Feasibility of B Fertilization on Canola and Alfalfa in Canadian Prairies

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Background:

Boron (B) is a unique non-metal micronutrient required in small amounts by plants for their normal growth and development. Like sulphur (S in sulphate form), B (as borate) is mobile in soil and is subject to leaching in the soil profile, but it is highly immobile in plants (in fact even more immobile in plants than S). In the Prairie Provinces of Canada, canola (*Brassica napus* L. *and B. rapa* L.) is a major cash crop, and alfalfa (*Medicago sativa* Leyss.) is also an important forage crop. In addition to S, canola and alfalfa are also considered heavy users of B. Yields of these crops can be severely affected by B deficiency, if the soil runs out of B any time in the growing season. Therefore, a steady supply of B during the peak vegetative, flowering, seed setting and/or seed development stages is essential for optimum dry matter and/or seed yield.

In western Canada, organic matter is the main source of plant-available B in soils. In the Parkland region of Saskatchewan and other Prairie Provinces, canola grown on sandy/eroded sandy soils (particularly in the Gray and Dark Gray soil zones with low organic matter) has been observed to exhibit symptoms (that appear under cool and wet conditions in spring and disappear later in the season when soil conditions are relatively warm and drier), which are similar to B deficiency. One of the challenges with B deficiency symptoms on canola are that they are very similar and often confused with mid- to late season S deficiency symptoms. For example: stunted plants with cupped, yellowish/reddish colour on younger (upper/top new born/growth) leaves, flowers paler than normal with abortion and poor pod development, often in patches in fields (Figues 1 & 2). The only/main difference between B and S deficiency symptoms on canola is that unlike S, terminal buds will die in canola plants under severe and persistent B deficiency. Problems with canola flower abortion and pod development have frequently been attributed to B deficiency, when in fact the crop has in all likelihood run out of an available supply of S. This problem has been observed throughout the canola growing region of western Canada, and is most likely associated with soils low in S, inadequate sulphate-S to balance N application. In some instances it can occur when farmers have used elemental S either alone or in blends with ammonium sulphate to try and meet S requirements of their canola crop. In some other instances, the farmers believed that adequate S was applied, and as a result drew the false conclusion that in fact the crop deficiency was due to low soil B levels. The objective of this report is to summarize information on seed yield and quality of canola and/or forage and seed yield of alfalfa related to B fertilization on some prairie soils expected or suspected to be B deficient.

Summary of Results of Field/Growth Chamber Experiments and Survey Trials on Canola, Alfalfa and Some Other Crops:

Experiments by AAFC Melfort Research Farm:

Canola: In north-eastern Saskatchewan, seven field experiments and many survey trials were conducted in 1997, 1998, 1999 and 2000 on Gray Wooded soils expected or suspected to be B deficient to find if low canola yields in the Saskatchewan Parkland are due to boron (B) deficiency in soil and to determine if canola yield and quality can be optimized by B fertilization. The treatments included application of B fertilizers (borate/borax form of B fertilizer) as broadcast followed by incorporation (0.9 to 3.6 lb B/acre) prior to seeding, seedrow placement at sowing (0.45 to 1.8 lb B/acre) and foliar spray at 10-20% bloom stage (0.2 and 0.45 lb B/acre), plus a zero-B control treatment.

Seed and straw yield tended to increase in very few of the treatments, with significant increase from incorporated B fertilization at one site for seed and three sites for straw (Tables 1 to 5). Protein content in seed was significantly increased by B fertilization at one site, while oil content in seed was not influenced by B fertilization in any field experiment (data not shown). The B fertilization treatments either increased or tended to increase B concentration and uptake of B in seed and straw in most cases. The increase in B concentration and uptake of B was usually greater in straw than in seed. Averaged across the sites, B uptake in seed was increased by 3.0, 1.7 and 0.5 g/acre with incorporated, seedrow and foliar B treatments, respectively. Corresponding methods showed an increase of B uptake in straw by 21, 15 and 10 g/ha.

Overall, while B application increased plant tissue B concentration in canola in some instances, B fertilizer had no consistent influence on seed yield, (except a significant increase in seed yield with incorporated B only at one site). In this study, plant-available B in the soil ranged between 0.11 to 0.82 ppm B, and in some fields the soils were considered low in plant-available B for canola for optimum growth/yield. In these fields, B deficiency on canola was suspected and B fertilizer application was expected to improve seed yield and quality. This did not happen, most likely because B deficiency in the field probably occurs in isolated patches.

Alfalfa: Field experiments were also conducted on alfalfa grown for forage and/or seed yield in 1999 to 2007. This was done on some northeastern Saskatchewan soils to find if low alfalfa yields, especially seed yield, in the Saskatchewan Parkland can be optimized by B fertilization, in addition to P, K, and/or S fertilizer application. Boron fertilizer at 1.8 lb B/acre was applied as surface broadcast in early spring. Regardless of the site-year, B fertilizer had no consistent influence on alfalfa forage and/or seed yield (Tables 6 to 9). Plant-available B in the soils in these studies was not analysed, but most soils were Gray/Dark Gray with loam texture and marginally low in S and/or P and K. Like canola, the findings of these alfalfa field experiments also suggest that B deficiency on alfalfa occurs rarely, if at all, but may occur in small sandy patches.

Experiments by University of Saskatchewan:

The Department of Soil Science, University of Saskatchewan conducted six field experiments in Saskatchewan (three in 2000 and three in 2001) on soils with marginal to deficient levels of available B according to the hot-water extraction test. A significant response of canola to B application (foliar or soil applied) was not detected in any of these trials. In a related growth chamber study using 27 soils with a range of B levels (deficient to sufficient), significant responses of canola to B application similarly were not detected.

Experiments by Agrium:

Agrium Fertilizer conducted 4 field experiments (2 in 1995 and 2 in 1996) on sites testing less than 0.5 ppm B in Alberta. There were no visual or yield responses to a variety of B treatments (soil and foliar) or B application rates.

Experiments by WESTCO:

A preliminary survey with 18 strip trials in 1999 and twenty-two replicated field experiments in 1999 to 2003 (Karamanos et al. 2003) were conducted by Western Cooperative Fertilizers Limited in Manitoba (in cooperation with University of Manitoba), Saskatchewan and Alberta. All but one strip trial showed no yield response of canola to B fertilizer on soils testing from 0.14 to 1 ppm hot-water extractable B. The same study concluded that hot-water extractable B, the commonly used soil testing extractant for B, is not an effective diagnostic tool for determining the B status of western Canadian prairie soils (Fig. 3). In other words, it doesn't matter what the soil test is, there are no responses to B.

Experiments by Alberta Agriculture:

In Alberta, B deficiencies have been suspected in canola and alfalfa grown on sandy Gray Wooded soils. However, research specifically documenting the response to added B fertilizer is limited. Brown and Dark Brown irrigated soils in southern Alberta will frequently test deficient for B. However, field research experiments with cereal crops found no response to additions of B fertilizer, and canola, pea and bean yields declined by 10 to 20% due to B toxicity after application of B fertilizer pre-plant banded at 2 lb B/acre with other nutrients.

Summary of Findings, Conclusions and Future Research Gaps/Needs:

The findings of field experiments and other field survey trials conducted in the Canadian Prairie Provinces indicate that B deficiency on canola occurs rarely, and most likely it occurs in small sandy patches/areas of the fields. Canola responds occasionally to B fertilization on soils suspected to be B deficient, and this suggests that B fertilization to canola may be needed only rarely. Like canola, the findings of alfalfa field experiments also suggest that B deficiency on alfalfa occurs rarely, if at all, and may occur in small sandy patches of the fields.

Given the lack of responses to B application when soil test B levels are low, B fertilizer recommendations based on the current soil testing procedures are unlikely to reflect real crop B requirements. The current soil testing procedure being used in western Canada to assess B levels is the hot water reflux method. This method of analysis was adopted based on a review of the scientific literature, and very limited western Canadian field evaluation. Therefore, future research is needed to calibrate soil test results under field conditions, using high B requiring crops like canola.

Soil test-B fertilizer recommendations based on very limited research are for annual broadcast application of inorganic salts. Critical levels of B in plant tissues are based on research from other agricultural zones (none is available from the Prairies), and recommended rates of B fertilizer are for foliar application. For foliar application, producers must consult/follow the label directions thoroughly for specific rate and timing.

Even after conducting (very limited) soil and plant tissue analyses, it is still very difficult to predict if a profitable yield response of a crop to B fertilizer would occur in a particular field. In some instances, producers apply B fertilizer to canola or other crops, without knowing if B application is increasing any crop yield. This may be costing them from $5 to $10 or more per acre, depending on the rate of application and source of B fertilizer. In order to save money and optimize the use of B fertilizer, the following suggestions are made to producers: Therefore, if and whenever B is suspected to be deficient in soil or B deficiency is suspected in a crop, (1) producers should/must make visual observations and familiarize themselves with the plant symptoms common to B deficiency and collect plant samples for tissue analysis; (2) apply B fertilizer to a portion of the affected area of the field in marked test strips, and obtain yields from the treated and untreated areas to determine if measurable yield response had occurred, and then consider B fertilization of whole/full fields on a regular basis; and (3) if it is already planned to use B fertilizer on canola, then leave some strips without B fertilizer in the field to compare seed yields with and without B fertilizer.

Application of B fertilizer at high rates can also cause toxicity in plants and result in yield reduction. Therefore, extreme care should be taken before applying B at high rates with the seed or close to the seed, because there is a narrow range between B deficiency and toxicity in plants. Based on a literature search and limited research in the Canadian Prairies, application of B fertilizers, using broadcast/incorporation, should not exceed 1.5 lb B/acre for canola (0.5 lb B/acre for cereals). It is best not to place B fertilizer with seed, because B can be toxic to seedlings when applied in contact with seed, especially when using narrow openers for seeding as they concentrate the seed and fertilizer into a narrow band. For foliar application, it is recommended not to exceed 0.32 lb B/acre rate, and also follow the label directions for the amount of water to be used and apply uniformly.

Literature Cited/References:

Bullock, D. G. and Sawyer, J. E. 1991. Nitrogen, potassium and boron fertilization of canola. J. Prod Agric. **4:** 550-555.

Gupta, U. C. 1968. Relationship of total and hot water soluble boron, and fixation of added boron to properties of Podzol soils. Soil Sci. Soc. Am. Proc. **32** 45-48.

Gupta, U. C. 1972a. Interaction of boron and lime on barley. Soil Sci. Soc. Am. Proc. **36:** 332-334.

Gupta, U. C. 1972b. The extraction and plant available B in some Saskatchewan soils. M.Sc. thesis, Department of Soil Science, University of Saskatchewan, Saskatoon, Saskatchewan, Canada. 44 pp.

Gupta, U. C. 1993. Boron and its role in crop production. CRC Press, Boca Raton, FL., U.S.A. 237 pp.

Gupta, U. C. and Cutcliff, J. A. 1972. Effects of lime and boron on brown-heart, leaf tissue calcium/boron ratios, and boron concentrations of rutabaga**.** Soil Sci. Soc. Am. Proc. **36:** 936-939.

Gupta, U. C. and Sanderson, J. B. 1993. Effect of sulfur, calcium, and boron on tissue nutrient concentration and potato yield. J. Plant Nutr. **16:** 1013-1023.

Gupta, U. C., Jame, Y. W., Campbell, C. A., Leyshon, A. J., and Nicholaichuk, W. 1985. Boron toxicity and deficiency: a review. Can. J. Soil Sci. **65:** 381-409.

Karamanos, R. E., Goh, T. B. and Stonehouse, T. A. 2003. Canola response to boron in Canadian prairie soils. Can. J. Plant Sci. **83**: 249–259.

Malhi, S.S. 2011. Relative response of forage and seed yield of alfalfa to S, P and K fertilization. J. Plant Nutr. 34: 888-908.

Malhi, S.S. and Goerzen, D.W. 2010. Improving yield in alfalfa seed stands with balanced fertilization. J. Plant Nutr. 33: 2157-2166.

Malhi, S. S., Raza, M., Schoenau, J. J., Mermut, A. R., Kutcher, R., Johnston A. M. and Gill K. S. 2003. Feasibility of boron fertilization for yield, seed quality and B uptake of canola in northeastern Saskatchewan. Can. J. Soil Sci. 83: 99-108.

Mortvedt, J. J. 1994. Boron diet essential for crops. Farm Chemicals. February 1994. 2 pp.

Nuttall, W. F., Ukrainetz, H., Stewart, J. W. B. and Spurr, D.T . 1987. The effect of nitrogen, sulphur and boron on yield and quality of rapeseed (*Brassica napus* L. and *Brassica compestris* L.). Can. J. Soil Sci. **67:** 545-559.

Nyborg, M. and Hoyt, P. B. 1970. Boron deficiency in turnip rape grown on gray wooded soils. Can. J. Soil Sci. **50**: 87-88.

Porter, P. M. 1993. Canola response to B and N grown on the southeastern coastal plain. J. Plant Nutr. **16:** 2371-2381.

Raza, M., Mermut, A. R., Schoenau, J. J. and Malhi, S. S. 2002. Boron fractionation in some Saskatchewan soils. Can. J. Soil Sci. **82:** 173-179.

Truog, E. 1946. Soil reaction influence on availability of plant nutrients. Soil Sci. Soc. Am. Proc. **11:** 305-308.

US Borax Inc. 1996. The boron bonus canola. US Borax Inc., 26877 Tourney Road, Valencia, CA 91355. No. 280412/1-96.

Wooding, F. J. 1985. Interior Alaska crops respond to boron applications. Agroborealis. **17:** 47-49.

Table 1. Some soil characteristics at seven different sites for the 0-6 inch depth of the Gray Luvisols for the growth chamber and field experiments (Source: Malhi et al. 2003)

Soil characteristic	Star City[z] 1997	Sylvania 1997	Carrot River I 1998	Carrot River II[z] 1998	Tisdale 1999	Carrot River III 1999	Carrot River IV 2000
Texture[y]	L	SL	SL	LS	SL	LS	LS
pH (1:2 water)	6.9	6.6	7.1	7.8	6.7	6.0	5.7
Org. matter, %	2.2	4.7	2.7	0.9	3.2	1.2	1.5
$CaCO_3$ equivalent, %	0.3	0.8	0.3	1.1	0.5	0.7	0.7
HWS-B[x], ppm	0.56	0.82	0.32	0.11	0.54	0.15	0.40
NO_3-N, ppm	5.8	59.4	13.0	5.2	4.8	3.2	6.2
P, ppm	10.5	6.3	12.0	68.0	16.0	39.0	23.6
K, ppm	240	156	66	240	109	197	166
SO_4-S, ppm	5.6	7.8	5.4	6.2	12.0	13.0	9.0
Ex. Na, meq/100g	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ex. K, meq/100g	0.6	0.5	0.2	0.5	0.3	0.4	0.5
Ex. Ca, meq/100g	10.2	18.0	12.8	2.9	12.4	2.7	4.1
Ex. Mg, meq/100g	1.7	4.6	1.8	<0.4	1.0	<0.4	<0.4
Cu, ppm	0.90	1.2	0.60	0.60	0.60	0.60	0.60
Fe, ppm	78	151	25	103	43	0.92	83
Mn, ppm	36.4	46.0	13.2	14.3	27.7	17.4	17.2
Zn, ppm	1.0	2.6	0.4	0.5	3.0	0.7	0.6

[z]Soil from these two sites was used in the growth chamber experiments.
[y]LS, SL and L refer to loamy sand, sandy loam and loam, respectively.
[x]HWS-B refers to hot water soluble boron.

Table 2. Seed and straw yield of canola (mean of 2 cultivars) with various B fertilizer treatments at Star City in northeastern Saskatchewan in 1997 (Source: Malhi et al. 2003)

Fertilizer treatment	Seed yield (bu/acre)	Straw yield (lb/acre)
Control (no B)	30.4	4099
Incorporated B		
0.9 lb B/acre	30.4	4295
1.8 lb B/acre	31.6	4268
3.6 lb B/acre	31.3	4590
Seedrow B		
0.45 lb B/acre	30.2	4233
0.9 lb B/acre	30.7	4268
1.8 lb B/acre	30.2	4259
Foliar B		
0.22 lb B/acre	29.3	3893
0.45 lb B/acre	30.0	5264
SEM (Fertilizer)[z]	1.1[ns]	246[ns]

[z]After the SEM values, [ns] refers to not significant.

Table 3. Seed and straw yield of canola (mean of 2 cultivars) with various B fertilizer treatments at Sylvania in northeastern Saskatchewan in 1997 (Source: Malhi et al. 2003)

Fertilizer treatment	Seed yield (bu/acre)	Straw yield (lb/acre)
Control (no B)	29.8	3616
Incorporated B		
0.9 lb B/acre	32.5	4116
18 lb B/acre	35.4	4108
Seedrow B		
0.45 lb B/acre (3/4 inch band)	28.6	3438
0.9 lb B/acre (3/4 inch band)	30.7	3384
0.45 lb B/acre (7.9 inch band)	32.0	3688
0.9 lb B/acre (7.9 inch band)	33.2	3902
Foliar B		
0.22 lb B/acre	25.7	2947
0.45 lb B/acre	27.3	3976
SEM (Fertilizer)[z]	1.4***	2.56**

[z]After the SEM values, ** and *** refer to significant at 0.01 and 0.001 level of probability, respectively.

Table 4. Seed and straw yield of canola in different field experiments with various methods, times and rates of B fertilizer application in northeastern Saskatchewan (Source: Malhi et al. 2003)

	Seed yield (bu/acre)						Straw yield (lb/acre[1])					
Fertilizer treatment	Carrot River I 1998	Carrot River II 1998	Tisdale 1999	Carrot River III 1999	Carrot River IV 2000	Seven[y] sites mean	Carrot River I 1998	Carrot River II 1998	Tisdale 1999	Carrot River III 1999	Carrot River IV 2000	Seven[y] sites mean
Control (no B)	30.0	9.8	19.8	18.0	11.1	23.2	9831	1250	6429	2250	1911	4349
Incorporated B												4634
0.9 lb B/acre	32.1	8.0	17.9	19.5	10.2	23.8	9403	947	7849	2348	1072	
1.8 lb B/acre	28.8	7.9	19.5	24.3	9.3	24.8	10483	893	9170	2741	1670	4581
Seedrow B												4420
0.45 lb B/acre	31.3	8.6	18.9	20.0	9.6	22.9	12073	1089	8474	2473	1795	
0.9 lb B/acre	29.1	8.0	19.6	20.7	10.7	23.4	11849	947	7286	2456	1964	4358
Foliar B												4170
0.22 lb B/acre	29.6	9.1	17.9	24.1	10.4	22.3	12644	1089	7081	2884	1839	4349
0.45 lb B/acre	27.9	8.6	18.9	21.1	10.7	22.5	10233	1063	6786	2590	2170	4634
SEM (Fertilizer)[z]	1.4[ns]	0.9[ns]	1.4[ns]	2.4[ns]	1.0[ns]	0.6[ns]	2052[ns]	116[ns]	953[ns]	266[ns]	114[ns]	251[ns]

[z]After the SEM values, [ns] refers to not significant.

[y]Means include the 1997 sites data also.

Table 5. Yield of canola seed and straw with different rates of B application for Star City and Carrot River II soils in growth chamber experiments (Source: Raza et al. 2002)

Rate of B (mg B/kg of soil)	Seed yield (g/pot)	Straw yield (g/pot)
Star City soil		
0	19.6	22.1
1	20.0	22.5
2	22.1	25.4
3	22.2	25.6
SEM^{z}	0.77^{ns}	0.34^{**}
Carrot River II soil		
0	17.4	20.5
1	19.6	20.6
2	19.6	21.0
3	19.6	21.1
SEM^{z}	$0.50^{\bullet}$	0.40^{ns}

^{z}After the SEM values, ^{ns} refers to not significant; and • and ** refer to significant at 0.10 and 0.01 level of probability, respectively.

Table 6. Alfalfa seed yields with and without fertilizers in different years in an 8-year (2000 to 2007) field experiment at Porcupine Plain, Saskatchewan (P Experiment 1) (Source: Malhi and Goerzen 2010)

Treatment	Seed yield (lb/acre)[z]				
	2000	2001	2003	2006	2007
No fertilizer (control)	76	149	76	349	195
K + S + 0 P (KS)	68	106	61	371	184
K + S + 9 P (KS9P)	67	127	74	378	233
K + S + 18 P (KS18P)	101	175	100	365	230
K + S + 27 P (KS27P)	88	204	104	427	262
K + S + 36 P (KS36P)	125	225	109	400	242
P + K (PK)	116	214	125	462	237
P + S (PS)	114	235	103	441	259
P + K + S + B (PKSB)	98	238	96	419	208
$LSD_{0.05}$	29	76	29	76	52
SEM[y]	13***	28***	11*	29*	18*

[z]There was little alfalfa seed yield in 2002, 2004 and 2005, so yields are not reported for these years.
[y]* and *** refer to significant effect in ANOVA at $P \leq 0.05$ and $P \leq 0.001$, respectively.

Table 7. Alfalfa seed and straw/forage yield with and without fertilizers in 2001 in a field experiment at Hudson Bay, Saskatchewan (K Experiment) (Source: Malhi and Goerzen 2010)

Treatment	Seed yield (lb/acre)	Straw yield (lb/acre)
No fertilizer (control)	52	1170
P + S + 0 K (PS)	91	1581
P + S + 9 K (PS9K)	168	1652
P + S + 18 K (PS18K)	131	1759
P + S + 27 K (PS27K)	154	1545
P + S + 36 K (PS36K)	106	1482
K + S (KS)	84	1411
P + K (PK)	76	1286
P + K + S + B (PKSB)	82	1741
$LSD_{0.05}$	ns	ns
SEM[z]	60[ns]	272[ns]

[z]ns refers to no significant effect in ANOVA.

Relative Response of Forage and Seed Yield of Alfalfa to S, P and K Fertilization

Table 8. Alfalfa forage dry matter yield (DMY) with and without fertilizers in an 8-year (2000 to 2007) study at Star City, Saskatchewan (Source: Malhi 2011)

Treatment	Forage DMY (lb/acre)							
	2000	2001	2002	2003	2004	2005	2006	2007
No fertilizer (control)	4510	1886	2257	1253	3843	5032	7820	8183
P + K + 0 S (PK)	4396	2220	2911	1597	4817	5544	7417	8316
P + K + 9 S (PK9S)	5232	2070	2630	1632	5685	6823	8275	10533
P + K + 18 S (PK18S)	5366	2061	2767	1681	5620	6889	8301	10330
P + K + 27 S (PK27S)	5418	2264	2985	1896	6131	7386	8183	10570
P + K + 36 S (PK36S)	5389	2459	2766	2053	6421	7060	7939	10729
K + S (KS)	5292	2627	3200	1667	5674	6582	8400	8373
P + S (PS)	5082	1831	2705	1739	5909	7244	8452	11063
P + K + S + B (PKSB)	5489	2174	2847	1891	6310	6861	8481	10369
$LSD_{0.05}$	564	ns	ns	419	891	963	ns	2542
SEM^z	194**	333^{ns}	295^{ns}	144*	395***	329*	263^{ns}	529**

^{z}•, **, *** and ns refer to significant treatment effects in ANOVA at P≤0.10, P≤0.01, P≤0.001 and not significant, respectively.

Table 9. Alfalfa seed yields in 6 years with and without fertilizers in an 8-year (2000 to 2007) study at Star City, Saskatchewan (Source: Malhi 2011)

Treatment	Seed yield (lb/acre)					
	2000	2001	2003	2004	2006	2007
No fertilizer (control)	321	14	39	35	442	433
P + K + 0 S (PK)	373	71	80	36	396	304
P + K + 9 S (PK9S)	408	15	62	21	416	339
P + K + 18 S (PK18S)	403	15	54	27	421	310
P + K + 27 S (PK27S)	363	22	62	27	390	417
P + K + 36 S (PK36S)	379	26	76	26	399	335
K + S (KS)	416	50	46	32	379	394
P + S (PS)	363	31	66	34	400	432
P + K + S + B (PKSB)	381	31	69	17	380	332
$LSD_{0.05}$	52	ns	22	ns	ns	ns
SEM^z	189*	19^{ns}	$8^{\bullet}$	7^{ns}	43^{ns}	43^{ns}

^{z}•, * and ns refer to significant effects in ANOVA at P≤0.10, P ≤ 0.05 and not significant, respectively.

Figure 1. Boron deficient alfalfa (left) showing reddish brown leaves, stunted growth and delayed flowering compare with Boron sufficient alfalfa (right) at Choiceland, SK (Photo courtesy Lyle Cowell).

Figure 2. Boron deficient canola at pre-bolting (left) showing reddened cupped leaves, at late flowering to early podding (center), showing reddened pods, and pale deformed flowers and at later podding (right) showing aborted and poorly developed pods and dead terminal buds (Photos courtesy Lyle Cowell).

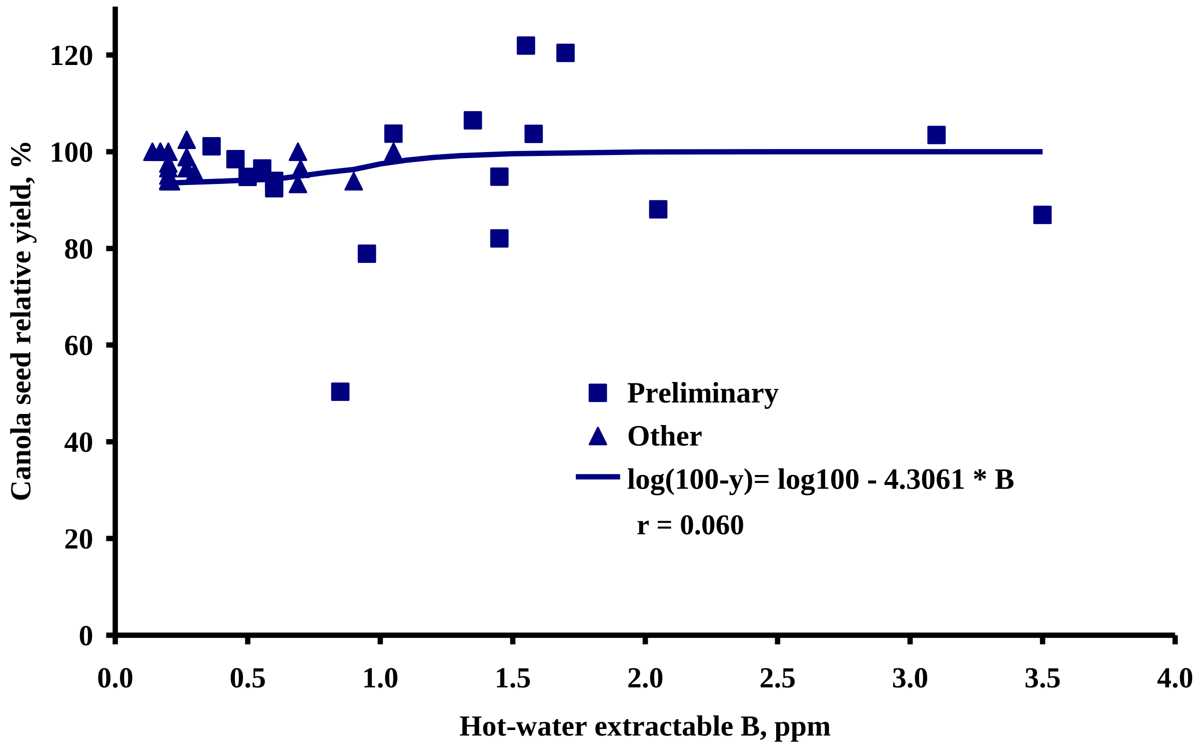

Figure 3. Relative yield of canola (*Brassica napus*) in relation to hot water extractable B levels in the 0-6 inch depth of eighteen sites from the preliminary survey-type research and nineteen research sites carried out across western Canada.