Annual Report

An Assessment of B Soil Tests – Is the Current Soil Testing Procedure Appropriate for Saskatchewan?

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Justification:

Micronutrients are essential nutrients that are required by plants in very small quantities. Although used in minute quantities, micronutrients are as important for plant production as macronutrients (e.g., N, P, K, and S) and micronutrient deficiencies can result in significant yield losses (Mortvedt et al., 1991). Essential micronutrients most notable for agricultural production include boron (B) copper (Cu), iron, (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn). Interest in the micronutrient status of Saskatchewan soils has been renewed during the past few years. For some Saskatchewan producers, their interest in micronutrients has been piqued by the publications of a number of articles in farm journals regarding the impact of micronutrient application on crop yields. In addition, there also have been reports of successful B application by some producers interested in managing micronutrients for maximum yield potential of higher value crops such as canola. However, B has not been studied extensively in Saskatchewan and the currently accepted soil and tissue test protocols and critical soil and plant tissue B levels were not developed specifically for Saskatchewan (Karamanos, pers. comm.). Therefore, it is entirely possible that some producers are failing to achieve their canola yield potential due to unidentified B deficiencies. Although reports of B deficiencies in western Canada have been sparse, B deficiencies have been confirmed for canola grown on sandy Gray soils (Karamanos, pers. comm.). In order to assist producers in their decision making regarding B application, an appropriate assessment of the N status of their soils is required.

Objective:

The objective of this project is to assess a variety of methods for determining soil B levels.

Description of Study:

Soils used in the laboratory and growth chamber studies were collected from fields throughout Saskatchewan and Alberta in August 2000. It was our intention to collect soils representing a range of B levels and thus we targeted soils with known or suspected B deficiencies as well as soils with B levels considered adequate. The soils were excavated to a depth of 15 cm, air-dried, sieved using a 6-mm screen and stored.

Each of the 30 soils collected were subject to laboratory analysis for selected physical and chemical characteristics (Table 1). In addition, soil B levels were determined using four different extraction methods: 1) hot water extractable B according to the standard protocol used by Enviro-Test Laboratories (North Dakota State University, 1988); 2) the DTPA - Sorbitol (diethylenetriaminepentaacetic acid) micronutrient extraction method, based on that developed by Lindsay and Norvell (1978) (as described in Geasting and Soltanpour. 1981 and Horneck et al., 1989); 3) extractable B in ammonium acetate by inductively coupled plasma spectrophotometry (modified from Gupta and Stewart, 1978); 4) a modified ammonium acetate/DTPA B extraction (Enviro-Test Laboratories, Warren Grieg, pers. comm.). The B analysis was conducted by Warren Greig of Enviro-Test Laboratories (Saskatoon).

Table 1. Characteristics of soils collected from fields across Saskatchewan and Alberta, August 2000. Enviro-Test laboratories conducted the initial characterization. The initial characterization was conducted using the standard hot water extractable B protocol (Enviro-Test Laboratories).

Soil	N	P	K	B	O.M.†	pH	Texture	EC‡
			$\mu g\ g^{-1}$		%			Sm^{-1}
1	31	128	918	1.99	9.3	6.7	Clay	0.01
2	8	32	362	0.58	2.9	6.9	Clay loam	0.01
3	51	19	338	0.54	2.7	6.6	Clay	0.04
4	4	17	661	0.80	5.1	6.7	Clay loam	0.01
6	8	12	551	1.00	4.9	6.8	Clay loam	0.01
7	9	130	945	0.84	2.5	7.4	Clay loam	0.01
8	5	107	202	0.51	3.3	6.9	Clay loam	0.01
9	17	45	561	0.64	3.8	6.2	Clay loam	0.01
10	21	22	520	0.47	3.9	6.2	Clay loam	0.01
11	37	89	981	0.88	3	5.5	Clay loam	0.01
12	27	99	840	0.97	3.8	5.9	Loam	0.01
13	12	27	1010	1.43	7	6.6	Sandy loam	0.01
14	17	55	1210	0.98	3.9	6.2	Clay loam	0.01
15	23	77	956	0.95	2.3	7.5	Clay	0.01
16	17	19	353	1.57	9.8	6.2	Clay loam	0.01
17	9	110	231	0.50	3.3	6.3	Sandy loam	0.01
18	7	67	172	0.38	2.7	6.3	Sandy loam	0.01
19	27	67	1420	1.29	4.3	6.6	Clay	0.01
20	9	95	290	0.71	4.6	6.2	Clay loam	0.01
21	21	81	152	0.41	2.1	7.3	Sandy loam	0.02
22	12	72	825	0.46	2.5	6.1	Sandy loam	0.01
23	35	122	491	0.46	4	5.3	Sandy loam	0.01
24	30	255	600	0.31	2.3	4.7	Clay loam	0.01
25	14	15	196	0.41	1.8	7	Sandy loam	0.01
26	14	45	706	1.22	4.5	6.8	Clay	0.01
27				0.28				
28								
29								
30								

† Organic matter
‡ Electrical conductivity

Following initial soil analysis, a growth chamber experiment was conducted to determine the relative responsiveness of the 27 soils to B application. The experiment was conducted using a completely randomized design with four replications. Two B treatments were used: 1) application of 1.2 mg B pot^{-1} (i.e., 1 mg kg^{-1}); 2) no B applied.

The experiment was conducted using 1.2 kg of soil placed in 15-cm diameter plastic pots. The pots were lined with plastic bags to prevent potential nutrient loss due to leaching. Sixty ml of modified half-strength Hoagland's B-free nutrient solution

(Hoagland and Arnon, 1938) was applied to each pot at the initiation of the experiment to prevent early nutrient deficiencies. Where B was applied, 16 ml of solution containing 6.86 mg of H_3BO_3 (equivalent to 1.2 mg B) was applied to the soil in each pot. All pots were then watered to field capacity using deionized water.

Plant growth and experimental conditions

Six canola (*Brassica napus* L. cv. SW RideR) seeds were planted per pot at a depth of 1 cm. The pots were arranged in a completely randomized design with four replications in a growth chamber (Model PGV 36, Controlled Environments Ltd., Winnipeg, MB). Growth chamber conditions were maintained at a 16-h day length and a mean day and night temperature of 22 and 18°C, respectively. Relative humidity was maintained between 60 and 70%. Seven days after emergence (DAE), plants in each pot were thinned to five per pot and finally to two per pot by 14 DAE. The plants were watered on a daily basis to maintain field capacity (by weight) using deionized water. In addition, each pot received a second application of 60 ml of modified half-strength Hoagland's B-free nutrient solution 21 DAE. Plants failed to emerge and thrive in soils 5, 8 and 29. It is possible that unknown herbicide residues restricted plant growth in these soils.

Harvesting and plant tissue analysis

The plants were harvested at the budding stage beginning 35-42 DAE to allow the plants to reach approximately the same growth stage at sampling. Plants in each pot were separated into roots and shoots. The roots were washed under running tap water and plant samples were dried at 60°C to a constant weight. The shoots were divided into lower shoots (consisting of the lower stem and leaves from the soil level to the third node below the emerging unfolded leaf at the shoot apex) and upper shoots (consisting of the stem segment and leaves above the upper three nodes including the shoot apex). The dry weights of all plant parts were determined. The lower shoots were ground using cyclone mill (Tecator model Cyclotec 1093) equipped with a 0.4-mm sieve. The ground materials were further finely ground in a rotating ball-bearing mill. The upper shoots were limited in quantity, hence grinding was done using a mortar and pestle to avoid loss of materials during grinding in cyclone and ball-bearing mills. Ground samples have been analyzed for B content; however, this analysis is relatively expensive and thus arrangements were made for Enviro-test to complete this analysis during the slow season. As a consequence, plant tissue B levels only recently became available and will be included in a future report.

Results and Discussion

Boron analyses of the 30 soils used in the laboratory study was completed by Enviro-Test laboratories and is reported are Table 2. Levels of extractable B were strongly influenced by extraction technique. Moreover, significant correlations were detected between extraction methods (Table 3). In particular, the hot water method was strongly correlated with the DTPA-sorbitol method whereas correlations with the 1 N ammonium acetate and the 1 N ammonium acetate/DTPA methods were not as strong although these correlations remained highly significant.

Table 2. Mean and standard deviation of soil B levels as determined using four different soil extraction methods.

	Method of B Analysis							
Soil Identification	Hot Water		DTPA-Sorbitol		1 N Ammonium Acetate		1 N Ammonium Acetate/DTPA	
	mg B kg^{-1}							
1	2.30	(0.16)	0.89	(0.06)	0.75	(0.01)	0.25	(0.01)
2	0.63	(0.06)	0.27	(0.05)	0.35	(0.02)	0.16	(0.03)
3	0.81	(0.02)	0.33	(0.05)	0.39	(0.02)	0.18	(0.02)
4	1.17	(0.04)	0.34	(0.02)	0.44	(0.02)	0.18	(0.03)
5	1.10	(0.06)	0.46	(0.07)	0.54	(0.02)	0.19	(0.04)
6	1.20	(0.10)	0.52	(0.02)	0.79	(0.02)	0.34	(0.03)
7	0.76	(0.06)	0.27	(0.02)	0.30	(0.01)	0.20	(0.04)
8	1.04	(0.04)	0.26	(0.01)	0.29	(0.01)	0.15	(0.01)
9	0.96	(0.30)	0.21	(0.02)	0.22	(0.01)	0.16	(0.03)
10	0.86	(0.04)	0.27	(0.01)	0.23	(0.01)	0.16	(0.03)
11	1.31	(0.06)	0.34	(0.04)	0.37	(0.01)	0.17	(0.03)
12	1.78	(0.14)	0.54	(0.04)	0.69	(0.03)	0.22	(0.04)
13	1.40	(0.06)	0.36	(0.02)	0.35	(0.00)	0.17	(0.05)
14	1.27	(0.12)	0.56	(0.06)	0.69	(0.01)	0.24	(0.09)
15	2.06	(0.12)	0.49	(0.04)	0.47	(0.01)	0.30	(0.17)
16	0.62	(0.08)	0.16	(0.01)	0.19	(0.00)	0.15	(0.01)
17	0.59	(0.06)	0.14	(0.01)	0.23	(0.10)	0.15	(0.02)
18	1.56	(0.07)	0.52	(0.04)	0.52	(0.03)	0.18	(0.01)
19	1.05	(0.02)	0.25	(0.03)	0.30	(0.02)	0.15	(0.01)
20	0.55	(0.03)	0.24	(0.04)	0.40	(0.00)	0.18	(0.02)
21	0.60	(0.01)	0.17	(0.01)	0.18	(0.01)	0.14	(0.01)
22	0.54	(0.03)	0.12	(0.09)	0.16	(0.01)	0.15	(0.01)
23	0.45	(0.06)	0.15	(0.05)	0.10	(0.01)	0.15	(0.01)
24	0.60	(0.04)	0.17	(0.02)	0.29	(0.01)	0.17	(0.03)
25	1.99	(0.08)	0.58	(0.03)	0.50	(0.03)	0.25	(0.07)
26	0.27	(0.03)	0.09	(0.02)	0.11	(0.02)	0.20	(0.10)
27	1.42	(0.21)	0.42	(0.02)	0.37	(0.01)	0.24	(0.05)
28	0.28	(0.02)	0.12	(0.01)	0.13	(0.01)	0.15	(0.03)
29	0.53	(0.02)	0.17	(0.01)	0.18	(0.01)	0.15	(0.02)
30	2.30	(0.16)	0.89	(0.06)	0.75	(0.01)	0.25	(0.01)

† Numbers in parentheses are the standard deviation of the mean of three replicates.

Table 3. Pearson correlation coefficients for the three soil B extraction techniques used in the laboratory study.

B Extraction Method	DTPA-Sorbitol	1 N Ammonium Acetate	1 N Ammonium Acetate/DTPA
Hot Water	0.906**	0.759**	0.650**
DTPA-Sorbitol		0.907**	0.708**
1 N Ammonium Acetate			0.747**

** Significant at P=0.01.

Interestingly, no significant relationships were detected between any of the soil test methods and either plant growth (shoot and root dry matter) (Table 4) or percent yield increase (data not shown). Segregating the data on the basis of soil texture did not improve these relationships (data not shown).

Table 4. Pearson correlation coefficients for the three soil B extraction techniques and shoot and root dry matter production (non of the correlations were statistically significant).

	Dry matter			
	Shoots			Roots
B Extraction Method	Upper	Lower	Total	
Hot Water	0.254	0.157	0.030	-0.126
DTPA-Sorbitol	0.231	0.232	0.101	-0.039
1 N Ammonium Acetate	0.217	0.321	0.226	0.190

Data from the growth chamber experiment is incomplete and we have only recently received the results from the plant tissue analysis. We are hopeful that data correlating plant B uptake and the soil extraction techniques used in the laboratory study will assist us in determining the suitability of these methods for determining critical soil B levels in Saskatchewan soils.

Current Activities:

The growth chamber experiment described in this report will be repeated. Lack of response to B in the first growth chamber experiment has led us to suspect that a factor (or factors) other than B may have limited yield potential and thus potential response to B. Although nutrients other than B were supplied to the plants in the first growth chamber experiment, the nutrient supply (applied to the soil prior to seeding) may simply have been inadequate. When the experiment is repeated, we will use multiple applications of nutrient solutions throughout the duration of the experiment.

Currently, we are also investigating the possibility that potential B response may depend on the canola variety. Indeed, there have been suggestions that B deficiencies are physiological in nature and are induced when crop growth exceeds the ability of the plant to actively transport enough B in the plant to areas of active tissue growth. It follows that varieties that exhibit rapid growth (e.g., hybrid varieties) may be more susceptible to B deficiencies and thus may be more responsive to B application. A growth chamber experiment is currently being conducted to examine the response of four different canola varieties (including a hybrid variety) to B application on three different soils with low levels of available B. This experiment will be completed within the next two weeks.

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