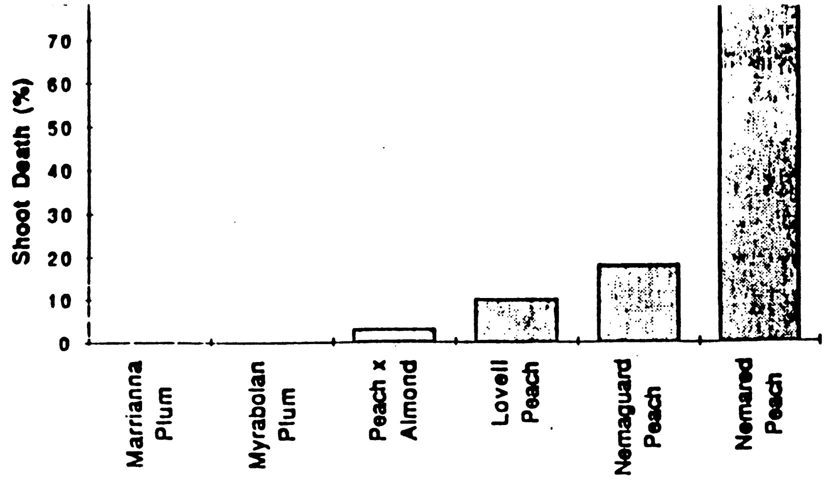


Figure 5 Shoot death at high B(5.0ppm) and high salinity (12 dS/m) for 6 rootstocks.

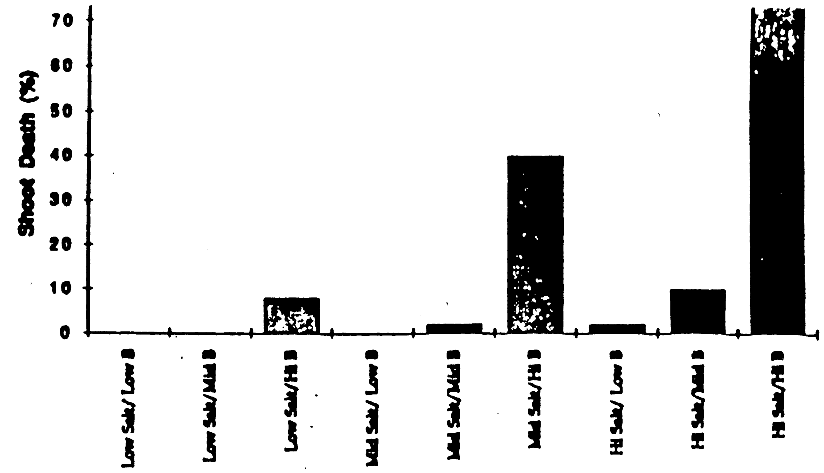


Figure 7 Shoot death of 'Nemared' peach grown under three levels of salinity (2, 6, 12 dS/m) and three levels of B (0.25, 5.0 and 10 ppm B).

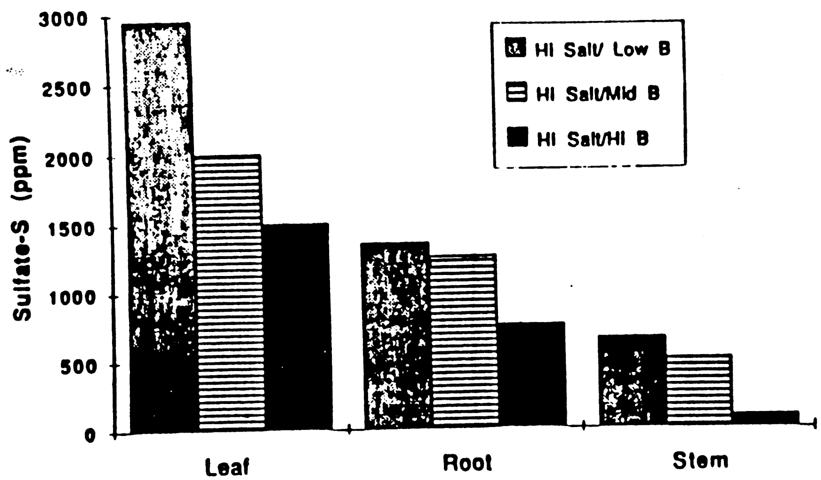


Figure 6 Influence of B treatment on tissue sulfate-S concentrations in leaf, root and stem of 'Nemared' peach rootstock grown under high salt (12 dS/m) and variable B treatment (0.25, 5.0 and 10 ppm B).

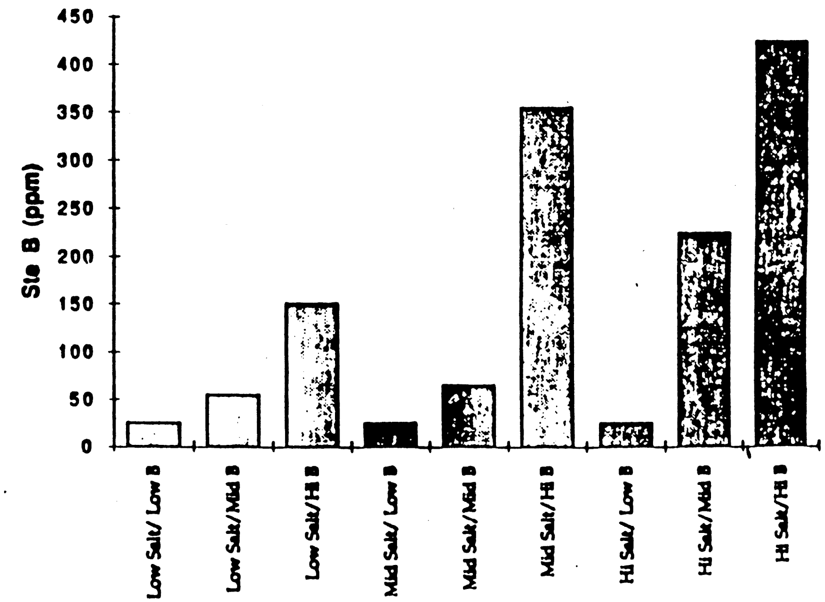
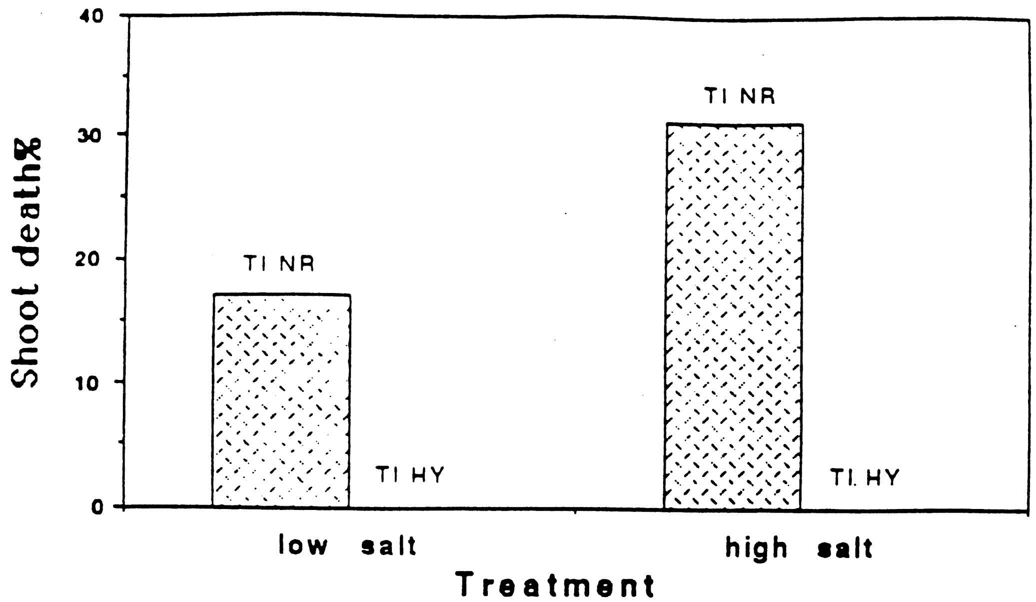


Figure 8 Stem B concentrations in 'Nemared' peach grown under three levels of salinity (2, 6, 12 dS/m) and three levels of B (0.25, 5.0 and 10 ppm B).



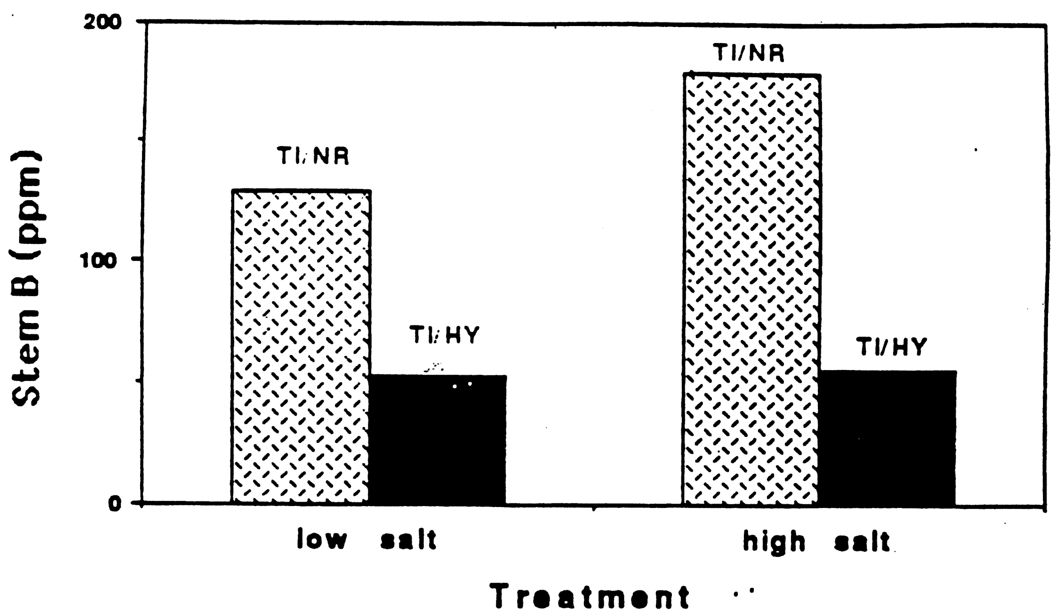


Figure 9 (upper) Shoot death of 'Titan' almond grafted onto 'Nemared' (NR), or 'Peach x Almond hybrid' (HY) rootstock. Data shown are for plants grown under low (2 dS/m) or high (12 dS/m) salinity treatment with high B (10 ppm).

Figure 10 (lower) Stem B concentration in 'Titan' almond grafted onto 'Nemared' (NR), or 'Peach x Almond hybrid' (HY) rootstock. Data shown are for plants grown under low (2 dS/m) or high (12 dS/m) salinity treatment with high B (10 ppm).