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Alkalinity enhances B-tolerance in Cucumber

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INTRODUCTION

Reuse of saline drainage water is a management option that is necessary for reducing the volume of drainage water produced on the west side of California's San Joaquin Valley (SJV). A potential limitation in implementing a drainage water reuse system is determining the extent by which boron, a naturally occurring element in the drainage water, affects the selection, growth and yield of crops in the reuse system.

Integration of vegetable crops into the schedule of rotations with saline-reclamation type crops such as wheat, cotton, and sugar beets has advantages that growers have waited to realize, such as increased income and crop rotation flexibility. However, as soil quality improves with respect to reduced salt and boron concentrations during the reclamation processes, unknown interactions between salinity and boron may affect subsequent production of more economically attractive vegetable crops.

Research articles related to growth and yield responses from increases in salinity and boron on crops as individual stresses are numerous (Bingham et. al., 1987; Eaton, 1944; Ehret and Ho, 1986; Maas and Grattan, 1999). However, studies addressing both stresses affecting the crop simultaneously are much more limited and the conclusions reached have been mixed. The predominant effect is an increased tolerance to boron by the plant with increased salinity (El-Motaium et al., 1994; Ferguson et. al., 2002; Grattan et. al., 1996; Holloway and Alston, 1992; Yadav et. al., 1989). However, decreased tolerance to boron in the presence of salinity stress has also been documented (Grieve and Poss, 2000, Alpaslan and Gunes, 2001; Wimmer et al., 2003).

Confounding the interpretations of salinity-boron interactions is the influence of the pH of the soil solution. Soil solution pH is known to effect boron availability in soils, boron-ion reactions and ion interactions. The pH conditions recorded in salinity and boron experiments (Ben-Gal and Shani, 2002, Yadav et. al., 1989, Sternberg et. al., 2001) were either slightly acidic (pH 6.5) or alkaline (pH 7.5-8.5) but pH was not used as an experimental variable. San Joaquin Valley soils that have the combination of high salinity and boron are alkaline in nature (pH range of 7.5 to nearly 9.0). Incorporation of pH into the factorial design of the experiment may provide insights into salinity-boron interactions and the modified tolerances of boron in the presence of salinity observed in many other studies.

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MATERIALS AND METHODS

An experiment was conducted in 2004 at the US Salinity Laboratory in Riverside, CA using large outdoor sand tanks to determine the interactive effects of salinity, boron and pH on the performance of cucumber (*Cucumis sativus* L. cv. Seminis Turbo hybrid). Twenty-four sand tanks, arranged in a randomized complete block design, were irrigated from individual reservoirs containing a modified half-strength Hoagland's nutrient solution combined with various salinity, boron, and pH treatments. Solutions were pumped to the outside sand tanks from reservoirs below several times daily and allowed to drain back to the reservoirs. pH adjustments on the reservoirs were performed most week days and salinity and boron concentrations were periodically monitored. Crop water use was determined volumetrically by reservoir water depletion.

Treatments included two salinity levels, 3 and 8 dS/m; three boron concentrations of 0.7, 5, and 8 mg/L; and two pH levels where solutions were frequently adjusted to 6.5 and 8. Treatments were replicated twice. Plants were routinely observed for foliar injury and fruit development. Data collected included fresh and dry weights of plants, leaves, stems, and roots as well as cucumber fruit weight and quantity. Collected tissues will be analyzed for various ions to determine their distributions within the plant and ion interactions. Boron isotope analysis will be performed on the solutions and fruit tissue to determine if isotopic composition (i.e. $^{11}B/^{12}B$) influences plant uptake. Data will be analyzed by analysis of variance using the 2 x 3 x 2 factorial design.

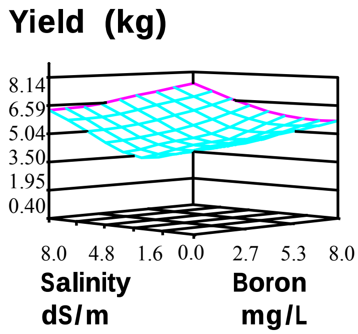
RESULTS AND DISCUSSION

Results of the experiment to date include statistical analyses of fresh and dry weights of plants, leaves, stems, fruits, and number of fruit, on the harvest dates of September 3, and September 17, 2004. Future analyses are to include ion partitioning patterns, boron isotope composition, and evapotranspiration. Table 1 presents the ANOVA analyses and corresponding probability levels performed on the data from the final harvest.

Table 1. ANOVA summary and probability values for the September 17, 2004 harvest.

Source	Total Fresh Biomass (kg)	Fresh Vine Weight (kg)	Fresh Fruit Weight (kg)	Number of Fruit per Plant
Salinity	< 0.001	< 0.001	0.0002	0.0004
Boron	0.0406	0.1100	0.0385	0.0717
Salinity-Boron	0.2503	0.6039	0.1721	0.2178
pH	< 0.001	< 0.001	< 0.001	0.0001
Salinity-pH	0.4657	0.1769	0.7994	0.9453
Boron-pH	0.0383	0.0468	0.0596	0.2053
Salinity-Boron-pH	0.9219	0.6942	0.9289	0.8302

These results indicate that salinity and pH were the most influential factors, both of which were highly significant ($P < 0.01$). Both increased salinity and increased pH reduced yield and plant biomass (Figures 1 and 2). Increased boron also reduced total biomass and fresh fruit weights ($P < 0.05$). Most interactions among the variables, however, were not significant. The only exception was a significant boron-pH interaction affecting the biomass and vegetative growth ($P<0.05$). The effect was nearly significant for the fresh fruit as well. These data indicate that under slightly acidic conditions, increased B had a much more dramatic reduction in plant biomass and yield than did the same increase under slightly alkaline conditions.



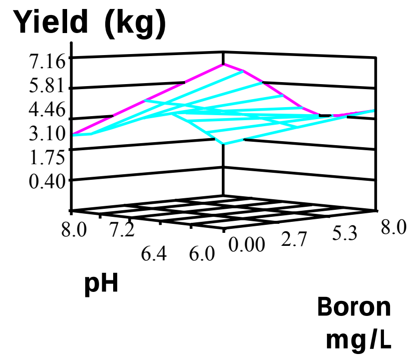


Figure 1. Predicted fresh yield (kg/plot) in relation to salinity and boron in the soil solution.

Figure 2. Predicted fresh fruit yields (kg/plot) in relation to pH and boron in the soil solution.

CONCLUSIONS

These preliminary data suggest that pH has a large affect on cucumber sensitivity to B. This is an important finding for crops grown in the slightly alkaline conditions of California's San Joaquin Valley.

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