FINAL REPORT

Improving Canola Yields With Balanced and Efficient Nutrition

S.S. Malhi

Agriculture and Agri-Food Canada,
Research Farm, P.O. Box 1240, Melfort, Sask., S0E 1A0

Phone: 306-752-2776 Ext. 230
Fax: 306-752-4911
E-Mail: malhis@em.agr.ca

Prepared for CANOLA COUNCIL OF CANADA
Saskatchewan Canola Development Commission
Manitoba Canola Grower Association

Submitted June 2001

ACKNOWLEDGEMENTS

I would like to thank Canola Council of Canada, Saskatchewan Canola Development Commission and Manitoba Canola Grower Association for financial assistance; EnviroTest Labs Saskatoon for soil and plant analyses; D. Leach, C. Hutcheson, T. Donald, K. Fidyk, K. Hemstad-Falk and N. Evenson for technical help; and Dr. K. S. Gill for help in the preparation of this report.

Project Title: Improving Canola Yields With Balanced and Efficient Nutrition

Experiment 1. Relative effectiveness of S fertilizer applied at different growth stages

I. Abstract:

Canola is the principal cash crop in the Prairie Provinces of Canada and majority of it is grown in the Parkland zone, where many soils are deficient or potentially deficient in plant-available sulphur (S) for canola. Because canola has high requirements for S and S is immobile in plants, its deficiency at any growth stage of the crop can drastically reduce its yield. On soils that are marginally low in plant-available S at seeding but well fertilized with N and P, sulphur deficiencies can manifest themselves during peak vegetative growing periods of canola, or later at flowering and seed formation. Field experiments were conducted from 1998 to 2000 on S-deficient soils in northeastern Saskatchewan, to compare the effects of S fertilization at different growth stages on seed yield and quality of canola. Potassium sulphate was applied at 15 and 30 kg S ha^{-1} rates at pre-seeding, seeding, bolting and flowering stages of canola. Fertilizer S was applied as pre-seeding incorporated into soil, sidebanded and seedrow placed at seeding; and topdressed and foliar applied at bolting and flowering. In all experiments, there was a marked seed yield increase response to N + S fertilization, no response to S alone and negative response to N alone. In one experiment, increases in canola yield from S fertilizer were generally similar for various times and methods of S application. But in other five experiments, topdressing at bolting and flowering increased seed yield less than foliar applied S. Yield increase was lower when S fertilizer was applied at flowering compared to that obtained at bolting or sowing. Topdress applications at flowering gave the lowest increase in seed yield. The application of S fertilizer at seeding gave the greatest increase in seed yield. Application of S fertilizer also increased oil content and total S concentration in canola seed. In summary, the results suggest that S deficiency for canola can be corrected and seed yield restored with application of sulphate-S fertilizer in the growing season, moderately to substantially until bolting stage and moderately as late as early

flowering stage. For correcting S deficiency within growing season, foliar application of S was more effective than topdressing in restoring canola seed yield in S-deficient soils.

II. Introduction:

In the Prairie Provinces, there are about 3.5 million ha of agricultural land under canola production, of which 1.6 million ha is in Saskatchewan. Canola is the major cash crop in the Parkland zone. Canola has high requirements for S (Grant and Bailey 1993). As S is immobile in plants, deficiency of S can occur at any growth stage and can cause considerable reductions in seed yield. In order to prevent any seed yield loss due to S deficiency, a constant supply of available S is thus needed throughout the growing season of canola. On soils marginally deficient in S, the application of higher rates of fertilizer N can result in faster depletion of S from soil, and this increases the instances and severity of S deficiency on canola during peak growing periods.

In recent years, many farmers in the Parkland zone incurred substantial loss in seed yield due to severe S deficiency, particularly at flowering and pod formation. More than 4 million ha of agricultural soils are deficient in S. Substantially greater areas are potentially deficient (Bettany et al. 1982; Doyle and Cowell 1993). Canola (rapeseed) grown on S-deficient Gray Wooded soils have been found to result in poor seed set (Nyborg et al. 1974; Nuttal et al. 1987). The S deficiency on canola can be eliminated by applying S fertilizers (Ukrainetz 1982; Janzen and Bettany 1984). But information is lacking on the relative effectiveness of S fertilization during the crop growing season.

III. Objectives:

To assess the amount of yield loss when S deficiency on canola occurs during the growing season; and to find if S deficiency on canola can be corrected and seed yield and quality of canola on S-deficient soils can be restored to its normal levels by applying sulphate-S fertilizer at different crop growth stages using different times and methods of application.

IV. Materials and Methods:

The field experiments were conducted on Gray Wooded soils (Star City in 1998, Porcupine plain in 1998 and 1999, South Tisdale in 1999 and 2000, and Archerwill in 2000) in northeastern Saskatchewan. Some characteristics of soils at the experimental sites are given in Table 1. At all sites, canola showed severe S-deficiency and the soil was considered to be deficient in available S. At all sites, each treatment was replicated four times in a RCBD. Individual plots were 1.8 m x 7.5 m. Each plot received a blanket application of 50 kg P_2O_5 and 25 kg K_2O ha^{-1}. The S fertilizer was applied at pre-seeding, seeding, bolting and flowering time of canola (for treatment details see Table 2). Data were recorded on seed yield. Seed samples were analyzed for oil content, protein content and total S concentration, by the ENVIROTEST Laboratories in Saskatoon.

V. Results and Discussion:

1998:

At Porcupine Plain, there was a substantial increase in canola seed yield from N + S ~~fertilizer~~ over the N only treatment (Table 2). Increases in canola yields from S fertilization were similar, regardless of times and methods of S application, thus indicating that canola yields can be restored on S-deficient soils with application of sulphate-S fertilizer as late as flowering (10% bloom). At this site, there was a good rainfall after topdress applications, both at bolting and flowering, to move the S fertilizer into subsoil where roots could intercept it. For seeding time, 30 kg S ha^{-1} gave significantly higher seed yield than 15 kg S ha^{-1} rate for incorporation and sidebanded S fertilizer, but there was no yield difference between the two S rates with seedrow application. In reality, lower rate of S tended to give more seed yield than the higher S rate, and application of 15 kg S ha^{-2} in seedrow had seed yield similar to 30 kg S ha^{-1} rate when incorporated or sidebanded. At bolting and flowering stages, 30 kg S ha^{-1} rate tended to give greater seed yield than the 15 kg S ha^{-1} rate but the differences were not significant.

There was a significant seed yield response of canola to S fertilizer at Star City also, but yields response differed with method, time and rate of S application (Table 3). At similar rate, seeding time S application tended to produce higher seed yield than bolting and flowering, except for the 15 kg S ha^{-1} foliar application at bolting. Application of S at bolting gave higher seed yield than at flowering. These observations indicated generally reduced effectiveness with delayed S application. Amongst seeding time treatments, incorporation tended to provide higher seed yield with relatively smaller differences between sidebanding and seedrow placed treatments. Topdressing was less effective in increasing canola yields than foliar applications at both bolting and flowering stages. The 30 kg S ha^{-1} produced more seed yield than the 15 kg S ha^{-1} rate, except for foliar application at flowering, and the differences between S rates were significant for pre-seeding incorporation and topdressing at bolting.

Seed yields of canola at both sites were much lower than normal. This was because of a heavy rain/wind storm near flowering, which caused a substantial damage to canola plants. In addition, there was also some hail damage to the crop at the Porcupine Plain site.

At Porcupine Plain, the oil content of canola seed was generally greater with N + S treatments than the N alone treatment (Table 4). Similarly, total S concentration in canola seed was increased with S fertilization. Total S concentrations in canola seed were generally greater at 30 kg S ha^{-1} than the 15 kg S ha^{-1} rate, and S application time or method had little or no influence on total S concentration. Protein content of canola seed was not affected by S application.

At Star City, application of S tended to increase oil content of canola seed in some cases, and the effect was not influenced by rate, time or method of S application (Table 5). Total S concentration in canola seed was substantially increased by S application and it was generally higher with 30 kg S ha^{-1} than 15 kg S ha^{-1}, but showed no influence of S application time or method. Protein content of canola seed was decreased with N + S application compared to N alone treatment, most likely due to a dilution effect from increased seed yield with N + S treatments. Application of N alone reduced seed yield at Porcupine Plain, but at Star City it tended to increase seed yield.

The first year results indicated that canola yields can be restored on S-deficient soils with application of sulphate-S fertilizer as late as flowering stage, provided there is enough rainfall after topdress application to move the S fertilizer into the subsoil where roots can intercept it. Compared to topdressing, foliar application of S seemed a more powerful technique to restore seed yield in S-deficient canola when S fertilizer is applied late in the growing season, especially when there is inadequate rainfall.

1999:

When both N and S fertilizers were applied, there was a substantial increase in seed yield of canola at both sites compared to N alone application, and the effect of S application varied with application time (Tables 6 and 7). Rate of 30 kg S ha^{-1} produced higher seed yield than 15 kg S ha^{-1}, except foliar application at flowering in Porcupine Plain, although the differences were not always significant. Pre-seeding and seeding time applications of S generally produced greater canola seed yield than its application at bolting or flowering. Between the bolting and flowering time applications, bolting time application generally resulted in greater seed yield. Both at bolting and flowering stages, foliar application of S was more effective than its topdressing, except for some treatments. Application of 120 kg N ha^{-1} alone reduced seed yield. These observations indicated that when N alone was applied, an N:S imbalance in plant may have reduced the seed yield.

Oil content in canola seed usually increased with N + S application compared to N alone treatments at both sites (Tables 8 and 9). At both sites, the N + S treatments significantly increased total S concentration in canola seed and increase was greater for 30 than 15 kg S ha^{-1}, with no effect of S application time or method. The protein content in canola seed tended to be less when N + S fertilizers were applied at seeding compared to N alone treatments. Application of S fertilizer at bolting and flowering tended to give higher protein content than at seeding.

The 1999 results were similar to the 1998 results in many ways. Application of N plus S increased canola seed yield whereas application of either of these alone did not benefit the yield. Similarly, the trend of greater increase in canola seed yield with foliar than topdress application was same for the both sites in 1999 and the Star City site in 1998. Also, greater seed yield increase with pre-seeding and seeding treatments than the bolting and flowering time applications was observed for the both sites in 1999 and the Star City in 1998. But Porcupine Plain site in 1998 showed no consistent effect of the S application time or method on the canola seed yield and it increased almost similarly with all the N + S treatments, apparently due to good rainfall after both topdress applications and low yield due to rain, wind and hail storm damage to canola plants.

2000:

At both sites, there was a marked increase in seed yield of canola with N + S treatments compared to N alone treatment, and the effect of S application varied with application time (Tables 10 and 11). Pre-seeding and seeding time applications of S generally produced greater canola seed yield than its application at bolting or flowering. Between the bolting and flowering time applications, bolting time application tended to give greater seed yield. At Archerwill, foliar application of S was more effective than its topdressing ~~of S~~ at the flowering stage.

Application of S alone to canola at 30 kg S ha^{-1} did not affect seed yield whereas application of 120 kg N ha^{-1} alone reduced seed yield at both sites (Tables 10 and 11). These observations indicated that the soil at both sites could supply sufficient amount of S in the absence of N fertilization and addition of S alone did not improve seed yield. When N alone was applied, an N:S imbalance in plant may have reduced the seed yield.

Oil content in canola seed was increased with N + S application compared to N alone treatments at both sites (Tables 12 and 13), but S application had no effect on protein content. The N + S treatments significantly increased total S concentration of canola seed, and the increase was greater with 30 kg S ha^{-1} than the 15 kg S ha^{-1} rate.

Overall, S application at seeding appeared to be the best strategy to overcome S deficiency and optimize canola seed yield. However, if S deficiency occurs during the canola growing season due to unforeseen circumstances, S application at bolting can recover the canola seed yield substantially and its application at early flowering can recover the seed yield moderately. Foliar application would be better method than topdressing.

VI. References:

Bettany, J.R., Janzen, H.H. and Stewart, J.W.B. 1982. Sulphur deficiency in the prairie provinces of Canada. Pages 787-800. *In* Proc. Int. Sulphur '82 Conf., Vol. 1, November, 1982. London, U.K.

Doyle, P.J. and Cowell, L.E. 1993. Sulphur. Pages 202-250. *In* Impact of Micronutrients on Crop Responses and Environmental Sustainability on the Canadian Prairies. Rennie, D.A. et al. eds.

Grant, C.A. and Bailey, L.D. 1993. Fertility management in canola production. Can. J. Plant Sci. 73: 651-670.

Janzen, H.H. and Bettany, J.R. 1984. Sulphur nutrition of rapeseed. 1. Influence of fertilizer nitrogen and sulphur rates. Soil Sci. Soc. Am. J. 48:100-107.

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 campestris* L.). Can. J. Soil Sci. 67: 545-559.

Nyborg, M., Bentley, C.F. and Hoyt, P.B. 1974. Effect of sulphur deficiency. Sulphur Inst. J. 10:14-15.

Ukrainetz, H. 1982. Oxidation of elemental sulphur fertilizers and response of rapeseed to sulphur on Gray Wooded soils. Pages 278-307. *In* Proc. 19th annual Alberta Soil Sci. Workshop. 23-24 February, 1982. Edmonton, Alberta.

Table 1. Some characteristics of soil (0-15 cm) at the experimental sites

Year	Site	Classification (Great Group)	Texture[a]	pH (1:2 wtaer)	SO_4-S (mg kg^{-1})
1998	Porcupine Plain	Gray Luvisol	CL	8.0	2.2
1998	Star City	Gray Luvisol	CL	7.0	3.6
1999	Porcupine Plain	Gray Luvisol	CL	7.8	8.6
1999	South Tisdale	Gray Luvisol	SL	6.5	10.0
2000	Archerwill	Gray Luvisol	SL	7.5	10.2
2000	South Tisdale	Gray Luvisol	SL	6.7	7.6

[a]CL and SL refer to clay loam and sandy loam, respectively.

Table 2. Relative effectiveness of sulphate-S fertilizer applied at different growth stages on seed yield of canola at Porcupine Plain in 1998

Method of application and growth stage		Sulphate-S rate (kg S/ha) 15	30
	Seed yield (kg/ha)		
No fertilizer	192		
N (120 kg N ha^{-1}) sidebanded at seeding	28		
S (30 kg S ha^{-1}) sidebanded at seeding	1437		
N[a] + S pre-seeding incorporated		1059	1335
N + S sidebanded at seeding		1025	1340
N + S seedrow placed		1300	1188
N + S topdressed at bolting		1084	1162
N + S foliar applied at bolting		1134	1205
N + S topdressed at flowering		1062	1203
N + S foliar applied at flowering		1086	1168
$LSD_{0.05}$	215		

[a]For the N + S treatments, 120 kg N ha^{-1} was applied at seeding.

Table 3. Relative effectiveness of sulphate-S fertilizer applied at different growth stages on seed yield of canola at Star City in 1998

Method of application and growth stage		Sulphate-S rate (kg S/ha) 15	30
	Seed yield (kg/ha)		
No fertilizer	355		
N (120 kg N ha^{-1}) sidebanded at seeding	512		
S (30 kg S ha^{-1}) sidebanded at seeding	1026		
N[a] + S pre-seeding incorporated		1059	1131
N + S sidebanded at seeding		868	1078
N + S seedrow placed		926	1069
N + S topdressed at bolting		744	968
N + S foliar applied at bolting		996	1022
N + S topdressed at flowering		594	716
N + S foliar applied at flowering		867	821
$LSD_{0.05}$	189		

[a]For the N + S treatments, 120 kg N ha^{-1} was applied at seeding.

Table 4. Relative effectiveness of sulphate-S fertilizer applied at different growth stages on oil content, protein content and total S concentration in canola seeds at Porcupine Plain in 1998

Treatment	S rate	Oil	Protein	Total S
	($kg\ ha^{-1}$)	(%)	(%)	($mg\ kg^{-1}$)
No fertilizer	0	34.8	24.7	2125
N (120 $kg\ ha^{-1}$) sidebanded at seeding	0	33.0	26.1	2075
S sidebanded at seeding	30	41.5	24.2	3650
N[a] + S pre-seeding incorporated	15	37.9	25.6	2950
	30	39.2	27.0	3925
N + S sidebanded at seeding	15	37.8	25.5	2750
	30	39.3	26.6	3675
N + S seedrow placed	15	38.6	24.7	2900
	30	39.3	25.8	3700
N + S topdressed at bolting	15	34.6	26.7	3025
	30	40.0	26.4	3600
N + S foliar applied at bolting	15	37.6	26.6	2850
	30	40.6	26.4	3725
N + S topdressed at flowering	15	38.5	25.9	3225
	30	39.0	26.6	3850
N + S foliar applied at flowering	15	38.8	26.1	3325
	30	39.9	26.6	3675
$LSD_{0.05}$		3.1	1.2	216

[a]For the N + S treatments, 120 kg N ha^{-1} was applied at seeding.

Table 5. Relative effectiveness of sulphate-S fertilizer applied at different growth stages on oil content, protein content and total S concentration in canola seeds at Star City in 1998

Treatment	S rate	Oil	Protein	Total S
	(kg ha^{-1})	(%)	(%)	(mg kg^{-1})
No fertilizer	0	35.6	21.7	2200
N (120 kg ha^{-1}) sidebanded at seeding	0	37.9	28.8	2700
S sidebanded at seeding	30	38.6	28.8	4225
N[a] + S pre-seeding incorporated	15	39.1	23.6	3150
	30	37.6	23.9	4100
N + S sidebanded at seeding	15	40.8	23.1	3125
	30	38.7	23.6	4000
N + S seedrow placed	15	37.4	23.0	2825
	30	39.0	23.4	3700
N + S topdressed at bolting	15	38.0	23.8	3550
	30	38.8	24.5	4500
N + S foliar applied at bolting	15	39.4	23.4	3500
	30	38.7	24.1	3800
N + S topdressed at flowering	15	37.9	24.1	3875
	30	37.8	24.5	4475
N + S foliar applied at flowering	15	38.5	24.1	3850
	30	37.8	24.7	4500
$LSD_{0.05}$		2.2	0.8	374

[a]For the N + S treatments, 120 kg N ha^{-1} was applied at seeding.

Table 6. Relative effectiveness of sulphate-S fertilizer applied at different growth stages on seed yield of canola at Porcupine Plain in 1999

Method of application and growth stage		Sulphate-S rate (kg S/ha) 15	30
	Seed yield ($kg\ ha^{-1}$)		
No fertilizer	972		
N (120 kg N ha^{-1}) sidebanded at seeding	10		
S (30 kg S ha^{-1}) sidebanded at seeding	1020		
N[a] + S pre-seeding incorporated		1890	2217
N + S sidebanded at seeding		2198	2291
N + S seedrow placed		2023	2334
N + S topdressed at bolting		1553	1840
N + S foliar applied at bolting		1693	1868
N + S topdressed at flowering		1204	1391
N + S foliar applied at flowering		1415	1333
$LSD_{0.05}$	335		

[a]For the N + S treatments, 120 kg N ha^{-1} was applied at seeding.

Table 7. Relative effectiveness of sulphate-S fertilizer applied at different growth stages on seed yield of canola at South Tisdale in 1999

Method of application and growth stage		Sulphate-S rate (kg S/ha) 15	30
	Seed yield (kg ha^{-1})		
No fertilizer	319		
N (120 kg N ha^{-1}) at seeding	140		
S (kg S ha^{-1}) at seeding	461		
N[a] + S pre-seeding incorporated		1060	1227
N + S sidebanded at seeding		891	1090
N + S seedrow placed		960	1076
N + S topdressed at bolting		665	670
N + S foliar applied at bolting		764	851
N + S topdressed at flowering		377	496
N + S foliar applied at flowering		575	641
$LSD_{0.05}$	210		

[a]For the N + S treatments, 120 kg N ha^{-1} was applied at seeding.

Table 8. Relative effectiveness of sulphate-S fertilizer applied at different growth stages on oil content, protein content and total S concentration in canola seeds at Porcupine Plain in 1999

Treatment	S rate	Oil	Protein	Total S
	(kg ha^{-1})	(%)	(%)	(mg kg^{-1})
No fertilizer	0	45.1	16.9	2075
N (120 kg ha^{-1}) sidebanded at seeding	0	41.2	20.2	2300
S sidebanded at seeding	30	48.4	16.7	2750
N[a] + S pre-seeding incorporated	15	45.8	18.4	2375
	30	47.0	18.3	2875
N + S sidebanded at seeding	15	43.8	18.4	2575
	30	47.0	18.1	2700
N + S seedrow placed	15	44.7	18.4	2275
	30	46.9	18.0	2825
N + S topdressed at bolting	15	44.2	20.6	2925
	30	43.5	20.6	3150
N + S foliar applied at bolting	15	44.5	20.8	2850
	30	44.6	20.8	3300
N + S topdressed at flowering	15	42.5	21.6	2950
	30	42.5	21.4	3275
N + S foliar applied at flowering	15	43.3	21.4	2725
	30	42.7	21.7	3375
$LSD_{0.05}$		2.12	0.81	258

[a]For the N + S treatments, 120 kg N ha^{-1} was applied at seeding.

Table 9. Relative effectiveness of sulphate-S fertilizer applied at different growth stages on oil content, protein content and total S concentration in canola seeds at South Tisdale in 1999

Treatment	S rate	Oil	Protein	Total S
	(kg ha^{-1})	(%)	(%)	(mg kg^{-1})
No fertilizer	0	42.1	19.5	2325
N (120 kg ha^{-1}) sidebanded at seeding	0	37.2	21.5	2075
S sidebanded at seeding	30	42.8	20.2	3075
N[a] + S pre-seeding incorporated	15	40.5	20.5	2750
	30	42.2	20.2	3075
N + S sidebanded at seeding	15	41.1	20.2	2625
	30	40.8	21.0	3025
N + S seedrow placed	15	40.9	20.8	2525
	30	40.8	20.8	3150
N + S topdressed at bolting	15	39.8	23.0	3150
	30	40.9	22.5	3625
N + S foliar applied at bolting	15	38.9	22.2	3100
	30	39.7	22.0	3575
N + S topdressed at flowering	15	40.0	22.8	3225
	30	39.4	23.5	3800
N + S foliar applied at flowering	15	39.2	23.0	3300
	30	39.0	23.5	3875
$LSD_{0.05}$		2.07	0.97	270

[a]For the N + S treatments, 120 kg N ha^{-1} was applied at seeding.

Table 10. Relative effectiveness of sulphate-S fertilizer applied at different growth stages on seed yield of canola at Archerwill in 2000

Method of application and growth stage		Seed yield (kg/ha) with sulphate-S at rates (kg S/ha) 15	30
No fertilizer	438		
N alone at 120 kg N/ha	65		
S alone at 30 kg S/ha	508		
N[a] + S pre-seeding incorporated		647	715
N + S sidebanded at seeding		657	718
N + S seedrow placed		624	634
N + S top dressed at bolting		375	315
N + S foliar applied at bolting		319	409
N + S top dressed at flowering		248	272
N + S foliar applied at flowering		273	314
$LSD_{0.05}$	143		

[a]For the N + S treatments, 120 kg N ha^{-1} was applied at seeding.

Table 11. Relative effectiveness of sulphate-S fertilizer applied at different growth stages on seed yield of canola at South Tisdale in 2000

Method of application and growth stage		Seed yield (kg/ha) with sulphate-S at rates (kg S/ha) 15	30
No fertilizer	158		
N alone at 120 kg N/ha	87		
S alone at 30 kg S/ha	220		
N[a] + S pre-seeding incorporated		732	741
N + S sidebanded at seeding		744	730
N + S seedrow placed		664	626
N + S topdressed at bolting		515	666
N + S foliar applied at bolting		554	658
N + S top dressed at flowering		390	519
N + S foliar applied at flowering		515	603
$LSD_{0.05}$	184		

[a]For the N + S treatments, 120 kg N ha^{-1} was applied at seeding.

Table 12. Relative effectiveness of sulphate-S fertilizer applied at different growth stages on oil content, protein content and total S concentration in canola seeds at South Tisdale in 2000

Treatment	S rate	Oil	Protein	Total S
	(kg ha^{-1})	(%)	(%)	(mg kg^{-1})
No fertilizer	0	41.5	21.0	3504
N (120 kg ha^{-1}) sidebanded at seeding	0	35.4	23.6	2336
S sidebanded at seeding	30	41.1	21.2	4603
N[a] + S pre-seeding incorporated	15	39.5	23.3	3868
	30	39.9	23.2	4734
N + S sidebanded at seeding	15	39.7	23.2	3622
	30	39.8	23.5	4579
N + S seedrow placed	15	39.4	23.8	3710
	30	39.4	23.9	4548
N + S topdressed at bolting	15	39.5	22.8	3655
	30	40.0	23.0	4126
N + S foliar applied at bolting	15	39.4	23.1	3730
	30	39.2	22.8	4028
N + S topdressed at flowering	15	39.5	24.1	3964
	30	39.7	23.8	4493
N + S foliar applied at flowering	15	40.2	23.1	3688
	30	39.7	23.3	4280
$LSD_{0.05}$		1.5	1.0	383

[a]For the N + S treatments, 120 kg N ha^{-1} was applied at seeding.

Table 13. Relative effectiveness of sulphate-S fertilizer applied at different growth stages on oil content, protein content and total S concentration in canola seeds at Archerwill in 2000

Treatment	S rate	Oil	Protein	Total S
	(kg ha^{-1})	(%)	(%)	(μg g^{-1})
No fertilizer	0	44.2	22.1	3075
N (120 kg ha^{-1}) sidebanded at seeding	0	39.0	23.8	2575
S sidebanded at seeding	30	44.9	21.9	3650
N[a] + S pre-seeding incorporated	15	41.2	26.3	3900
	30	42.6	25.9	4225
N + S sidebanded at seeding	15	42.7	26.5	3750
	30	42.3	25.8	4175
N + S seedrow placed	15	41.6	26.2	3800
	30	42.4	25.9	4275
N + S topdressed at bolting	15	41.4	26.9	4000
	30	40.8	27.9	4625
N + S foliar applied at bolting	15	41.2	27.8	4325
	30	40.8	27.3	4625
N + S topdressed at flowering	15	40.0	26.9	3950
	30	40.2	26.9	4375
N + S foliar applied at flowering	15	40.1	27.0	4000
	30	39.7	27.2	4375
$LSD_{0.05}$		1.6	0.9	255

[a]For the N + S treatments, 120 kg N ha^{-1} was applied at seeding.

Experiment 2. Rates, times and methods of B application

1. Abstract:

On sandy soils of northeastern Saskatchewan, canola has been observed to exhibit symptoms similar to boron (B) deficiency. Field experiments were conducted in 1998, 1999 and 2000 on some northeastern Saskatchewan soils expected to be B deficient, to find if canola seed yield and quality can be improved with B fertilization. Boron fertilizer was applied as *pre-seeding* broadcast followed by incorporation, seedrow placement at seeding or as foliar spray at 10-20% bloom stage. Regardless of the site, year, canola cultivar as well as B fertilizer rate, time and method of application, B fertilization had no consistent influence on seed yield, protein content and oil content. The results of these experiments and other field survey trials suggest that B deficiency on canola occurs rarely, if at all and may occur in small patches. Some producers apply B fertilizer to canola without knowing if B application increases crop yield. In order to save money and optimize the use of B fertilizer, following suggestions are made to the canola producers: (a) apply B fertilizers in test strips to find out if there is any increase of seed yield and then consider B fertilization of whole fields on a regular basis, and (b) 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.

2. Introduction:

Canola is one of the main crops in the Canadian Prairies and Parkland zone of Saskatchewan is the major canola producing area. Many farmers in the Parkland zone have been experiencing a reduction in canola yield. Failure to develop flower buds and poor seed set have been observed, more often on sandy soils of the Carrot River region in northeastern Saskatchewan. As these observations match B deficiency symptoms, B deficiency in soils is suspected to be responsible for the yield losses.

Canola is considered a heavy user of B and is severely affected by its deficiency (US Borax 1996). Boron being immobile in plants, its steady supply during the peak vegetative, flowering, seed setting and seed development stages is essential for optimum crop yield (Mortvedt 1994). Foliar fertilization is an effective way to supply B to plants, especially when root activity is restricted by dry soil (Mortvedt 1994). Symptoms of B deficiency on rapeseed plants did not appear until the reproductive stage, when upper parts of plants formed pods but failed to set seed (Wooding 1985). Seed developed only in pods located on lower parts of the plant. Also, B deficiency delayed maturity and kept the plants in an indeterminate stage of growth with flowers forming up to the time of first frost kill. Among rapeseed, barley and potato test crops, rapeseed responded most to B fertilization. Fertilizer rate of 0.55 to 2.22 kg B ha^{-1} increased rapeseed yield by 58 to 77% and no B toxicity symptoms were observed, which indicated that rapeseed may not have the sensitivity that many other crops have to excessive amounts of B.

Fertilization at 0.7 mg B kg^{-1} of a clay soil was considered adequate for *Brassica napus* L. and improved its plant height, siliqua-bearing branch number per plant, siliqua number per plant, seed number per siliqua, seed yield and oil content (Hu et al. 1994). Boron fertilization enhanced rapeseed yield by decreasing number of sterile florets and improving pod development (Nuttall et al. 1987). The yield response was not significantly related to soluble soil B. But it was significantly related to the combination of soluble soil S + B concentration, which increased the seed yield by 0.38 to 0.78 Mg ha^{-1}. Combination of B with N decreased protein level and increased oil content. Canola yield on soils having 0.6 to 0.9 mg B kg^{-1} soil was not affected by B fertilization, although B concentration in plants was significantly increased and 20-30 mg B kg^{-1} in plant tissue was considered adequate for optimum yield (Bullock and Sawyer 1991).

Observations of symptoms on canola plants similar to B deficiency in our area and the literature review indicated that information on the response of current canola cultivars could be very useful to develop appropriate B fertilizer recommendations. Project was therefore undertaken to ascertain if low canola seed yields in the Saskatchewan Parkland area are due to B deficiency in soil, to determine if canola yield and quality can be optimized by B fertilization, and to determine appropriate rate, time and method of B fertilization to optimize canola yield on some soils expected to be B deficient.

III. Objectives:

1. To find if low canola yields in the Saskatchewan Parkland are due to boron (B)

deficiency in soil and detremine if canola yield and quality can be optimized by B fertilization.

2. To determine the best rate, time and method of application of boron fertilizer in optimizing yield and quality of canola on B-deficient soils.

IV. Materials and Methods:

Field experiments were conducted in northeastern Saskatchewan in ~~1997,~~ 1998 and 1999. Mean annual precipitation of the area is about 450 mm and 60% of it is normally received in the growing season (May to August). Soil characteristics at the experimental sites are given in Table 1. Boron fertilizer was applied according to the treatments; i.e. *pre-seeding* broadcasting followed by incorporation, 2 cm wide seedrow band placed, or foliar spray at 10-20% bloom stage. Borate granular (US Borax, 14.3% B) was used for the incorporation and in seedrow treatments whereas Solubor (soluble powder, 20.5% B) was used for foliar application. Details of the treatments at various sites sites are presented in different tables.

1998: Field experiments were conducted at two sites near Carrot River. *Brassica napus* L. (cv. Quantum) was seeded at both sites. A randomized complete block with four replications was used to arrange 7 m by 1.7 m plots. All the plots were cultivated and harrow packed. The N (100 kg N ha^{-1}), P (22 kg P ha^{-1}), K (20 kg K ha^{-1}) and S (20 kg S ha^{-1}) fertilizers were applied at or prior to seeding. Boron fertilizer was applied according to the treatments given in Table 2. For the incorporation treatment, the B fertilizer was broadcast on surface and incorporated into the soil using a rotovator. Canola was seeded with a Fabro drill equipped with knives, at 1.25 cm depth. For seed yield determination, a 1.25 m by 7.0 m strip was harvested with a combine. Representative seed samples were collected for determination of oil content, protein content and total B concentration.

1999: Field experiments were conducted at two sites (Carrot River and South Tisdale). *Brassica napus* L. (cv. Quantum) was seeded at both sites. A randomized complete block with four replications was used to arrange the 7 m by 1.7 m plots. The N (100 kg N ha^{-1}), P (22 kg P ha^{-1}), K (20 kg K ha^{-1}) and S (20 kg S ha^{-1}) fertilizers were applied at or prior to seeding.

Boron fertilizer was applied according to the treatments given in Table 4. The N, P and S fertilizers for all the plots plus B fertilizer for the incorporation treatments were broadcast on the untilled field and it was followed by a rotovation to depth of 5 cm. Canola was seeded with a Fabro drill equipped with knives, at 1.25 cm depth. For seed yield determination, a 1.25 m by 7.0 m strip was harvested with a combine. Representative seed samples were collected for determination of oil content, protein content and total B concentration.

2000: *A* field experiment was conducted at Carrot River. The Materials and Methods were similar to 1999.

V. Results and Discussion:

1998:

There was seed yield increase from N fertilizer at both sites, whereas there was no response to S fertilization (Table 2). There was no additional increase in seed yield from B fertilization compared to the NPKS treatment, regardless of the rate, time or method of B application. Extractable B in soil was 0.30 mg kg^{-1} at Carrot River I and 0.14 mg kg^{-1} at Carrot River II. Response to B fertilization was expected at Carrot River II site due to low extractable B in soil. Very low canola yields from all treatments due to very dry soil moisture conditions in spring and early summer, were considered responsible for the lack of any response to B fertilizer.

Protein content in seed increased and oil content tended to decline whenever N was a part of fertilizer treatment (Table 3). Application of B had no effect on protein and oil content in seed, but increased B concentration in seed.

1999:

Nitrogen fertilizer alone increased seed yield at Carrot River II but had no effect on seed yield at South Tisdale (Table 4). There was no response of canola seed yield to S fertilization alone at both sites. Application of NPKS fertilizers significantly increased seed yield at both sites. At Carrot River II, incorporation of 2 kg B ha^{-1} and foliar application of 0.25 kg ha^{-1} increased seed yield of canola compared to NPKS treatment but the increases were not statistically significant. In other B treatments, there was no significant effect of B fertilization on seed yield compared to the NPKS treatment at either of the sites, regardless of the rate, time or method of B application.

Incorporation of 2 kg B ha^{-1} tended to increase B concentration in seed (Table 5). The B treatments had no consistent effect on protein or oil content in seed. Application of N alone tended to increase protein content and reduce oil content in seed. Sulphur application had no consistent effect on any of the seed quality parameters.

2000:

The N fertilizer alone treatment increased seed yield (224 kg/ha) as compared to unfertilized control with 87 kg/ha (Table 6). There was no response to S fertilization alone. The application of S along with N fertilizer increased seed yield greatly compared to N only treatment. Regardless of the rate, time or method of B application, there was no effect of the B fertilization on seed yield compared to the NS treatment. Incorporation of 2 kg B ha^{-1} tended to increase B concentration in seed. The B treatments had no consistent effect on protein or oil content in seed.

VI. Summary and Conclusions:

Plant-available B in soil ranged between 0.11 to 0.54 mg B kg^{-1}. Boron deficiency on canola was expected in most of these fields, and B application was expected to increase seed yield and improve seed quality in some of these soils, but it did not happen. Some producers apply B to canola without knowing if B application increases crop yield. This may be costing the producers between \$5 to \$10 per acre, depending on the rate of application and source of B fertilizer. The results of our experiments and field survey trials suggest that B deficiency on canola occurs rarely, if at all and may occur in small patches on sandy soils of the Carrot River area. Application of B did not increase canola yield in any of the study years consistently.

Even after conducting soil and plant tissue analyses, it still can be difficult to predict if a profitable yield response will occur. Therefore, if B is suspected to be deficient in soil it should be applied to selected portions of the B deficiency suspected areas of the field in marked test strips. Visual observations and yields from the treated and untreated areas should be compared to determine if measurable yield response had occurred. In order to save money and optimize the use of B fertilizer, canola producers can use the following suggestions:

1. Apply B fertilizers in test strips to find out if there is any increase in seed yield and only then consider B fertilization of whole fields on a regular basis.
2. 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.

VII. References:

Bullock, D.G. and Sawyer, J.E. 1991. Nitrogen, potassium and boron fertilization of canola. J. Prod Agric. 4(44): 550-555.

Hu, Y.S., Ma, Y.H., Sun, Y.L., and Guo, G. 1994. Effect of B application on the agronomic traits, yield and oil content of a double-row rape (*Brassica napus* L.) cultivar. Oil Crops in China. 16(3): 43-46.

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

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.

US Borax Inc. 1996. The boron bonus canola. US Borax Inc.

Wooding, F.J. 1985. Interior Alaska crops respond to boron applications. Agroborealis. 17(1): 47-49.

Table 1. Some characteristics of soil (0-15 cm) at the experimental sites

Year	Site	Classification (Great Group)	Texture[a]	pH (1:2 water)	B ($mg\ kg^{-1}$)
1998	Carrot River I	Gray Luvisol	SL	7.1	0.32
1998	Carrot River II	Gray Luvisol	LS	7.8	0.11
1999	South Tisdale	Gray Luvisol	SL	6.7	0.54
1999	Carrot River II	Gray Luvisol	LS	6.0	0.15
2000	Carrot River II	Gray Luvisol	LS	5.7	0.40

[a]LS, SL and L refer to loamy sand, sandy loam and loam, respectively.

Table 2. Seed yield of canola at two sites near Carrot River in 1998

Fertilizer treatment	Seed yield (kg ha^{-1})	
	Carrot River I	Carrot River II
No Fertilizer	1070	327
N,P,K	1629	488
P,K,S	1032	391
N,P,K,S	1676	552
N,P,K,S + Incorporated B		
1.00 kg B ha^{-1}	1796	446
2.00 kg B ha^{-1}	1609	442
N, P, K,S + Seedrow B		
0.50 kg B ha^{-1}	1749	481
1.00 kg B ha^{-1}	1634	447
N,P,K,S + Foliar B		
0.25 kg B ha^{-1}	1665	509
0.50 kg B ha^{-1}	1561	482
$LSD_{0.05}$	246	144

Table 3. Thousand kernel weight (TKW), bushel weight (BW), protein content, total B and oil content of canola seed at two sites in 1998

Treatment	Protein (%)	Total B (mg kg^{-1})	Oil (%)
Carrot River I			
No Fertilizer	19.5	7.4	42.8
N,P,K	22.1	7.4	41.4
P,K,S	19.9	7.3	41.9
N,P,K,S	22.0	7.1	40.5
N,P,K,S + Incorporated B			
1.00 kg B ha^{-1}	21.8	8.2	41.2
2.00 kg B ha^{-1}	21.9	8.6	42.4
N,P,K,S + Seedrow B			
0.50 kg B ha^{-1}	22.6	8.1	41.1
1.00 kg B ha^{-1}	22.5	8.3	40.2
N,P,K,S + Foliar B			
0.25 kg B ha^{-1}	22.5	7.9	41.4
0.50 kg B ha^{-1}	22.4	7.4	41.4
LSD	0.9	0.8	ns
Carrot River II			
No Fertilizer	23.9	9.4	41.9
N,P,K	26.6	9.1	37.5
P,K,S	23.0	9.2	41.4
N,P,K,S	25.8	8.9	39.2
N,P,K,S + Incorporated B			
1 kg B ha^{-1}	27.5	10.2	38.0
2kg B ha^{-1}	27.5	11.5	39.6
N,P,K,S + Seedrow B			
0.5 kg B ha^{-1}	27.8	9.9	36.1
1.0 kg B ha^{-1}	28.1	9.6	37.2
N,P,K,S + Foliar B			
0.25 kg B ha^{-1}	27.4	9.4	40.1
0.50 kg B ha^{-1}	28.1	9.4	37.4
LSD	1.64	0.8	2.3

[a] ns refers to not significant.

Table 4. Seed yield of canola at two sites in northeastern Saskatchewan in 1999

Fertilizer treatment	Seed yield ($kg\ ha^{-1}$) South Tisdale	Carrot River II
No Fertilizer	140	366
N,P,K	47	906
P,K,S	248	411
N,P,K,S	1111	1006
N,P,K,S + Incorporated B		
1.00 kg B ha^{-1}	998	1092
2.00 kg B ha^{-1}	1092	1355
N,P,K,S + Seedrow B		
0.50 kg B ha^{-1}	1056	1117
1.00 kg B ha^{-1}	1101	1165
N,P,K,S + Foliar B		
0.25 kg B ha^{-1}	995	1351
0.50 kg B ha^{-1}	1061	1176
$LSD_{0.05}$	205	366

Table 5. Protein content, total B and oil content of canola seed at two sites in 1999

Fertilizer treatment	Protein (%)	Total B ($mg\ kg^{-1}$)	Oil (%)
South Tisdale			
No Fertilizer	18.8	10.1	41.9
N,P,K	20.1	11.2	39.2
P,K,S	18.9	10.2	44.2
N,P,K,S	19.2	11.2	42.4
N,P,K,S + Incorporated B			
1.00 kg B ha^{-1}	19.5	11.0	42.4
2.00 kg B ha^{-1}	19.5	12.0	42.3
N,P,K,S + Seedrow B			
0.50 kg B ha^{-1}	19.2	11.0	44.2
1.00 kg B ha^{-1}	19.2	11.2	43.4
N,P,K,S + Foliar B			
0.25 kg B ha^{-1}	18.0	11.0	43.0
0.50 kg B ha^{-1}	19.1	11.0	43.4
$LSD_{0.05}$	ns	0.9	2.1
Carrot River II			
No Fertilizer	19.5	9.2	43.4
N,P,K	20.9	9.6	42.3
P,K,S	19.2	9.6	43.6
N,P,K,S	22.2	9.4	42.0
N,P,K,S + Incorporated B			
1 kg B ha^{-1}	22.2	9.9	41.6
2kg B ha^{-1}	22.5	10.9	41.5
N,P,K,S + Seedrow B			
0.5 kg B ha^{-1}	21.4	9.4	43.0
1.0 kg B ha^{-1}	22.4	10.4	42.0
N,P,K,S + Foliar B			
0.25 kg B ha^{-1}	21.9	9.6	42.4
0.50 kg B ha^{-1}	22.0	9.9	41.4
$LSD_{0.05}$	1.4	ns	ns

[a] ns refers to not significant.

Table 6. Seed yield of canola and protein content, oil content and total B in canola seed with various B fertilizer treatments at Carrot River II in northeastern Saskatchewan in 2000

Fertilizer treatment	Seed yield (kg ha^{-1})	Protein (%)	Oil (%)	Total B (mg kg^{-1})
Control	87	25.6	40.0	9.5
N,P,K	224	25.5	40.2	9.5
P,K,S	83	26.0	39.4	9.2
N,P,K,S	617	26.8	39.4	9.8
N,P,K,S+ incorporated B				
1.00 kg B ha^{-1}	573	26.8	39.1	10.0
2.00 kg B ha^{-1}	517	26.9	39.8	11.2
N,P,K,S+ seedrow B				
0.50 kg B ha^{-1}	542	26.5	39.0	9.8
1.00 kg B ha^{-1}	601	27.2	39.3	10.0
N,P,K,S+ foliar B				
0.25 kg B ha^{-1}	579	26.8	38.8	9.8
0.50 kg B ha^{-1}	604	26.9	38.9	9.8
$LSD_{0.05}$	146	0.7	1.6	0.8