Does salinity reduce Boron's toxic effect in Broccoli?

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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.

Boron is a concern for several reasons. First, boron is an element that is essential for crops but has a small concentration window between what is considered deficient and that which is potentially toxic. Second, it has a higher affinity to the soil than common salts, thus it requires much more water to reclaim soil B to pre-existing levels than it does to reduce the salinity to pre-salinization levels. Furthermore, the B concentration in San Joaquin Valley drainage water varies widely but in nearly all cases, it far exceeds levels that would result in toxic conditions based on B-tolerance guidelines.

The question is often raised, are the effects of salinity and boron on crops additive, synergistic or antagonistic? Despite the common occurrence of high boron and high salinity in many parts of the world, very little research has been done to study the interaction of the two. For those that have been done, contradictory results have been obtained (Alpaslan and Gunes, 2001; El-Motaium and Brown, 1994; Grieve and Poss, 2000; Holloway, and Alston. 1992; Wimmer et al., 2003; Yadav et al. 1989). Greenhouse studies are underway to evaluate B tolerance particularly in relation to salinity. Our goal is to answer this question. If the effects of the two are antagonistic, then B may not be as limiting a factor in reuse systems than previously thought.

MATERIALS AND METHODS

A greenhouse experiment was conducted using an elaborate sand tank system at the USDA-ARS, George E. Brown, Jr. Salinity Laboratory located at the UC Riverside campus. The experiment was designed to determine the interactive effects of salinity and boron on broccoli performance including growth, yield, injury, and ion relations. Broccoli (*Brassica oleracea* L., botrytis group, cv Seminis PX511018) was selected because it is a crop common to the Westside of the SJV and is known to be moderately sensitive to salinity and moderately sensitive to B in non-saline systems.

The sand-tank system creates a uniform and controlled environment and consists of 60 large tanks (1.2 m x 0.6 m x 0.5 m deep) filled with washed sand. Each tank is irrigated with a solution prepared in individual reservoirs having a volume of approximately 890 L. Salinity-B treatments were complemented with modified half-strength Hoagland's nutrient solution. Solutions were pumped several times per day from storage reservoirs, located below the sand-tank facility, to the sand tanks and then returned to the reservoirs by gravity

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flow. Each reservoir irrigated three replicate tanks. Total evapotranspiration from each tank was measured by solution-volume changes in the storage reservoirs and water lost was replenished to maintain constant osmotic potentials in the treatment irrigation waters. Non-planted tanks were used to determine potential evaporation.

The irrigation treatments consisted of three salinity levels representing non-saline (1.5 dS/m), moderately saline (11dS/m) and saline (18 dS/m) conditions. Based on sand-water (ECsw)- ECe relations from earlier work, these saline treatments translate into average rootzone salinities (ECe) of 0.7, 5.0 and 8.2 dS/m. Each salinity level was comprised of either 1) chloride dominated salts or 2) synthetic saline drainage water with an ion composition typical to that found in shallow, saline water tables in the western SJV. Each of these treatments had three boron concentrations ranging from very low, such as that found in solution cultures (i.e. 0.23-0.5 mg/L), high (14 mg/L) and very high B concentrations (28 mg/L). The pH of the solutions was maintained between (5.7 and 6.7) using additions of sulfuric acid.

Broccoli was planted on 4 February, 2003 and salinization began 16 days later when plants had approximately two leaves. Several plants were periodically harvested from each tank for biomass and ion accumulation. Broccoli was first harvested on March 28th and again on April 24th. On April 24th, total shoot biomass was determined and plants were divided into leaf blades, leaf margins, and petioles. The remainder of the plants were harvested at maturity on May 21st (90 days after salinization). Broccoli shoots were divided into heads, stems, young leaves (most fully expanded leaf and younger), and old leaves (all remaining leaves). Immature heads, from salt-stressed treatments, were given the opportunity to mature and these heads were harvested on May 29th. Fresh and dry weight measurements were made on all harvested biomass. Tissue ion concentrations (e.g. B, Na, Ca, Mg, Cl, K and S) were determined on total shoots and various organs from the April 24th harvest and will be determined on the various organs of the crop at final harvest. ANOVA and surface regression model analysis were performed on the data.

RESULTS AND DISCUSSION

Results from this study indicate that both Cl-based salts and those characteristic of shallow saline drainage water (i.e. a mixture of salts dominated by sodium sulfate) showed a significant salinity-boron interaction. At high salinity, increased B concentration was less detrimental, both visually and quantitatively (i.e. biomass), than it was at low salinity. That is, plants could tolerate a higher solution B-concentration at higher salinity. However there was no significant difference between salt types. The effects on head weights were more exaggerated than those on shoot biomass (Figure 1). Therefore these data indicate that salinity and B are antagonistic.

Extensive ion analyses have been conducted to evaluate the influence of salinity on ion uptake and distribution within broccoli shoots. The mid-season (April 24th) vegetative-harvest included whole shoot samples as well as leaf blade, leaf margins and petioles. Shoot B concentration was influenced by salinity, but interestingly the direction of influence was dependent upon the B concentration in the solution (Table 1). Regardless of the composition of the salinizing solution, increased salinity increased shoot B concentration when B concentrations in the solution were relatively low (i.e. 0.5 mg/L). At the highest solution B concentration (28 mg/L), increased salinity reduced shoot B concentration. Solution B in itself had very little influence on shoot ion accumulation but both salinity (i.e. EC) and salinity composition had very strong influences on shoot tissue ion composition. A detailed summary is provided in another report along with a discussion on the distribution of ions within the shoot.

Cumulative water use of broccoli was evaluated in relation to the various treatments. Cumulative ET was, for the most part, directly related to cumulative biomass; the higher the cumulative biomass the higher the cumulative ET (data not shown). Stable isotopic ratios of oxygen in the solution were used to separate evaporation and transpiration. With these estimates, we were able to provide insight into whether B uptake is truly passive with the transpiration stream as many have suggested in the literature or whether the plant is able to regulate the amount of B absorbed and transported to the shoot. In no treatment did shoot B accumulate to a level predicted based on transpiration volume times solution B-concentration. Plants treated with low B contained the largest percent of B uptake (10-60%), expressed relative to predicted passive uptake. Salinity treatments, regardless of composition, represented the higher percentage range. On the other hand, plants treated with high B (14 or 28 mg/L) only accumulated 1-2% of that predicted if uptake and accumulation were truly passive. Therefore under conditions of high external B, the amount of B that is absorbed and/or transported to shoots of broccoli (and perhaps other species) is controlled by some unknown mechanism, a finding that deserves further investigation.

Table1. Boron concentrations (mg/kg dry wt.) in broccoli shoots sampled 24 April, 2003. Comparison among salinity (EC) levels at different B concentrations (mg/L).

EC	BORON 1	BORON 14	BORON 28	BORON 1	BORON 14	BORON 28
(dS/m)	Chloride	Chloride	Chloride	SJV	SJV	SJV
1.5	43.73 b	232.00a	469.00a	51.40 b	192.67a	489.00a
11	79.93ab	118.90 b	292.33 b	48.60 b	127.67 b	245.67 b
18	117.67a	234.33a	269.00 b	125.33a	212.00a	224.00 b

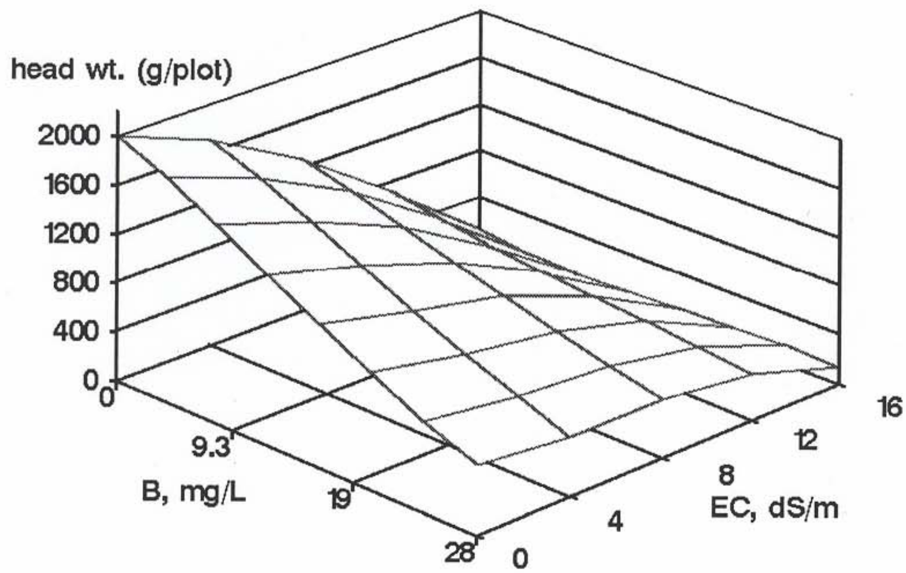

Figure 1. Predicted fresh head weight of broccoli in relation to salinity and boron in the soil solution

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