# Sulphur Fertilization: What has Changed?

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## Introduction

Sulphur (S) is an essential plant nutrient. It is required by plants in amounts similar to phosphorus (P), thus it is grouped with nitrogen (N), potassium (K) and P as the fourth major plant nutrient. Sulphur is an important component of several essential amino acids and so is important for both protein quality and quantity. It is also involved in nitrogen metabolism, photosynthesis, synthesis of oils in oilseed crops such as canola, and in synthesis and function of enzymes, vitamins and other organic compounds. Sulphur deficiencies can have a major impact on crop yield.

Sulfur deficiency symptoms include reduced plant growth and chlorosis of the younger leaves, beginning with interveinal yellowing that gradually spreads over the entire leaf area (Figure 1). Sulphur is somewhat immobile in the plant, so that deficiency symptoms tend to occur first in younger leaves. Plants may be small and spindly with short, slender stalks. As the deficiency becomes more severe, leaf cupping and a more erect leaf structure is often observed, especially in canola (*Brassica napus* L. and *B. rapa* L.) (Franzen and Grant, 2008). Plants grow slowly and maturity may be delayed. Plants may flower but have reduced seed set as is the case for rapeseed (canola), lentils and alfalfa. Photos of S deficiency symptoms are available from many sources, including printed works (e.g., Bennett, 1993) and online sources (e.g., http://www.back-to-basics.net/nds/index.htm). Under mild to moderate S deficiency visual symptoms may not always be a reliable indicator.

Figure 1. Sulphur deficiency in canola.

There are a number of factors that have changed over the years that affect sulphur nutrition. Sulphur deficiencies are becoming more prevalent due to decreasing aerial deposition of S in air pollution as a result of clean air legislation, an increase in the use of high-analysis fertilizers that contain little S, decreased use of S-containing pesticides, greater S removals with everincreasing crop yields, and continued losses through erosion of topsoil and nutrient leaching. Consequently, S has emerged as a major limiting factor in many cropping systems where deficiencies had not been a problem before.

On the prairies, several other important production trends are influencing the risk of S deficiencies. Widespread adoption of reduced tillage may slow organic matter breakdown, leading to less release of S by mineralization. Also, under reduced tillage, rotations are often extended and more oilseed crops included because of the extra available moisture. Continuous cropping and inclusion of high S-extracting crops such as canola in a rotation will increase S depletion and the occurrence of S deficiencies. Increased removal of S from higher yields can also enhance S deficiencies. The increasing frequency of production of canola in prairie rotations and the use of high yielding hybrid canola therefore has led to greater S removal and greater risk of S deficiencies. Sulphur deficiencies also tend to be more common under wet conditions, as sulphate-S may leach below the rooting zone under very wet conditions.

## Crop Requirements

The effect of increasing canola production on the incidence of S deficiency relates directly to the high S content of canola relative to other commonly grown annual crops. The S content of plants differs greatly among crop species, among cultivars within a species, and with developmental stage. In general, the oilseed crops, such as oilseed rape (*Brassica napus* L.), canola, and sunflower (*Helianthus annuus* L.), and legumes, such as alfalfa (*Medicago sativa* L.) and soybean (*Glycine max* L. Merr.), have a much higher requirement for S per unit of production than the small grains and maize. Wheat, barley and flax have low concentrations of S varying from 0.15% to 0.20% at shot blade and flowering, and have high N:S ratios of 15 to 16 at optimum yield. In comparison to the cereal crops, canola at flowering and alfalfa at full bud generally have much higher concentration of S (0.25% to 0.30% S) and lower N:S ratios (12 for canola and 14 for alfalfa) for optimum yield. Among crops grown for seed on the prairies, canola has the highest S requirement and removes the largest quality of S at harvest. Therefore, increasing the frequency of canola production in the rotation will increase S depletion and the risk of S deficiency, unless the native S content of the soil is high or the S removed is replenished by fertilizer application. Forage crops can remove even higher amounts of S from the soil than canola since most of the aboveground biomass is harvested, so the risk of S deficiency is also increased by frequent production of forages.

Table 1: Sulphur removal by various crops

| | **Wheat** | **Canola** | **Peas** | **Alfalfa** | **Corn** | **Soybeans** |
|---|---|---|---|---|---|---|
| **Yield (bu/ac)** | **50** | **50** | **50** | **5 t/ac** | **100** | **35** |
| **Sulphur removal (lb/ac)** | **5** | **16** | **7** | **34** | **7** | **4** |

## Sulphur Demand of Hybrid as Compared to Open-Pollinated Canola

Most of the canola currently produced on the prairies are hybrid cultivars that have a higher yield potential than older open pollinated cultivars (Carew and Devadoss, 2003; Carew and Smith, 2006). In recent studies conducted across western Canada, hybrid cultivars produced higher yields at a given S level than did open pollinated cultivars (Karamanos et al., 2005; Brandt et al., 2007). However, the optimum yield of hybrid cultivars could be attained with S levels similar to those required for optimum yield of open pollinated cultivars in spite of the yield differential, indicating that the hybrid cultivars may be better able than the open pollinated cultivars to extract S from the soil (Karamanos et al., 2005; Malhi and Gill, 2006; Karamanos et al., 2007). Riekman (2005) compared S uptake and accumulation by hybrid and open-pollinated canola cultivars and monitored soil moisture content throughout the 2003 growing season at a site in Rosebank, Manitoba. At maturity, S tissue concentration was lower in hybrid than open-pollinated canola. Hybrid canola (45H21) removed 58 mm more water than an open-pollinated cultivar (Conquest) from the 10 to 110 cm depth. Overall, the hybrids appeared to be more efficient than open-pollinated lines at extracting water and nutrients from the soil and converting them to biomass and seed yield (Reikman, 2005).

## Developments in Sulphur Fertilization

The principles of sulphur fertilization have not changed in recent years. Plants absorb S in the sulphate ($SO_4^=$) form, therefore soluble inorganic sulphate-based fertilizers such as ammonium sulphate are quickly available to and absorbed by plants. Similarly, although thiosulphate cannot be directly utilized by the plant, it converts to sulphate within one to two weeks on warm soils and so is quickly available for crop uptake (Figure 2).

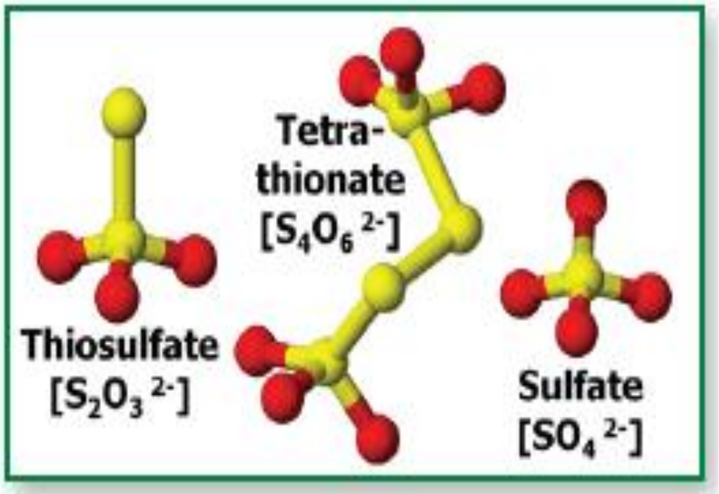

Figure 2. Thiosulphate fertilizer converts rapidly to plant-available sulphate (www.ipni.net)

In contrast, the S in fertilizers such as S-bentonite and elemental S must be oxidized to sulphate before it can be used by plants. The oxidation process is mainly microbiological, with microorganisms in the soil converting the S to sulphate forms in the presence of oxygen. Placement of elemental S should maximize the contact between the fertilizer and soil microorganisms in order to encourage oxidation. The elemental S sources should be applied as far in advance of seeding as possible and should be thoroughly mixed with the soil. Use of finely divided fertilizer particles will maximize soil-fertilizer contact, increasing the rate of oxidation. Since banding reduces contact between soil and fertilizer, it is not a desirable method of application for elemental S. Cultivation increases contact between the soil and fertilizer and enhances oxidation of elemental S. Oxidation rate is reduced as soil temperature decreased or under very wet or very dry conditions (Janzen and Bettany, 1987). Under reduced tillage, the combination of lower soil temperatures during the spring and summer period and the removal of the mixing action of cultivation may slow the conversion of elemental S to sulphate, reducing the rate at which it becomes available for crop growth. On the other hand, a more active microbiological population near the soil surface under reduced tillage and the maintenance of higher soil temperatures through the fall period may enhance oxidation of elemental S.

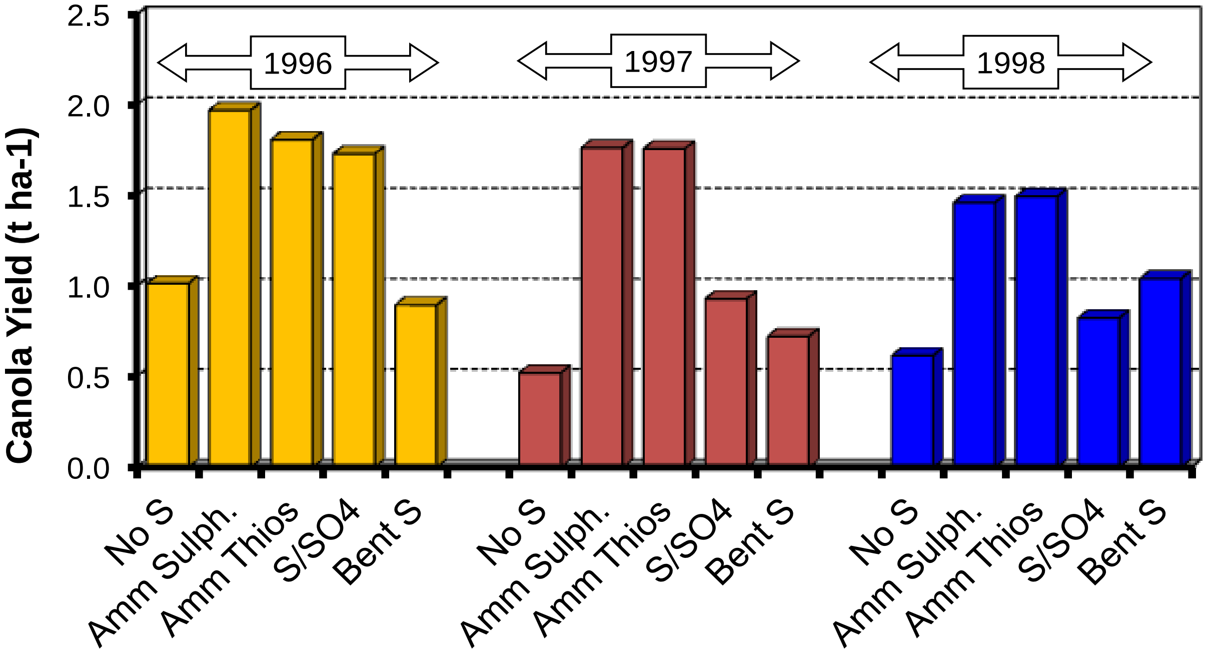

Figure 3. Canola yield over three years from a single 20 kg S ha$^{-1}$fertilizer application in 1996 at Melfort, SK (Grant et al., 2003; Grant et al., 2004). Yields presented are the average of both broadcast and in-soil banded fertilizer applications.

It is recommended that when forms of S fertilizer other than sulphates are to be used, they should be broadcast and worked in to the soil well in advanced of seeding to permit formation of adequate amounts of sulphate to meet the crop requirements. This may require application a year or more in advance of seeding. Under the conditions at Melfort, Saskatchewan, the elemental sources were not able to provide adequate available sulphate to the crop in the year of application, with limited benefits occurring even two years after application (Figure 3). In the third year after application, the elemental benetonite product produced a yield increase, particularly where the fertilizer had been broadcast (Figure 4). Therefore, on soils where a sulphur deficiency exists, a sulphate source should be used to ensure adequate available S for crop growth. Elemental forms of S may have a role in rotational management, for soil maintenance when sulphur levels in the soil are marginal, or in perennial crops where residual benefits are desirable. However, it is important to note that there were still also significant residual benefits from the ammonium sulphate and ammonium thiosulphate application even in the third year after application. Residual benefits from sulphate fertilizers may be due to carry-over of $SO_4^{=}$-S and/or mineralization of high-S crop residues that contribute available S to subsequent crops (Jackson, 2000; Grant et al., 2003).

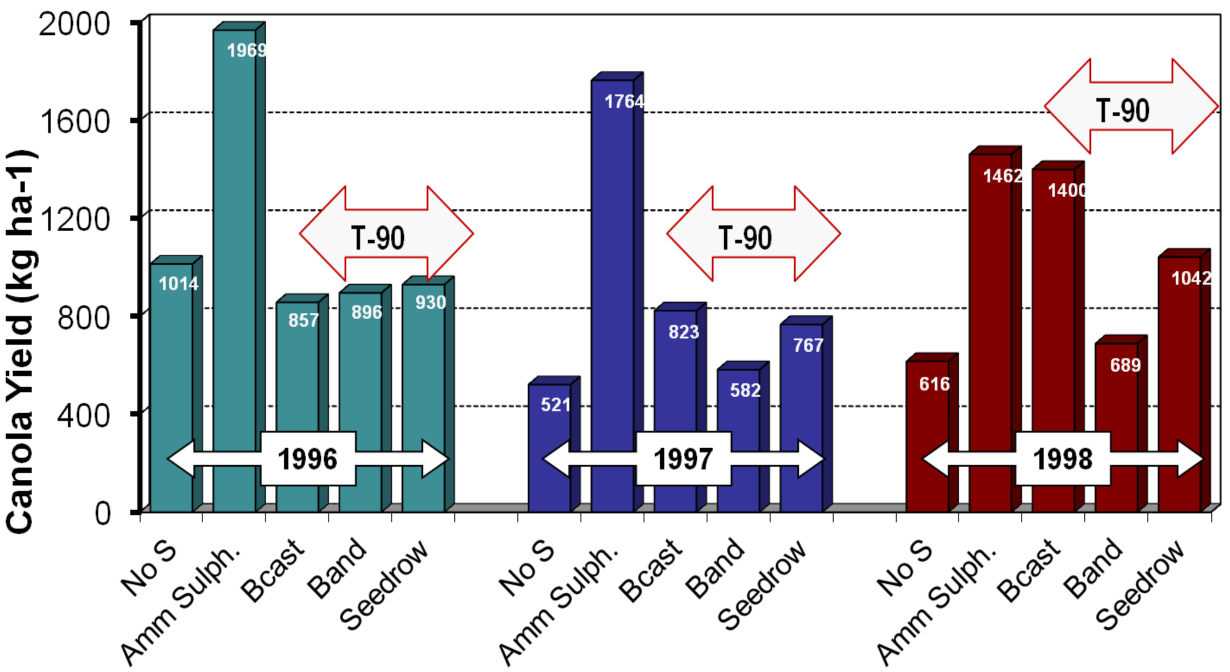

Figure 4. Canola yield over three years from a single 20 kg S ha$^{-1}$fertilizer application in 1996 The bentonite elemental sulphate fertilizer was broadcast, banded or seed-row placed while the ammonium sulphate was broadcast (Grant et al., 2003; Grant et al., 2004).

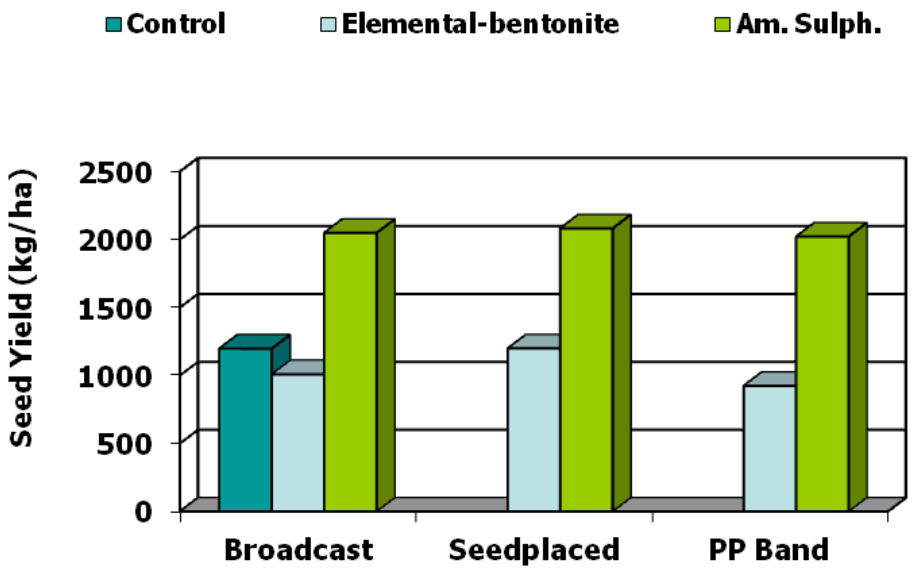

Figure 5. Canola yield as affected by placement of ammonium sulphate or a bentonite elemental sulphur fertilizer, in the year of application (Grant et al., 2003; Grant et al., 2004).

In contrast to elemental sources, sulphate sources are immediately available for crop uptake if sufficient moisture is present to dissolve the fertilizer. Sulphate will also move readily through the soil in the soil water. Therefore, broadcasting, banding or seed-placement are all suitable placements for sulphate sources (Figure 5). Under dry conditions, banding may avoid stranding the fertilizer in dry surface soils. Unlike N, S is not subject to losses by volatilization or denitrification, so there is not as much advantage of banding over broadcast applications in terms of S efficiency. Seed-placement of S is also an option, but with small seeded crops such as canola, care must be taken to avoid seedling damage from excessive fertilizer levels.

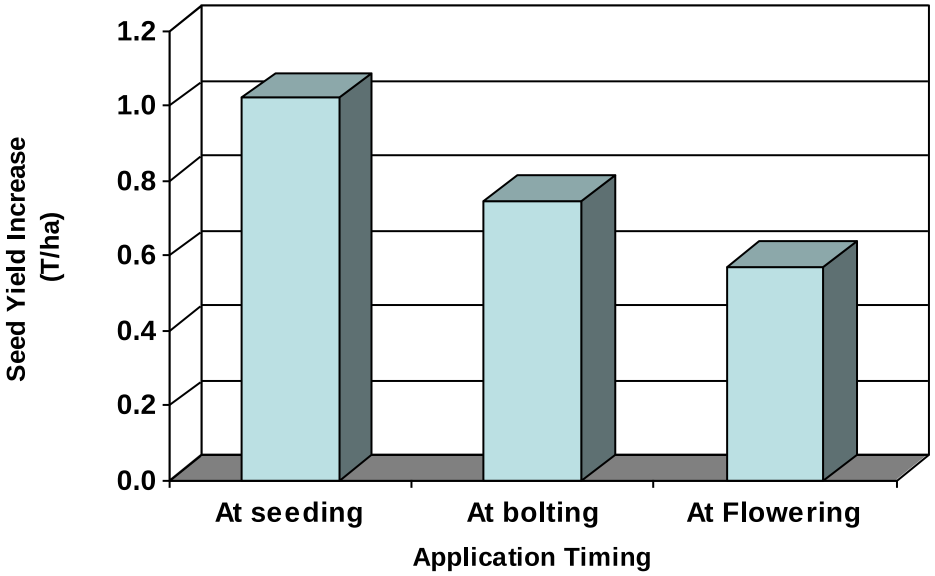

Figure 6. Effect of timing of application of ammonium sulphate on yield increase of canola (Malhi and Leach, 2002).

If a deficiency is noticed in a canola field, application of a sulphate fertilizer can correct the deficiency and recover some of the yield potential of the crop (Figure 6). However, under S-deficient conditions, in-crop fertilization will not normally produce as high a yield as if the S was supplied at the time of seeding.

MicroEssentials S15 (13-33-0-15S) is a fertilizer product composed of monammonium phosphate, ammonium sulphate and elemental sulphur formulated in a single granule. There may be some advantages to the product in improved distribution of nutrients and increased seedling safety as compared to a blend of ammonium sulphate and monoammonium phosphate. However, the formulation does not appear to hasten the conversion of the elemental S to the available sulphate form. Therefore, since ½ of the S in the product is in the elemental form, one should assume that only ½ of the S will be plant-available in the year of application. This was supported by growth chamber studies conducted at the University of Manitoba, that showed S uptake and crop biomass yield produced by the MicroEssentials S15 was intermediate between an elemental product and ammonium sulphate (Figure 7).

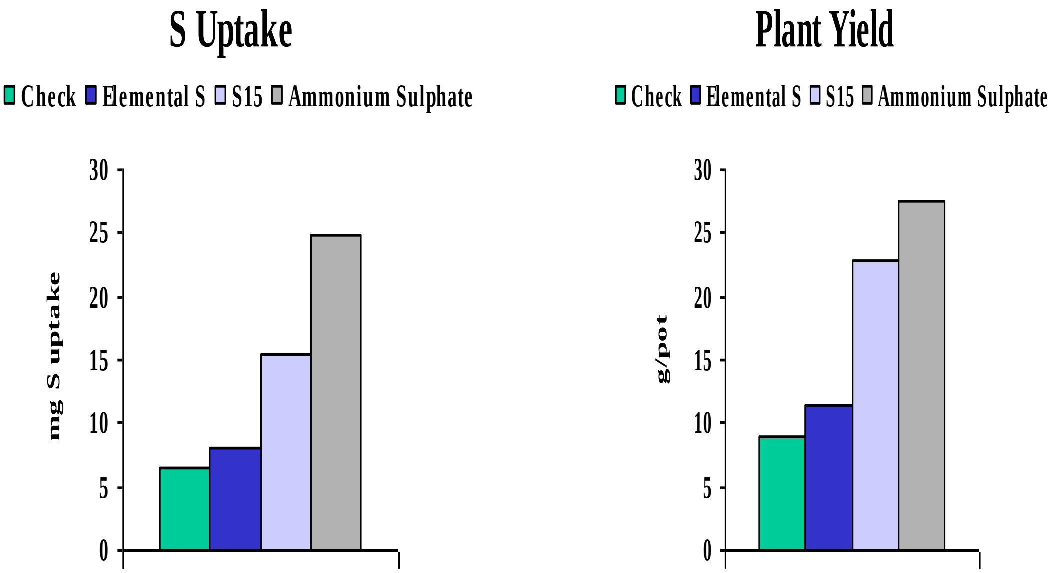

Figure 7. Sulphur uptake and plant biomass yield produced by MicroEssentials S15 was intermediate between elemental S and ammonium sulphate (Kroeker 2005 – unpublished)

## Summary

Sulphur is a critical nutrient for crops, particularly canola and forage legumes. Sulphur deficiencies appear to be increasing due to soil degradation, lower inputs from air pollution, use of higher analysis fertilizers that do not contain S as a contaminant, higher crop yields, and increased production of canola in the rotation. Hybrid canola cultivars produce a higher yield than open-pollinated cultivars and seem to be more effective at extracting S from the soil. Therefore, they do not appear to initially require higher levels of S fertilizer than open-pollinated cultivars for optimum yield. However, in the long-term they may deplete soil S leading to increased requirement for S to maintain the soil supply.

Management of S fertility offers much flexibility and various sources, timings and placements of S can be used effectively to provide the S needed by the crop. If a deficiency exists and a response is required in the growing season after application, a sulphate source is required to ensure that sulphur deficiency does not limit crop growth. Residual benefits may occur for several years after application of sulphate fertilizer sources. Elemental sources may have a role in long-term rotational planning but do not normally oxidise rapidly enough to provide sufficient S for crop production for at least one year, and possibly several years, after application. Banding elemental sources delays oxidation, so elemental forms should be broadcast and incorporated to encourage oxidation. MicroEssentials S15, which contains 50% elemental S and 50% ammonium sulphate combined with monoammonium phosphate in the same granule, may provide increased seedling safety as compared to a blend of ammonium sulphate and monoammonium phosphate, but the elemental portion of the fertilizer is not rapidly oxidized. Therefore, application rates for MicroEssentials S15 should be calculated based on the 50% of the S that is in the sulphate form.

## References

Brandt, S.A., Malhi, S.S., Ulrich, D., Lafond, G.P., Kutcher, H.R., Johnston, A.M., 2007. Seeding rate, fertilizer level and disease management effects on hybrid versus open pollinated canola (Brassica napus L.). Can. J. Plant Sci. 87, 255-266.

Carew, R., Devadoss, S., 2003. Quantifying the Contribution of Plant Breeders' Rights and Transgenic Varieties to Canola Yields: Evidence from Manitoba. Can. J. Agr. Econ. 51, 371-395.

Carew, R., Smith, E.G., 2006. Assessing the contribution of genetic enhancements and fertilizer application regimes on canola yield and production risk in Manitoba. Can. J. Agr. Econ. 54, 215-226.

Franzen, D.W., Grant, C.A., 2008. Sulfur Response Based on Crop, Source, and Landscape Position. In: Jez, J. (Ed.), Sulfur: A Missing Link between Soils, Crops, and Nutrition. American Society of Agronomy, Madison, WI, pp. 105-116.

Grant, C.A., Johnston, A.M., Clayton, G.W., 2003. Sulphur fertilizer and tillage effects on early season sulphur availability and N:S ratio in canola in western Canada. Can. J. Soil Sci. 83, 451-463.

Grant, C.A., Johnston, A.M., Clayton, G.W., 2004. Sulphur fertilizer and tillage management of canola and wheat in western Canada. Can. J. Plant Sci. 84, 453-462.

Jackson, G.D., 2000. Effects of nitrogen and sulfur on canola yield and nutrient uptake. Agron. J. 92, 644-649.

Janzen, H.H., Bettany, J.R., 1987. Oxidation of elemental sulfur under field conditions in central Saskatchewan. Can. J. Soil Sci. 67, 609-618.

Karamanos, R.E., Goh, T.B., Flaten, D.N., 2007. Nitrogen and sulphur fertilizer management for growing canola on sulphur sufficient soils. Can. J. Plant Sci. 87, 201-210.

Karamanos, R.E., Goh, T.B., Poisson, D.P., 2005. Nitrogen, phosphorus, and sulfur fertility of hybrid canola. J. Plant Nutr. 28, 1145-1161.

Malhi, S.S., Gill, K.S., 2006. Cultivar and fertilizer S rate interaction effects on canola yield, seed quality and S uptake. Can. J. Plant Sci. 86, 91-98.

Malhi, S.S., Leach, D., 2002. Optimizing yield and quality of canola seed with balanced fertilization in the Parkland zone of western Canada. Proc. Soils and Crop Workshop (Disc Copy).

Reikman, M.R., 2005. The Effect of Canola Cultivar on Water Extraction and Nitrogen and Sulphur Uptake. Soil Sci. University of Manitoba, Winnipeg.