YIELD AND UPTAKE OF N AND S BY CANOLA AND WHEAT IN THE GROWTH CHAMBER AS INFLUENCED BY N AND S SUPPLY FROM SOIL AND FERTILIZER

P. Qian, J. J. Schoenau and K. J. Greer
Department of Soil Science
University of Saskatchewan

W. Wu
Institute of Soil Science
Jilin Academy of Agricultural Science
P. R. China

Introduction

A balanced soil N and S supply is imperative for crops since both nutrients are required for protein synthesis [9,11]. Sulfur fertilization is becoming a more and more important consideration with increasing rates of N application for higher yield and better quality [1,2]. This is particularly true if the crop has a high S demand, like canola.

Several studies have shown that an N:S ratio of between 9 to 16 in the plant tissue is required by various crops to achieve optimum plant growth [2,3,4,7,10,11,12]. An inadequate ratio of N and S supplied by soil will lead to one nutrient, either N or S, becoming the limiting factor for plant growth [1,6,15]. The objectives of this study were: 1) to evaluate the effect of N and S fertilization on yield and uptake of N and S in the growth chamber by two major Saskatchewan crops: canola and Canadian prairie spring (CPS) wheat and 2) to determine the N:S ratio in the two crops as a function of N and S fertilization and its relationship with N and S soil supply as predicted through assessment of soil available N:S ratio.

Materials and Methods

Growth Chamber Study

Three Saskatchewan soils were selected for a growth chamber study: a Waitville association (Luvisolic) soil of low available S content, and an Ardill (Brown) and Meota (Black) association soil of low available N and S. The chemical properties are shown in Table 1.

Table 1 Physical and chemical properties of the soils tested

Soils	NO_3-N	SO_4-S	N:S ratio	P	K	Organic C	pH	E.C.
	$CaCl_2$ extractable			$NaHCO_3$ extractable				
	--------ug/g--------			--------ug/g ----		%		ds/m
Waitville	12.6	1.0	12.6	1.1	228	1.60	5.5	0.11
Ardill	4.2	2.7	1.6	3.2	190	0.64	7.8	0.15
Meota	2.2	3.0	0.7	3.1	203	2.10	8.5	0.10

The bulk surface soil samples (O-20 cm) were air-dried and screened (2 mm) after removed from the field. Different rates of N and S, along with basal nutrients which included P, K, and micronutrient application (Tables 2 & 3) were mixed with 5 Kg of soil. After application of the various rates of N and S fertilizer, soils were equilibrated for 48 hours (80% of field capacity) and then were air-dried for 1 week at room temperature. Then 1.6 Kg of soil was placed in 1 L plastic pot, wetted to field capacity with deionized water and seeded. Each treatment was prepared in triplicate.

Table 2 Rates of N and S application used in the growth chamber study for the three soils selected¶

Waitville		Ardill		Meota	
N	S	N	S	N	S
---------------------------------- ug/g -----------------------------------					
0	0	0	0	0	0
320	0	0	20	0	40
320	40	200	20	200	40
320	80	400	20	320	0
				320	20
				320	40
				320	80

¶ N source is NH_4NO_3 (Ammonium nitrate) and S source is Na_2SO_4 (sodium sulphate)

Two crops were used in this study: canola ***(Brassica campestris var. Profit)*** and wheat (Canada prairie spring wheat var. ***Biggar).*** Ten seeds of canola and 12 seeds of wheat were planted in each pot. After emergence, the seedlings were thinned to 3 per pot for canola and 6 per pot for wheat.

During the growing period, deionized water was added to soil as needed and the temperatures were maintained at 24°C daytime and 16°C at night. Plants were harvested after ***35 days*** of growth for the Waitville soil and Ardill soil and after 44 days of growth for the Meota soil. At this point, the tops were removed and the roots removed from the soil by rinsing. The roots and tops were dried separately at 60°C until dry, and dry matter weights recorded. The plant samples were then ground through a l-mm stainless steel screen and stored for chemical analyses.

Table 3 Amount and chemical composition of the basal nutrients added

Nutrient element	Amount of element	Chemical source used
	----- ug/g ------	
P	90.0	$Ca(H_2PO_4)_2 \cdot 2H_2O$
K	180.0	KCl
Mg	10.0	$MgCl_2.6H_2O$
Zn	4.0	$ZnCl_2$
Mn	5.0	$MnCl_2.4H_2O$
Cu	0.6	$CuCl_2.H_2O$
Mo	0.6	$Na_2Mo_4 \cdot 2H_2O$
B	1.5	H_3BO_3

Chemical Analyses

Soils: Soil organic C was determined using a Leco C analyzer. Soil pH and electric conductivity were measured on a 1:5 soil-water suspension. Available P and K were extracted using 0.5 M NaHC03 solution, and measured by colorimetry and flame photometry, respectively. Available N and S were extracted using 0.001 M CaC12 solution and after fertilization using anion exchange membrane (AEM) burial. Anion exchange membrane (in HCO_3^- form) encapsulated in plastic applicators were inserted into field moist samples one week after fertilizer treatments were added to the soil for 1 hour (8).

Plants: Plant tops and roots were analyzed for total N and total S. Total N was determined by digestion of plant tissue in sulfuric acid-peroxide to convert all organic N to NH4 using a temperature-controlled digestion block [14], followed by colorimetric measurement. Total S was determined by digesting plant tissue with sodium hypobromide [13], followed by inductively coupled plasma emission spectrometric measurement.

Results and Discussion

Effects of added N and S fertilizer on soil available N:S ratio

The changes in available NO_3-N and SO_4-S in soil after fertilization are reflected in the ratio of sorbed NO_3^- and SO_4^{2-} on buried AEM (Tables 4,5 and 6). The addition of high rates of N without S (320 N-OS) gave rise to very high ratios of available N to S on the resin strip after 1 hour burial. Resin strip burial in the field after fertilization may be useful as a quick check on the suitability of the balance of available nutrients, particularly if some event has occurred in the field since fertilizer application which may have disrupted the balance.

Table 4 Relative N and S availability as determined by AEM burial in Waitville soil after fertilization

Addition of		Nutrient sorbed on AEM		N:S ratio	
N	S	NO_3-N	SO_4-S	AEM	calculated9
---------- ug/cm^2 ----------					
0	0	5.1	0.19	27.1	12.6
320	0	50.9	0.16	318.0	333.0
320	40	68.7	5.31	12.9	8.1
320	80	58.4	6.11	9.6	4.1

§ N:S ratio calculated from sulfate and nitrate initially present in soil plus added fertilizer.

Table 5 Relative N and S availability as determined by AEM burial in Ardill soil after fertilization

Addition of		Nutrient sorbed on AEM		N:S ratio	
N	S	NO_3-N	SO_4-S	AEM	calculated§
———— ug/cm2 ————					
0	0	2.1	0.4	5.7	1.6
0	20	3.0	4.0	0.8	0.2
200	20	38.4	4.2	9.2	9.9
400	20	59.3	2.8	21.3	17.8

§ N:S ratio calculated from sulfate and nitrate initially present in soil plus added fertilizer.

Table 6 Relative N and S availability as determined by AEM burial in Meota soil after fertilization

Addition of		Nutrient sorbed on AEM		N:S ratio	
N	S	NO_3-N	SO_4-S	AEM	calculated§
---------- ug/cm2 ----------					
0	0	3.4	0.7	5.0	0.7
0	40	4.9	5.8	0.8	0.1
200	40	31.8	6.3	5.1	4.7
320	0	50.5	0.5	112.0	107.0
320	20	54.0	3.1	17.7	14.0
320	40	64.3	6.0	10.3	7.5
320	80	43.4	9.7	4.5	3.9

§ N:S ratio calculated from sulfate and nitrate initially present in soil plus added fertilizer.

Influence of N and S fertilizer rates and soil available N:S ratio on crop dry matter yield

Dry matter yields of canola and wheat are presented in Tables 7, 8 and 9. Addition of S alone in the low N Meota and Ardill soils did not cause a significant ($p=0.05$) increase in yields for either canola or wheat. The lack of response to S alone can be attributed to N deficiency limiting response. Addition of N alone did not result in yield response in the Waitville soil but showed a significant ($p=0.01$) yield increase in Meota soil. The difference in N response between the Waitville soil and the Meota soil can be attributed to the different N:S ratios in these two soils. In the Waitville soil, the N:S ratio after fertilization was 3 18 (Table 7) which indicated an extreme limitation of S deficiency relative to N supply while in the Meota soil, the N:S ratio after fertilization, with the same amount of N applied, was only 112 (Table 9).

When N and S were both applied, the yields of crops tested increased significantly and dramatically. Maximum dry matter yields for both canola and wheat in the Waitville soil occurred in the treatment of applying 320 ppm N together with 40 ppm S, in which an available soil N:S ratio of 12.9 was found (Table 7). In the At-dill soil, the maximum dry matter yield was found in the 200 ppm N plus 20 ppm S treatment for the two crops tested, where available soil N:S was 9.2 (Table 8). Increasing the N rate to 400 ppm reduced the canola yield compared to the 200 ppm N treatment, presumably due to disruption of the N:S balance. Janzen [5] showed that high rates of N addition without addition of fertilizer S could cause yield reduction of canola in S deficient soil, compared to no N fertilizer addition at all. For Meota soil, the maximum dry matter yields were also observed in the treatment of applying 200 ppm N together with 40 ppm S, where the available N:S ratio was about 5: 1, and the treatment of applying 320 ppm together with 40 ppm S, where available N:S ratio was 10.7.

Table 7 Dry matter yields of canola and wheat grown in the growth chamber on Waitville association soil under different rates of N and S application

Treatment		Nutrient sorbed on AEM¶			Canola yield		Wheat yield	
N	S	NO_3-N	SO_4-S	N:S	Whole plant	Top only	Whole plant	Top only
		-------ug/cm^2------			------------- g/pot -------------			
0	0	5.1	0.19	27.1	1.58	1.40	2.76	1.91
320	0	50.9	0.16	318.0	1.48	1.31	2.75	2.00
320	40	68.7	5.31	12.9	5.56	4.90	6.25	5.32
320	80	58.4	6.11	9.6	5.03	4.51	5.75	4.89
LSD (0.05)					0.35	0.28	0.38	0.29
LSD (0.01)					0.47	0.41	0.55	0.42

¶ Measured one week tier fertilization.

Table 8 Dry matter yields of canola and wheat grown in the growth chamber on Ax-dill association under different rates of N and S application

Treatment		Nutrient sorbed on AEM¶			Canola yield		Wheat yield	
N	S	NO_3-N	SO_4-S	N:S	Whole plant	Top only	Whole plant	Top only
		-------ug/cm^2------			------------------ g/pot ------------------			
0	0	2.1	0.37	5.7	0.52	0.48	1.14	0.68
0	20	3.0	3.97	0.8	0.59	0.48	1.11	0.61
200	20	38.4	4.2	9.2	4.09	3.53	2.77	2.05
400	20	59.3	2.8	21.3	2.03	1.72	2.34	1.72
LSD (0.05)					0.13	0.13	0.12	0.09
LSD (0.01)					0.18	0.19	0.18	0.13

¶ Measured one week after fertilization.

The results for the two crops on the three soils indicate that a range in available N:available S ratio of about 5 to 17 is suitable to maintain N:S balance in the plant, with a ratio between 5 and 12 probably optimal for canola or wheat. Above these ratios, yield reduction are possible due to excess N availability in relation to S. A ratio lower than the above range indicates an excess of S availability in relation to N. However, toxicity and yield reduction associated with this condition were not present and are unlikely to be a problem with either crop.

Root growth by the two crop species responded differently than the tops to the fertility treatments. Adding S together with N significantly increased the yield of canola root but not the yield of wheat roots (Tables 7, 8 and 9).

Table 9 Dry matter yields of canola and wheat grown in growth chamber on Meota association under different rates of N and S application

Treatment		Nutrient sorbed on AEM¶			Canola yield		Wheat yield	
N	S	NO_3-N	SO_4-S	N:S	Whole plant	Tops only	Whole plant	Top only
		-------- ug/cm^2 ----			------------------ g/pot ----------------			
0	0	3.4	0.68	5.0	0.81	0.38	1.92	0.97
0	40	4.9	5.81	0.8	1.14	0.65	1.83	0.87
200	40	31.8	6.30	5.1	8.98	5.76	4.69	3.22
320	0	50.5	0.45	112.1	2.28	1.71	2.71	1.46
320	20	54.0	3.05	17.7	8.34	5.35	4.39	3.03
320	40	64.3	5.95	10.7	8.77	5.78	4.28	2.99
320	80	43.4	9.67	4.5	8.26	5.19	4.19	3.07
LSD (0.05)					0.57	0.54	0.26	0.28
LSD (0.01)					0.78	0.74	0.35	0.38

¶ Measured one week after fertilization.

The ratio of N:S in plant tissue and its relationship with the ratio of available N:S in soil

The N:S ratio found in the root tissues for both canola and wheat, in most cases, were lower than those found in the tops. However, this trend is less for wheat than for canola.(Tables 10, 11 and 12). At the identified optimum rates of applied N and S: 320 N-40 S for Waitville, 200 N-20 S for Ardill, 200 N-40 S and 320 N-40 S for Meota, the soil available N:S ratio indicated by 1 hour AEM burial closely approximated the N:S ratio found in the plant tissue at harvest, ranging from about 5 to 12 (Tables 10, 11, 12). Some differences between the crops were observed, with canola having lower N:S ratio in tissue than wheat at corresponding fertilizer rates, reflecting greater S demand by canola.

Table 10 N:S ratio in canola and wheat tissue under different rates of N and S application in Waitville soil

			Canola			Wheat		
Treatment		Soil N:S	Yield	Tissue N:S		Yield	Tissue N:S	
N	S		Whole plant	Whole	Top	Whole plant	Whole	Top
			-- g/pot --			-- g/pot --		
0	0	27.1	1.58	9.9	14.1	2.76	11.8	12.2
320	0	318.2	1.48	22.6	38.5	2.75	33.8	44.1
320	40	12.9	5.56	7.7	7.9	6.25	12.4	11.7
320	80	9.6	5.03	4.8	4.3	5.75	10.1	11.5
LSD (0.05)			0.35			0.38		
LSD (0.01)			0.47			0.55		

Table 11 **N:S** ratio in canola and wheat tissue under different rates of N and S application in Ardill soil

				Canola			Wheat	
Treatment		Soil N:S	Yield		Tissue N:S	Yield		Tissue N:S
N	S		Whole plant	Whole	Top	Whole plant	Whole	Top
			-- g/pot --			-- g/pot --		
0	0	5.7	0.52	3.6	4.5	1.14	8.6	8.7
0	20	0.8	0.59	1.4	0.9	1.11	5.2	5.0
200	20	9.2	4.09	7.1	10.3	2.77	11.0	11.3
400	20	21.3	2.03	9.7	12.9	2.34	12.3	12.3
LSD (0.05)			0.35			0.38		
LSD (0.01)			0.47			0.55		

Table 12 N:S ratio in canola and wheat tissue under different rates of N and S application in Meota soil

			Canola			Wheat		
Treatment		Soil N:S	Yield	Tissue N:S		Yield	Tissue N:S	
N	S		Whole plant	Whole	Top	Whole plant	Whole	Top
			-- g/pot --			-- g/pot --		
0	0	5.0	0.81	5.3	4.3	1.92	9.1	9.4
0	40	0.8	1.14	1.9	1.0	1.83	5.9	5.9
200	40	5.1	1.98	5.4	4.6	4.69	10.4	11.2
320	0	112.0	2.28	24.0	50.7	2.71	28.6	32.1
320	20	17.7	8.34	12.5	16.2	4.39	13.6	14.2
320	40	10.7	8.77	8.1	8.5	4.28	11.9	14.2
320	80	4.5	8.26	5.0	4.3	4.19	11.5	13.6
LSD (0.05)			0.57			0.26		
LSD (0.01)			0.78			0.35		

Conclusion

The highest dry matter yield, for the two crops on the three soils tested, was achieved where the available N:available S ratio in soil and plant tissue was found in the range between 5 and 12. Addition of N or S alone, with the exception of the N treatment on the Meota soil, did not cause significant yield increase.

The soil N:S ratio measured by AEM burial, which reflected the supply of available N and S in soil after fertilization, was close to the N:S ratio in the plant at harvest. One hour burial of AEM in the field may be a useful tool to quickly test if a balanced N and S supply is present to achieve a good crop yield.

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