2014 Annual Report

for the

Agricultural Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Optimal Fertilizer Management for Flax Production

(Project #20130375)

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Project Identification

1. **Project Title:** Optimal Fertilizer Management for Flax
2. **Project Number:** 20130375
3. **Producer Group Sponsoring the Project:** Saskatchewan Flax Development Commission (SaskFlax)
4. **Project Location(s):** Indian Head, Saskatchewan, R.M. #156
5. **Project start and end dates (month & year):** April 2014 to February 2015
6. **Project contact person & contact details:**

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Objectives and Rationale

7. **Project objectives:**

To demonstrate the response of flax to applications of varying rates of nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) fertilizer. Implications of phosphorus, potassium and sulphur fertilizer placement (seed-placed versus side-banded) on flax emergence and seed yield were also investigated.

8. **Project 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 P2O5/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 initiated 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.

Methodology and Results

9. **Methodology:**
Field demonstrations were completed in 2013 and 2014 by the Indian Head Agricultural Research Foundation (IHARF) on behalf of the Saskatchewan Flax Development Commission (SaskFlax). The trials were located near Indian Head, Saskatchewan (R.M. #156) on an Indian Head Heavy Clay (Rego thin Black Chernozem) soil. The specific focus of the trials was to demonstrate the response of flax to varying rates and placement methods of granular N, P, K and S fertilizer. Fifteen fertilizer treatments were arranged in a randomized complete block design (RCBD) and replicated four times. All N fertilizer was side-banded urea while monoammonium phosphate, potassium chloride and ammonium sulphate were either side banded or seed-placed according to the protocol. The treatments which were evaluated are provided in Table 1.

In both years, flax was direct seeded into spring wheat stubble using a SeedMaster plot drill equipped with 8 openers spaced 30 cm apart and a trimmed plot length of 10.5 m. With an opener width of 20 mm, this drill has an effective seed bed utilization of 6.25%. The seeding rate used was 50-56 kg ha^{-1} and rates and placements of urea, monoammonium phosphate (MAP), potassium chloride (KCl) and ammonium sulphate (AS) were varied as per protocol. Weeds were controlled using registered pre-emergent and in-crop herbicide applications and foliar fungicide was applied to ensure that disease was not a limiting factor. In 2014, pre-harvest glyphosate was applied to terminate and dry down wild oats that were not controlled by the in-crop herbicide and to assist with crop dry down. The centre five rows of each plot were straight-combined when fit to do so using a Wintersteiger plot combine. Selected agronomic information and dates of field operations are provided in Table 2.

Table 1. Fertilizer Treatments evaluated in ADOPT Flax Fertility Demonstration.					
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	0	0	0	n/a
9	90	15	7.5	7.5	side-banded
10	90	15	0	0	seed-placed
11	90	15	7.5	7.5	seed-placed
12	90	30	0	0	side-banded
13	90	30	15	15	side-banded
14	90	30	0	0	seed-placed
15	90	30	15	15	seed-placed

*side-banded fertilizer was place 38 mm beside and 20 mm below seed-row; **seed-bed utilization of 6.25% (20 mm opener on 30 cm spacing); ***2014 only

Composite soil samples were collected in the early spring and submitted to ALS Laboratories to estimate residual nutrient availability and other soil properties for each site. Plant densities were estimated by counting the number of seedlings in 2 m of crop row per plot in 2013 and 4 m of crop row in 2014. No lodging was observed at any point for any treatments during the growing season in either year, therefore lodging ratings were not completed. All harvest samples were cleaned and weighed with yields expressed in kg ha^{-1} at a constant seed moisture content of 10%. Growing season weather data was monitored and recorded using the nearest Environment Canada weather station which was located approximately within 2 km the field sites for each year. Plant density and yield data were analysed using the GLM procedure of SAS with Tukey's studentized range test used to separate treatment means. Predetermined contrasts were used to evaluate the overall response of various fertilizer applications and to compare placement methods for different combinations of P, K and S fertilizer. All treatment effects and differences between means were declared significant at $P \leq 0.05$.

Table 2. Selected agronomic information for flax variety demonstrations at Indian Head (2013-14).		
Description	**2013**	**2014**
Previous Crop	Spring Wheat	Spring Wheat
Soil Sampling	May 14	May 11
Pre-Emergent Herbicide	May 17 590 g glyphosate ha^{-1}	May 18 890 g glyphosate ha^{-1} + 140 g sulfentrazone ha^{-1}
Variety	Nulin 50	CDC Bethune
Seeding Rate	50 kg ha^{-1}	56 kg ha^{-1}
Seeding Date	May 11	May 11
In-Crop Herbicide 1	June 12 40 g tepraloxydim ha^{-1}	July 7 99 g clopyralid ha^{-1} + 553 g MCPA ester ha^{-1} + 211 g sethoxydim ha^{-1}
In-Crop Herbicide 2	June 24 280 g bromoxynil ha^{-1} + 280 g MCPA ester ha^{-1}	n/a
In-Crop Herbicide 3	June 28 40 g tepraloxydim ha^{-1}	n/a
Emergence Counts	May 29	June 11
Foliar Fungicide	July 10 99 g pyraclostrobin ha^{-1}	July 12 99 g pyraclostrobin ha^{-1}
Pre-Harvest Application	n/a	September 5
Harvest Date	September 23	September 18

10. Results:

The results of the spring soil test analyses for each site are provided in Table 3. Soil texture was classified as a clay loam at both sites with similar pH in the upper 15 cm depth. Residual N was relatively low at both sites while P and S levels were lower in 2013 than in 2014. Potassium was not considered limiting in either year. Percent organic matter was 3.9% in 2013 and considerably higher at 4.7% in 2014. On average, a 1500 kg ha^{-1} (24 bu ac^{-1}) flax crop requires a total (soil + fertilizer) of 78 kg N ha^{-1}, 22 kg P_2O_5 ha^{-1}, 49 kg K_2O ha^{-1} and 16 kg S ha^{-1}.

Table 3. Residual soil nutrient levels for flax fertility demonstration sites at Indian Head, Saskatchewan (2013-14). The previous crop in both years was spring wheat.

Soil Property / Recommendation	2013	2014
	------------------------- kg/ha -------------------------	
N (60 cm)	35	24
P (15 cm)	20	44
K (15 cm)	>672	>605
S (60 cm)	29	55
Organic Matter (%)	3.9	4.7
pH (15 cm)	7.8	7.9
Texture	clay-loam	clay-loam

[Z] ALS Laboratories (Saskatoon, SK)

Mean monthly temperatures and precipitation amounts for the 2013-14 growing seasons at Indian Head are presented relative to the long-term averages in Table 4. While both springs were late with respect to snow melt and accessing fields, May was drier than normal in both years. Temperatures in May were above normal in 2013 but cooler in 2014. In contrast, June was wetter and cooler than normal in both years, especially in 2014 when more than 2.5 times the long-term normal precipitation fell. This resulted in substantial crop injury and delayed in-crop herbicide applications in 2014. July was cooler but drier than normal in both years, with very little precipitation in 2014; however, the extreme wet weather in June meant that soil moisture was abundant until towards the end of the month. August was extremely dry in 2013 and extremely wet in 2014; however, the flax was advanced enough at this point that the severe conditions were not particularly harmful or beneficial in either case. All things considered, growing conditions were more favourable in 2013 than they were in 2014 which was reflected in the yields and quality of most crops in the region over this two year period.

Table 4. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) normals for the 2013 and 2014 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
2014	10.2	14.4	17.3	17.4	14.8
Long-term	10.8	15.8	18.2	17.4	15.6
		Precipitation (mm)			
2013	17.1	103.8	50.4	6.1	177
2014	36	199.2	7.8	142.2	385
Long-term	51.8	77.4	63.8	51.2	244

Mean plant densities and seed yields for the individual fertilizer treatments in both years are presented along with the overall *F*-test results in Table 5. Both seed yields and plant densities were significantly affected by fertilizer in both years. Overall plant densities were much lower in 2013 (211 plants m^{-2} on average) than in 2014 (436 plants m^{-2} on average); however, this may have been partly due to the measurements being completed earlier in 2013, possibly before emergence was complete. In 2013, none of the measured plant populations were above the commonly recommended target of 300 plants m^{-2} while in 2014 all treatment means were above this threshold.

Overall, mean seed yields were much higher in 2013 than in 2014 with excess moisture and heavy wild oat pressure being the major limiting factors in the second year of the study. In 2013 the average yield exceed 3000 kg ha^{-1} (48 bu ac^{-1}) while in 2014 the overall mean yield was less than half of that at 1224 kg ha^{-1} (19 bu ac^{-1}). In 2014, soils at the site were saturated throughout the month of June with standing on the plots for extended periods of time. In addition to setting back and injuring the crop, this resulted in a substantial delay in the in-crop herbicide applications and spraying was completed at a time when the flax and weeds were still highly stressed due the excess moisture. This, combined with suspected Group 1 herbicide resistance, resulted in poor control of wild oats which was a major contributing factor to the low yields in 2014.

Table 5. Mean plant densities and seed yields observed with varying fertilizer rates and placements at Indian Head (2013-14). Means within a column followed by the same letter do not significantly differ according to Tukey's studentized range test ($P \leq 0.05$).

Trt	Fertilizer Treatment	Plant Density				Seed Yield			
		2013		2014		2013		2014	
		------------- plants m^{-2}		--------------		-------------- kg ha^{-1}		---------------	
1	0-0-0-0	266	a	467	ab	2269	e	701	b
2	45-0-0-0	212	ab	393	b	2838	d	963	ab
3	45-15-0-0 (SB)	175	ab	417	ab	2858	cd	1050	ab
4	45-15-8-8 (SB)	240	ab	430	ab	3045	bcd	1269	ab
5	45-15-0-0 (SP)	273	ab	450	ab	2978	bcd	1057	ab
6	45-15-8-8 (SP)	201	ab	508	a	3037	bcd	1194	ab
7	90-0-0-0	—		390	b	—		1225	ab
8	90-15-0-0 (SB)	202	ab	456	ab	3122	abcd	1232	ab
9	90-15-8-8 (SB)	201	ab	429	ab	3306	ab	1307	a
10	90-15-0-0 (SP)	198	ab	444	ab	3108	abcd	1328	a
11	90-15-8-8 (SP)	202	ab	410	ab	3235	ab	1341	a
12	90-30-0-0 (SB)	267	ab	417	ab	3228	abc	1275	ab
13	90-30-15-15 (SB)	246	ab	462	ab	3452	a	1362	a
14	90-30-0-0 (SP)	120	b	455	ab	3269	ab	1531	a
15	90-30-15-15 (SP)	145	ab	415	ab	3332	ab	1531	a
S.E.M.		28.3		20		73.9		119	
Coefficient of V. (%)		26.9		9.2		4.8		19.4	
Pr > *F*		0.012		0.014		<0.001		0.002	

SB – side-band; SP – seed-placed

For a more in depth interpretation of the results of this demonstration, single degree of freedom contrasts were used to compare specific fertilizer applications and placement methods and these results are presented separately for 2013 (Table 6) and 2014 (Table 7).

Focussing on effects on flax establishment (plant density) there was an overall reduction in plants in the fertilized plots relative to the unfertilized check in 2013 ($P = 0.050$) but not in 2014 ($P = 0.121$). However, closer inspection of the other comparisons suggests that the decline in 2013 was mostly due to seed placement of higher rates of MAP, AS and KCl (Table 6). For example, the only comparisons which were significant at $P \leq 0.05$ were for 30-0-0 SB vs. SP ($P < 0.001$) and 30-15-15 SB vs SP ($P = 0.016$) where seed placement resulted in an overall stand reduction of 28-55% relative to side-banding. Averaged across all P-K-S rates, plant populations were 14% lower with seed placement when compared to side-banding ($P = 0.058$). In 2014, where plant counts were completed later and populations were much higher, none of the contrasts were significant and there were no consistent trends suggesting lower plant densities when P-K-S fertilizer was seed-placed (Table 7).

Table 6. Predetermined contrast comparisons for effects of selected groups of flax fertilizer treatments at Indian Head in 2013.

Contrast Description	Plant Density			Yield		
	------- plants m^{-2} -------		Pr > *F*	-------- kg ha^{-1} --------		Pr > *F*
Check vs. rest	266	206	0.050	2261	3139	<0.001
45N vs 90N	222	201	0.288	2980	3193	<0.001
0P vs 15P	212	224	0.720	2838	2918	0.385
0P vs 30P	—	—	—	—	—	—
90-15-0-0 vs 90-30-0-0	201	195	0.812	3115	3248	0.079
N-P vs N-P-K-S	206	206	0.987	3094	3234	0.002
45-15-0-0 vs 45-15-8-8	224	220	0.897	2918	3041	0.104
90-15-0-0 vs 90-15-8-8	200	201	0.977	3115	3270	0.042
90-30-0-0 vs. 90-30-15-15	194	196	0.943	3248	3392	0.059
SB vs SP	222	190	0.058	3168	3160	0.841
15-0-0 SB vs SP	189	236	0.103	2990	3043	0.477
15-8-8 SB vs SP	221	202	0.509	3176	3136	0.598
30-0-0 SB vs SP	267	120	<0.001	3228	3269	0.700
30-15-15 SB vs SP	202	145	0.016	3452	3332	0.258

Table 7. Predetermined contrast comparisons for effects of selected groups of flax fertilizer treatments at Indian Head in 2014.

Contrast Description	Plant Density			Yield		
	------ plants m^{-2} ------		Pr > *F*	-------- kg ha^{-1} --------		Pr > *F*
Check vs. rest	467	434	0.121	701	1262	<0.001
45N vs 90N	440	426	0.287	1107	1287	0.021
0P vs 15P	392	441	0.007	1094	1287	0.485
0P vs 30P	390	436	0.070	1225	1403	0.229
90-15-0-0 vs 90-30-0-0	450	436	0.507	1280	1403	0.306
N-P vs N-P-K-S	440	442	0.815	1245	1334	0.201
45-15-0-0 vs 45-15-8-8	433	469	0.085	1053	1232	0.140
90-15-0-0 vs 90-15-8-8	450	420	0.146	1280	1324	0.711
90-30-0-0 vs. 90-30-15-15	436	439	0.903	1403	1447	0.713
SB vs SP	435	447	0.308	1249	1330	0.242
15-0-0 SB vs SP	436	447	0.598	1141	1192	0.667
15-8-8 SB vs SP	429	459	0.146	1288	1268	0.863
30-0-0 SB vs SP	417	455	0.196	1275	1530	0.134
30-15-15 SB vs SP	462	415	0.110	1362	1531	0.317

Focussing on seed yield, the overall response to fertilizer was highly significant ($P < 0.001$) in both 2013 and 2014 and in both cases the 90 kg N ha^{-1}rate resulted in higher flax yields than the 45 kg N ha^{-1} rate ($P < 0.001$-0.021). Despite the higher yields at the higher N rate, it is uncertain what the optimal N rate may have been as, with only two rates, it is impossible to determine whether yields would have been maximized at an intermediate rate or rates exceeding 90 kg N ha^{-1} may have been beneficial. In 2013, the data suggested that yields were further increased with the addition of P, K and S fertilizer; however, due to the very high residual K levels and relatively S levels in 2013, much of the yield increase observed with K-S fertilization was likely due to the ammonium sulphate. Despite the reduced plant densities observed with higher rates of seed-placed P-K-S fertilizer, yields were equal for the two placement methods in all possible cases. In 2014, where residual P and S levels were higher, yields were lower and other factors (i.e. excess moisture and higher weed competition) were limiting, there was no statistically significant evidence of a yield response to P, K or S fertilizer application in flax. Similar to the previous year, there were significant yield differences attributed to placement of P-K-S fertilizer in 2014.

Project Extension Activities

This demonstration was shown at the Indian Head Crop Management Field Days on July 23, 2013 and on July 22, 2014 which were attended by approximately 200 producers and industry representatives each year. A dedicated Flax Field Day was co-hosted by IHARF and SaskFlax on July 23, 2013 which was attended by 68 participants. At the 2014 IHARF field day, the discussion at the site was led by Zafer Bashi (Saskatchewan Ministry of Agriculture) and Christiane Catellier (IHARF) and revolved around some the current opportunities and challenges of flax production in Saskatchewan. Signs were in place to identify treatments and acknowledge the support of the Agricultural Demonstrations of Technologies and Practices (ADOPT) program. The results were also presented by Chris Holzapfel (IHARF) at both the Agronomy Research Update at the University of Saskatchewan in December 2013 and at the Agri-ARM Research Update on January 15, 2015 at Prairieland Park during the Crop Production Show. Finally, results from this project will be made available in the 2014 IHARF Annual Report (available online) and also made available through a variety of other media (i.e. oral presentations, popular agriculture press, fact sheets, etc.) where there is opportunity to do so.

11. Conclusions and Recommendations

Over the two year period, this demonstration has shown that flax is most responsive to fertilizer applications when residual nutrients are low and other factors, such as soil moisture and competition with weeds are not limiting to yield. While it is broadly accepted that flax is sensitive to seed-placed fertilizer, rates of 15 kg P_2O_5 as MAP did not affect plant populations in either year, even when applied with low rates of AS and KCl. When 30 kg P_2O_5 ha^{-1} was placed in the seedrow, plant populations were significantly reduced in 2013, regardless of whether AS or KCl was applied, but had no effect on flax establishment in 2014. Side-banded P, K and S fertilizer did not impact flax establishment, regardless of the rates applied in this demonstration. Flax yields were increased with fertilizer application in both years and, in both cases, 45 kg N ha^{-1} was not sufficient to reach maximum yield. It is not certain whether the optimum N rate was somewhere between 45-90 kg N ha^{-1} or higher than 90 kg N ha^{-1}. Particularly in 2013, yields tended to be highest when 90 kg N ha-1, 30 kg P_2O_5 ha-1 and 15 kg K2O / S ha-1 were applied; however, the increases were not always statistically significant. The observed benefit to K and S fertilization was likely attributable more to the AS than the KCl as residual K levels were extremely high at both sites, which is typically for most fine-textured soils in Saskatchewan. The weaker response to fertilizer, particularly P-K-S, in 2014 was mainly attributed to the much lower yields (due to excess precipitation and heavy wild oat pressure) and higher residual P and S levels. That said, adequate P fertilization is important for maintaining soil fertility and productivity over the long-term, regardless of crop response within individual years. Despite the observed reduction in plants observed at the higher rates of seed-placed P-K-S fertilizer in 2013, there were no differences in yield for the two placement methods in either year regardless of the rates or combinations of nutrients applied. This reinforces previous research results showing that either method of application is acceptable but, if rates that have potential to cause crop injury are required side-banding may be the preferred option. Overall, these results suggest that full and balanced fertility is important for enhancing flax yields but soil testing will help determine optimal rates and the overall probability of response to fertilizer applications. Once rates have been decided and the crop is established, environmental conditions (some of which are difficult to predict) are still important determining factors. Furthermore, other potential yield limiting factors such as weeds and disease must still be monitored and controlled for maximum yields and full benefits to fertilizer applications to be realized.

Supporting Information

12. Acknowledgements:

The 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.

13. Appendices

No additional appendices are included with this report.

Abstract

14. Abstract/Summary:

The Indian Head Agricultural Research Foundation (IHARF) conducted field demonstrations in 2013 and 2014 on behalf of the Saskatchewan Flax Development Commission (SaskFlax) to demonstrate the response of flax to applications of varying rates of nitrogen (N), phosphorus (P) and sulphur (S) fertilizer. Implications of phosphorus, potassium and sulphur fertilizer placement on flax emergence and seed yield were also investigated. Fifteen fertilizer treatments in total were arranged in a RCBD and replicated four times. All N fertilizer was side-banded urea while monoammonium phosphate, potassium chloride and ammonium sulphate were either side banded or seed-placed according to the protocol. Flax plant populations were reduced with seed-placed P-K-S fertilizer, but only in 2013 and only at the higher rates. Side-banded P-K-S fertilizer did not affect plant populations in either year, regardless of the rates applied. There was a strong overall flax yield response to fertilizer in both years relative to the unfertilized check; however, the yield response to P-K-S was more prominent in 2013 where overall yields were much higher and soil residual P and S levels were lower. While the project has demonstrated the overall need for adequate fertility to maximize flax yields it has also