Management of Sulphur Fertilizers

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Abstract

Sulphur (S) is an important macro-nutrient in the production of canola, a high protein oilseed crop. In the absence of adequate S, canola yield response to added fertilizer N can be completely eliminated. A study was initiated at Brandon, Manitoba, Beaverlodge, Alberta and Melfort, Saskatchewan in 1996 to evaluate the effect of S fertilizer source, placement and application time on the yield and quality of conventional and zero-till seeded canola and spring wheat. The S, including ammonium sulphate (AS), solution ammonium thio-sulphate (ATS) and bentonite clay based elemental S marketed as Tiger-90 (T-90), were all applied at 18 lb S/ac. All treatments received a total N rate of 90 lb/ac, along with MAP at 40 lb P_2O_5/ac, or 18 lb P/ac. The broadcast fertilizer S was incorporated only with the conventional tillage plots. Where responses to S were recorded, ammonium sulphate (AS) and ammonium thio-sulphate (ATS) corrected S deficiencies in both the application year, and when re-cropped to canola in the following two years. Only when broadcast did T-90 provide a response equivalent to AS. However, this occurred 24 months after application. When the elemental S was pre-seeding banded or seed placed insufficient sulphate was available after 24 months to correct S deficiencies, resulting in yield reductions. Under severe S deficiencies recorded in 1998 a response was recorded for spring wheat to S. The results of this research indicate that in the northern Great Plains region sulphate-S is required to meet short-term S deficiencies in canola. Use of T-90 elemental S requires that the product be broadcast applied at least 24 months prior to crop requirement to allow for oxidation to plant available sulphate-S. Development of finely ground elemental S products will help to increase the conversion to sulphate-S, meeting crop requirements in a shorter time period after application.

Introduction

Sulphur (S) is the third most limiting nutrient on the Canadian Prairies, after nitrogen and phosphorus. It is estimated that 30% of the 36 million hectares of cultivated land in Alberta, Saskatchewan and Manitoba show S deficiencies (Doyle and Cowell, 1993). The majority of these deficiencies occur on the Gray Luvisolic soils, which are developed under deciduous forest vegetation and have low organic matter. Sulphur is an important component of proteins and amino acids, so high protein crops such as pulses and alfalfa tend to remove more S, as well as being prone to S deficiencies more often than cereals. Canola, a high protein oilseed crop developed in western Canada from rapeseed, has particularly high requirements for S (Grant and Bailey, 1993). In addition, S is also important in ensuring adequate protein content and baking quality in wheat. Instances of S deficiencies are likely to increase in the future, due to increasing production of canola and field peas in rotation with wheat and barley. Increasing crop yield potentials, higher N application rates, more continuous cropping and reduction of atmospheric deposition of S compounds will encourage increased S depletion and higher S fertilizer requirements.

Sulphur is normally applied either as elemental S or as a sulphate fertilizer source. Plants take up only sulphate-S, so elemental S must be oxidized to sulphate forms before being used by plants. Microbial oxidation of S is influenced by soil temperature, soil moisture, microbial activity, soil aeration, and pH as well as by factors influencing dispersion of the S, such as tillage, particle size and placement method. Spring applied elemental S at seeding is not recommended for annual crops, because the oxidation rate is not rapid enough to satisfy the S requirements of the crop (Noellemeyer et al., 1981). However, elemental S may produce a residual benefit for several years after application and may be suited to building long-term soil fertility.

While most of the S fertilizer research on the Canadian prairies has been conducted under conventional tillage, zero-tillage acreage is expanding rapidly in the region. Reduced tillage practices may impact profoundly on S management. Sulphate S is mineralized from soil organic matter, which may change under zero tillage due to changes in soil temperature, aeration, organic matter distribution, and physical disturbance of occluded organic matter (Doran and Smith, 1987). These changes would influence the S availability from the soil, S fertilizer rates to optimize grain yield, and the likelihood of a yield response to fertilizer S application. Changes in soil physical, chemical and biological properties would also impact on the rate of S oxidation and the rate of conversion of fertilizer elemental S to plant-available sulphate-S. This could change the relative performance of elemental S as compared to sulphate-S as a source of S fertilizer for annual crops. Optimal placement of S may also differ with tillage, due to effects of soil moisture, rooting, organic matter and microbial biomass distribution, and stratification of pH and nutrients (Doran and Smith, 1987, Grant and Bailey, 1994, Lafond et al., 1992).

Materials and Methods

A study was initiated at Brandon, Manitoba, Melfort, Saskatchewan and Beaverlodge, Alberta, in 1996 to evaluate the effect of S fertilizer source, placement and application time on the yield and quality of conventional and zero-till spring wheat and canola. A four replicate split plot design was used for each crop, with tillage as the main plot (conventional and zero-till), and 13 S form, placement and application time combinations, including:

1. Control	CK
2. Fall broadcast Tiger-90	F. Bcst T-90
3. Fall broadcast ammonium sulphate (AS)	F. Bcst AS
4. Fall dribble ammonium thio-sulphate	F. Drib ATS
5. Spring broadcast Tiger-90	S. Bcst T-90
6. Spring broadcast elemental S 99%	S. Bcst ES
7. Spring broadcast ammonium sulphate	S. Bcst AS
8. Spring dribble ammonium thio-sulphate	S. Drib ATS

9. Spring pre-plant banded Tiger-90 S. Bd T-90
10. Spring pre-plant banded ammonium sulphate S. Bd AS
11. Seed placed Tiger-90 SR T-90
12. Seed placed ammonium sulphate SR AS
13. Spring broadcast ES-AS blend S. Bcst ES-AS

No fall treatments were applied at Melfort for the 1996 growing season. All S was applied at 18 lb S/ac. Nitrogen not part of the S product was applied as urea to achieve a total N rate of 90 lb/ac, along with MAP at 40 lb P_2O_5/ac, or 18 lb P/ac. The experiment was established in 1996 (Trial 1), 1997 (Trial 2) and 1998 (Trial 3). The broadcast fertilizer S was incorporated only with the conventional tillage main plots. Data collection included soil N, P, K, S, pH and conductivity, seedling emergence, dry matter and tissue N and S at flowering, grain and straw yield, seed protein and S concentration. To measure residual response, canola was seeded in year 2 onto the plot area where wheat was grown with S treatments in year 1 of the study, however, no S was applied in year 2. Similarly, where canola was grown in year 1, wheat was seeded over the plot area in year 2 with a blanket application of 90 lb N/ac and 40 lb P_2O_5/ac. For the 1996 study (Trial 1), canola was re-seeded onto wheat stubble in 1998 providing a canola'96-wheat'97-canola'98 response to S treatments applied once in the spring of 1996.

Results and Discussion

While soil S levels were low at both Brandon and Beaverlodge on the test area, very little or no crop yield response was recorded to S application. As a result data will be presented for the Melfort trial site only where significant differences between treatments were recorded in 1996 and 1998. In addition, there were few differences recorded between the tillage treatments, with conventional till and zero-till responding in a similar manner to all fertilizer forms and placement methods. As a result these two tillage treatments have been combined for this presentation.

Trial 1 – 1996 Application

The low residual soil S (8 lb SO_4-S/ac in 0-12 in) resulted in a large canola grain yield response to S fertilizer at Melfort in 1996, and the 1997 re-crop (Table 1). Both ammonium sulphate (AS) and ammonium thio-sulphate (ATS) increased canola yields over the unfertilized control in both years. Whether the AS was banded, broadcast or seed placed resulted in a similar grain yield response in the 1996 application year. However, in the 1997 re-crop year there was little residual S response from the seed placed AS, while band and broadcast application provided a good response, indicating that placement of the fertilizer influenced crop uptake of S. The S blend (treatment 13), which is 50% elemental S (99% S) and 50% ammonium sulphate, was found to be equal to ammonium sulphate in the application year, however significantly lower in the re-crop year. This blend provided a 9 lb/ac rate of ammonium sulphate, a rate which provided little residual S response for the re-crop year. Elemental S and Tiger-90 was found to provide no S response over the check in 1996 application year, or the 1997 re-crop year. Only in year 3, 24 months after application, did we observe a response to the Tiger 90 elemental S fertilizer. However, the response occurred only when the Tiger 90 was broadcast, with band and seed row application still not providing the same yield response in canola as ammonium sulphate. The other very interesting item to note in the data is the high level of residual response we obtained from one single application of ammonium sulphate. Three years after application we were still recording a doubling in canola grain yields from one single 18 lb/ac application, indicating that on these loam and sandy loam textured soils we did not experience leaching of the sulphate.

On average, tillage had no effect on canola grain yield response in either the 1996 or 1997 application years (data not shown). However, no-till canola yields were lower in the 1997 re-crop year. While little difference was observed between the conventional and no-till grain yield for the response AS and ATS treatments (7, 8 and 10), the remaining treatments were considerably lower with no-till.

Few differences were observed in spring wheat in 1996, indicating that wheat has much lower S needs to balance N. Seed row applied AS was superior to spring broadcast AS in 1996, and the AS treatments proved to be superior to T-90 in the 1997 re-crop year. While these differences were small, application of plant-available SO_4-S would have produced economic responses at this trial site.

Trial 2 – 1997 Application

No significant differences were recorded to the S treatments in 1997, even though the soil test showed S levels of less than 12 lb s/ac in the surface 12" (Table 1). This soil test result would provide a recommendation for 20-25 lb S/ac for a 30 bu/ac canola crop. We found out that the farmer had applied 10 lb SO_4-S to the field in the year prior to the trial, and expect that there was adequate residual S to meet crop requirements. This lack of response to S, while soil tests showed low soil S levels, was the reason for the lack of response at the Brandon and Beaverlodge experimental locations. However, this residual S response from 1996 application by the farmer at Melfort was gone by 1998 during the re-crop year. All S forms showed a positive response over the no S check (Table 1). Broadcast application of T-90 were superior to seed row applied T-90, indicating increased availability of this elemental S product when surface broadcast. While differences in grain yield were small, fall broadcast T-90 was superior to spring broadcast and spring band applications of T-90 in 1998, again indicating improved conversion of the elemental S to sulphate with increased time (18 months) from application. These results support the re-crop results observed in Trial 1, showing that broadcast application is likely the only efficient method of applying the T-90 sulphur product.

Trial 3 – 1998 Application

The trial site selected for S fertilizer application in 1998 was recently broken from alfalfa and had 16 lb S/ac in the surface 12". Results indicate that there was a severe S deficiency in this field, as there was an almost complete crop failure where SO_4-S was not added (Table 1).

Fall applied AS was not as good as spring AS in increasing grain yield, indicating there was some loss over winter. Problems at seeding resulted in an error and the spring pre-plant banded AS treatments were not included. The lack of S was obvious during the growing season at this trial, with seedling, early plant growth and flowering all showing the classic deficiency symptoms.

While not significant, it is at this very deficient site that the most variable wheat yields were recorded (Table 1). Ammonium sulphate treatments were on average 43 bu/ac, while the Tiger 90 elemental S and no S check was 37 bu/ac. The plots not receiving SO_4-S showed what appeared to be N deficiency during tillering and the on-set of stem elongation, however, this appeared to subside as the plant moved into heading. The yield differences indicate that while not as devastating to final yield as canola, early season S deficiencies can reduce spring wheat yields.

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Table 1. Grain yield (bu/ac) response of spring wheat and canola to sulphur fertilizer form, placement and time of application at Melfort Saskatchewan in 1996, 1997 and 1998, and residual responses for 1996 and 1997 application years.

	Trial 1					Trial 2				Trial 3	
	1996		1997		1998	1997		1998		1998	
Treatment	Canola	Wheat	Wheat	Canola	Canola	Canola	Wheat	Wheat	Canola	Canola	Wheat
1. Check	21.6	38.7	29.0	8.1	11.0	37.2	44.9	59.1	23.7	1.2	37.4
2. F. Bcst T-90†	-	-	-	-	-	36.6	45.6	59.7	35.4	1.5	38.3
3. F. Bcst AS	-	-	-	-	-	39.1	40.3	58.8	32.9	17.2	42.6
4. F. Drib. ATS	-	-	-	-	-	39.2	42.3	58.6	33.3	19.7	39.0
5. S. Bcst T-90	20.0	38.3	27.8	11.8	25.0	32.4	42.6	58.0	32.2	2.5	35.8
6. S. Bcst ES	23.1	39.2	29.6	5.7	10.6	39.1	42.3	59.6	29.1	1.2	36.6
7. S. Bcst AS	36.9	38.0	30.5	31.0	24.0	36.7	42.0	60.6	33.0	24.0	43.7
8. S. Drib ATS	34.6	40.6	30.2	31.6	26.7	37.6	41.6	58.2	30.5	21.8	41.9
9. S. Bd T-90	16.6	39.4	25.4	7.1	12.3	39.1	42.2	56.1	31.1	5.5	37.8
10. S. Bd AS	36.4	39.8	31.5	31.1	28.1	31.9	42.0	57.7	30.5	-‡	-
11. SR T-90	21.6	39.8	29.1	9.7	18.6	34.8	43.7	57.4	25.4	2.3	34.8
12. SR AS	37.5	41.7	29.8	10.0	26.1	34.5	45.0	58.8	30.1	25.1	43.0
13. S. Bcst ES-AS	33.3	40.7	29.3	12.9	14.7	39.1	41.2	58.0	29.2	22.5	37.7
Contrast											
Ck vs AS	0.0001	NS	NS	0.0001	0.0001	NS	NS	NS	0.0001	0.0001	NS
Ck vs ATS	0.0002	NS	NS	0.0001	0.0001	NS	NS	NS	0.0001	0.0001	NS
Ck vs T-90	NS	NS	NS	NS	0.0046	NS	NS	NS	0.0001	NS	NS
ES vs T-90	NS	NS	NS	NS	0.0031	NS	NS	NS	NS	NS	NS
T-90: Bcst vs SR	NS	NS	NS	NS	0.0496	NS	NS	NS	0.0001	NS	NS
AS: Bcst vs SR	NS	0.0382	NS	0.0010	NS	NS	NS	NS	NS	0.0074	NS
AS: Bcst vs Bd	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.0001	NS
T-90 vs AS	0.0001	NS	0.0100	0.0001	0.0002	NS	NS	NS	NS	0.0001	0.0017
AS vs ATS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV	23	9	10	36	33	11	10	7	15	33	14

† See materials and methods for details on sulphur treatments.

‡ Treatment not included due to seeding error in 1998