Extra Boron Maintains Root Growth under Toxic Aluminum Conditions

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Missouri research shows that boron (B) can help plants cope with toxic concentrations of exchangeable soil aluminum (Al).

ACIDIC, high Al soils are common throughout the United States and the world. In fact, Al toxicity limits yield to a greater degree than any other abiotic stress, except for drought. One of the first obvious effects of Al toxicity in plants is root growth inhibition. However, since high Al may exist in subsoil layers, impaired root growth generally goes unnoticed. Later, the above-ground plant may be stunted by a lack of nutrients and water, resulting in reduced yields.

Boron deficiency symptoms first appear as stunted root growth and many of the specific effects on root cell membranes and walls are identical to those reported for roots suffering from Al toxicity. Because these symptoms were so similar, we developed the hypothesis that Al toxicity may induce B deficiency in plants. The last few years we have completed a number of experiments to determine if higher than normal levels of B would alleviate symptoms of Al toxicity, specifically by increasing root growth.

Missouri Studies

We used a mini-rhizotron system in order to watch root growth of alfalfa in reconstructed soil. Our mini-rhizotron consisted of 3-inch diameter, 4-foot long PVC pipes with a portion of the wall removed and replaced with clear Plexiglas. The bottom half of the tube was filled with an acidic, high Al subsoil (Creldon silty clay loam, 9 to 15 inches below the surface, 26 percent exchangeable Al) from southwest Missouri. Then a layer of black potting soil was added to clearly define the soil zones. The top half of each tube was filled with a good central Missouri silt loam topsoil.

Alfalfa was planted in the tubes and tubes were placed in a rack in the greenhouse with the flat Plexiglas facing downward at an angle of 25 degrees off vertical so roots would grow along the clear surface. The tubes were covered with plywood and black plastic to keep the roots in darkness except when measurements or photographs were made. Analyses of both soils used in this experiment indicated that B levels were in the normal range. Some of the soils were supplemented with the equivalent of 2 lb/A B as boric acid before they were added to the rooting tubes. In one case only topsoil received B, in another case only the high Al soil received B, and in yet another case both topsoil and Al soil were treated with supplemental B. Control tubes received no B in either topsoil or Al soil. One set of tubes served as a double control in that it had the silt loam topsoil throughout the entire tube and did not receive supplemental B. **These tubes served to show that under our conditions, the high Al soil in the bottom half of the other tubes would actually inhibit root growth.**

Soil Studies

Dry weight of top growth measured at the end of the experiment was similar whether or not supplemental B was added to the soil. Top growth from the double control (topsoil throughout tube) had a greater dry weight than any of the treatments

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(Extra Boron . . . from page 3)

containing Al soil, confirming that the Al soil was toxic to top growth.

In order to monitor root growth, the tubes were uncovered weekly, and length of the longest root along the Plexiglas plate was measured. Roots grew identically through the topsoil with no effect of B treatment. However, after five weeks roots reached the high Al subsoil and treatment effects became apparent.

In tubes not supplemented with B, root growth was slowed considerably upon reaching the high Al soil compared to those in the all topsoil tube. So the high Al soil was toxic to root growth. **In tubes where both the topsoil and the high Al soil were supplemented with B, roots continued to grow into the Al soil (Figure 1).**

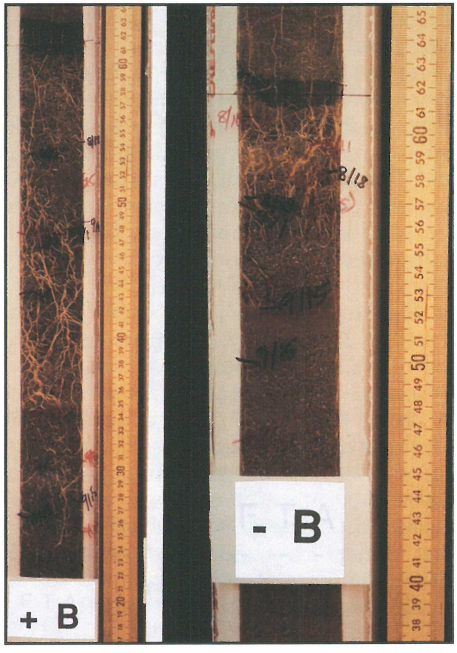

Figure 1. Root penetration into an Al soil layer with or without incorporated B is compared. The tube on the left contains topsoil and Al soil with B added to the topsoil and Al soil at a rate of 2 lb/A. At week 12, the roots had penetrated about 15 inches into the Al soil layer. The tube on the right contains topsoil and Al soil without B added. At week 12 the roots had penetrated only about 6 inches into the Al soil layer. (-B = without boron, +B = with boron)

Several different types of root measurements were made and all of them showed that B supplementation helped maintain root growth in the high Al soil. After 15 weeks, roots were removed from the tubes and total root lengths in the different soil zones determined. These measurements confirmed that supplemental B apparently helped maintain root growth in a normally toxic, high Al soil (**Figure 2**).

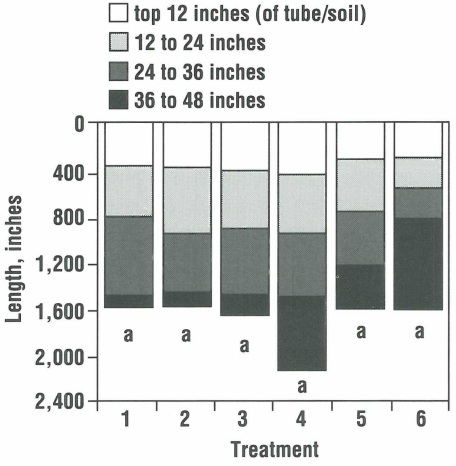

Figure 2. Alfalfa root length in four layers of soil as affected by B treatments. Soil-applied B helped maintain root growth in high Al soil under controlled conditions. (Treatments: 1 = Control; 2 = Foliar B; 3 = B in topsoil; 4 = B in topsoil and Al soil; 5 = Foliar B + B in topsoil and Al soil; 6 = No B, no Al soil.)

While an effect on top growth was not seen in our treatments with Al soil, whether or not B was added, the conditions of the experiments were such that nutrients and water were not limiting. In a field situation, limited root volume could produce nutrient and water stress and, as a result, decreased yield. Boron additions could cause deeper rooting depth in Al soil for better drought tolerance and exploration of larger soil volume, resulting in a greater potential for obtaining nutrients. Unfortunately, it is difficult to claim a

direct B/Al interaction in a medium as complex as soil. Therefore, we decided to do some hydroponic or water experiments with a defined medium in order to prove a direct B/Al interaction.

Hydroponic Studies

Hydroponic experiments were conducted with both alfalfa and squash. Squash proved to be more vigorous and fast-growing under our hydroponic conditions. An Al concentration series was evaluated to find a concentration that would limit root growth. Then a B concentration series was used to find the optimum B concentration for root growth. Thereafter, a toxic Al concentration was used with a series of B concentrations ranging from deficient to beyond the normal levels.

When deficient or normal levels of B were used, Al caused severe root growth inhibition. At high levels of B, root growth was maintained even in the presence of Al (**Figure 3**).

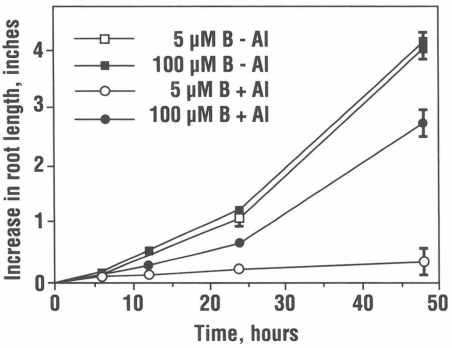

Figure 3. High concentrations of B in the growth medium in the presence of high concentations of Al significantly increased the growth of squash roots. Values are the means of 12 plants.

Conclusions

These experiments show that higher than normal B concentrations protected root growth in situations where high Al would normally be inhibitory. Like most research, these results raise a new question: Is the B requirement for normal plant growth and development higher under toxic Al conditions?

A word of caution–B is a micronutrient with a very narrow window for optimum plant growth and development. Care must be taken to increase the B levels, but not to the degree of toxicity. In addition, B does not replace lime in terms of raising soil pH or providing essential calcium (Ca). ■

1994 Meeting Dates Announced

GROWERS, agricultural supply industry personnel, researchers and Extension workers in the U.S. and Canada will want to take note of announced meeting dates for two conferences planned for March, 1994.

The **Great Plains Soil Fertility Conference is slated for March 8-9, 1994**, at the Stouffer Concourse Hotel, 3801 Quebec Street, Denver, Colorado. The program of this biennial event includes reports and discussion of current research and educational programs in soil fertility and crop production in the Great Plains states and Prairie provinces of the U.S. and Canada. Provinces and states included in the Conference are Alberta, Saskatchewan, Manitoba, Montana, North Dakota, Wyoming, South Dakota, Colorado, Nebraska, Kansas, Oklahoma, New Mexico and Texas.

A second meeting, the **1994 Intensive Wheat Management Conference, is planned for March 10-11** in Denver, also at the Stouffer Concourse Hotel. This Conference, the fifth in a series covering the U.S. and Canada, will focus on improved wheat management for more efficient production, higher yields, and higher profitability. The program will highlight technology transfer and implementation of best management practices. Research reports will also be included.

Registration materials and program specifics will be available for both meetings in the Fall of 1993. For more information contact the Potash & Phosphate Institute, 2805 Claflin Road, Suite 200, Manhattan, KS 66502, phone 913-776-0273.