

Sulphur Fertilizer Application in Crop Production

Introduction

Sulphur (S) is an essential plant nutrient for all crop production. This situation is especially true for canola, which has a higher requirement for S than other annual crops such as wheat (Table 1).

Sulphur is essential for protein synthesis and the formation of chlorophyll. Sulphur is required in the development of fertile canola flowers and must be present for good nodule development on alfalfa roots.

Crop	Yield	Crop Part	Nutrients Removed (lbs/acre)			
			N	P	K	S
Canola	35 bu/ac	Seed/straw	105	22	69	21
Wheat	50 bu/ac	Straw/straw	106	17	67	13
Alfalfa	5 tons/ac	Total	290	32	250	30

Adapted from Alberta Agriculture, Food and Rural Development, Soil and Crop Diagnostic Centre Laboratory Yield Increase tables (N = nitrogen, P = phosphorus, K = potassium, S = sulphur)

In Alberta, 7 million acres are considered S deficient for optimum canola production, and the acreage is increasing. Plants use S in the sulphate (SO₄-S) form, which like nitrate (NO₃-N), is very mobile in the soil and leachable.

Soil organic matter is the primary source of plant available SO₄-S. Soils that are sandy, low in organic matter and found in upper to mid-slope positions are especially prone to S deficiency since the small amount of SO₄-S released from organic matter is susceptible to leaching loss.

Soils most prone to S deficiency are the Grey Wooded, Thin Black and Black soils (Figure 1) because they were formed in areas of relatively high rainfall (>leaching) and have greater yield potential

(high S demand). Brown and Dark Brown soils are usually not considered S deficient because they often have gypsum (CaSO₄) laden subsoils. However, within all soil zones, various combinations of high rainfall, high yield potential, low organic matter, topography and coarse texture predispose fields to S deficiency.

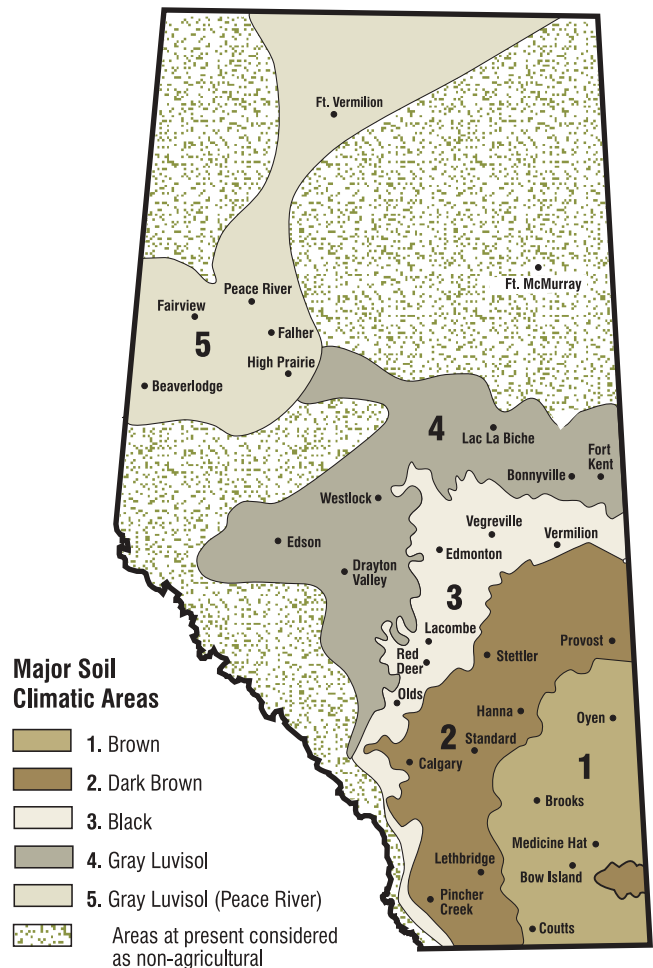


Figure 1. Soils map of Alberta

Sulphur deficiency symptoms

Sulphur deficiency symptoms vary between crops. In canola, deficiency symptoms may begin as early as the one leaf stage (Figure 2a), with the newest leaves turning yellowish green with dark vein coloration. Leaves may take on a “cupped” appearance, later reddening from the leaf margins (Figures 2b and 2c). Flowers are small and pale, and they produce small underdeveloped purple pods (Figure 2d). Under mild S deficiency, there may be good vegetative growth, but flowers and pods will be underdeveloped.



Figure 2a: Sulphur deficiency symptoms in canola: sulphur deficient seedling.

For cereals and forage grasses, yellowing of newly emerging leaves is a strong indicator of S deficiency (Figure 3). Depending on the degree of deficiency, the leaves may be a shade of light green to entirely yellow. Yellowing of the new growth occurs because S is immobile in the plant. Thus, newly emerging leaves cannot “scavenge” S from older leaves. This situation is in contrast to nitrogen deficiency symptoms in which the older leaves turn yellow first because nitrogen is being “scavenged” from older leaves to support new growth.



Figure 2b: Sulphur deficiency symptoms in canola: leaf cupping.



Figure 2c: Sulphur deficiency symptoms in canola: dark vein coloration and purpling of leaf margins.



Figure 2d: Sulphur deficiency symptoms in canola: small pale flowers and poor pod development.



Figure 3. Yellowing of newly emerging leaves is an indicator of sulphur deficiency in wheat, other cereals and forage grasses.

Sulphur deficient alfalfa is short in stature with pale green to yellow leaves (Figure 4a and b). The yellowing is often but not always localized to newly emerging leaves. Sulphur deficiency can result in nitrogen deficiency in alfalfa since S is required for health and function of nitrogen fixing nodules.



Figure 4a. Sulphur deficiency in alfalfa: deficient plant on left is short in stature with yellowing most severe on young leaves.



Figure 4b. Sulphur deficiency in alfalfa: In the field, sulphur deficient alfalfa on the right.

Similar symptoms

Many other stressors can cause similar symptoms in canola to those caused by S deficiency. Group 4 herbicides such as 2,4-D or dicamba (Banvel) can cause leaf cupping in canola (Figure 5a); however, these leaves lack the dark vein coloration associated with S deficiency.



Figure 5a. Canola leaf cupping from Banvel injury.



Figure 5b. Purpling of older leaves resulting from Muster sprayed just prior to heavy rainfall.

Like S deficiency, Group 2 herbicides can cause purpling of canola leaves, but unlike the leaves of S deficient canola, the purpling does not develop from the leaf margins. Figure 5b shows Muster (ethametsulfuron-methyl) injury on canola. Muster is a registered herbicide (Group 2) on canola, but injury can occur if a heavy rainfall occurs shortly after spraying, facilitating the uptake of the herbicide via the roots.

Other Group 2 herbicides such as Ally (metsulfuron-methyl) or Pursuit (imazethapyr) can carryover in the soil and cause purpling of the older canola leaves. If Group 2 herbicides are sprayed directly on canola as a tank contaminant, purpling of the youngest leaves will occur.

Boron deficiency can produce thin purple pods in canola, which are hard to distinguish from S deficiency symptoms. Fortunately, boron deficient soils are relatively uncommon. Sun scald produces purpling, but the discoloration is confined to the “sunny” side of stems and pods.

Indirect causes of sulphur deficiency

Sulphur deficiency in canola can occur despite adequate application of S fertilizer. Any stressor causing root pruning, reducing the plant’s ability to take up nutrients, can potentially produce S and other nutrient deficiencies. Herbicide carryover and acidic soils can cause root pruning and S deficiency symptoms. Root rot disease, which is preventable with seed treatment, can cause the development of sulphur deficiency in canola (Figure 6).



Figure 6. Canola grown from bare seed (left) versus Vitavax-treated (right). Inset: Close-up of canola grown from bare seed showing sulphur deficiency resulting from seedling blight.

Soil testing for sulphur

Crop-available S in the soil is determined by measuring the soluble sulphate content. This soil test provides a reliable basis for making S fertilizer recommendations if a representative sample can be obtained from the field.

Ideally, samples should be taken just before seeding. However, fall sampling will also provide reliable fertilizer recommendations when taken after the surface soil temperature drops below 5°C (generally after October 1).

Either a soil sampling auger or probe should be used to obtain samples. Take soil samples from 0 to 6 in., 6 to 12 in. and 12 to 24 in. depths. Fertilizer recommendations for phosphorous and potassium are based on the 0 to 6 in. depth. Soil testing laboratories will provide fertilizer recommendations for S based on a 0 to 6 in. depth; however, this approach may provide a poor recommendation because available S in the subsoil will be missed. With each extra sample taken from a greater soil depth (6 to 12 in., 12 to 24 in.), the fertilizer recommendations for S become more precise.

Even with proper sampling depth, obtaining a representative sample from the field can still be a challenge. Studies across all soil zones have found the level of crop-available S can vary greatly within a field.

For example, grid sampling (0-60 cm) within a field near Stettler found sulphate levels varied from 9 to 6,330 mg/Kg with the average being 588 mg/Kg. Based on a random composite sample, no fertilizer recommendation for S would be made for this field. However, the mode (the value of most frequent occurrence) was 11 mg/Kg. Based on this number, S fertilizer **would** be recommended. If the soil test results from the composite

sample were followed, the majority of this field would be lacking adequate S. Obtaining a representative sample from fields highly variable in available S is difficult.

The benchmark system of soil sampling can help with fertilizer decisions. With the benchmark system, representative site(s) that are 100 feet by 100 feet are located within the field. Every year, 15 to 20 sample cores are taken from each benchmark site. Provided the benchmark sites are representative, this system gives a better indication of the nutrient status of the field and how it varies from year-to-year. Finding good benchmark sites may be difficult. However as a general rule, top slope and sandy soils are often associated with S deficiency and should be sampled separately from low-lying or heavy textured soils.

Sulphur fertilizer type and method of application

Sulphur fertilizers are most commonly available in either the soluble sulphate or elemental forms (S°). In Alberta, products containing ammonium sulphate (21-0-0-24, 20-0-0-24 and 19-3-0-22) predominate the marketplace whereas products comprised of elemental S°, 0-0-0-90 (Tiger 90_{CR}) and 0-0-0-95 (SulFer 95), are only recently finding increased market acceptance.

Provided there is adequate soil moisture, ammonium sulphate fertilizers quickly dissolve to release SO₄-S (the sulphate form). As stated earlier, SO₄-S is highly mobile in the soil and is the only form of S directly utilized by plants.

Because ammonium sulphate fertilizers are so rapidly available, they can be applied to crops in many different ways. The efficiency of soluble sulphate fertilizer is the same whether it is broadcast and incorporated or banded. However, banding may favor crop growth over weeds, since this method places the fertilizer in closer proximity to the crop. Some sulphate loss to runoff may occur if ammonium sulphate fertilizers are broadcast on deep snow covering frozen ground, particularly if slopes are steep.

If detected early enough, S deficiency can be corrected in many crops by broadcasting ammonium sulphate. In the case of canola, broadcasting ammonium sulphate up until early flower can correct much of the S deficiency provided there is enough rain to dissolve and move the SO₄-S into the root zone (Figure 7). The greatest risk from using soluble sulphate fertilizers occurs on sandy soils subjected to heavy rainfall. Under these conditions, SO₄-S may leach below the rooting zone.



Figure 7. Canola on the left was rescued from sulphur deficiency by applying 100 lbs/ac of 20-0-0-24 applied at early flower.

For fertilizer manufacturers and producers, elemental sulphur (S°) has the advantages of ready supply, lower production costs and, because of its high analysis, lower transportation cost and fewer drill fills during field operations. In addition, the application of S° does not add any extra nitrogen, which could reduce yields of legumes such as alfalfa. Excessive soil nitrogen can reduce legume yields by interfering with proper nodule formation. Despite these benefits, the adoption of S° has been limited.

Elemental sulphur must be oxidized by soil microbes to SO₄-S before it is available to crops. Thus, it takes considerably more time for S° to become available compared to soluble sulphate forms of fertilizer. The rate of conversion from S° to plant available SO₄-S mainly depends on the particle size to which the product degrades and the method of application. Research has determined that S° granules that break down into particles smaller than 150 Microns (10⁻⁶ m) convert quickly, since particles of this size (and smaller) provide sufficient surface area for microbes to act on. After two simulated wet/freeze cycles and one rainfall, SulFer 95 (0-0-0-95) are all <74 microns whereas only 25 per cent of Tiger 90 particles were <150 microns.

The evolution of elemental S° products is rapid. Some of the products available at the time of this publication include Tiger 90cr, SulFer 95, Montana 90, Keg River 85 and Brimstone 90. Industry is continually striving to improve the dispersing nature of their S° products, making it difficult to give current comparisons between various S° products.

Regardless of brand, all S° products should be surface broadcast without immediate (or no) incorporation for at least a year before the crop. Elemental sulphur sitting on the soil surface is more easily oxidized by soil microbes because rainfall and freeze/thaw cycles break down and disperse the granules.

Banding or immediate incorporation is an inefficient method of applying S°. The surrounding soil keeps the S° granule intact, reducing the exposed S° surface area and vastly reducing the conversion rate to SO₄-S. Even with broadcast applications, the rate of conversion from S° to SO₄-S can vary from less than a year to several years or more.

One research study showed that surface applied applications after seeding of the S° product SulFer 95 produced yields similar to 20-0-0-24 (Table 2). By contrast, another study demonstrated that on sandy dry soils, the rate of conversion of S° can be much slower. Canola yields were found to be significantly greater when fertilized with a spring banded application of ammonium sulphate (20-0-0-24) compared to spring or even fall broadcast Tiger 90 or SulFer 95 (Table 3, Figure 8). In both studies, surface applied applications of Tiger 90 produced lower yields compared to SulFer 95, indicating a slower conversion rate.

Table 2. Effect of sulphur source and method of application on Polish canola yield (two years)			
Fertilizer	S Rate (lb S/ac)	Application Method	Yield (bu/ac)
No S and No N	0	None	34
N only ¹	0	None	25
20-0-0-24 plus N	30	Band	39
S95 plus N	30	Band	35
S95 plus N	30	Surface after seeding (SAS)	38
T90 plus N	30	Band	29
T90 plus N	30	Surface after seeding (SAS)	32

¹ N applied as a band at 120 lb N/ac.

Table 3. Effect of sulphur source and method of application on Argentine canola yield (Fort Vermilion)¹			
Fertilizer	Rate (lb/ac)	Application Method	Yield of Check (%)
No S	0	None	2.1
20-0-0-24 Check	30	Spring banded	100
T90	30	Spring broadcast	7.6
T60	30	Spring broadcast	58.3
Sulfer 95	30	Spring broadcast	23.8
T90	30	Fall broadcast	9.8
T60	30	Fall broadcast	49.8
Sulfer 95	30	Fall broadcast	35.7

¹ All treatment received 72 lb/ac of banded N and 75 lb/ac of broadcast P₂O₅.

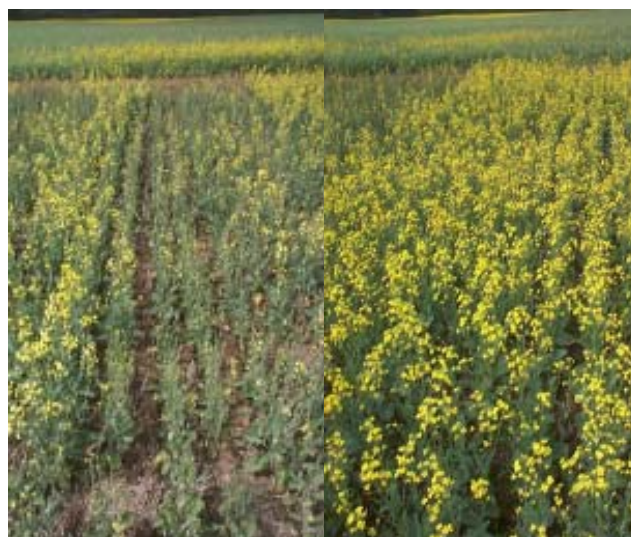


Figure 8. Fall applied Tiger 90 (left) vs spring banded 20-0-0-24 (right).

Animal manure as S fertilizer

Animal manure, particularly liquid swine effluent, is low in S relative to nitrogen. It has been observed that N:S ratios varied from 7:1 to 17:1 for cattle manure and from 13:1 to 25:1 for pig slurry. The majority of these N:S ratios are too great for optimum canola production, which requires an N:S ratio of 7:1. In the majority of cases, supplemental S fertilization will be required when using animal manure to fertilize canola.

Summary

Sulphur is an essential plant nutrient that is of particular importance to canola production. Sulphur deficiency is common in Alberta soils and is increasing. Sulphur deficiency symptoms vary between crops. Symptoms of S deficiency in canola include leaf cupping, purpling and underdeveloped pods. If applied early enough, a broadcasted application of ammonium sulphate can correct S deficiency.

Fertilizer recommendations should be based on representative soil samples taken to depths of 12 or 24 inches. Fertilizers that supply S in the sulphate form are immediately available to crops. Elemental S° fertilizers must be surface applied where they can be oxidized to plant available SO₄-S. Depending on soil type and environmental conditions, this conversion can take from less than a year to more than two years.

Prepared by:

Mike Hall - Integrated Crop Management Specialist,
Alberta Agriculture, Food and Rural Development,
Fort Vermilion (780) 927-3713

Elston Solberg - Manager,
Agri-Knowledge Division, Agri-Trend Agrology

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Figure 2b - Phil Thomas

Figure 4a & 5a - Agronomy Unit collection

All remaining photos taken by Mike Hall

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