2015 Annual Report

for the

Saskatchewan Flax Development Commission

Project Title: Optimal Nitrogen, Phosphorus and Sulphur Fertility in Flax

(Project #15-2424)

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Project Identification

1. **Project Title:** Optimal Nitrogen, Phosphorus and Sulphur Fertility in Flax
2. **Project Number:** 15-2424
3. **Producer Group Sponsoring the Project:** Saskatchewan Flax Development Commission
4. **Project Location(s):** Indian Head, Saskatchewan, R.M. #156
5. **Project start and end dates (month & year):** April 2015 to January 2016
6. **Project contact person & contact details:**

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Objectives and Rationale

7. **Project objectives:**

The objective of this project was to demonstrate the response of flax to applications of varying rates of nitrogen (N), phosphorus (P) and sulphur (S) fertilizer applications.

8. **Project Rationale:**

For most crops, including flax, fertilizer is one the largest input costs and 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^{-1} (depending on residual N and soil moisture) are typically applied. On the other hand, flax response to P fertilizer has been less consistent and pronounced than for many other crops, including spring wheat and canola. Still, significant responses have been detected when residual P availability is low and many producers see applying at least enough P fertilizer to replace what the crop removes as an important strategy for maintaining soil productivity over the long term. While sulphur deficiencies can potentially limit yields in any crop, serious deficiencies in these nutrients are relatively uncommon in most soils in Saskatchewan and documented flax seed yield responses to S fertilizer application are relatively rare. The proposed project will demonstrate the potential response (or lack thereof) to applications of varying rates and placements of N, P, K and S fertilizer in the thin-Black soil zone of southeast Saskatchewan.

Methodology and Results

9. **Methodology:**

A field trial with flax was established on a heavy clay soil east of Indian Head, Saskatchewan (R.M. #156; -103.563 W 50.554 N). Nineteen fertilizer treatments were arranged in a Randomized Complete Block Design and replicated four times. The treatments were an unfertilized control plus a factorial combination of three N fertilizer rates (45, 90 and 135 kg N ha^{-1}), three P fertilizer rates (0, 22 and 45 kg P_2O_5 ha^{-1}) and two S fertilizer rates (0 and 22 kg S ha^{-1}).

On May 3, a three depth (0-15, 15-30, 30-60 cm) composite soil sample was collected and submitted to ALS Laboratory Group (Saskatoon, SK) for residual nutrient analyses. The variety CDC Bethune was direct-seeded into spring wheat stubble at 54 kg ha^{-1} on May 4 using a SeedMaster plot drill with eight openers on 30 cm spacing. While rates were varied as per protocol, all fertilizer was side-banded and the products used were urea (46-0-0), monoammonium phosphate (11-52-0) and ammonium sulphate (21-0-0-24). Urea rates were always adjusted to account for any N provided in the monoammonium phosphate and ammonium sulphate. Weeds were controlled using pre-emergent applications of 4.4 l Avadex BW ha^{-1} (April 29) followed by 890 g glyphosate ha^{-1} tanked mixed with 0.292 l Authority 480 ha^{-1} (April 29). In-crop, 1.4 l Venture L ha^{-1} was applied on June 10 followed by 2.0 l Curtail M ha^{-1} on June 13 and a final application of 0.185 l Centurion ha^{-1} (plus 0.5% Amigo) on June 24 to control a late flush of volunteer wheat. To minimize the potential for disease to become a limiting factor, 0.4 l Priaxor ha^{-1} was applied on July 3. The plots were terminated with 890 g glyphosate ha^{-1} on August 24 and the centre five rows of each plot were straight-combined on September 12.

Various data were collected over the course of the growing season and from the harvested grain samples. Plant emergence was determined on June 2 by counting the number of seedlings in two separate 1 m rows per plot and calculating the average plants m^{-2}. Days from planting to maturity (75% of bolls turned brown) was recorded for each plot. Yields were determined from the harvested grain samples and are corrected for dockage and to 12% seed moisture content. Test weights were determined using standard Canadian Grain Commission methodology and are expressed in g 0.5 l^{-1}.

Response data were analysed using the GLM procedure of SAS 9.3 with the effects of N rate (NR), P rate (PR) and S rate (SR) considered fixed along with all possible interactions (NR×PR, NR×SR and PR×SR) and the effect of replicate considered random. Because the unfertilized control could not be included in the factorial analyses, a second model simply treated all 19 fertilizer treatments as fixed and replicate as random. Treatment means were separated using Fisher's protected LSD test and orthogonal contrasts were used to determine whether the responses to N and P rate were linear or quadratic (curvilinear) in shape. All treatment effects and differences between means were considered significant at $P \leq 0.05$.

10. Results:

Soil test results and Growing Season Weather

Soil test results for the trial site are presented in Table 1. In general, all macronutrients except for K were considered deficient to marginal, with reasonably good potential for a yield response to N, P and S fertilization. The pH of the soil was 8.0 for the 0-15 cm profile and the soil was classified as a non-saline clay loam (thin-Black Chernozem). The soil test recommendation for a yield of 2500 kg ha^{-1} (40 bu/ac) was 118-128 kg N ha^{-1}, 34-39 kg P2O5 ha^{-1} and 17-22 kg S ha^{-1} (ALS Laboratory Group, Saskatoon, SK)

Table 1. Soil test results for the Indian Head (2015) flax fertility demonstration. The samples were collected on May 3 and submitted to ALS Laboratory Group for analyses.

Soil Depth	Nitrogen (NO_3)	Phosphorus (P)	Potassium (K)	Sulphur (SO_4)	pH
	------------	------------ kg ha^{-1}	------------	------------	—
0-15 cm	15	16	> 605	3	8.0
15-30 cm	10	—	—	3	8.3
30-60 cm	10	—	—	7	8.3
Total [Z]	35	16	> 605	13	—

[Z] 0-60 cm for N and S; 0-15 cm for P and K

Mean monthly temperatures and precipitation amounts for the 2015 growing season at Indian Head are presented relative to the long-term averages in Table 2. While seed and fertilizer were placed into adequate soil moisture, the spring as whole was extremely dry with no significant precipitation events until late in the third week of June. From this point onwards, moisture conditions were generally considered adequate and flax yields were considered about average overall.

Table 2. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2013-15 growing seasons at Indian Head, SK.

Year	May	June	July	August	Avg. / Total
			Mean Temperature (°C)		
2015	10.3	16.2	18.1	17.0	15.4
Long-term	10.8	15.8	18.2	17.4	15.6
			Precipitation (mm)		
2015	15.6	38.3	94.6	58.8	207
Long-term	51.8	77.4	63.8	51.2	244

Flax Response to Nitrogen, Phosphorus and Sulphur Fertilization

Flax emergence was affected by N rate but not P rate or S rate and there were no significant interactions between nutrients detected (Table 3). While flax emergence was excellent and final plant populations were always well above the minimum recommended density of 300 plants m^{-2}, there was a significant linear reduction in plants m^{-1} with increasing rates of side-banded N (Tables 3 and 4). At 45 kg N ha^{-1}, regardless of the P or S rate, plant populations did not significantly differ from the unfertilized control (Table 5, Appendices).

Flax maturity was also affected by N rate but not P rate or S rate and, again, there were no interactions between the nutrient types. While maturity dates at all three N levels (45, 90 or 135 kg N ha^{-1}) significantly differed (Table 3), the response was considered primarily quadratic as there was a larger delay in maturity when N was increased from 45 to 90 kg N ha^{-1} than when the rates were increased from 90 to 135 kg N ha^{-1} (Tables 3 and 4). Relative to the control, maturity was delayed by 3.7 days at the highest N rate.

Flax seed yield was affected by both N rate and P rate but not S rate and, again, there were no significant interactions between nutrient types (Table 3). Focussing on N, mean flax yields were within 59 kg ha^{-1} (0.9 bu/ac) for rates ranging from 45-135 kg N ha^{-1} but were significantly higher at 90 kg N ha^{-1} than for either the 45 or 135 kg N ha^{-1} rates. Consequently, the response to N was characterized as quadratic ($P = 0.002$) as opposed to linear ($P = 0.551$). While the response to N rates beyond 45 kg ha^{-1} was relatively weak, there was a strong overall response to N fertilizer with mean yields coming in at 553 kg ha^{-1} (9 bu/ac), or 35%, higher than the control where no fertilizer was applied. The response to P fertilizer was smaller in magnitude than for N but was also highly significant and linear (Tables 3 and 4). On average, P fertilizer increased flax yields by approximately 58 kg ha^{-1} (0.9 bu ac^{-1}). Despite the low residual levels, there was no yield response to S fertilizer application.

Test weight was only affected by N fertilizer rate and there were no interactions between any nutrient types for this variable. Test weight increased linearly with N rate; however the biggest gains appear to be at the lower rates with no significant difference between the values observed at 90 and 135 kg N ha^{-1} (Table 3 and 4).

Table 3. Main effect means, analyses of variance and orthogonal contrasts for flax plant density, maturity, yield and test weight at Indian Head (2015). Data were analyzed using the GLM procedure of SAS and values followed by the same letter do not significantly differ (Fisher's protected LSD test).

	Plant Density	Maturity	Grain Yield	Test Weight
Main Effect	---------- cm --------	-------- 1-10 --------	-------- kg ha^{-1} -------	------- g 0.5 l^{-1} -------
Control [Z]	605.7	99.3	1565	326
Nitrogen Rate				
45 kg N ha^{-1}	590 a	101.0 c	2106 b	328 b
90 kg N ha^{-1}	530 b	103.0 b	2153 a	331 a
135 kg N ha^{-1}	513 a	104.0 a	2094 b	332 a
S.E.M.	12.7	0.03	13.7	0.8
Phosphorus Rate				
0 kg P_2O_5 ha^{-1}	550 a	102.7 a	2079 b	330 a
22 kg P_2O_5 ha^{-1}	537 a	102.7 a	2126 a	331 a
45 kg P_2O_5 ha^{-1}	546 a	102.6 a	2148 a	330 a
S.E.M.	12.7	0.03	13.7	0.7
Sulphur Rate				
0 kg S ha^{-1}	549 a	102.6 a	2110 a	331 a
22 kg S ha^{-1}	539.4	102.7 a	2125 b	330 a
S.E.M.	10.4	0.03	11.2	0.6
C.V. (%)	11.5	0.2	3.2	1.1
Effect [Y]	---------- p-value ----------			
NR	< 0.001	< 0.001	0.008	0.006
PR	0.763	0.431	0.003	0.463
SR	0.510	0.086	0.332	0.340
NR × PR	0.613	0.313	0.883	0.297
NR × SR	0.941	0.152	0.177	0.994
PR × SR	0.110	0.214	0.335	0.958

[Z] Due the experimental design the unfertilized control was not included in the statistical analyses
[Y] P-values ≤ 0.05 indicate that an effect/contrast was significant and not due to random variability

Table 4. Orthogonal contrasts for flax plant density, maturity, yield and test weight response to N and P fertilizer rate at Indian Head (2015). Data were analyzed using the GLM procedure of SAS and p-values below 0.05 are considered statistically significant.

	Plant Density	Maturity	Grain Yield	Test Weight
Contrast	---------- p-value ----------			
NR (lin)	< 0.001	< 0.001	0.551	0.001
NR (quad)	0.167	< 0.001	0.002	0.272
PR (lin)	0.848	0.205	<0.001	0.690
PR (quad)	0.480	0.806	0.481	0.262

Extension and Acknowledgement

This demonstration was a formal stop during the 2015 Indian Head Crop Management Field Day which was held on July 21. The tour was attended by over 200 registered guests and signs were in place to acknowledge the support of the Saskatchewan Flax Development Commission (SaskFlax). Results from this project will be made available in the 2015 IHARF Annual Report (available online) and also through a variety of other media (i.e. oral presentations, popular agriculture press, fact sheets, etc.) as opportunities arise.

11. Conclusions and Recommendations

Despite being a relatively dry year with very little precipitation for the first six weeks after planting, moisture conditions improved for the latter half of the season and flax yields were considered about average. Soil test results indicated that residual N, P and S levels were all quite low and the soil test recommendation for a yield of 2500 kg ha^{-1} (40 bu/ac) was 118-128 kg N ha^{-1}, 34-39 kg P2O5 ha^{-1} and 17-22 kg S ha^{-1} (ALS Laboratory Group, Saskatoon, SK). Overall, there was a strong response to N with yield increases of approximately 35% relative to the control with the addition of N fertilizer. Yields increased further when the rate was increased from 45 to 90 kg N ha^{-1} but only by 47 kg ha^{-1} and yields were slightly lower with further increases to 135 kg N ha^{-1}. The response to P fertilizer was significant, but again small with an average increase of 69 kg ha-1 (1.1 bu/ac) at 45 kg P_2O_5 relative to 0 P_2O_5. That said, the crop grown removed approximately 25-30 kg ha^{-1} in the seed; therefore, maintaining residual soil would have required fertilizer rates within this range. Despite low residual levels and reasonably high yields, there was no evidence of a crop response to S fertilizer application. Flax is recognized as a crop that is able to extract soil nutrients efficiently through root exploration and mycorrhizal association and these results support that position; however, further research is required to better understand flax response to N, P and S fertilizer applications under field conditions.

Supporting Information

12. Acknowledgements:

This project was financially supported by the Saskatchewan Flax Development Commission (SaskFlax). Many of the crop protection products used in the project were provided in-kind by BASF, Bayer CropScience and Syngenta. The support and contributions of Christiane Catellier, Dan Walker, Carly Miller and Danny Petty are greatly appreciated.

13. Appendices

Table 5. Individual treatment means and analyses of variance (non-factorial) for flax plant density, maturity, yield and test weight at Indian Head (2015). Data were analyzed using the GLM procedure of SAS and values followed by the same letter do not significantly differ (Fisher's protected LSD test).

	Plant Density	Maturity	Grain Yield	Test Weight
kg N-P_2O_5-K_2O-S	---------- cm --------	-------- 1-10 --------	------- kg ha^{-1} ------	------ g 0.5 l^{-1} ------
45-0-0	624 a	100.9 d	2076 bcd	328 a
45-22-0	562 a-e	101.0 d	2104 bcd	332 a
45-45-0	604 ab	100.9 d	2124 bcd	327 a
45-0-22	559 a-e	101.1 d	2055 cd	328 a
45-22-22	569 a-d	101.0 d	2151 bc	330 a
45-45-22	622 a	101.0 d	2124 bcd	326 a
90-0-0	544 a-e	103.0 c	2102 bcd	332 a
90-22-0	589 abc	103.0 c	2156 b	332 a
90-45-0	476 e	103.1 c	2119 bcd	331 a
90-0-22	528 b-e	103.0 c	2114 bcd	332 a
90-22-22	487 ed	103.0 c	2162 b	330 a
90-45-22	554 a-e	103.0 c	2266 a	331 a
135-0-0	514 cde	104.0 ab	2085 bcd	332 a
135-22-0	521 b-e	104.0 ab	2079 bcd	333 a
135-45-0	508 cde	103.9 b	2145 bc	334 a
135-0-22	529 b-e	104.3 a	2042 d	331 a
135-22-22	493 de	104.0 ab	2103 bcd	332 a
135-45-22	513 cde	104.0 ab	2111 bcd	331 a
0-0-0	606 ab	99.3 e	1565 e	326 a
S.E.M	30.5	0.10	34.7	1.9
C.V.	11.1	0.2	3.3	1.1
Pr > *F*	0.012	< 0.001	< 0.001	0.182

Table 6. Main effect means, analyses of variance and orthogonal contrasts for flax yield at Langbank (SeedMaster Research Farm 2015). Data were analyzed using the GLM procedure of SAS and values followed by the same letter do not significantly differ (Fisher's protected LSD test).

	Plant Density	Maturity	Grain Yield	Test Weight
Main Effect	---------- cm --------	-------- 1-10 --------	-------- kg ha^{-1} -------	------- g 0.5 l^{-1} -------
Control [Z]	—	—	1699	—
Nitrogen Rate				
45 kg N ha^{-1}	—	—	1748 a	—
90 kg N ha^{-1}	—	—	1686 a	—
135 kg N ha^{-1}	—	—	1716 a	—
S.E.M.	—	—	34.1	—
Phosphorus Rate				
0 kg P_2O_5 ha^{-1}	—	—	1674 a	—
22 kg P_2O_5 ha^{-1}	—	—	1701 a	—
45 kg P_2O_5 ha^{-1}	—	—	1778 a	—
S.E.M.	—	—	34.1	—
Sulphur Rate				
0 kg S ha^{-1}	—	—	1705 a	—
22 kg S ha^{-1}	—	—	1729 a	—
S.E.M.	—	—	27.9	—
C.V. (%)	—	—	9.7	—
Effect [Y]	------------------------------ p-value ------------------------------			
NR	—	—	0.441	—
PR	—	—	0.102	—
SR	—	—	0.546	—
NR × PR	—	—	0.238	—
NR × SR	—	—	0.954	—
PR × SR	—	—	0.756	—

[Z] Due the experimental design the unfertilized control was not included in the statistical analyses

[Y] P-values ≤ 0.05 indicate that an effect/contrast was significant and not due to random variability

Abstract

14. Abstract/Summary:

A flax field trial was conducted at Indian Head to demonstrate the response to N, P and S fertilizer rates. The treatments were a factorial combination of three N rates (45, 90 and 135 kg N ha^{-1}), three P rates (0, 22 and 45 kg P_2O_5 ha^{-1}) and two S rates (0 and 22 kg S ha^{-1}) plus an unfertilized control. All fertilizer was side-banded. There was a slight reduction in plant density with increasing N rates; however, populations were well above 300 plants m^{-2} for all treatments. Emergence was not affected by P or S rate. Maturity was also only affected by N rate with a 3.7 day delay at 135 kg N ha^{-1} relative to the control. Seed yield was affected by N and P rate but not S and there were no interactions amongst nutrient types. Increasing the N rate from 0-45 kg ha^{-1} resulted in an average yield increase of 35%; however, further increasing the rate to 90 kg N ha^{-1} only resulted in an additional 2% yield increase. The yield response to P was small but significant with a mean increase of 3.3% at 45 kg P_2O_5 ha^{-1}. Test weight increased with N fertilization to rates of at least 90 kg N ha^{-1} at which point further increases in N no longer resulted in significant increases in test weight.