Soybean Yield Response to Foliar- and Soil-Applied Boron Rates

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RESEARCH PROBLEM

Boron (B) is one of the essential micronutrients required for optimal crop production. Its role in plants is still not well understood due to the low plant requirement for B. However, B has been shown to help preserve membrane stability of cells, increase ion transport capacity, and is involved in pollen germination (Al-Molla, 1985). The identification and continued occurrence of B deficiency symptoms in some Arkansas soybean [*Glycine max* (Merr.) L.] production regions has prompted researchers to initiate trials to address the need for B fertilization of soybean in Arkansas. The primary objective of these preliminary studies was to assess the yield response of soybean to selected soil- and foliar-applied B rates.

BACKGROUND INFORMATION

Boron deficiency of soybean was first documented two years ago in some soybean production areas in Arkansas (Slaton et al., 2002). However, this nutritional problem probably was present, but less widespread, long before it was identified. Boron deficient fields were again identified during the 2002 season, and as in the previous season, they tended to be localized in counties north of I-40 and West of Crowley's ridge. Fields with severe B-deficient conditions experienced losses equivalent to 50% of their typical yields. Deficiency symptoms appeared across entire fields or as isolated spots in soybean fields that were otherwise healthy.

Visual deficiency symptoms include wrinkled leaves, stunted plants with short internodes, and death of the terminal, with the severity of symptoms varying among fields. A more detailed description of the symptoms is provided by Slaton et al. (2002). Deficiency symptoms during the 2001 season were observed after the first irrigation, close to the V10 growth stage. During the 2002 season however, symptoms were identified as early as the V6 growth stage.

PROCEDURES

A series of studies was established on three farmer fields to assess the yield response of soybean to various soil- and foliar-applied B rates. The Poinsett County site had no previous history of B deficiency. The Cross County 1 site exhibited B-deficiency symptoms in 2000 (Lanny Ashlock, personal communication). The test at the Cross County 2 site was established after severe B-deficiency symptoms were noticed at the V6 growth stage. Soil samples (4-inch sample depth) were extracted using the Mehlich 3 procedure at an extraction ratio of 1:10.

At the Poinsett County site (Skip Covington farm, Calloway silt loam) the grower drill-seeded (7- inch row spacing) soybean D&PL 5915 on 10 June 2002. Plots 15 ft wide by 30 ft long were established at the V2 growth stage. Boron (Solubor) was foliar applied at rates of 0.5, 1.0, and 2.0 lb B/acre at the V2 (2 July), V10 (29 July), and split applied at V2 and V10 using a backpack CO_2 sprayer calibrated to deliver 10 gal/acre. The split application was made by applying one-half of each B rate at V2 and the remaining one-half applied at V10. Before the V10 B application, whole plant and the most recently matured trifoliate leaves were sampled from each plot for analysis for B concentration. Tissue B concentrations are reported for only the control, all rates applied at V2, and the 0.5 lb B/acre rate applied at V10 (0.25 lb B/acre at V2). The grower managed plots with respect to preplant fertilization, pest management, seeding rates, and irrigation (flood-irrigated). A 28-ft long section of the middle three rows was hand harvested from each plot on 14 Nov 2002. Yields were adjusted to 13% moisture for statistical analysis. Treatments were arranged as randomized complete block, 3 (growth stage) by 3 (B rate) factorial design and compared to an untreated control. Each treatment was replicated five times. Tissue B concentration was analyzed as a randomized complete block design for B applied at the V2 growth stage.

At the Cross County 1 site (DeWitt silt loam) the soybean cultivar Northrup King 57-A4 was drill-seeded (7.5-inch row spacing) on 1 June 2002. Foliar applied B (Solubor) treatments were 0.5, 1.0 and 2.0 lb B/acre applied at the V2 stage, 0.5, 1.0, and 2.0 lb B/acre applied at the V10 stage, and 0.25, 0.5, and 1.0 lb B/acre applied at both the V2 and V10 growth stages. Foliar applications were made using a backpack CO_2 sprayer. Plots were arranged as a 3 (B rate) by 3 (growth stage) completely randomized block, with each treatment replicated six times. A second study evaluating soil-applied B was also established at this site. Boron (Granubor) was broadcast applied after soybean emergence at rates of 0, 1, 2, 4, 6, and 8 lb B/acre. Plots at both sites were 10 ft wide by 25 ft long, with 3 ft alleys separating plots. Plots were arranged as complete randomized blocks with 6 replications. Plots at both sites were harvested with a small plot combine on 19 November with the effective harvested area being 125 ft^2.

The Cross County 2 site (Calloway silt loam) was seeded on 36-inch rows with the cultivar D&PL 5915. Plots 12 ft wide by 25 ft long, arranged as complete randomized blocks, were established on 9 July when plants were in the V6 stage. Boron (Solubor) was applied at rates equivalent to 0, 1, 2, 4, and 6 lb B/acre using a backpack CO_2 sprayer. Treatments were replicated four times. The middle two rows from each plot were hand-harvested on 13 November, placed in a bag, and subsequently transported to the Cotton Branch Station where they were shelled.

Soil samples at the Cross County locations were collected prior to the application of B, with tissue samples collected at the R2 stage. Soil and tissue samples were analyzed according to standard procedures. Soybeans were grown according to the farmers' conventional practices, with both sites being irrigated. Reported yields were normalized to a moisture content of 13% and 60 lb/bushel. Yield and tissue-B concentration data were analyzed with the PROC GLM and lsmeans procedure of SAS at a significance level of 95 or 90%.

RESULTS AND DISCUSSION

Soil pH at all three test sites was >7.5 and Mehlich 3 extractable soil-B was <3 lb B/acre and are representative of most soybean fields in northeast Arkansas (Table 1). Very subtle B-deficiency symptoms were noted in the test area at Poinsett County, but no B-deficiency symptoms were noted at the test area or in the remainder of the field at the Cross County site 1. The grower had applied 1 lb B/acre as Granubor with preplant P and K fertilizers to the field area surrounding the test site. As mentioned previously, the Cross County 2 test was established on a field that exhibited severe and relatively uniform B deficiency by the V6 growth stage.

Soybean yields at the Poinsett County site were not affected by B fertilization, however there was a trend for yields to increase when foliar-applied B was applied, especially at the V2 stage (Table 2). Delayed harvest due to wet soil conditions resulted in some yield loss from shattering as evidenced by the low yields shown in Table 2. The problems at harvesting may have masked potential significant yield differences among treatments. Boron concentrations in soybean tissues increased with increasing B rates. Tissue-B concentrations were less than the 20 mg B/kg critical concentration for all B rates <1.0 lb B/acre. Tissue-B concentration data suggest that 1 to 2 lb B/acre application rates applied at the V2 stage were needed to raise soybean tissue B concentrations above the critical threshold.

At the Cross County 1 site a significant ($P<0.10$) soybean yield response to foliar B rate was observed, but only when B was split-applied at rates totaling 2.0 lb B/acre. Tissue-B concentrations were all within the 20 - 60 mg B/kg suggested sufficiency level. However, there was a significant increase in B tissue concentration for rates >1.0 lb B/acre when compared to the control, regardless of application time (Table 3).

No significant yield responses to soil-applied B rates were observed (Table 4). There was a trend for yields to increase with the 1 lb B/acre rate, and then to decrease with B rates >2 lb B/acre. Boron tissue concentrations were within the suggested sufficiency levels for treatments <2 lb B/acre and were in the suggested B-toxicity range (>60 mg B/kg) for soybean receiving >2 lb B/acre. This situation, perhaps, is responsible for the observed trends.

A B deficiency was also identified at the Cross County 2 site when soybean plants were at the V6 growth stage. Boron concentrations in soybean tissue were initially below 20 mg B/kg (deficient), but increased proportionally with increasing B application rates and appeared to fall into the toxicity range (>60 mg B/kg) in plots receiving rates equivalent to 4 and 6 lb B/acre (Table 5). Boron-deficient plants did not fully recover after B was applied, but there was a trend for yields to increase when 1 and 2 lb B/acre were applied and then decreased with the 4 and 6 lb B/acre rates.

PRACTICAL APPLICATIONS

Preliminary studies to assess the yield response of soybean to soil- and foliar-applied boron applications were conducted. The yield response to foliar-applied B during the 2002 season was significant in one out of three studies, but there was a trend for yields to increase with increasing B rates at the other locations. It appears that under B-deficient conditions, 1 lb B/acre is necessary to raise the tissue concentrations to the suggested sufficiency range of 20-60 mg B /kg. Under the conditions of these preliminary tests, soil and foliar rates >2 lb B/acre raised the B-tissue levels to the toxicity range (>60 mg/kg). These preliminary results demand further evaluation of the response of soybean to B fertilization under both deficient and B-sufficient conditions. There is a need to continue building a database that will allow for the development of recommendations to address this nutritional disorder. Until more information is gathered to allow for more specific practices, farmers in the affected areas should consider applying 1.0 lb B/acre as part of their preplant fertilization program.

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Table 1. Selected soil chemical properties from three test sites located in grower production fields used for soybean B fertilization studies in 2002.

		Mehlich 3 extractable nutrients								
Site	pH	P	K	Ca	Mg	S	Mn	Cu	Zn	B
		(lb/acre)								
Poinsett	8.1	95	358	4918	564	13	564	3.8	2.9	1.5
Cross 1	7.8	24	186	3690	636	27	636	2.3	8.3	2.8
Cross 2	8.3	58	234	4956	567	12	189	3.2	2.7	1.4

Table 2. Effect of rate and timing of foliar B applications on soybean yield, trifoliate leaf, and whole-plant B concentration for soybean grown on a silt loam soil in Poinsett County during 2002..

B rate	Application time	Soybean yield	Trifoliate leaf	Whole-plant
(lb/acre)		(bu/acre)	-------------------- (mg B/kg) ---------------------	
0	None	20.3	11.0	11.3
0.5	V2	26.4	16.5	16.9
1.0	V2	28.6	26.4	22.3
2.0	V2	23.7	35.6	27.3
0.5	V10	24.2	—	—
1.0	V10	23.8	—	—
2.0	V10	21.5	—	—
0.5	V2 + V10	25.8	12.8	12.3
1.0	V2 + V10	23.2	—	—
2.0	V2 + V10	27.7	—	—
LSD(0.05)		NS[z]	3.3	3.6
P-values for main effects and treatment interactions				
B rate		0.8969	<0.0001	<0.0001
Time of application		0.4656	—	—
Rate x time interaction		0.6588	—	—

[z] NS = not significant.

Table 3. Soybean yield response to foliar B application rate and time (growth stage) at the Cross County 1 site in 2002.

B Rate	Application time	Cross County 1	B tissue concentration
(lb B/acre)		(bu/acre)	(mg/kg)
0 (control)	none	53.1	30.8
0.5	V2	54.3	36.0
1.0	V2	55.1	38.5*[z]
2.0	V2	54.8	43.6*
0.5	V10	54.3	34.4
1.0	V10	53.2	42.2*
2.0	V10	55.4	41.4*
0.25	V2 + V10	52.1	34.9
0.5	V2 + V10	54.2	35.1
1.0	V2 + V10	58.3	41.7*
LSD (0.05)		NS	
P-values for main effects and treatment interactions			
B rate		0.057	
Time of application		0.564	
Rate × time interaction		0.871	

[z] * = significantly different from the control treatment at 95% significance level.

Table 4. Trifoliate leaf B concentrations and soybean yield response to varying soil-applied B rates at the Cross County 1 site.

B application rate	Yield	B tissue concentration
(lb B/acre)	(bu/acre)	(mg/kg)
0	50.1	28.2
1	53.5	51.8
2	52.5	57.4
4	51.4	68.3
6	50.1	78.4
8	50.1	83.9
p- value	0.28	<0.0001
LSD	NS	10.6