# Sulphur for Wheat Protein

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**Abstract**

The effectiveness of supplementing Sulphur (S) to Canada west red spring (CWRS) and Durum wheat to increased grain protein levels was assessed in a three-year 10 trial experiment. Five rates of N (0, 36, 54, 72 and 90 lb/acre) and two rates of S (0 and 22 lb S/acre) were arranged in a complete randomized block design with either four or six replicates. Soils at the sites varied from S deficient to S sufficient, based on criteria utilized in western Canada. Application of 22 lb S/acre resulted in no yield increases; a protein content increase was obtained in a soil that contained extremely low S levels in the 0-12 inch depth. Protein content in the grain was directly related to N fertilization and growing season (May, June, July) precipitation. Hence, deliberate and indiscriminate application of S to increase protein in CWRS and Durum wheat grain is not a recommended practice, unless S deficiency is corrected in which case an indirect benefit of increased grain protein might ensue.

**Introduction**

The need of proper sulphur (S) fertilization of wheat on S deficient soils in western Canada was established in the sixties (Bentley et al. 1960; Nyborg 1968). Further, milling and baking quality of wheat appears to be closely associated with a optimum balance between sulphur and nitrogen, since sulphur is both a building block for proteins and enzymes and S-containing amino acids are important in forming the high-quality glutenins and gliadins (Alberta Agriculture, Food and Rural Development, 2006; Zhao et al. 1999a,b). Malhi et al. (2009) found no effect of timing of S application on seed yield and protein concentration in any year of a long-term rotation, except that fall application was superior to the spring one for straw yield and S uptake in the first year of the experiment, and for seed total S concentration and S uptake in the second year. Protein concentration in seed was not consistently affected by S fertilizers or by S rates and application times in any year. Flaten (2004) described a comprehensive study by the University of Manitoba, which showed that analysis of grain samples for total S, N, and N:S ratio accurately predicted the concentration of S, N, and N:S ratio in flour of CWRS wheat and that application of S fertilizer is likely to benefit the bread making quality of CWRS wheat grown in western Canada, wherever soil S is marginal to deficient for wheat yield. Sulphur fertilization significantly increased grain S concentration at six of twelve sites. Loaf volume was significantly improved at two of seven sites, with four more sites demonstrating slight improvements, when S fertilizer was applied. Sulphur fertilization also improved dough extensibility at six of seven sites (four significantly). Finally, S fertilization resulted in occasional increases in grain yield for CWRS wheat, where S concentrations in conventional $SO_4$-S tests indicate adequate supplies of soil S.

Grant et al. (2004) found that in contrast to canola, sulphur fertilization did not increase wheat yield, even when soil sulphate was low.

The objective of this study was to ascertain whether application of S under a variety of agroecological conditions had an impact on the grain protein content on CWRS and Durum wheat.

**Materials and Methods**

Ten trials in the experiment were carried out between 1998 and 2000 at 10 sites in Alberta and Saskatchewan (Table 1). Treatments were arranged in a randomized complete block design (RCBD) and included a combination of five rates of N (0, 36, 54, 72 and 90 lb/acre) and two rates of S (0 and 22 lb/acre) that were replicated four or six times. Nitrogen (46-0-0 plus 20-0-0-24) and S (20-0-0-24)treatments were side-banded 1-inch to the side and 1-inch below the seed at seeding time. CWRS or Durum wheat was seeded at rates ranging from 308 to 352 seeds $m^{-2}$ depending on cultivar and the seeding implement, which was either an air-seeder equipped with 3/4 -inch knives and shanks spaced 9 inches apart or a double disk drill with shanks spaced 7 inches apart (Table 1). Phosphorus (0-50-0) was applied with the seed at a blanket rate of 27 lb $P_2O_5$/acre to all treatments.

Table 1. Experimental design[1] parameters of each trial.

| Location | Previous Crop | Crop | Cultivar | Seeding date | Harvest date | Plot Length (m) |
|---|---|---|---|---|---|---|
| Enchant[2] | Beets | Durum | Malita | Apr 24 | Aug 11 | 7.6 |
| Airdrie[3] | Barley | Wheat | Roblin | May 13 | Sep 2 | 7.0 |
| Irricana - A | Barley | Wheat | Mckenzie | Apr 29 | Aug 14 | 3.3 |
| Carstairs[3] | Canola | Wheat | Roblin | May 20 | Aug 25 | 3.0 |
| Red Deer | Pea | Wheat | AC Barrie | May 15 | Aug 24 | 7.6 |
| Ft. Saskatchewan | Barley | Wheat | Mckenzie | May 6 | Aug 25 | 7.6 |
| Swift Current – A[2] | Wheat | Durum | Malita | May 21 | Aug 27 | 7.6 |
| Swift Current - B | Fallow | Durum | Malita | May 21 | Aug 27 | 7.6 |
| Lamont | Canola | Wheat | Mckenzie | May 27 | Sep 14 | 7.6 |
| Irricana - B | Barley | Wheat | AC Barrie | Apr 27 | Aug 25 | 7.6 |

[1] RCBD = Randomized complete block design. [2] Experiment with four replicates. [3] Experiments with 7-inch row spacing

Composite soil samples from 0-6, 6-12, and 12-24 inch depth were collected from each site prior to establishing a trial and were submitted to a soil testing laboratory for routine analysis, including available N and S (Table 2). A rain gauge was installed at each site and was monitored regularly. Readings were compiled on a monthly basis until harvest. Soil water content at seeding time, May, June and July precipitation and a threshold value of water that is required before a base yield for a crop is established (Karamanos and Henry 2007) are compiled in Table 3. Six rows of varying length (Table 1) were harvested from each plot using a Wintersteiger Nurserymaster Elite combine and the grain samples were dried at 60°C by forced air and weighed to determine grain yield. Grain yield per plot was calculated with moisture content corrected to 13.5 %. Percentage protein was estimated by multiplying N in a Kjeldahl digest with 5.7.

Table 2. Soil properties of experimental sites.

| Site | Depth (inches) | OM (%) | Texture | pH | EC (mS cm$^{-1}$) | $NO_3$ - N | P | K | $SO_4$ - S | Cl |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (lb/acre) | | | | |
| Enchant | 0-6 | 2.3 | L | 8.0 | 1.6 | 5 | 39 | 536+ | 48+ | 40 |
| | 6-12 | | L | 7.9 | 3.2 | 5 | | | 48+ | 40 |
| | 12-24 | | L | 8.2 | 3.7 | 7 | | | 96+ | 72 |
| Airdrie | 0-6 | 6.4 | L | 7.7 | 0.7 | 33 | 10 | 316 | 5 | 17 |
| | 6-12 | | CL | 8.3 | 0.4 | 21 | | | 4 | 12 |
| | 12-24 | | C | 8.1 | 0.4 | 48 | | | 6 | 23 |
| Irricana - A | 0-6 | 4.6 | CL | 7.2 | 0.9 | 17 | 12 | 421 | 24 | 12 |
| | 6-12 | | L | 8.0 | 0.7 | 11 | | | 29 | 12 |
| | 12-24 | | CL | 8.2 | 6.6 | 8 | | | 86+ | 22 |
| Carstairs | 0-6 | 5.7 | L | 6.3 | 0.2 | 9 | 27 | 479 | 12 | 9 |
| | 6-12 | | CL | 7.0 | 0.2 | 4 | | | 8 | 6 |
| | 12-24 | | CL | 7.8 | 0.7 | 11 | | | 21 | 22 |
| Ft. Saskatchewan | 0-6 | 10.7 | L | 6.6 | 0.5 | 16 | 13 | 312 | 6 | 21 |
| | 6-12 | | C | 7.4 | 0.4 | 11 | | | 4 | 19 |
| | 12-24 | | C | 7.8 | 0.6 | 25 | | | 23 | 39 |
| Red Deer | 0-6 | 9.8 | C | 7.6 | 0.4 | 25 | 4 | 362 | 5 | 15 |
| | 6-12 | | C | 7.7 | 0.4 | 16 | | | 2 | 7 |
| | 12-24 | | C | 8.0 | 0.4 | 14 | | | 55 | 6 |
| Swift Current-A | 0-6 | 2.3 | L | 6.7 | 0.5 | 45 | 25 | 379 | 5 | 4 |
| | 6-12 | | L | 7.9 | 0.5 | 20 | | | 5 | 3 |
| | 12-24 | | L | 8.4 | 0.2 | 21 | | | 9 | 5 |
| Swift Current-B | 0-6 | 2.3 | L | 6.7 | 0.5 | 20 | 31 | 364 | 5 | 12 |
| | 6-12 | | L | 7.9 | 0.5 | 8 | | | 5 | 8 |
| | 12-24 | | L | 8.4 | 0.2 | 12 | | | 9 | 12 |
| Lamont | 0-6 | 4.5 | L | 6.8 | 0.5 | 29 | 21 | 104 | 37 | 12 |
| | 6-12 | | L | 8.4 | 1.4 | 26 | | | 48+ | 18 |
| | 12-24 | | L | 8.0 | 6.2 | 19 | | | 96+ | 22 |
| Irricana - B | 0-6 | 3.6 | CL | 6.3 | 0.4 | 8 | 26 | 482 | 13 | 20 |
| | 6-12 | | C | 7.4 | 0.6 | 3 | | | 18 | 11 |
| | 12-24 | | C | 7.7 | 1.3 | 14 | | | 74 | 20 |

Grain yield and uptake from individual trials were subjected to ANOVA for a randomized complete block using SYSTAT 8.0 (SPSS 1998) and effects were separated via orthogonal contrasts to find differences at significance levels of $P<0.10$, 0.05, and 0.01. Combined analysis for all experiments was carried out based on the analysis of a series of experiments described by Cochran and Cox (1992) considering that all effects were fixed.

**Results and Discussion**

Wheat yield in the 10 trials ranged from 14.3 to 83.9 bu/acre with an overall average of 52.7 bu/acre. Both average and maximum yield at each trial site were directly related to water use as defined by Karamanos and Henry (2007), i.e., soil water at seeding time plus May, June and July (growing season) precipitation minus a threshold value for the agroecological zone (Fig. 1); almost 70 percent of the average yield could be explained by the May, June and July precipitation alone. There was a highly significant (P<0.01) response of wheat grain yield to fertilization with both N and S fertilizers (Fig. 2) and response to N was significant in 8 of the 10 trials.

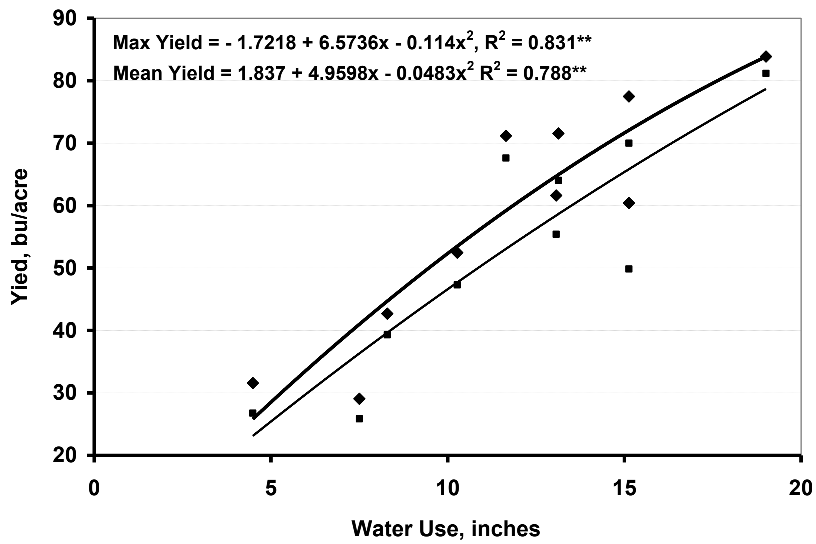


Figure 1. Relationship between average yield of all fertilizer treatments per trial and water use {spring soil moisture plus May, June July precipitation minus a threshold value as defined by Karamanos and Henry (2007)}.

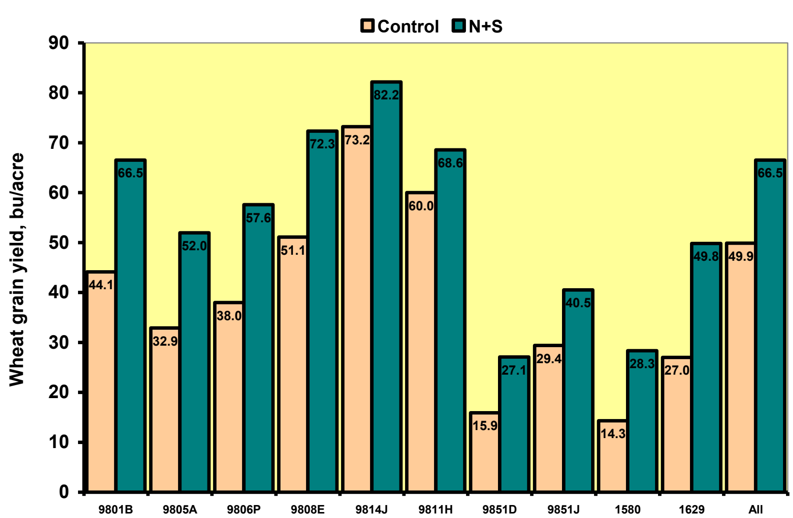


Figure 1. Response of wheat grain yield to fertilizer (nitrogen plus sulphur) application.

Karamanos (1996) suggested that only the 0-12 inch depth is utilized for S recommendations due to the extreme variability of this nutrient in the 12-24 inch depth that is normally associated with the presence of gypsum crystals in that depth that can be dissolved in the extractants used to determine $SO_4$-S, but may not be accessible by plant roots. The criteria developed for cereals using that depth ranged between 5 and 10 lb $SO_4$-S/acre depending on agroecological zones in western Canada (Meyers and Karamanos 1997). This would result in three sites (Aidrie Swift Current and Red Deer) being characterized as deficient. However, in none of the sites characterized as deficient was there a response of wheat grain yield to S fertilization (Fig. 3). Hence, three possible explanations may be derived, namely, either that S requirements for CWRS and Durum wheat in western Canadian soils can be limited, or that the applied rate of 22 lb $SO_4$-S/acre was not sufficient to correct S deficiency, or criteria based on $SO_4$-S levels are inadequate.

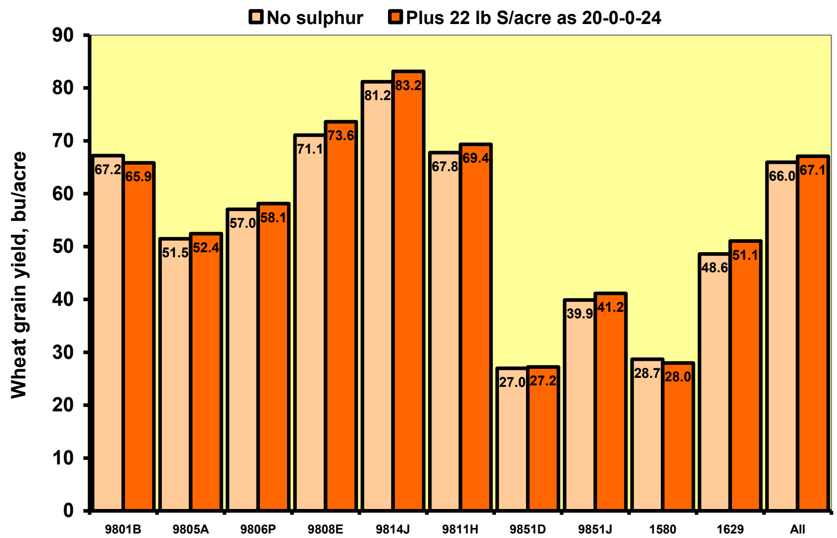


Figure 3. Response of wheat grain yield to sulphur fertilizer application.

Protein content in the wheat grain ranged from 8.8 to 15.7%. In contrast to grain yield, the relationship between protein content and water use was inverse and relatively weak (significant at $P<0.1$) but was very strongly ($P<0.5$) related to May, June and July precipitation (Fig. 4), thus suggesting that May, June and July precipitation played a pivotal role in determining the final protein content in wheat grain. Sulphur appeared to contribute little to the final protein content, as significant effects were obtained at the Red Deer only, the soil of which was S deficient. Overall, protein content was directly related to N application rate (Fig. 5). Considering that routine protein assay is based on determination of organic N by kjeldahl digestion and subsequent multiplication by 5.7 to convert it % protein in wheat grain, the relationship in Fig. 5 is not surprising. Further, any benefit arising form S application can only ensue as a result of N×S interaction or increased N uptake when S deficiency is corrected by S application. Hence, benefits obtained in the Red Deer site can be attributed to the latter, although no yield benefit was obtained at that site.

An interesting trend emerged when maximum yield and the corresponding protein content were plotted against May, June and July precipitation in ascending order (Fig. 6); when May, June and July precipitation was approximately 8 inches or less, protein content was approximately 15.0%, whereas at precipitation above 8 inches approximately 12.0%. Sulphur had no impact in all but one sites. The relationship between protein content and N rate and the corresponding wheat grain yield combined with that of % protein and water use clearly suggests that the protein content is influenced primarily by growing season precipitation.

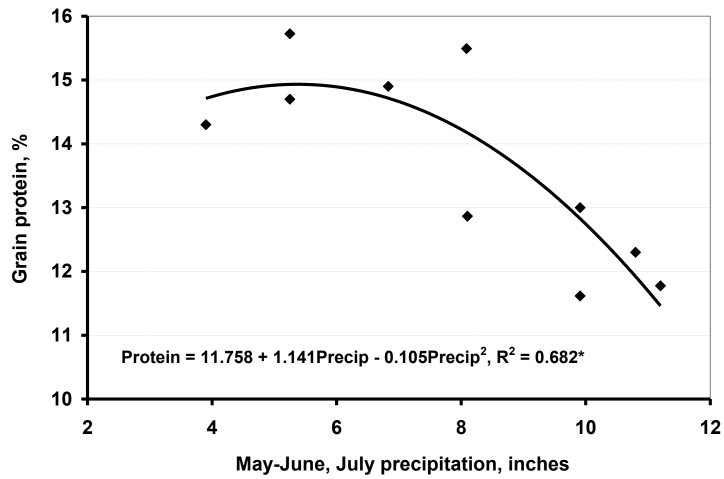


Figure 4. Relationship between grain wheat protein and growing season precipitation.

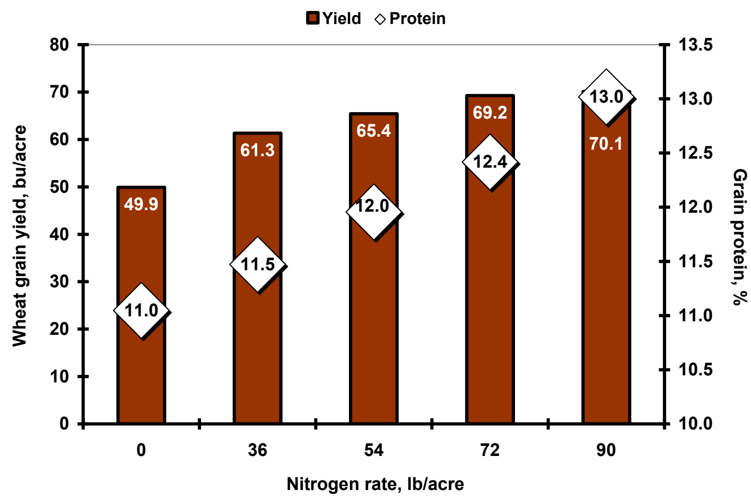


Figure 5. Average grain yield and protein content of all sites in this experiment.

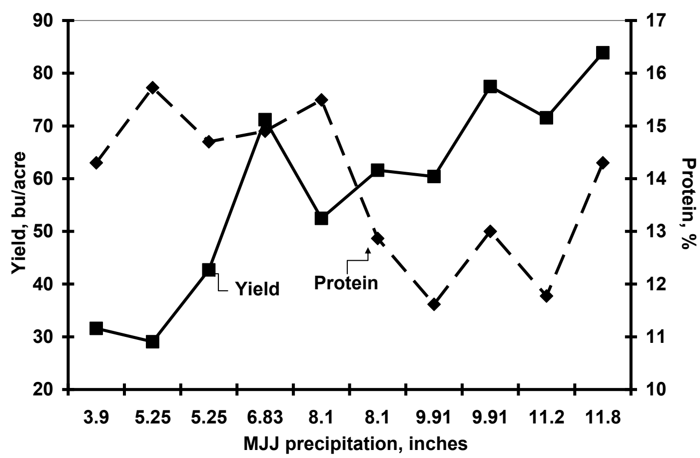


Figure 6. Interrelationship between grain protein and yield based on total growing season precipitation at each of the experimental sites.

## Conclusion

Application of S to CWRS and Durum grown under diverse agroecological conditions and on soils with a range of $SO_4$-S levels in the 0-24 inch depth did not influence protein content of wheat grain in nine of the ten cases included in this study. The only increase was observed in wheat grown on the only soil with less than 8 lb $SO_4$-S/acre in the 0-12 inch depth.

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