1. PROJECT TITLE:

Optimal Fertilizer Management for Flax Production

2. PROJECT NUMBER: #20120371

3. PRODUCER GROUP SPONSORING THE PROJECT

Saskatchewan Flax Development Commission
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4. PROJECT LOCATION

This project was conducted on rented land near Agriculture and Agri-Food Canada's Indian Head Research Farm. The legal land description: NE 31 18 12 W2 (RM #156).

5. PROJECT START AND END DATES

Start date: April 1, 2013
End date: January 30, 2014

6. PROJECT CONTACT PERSONS

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7. PROJECT OBJECTIVE

- To demonstrate the response of flax to applications of varying rates of nitrogen (N), phosphorus (P) and sulphur (S) fertilizer. Implications of nitrogen, potassium and sulphur fertilizer placement on flax emergence and seed yield, and potential merits of split nitrogen applications were investigated.

8. RATIONALE

For most crops—including flax—fertilizer is one of 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 typical application rates range from approximately 35 to 80 kg N/ha, depending on residual N and soil moisture. On the other hand, flax response to P fertilizer is less consistent and pronounced than for many other crops, including spring wheat and canola.

However, many producers see applying at least enough P fertilizer to replace what the crop removes as an important strategy for maintaining soil fertility and quality. Flax is particularly sensitive to seed-placed P and therefore, it is recommended that no more than 20 kg P_2O_5/ha be placed in the seed row. Side-banding is also an effective method of applying P in flax and is safer than seed row placement when high rates are utilized. While deficiencies of potassium (K) and sulphur can potentially limit yields in any crop, serious deficiencies in these nutrients are relatively uncommon in most soils in Saskatchewan and flax seed yield responses to K and S fertilizer application are relatively rare.

This project was to demonstrate the potential response (or lack thereof) to applications of varying rates and placements of N, P, K and S fertilizer and educate growers on potential toxicity issues with seed-placed fertilizer.

9. METHODOLOGY

A field trial was completed in 2013 by the Indian Head Agricultural Research Foundation (IHARF) on behalf of the Saskatchewan Flax Development Commission. The trials were located near Indian Head, Saskatchewan (R.M. #156) on an Indian Head Heavy Clay (Rego thin Black Chernozem) soil. The focus of the trial was to demonstrate the response of flax to varying rates and placement methods of granular N, P, K and S fertilizer. Fourteen fertilizer treatments were arranged in a RCBD and replicated four times. All N fertilizer was side-banded urea while monoammonium phosphate was either side banded or seed-placed according to the protocol. The treatments which were evaluated are provided in Table 1.

The variety Nulin 50 was seeded directly into spring wheat stubble on May 11 using a SeedMaster plot drill equipped with 8 openers spaced 30 cm apart and a trimmed plot length of 10.5 m. The seeding rate used was 50 kg ha^{-1} and rates and placements of urea, monoammonium phosphate, potassium chloride and ammonium sulphate were varied according to the protocol. Nitrogen was always side-banded while P, K and S were either side-banded or seed-placed. All plots received a pre-emergent burnoff of 590 g glyphosate ha^{-1} on May 17, an in-crop application of 280 g bromoxynil ha^{-1} plus 280 g MCPA ester ha^{-1} (June 24) along with two separate applications of 40 g tepraloxydim ha^{-1} (June 12 and June 28) to control multiple flushes of wild oats. A single application of 99 g pyraclostrobin ha^{-1} was applied on July 10 to minimize the potential effects of pasmo.

A composite soil sample was collected from the site on May 14 and submitted to ALS Laboratories for nutrient analyses. Plant densities were estimated by counting the number of seedlings in 2 m of crop row per plot on May 29. No lodging was observed at any point during the growing season, therefore lodging ratings were not completed. The centre five rows of each plot were straight-combined on September 23 using a Wintersteiger plot combine and all harvest samples were cleaned, weighed and yields were converted to kg ha^{-1} and corrected to 10% seed moisture content. Plant density and yield

data were analysed using the GLM procedure of SAS and Tukey's studentized range test with treatment differences declared significant at $P \leq 0.05$. Predetermined contrasts were used to evaluate the overall response of fertilizer application and compare placement methods for various combinations of P, K and S. Growing season weather data was monitored and recorded using the nearest Environment Canada weather station which was located approximately 1.75 km southwest of the field site.

Table 1. Fertilizer Treatments

Trt. #	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K2O)	Sulphur (S)	PKS Placement
	---------- kg ha^{-1} ----------				
1	0	0	0	0	n/a
2	45	0	0	0	n/a
3	45	15	0	0	side-banded*
4	45	15	7.5	7.5	side-banded
5	45	15	0	0	seed-placed**
6	45	15	7.5	7.5	seed-placed
7	90	15	0	0	side-banded
8	90	15	7.5	7.5	side-banded
9	90	15	0	0	seed-placed
10	90	15	7.5	7.5	seed-placed
11	90	30	0	0	side-banded
12	90	30	15	15	side-banded
13	90	30	0	0	seed-placed
14	90	30	15	15	seed-placed

*side-banded fertilizer was place 38 mm to the side and 20 mm below seed-row
**seed-bed utilization of 6.25% (20 mm opener width on 30 cm spacing)

10. RESULTS

10-A. PROJECT RESULTS

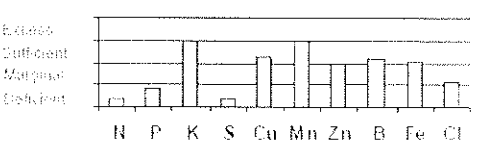
Figure 1. Soil test information for site of flax fertility trial at Indian Head, SK (2013).

SOIL TEST CHARACTERISTICS

Depth (inches)	Texture	pH 1:2 H_2O	E.C. 1:2 H_2O (mS/cm)	E.C. Calc. Sat Ext (mS/cm)	Salinity Rating	Organic Matter %	NH_4N (lb/ac)	Calculated CEC (meq/100g)	Ca	Mg	K	Na	Ca	Mg	K	Na
									ppm				% of CEC			
0-6	Loam	7.8	0.2	0.5	Non Saline	3.9										
6-24	Clay Loam	8.5	0.2	0.4	Non Saline											

SOIL TEST NUTRIENT LEVELS

Depth (inches)	NO_3-N	P	K	SO_4-S	Cu	Mn	Zn	B	Fe	Cl
	lb/ac									
0-6	13	18	600	8	4.5	27.1	1.1	2.3	24	10
6-24	18			18						15



- Soil was classified as a loam, clay loam with a relatively high pH of 7.8 to 8.3.
- Considered deficient/marginal in N, P, and S and marginal/sufficient for all other nutrients except for K and Mn which were sufficient.
- Relatively low soil organic matter (for the region) of 3.9%.

Weather

Table 2. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) normals for the 2013 growing season at Indian Head, Saskatchewan

Year	May	June	July	August	Avg. / Total
	Mean Temperature (°C)				
2013	11.9	15.3	16.3	17.1	15.2
Long-term	10.8	15.8	18.2	17.4	15.6
	Precipitation (mm)				
2013	17.1	103.8	50.4	6.1	177
Long-term	51.8	77.4	63.8	51.2	244

There were above-average temperatures in May and cooler than normal temperatures in July; otherwise close to normal temperatures. It was drier than normal overall, but well above normal precipitation in June. It was very dry late in summer.

Flax Emergence

- In all cases, the measured plant populations were below the recommended minimum of 300 plants m^{-2}; however it is possible that some further emergence occurred after the measurements were completed.
- Overall variability in flax plant populations was high (CV = 27%); however populations were significantly affected by fertilizer treatment ($P = 0.012$) with the highest densities achieved in the unfertilized check and the lowest when 30 kg P_2O_5 was applied in the seed-row.
- According to contrasts, flax densities were not reduced with seed-applied fertilizer until a minimum of 30 kg P_2O_5 ha^{-1} was applied in the seed-row and additional K and S fertilizer did not result in further reductions in plant populations.
- Increasing the rate of side-banded N from 45 kg N ha^{-1} to 90 kg N ha^{-1} did not affect plant densities.

Flax Seed Yield

- Excellent overall flax yields were achieved with the check yielding 2,269 kg ha^{-1} (36 bus/ac) and a strong response to granular fertilizer with an overall yield increase of 36% to 3139 kg ha^{-1} (50 bus/ac) when averaged across all fertilized treatments ($P < 0.001$).
- Flax yields achieved with 45 kg N ha^{-1} were significantly lower than with 90 kg N ha^{-1} ($P < 0.001$).
- Yields with 30 kg P_2O_5 ha^{-1} tended to be higher than when only 15 kg P_2O_5 was applied but increase was not significant at the desired probability level ($P = 0.079$).
- At the high N and P rates, additional K and S fertilizer tended to result in further increases in yield, although again not quite significant at the desired probability level ($P = 0.059$).

- No differences in flax yield observed between side-banded versus seed-placed P, K and S fertilizer, even at the high rates where significant reductions in plant populations were observed (P = 0.26-0.70).

Table 3. Mean plant densities and seed yields observed for flax fertilizer treatments at Indian Head (2013).

Trt #	Treatment Description	Plant Density (plants m^{-2})	Seed Yield (kg ha^{-1})
1	0-0-0-0	266 a*	2269 e
2	45-0-0-0	212 ab	2838 d
3	45-15-0-0 (SB)	175 ab	2858 cd
4	45-15-8-8 (SB)	240 ab	3045 bcd
5	45-15-0-0 (SP)	273 ab	2978 bcd
6	45-15-8-8 (SP)	201 ab	3037 bcd
7	90-15-0-0 (SB)	202 ab	3122 abcd
8	90-15-8-8 (SB)	201 ab	3306 ab
9	90-15-0-0 (SP)	198 ab	3108 abcd
10	90-15-8-8 (SP)	202 ab	3235 ab
11	90-30-0-0 (SB)	267 ab	3228 abc
12	90-30-15-15 (SB)	246 ab	3452 a
13	90-30-0-0 (SP)	120 ab	3269 ab
14	90-30-15-15 (SP)	145 b	3332 ab
	SE	28.3	73.9
	Pr > *F*	0.012	<0.001
	CV	26.9%	4.8

SB – side-banded P, K and S fertilizers
SP - seed-placed P, K and S fertilizers
* Means within a column followed by the same letter do not significantly differ according to Tukey's studentized range test

Table 4. Predetermined contrast comparisons for selected groups of flax fertilizer treatments.

Trt #	Contrast Name*	Plant Density (plants m^{-2})	Seed Yield (kg ha^{-1})
		---------- p-value** ----------	
1	Check vs. rest (1 vs. 2-14)	**0.050**	**<0.001**
2	45 N vs. 90 N (3-6 vs. 7-10)	0.288	**<0.001**
3	90-15-0 vs. 90-30-0 (7&9 vs. 11&13)	0.812	0.079
5	90-30-0-0 vs. 90-30-15-15 (11&13 vs. 12&14)	0.943	0.059

6	15 P_2O_5 (SB vs. SP) (3&7 vs. 5&9)	0.103	0.477
7	15 P_2O_5 8 K_2O 8 S (SB vs. SP) (4&8 vs. 6&10)	0.509	0.598
8	30 P_2O_5 (SB vs. SP) (11 vs. 13)	**<0.001**	0.700
9	30 P_2O_5 15 K_2O 15 S (SB vs. SP) (12 vs. 14)	**0.016**	0.258
*Only predetermined contrasts of treatments or groups of treatments were included **Differences between means for specified groups of treatments are considered significant at $P \leq 0.05$			

10-B. PROJECT EXTENSION ACTIVITIES

This project was presented at a field day at the AAFC Research Station in Indian Head on July 25, 2013. There were 68 people in attendance, including producers, researchers, industry and staff.

The day began with registration and coffee in the morning, followed by introductions and an explanation of the ADOPT program. The group travelled to the field plots and toured each of the four demonstration sites featuring flax varieties, fertilizers, herbicides, fungicides and seeding date and seeding rates. The group returned to the Research Station for lunch and a question-and-answer session on the national re-constituted flaxseed program. The day closed with a special presentation from the SaskFlax Board to IHARF in memory of Dr. Guy Lafond.

Promotional activities for the event included:

Item	*Where displayed*	*Estimated audience*
Event posting	Events calendar of SaskFlax, IHARF and Ministry of Agriculture websites	2,500
Web page/registration page	IHARF website	500
News release	SaskFlax website	500
Notice	Summer issue *Canadian Flax Industry Update* print newsletter	6,500
News release	Agriculture media and Saskatchewan Weekly Newspaper members	+100
Advertisement	*The Western Producer*	22,000
Pamphlet	Mailed to IHARF contact list	300
Announcement	Annual Indian Head Crop Management Field Day	200
Field signs	At the demonstration plots	265
Post-event news release	SaskFlax website	500
Report on the field day	Fall issue *Canadian Flax Industry Update* print newsletter	6,500

11. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- Lower overall plant populations than desired but still achieved impressive seed yields for the region, regardless of the observed populations.
- Flax is sensitive to seed-placed fertilizer but rates up 15 kg P_2O_5 ha^{-1} appeared to be safe, even with the addition of low rates of seed-placed K and S. Placing 30 kg P_2O_5 in the seed-row resulted in significant reductions in plant populations but did adversely affect yield.
- Side-banded PKS fertilizer did not affect flax populations, regardless of the rates applied.
- Strong yield response to fertilizer with the check yielding significantly lower than all other fertilized treatments, an average yield increase of 38% and increases as high as 47% for individual treatments (90-30-15-15, side-banded).
- 45 kg N ha^{-1} was not sufficient to optimize yield.
- Yields tended to be highest with full fertility packages whereby the highest yields were achieved with 90 kg N ha^{-1}, 30 P_2O_5 ha^{-1} and when P and K fertilizer were also applied; however differences between individual treatments that received a minimum of 90 kg N ha^{-1} were not significant.
- The presentation on July 25 by Ken Panchuk of the Saskatchewan Ministry of Agriculture prompted many questions from the growers in attendance. He addressed soil nutrients that are important to all crops in growers' rotations. As yield and moisture are extremely important, growers had the opportunity to learn more about fertility tools that could work in their operations. This topic was so well received that SaskFlax arranged for Mr. Panchuk to present similar information at the CropSphere conference in Saskatoon on January 14, 2014.
- Demonstration projects like this provide opportunities for dialogue with other producers and researchers, and offer practical advice.

Recommendations

A recommendation for similar research in the future would be to drop the two split N treatments and add a 90-0-0 treatment for a total of 15 treatments. The split N is difficult in terms of labour, equipment and time constraints but the 90-0-0 is easy to include and would allow for separate orthogonal contrasts for the response to N and P (also K&S together) to describe whether an observed rate response was significant, linear or quadratic.

12. ACKNOWLEDGEMENTS

These demonstrations were funded by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward bi-lateral agreement. This support was acknowledged as follows:

- Signs acknowledging ADOPT and FMC were in place for both the IHARF Crop Management Field Day (194 attendees) on July 23, 2013 and the Flax Crop Walk on July 25, 2013 (68 attendees)
- advertisement in *The Western Producer* on July 11, 2013
- insert mailed to IHARF's contact list of 7,000
- articles in both the summer and fall issues of the 2013 *Canadian Flax Industry Update*, a newsletter mailed to registered flax producers in Saskatchewan and Manitoba
- news releases both prior to and following the field day on July 25, 2013

13. APPENDICES

No additional appendices are included with this report.

14. ABSTRACT/SUMMARY

Indian Head Agricultural Research Foundation conducted a field demonstration on behalf of SaskFlax to demonstrate the response of flax to applications of varying rates of nitrogen (N), phosphorus (P) and sulphur (S) fertilizer. Implications of nitrogen, potassium and sulphur fertilizer placement on flax emergence and seed yield, and potential merits of split nitrogen applications were also investigated.

Fourteen fertilizer treatments were arranged in a RCBD and replicated four times. All N fertilizer was side-banded urea while monoammonium phosphate was either side banded or seed-placed according to the protocol.

The project concluded that flax is sensitive to seed-placed fertilizer but rates up 15 kg P_2O_5 ha-1 appeared to be safe. Placing 30 kg P_2O_5 in the seed-row resulted in significant reductions in plant populations but adversely affected yield. In addition, side-banded PKS fertilizer did not affect flax populations, regardless of the rates applied. There was a strong yield response to fertilizer with the check, yielding significantly lower than all other fertilized treatments.

The project was demonstrated at the IHARF Crop Management Field Day (194 attendees) on July 23, 2013 and at the Flax Crop Tour on July 25, 2013 with 68 participants.

15. EXPENDITURE STATEMENT