EFFECTS OF BORON DEFICIENCY ON LEAF PHOTOSYNTHESIS AND NONSTRUCTURAL CARBOHYDRATE CONCENTRATIONS OF COTTON DURING EARLY GROWTH

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RESEARCH PROBLEM

In crop growth and development, boron (B) is an essential trace element. Boron deficiency is common in highly leached, acidic sandy soils of cotton (*Gossypium hirsutum* L.) growing regions in the world. Boron is particularly important in pollen germination and pollen tube growth resulting in successful fruit setting. Therefore, B deficiency during flowering and fruiting may significantly reduce boll retention, resulting in a low yield. A better understanding of the effect of B deficiency during the early growth of cotton on leaf photosynthesis and physiological characters can help us to make cotton production recommendation and to improve yield.

BACKGROUND INFORMATION

Reports of cotton yield response to soil or foliar application of boron has been inconsistent. Howard *et al*. (1998) and Miley *et al*. (1969) reported that soil- or foliar-B application increased yield. In contrast, some studies have shown no positive or negative effect on cotton yield from supplemental B application (Heitholt, 1994). These contrasting results may be associated with soil texture, soil pH, soil fertility, and soil B level. The objective of our study was to determine the effects of B deficiency during early growth on leaf photosynthesis, chlorophyll, and nonstructural carbohydrate contents of leaves and floral buds under growth chamber conditions

RESEARCH DESCRIPTION

The experiment was conducted in a growth chamber at the Altheimer Laboratory, University of Arkansas in Fayetteville. The growth chamber was programmed for a 12-h photoperiod, with day/night temperatures of 30/25°C and relative humidities of 60 to 80%. Cotton cultivar 'Suregrow 125' was planted in 2-L pots filled with washed sand. Each pot had a 2-cm hole in diameter in the base for drainage. All pots were watered with half-strength modified Hoagland's nutrient solution during the first two

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weeks after planting to maintain a sufficient nutrient and water supply.

At 2 weeks after planting, plants of similar size were divided into two identical groups. One group had sufficient B (+B) and received the normal nutrient solution with B, the other group was B deficient (–B) and the sand medium was flushed with excess deionized water to remove B from the pots. Thereafter, the –B treated plants were watered with B-free nutrient solution.

During B deficiency, the net photosynthetic rate, stomatal conductance, and transpiration rate of uppermost expanded main-stem leaves were taken weekly using a LI-6200 portable photosynthesis system (Li-Cor, Inc., Lincoln, Nebracka). At the same time, nonstructural carbohydrate concentration of the leaves determined. Additionally, at 4 and 5 weeks after B removal when –B plants showed B deficient symptoms (dark bands on petioles), leaf cell membrane leakage was determined. The experiment was arranged a randomized complete block design with four replications. The *t* test was performed to determine significant ($P \leq 0.05$) differences between treatment means.

RESULTS

Leaf Photosynthesis Characters

Leaf net photosynthetic rates were not different between +B and –B treatments in the first 3 weeks after removal of B (Table 1). Thereafter, –B-treated plants had significantly lower leaf net photosynthetic rate than the +B control plants ($P < 0.05$). Compared to +B plants, leaf photosynthetic rate of –B-treated plants decreased 8% at 4 weeks and 39% at 5 weeks after removal of B. Decreased photosynthetic rate from B deficiency was closely related to a lower stomatal conductance because under severe B deficient conditions (4 and 5 weeks after B removal), leaf photosynthesis, stomatal conductance and transpiration rate decreased simultaneously (Table 1). Furthermore, a significant increase in cell membrane leakage of –B plants may also be one of the causes leading to lower photosynthesis (Fig. 1).

Nonstructural Carbohydrates

There were no differences in leaf glucose, fructose, and sucrose concentrations between +B and –B treatments 5 weeks after B removal (Fig. 3). However, leaf starch concentration of B deficit plants doubled compared to B sufficient plants ($P < 0.01$). Furthermore, B deficient plants also showed significantly lower floral bud nonstructural carbohydrates than the control plants (Fig. 3). These results indicated that B deficiency depressed photo-assimilate translocation from leaves to fruits, resulting in fruit shedding.

PRACTICAL APPLICATION

Boron deficiency during the early growth of cotton considerably decreased leaf photosynthetic rate and carbohydrate transport from leaves to fruits, and depressed plant growth and dry matter accumulation, resulting in increased fruit abscission. Therefore, in boron deficient areas, soil or foliar application of boron is necessary for optimum cotton plant growth, physiology, and lint yield.

LITERATURE CITED

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Miley, W.N., G.W. Hardy, M.B. Sturgis, and J.E. Sedberry, Jr. 1969. Influence of boron, nitrogen, and potassium on yield, nutrient uptake, and abnormalities of cotton. Agron. J. 61:9-13.

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Table 1. Changes in the net photosynthetic rate (Pn), stomatal conductance (g_s), and transpiration rate (E) of upper-most expanded main-stem leaves during the onset of B deficiency.

	Pn		g_s		E	
Time[z]	+B	–B	+B	–B	+B	–B
(weeks)	(µmol m^{-2} s^{-1})		(cm s^{-1})		(mmol m^{-2} s^{-1})	
1	18.4	18.5	2.9	2.7	14.1	12.3
2	20.7	18.9	2.8	3.0	13.7	11.8
3	19.8	18.7	3.8*	2.6	15.1	12.0
4	22.4*	20.7	4.1**	1.8	15.8*	11.5
5	18.9*	11.6	3.8**	1.1	14.0*	4.9

[z] Measurement times after B was removed from the nutrient solution for the –B treatment.
* and ** indicate that differences between +B and –B treatments are significant at $P < 0.05$ and $P < 0.01$ levels, respectively.

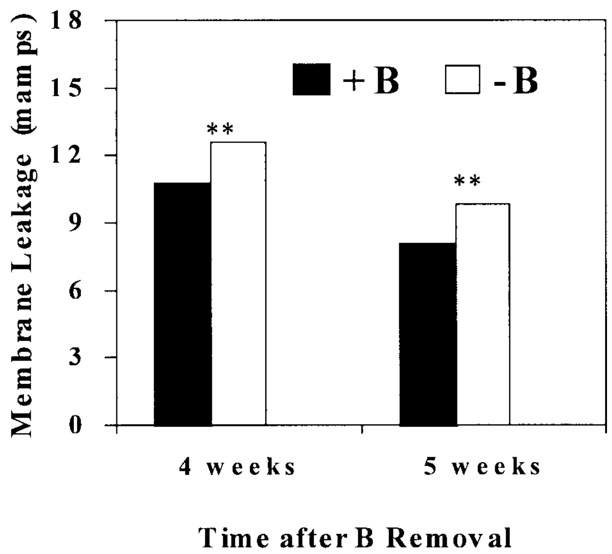

Figure 1. Effect of B deficiency on leaf cell membrane leakage. ** indicates significant difference at 0.01 level between two treatments.

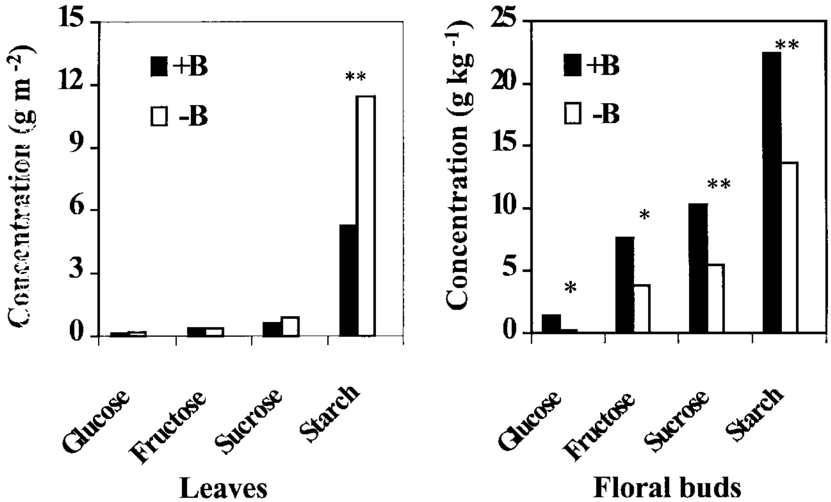

Figure 2. Effect of B deficiency on nonstructural carbohydrate concentration of leaves and 10-d floral buds 5 weeks after removal of B.