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EFFECT OF SOIL AND FOLIAR-APPLIED BORON ON THE PHYSIOLOGY AND YIELD OF COTTON UNDER TWO NITROGEN REGIMES

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Abstract

Current Boron (B) recommendations are based largely on research conducted nearly 30 years ago and little is known of the physiological effect that B has on the cotton plant. For this reason a growth chamber study and a series of field studies were conducted to determine the agronomic and physiological implications of B fertilization. Data collected from the growth chamber provided evidence that cotton plants with adequate B nutrient levels showed an increased rate of net leaf photosynthesis, increased nonstructural carbohydrate concentrations in floral buds and increased dry matter concentrations of plant component parts. However, there has been no clear trend for increased yield or components of yield from added B in three years of field research.

Introduction

Boron (B) has long been known as an essential micronutrient element required for optimal growth and development of cotton (*Gossypium hirsutum* L.) plants. Current production recommendations in Arkansas call for initial pre-plant soil applications of 1.0 to 2.0 lb B/acre or two to six foliar applications of 0.1 lb to 0.2 lb B/acre. This is based largely on research conducted by Miley (1966), Baker et al. (1956), and Maple and Keogh (1963). Boron deficiency is common in highly leached and acidic sandy soils of cotton growing regions in the world. Boron is important in pollen germination and pollen tube growth for successful fruit formation. Therefore, B deficiency during flowering and fruiting may significantly reduce boll retention, resulting in low yield and poor fiber quality. However, little is known about the effect of B deficiency during the early growth of cotton prior to squaring on subsequent growth and physiology of the plant. It is hypothesized that improved B fertility will increase dry matter accumulation of both reproductive and vegetative components, increase photosynthetic efficiency, and increase fruit carbohydrate concentrations. Secondly, it is believed that improved B nutrition will increase boll weight and number, and total lint yields. To test this hypothesis the following objectives were designed. The first research objective was to determine the effect that B deficiency had on the physiology of the cotton plant. A second objective was to determine how B fertilization impacted boll retention, boll development and overall lint yield.

Materials and Methods

Growth Chamber

A growth chamber study was conducted in Fayetteville, Arkansas in 1999 to determine the physiological effect of B fertility on cotton. The growth chamber was programmed for a 12-h photoperiod, with day/night temperatures of 30/25 ^{o}C and relative humidities of 60 to 80%. Seeds of cotton cultivar Suregrow 125 were planted in 2-L pots filled with washed sand. After emergence, seedlings were thinned to one plant per pot. All pots were watered with half-strength Hoagland's nutrient solution during the first two weeks after planting to maintain a sufficient nutrient and water supply. At 2 weeks after planting, plants of similar size were selected and divided into two treatments (treatments listed below). Measurements from the growth chamber study included an assessment of dry matter accumulation of plant components and nonstructural carbohydrate concentrations of 15-day-old floral buds at four and five weeks after B removal. Also, net photosynthetic rate, stomatal conductance and transpiration rate of upper-most expanded leaves were determined weekly from one week after B removal until five weeks after B removal.

Treatments

- Sufficient B (+B),received nutrient solution **with** B.
- Deficient B (-B),received nutrient solution **without** B.

Field Studies

Field studies were planted during early to mid May each year (2000-2002) at Clarkedale, Arkansas (northeast Arkansas) to determine what effect B fertility had on lint yields. Each year the study was planted in a split-plot design with five replications and six treatments (listed below). Additional measurements taken included specific leaf weight (SLW) and chlorophyll content measured three weeks after first flower and yield components at final harvest.

Treatments

- High N--control with no Boron.
- High N--soil B @ 1.0 lb B/acre
- High N--foliar B @ 0.2 lb B/acre @ first flower (FF), FF+2weeks, FF+4weeks
- Low N--control with no Boron
- Low N--soil B @ 1.0 lb B/acre.
- Low N--foliar B @ 0.2 lb B/acre @ FF, FF+2weeks, FF+4weeks.
  **Low N applied at 50 lb/A, High N applied at 100 lb/A.

Results and Discussion

Dry Matter Accumulation and Partitioning

During the first three weeks after B removal, no statistical differences were observed in plant dry matter accumulation between +B and -B treatments (data not shown). At four and five weeks after B was withheld, total dry matter of -B treated plants decreased 32-37% (Table 1) (Zhao and Oosterhuis, 2002). Depressed dry matter accumulation for the -B plant was closely associated with decreases in both leaf area (not shown) and leaf net photosynthetic rate (Table 2) (Zhao and Oosterhuis, 2002). Of all the major plant components (leaves, stems, roots and fruits), fruit dry weight showed the greatest decrease (69%) and leaf dry weight exhibited the smallest decrease (23%) when averaged over the two sampling dates at four and five weeks after B removal. Decreased fruit dry weight was closely related to the higher fruit shedding and less fruiting sites.

Leaf Photosynthetic Characters

Leaf net photosynthetic rates were not different between +B and -B treatments in the first three weeks after removal of B (Table 2). Thereafter, the -B-treatment showed significantly lower leaf net photosynthetic rates than the +B control plants ($P \leq 0.05$) (Zhao and Oosterhuis, 2002). Compared to +B plants, leaf photosynthetic rate in the –B treatment plants decreased 8% at four weeks and 39% at five weeks after removal of B from the nutrient solution. Decreased photosynthetic rate from B deficiency was closely related to a lower stomatal conductance because under severe B deficient conditions (four and five weeks after B removal), leaf net photosynthetic rate, stomatal conductance and transpiration rate decreased simultaneously (Table 2).

Nonstructural Carbohydrates

At four weeks after first flower, B deficit plants showed lower ($P<0.01$) floral bud sucrose and starch levels than the control plants (Figure 1) (Zhao and Oosterhuis, 2002). By five weeks after first flower, sucrose, fructose and starch concentrations were reduced further by B deficit conditions (Figure 1). These results indicated that B deficiency depressed photo-assimilate translocation from leaves to fruit, resulting in fruit shedding.

Specific Leaf Weight (SLW) and Chlorophyll

When averaged over B, high N plants significantly reduced SLW and significantly increased chlorophyll content (Table 3). There was a significant interaction between B and N for increasing chlorophyll content but not for changing the SLW of cotton leaves.

Yield Components

There was not a significant interaction ($P<0.05$) between B and N treatments for increasing the number of bolls or average weight of bolls collected from a two meter row length at harvest (Table 4). These yield components also failed to show a significant effect at the individual B or N level. Averaged over B, the high N treatment resulted in the highest numerical boll number but had the lowest average boll weight.

Lint Yields

Soil or foliar B treatments had no significant affects on lint yields irrespective of soil N level (Table 5). Also, there were no significant differences in yield for the N treatments when averaged over B treatments. This lack of significant differences is likely due to high initial N and B levels in the soil at time of planting each year.

Summary

In the growth chamber, B deficiency reduced photosynthetic rate, leaf carbon fixation and assimilate translocation, resulting in an increase in leaf starch and a decrease in floral bud nonstructural carbohydrates. Decreased net photosynthetic rate of B-deficient plants may be associated with decreased stomatal conductance, lower cell membrane integrity, and build-up of starch. B deficiency also increased fruit shedding and SLW of cotton plants. B deficiency decreased plant dry matter accumulation and partitioning, with the greatest effect on fruit dry matter accumulation and the smallest on leaf dry matter accumulation. In repeated field studies there was no evidence for B to consistently or significantly enhance lint yield, number of bolls per acre, average boll weight, SLW or chlorophyll regardless of application method. Overall, B appears to play a very important role to cotton plants from a physiological standpoint, however, agronomically B fertilization has failed to show any signs of consistent improvements in lint yields.

References

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Table 1. Effect of B deficiency on dry matter accumulation and partitioning of growth chamber-grown cotton plants.

Tissue	4 weeks after B removal		5 weeks after B removal	
	+B	**-B**	**+B**	**-B**
	g $plant^{-1}$			
Leaves	14.64*	10.40	24.09*	20.51
Stems	9.69*	6.07	19.09**	11.81
Roots	6.19*	3.55	8.42*	5.57
Fruits	1.94*	0.97	4.82**	0.60
Total	32.46*	20.63	56.42**	38.49

* and ** indicate that differences between +B and –B treatments are significant at $P \leq 0.05$ and $P \leq 0.01$ levels, respectively.

Table 2. Changes in the net photosynthetic rate (Pn), stomatal conductance (g_s), and transpiration rate (E) of upper most expanded main-stem leaves during B deficiency of growth chamber plants.

Time† (weeks)	Pn		g_s		E	
	+B	**-B**	**+B**	**-B**	**+B**	**-B**
	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

† Measurement times after B was removed from nutrient solution for –B treatment. * and ** indicate that differences between +B and –B treatments are significant at $P \leq 0.05$ and $P \leq 0.01$ levels, respectively.

Table 3. Effect of soil- and foliar-applied B under two nitrogen regimes on the specific leaf weight and chlorophyll content of cotton measured three weeks after first flower during the 2002 growing season at Clarkedale, AR.

Treatment	**chlorophyll content[1] SPAD units**	**specific leaf weight g/m^2**
High N-control	45.6	63.0
High N-soil B	46.1	61.6
High N-foliar B	45.6	62.8
Low N-control	39.8	64.7
Low N-soil B	35.6	64.0
Low N-foliar B	40.2	64.1

[1]There was a significant B x N interaction @ $P \leq 0.05$.

Table 4. Effect of soil- and foliar-applied B under two nitrogen regimes on yield components of cotton measured at final harvest during the 2002 growing season at Clarkedale, AR.

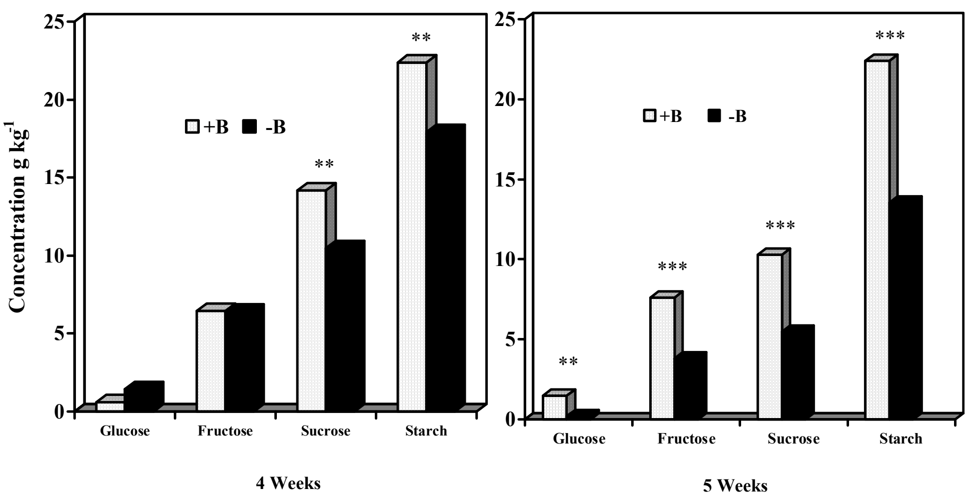
Treatment	Boll number[1] #/A	Average boll weight[1] g/boll
High N-control	146,400	3.86
High N-soil B	162,900	3.84
High N-foliar B	146,900	3.73
Low N-control	146,800	4.08
Low N-soil B	143,800	3.66
Low N-foliar B	156,100	3.89

[1]There was not a significant B x N interaction @ $P \leq 0.05$.

Table 5. Effect of soil- and foliar-applied B under two nitrogen regimes on the lint yield of cotton in Clarkedale, Arkansas from 2000 to 2002.

Treatment	2000	2001	2002	3 year average
	lint yield (lb/acre)			
High N-control	1348	965	829	1047
High N-soil B	1462	921	834	1072
High N-foliar B	1302	911	835	1016
Low N-control	1296	998	809	1034
Low N-soil B	1352	961	775	1029
Low N-foliar B	1392	902	808	1034
LSD (0.05)	NS[1]	NS	NS	NS

[1]NS=Non Significant @ $P \leq 0.05$.



** and *** indicate that differences between +B and –B treatments are significant at $P \leq 0.01$ and $P \leq 0.001$ levels, respectively.

Figure 1. Effect of B deficiency on nonstructural carbohydrate concentrations in the 15-d-old floral buds at 4 and 5 weeks after B removal.