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Soil Boron Extractions as Indicators of Boron Toxicity

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1 INTRODUCTION

Boron is a nutrient element required by plants in trace amounts. The range between B toxicity and deficiency is narrow. Boron deficiency in crop plants is widespread throughout the world and causes yield decrement. For this reason, a variety of soil tests for plant available B have been developed. Soil tests developed to predict B deficient soils have not generally been evaluated for their ability to predict soil conditions conducive to producing B toxicity effects in plants.

Management options for reducing drainage water volumes on the west side of the San Joaquin Valley of California have the potential to adversely impact crop yields due to a build-up of soil solution B concentration. Shallow groundwater usage by crops improves irrigation efficiency because a portion of the applied water lost to deep percolation is recovered and, therefore, the drainage volume and depth of water application are reduced. However, such a management system has the potential to adversely impact crop yield due to increased salinity and increased B concentration in the groundwater relative to the irrigation water.

The objectives of this study were: (1) to determine extractable soil B with various extractants: ammonium acetate, DTPA-sorbitol, saturation, and 1:1 soil:water; (2) to determine uptake of B by field and container grown plants; (3) and to evaluate the ability of the soil B extractants to predict B content of cotton, melons, and alfalfa under conditions of potential B toxicity.

2 MATERIALS AND METHODS

For the container study, soil was collected from Section 4 of the Broadview Water District in the San Joaquin Valley of California. The soil is a silty clay belonging to the Lillis soil series and classified as a very-fine, smectitic, thermic Halic Haploxerert. Subsamples of soil were treated to attain seven different B levels. Each treatment was replicated four times. The 28 containers were placed outdoors in a randomized block design and planted to muskmelon (*Cucumis melo* L.) variety *Top Mark*. The plants were fertilized and irrigated as needed. Plant leaves were sampled prior to fruit set and at harvest. Leaves, stems, and fruits were sampled at harvest. Soils were sampled at the start of the experiment and after harvest. Additional experimental details can be found in Goldberg et al. (2003).

For the field study, soil and plant samples were collected from Sections 4 and 13 of the Broadview Water District. Ten sites were sampled for alfalfa at the time of soil sampling. Twenty-eight sites were sampled for melons prior to fruit set and at maturity. Twenty-seven

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sites were sampled for cotton at flowering and two subsequent times throughout the growing season. Additional experimental details can be found in Goldberg et al. (2002).

The soils samples were extracted with distilled water, 1 M ammonium acetate, and DTPA-sorbitol. The DTPA-sorbitol extractant is being recommended by the North American Proficiency Testing Program for estimating the potential soil bioavailability of Zn, Cu, Mn, Fe, and B. It contains 0.005 M diethylenetriaminepentaacetic acid, 0.01 M $CaCl_2$, 0.1 M triethanolamine (TEA) adjusted to pH 7.3, and 0.2 M sorbitol. Boron concentrations in the ammonium acetate, sorbitol, and saturation extracts were analyzed using inductively coupled plasma spectrometry. Boron concentrations in the 1:1 soil:water extracts were determined colorimetrically using the Azomethine-H method.

3 RESULTS AND DISCUSSION

In the container study, marginal chlorosis was found on the melon leaves for all B treatments. The number of days to first flowering was significantly delayed at the highest two B treatments as seen in Figure 1. Fruit set was completely inhibited at the highest B treatment. Since fruit is the marketable plant part of melons, these effects are a much better indicator of B damage than reductions in dry matter production.

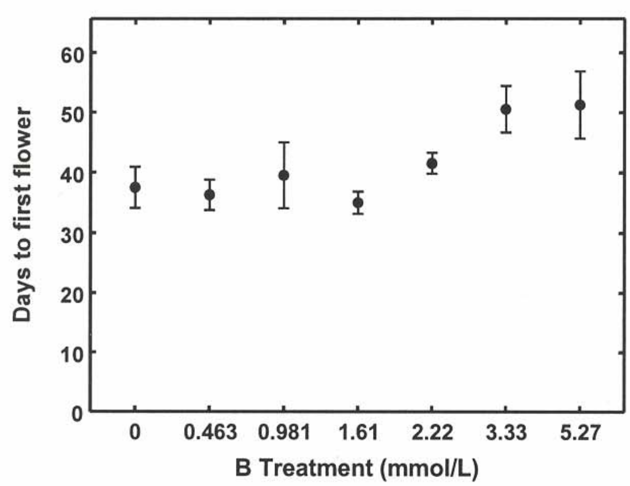

Figure 1. Delay in flowering of melons as a function of B treatment. Error bars represent one standard deviation from the mean of four replicates per treatment.

Correlations between different initial soil B extractions and B content of various melon parts at harvest were highly significant. Correlations for melon stems and fruits were much higher than for melon leaves. This is surprising since leaves are the plant parts recommended for plant testing analysis. The correlation of soil extractable B with fruit B was especially high ($r > 0.99^{**}$). This is very encouraging since fruits are the marketable parts of melons. Figure 2 indicates the ability of the DTPA-sorbitol soil test to predict B content of melon leaves, stems, and fruits.

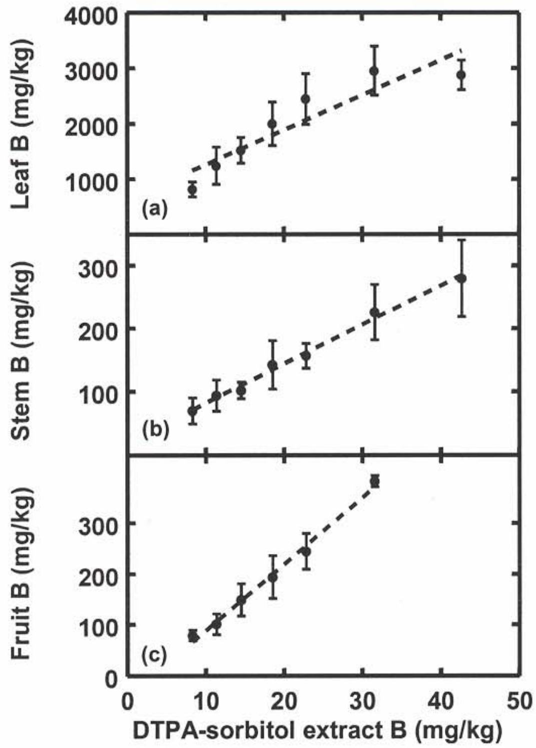

Figure 2. Ability of DTPA-sorbitol extractable B to predict B content of melons: (a) leaf B; (b) stem B; (c) fruit B. Error bars represent one standard deviation from the mean of eight plants per treatment.

In the field study, there were statistically significant positive relationships between various extractable soil B concentrations and B content of melon leaves. The correlation between soil B and plant B was higher for the sampling prior to fruit set. This is not surprising since sampling of melon leaves before fruit set is the recommended protocol for plant analysis. Figure 3 shows the relationship between DTPA-sorbitol extractable B and whole plant B for the root zone averaged depth (0-90 cm).

For cotton, the relationships between extractable soil B content and B content of leaves and whole plants were positive and statistically significant. The correlation between soil B and plant B were highest for the latest plant sampling and the deepest horizon, while the correlation for plant B at flowering was very weak. This is surprising since the recommended time for sampling cotton for plant analysis is at flowering. Figure 4 shows the relationship between DTPA-sorbitol extractable B and leaf B near the end of the growing season for the root zone averaged depth (0-180 cm).

4 CONCLUSIONS

Historically, evaluations of the ability of B soil tests to predict plant B content have been conducted in greenhouse studies. Such conditions provide a much more controlled environment than the field where clay content and water content vary considerably. Ammonium acetate, DTPA-sorbitol, and soil:water extracts were well able to predict B content of container grown melons. However, these extracts provided only poor predictability of B content of field grown crops despite statistically significant relationships.

These results would draw into question the ability of one set of soil B extracts to represent the soil solution B experienced by plants under field conditions. Nevertheless, under uniform B conditions, soil tests of available B provide predictions of melon yield under toxic conditions comparable in quality to those obtained from plant analysis. For such conditions, B soil tests are preferable because they can predict yield reductions at the beginning of the growing season.

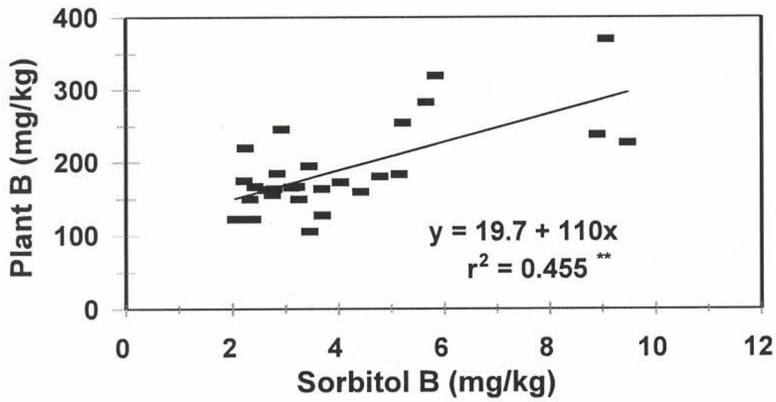

Figure 3. Boron content of melon plants prior to fruit set as a function of DTPA-sorbitol extractable soil B content depth averaged over the root zone (0-90 cm).

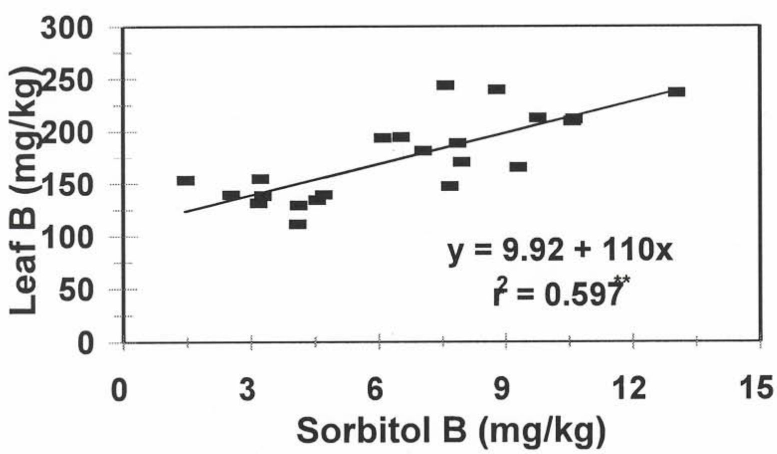

Figure 4. Boron content of cotton leaves at the end of the growing season as a function of DTPA-sorbitol extractable soil B content depth averaged over the root zone (0-180 cm).

5 REFERENCES

Goldberg, S. Shouse, P.J., Lesch, S.M., Grieve, C.M., Poss, J.A., Forster, H.S., & Suarez, D.L. 2002. Soil boron extractions as indicators of boron content of field-grown crops. *Soil Sci.* 167:720-728.

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