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RESEARCH ARTICLE

Yield and Quality Response of Canola to Seed Row and Side Banded Ammonium Sulfate and Ammonium Thiosulfate

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ABSTRACT

Ammonium sulfate (AMS) and ammonium thiosulfate (ATS) are two of the most common sulfur products applied during canola seeding in the Canadian Prairies. A better understanding of how application methods affect the efficiency of these products is warranted. A field trial was conducted on a clay loam soil in Pense, Saskatchewan to evaluate the effect of seed row and side banded sulfur applications on canola yield and quality. Plots received 34 kg ha^{-1} sulfur either from AMS or ATS applied during seeding either in the seed row (SR) or side banded (SB). A treatment without sulfur was included as a control. All plots received the same amounts of all other nutrients. Results showed that average seed yields increased for all sulfur-treated plots, however, only side banded applications (AMS(SB): 4020 kg ha^{-1}, ATS (SB): 3883 kg ha^{-1}) were significantly better than the control (3072 kg ha^{-1}). Side banded sulfur applications generally produced more protein than seed row applications and were significantly different from the control. AMS (SB) had the highest protein content (21.07%) while the control had the least (18.13%). Oil content was similar except for AMS (SB) (46.72%) which was significantly lower than the control (48.68%). However, this oil difference was more than compensated by the increased yield from AMS (SB). Applying AMS and ATS in the seed row can decrease the yield and protein response that might otherwise be seen when these products are side banded. There were no significant differences in the measured parameters between AMS and ATS.

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Introduction

Canola (*Brassica napus* L.) is considered Canada's most valuable crop because of its immense contributions to the Canadian economy (Bandara et al., 2018). Canola seeds are processed into oil and meal, which are then used to manufacture a wide variety of products. It is also desirable as a feedstock for biodiesel production (Blackshaw et al., 2011).

Canola production typically requires more plant nutrients than cereals (Rathke et al., 2005), and sulfur is one of its key nutrients. Compared to cereals, canola has a high sulfur demand and is particularly sensitive to sulfur deficiency (Urton et al., 2018). Pods per plant and biological yield has been found to increase with increase in sulfur level (Ahmad et al., 2011). In the Canadian Prairies, sulfur is the third most limiting nutrient, after nitrogen and phosphorus (Grant et al., 2004; Malhi et al., 2005). Sulfur deficiencies in Prairie soils are becoming increasingly common because of higher crop yields and reduction of atmospheric deposition of sulfur compounds (Grant et al., 2004). The spatial variability of sulfur in a field (Piotrowska-Długosz et al., 2017; Behera et al., 2021) has often meant that soil sulfur test results of composite soil sampling may not be reliable in making sulfur fertilizer recommendations for an entire field.

Ammonium sulfate (AMS) and ammonium thiosulfate (ATS) are two of the most common sulfur products used by canola farmers. Ammonium sulfate is especially useful where both nitrogen and sulfur are needed, because of its higher

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nitrogen concentration. Because all the sulfur in AMS is in the plant-available sulfate form, AMS is also desirable where immediate sulfur availability is required. In ammonium thiosulfate only a portion of its sulfur becomes immediately available when applied to the soil (Malhi et al., 2005), while the remainder has to be converted to plant-available sulfate by bacteria. Ammonium thiosulfate may therefore be beneficial in situations where the slow release of sulfur is desired to continue supplying sulfur to plants during the growing season. This is especially advantageous in situations where sulfate is not adequately adsorbed onto organic matter and clay particles and is therefore, vulnerable to leaching. However, this slow-release nature of ammonium thiosulfate may also be detrimental when, because of unfavourable soil and weather conditions, the elemental sulfur portion does not convert quickly enough to plant-available sulfate when plants need sulfur. Because sulfur oxidation is mainly due to microbiological processes, the rate of conversion of elemental S to sulfate is influenced by factors such as soil moisture, aeration, pH and temperature (Germida & Janzen, 1993).

Ammonium thiosulfate may also improve nitrogen use efficiency because it can delay urea hydrolysis (Sullivan & Havlin, 1992) thereby reducing ammonia volatilization. It has also been found to slow down the rate of nitrification (Gezerman, 2019) thereby reducing the loss of nitrogen through nitrate leaching. However, these inhibitory capabilities are not as effective as commercially available products, such as NBPT, designed specifically for that purpose (McCarty et al., 1990).

Seed placement and side banding are two methods that farmers can use when applying fertilizers during spring seeding. Seed placement gives newly emerged seedlings early access to the applied nutrients and is especially beneficial for those nutrients that are less mobile in the soil (Qian et al., 2012). However, seed placement can inhibit seed germination and crop emergence because of the salt toxicity of fertilizers. Malhi et al. (2005) noted that the effectiveness sulfur placement method depends on the form of sulfur in the product (Sulfate-S or Elemental-S) as well as soil and weather conditions.

The aim of this study was to determine the effect of method of application on the efficiency of ammonium sulfate and ammonium thiosulfate in improving canola yield and quality in the year of application.

Materials and Methods

Trial Establishment

The trial was conducted in Pense, Saskatchewan, Canada (50°23'54.1"N 105°03'07.6"W) in 2020. Total rainfall received during the 2020 growing months of May to August was 135 mm. The 30-year rainfall average in this area for these months is 197 mm. Maximum daily temperatures for this period ranged from 19.9 °C in May to 38.5 °C in August. The soil is a clay loam (pH: 8.5). Wheat had been grown on this field during the previous season.

In early Spring, an area of the field was marked out into plots consisting of six 6 m-long rows with 25 cm row spacing. Plots were clearly identified with plot stakes. The plots and trial area were separated sufficiently by distance and buffer crop to prevent drift and damage while conducting assessments.

Three soil samples (0-15 cm) were taken per plot, bulked into one sample per plot (making a total of 15 composite samples for the trial site) and analyzed for soil properties. The soil characteristics of the experimental site are listed in Table 1.

Table 1. Some soil properties of the experimental site before application of treatments

Parameter	Mean
pH (water)	8.5
OM (%)	3.8
CEC (meq $100g^{-1}$)	40.7
Nitrate (ppm)	23
P (Olsen) ppm	13
K (ppm)	558
S (ppm)	17
Mg (ppm)	1337
Ca (ppm)	7120
Zn (ppm)	2.6
Fe (ppm)	109
Cu (ppm)	5.2
B (ppm)	1.6
Al (ppm)	483
Mn (ppm)	170
Silt (%)	49.48
Clay (%)	34.08
Sand (%)	16.44
EC (1:1) dS m^{-1}	1.1

Experimental Layout and Treatments

The trial was setup in a randomized complete block design (RCBD) with five treatments and three replicates. Two sulfur products (Ammonium sulfate (AMS) and Ammonium thiosulfate (ATS)) were used in the trial. These were applied during seeding either in the seed row (SR) or side banded (SB). A treatment without sulfur was included as a control. The treatment list is shown in Table 2.

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Table 2. Treatment list

ID	Sulfur Treatments	Rate of Sulfur Application (kg ha^{-1})	Product Rate (kg ha^{-1})	Method of Application	Nutrient Analysis (% wt.)			
					N	P_2O_5	K_2O	S
1	No S (Control)	None	None	N/A	-	-	-	-
2	Ammonium sulfate (AMS)	34	140	Seed row (SR)	21	0	0	24
3	Ammonium thiosulfate (ATS)	34	129	Seed row (SR)	12	0	0	26
4	Ammonium sulfate (AMS)	34	140	Side banding (SB)	21	0	0	24
5	Ammonium thiosulfate (ATS)	34	129	Side banding (SB)	12	0	0	26

Seeding and Product Application

Canola (L233P) was seeded 18 May 2020 at a seeding rate of 6 kg ha^{-1}, depth of 1 inch (2.5 cm) and operating speed of 2 mph using a small plot SeedMaster drill. At seeding, fifty-six (56) kg ha^{-1} phosphorus (MAP: 11-52-0) was side banded, and nitrogen (urea: 46-0-0) was side banded to achieve a rate of 56 kg ha^{-1} of N (adjusting for the N contents of AMS, ATS and MAP). Seventy-eight (78) kg ha^{-1} of N had been applied in the fall. Thirty-four (34) kg ha^{-1} of S (either from AMS or ATS) were applied either side banded 0.75 inch (1.9 cm) below and away from the seed row, or directly with the seed in the seed row. No sulfur was applied to the control plots.

Trial Maintenance and Monitoring

Three weeks after planting, when the plants were at 2-3 leaf stage, plant stand counts were taken using a hula hoop. Three counts (top, middle and bottom) were done per plot and averaged. Because of pressure from volunteer wheat, an herbicide application of 4 L ha^{-1} Liberty and 0.19 L ha^{-1} Centurion was sprayed on 23 June using a handboom. Fungicide Lance WDG (350 g ha^{-1}) and Boron 10% (1.2 L ha^{-1}) were applied on 12 July as a precaution for *Sclerotinia*, and to add Boron. Tissue sampling was done in July and August and samples were analyzed for nutrient content following standard laboratory procedures.

Harvesting

Plots were harvested on 10 September 2020 using a Wintersteiger small plot combine with a HarvestMaster Classic GrainGage to collect yield data. Moisture content at harvest was determined and yield adjusted accordingly to provide dry yield. Protein and oil contents in seed were determined using near infrared spectroscopy (Prem et al., 2012). Thousand seed weight (TSW) was determined by counting and weighing seeds. Yield and quality data were analyzed using ANOVA and differences separated using a Tukey test.

Results and Discussion

Plant Count

The effect of the treatments on plant count is shown in Figure 1. The data show a numerical reduction of plant count when AMS and ATS were applied in the seed row compared to the control or when these products were applied side banded. This is attributed to the increased contact of product with seed when applied in the seed row, which leads to higher salt toxicity effect of the sulfur products (Qian et al., 2012). These sulfur products have high salt indexes and when applied to calcareous soils such as this, can produce significant amounts of ammonia resulting to ammonia toxicity and osmotic damage (Grant et al., 2004).

Plant count for side banded ATS was significantly higher than plant count for seed row applied AMS and ATS. This difference in plant population may, however, not affect final yield because canola naturally compensates for variations in plant population over relatively wide plant population ranges, with very little effect on final yield (Angadi et al., 2003).

Nutrient Uptake

Sulfur application numerically increased nitrogen uptake both in the July sampling and the August sampling (Figure 2). However, differences between treatments were not statistically significant. Increase in N uptake as a result of sulfur application has been reported by several authors such as Urton et al. (2018). Our data did not identify any other notable nutrient uptake trend at the two sampling times. The lower nitrogen content in August compared to July support the observation that in general, nitrogen concentrations in plant tissue decrease with age (Sedberry et al., 1987). This decline is attributed to a dilution effect because during aging, the plant biomass increases comparably more than the nutrient accumulation (van Maarschalkerweerd & Husted, 2015).

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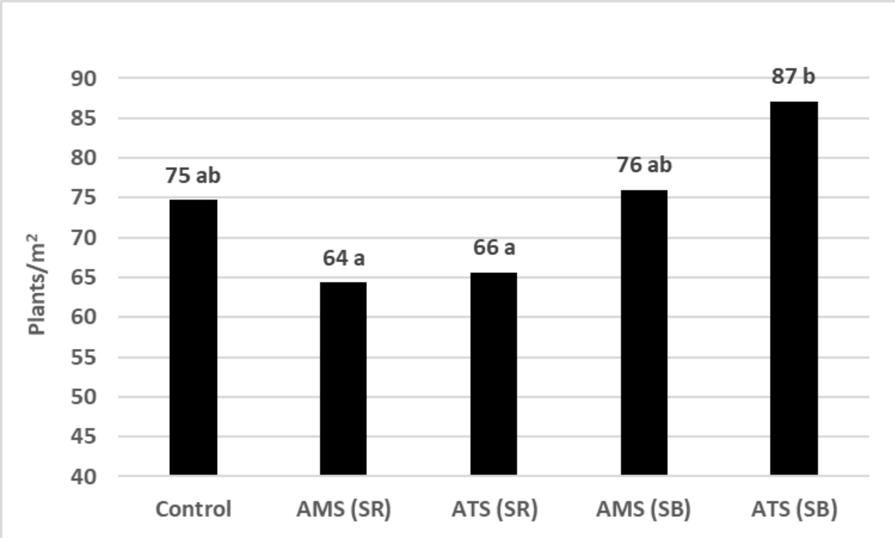

Figure 1. Effect of seed row (SR) and side banded (SB) sulfur products on canola plant count 3 weeks after planting. Means with the same letter are not significantly different from each other (p<0.05).

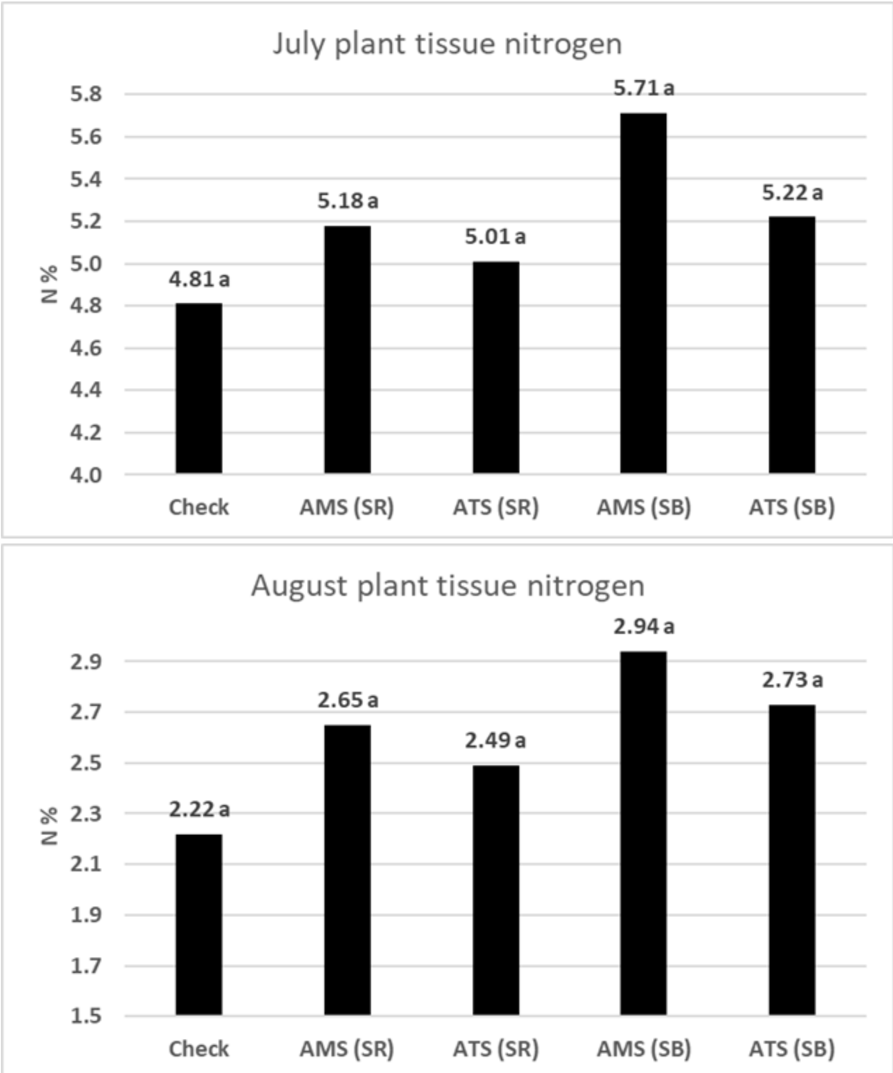

Figure 2. Effect of seed row (SR) and side banded (SB) sulfur products on nitrogen content of canola tissue. Means with the same letter are not significantly different from each other (p<0.05).

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Yield

Average yield from sulfur-treated plots were higher than the control, highlighting the usefulness of sulfur in canola production even when soil tests do not identify serious sulfur deficiency (Figure 3). Because sulfur is immobile in plants, its deficiency at any growth stage can cause a reduction in seed yield (Malhi & Gill, 2002). Grant et al. (2004) found that ammonium sulfate and ammonium thiosulfate were effective sulfur sources to enhance crop growth in the year of application.

Side-banded sulfur produced higher average yields than seed row application. Only side banded treatments were significantly different from the control ($p<0.05$). This trend agrees with Malhi and Gill (2002) who from a study on six sites across Northern Saskatchewan reported that 30 kg S ha^{-1} applied side-banded produced on average, a higher seed yield (1068 kg ha^{-1}) than seed row treatments (915 kg ha^{-1}).

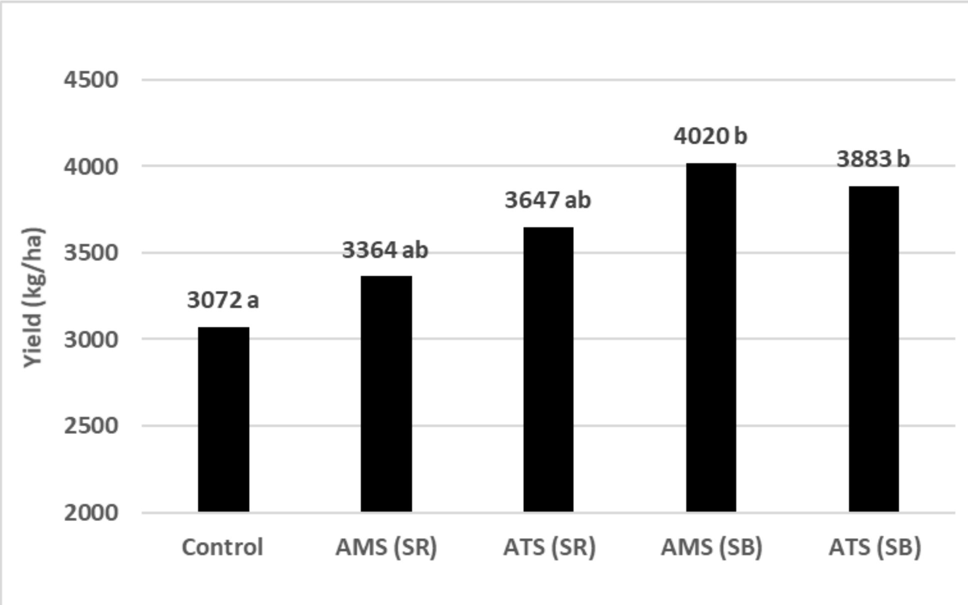

Figure 3. Effect of seed row (SR) and side banded (SB) sulfur products on canola yield. Means with the same letter are not significantly different from each other ($p<0.05$).

Oil, Protein Content and Thousand Seed Weight

Effect of treatments on oil, protein content and thousand seed weight (TSW) are shown in Figure 4.

The control had the highest average oil content although it was only significantly different ($p<0.05$) from AMS (SB). Effect of sulfur on canola oil has been varied with studies reporting either an increase (e.g., Grant et al., 2003; Govahi & Saffari, 2006; Ahmad et al., 2011), or a decrease (e.g., Wetter et al., 1970). However, even where there is a decrease in percent oil content, total oil yield per hectare will be increased because of the increase in seed yield (Wetter et al., 1970).

Sulfur application resulted to an increase in protein content. The control had the lowest protein content and was significantly different from all other treatments except ATS (SR). These results are useful considering the growing importance of canola as a desirable source of plant protein for both livestock and human consumption (Campbell et al., 2016). Other studies have also reported increase in seed protein content as a result of sulfur application (e.g., Malhi & Gill, 2006; Ahmad et al., 2007).

Although not statistically significant, there was an average increase in thousand seed weight (TSW) for sulfur applications (except when AMS was applied in the seed row). Ahmad et al. (2011) found significant increases in seed weight for sulfur level up to 40 kg ha^{-1}. Govahi and Saffari (2006) also found that TSW increased with increasing levels of sulfur application. Larger seeds have been shown to produce more vigorous plants and higher yields. For example, Elliott et al. (2008) found that compared with small seeds, large seeds improved seedling establishment, shoot weight, biomass and yield.

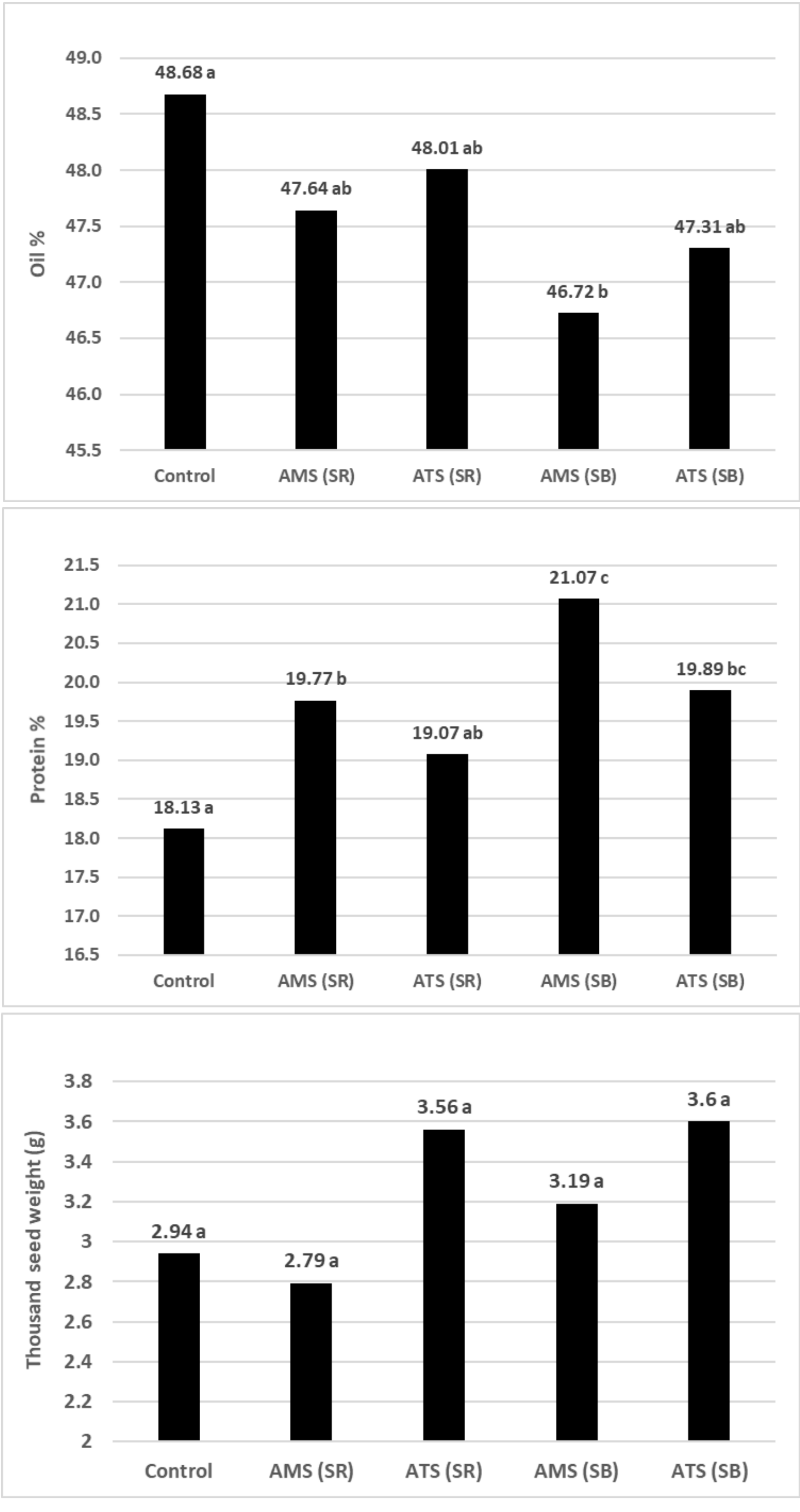

Figure 4. Effect of seed row (SR) and side banded (SB) sulfur products on canola thousand seed weight, oil, and protein content. Means with the same letter are not significantly different from each other ($p<0.05$).

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Conclusion

This study sought to determine how method of sulfur application affects canola yield and quality, and to understand how two sulfur products (ammonium sulfate and ammonium thiosulfate) differ in their effect in the year of application. Results showed that side banding these products provided better yield and protein improvements than applying them in the seed row. Results also showed that there were no significant differences between AMS and ATS under the conditions of this study for any of the parameters evaluated.

Conflict of Interest

The authors declare that they have no conflict of interest.

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