The Effect of Soil and Foliar Boron Fertilization on Canola Yield

Rigas E. Karamanos[1], Tee Boon Goh[2] and Tony A. Stonehouse[1]

[1]Western Cooperative Fertilizers Limited, Calgary, AB; [2]University of Manitoba, Winnipeg, MB

Introduction

Boron represents one of the least studied micronutrients in prairie soils. Earlier studies had to contend with inefficient and often cumbersome chemistries for determination of this nutrient. The advent of ICP (Inductively Coupled Plasma Spectrometry) has allowed development of routine techniques for determination of low boron levels in soils. No calibration work has taken place in western Canada on boron. Hot-water extractable boron, initially developed by Berger and Truog (1939), and subsequently modified by Wear (1965) and Gupta (1979), still remains the prevalent method for assessing soil "available" boron. Hot-water soluble levels of <0.35 ppm are generally considered as deficient (Sims and Johnson 1991). An attempt to calibrate N NH4Oac-extractable boron by Tomasiewicz et al. (1989) using 19 sites the majority of which contained "available" boron levels of less than 0.35 ppm and growing canola, mustard, wheat and flax was unsuccessful. Recent work in Saskatchewan (Malhi et al. 2000) resulted in no consistent results of boron application to seed yield, seed characteristics or disease pressure of canola.

The objective of this project was to attempt to identify soils in western Canada that might respond to boron application, calibrate the existing soil test (hot-water extractable) and derive proper fertilization techniques.

Materials and Methods

Preliminary Survey

A preliminary survey-type study carried out by Western Co-operative Fertilizers Limited (Westco) in 1999 on eighteen sites in the three Prairie Provinces. This project was carried out in cooperation with the Westco Agronomic Crop Enhancement (ACE) Specialists. Each participating ACE Specialist was asked to select a site and, if possible, sample the same at 0-6, 6-12 and 12-24 inch intervals. The samples were submitted to a local Soil Testing laboratory for hot-water extractable B assay. Each ACE Specialist was then provided with a CO_2 sprayer and pre-packaged quantities of a liquid B product (9% B) for foliar application to cover an area approximately 5m X 30 m of canola crop at early flowering stage with 0.5 and 1.0 lb B/acre. An adjacent untreated strip of equal dimensions was also marked to represent the control. At harvest three two-m^2 areas (with some exceptions as per Table 1) were hand harvested, placed in cloth bags and immediately couriered for next day delivery at the Westco Calgary facility, where the samples were dried at 60 ^oC under forced air. The samples were then thrashed and the seed weights were recorded. The legal locations of all sites along with the treatments applied and the canola variety and seeding dates, when available, are provided in Table 1.

The weight from the corresponding sampling areas at each site was averaged and depending on the treatments employed per site two or three averages were derived. There was no attempt to carry out any statistical analysis other than regression analysis between seed yield and hot-water extractable B levels.

Table 1. Site location and characteristics as well as soil hot water extractable B levels.

Legal Land Location		Variety	Treatments lb B/acre	Seeding date	Harvest date	Harvest area Size, m^2	Harvest area Number	Hot-water extractable B (ppm) 0-6 in.	6-12 in.	0-12 in.	12-24 in.
SE 23-13-1	E1		0, 0.5, 1.0	15-May	20-Aug	2	3	2.05	2.50	2.28	1.80
SE 33-12-2	E1	Q2	0, 1.0	2-May	6-Aug	2	3	3.50	1.02	2.26	0.56
NE 26-36-22	W2	Invigor	0, 0.5, 1.0		3-Sep	2	3	1.70	1.70	1.70	1.20
SE 5-42-15	W2	Quest	0, 0.5	28-May	9-Sep	2	3	0.85	0.50	0.68	0.28
SW 25-44-17	W2	Invigor 2273	0, 0.5	24-May	31-Aug	2	3	0.95	0.58	0.77	0.48
SW 8-44-15	W2	Quantum	0, 0.5	25-May	3-Sep	2	3	1.45	0.90	1.18	0.68
42-16	W3	46A73	0, 0.5, 1.0	22-May	5-Sep	2	3	1.35	0.94	1.15	no value
NW 35-33-8	W3	RR	0, 0.5, 1.0	23-May	5-Sep	2	2	1.55	0.94	1.25	1.10
SW 16-29-23	W3		0, 0.5		12-Aug	2	2	3.10	5.20	4.15	5.70
NE 20-55-22	W4	Quest	0, 0.5, 1.0	2-May	25-Aug	2	1	1.05	0.98	1.02	0.72
NE 33-51-9	W4	44A89	0, 0.5	26-May	5-Sep	1.5	3	1.45	1.20	1.33	0.68
NE 5-56-21	W4	45A71	0, 1.0	13-May	24-Aug	2	3	0.40	0.26	0.33	0.32
NW 19-56-22	W4	Quest	0, 1.0	6-May	19-Aug	2	3	0.40	0.72	0.56	0.50
NW 29-56-19	W4	SW Arrow	0, 1.0	14-May	9-Sep	2	3	1.90	1.40	1.65	0.80
SW 16-52-1	W4	Invigor 2273	0, 0.5, 1.0	9-May	20-Sep	2	3	1.70	no value	no value	no value
SW 6-10-14	W4	LG 3965	0, 0.5, 1.0		18-Aug	2	3	0.60	0.48	0.54	0.46
SE 10-78-5	W6	Quest	0, 1.0		5-Sep	2	3	no value	no value	1.58	no value
SW 17-77-6	W6	45A71	0, 0.5		5-Sep	2	3	no value	no value	0.60	no value

Field Studies

A number of experiments were carried out to address both soil testing criteria and proper placement of products and product efficacy in all three Prairie Provinces. Hot-water extractable B levels at the various sites are given in Table 2.

Table 2. Soil test B levels of the test sites.

Year	Location	Depth	Hot water extractable[1] B, ppm
1999	Irricana	0 – 6”	0.7±0.15[2]
		6 – 12”	0.7±0.11
		12 – 24”	0.7±0.08
	Wetaskiwin	0 – 6”	0.38±0.06
		6 – 12”	0.29±0.06
		12 – 24”	0.19±0.04
	Rimbey	0 – 6”	0.6±0.09
		6 – 12”	0.3±0.07
		12 – 24”	0.3±0.06
	Rimbey	0 – 6”	0.3±0.04
		6 – 12”	0.2±0.09
	Lamont	0 – 6”	0.6±0.12
		6 – 12”	0.4±0.19
	Lamont	0 – 6”	0.6±0.13
		6 – 12”	0.4±0.13
		12 – 24”	0.3±0.05
2000	Grimshaw	0-6”	0.25
	Peoria	0-6”	1.0
	Choiceland	0 – 6”	0.17±0.02
		6 – 12”	0.20±0.03
		12 – 24”	0.22±0.04
	Star City	0 – 6”	0.20
		6 – 12”	0.18
		12 – 24”	0.14
	Carberry	0 – 6”	0.17±0.02
		6 – 12”	0.20±0.03
		12 – 24”	0.22±0.04
	Neepawa	0 – 6”	0.69
		6 – 12”	0.52
		12 – 24”	0.38
2001	Elm Creek	0 – 6”	0.14±0.06
	Miami	0 – 6”	0.53±0.09

[1]Berger and Truog (1939).

[2] indicates standard deviation of six sample analysis.

1999 experiments

Effect of soil and foliar B products on canola yield. A series of five experiments were carried out in 1999 to assess the effect of soil and foliar B on the yield of Quest canola in Alberta. The location and a brief experimental plan per site are shown in Table 3. The experimental design at these sites was a split-plot with three broadcast and incorporated soil B rates (0, 1.5 lb B/acre) as main plots and three foliar products (none, Solubor and Micro-Plus B) as sub-plots. All treatments were replicated six times.

Table 3. Location and brief plan of experimental sites of canola in 1999.

			Seeding	Harvest		Nutrient application rate, lb/ac			
Test No.	Location	Province	date	date	Implement	N	P	K	S
1544	Irricana	AB	May-06	Sept-22	Airseeder	72	14	45	17
1564	Wetaskiwin	AB	May-25	Oct-08	DD Drill	81	27	50	18
1570	Rimbey	AB	May-26	Oct-14	Airseeder	72	27	50	18
1574	Rimbey	AB	May-25	Oct-18	Airseeder	99	27	27	22
1588	Lamont	AB	May-26	Sept-14	Airseeder	72	27	50	18

Effect of foliar B on canola yield. At another series of two experiments a foliar application of 0.5 lb B/acre was replicated six times along with foliar applications of Cu (0.2 lb/acre), Mn (0.5 lb/acre) and Zn (0.3 lb/acre) (Table 4).

Table 4. Location and brief plan of experimental sites of canola in 1999.

			Seeding	Harvest		Nutrient application rate, lb/ac			
Test No.	Location	Province	date	date	Implement	N	P	K	S
1573	Rimbey	AB	May-25	Oct-13	Airseeder	99	27	27	22
1585	Lamont	AB	May-26	Sept-14	Airseeder	90	27	50	18

Each site received all the weed control treatments that were necessary and appropriate for the area as recommended. Each plot was 6 feet (1.35 m) wide and 25 feet (7.6 m) long and crops were seeded with the implement indicated in Tables 3 and 4 at 9 inch (22.5-cm) spacing. Tissue and soil samples were obtained from each plot at early flowering and were submitted to a local Soil Testing laboratory for analysis. At maturity, the plots were harvested using a Wintersteiger Nurserymaster Elite experimental combine and the grain samples were dried at 60 ^{o}C by forced air and weighed to determine grain yield.

2000 experiments

Effect of broadcasting and incorporating various rates of soil B. Two series of experiments were carried out, namely, one consisting of three experiments where a single rate of soil applied B (1.5 lb B/acre) was broadcast and incorporated and a second, consisting of five experiments where rates of 0, 0.75, 1.5, 2.25, 3.0, 3.75 and 4.5 were broadcast and incorporated (Table 5).

Effect of seed-placing various rates of soil B. Three experiments were carried in Alberta and Saskatchewan (Table 6).

Rates of 0, 0.75, 1.5, 2.25 and 3.0 were replicated six times.

Effect of soil and foliar B on canola yields. Two experiments were carried in Saskatchewan and Manitoba (Table 7).

The experimental design was a split-plot design with two rates of soil B (0 and 1.5 lb/acre) as the main plots and three foliar B rates (0, 0.25, and 0.50 lb B/acre) as sub-plots.

Table 5. Location and brief plan of experimental sites of broadcast and incorporated B rate experiments in 2000.

Test				Seeding	Harvest		Rate, lb/ac			
No.	Location	Province	Variety	date	date	Implement	N	P	K	S
1676	Grimshaw	AB	SW Rider	May-03	Oct-03	Airseeder	51	25	90	22
1677	Grimshaw[a]	AB	SW Rider	May-03	Oct-03	Airseeder	51	25	90	22
1683	Peoria	AB	Invigor 2153	May-24	Oct-04	Hoedrill	106	25	92	33
1684	Peoria[a]	AB	Invigor 2153	May-24	Oct-04	Hoedrill	106	25	92	33
1687	Choiceland	SK	SW Rider	May-03	Sept-07	Airseeder	106	25	92	33
1700	Star City	SK	SW Rider	May-01	Sept-07	Hoedrill	106	25	92	33
1703	Star City[a]	SK	SW Rider	May-01	Sept-07	Airseeder	51	25	90	32
1727	Neepawa	MB	SW Rider	May-07	Aug-28	Hoedrill	106	25	92	33

[a] Denotes a test where one single B rate was applied.

Table 6. Location and brief plan of experimental sites of seed-placed B rate experiments in 2000.

Test				Seeding	Harvest		Rate, lb/ac			
No.	Location	Province	Variety	date	date	Implement	N	P	K	S
1675	Grimshaw	AB	SW Rider	May-03	Oct-03	Airseeder	51	25	90	22
1682	Peoria	AB	Invigor 2153	May-24	Oct-04	Hoedrill	106	25	92	33
1701	Star City	SK	SW Rider	May-01	Sept-07	Hoedrill	106	25	92	33

Table 7. Location and brief plan of experimental sites of foliar B rate experiments in 2000.

Test				Seeding	Harvest		Rate, lb/ac			
No.	Location	Province	Variety	date	date	Implement	N	P	K	S
1702	Star City	SK	SW Rider	May-01	Sept-07	Hoedrill	78	23	92	33
1725	Carberry	MB	SW Rider	May-06	Aug-30	Hoedrill	78	23	92	33

Each site received all the weed control treatments that were necessary and appropriate for the area as recommended. Each plot was 6 feet (1.35 m) wide and 25 feet (7.6 m) long and crops were seeded with the implement indicated in Tables 5 to 7 at 9 inch (22.5-cm) spacing. Tissue

and soil samples were obtained from each plot at early flowering and were submitted to a local Soil Testing laboratory for analysis. At maturity, the plots were harvested using a Wintersteiger Nurserymaster Elite experimental combine and the grain samples were dried at 60 ^{o}C by forced air and weighed to determine grain yield.

2001 experiments

Effect of soil and foliar B on canola yields. Two experiments were carried in Manitoba (Table 8). The experimental design was identical to that of the 2000 experiments.

Table 8. Location and brief plan of experimental sites of foliar B rate experiments in 2001.

Test				Seeding	Harvest		Rate, lb/ac			
No.	Location	Province	Variety	date	date	Implement	N	P	K	S
1796	Elm Creek	MB	SW Rider	May-25	Aug-22	Hoedrill	86	27	54	18
1804	Miami	MB	SW Rider	May-12	Aug-21	Hoedrill	78	22	54	18

All data were subject to basic statistics, regression analysis and/or analysis of variance as appropriate using SYSTAT 8.0 (SPSS Inc. 1998).

Results and Discussion

Preliminary Survey

The preliminary survey-type study that was carried out in 1999 suggests that hot-water extractable boron is probably of little or no value in assessing the boron status of western Canadian soils (Figure 1).

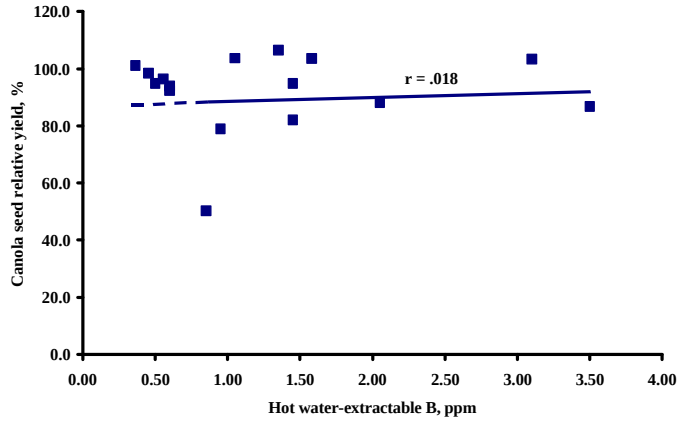

Figure 1. Relative yield of canola (*Brassica napus*) in relation to hot-water extractable boron levels in the 0-6" depth of eighteen sites from the preliminary survey-type research carried out across western Canada in 1999.

Inclusion of hot-water extractable levels in the 0-12" or 0-24" depth did not improve the correlation with relative canola seed yields significantly (r=0.245 and r=0.261, respectively).

Plant analysis on canola tissue from the eighteen sites sampled at early flowering offered no viable alternative in interpreting the obtained yield results (Figure 2).

The Effect of Broadcast and Incorporated Soil B on Canola Yield

There was no significant yield increase due to broadcast and incorporated application of B in any of the eight experiments carried out in 2000 (Tables 9 and 10). A small but significant yield reduction was observed with high B application rates at the Star City site. The hot-water extractable levels in the soil of three of the five sites were far below 0.35 ppm, which is considered a critical level for B deficiency (Table 2).

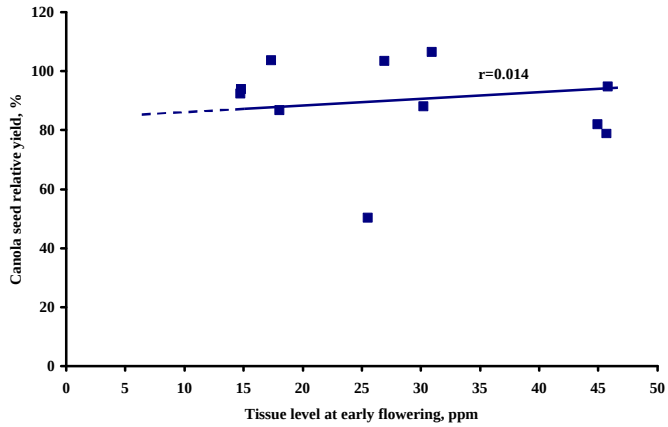

Figure 2. Relative yield of canola (*Brassica napus*) in relation to plant tissue levels at early flowering of eighteen sites across western Canada in 1999.

Table 9. The effect of broadcast and incorporated B applied at a rate of on the yield of canola in 2000.

	Boron Source (1.5 lb B/ac)				
	Check	Micromate	Granubor	ANOVA (P) [a]	LSD
Grimshaw	42.3	44.5	44.9	NS	7.2
Peoria	31.3	31.8	31.2	NS	2.4
Star City	39.9	41.7	42.5	NS	3.9

[a] ,*,** Significant at P ificant

The Effect of Seed-Placed Soil B on Canola Yield

Boron fertilizers are generally broadcast and incorporated, as concentrations of greater than 3.5 ppm of hot-water extractable B are considered toxic (Sims and Johnson 1991). Further, most of the calibration work has been carried out with crops other than canola and on soils that are generally very low in organic matter. Boron seed-placement is thus being avoided, since B placement in concentrated bands induces B toxicity. Touchton and Boswell (1975a,b) observed that potential B toxicity exists for annual crops when fertilizer application rates are greater than 3 to 4 lb/acre.

Seed-placement of up to 3 lb B/acre had very little or no impact on the yield of canola (Table 11). Although the yield reduction at Star City was significant at $P<0.05$, at 3 lb B/acre it only represents a 4.8 percent yield reduction. The lack of toxic effects may be related to the relatively high organic matter levels (3.4, 3.9 and 4.1 percent for Peoria, Star City and Grimshaw, respectively) compared to the soils where the toxicity criterion was developed.

Table 11. The effect of seed-placed B applied at five different rates on the yield of canola in 2000.

	Boron Rate (lb B/ac) - Seed-placed					
Location	0.00	0.75	1.50	2.25	3.00	LSD
Grimshaw	48.1	47.4	51.1	48.6	49.2	4.3
Preoria	27.6	28.3	28.3	26.3	27.6	1.8
Star City	49.6	49.0	48.4	47.3	47.2	2.6
CONTRASTS [a]		Grimshaw	Peoria	Star City		
Boron - Linear		NS	NS	*		
Boron - Quadratic		NS	NS	NS		
Boron - Cubic		NS		NS		
Boron - Residual		NS	NS	NS		

[a] ,*,** Significant at P
NS, not significant

Effect of Foliar B Application on Canola Yield

Foliar B applications have consistently provided better results with crops such as nuts, vines, and fruit orchards compared to soil applications (Martens and Westerman 1991). There were no significant yield increases in any of the eight experiments carried out in 1999 and 2000 (Tables 12 to 18).

ricana in 1999.

Foliar Boron means
6.3
5.8
8.3

etaskiwin in

Foliar Boron means
3.8
3.0
3.6

imbey in 1999.

Foliar Boron means
7.4
5.3
6.8

imbey in 1999.

Foliar Boron means
58.6
51.1
57.6

amont in 1999.

Foliar Boron means
25.0
22.1
28.3

Table 17. The effect of soil and foliar applied B on the yield of SW Rider canola at Star City in 2000.

Soil Boron (lb B/ac)	Foliar Boron Rate (lb B/ac) [c,d] 0.00	0.25	0.50	soil B means [a]
0.0	45.2	45.8	45.7	45.6
1.5	46.8	47.2	45.7	46.6
foliar B means [a]	46.0	46.5	45.7	46.1
Contrasts		Significance		
Soil Boron (S)		NS		
Foliar Boron - Linear (FL)		NS		
Foliar Boron - Non-Linear (FNL)		NS		
S X FL		NS		
S X FNL		NS		

[a],*,** Significant at P 0.10, 0.05 and 0.01 respectively; NS, not significant

[b] Values followed by the same letter are not significantly different using Tukey HSD (P 0.05)

There were two significant effects due to foliar application, but were not associated with a response to foliar B. Rather, one of the foliar products that were used in 1999 at the Rimbey and Lamont sites resulted in a significant yield reduction (Table 19). The reduction may be a result of the application method.

Table 19. Contrasts for the Rimbey (1574) and Lamont sites in 1999.

Contrasts (Yield)	Rimbey [a]	Lamont [a]
Linear Response to Soil Boron (L)	NS	NS
Non-linear Response to Soil Boron (NL)	NS	NS
Response to Foliar Boron (F)	**	NS
Solubor vs Micro-Plus (S vs M)	**	**
L x F Response	NS	NS
NL x F Response	NS	NS
L x S vs M Response	NS	NS
NL x S vs M Response	NS	NS

[a] ,*,** Significant at P 0.10, 0.05 , and 0.01 respectively; NS, not significant

Conclusion

Canola did not respond to B application, even on soils containing <0.15 mg kg^{-1} of hot water-extractable B, thus suggesting that responses to B are rare on prairie soils and in any event hot water extractable B is not an appropriate index to identify B deficiencies (Figure 3).

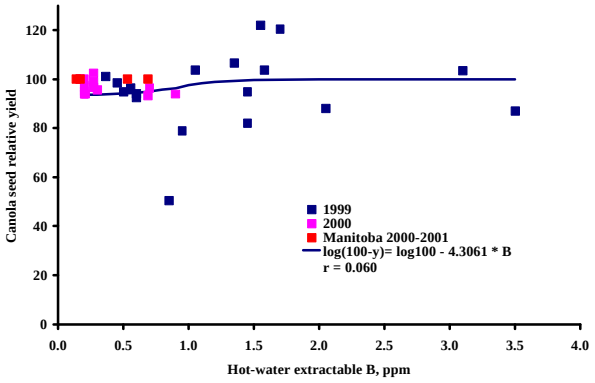

Figure 3. Relative yield of canola (*Brassica napus*) in relation to hot-water extractable boron levels in the 0-6" depth of eighteen sites from the preliminary survey-type research and nineteen research sites carried out across western Canada.

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