Optimizing Yield and Quality of Canola Seed with Balanced Fertilization in the Parkland Zone of Western Canada

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Abstract

A number of field experiments were conducted from 1998 to 2001 (or are underway) in northeastern Saskatchewan to determine the effects of various rates (0 to 30 kg S/ha), sources (sulphate S – potassium sulphate and ammonium sulphate; and elemental S – ES 90 and ES 95), times (autumn, sowing, bolting and flowering) and methods (incorporation, sideband, seedrow, topdress and foliar) of S application, ratios of fertilizer N:S (0 to 150 kg N/ha and 0 to 30 kg S/ha) and cultivars (Quantum – *Brassica napus*, AC Excel – *Brassica napus*, Maverick – *Brassica rapa* and AC Parkland – *Brassica rapa*) on seed yield and quality of canola. The S deficiency on canola can be corrected and seed yields restored with application of sulphate-S fertilizer in the growing season, substantially until bolting growth stage and moderately at early flowering stage. There was no significant increase in seed yield from the elemental S fertilizers in the initial year of application. Even after three annual applications, the elemental S fertilizers had seed yields lower than the sulphate-S fertilizers in many cases particularly when the S fertilizers were applied in spring. Autumn-applied elemental S usually had greater seed yield than the spring-applied elemental S. Autumn-applied ammonium sulphate produced lower seed yield than spring-applied ammonium sulphate in some cases. For higher N application rates, there was a need of increased amount of fertilizer S to adequately meet the S requirements of canola. The severity of S deficiency, increase in seed yield of canola from applied S and seed quality varied with canola cultivars. In general, Quantum had the highest seed yield, followed by AC Excel, Maverick and AC Parkland. Application of S fertilizer also increased oil content in canola seed. In conclusion, seed yield and quality of canola can be optimized with proper S fertilizer management.

Introduction

Canola is one of the major cash crops in the Prairie Provinces of Canada and most of it is grown in the Parkland region where many soils are deficient or potentially deficient in sulphur (S). The S deficiency in the Parklands and forest edge of the Canadian prairies occurs most often in Gray and Dark Gray soils, and less frequently in some coarse-textured Black soils. There are more than 4 million ha of agricultural soils deficient in S and substantially greater areas are potentially deficient (Bettany et al. 1982; Doyle and Cowell 1993). Canola (rapeseed) grown on S-deficient Gray Luvisolic soils has been found to poor seed set (Nyborg et al. 1974; Nuttal et al. 1987).

Canola requires high amounts of S (Grant and Bailey 1993). Unlike nitrogen (N), S does not move from older to actively-growing plant parts. If the supply of available S in soil is exhausted prior to pod or seed formation, the resulting yield loss can be devastating. Therefore, canola plants need a constant supply of available S throughout the growing season in order to prevent any seed yield loss due to S deficiency.

High yielding cultivars of canola are becoming more popular as their potential for great increases in seed yield is realized. In addition, as producers continue to push up the yields by applying higher rates of N and phosphorus (P) fertilizers, soils are being depleted of S and there are more instances of S deficiency on canola in the growing season, even on medium- to fine-textured Black soils. On soils that are marginally low in plant-available S at sowing but well fertilized with N and P, the S deficiencies can manifest themselves during peak vegetative growing periods of canola, or later at flowering and seed formation. The S deficiencies at any growth stage can drastically reduce canola seed yield; devastating the producer. The S deficiency on canola can be prevented by applying sulphate-S fertilizers at sowing time (Ukrainetz 1982; Janzen and Bettany 1984). In recent years, many farmers in the Parkland zone have experienced substantial loss in seed yield due to severe S deficiency, particularly at flowering and pod formation, but information is lacking on the effectiveness of S fertilization in the growing season

Traditionally, S applied in fertilizers was in sulphate form, which is readily available to plants. Now, there are a wide variety of commercial fertilizers that contain S in an elemental form. Elemental S is not plant-available and it must be converted to sulphate by soil microorganisms. Elemental S fertilizers may cost less per unit of S than the sulphate-S fertilizers, but their effectiveness depends on how quickly the S is oxidized to sulphate-S for plant uptake. There are few studies on the relative effectiveness of elemental versus sulphate-S fertilizers in increasing canola yield response to applied S on S-deficient soils (Ukrainetz 1982; Solberg 1986). Information on the comparisons of repeated annual applications of sulphate-S and elemental S fertilizers in a crop rotation that includes canola is lacking.

Sulfur enhances the utilization of N, and high oilseed and protein crops require more S. On marginally S-deficient soils in the Parkland zone, application of high rates of N and other fertilizers results in faster depletion of S in soil and increases instances of S deficiencies in canola during the growing season. This can cause substantial reduction in seed yield, apparently due to N:S imbalance in canola. Canola has high requirements for S which may vary with cultivars depending on the differences in growth rate, yield potential, rooting system and genetics.

Materials and Methods

A number of field experiments were conducted (or are underway) in northeastern Saskatchewan to determine the effects of various rates (0 to 30 kg S/ha), sources (sulphate S – potassium sulphate and ammonium sulphate; and elemental S – ES 90 and ES 95), times (autumn, sowing, bolting and flowering) and methods (incorporation, sideband, seedrow, topdress and foliar) of S application, ratios of fertilizer N to S (0 to 150 kg N/ha and 0 to 30 kg S/ha) and cultivars on seed yield and quality of canola.

Correcting S Deficiency in Canola in the Growing Season:

A 3-year study was conducted from 1998 to 2000 on S-deficient soils to determine the extent to which canola yields can be restored when S deficiency appears in the growing season. The study focused on the effects of different rates and application methods of sulphate-S fertilizer (potassium sulphate) at various growth stages (sowing, bolting and flowering) of canola grown on S-deficient soils at six locations in northeastern Saskatchewan. The rates of S were 15 and 30 kg S/ha. Methods of S application were incorporated into soil prior to sowing, sidebanded and seedrow placed at sowing, and topdressed granular or foliar spray of liquid S fertilizer at bolting and flowering.

Effectiveness of Elemental S vs Sulphate-S Fertilizers on Canola:

Two 4-year (1999 to 2002) field experiments using commercial elemental S and sulphate-S fertilizers were established in 1999 on S-deficient soils. Autumn applications were surface-broadcast in late September or early October and incorporated into soil at sowing. Spring applications were surface-broadcast and incorporated into soil at sowing. All plots received blanket application of 120 kg N/ha.

Maximize Canola Seed Yield with Proper N:S Fertility:

Field experiments were conducted in 1999 and 2001 on soils deficient in both S and N to determine proper fertilizer N:S ratio using combinations of four rates of N (0, 50 100 and 150 kg N/ha) and S (0, 10, 20 and 30 kg S/ha) for optimum seed yield and quality of canola.

Sensitivity of Canola Cultivars to S Deficiency and Seed Yield Response to Applied S:

Field experiments were conducted in 1999 and 2001 on S-deficient soils to determine differences in response of selected canola cultivars (Quantum – *Brassica napus*, AC Excel – *Brassica napus*, Maverick – *Brassica rapa* and AC Parkland – *Brassica rapa*) to S deficiency and to applied S in relation to seed yield and quality. All plots received blanket application of 120 kg N/ha.

Results and Discussion

Correcting S Deficiency in Canola in the Growing Season:

In all of the six field experiments on soils deficient in both S and N, there was a marked seed yield increase from N and S fertilization. On the other hand, there was a reduction in seed yield in the N alone treatment compared to no fertilizer treatment. On average of six sites, there was a good seed yield response of canola to potassium sulphate at the bolting stage (Table 1), when used as a rescue treatment if S deficiency symptoms show up. There was also correction of S deficiency in canola and moderate restoration of yield with potassium sulphate application at early flowering.

Yield increase was lower when S fertilizer was applied at flowering compared to that obtained at bolting or sowing. Applications of S fertilizer at sowing gave the greatest increase in seed yield.

Foliar application of S was slightly more effective than topdressing in restoring seed yield in S-deficient canola. The findings also suggest that the efficacy of topdressed S fertilizer is dependent on the amount of rainfall after topdress application to move the S fertilizer into the subsoil where roots can intercept it. Application of S fertilizer also increased oil content in seed.

Table 1. Relative effectiveness of sulphate-S fertilizer applied at different growth stages on increase in seed yield of canola (average of six experiments)

	Seed yield increase (kg/ha) from applied sulphate-S at rates (kg S/ha)	
Fertilizer treatment	15	30
N[a] + pre-seed incorporated S	935	1088
N + sidebanded S at sowing	924	1068
N + seedrow placed S	943	915
N + topdressed S at bolting	683	797
N + foliar applied S at bolting	770	862
N + topdressed S at flowering	506	626
N + foliar applied S at flowering	649	673

[a]N refers to 120 kg N/ha applied at sowing.

Effectiveness of Elemental S vs Sulphate-S Fertilizers on Canola:

In 1999, there was little or no increase in seed yield from elemental S fertilizers in the first year when applied in spring at sowing (Tables 2 and 3). Application of elemental S fertilizers in the previous autumn increased seed yield moderately at one site which was greater than its application in spring, but the yield increase was much less than ammonium sulphate. Autumn-applied ammonium sulphate was less effective in increasing seed yield at one site than spring-applied ammonium sulphate. This indicates over-winter loss of sulphate-S from the root zone soil.

In 2000 (after two annual applications), elemental S fertilizers corrected S-deficiency in canola, but seed yields from the elemental S fertilizers were lower than ammonium sulphate in most cases (Tables 4 and 5). Autumn-applied elemental S was more effective in increasing seed yield of canola than spring-applied elemental S. Autumn-applied ammonium sulphate tended to produce less seed yield than spring-applied ammonium sulphate at one site.

In 2001 (after three annual applications), seed yields with elemental S fertilizers were significantly greater than the zero-S check treatment (Tables 6 and 7). But, yield increases from the elemental S fertilizers (especially when applied in spring) were still less than ammonium sulphate in many cases. Autumn-applied elemental S usually had greater increase in seed yield than spring-applied elemental S. Autumn-applied ammonium sulphate tended to be inferior to spring-applied ammonium sulphate at one site.

Table 2. Seed yield increase from various S fertilizers applied at two rates to canola near Tisdale in northeastern Saskatchewan in 1999

Source of S	Rate of S (kg S/ha)	Seed yield increase (kg/ha) from applied S: Autumn-applied	Spring-applied
ES 90	10	0	0
	20	22	0
ES 95	10	22	0
	20	80	0
Agrium Plus	10	64	54
	20	241	473
Ammonium sulphate	10	83	346
	20	272	828

Table 3. Seed yield increase from various S fertilizers applied at 15 kg S/ha to canola at Porcupine Plain in northeastern Saskatchewan in 1999

Source of S	Seed yield increase (kg/ha) from applied S: Autumn-applied	Spring-applied
ES 90	602	6
ES 95	843	11
Agrium Plus	1643	1367
Ammonium sulphate	1907	2087

Table 4. Seed yield increase from various S fertilizers applied at two rates to canola near Tisdale in northeastern Saskatchewan in 2000

Source of S	Rate of S (kg S/ha)	Seed yield increase (kg/ha) from applied S: Autumn-applied	Spring-applied
ES 90	10	284	31
	20	572	94
ES 95	10	233	44
	20	612	156
Agrium Plus	10	542	615
	20	885	760
Ammonium sulphate	10	667	747
	20	728	919

Table 5. Seed yield increase from various S fertilizers applied at 15 kg S/ha to canola at Porcupine Plain in northeastern Saskatchewan in 2000

Source of S	Seed yield increase (kg/ha) from applied S	
	Autumn-applied	Spring-applied
ES 90	1432	704
ES 95	892	655
Agrium Plus	1508	1612
Ammonium sulphate	1645	1703

Table 6. Seed yield increase from various S fertilizers applied at two rates to canola near Tisdale in northeastern Saskatchewan in 2001

Source of S	Rate of S (kg S/ha)	Seed yield increase (kg/ha) from applied S	
		Autumn-applied	Spring-applied
ES 90	10	65	105
	20	349	195
ES 95	10	159	56
	20	275	109
Agrium Plus	10	292	344
	20	405	419
Ammonium sulphate	10	394	346
	20	368	399

Table 7. Seed yield increase from various S fertilizers applied at 15 kg S/ha to canola at Porcupine Plain in northeastern Saskatchewan in 2001

Source of S	Seed yield increase (kg/ha) from applied S	
	Autumn-applied	Spring-applied
ES 90	498	204
ES 95	204	85
Agrium Plus	677	561
Ammonium sulphate	675	803

-ES 90 and ES 95 are elemental S fertilizers and Agrium Plus contains both elemental S and sulphate-S.

Maximize Canola Seed Yield with Proper N:S Fertility:

In the zero-S treatments, canola exhibited S deficiency in the growing season and S deficiency became more severe and reduced seed yield when N was applied without S (Table 8). In the S treatments, seed yields of canola increased with increasing N rate but maximum yields were attained when rate of S was also increased to 20 or 30 kg S/ha. The results suggest that the use of S fertilizer was critical to achieve any response to N fertilization. It is estimated that in canola the N:S ratio should be in the range of 5-7 N to 1 S. The ratio should take the amount of N and S in the soil into consideration, in addition to the amount of N and S applied in fertilizers.

Table 8. Seed yield of canola with different rates of N and S in northeastern Saskatchewan (average of four experiments)

Rate of N (Kg ha^{-1})	Seed yield (kg ha^{-1}) at four S rates (kg ha^{-1})			
	0	10	20	30
0	464	612	657	652
50	256	886	969	1025
100	107	904	1202	1286
150	47	741	1289	1313

Sensitivity of Canola Cultivars to S Deficiency and Seed Yield Response to Applied S:

The severity of S deficiency in the zero-S treatment, and seed yields without and with applied S varied with canola cultivars (Table 9). In the zero-S treatment, mean seed yield was highest with AC Excel and lowest with AC Parkland. In the S-fertilized plots, Quantum produced the highest seed yield, which was closely followed by AC Excel, then Maverick and with the least yield from AC Parkland. These data suggest the possibility of adjusting the S fertilization rate according to the cultivar being grown, but further research would be needed to fine tune the recommendations for each cultivar.

Table 9. Seed yield of four canola cultivars with different rates of applied S in northeastern Saskatchewan (average of three experiments)

Cultivar	Rate of S (kg S ha^{-1})			
	0	5	10	15
Quantum	329	937	1197	1167
AC Excel	479	722	952	1016
Maverick	332	474	653	711
AC Parkland	169	342	523	570

Conclusions

1. ***Correcting S Deficiency in Canola in the Growing Season:*** The S deficiency in canola can be corrected and seed yield restored with application of potassium sulphate fertilizer in the growing season, substantially until bolting stage and moderately until early flowering stage. The ideal time for S fertilization is at sowing, but growers should consider applying sulphate-S fertilizer if S deficiencies appear in canola in the growing season.

2. ***Effectiveness of Elemental S vs Sulphate-S Fertilizers on Canola: The*** elemental S fertilizers were not very effective compared to ammonium sulphate when it came to correcting sulphur deficiencies and increasing canola seed yields in the first year of application. Seed

yields with elemental S fertilizers were less than ammonium sulphate after two annual applications. Even after three annual applications, the elemental S fertilizers had lower seed yields than ammonium sulphate in many cases, especially when they were applied in spring. Autumn-applied elemental S was generally more effective in increasing seed yield of canola than spring-applied elemental S. Autumn-applied ammonium sulphate produced lower seed yield than spring-applied ammonium sulphate in some cases. These experiments will be continued for another year to find if seed yields from the elemental S fertilizers would be equal to sulphate-S fertilizers.

3. ***Maximize Canola Seed Yield with Proper N:S Fertility**:* For higher N application rates, there is a need of increased fertilizer S to adequately meet the S requirements of canola for optimum seed yield. Canola growers who find their high-yielding cultivars are not responding to high rates of N should look deeper into their fertility program and consider balancing N:S applications.

4. ***Sensitivity of Canola Cultivars to S Deficiency and Seed Yield Response to Applied S**:* The severity of S deficiency and increase in seed yield of canola from applied S may vary with canola type and/or cultivar.

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