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for the

Agricultural Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Exploring the Merits of Sulphur Fertilization in Flax Production

(Project #20150390)

Principal Applicant: Chris Holzapfel, MSc, PAg

Indian Head Agricultural Research Foundation, Box 156, Indian Head, SK, S0G 2K0

Correspondence: cholzapfel@iharf.ca

Project Identification

1. **Project Title:** Exploring the merits of sulphur fertilization in flax production
2. **Project Number:** 20150390
3. **Producer Group Sponsoring the Project:** Indian Head Agricultural Research Foundation
4. **Project Location(s):** Indian Head, Saskatchewan, R.M. #156
5. **Project start and end dates (month & year):** Apr-2016 to Feb-2017
6. **Project contact person & contact details:**

Chris Holzapfel, Research Manager
Indian Head Agricultural Research Foundation
P.O. Box 156, Indian Head, SK, S0G 2K0
Phone: 306-695-4200
Email: cholzapfel@iharf.ca

Objectives and Rationale

7. **Project objectives:**

The objective of this project was to demonstrate the response of three modern, high yielding flax varieties to varying rates of sulphur (S) fertilizer and explore whether S fertility is a potential factor limiting regional flax yields.

8. **Project Rationale:**

For most crops, including flax, fertilizer is one the largest input costs but typically provides a large return on investment when appropriate rates are applied. Flax often responds well to N fertilizer application and rates ranging from approximately 35-80 kg N/ha (depending on residual N and soil moisture) are typically applied. In contrast, flax response to P fertilizer is less consistent and pronounced than for many crops; however, responses do occur in low P soils and strategies that at least provide enough P fertilizer to offset crop removal are generally seen as important for maintaining soil fertility and quality. While deficiencies of potassium (K) are unlikely in the heavy clay soils near Indian Head (and much of Saskatchewan), sulphur (S) availability is more frequently considered marginal and may potentially limit yields under some circumstances. While documented responses to S fertilizer application are relatively rare for flax, field trials at Indian Head in 2013 detected an average 2.2 bu/ac yield increase (4.5%) with the addition of 12 lb S/ac. In 2014 under less favourable conditions, mean yields with S were 1.4 bu/ac (7%) higher than without; however, the site was variable and the observed difference was not statistically significant. In 2013 and 2014, the observed responses could not positively be attributed to S exclusively since the blend used (14-20-10-10) also provided K_2O in the form of potash. In 2015, despite reasonably high yields (2118 kg/ha or 34 bu/ac) and low residual S, no response to S fertilizer was detected. This project was initiated to demonstrate the potential response (or lack thereof) to varying rates of ammonium sulphate (21-0-0-24) fertilizer for three flax varieties. While the S component of the work was somewhat exploratory, it was also intended to promote sound agronomic management of flax while simultaneously demonstrating the relative performance of three top yielding, modern varieties under field conditions and a no-till, continuous cropping system.

Methodology and Results

9. Methodology:

A field trial with flax was established on barley stubble near Indian Head, Saskatchewan (50.549º N, -103.574º W) in the spring of 2016. The treatments were arranged in a four replicate Randomized Complete Block Design (RCBD) and included a full factorial combination of three varieties (CDC Bethune, CDC Glas and CDC Neela) and four rates of sulphur fertilizer (0, 15, 30 and 45 kg S/ha) for a total of 12 treatments.

Pertinent agronomic information is provided in Table 1. All plots were direct-seeded into barley stubble on May 8 using a SeedMaster plot drill with eight openers on 30 cm row spacing. The varieties were varied as per protocol but all were seeded at target depth of approximately 20 mm (3/4") and a 52.5 kg/ha seeding rate (not adjusted for seed size or percent germination). Nitrogen was held constant at 100 kg N/ha for all treatments (supplied as side-banded urea) along with 30 kg P_2O_5/ha (supplied as seed-placed monoammonium phosphate). Sulphur rate varied as per protocol but was supplied as side-banded ammonium sulphate (21-0-0-24). Weeds were controlled using registered pre-emergent and in-crop herbicide applications and fungicide was applied preventatively at mid-bloom (Jul-3) to prevent Pasmo from becoming a yield limiting factor. Pre-harvest glyphosate was applied for weed control and to assist with crop dry-down at physiological maturity (Aug-21, ~75% boll colour change) and the centre 5 rows of each plot was straight-combined as soon after it was fit to do so as possible (Sep-16).

Table 1. Selected agronomic information for ADOPT flax sulphur response demonstration at Indian Head in 2016.

Factor / Field Operation	Indian Head – 2016
Pre-emergent herbicide	2250 g triallate/ha (May-7) 140 g sulfentrazone/ha (May-9) 890 g glyphosate/ha (May-15)
Fertility (kg N-P_2O_5-K_2O/ha)	100-30-0 (S varied as per protocol)
Seeding Date	8-May
Cultivar	varied as per protocol
Seeding Rate	52.5 kg/ha
Row spacing	30 cm
In-crop herbicide	100 g clopyralid/ha + 555 g MCPA ester/ha (Jun-13) 50 g tepraloxydim/ha (Jun-18)
Fungicide	75 g fluxapyroxad/ha + 150 g pyraclostrobin/ha (July 3)
Insecticide	none applied
Pre-harvest herbicide	890 g glyphosate/ha (Aug-21)
Harvest date	Sep-16 (centre 5 rows)

Emergence was measured at approximately four weeks after planting (Jun-2) by counting the number of seedlings two separate 1 m sections of crop row per plot. The Julian date where the crop reached maturity was recorded for each plot and maturity was defined as 75% boll colour change. Yields were determined from the harvested grain samples which were corrected for dockage and to 10% seed moisture content. Weather data were estimated from a privately-owned weather station located on the field trial site.

All response data were analysed using the GLM procedure of SAS with the effects of variety (V), sulphur rate (S) and interactions between the two factors (V × S) considered fixed and replicate effects considered random. Fisher's protected LSD test was used to separate treatment means and orthogonal contrasts were used to determine whether S responses were insignificant, linear or curvilinear (quadratic). All treatment effects and observed differences between means were considered statistically significant at $P \leq 0.05$.

10. Results:

Growing Season Weather & Soil Test Information

Mean monthly temperatures and precipitation amounts for the 2016 growing season at Indian Head along with the long-term averages (1981-2000) are presented in Table 2. The season was initially dry but with excellent conditions for early planting and seed was placed into good soil moisture. Although early May was warm and dry, large amounts of precipitation were received late in the month and amounted to 140% of the long-term average. Total precipitation for June was 81% of average while July was wet (177%) and August was relatively dry (58%) compared to the long-term average. The total amount of precipitation from April 1 through August 31 was 292 mm (11.7"), 9% above the long-term average. Temperatures were substantially higher than normal for May and June and then approximately normal in July and August. While there was hail on July 18 (late bloom / early boll filling), damage to the flax appeared to be minimal and uniform across the study area; therefore, was not believed to have negatively affected data quality.

Table 2. Mean monthly temperatures and precipitation amounts along with long-term averages (LT; 1981-2010) averages for the 2016 growing season at Indian Head, Saskatchewan.

Year	April	May	June	July	August	Avg/Tot
	------ Mean Temperature (°C) ------					
2016	3.8	14.0	17.5	18.5	17.2	14.2
LT [z]	4.2	10.8	15.8	18.2	17.4	13.3
	------ Precipitation (mm) ------					
2016	13.9	72.6	63	112.8	29.8	292
LT [z]	22.6	51.8	77.4	63.8	51.2	267

A composite soil sample for the study area was collected prior to seeding (May-5) and submitted to AgVise Laboratories for various analyses (Table 3). Soil pH for the upper 15 cm was 7.8 with 3.7% organic matter and a relative high cation exchange capacity of 45.4 Meq. Residual soil S was relatively low at 3 ppm for the upper 15 cm and 2 ppm for the 15-60 cm depth, or approximately 14 kg/ha total S.

Table 3. Soil test results for the 2016 flax sulphur response demonstration at Indian Head, Saskatchewan.

Soil Depth	pH	O.M.	NO_3-N	Olsen-P	K	S	C.E.C.
(cm)		---- % ----	- ppm [z] -	-- ppm --	-- ppm --	-- ppm --	-- Meq --
0-15	7.8	3.7	6.0	7	555	3	45.4
15-60	8.2	–	2.0	–	–	2	–
kg/ha	–	–	22.7	12.5	991	14.4	–

[z] Based on estimated soil bulk density and observed soil test ppm values

Crop Response to Variety and Sulfur Fertilizer Rate

Variety effects on plant density and both variety and sulphur fertilizer rate effects on maturity and seed yield are presented along with all main effect means in Table 4.

Plant densities were high, attributable to the relatively high seeding rates and favourable conditions for emergence. Averaging 584 plants/m^2, plant densities were similar for all three varieties and well beyond the minimum of 300 plants/m^2 density recommended for optimum yield potential. Again, plant densities were only completed for the 30 kg S/ha rate and solely intended to compare establishment amongst varieties as the side-banded S was not expected to affect emergence.

Maturity varied slightly albeit significantly with variety but was not affected by S rate and no variety by sulphur rate (V × S) interaction was detected. Averaging just over 102 days from planting, maturity (75% boll colour change) was relatively early for all varieties; however, this was not unexpected given the warm season and rapid, even emergence. Maturity was similar for Bethune and Neela, averaging 102.0 days and slightly but significantly higher at 102.6 days for CDC Glas. Although the quadratic response for S effects on fertilizer was significant ($P = 0.043$), the spread between the minimum and maximum observed values was only 0.4 days.

Seed yields were well above average with an overall mean of 3224 kg/ha or 51 bu/ac. Yields differed slightly but significantly for each variety whereby Bethune yielded the lowest (3137 kg/ha or 49.9 bu/ac) Neela was intermediate (3209 kg/ha or 51.0 bu/ac) and CDC Glas was the top yielding variety (52.8 bu/ac). At 103% and 106% of Bethune for Neela and Glas, respectively, these results are consistent with the 2017 Saskatchewan Guide which ranks these two varieties at 107% and 110%, respectively. While the overall F-test for S rate was not significant at the desired probability ($P = 0.063$), yields tended to be higher where S was applied and the quadratic response was significant ($P = 0.029$). At only 3% (89 kg/ha or 1.4 bu/ac) when averaged across the treatments where S was applied, the magnitude of the response was small and similar for all rates; thus indicating that 15 kg S/ha was sufficient to optimize yields. While the V × S interaction was not significant, individual treatment means are presented in the Appendices (Table 5). While no interaction was detected, inspection of the individual treatment means and contrast results for individual treatments suggested that the greatest response was observed with CDC Neela. For this variety, the average yield increase with S fertilizer was 6% and it was the only variety where the quadratic response to S rate was significant ($P = 0.003$).

Table 4. Flax variety and sulphur fertilizer rate effects on flax plant density, maturity and yield (Indian Head 2016). Means followed by the same letter do not significantly differ (Fisher's protected LSD test, $P \leq 0.05$).

Main Effect	Plant Density	Maturity	Seed Yield
Variety	----- *plants/m²* -----	--------- *days* ---------	-------- *kg/ha* --------
CDC Bethune	575 a	102.0 b	3137 a
CDC Glas	570 a	102.6 a	3325 c
CDC Neela	607 a	102.0 b	3209 b
S.E.M.	26.3	0.09	24.9
Sulphur Rate			
0 kg S/ha	–	102.1 a	3157 a
15 kg S/ha	–	102.4 a	3253 a
30 kg S/ha	–	102.3 a	3260 a
45 kg S/ha	–	102.0 a	3225 a
S.E.M.	–	0.11	28.8
C.V. (%)	9.0	0.4	3.1
R^2	0.420	0.619	0.850
	------------------------------ *Pr > F (p-value)* ------------------------------		
Variety (V)	0.593	< 0.001	< 0.001
Sulphur Rate (S)	–	0.169	0.063
V × S	–	0.177	0.160
S Response – linear	–	0.448	0.109
S Response – quadratic	–	0.043	0.029

Extension and Acknowledgement

Due to logistic considerations this project was not shown as part of the Indian Head Crop Management Field Day in 2016. However, the trial was highlighted on tour coordinated by Seed Hawk during the Farm Progress where 15-20 Australian producers and agronomists (June 16, 2016) and on another co-hosted with Richardson Pioneer (July 27, 33 guests). In addition, the site was visited by numerous growers, agronomists and researchers over the season. A summary of this work will be included in the 2016 IHARF Annual Report which, in addition to the full report, will be available online. Results will also be made available through a variety of other media (i.e. oral presentations, popular agriculture press, social media, fact sheets, etc.) as opportunities arise.

11. Conclusions and Recommendations

This project has demonstrated several important matters pertaining to flax production in Saskatchewan. For all treatments, establishment was excellent and maturity was early, presumably a result of the early seeding, excellent emergence and warm weather conditions. Notably, with average yields of 3224 kg/ha, the demonstration showed that flax has potential to yield quite high under sound agronomic management and favourable growing conditions. Furthermore, and consistent with the 2017 Saskatchewan Seed Guide, the trial showed that the newer flax varieties CDC Neela and CDC Glas have slightly but significantly higher yield potential than the check variety CDC Bethune. At Indian Head in 2016, the yield advantages were approximately 2% and 6% higher for Neela and Glas, respectively. While the gains were modest at only 3% when averaged across varieties, there was evidence of a response to S fertilizer; however, bear in mind that this was under high yielding, low residual soil S conditions and cannot likely be expected under all circumstances. While there was no overall interaction between variety and S rate detected, results for individual varieties suggested that the response was strongest with CDC Neela where the overall increase was 6%. The quadratic response indicated that relatively small rates of S fertilizer (i.e. 15 kg S/ha) are sufficient to optimize yield when additions are this nutrient are required. Soil testing is generally recommended as the best method to assess the potential for crop response to various nutrient applications. Because S is highly variable across the landscape, high soil test levels do not always guarantee that this nutrient will not be limiting, at least in certain parts of the field; however, low soil test S levels can generally be trusted to suggest a high probability that this nutrient may be limiting with certain crops.

Supporting Information

12. Acknowledgements:

This project was supported by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement. Acknowledgement of the Saskatchewan Ministry of Agriculture's support for this demonstration will be included as part of all written reports and oral presentations that arise from this work. The crop protection products evaluated in this demonstration were provided in-kind by BASF and FMC of Canada. The technical, administrative and professional support of Danny Petty, Dan Walker, Karter Kattler, Carly Miller, Andrea De Roo and Christiane Catellier is greatly appreciated.

13. Appendices

Table 5. Flax variety and sulphur fertilizer rate effects on flax plant density, maturity and yield (Indian Head 2016). Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

Effect	Maturity	Seed Yield
Variety × S Rate	---------------- *days* ----------------	---------------- *kg/ha* ----------------
Bethune – 0 kg S/ha	101.9 c	3102 c
Bethune – 15 kg S/ha	102.3 bc	3165 bc
Bethune – 30 kg S/ha	102.1 bc	3188 bc
Bethune – 45 kg S/ha	101.9 c	3092 c
S.E.M.	0.19	49.8
Orthogonal Contrasts	------------------------------ *Pr > F (p-value)*	------------------------------
S Response (linear)	0.883	0.967
Bethune – S (quadratic)	0.108	0.122
Variety × S Rate	---------------- *days* ----------------	---------------- *kg/ha* ----------------
Glas – 0 kg S/ha	102.6 ab	3297 ab
Glas – 15 kg S/ha	103.0 a	3303 ab
Glas – 30 kg S/ha	102.6 ab	3307 ab
Glas – 45 kg S/ha	102.1 bc	3393 a
S.E.M.	0.19	49.8
Orthogonal Contrasts	------------------------------ *Pr > F (p-value)*	------------------------------
S Response (linear)	0.034	0.199
Bethune – S (quadratic)	0.027	0.428
Variety × S Rate	---------------- *days* ----------------	---------------- *kg/ha* ----------------
Neela – 0 kg S/ha	101.9 c	3070 c
Neela – 15 kg S/ha	101.9 c	3290 ab
Neela – 30 kg S/ha	102.0 c	3286 ab
Neela – 45 kg S/ha	102.1 b	3189 bc
S.E.M.	0.19	49.8
Orthogonal Contrasts	------------------------------ *Pr > F (p-value)*	------------------------------
S Response (linear)	0.308	0.124
Bethune – S (quadratic)	0.743	0.003

Abstract

14. Abstract/Summary:

A field trial was established in 2016 near Indian Head, Saskatchewan to demonstrate the relative performance of modern flax varieties along with the potential for response to sulphur (S) fertilization. In general, growing season conditions were considered excellent and the overall average seed yield was 3224 kg/ha (51 bu/ac), well above-average for the region. Establishment was better than expected for all varieties with no differences detected amongst them an average plant density of 584 plants/m^2. Maturity differed slightly amongst varieties but not S rates and all treatments matured early with a maximum spread of 1.1 days amongst individual treatments. While all varieties yielded high (>3000 kg/ha), CDC Neela yielded 102% of CDC Bethune and CDC Glas was the highest yielder at 106% of Bethune. There was a slight yield increase of approximately 3% associated with low S fertilizer rates (15 kg S/ha) when averaged across varieties. While no significant interaction was detected between variety and S rate, inspection of results for individual varieties suggested that the response was strongest with CDC Neela. These observations are only based on a single site-year of response data and additional field trials are required to make more concrete S fertility recommendations for flax. While this demonstration was not featured at the Indian Head Crop Management Field Day for logistic reasons, it was highlighted during two other private tours and visited by multiple farmers and agronomists over the course of the season. Furthermore, a summary of this work will be included in the 2016 IHARF Annual Report which, along with the full report, will be available online. Results will also be made available through a variety of other media (i.e. oral presentations, popular agriculture press, social media, fact sheets, etc.) as opportunities arise.