Irrigated Soybean Yield Response to Boron Application Time and Rate

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BACKGROUND INFORMATION AND RESEARCH PROBLEM

Boron (B) deficiency of soybean [*Glycine max* (Merr) L.] continues to be a common yield- and growth-limiting factor in several counties in northeast Arkansas. Although B-fertilization guidelines have been developed and presented at Extension grower meetings, many soybean growers in northeast Arkansas have not incorporated B into their soybean fertilization programs. Other than field location (county), field history, soil pH, and soil texture, more specific B-fertilization guidelines regarding the soil characteristics that are likely to identify B-deficient soils have yet to be developed. A survey of Arkansas soybean fields, when finished, may identify more specific soil characteristics that can be used to distinguish soils that are prone to B deficiency (Mozaffari et al., 2003). In the meantime, we have continued to establish B-fertilization trials in northeast Arkansas to build a database of soil chemical traits, trifoliate leaf-B concentrations, and yield response of soybean to B fertilization. The primary objectives of field trials conducted in 2004 were to identify the times and rates of B fertilization that produce maximal soybean yields and to identify the range of B concentrations in trifoliate leaves of soybean that are considered deficient and sufficient during vegetative (about V6 stage) and reproductive (R2 stage) growth.

PROCEDURES

Boron-fertilization trials were established in four commercial soybean fields located west of Crowley's Ridge on silt loam soils in Poinsett County during 2004. Selected information for each site is listed in Table 1. The cultivar was selected by each grower and soybean was drill-seeded into conventionally tilled seedbeds at all sites except Covington where soybeans were drilled (replant) into an untilled seedbed. The Covington and Morgan field tests were established in replanted fields where the first soybean stand failed due to excessive rainfall. The previous soybean stand was destroyed by tillage at the Morgan site, but at the Covington site soybean was seeded into the existing stand, which was thin and non-uniform. Boron fertilizer was applied preplant as Granubor (1 lb B/acre) at the fields surrounding tests at the Covington and Block sites and to soybean foliage (mid-August) at the Morgan site. In all cases, direct B application to the flagged research areas was avoided. No B fertilizer was applied to the field surrounding the Johns research site. Before B was applied, a composite soil sample was collected from the 0- to 4-inch depth from each unfertilized control plot at each site to determine soil chemical properties. Soil samples were dried at 55°C in a forced-draft oven and crushed, pH was determined in a 1:2 soil weight-water volume mixture by electrode, and subsamples of soil were extracted using the Mehlich-3 method (Mehlich, 1984). Elemental concentrations of Mehlich-3 extracts were determined by inductively coupled plasma spectroscopy (ICPS). Selected soil chemical properties for each site are listed in Table 2.

Boron was applied at rates of 0, 0.5, 1.0, and 2.0 lb B/acre from shortly after seeding to the V2 stage (V1 stage) or at the R1-R2 stage (R2 stage) of soybean. At the Block and Morgan sites, the V1-stage B was applied as a B solution (Solubor DF, 17.5%B) using a CO_2 backpack sprayer calibrated to deliver 10 gal solution/acre. At the Covington and Johns sites, granular B (Granubor, 15% B) was carefully broadcast by hand to each plot due to windy conditions. At the R2 stage, B at all sites was applied as a solution (Solubor DF) to soybean foliage with a CO_2 backpack sprayer calibrated to deliver 10 gal solution/acre. Each plot was 12-ft wide, 20-ft long, and plots were separated by an 18-inch wide alley. Phosphorus (50 lb P_2O_5/acre as triple superphosphate) and K (80 lb K_2O/acre as muriate of potash) fertilizers were broadcast to all plots. Soybean was irrigated as needed and managed by each cooperating grower and rice was the previous crop (2003) grown at all sites.

Mature trifoliate-leaf samples (20/plot) were collected from the unfertilized controls and each plot received B fertilizer at the V1 stage at one or two times (V6 and/or R2 stages) during the season at each site (Table 1). Samples were placed in paper bags, dried to a constant moisture at 60°C, and ground to pass a 1-mm sieve. A subsample of tissue was digested in concentrated HNO_3 and 30% H_2O_2 and elemental concentrations of the digests were determined by ICPS. At maturity, a 5-ft wide section from the center of each plot was harvested with a plot combine for grain-yield determination. Harvest-moisture content and weight of the harvested soybean grain were determined immediately and yields were adjusted to 13% moisture for statistical analysis.

Each experiment was a randomized complete block with a split-plot treatment structure, where B application rate (0.5, 1.0, 2.0 lb B/acre) was the whole-plot factor and B application time (V1, R2, and none) was the split-plot factor. The 0 lb B/acre rate was treated as an application time (None) in the statistical design. Each treatment was replicated six times. Since tissue was collected from selected treatments, trifoliate leaf-B concentration was analyzed as a randomized complete block design. Data from each site were analyzed separately. At the Johns site, excessive rainfall and poor drainage resulted in early-season stand loss in some plots within the first three replications. Yield from these plots was entered as missing data. Yield data were analyzed using the PROC GLM procedure in SAS version 8.2. (SAS Institute, Inc., Cary, N.C.). Mean separations were performed by Fisher's Protected Least Significant Difference method at a significance level of $\alpha = 0.10$.

RESULTS

Boron deficiency symptoms were observed only in areas of the Morgan field, but not in the research area during early August. The most severe B-deficiency symptoms were observed near the well-water inlet. The growers subsequently applied B to the field area surrounding the research test. Delayed maturity, a symptom of B deficiency, of soybean receiving no B, was noticed only at the Covington site. Soil water pH was >7.0 in only the Covington and Morgan fields, but all fields had low Mehlich-3-extractable B (Table 2).

The interaction between B application rate and time was not significant for seed yield at any site. Significant soybean yield increases, attributed to B fertilization, occurred only at the Covington site (Table 3). Boron applied at the R2 stage, averaged across B rates, produced a significantly greater yield than the unfertilized control, but was not different than the mean yield of soybean receiving B at the V1 stage. No positive yield response at the Block and Johns sites was expected since soil pH was <7.0. Boron rate, averaged across application times, had no significant influence on soybean yields (Table 4). Yield means for B application rate (0.5, 1.0 and 2.0 lb B/acre) were averaged across B application times (V1, R2, and None) and included an untreated control in calculation of the mean yield.

The B concentration of mature trifoliate soybean leaves at all samples times and sites was significantly affected by B application rate at the V1 stage (Table 5). Boron concentrations increased as B rate increased, but the range of B concentrations varied considerably among sites and growth stages. For example, the V6-stage B concentrations at the Johns Farm were quite high shortly after B application when soil was very moist due to continuous rainfall, but declined considerably by the R2 stage. Tissue-B concentrations at the R2 stage of soybean receiving no B were <20 mg B/kg at all sites except the Block Farm suggesting that soybean could have benefitted from B fertilization. Based on trifoliate-B concentration, soybean was B-deficient only at the Covington site which showed positive yield increases to B fertilization (Table 3). At sites where tissues were collected twice, B concentrations declined as plant development progressed suggesting that the critical B concentration for soybean during vegetative stage is different from that at the R2 stage (Table 5). Additional data are needed to determine if B-deficiency can be predicted by sampling soybean tissues during vegetative growth.

PRACTICAL SIGNIFICANCE

Positive soybean yield increases to B fertilization are most likely to occur on alkaline silt loam soils with no history of B fertilization. No particular B-application time or rate showed consistent, significant benefits over another across all 2004 trial sites. However, there appears to be little or no need to apply more than 1 lb B/acre. Data from 2004 suggest that soils with pH <7.0 may also convey low tissue-B concentrations. Until more specific criteria can be delineated, growers should consider applying 0.5 to 1.0 lb B/acre to soybean grown on neutral to alkaline silt loam soils west of Crowley's Ridge so that B deficiency does not limit soybean growth or yield.

LITERATURE CITED

Mozaffari, M., N.A. Slaton, L. Espinoza, and R.E. DeLong. 2003. Preliminary evaluation of boron status of soybean fields in Arkansas. *In* N.A. Slaton (ed.) W. E. Sabbe Arkansas Soil Fertility Studies 2002. University of Arkansas Agricultural Experiment Station Research Series 502:57-59. Fayetteville, Ark.

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Table 1. Selected soil and agronomic information from four B fertilization studies in 2003.

			Plant	B application dates		Plant sample dates		Harvest
Site	Soil series[z]	Cultivar	date	V1	R2	V6	R2	date
			(day - month)					
Covington	Henry	Prog5822RR	15 July	15 July	12 Aug	--	12 Aug	10 Nov
Block	Hillemann	DK5366RR	9 May	4 June	7 July	16 June	7 July	6 Oct
Johns	Hillemann	DPL5915RR	19 May	16 June	12 Aug	14 July	12 Aug	10 Nov
Morgan	Hillemann	Armor 58V8	July 2	15 July	12 Aug	--	12 Aug	10 Nov

[z] Soil series as identified in County Soil Survey Maps for Poinsett County, Ark.
[y] Approximate seeding dates.

Table 2. Selected soil chemical properties from four B fertilization trials with soybean conducted in Poinsett County grower fields during 2004.

	Soil	Mehlich-3-extractable soil nutrients										
Farm-site	pH	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	B
		(mg/kg)										
Block	6.4	15	86	1614	255	13	50	527	176	2.9	0.9	0.1
Covington	7.4	60	93	1652	269	76	52	286	35	7.4	1.1	0.1
Johns	6.0	19	157	1031	276	80	45	362	58	6.1	1.2	0.1
Morgan	8.5	17	122	3968	353	9	65	248	196	18.9	1.7	0.3

Table 3. Influence of B-fertilizer application time, averaged across B rates, on soybean yield at four sites in Poinsett County during 2004.

B application time	Block Farm	Covington Farm	Johns Farm	Morgan Farm
	---------- (bu/acre) ----------			
None	66	31	58	54
V1 stage	65	34	56	54
R2 stage	65	33	59	54
LSD (0.10)	NS[z]	2	2	NS
P-value	0.9821	0.0105	0.0521	0.8861
C.V., %	8.8	8.5	5.6	7.9

[z] NS, not significant at the 0.10 level.

Table 4. Influence of B-fertilizer application rate, averaged across two B application times, on soybean yield at four sites in Poinsett County during 2004.

B fertilizer rate	Block Farm	Covington Farm	Johns Farm	Morgan Farm
	---------- (bu/acre) ----------			
0.5	67	32	57	54
1.0	66	34	58	55
2.0	64	34	56	53
LSD(0.10)	NS[z]	NS	NS	NS
P-value	0.6884	0.2579	0.5296	0.4679
C.V., %	8.8	8.5	5.6	7.9

[z] NS, not significant at the 0.10 level.

Table 5. Influence of B-fertilizer application rate (V1 application time) on the B concentration of mature trifoliate soybean leaves at the V6 and/or R2 stage at four sites in Poinsett County during 2004.

	Block Farm		Covington Farm	Johns Farm		Morgan farm
B fertilizer rate	V6	R2	R2	V6	R2	R2
(lb B/acre)	---------- (mg B/kg) ----------					
0	40.1	29.2	10.3	40.5	19.8	19.4
0.5	45.1	34.4	31.2	63.2	30.3	25.8
1.0	44.7	36.3	48.7	83.1	35.8	36.1
2.0	52.0	40.2	62.3	132.0	38.0	45.1
LSD(0.10)	3.5	3.0	7.9	18.6	8.5	3.2
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
C.V., %	7.4	8.5	22.5	21.8	27.1	10.6