Preliminary Evaluation of Boron Status of Soybean Fields in Arkansas

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RESEARCH PROBLEM

Boron is an essential micronutrient for soybean [*Glycine max* (Merr.) L.] growth and development. Boron deficiency will reduce soybean yields by stunting plant growth and reducing branching and pod formation. The primary objective of this study was to determine B concentrations in soybean tissues, soils, and irrigation waters by surveying random soybean fields in Arkansas. This information will be useful in identifying the geographic areas and soil properties that may be associated with B deficiency of soybean and/or require B fertilization or alternative management practices that will assist growers in avoiding economic losses due to B deficiency. This report describes the first year of a three-year study on the B status of soybean fields in Arkansas.

BACKGROUND INFORMATION

Arkansas farmers produced more than 91 million bushels of soybean in 2001. Proper crop nutrition is a requirement for producing good soybean yields. During the 2001 growing season, symptoms consistent with B deficiency appeared in many soybean fields in eastern Arkansas (Slaton et al., 2002). Soybean plants that exhibited the B-deficiency symptoms had lower B concentrations than normal appearing plants. Field observations raised concern that B deficiency may be limiting soybean yields and consequently growers' income. An assessment of current B status of soybean fields in eastern Arkansas is needed to identify potential problem areas and factors that influence B availability. This information will then be used to identify and develop research and extension programs to help soybean growers manage their B fertility in a profitable manner.

PROCEDURES

Eleven major soybean-producing counties of eastern Arkansas were selected for study in 2002 (Table 1). Plant and soil samples were collected from field areas at least 100 ft from the edge of the field and 100 ft from the irrigation source inlet. The most recently matured trifoliate leaf was collected from 30 soybean plants staggered across five rows. Five whole plants were also sampled from each field by collecting one plant from each of the five rows used for trifoliate leaf sample collection. Latitude and longitude coordinates from the sample site of each field were recorded. Whole-plant and trifoliate leaf samples were collected when soybean plants were at full bloom (R2 growth stage). Soil samples were collected from the top 6 inches in each row and composited. When possible, irrigation water samples were also collected from the well or reservoir. Soybean tissue nutrient (P, K, Ca, Mg, Na, S, Fe, Mn, Cu, Zn, and B) concentrations were determined by digestion with concentrated HNO_3 and 30% H_2O_2 as described by Jones and Case (1990) and measured by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). Soil pH and Mehlich-3 (1:10 extraction ratio) extractable nutrients, including B and Ca, and irrigation water pH and B were also measured. The B concentrations in soybean plant tissues, soil, and irrigation water are presented with descriptive statistics (Table 1). A correlation analysis was also performed to relate plant (whole-plant or trifoliate leaf) B concentrations to soil and irrigation water chemical properties (B and pH).

RESULTS AND DISCUSSION

Chemical characteristics of soil, plant, and water samples were summarized for all counties combined and by county and are listed in Table 1. In general, irrigation water was alkaline and contained low concentrations of B. Although the total amount of B applied via irrigation water cannot be calculated without quantitative information on the amount of irrigation water applied during the growing season, the water B concentrations are considered low and would not result in B toxicity of crops grown in Arkansas. Wilcox and Durham (1967) suggested that irrigation-water B concentrations >0.3 mg B/L could possibly lead to B toxicity of plants, depending on plant susceptibility to B toxicity. It is not known whether the B concentrations of irrigation-water sources in Arkansas are sufficient to supply the B requirements for crops such as soybean, but it is clear that the use of these irrigation-water sources has not lead to an accumulation of B in the surface soil horizons. Mehlich-3 extractable B ranged from 0.1 to 4.1 lb B/kg soil. The mean and median soil B concentrations were 0.8 and 0.6 lb B/kg, respectively. Only three soils contained >2.0 lb B/kg, indicating generally low B concentrations in soils used for soybean production in the study area. Arkansas, Craighead, Lee, and Phillips county had the lowest soil B concentrations while soils from Mississippi and Jefferson county, both cotton-producing counties where soybean is grown primarily on clay soils, had the highest B concentrations. The average soil pH of all sampled soybean fields was 6.5 and ranged from 4.2 to 7.6.

Trifoliate-leaf tissue-B concentrations ranged from 7 to 91 mg B/kg relative to the critical B level of 20 mg/kg reported by Benton (1998). The median trifoliate-leaf B concentration was 42 mg B/kg and only one sample, from Jefferson County, had a leaf-B concentration above the toxic concentration of >63 mg B/kg suggested by Prasad and Power (1997). Mean leaf-B concentrations for Craighead and Jackson counties were 20 and 23 mg B/kg, respectively. Tissue-B concentrations as low as 7 and 16 mg B/kg were found suggesting that B deficiency was limiting soybean yields in some of the fields in these two counties. Arkansas, Jefferson, and Lee county had the highest leaf-B concentrations. Whole-plant B concentrations tended to be slightly lower than the trifoliate leaves with a range from 8 to 87 mg B/kg and a median value of 36 mg B/kg. The northeast Arkansas counties (i.e., Craighead and Jackson) west of Crowley's Ridge and north of I-40 had the lowest tissue-B concentrations and are the same areas where B deficiency has been observed in commercial soybean fields in 2001 and 2002. In contrast, B deficiency of soybean has not been observed in counties south of I-40 or east of Crowley's Ridge which tended to have mean, median, and B concentration ranges well above the established critical trifoliate-leaf concentration of 20 mg B/kg. Correlation of plant, soil, and irrigation water properties failed to show highly significant relationships that might be useful in explaining why B deficiency occurs in certain areas (Table 2).

PRACTICAL APPLICATIONS

Survey results from the first year show that B is most likely to limit soybean growth and yield in counties west of Crowley's Ridge and north of I-40, especially on silt loam soils. Although soils in other soybean-producing areas included in the 2002 survey also have high soil pH and low Mehlich 3 extractable soil B, tissue samples indicate that B nutrition is not limiting in these areas (i.e., southeast Arkansas). Information on soybean response to B fertilizer application and improved diagnostic tools are needed to provide Arkansas growers' with the technical information they need to eliminate soybean yield losses due to B deficiency.

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Table 1. Boron and pH content of soybean fields in 11 soybean-producing counties in Arkansas in 2002.

	pH		B			
County	Soil mean (range)	Irrigation water mean (range)	Irrigation water mean (range)	Soil mean (range)	Leaf mean (range)	Whole-plant mean (range)
			(mg B/L)	(lb B/acre)	---------------- (mg B/kg)	--------------
All counties	6.5 (4.2-7.6)	7.5 (6.8-8.0)	0.009 (0.005-0.024)	0.8 (0.1-4.1)	40 (7-91)	35 (8-87)
Arkansas	6.3 (5.1-7.6)	7.5 (7.2-7.8)	0.016 (0.005-0.033)	0.6 (0.3-0.9)	45 (37-53)	39 (33-47)
Chicot	6.5 (5.6-7.1)	7.7 (7.5-7.8)	0.009 (0.005-0.021)	1.1 (0.2-1.9)	43 (32-56)	39 (35-48)
Craighead	6.4 (5.5-7.0)	7.3 (7.3-7.3)	0.005 (0.005-0.005)	0.3 (0.2-0.4)	20 (16-27)	23 (19-26)
Crittenden	6.0 (5.0-6.6)	ND[z]	ND	0.6 (0.1-1.0)	49 (42-56)	45 (40-50)
Jackson	6.7 (6.4-6.9)	7.3 (6.8-7.7)	0.005 (0.005-0.005)	1.4 (0.4-4.1)	23 (7-35)	22 (8-37)
Jefferson	6.8 (6.3-7.3)	7.4 (7.1-7.8)	0.010 (0.005-0.019)	1.4 (0.8-2.6)	61 (47-91)	56 (44-87)
Lee	6.7 (6.0-7.1)	ND	ND	0.5 (0.2-0.9)	49 (45-52)	36 (33-40)
Mississippi	6.7 (6.1-7.1)	7.2 (7.2-7.2)	0.005 (0.005-0.005)	1.4 (1.2-1.6)	41 (39-44)	40 (36-46)
Phillips	5.4 (4.2-6.4)	ND	ND	0.2 (0.1-0.4)	46 (35-57)	39 (36-42)
Prairie	6.6 (6.4-6.8)	7.5 (7.2-7.8)	0.005 (0.005-0.005)	0.6 (0.2-1.0)	ND	ND
St. Francis	6.9 (6.2-7.2)	7.7 (7.4-8.0)	0.009 (0.005-0.024)	0.7 (0.1-1.2)	35 (28-45)	27 (19-40)

[z] ND = no data.

Table 2. Correlation matrix relating soil, water, and plant properties using the data from all 11 counties combined.

	Soil pH	Soil B	Water B	Leaf Ca	Leaf B	Plant Ca	Plant B
Soil pH							
r[z]	1.00	0.30	-0.33	-0.07	-0.17	0.44	-0.24
p		0.039	0.111	0.641	0.270	0.004	0.129
n	49	49	25	43	43	40	40
Soil B							
r	0.30	1.00	0.05	0.08	0.12	0.10	0.19
p	0.038		0.799	0.593	0.438	0.527	0.229
n	49	49	25	43	43	40	40
Water B							
r	-0.33	0.05	1.00	0.26	0.32	0.05	0.01
p	0.111	0.799		0.248	0.152	0.837	0.953
n	25	25	25	21	21	20	20
Leaf Ca							
r	-0.07	0.08	0.26	1.00	0.49	0.36	0.33
p	0.641	0.594	0.248		0.001	0.022	0.035
n	44	44	21	44	44	40	40
Leaf B							
r	-0.17	0.12	0.32	0.49	1.00	0.20	0.85
p	0.269	0.438	0.152	0.001		0.20	<0.0001
n	44	44	21	44	44	40	40
Plant Ca							
r	0.44	0.103	0.05	0.36	0.20	1.00	0.10
p	0.0044	0.526	0.837	0.022	0.208		0.549
n	40	40	20	40	40	40	40
Plant B							
r	-0.24	0.20	0.01	0.33	0.85	0.097	1.00
p	0.129	0.229	0.953	0.035	<0.0001	0.549	
n	40	40	20	40	40	40	40

[z] r = correlation coefficient; p = probability level; n = number of samples.