Agriculture Demonstration of Practices and Technologies (ADOPT)

Project Final Report

The final project report should be made available electronically (MS Word). Additional data tables and or graphs may be submitted in spreadsheet format. Due to formatting, printing and distribution requirements, final reports will not be accepted as PDF documents. Completed reports must be returned by email to Evaluation.Coordinator@gov.sk.ca.

Project Title: Resubmission: Reduction of Cadmium Uptake in Flax Using Agronomic Strategies

Project Number: 20220473

Producer Group Sponsoring the Project: Saskatchewan Flax Development Commission

Project Location(s): *Provide the name or number of the rural municipality, nearest town or legal land location if possible. Provide the name of any cooperating landowner(s).* SERF (Redvers), IHARF (Indian Head), WARC (Scott), ECRF (Yorkton)

Project start date *(month & year):* 4/15/2023

Project end date *(month & year):* 2/10/2024

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Abstract *(maximum 200 words)*

Cadmium (Cd) accumulation in flax is a concern for Saskatchewan producers after the European Union established a limit of 0.5 ppm of Cd for imported flaxseed in 2021. While Cd is naturally present in SK soils, more is added through the application of Monoammonium Phosphate (MAP) fertilizer contaminated with Cd from its parent rock. This demonstration intended to evaluate the efficacy of zinc and calcium fertilization in reducing Cd levels in flax. The demonstration was established at four SK Agri-ARM sites - WARC (Scott), ECRF (Yorkton), IHARF (Indian Head), and SERF (Redvers). Seven treatments were evaluated: 1) Untreated control, 2) Zn at 2.5 kg/ha, 3) Zn at 1.25 kg/ha, 4) Zn at 5 kg/ha, 5) Gypsum at 107 kg/ha, 6) Gypsum at 53.5 kg/ha, and 7) Gypsum at 214 kg/ha. 2023 was the second year of the trial. Flax variety CDC Rowland was used and data on plant density, plant height, and yield were collected. Soil and MAP samples were collected in the beginning of the experiment and sent to the lab for Cd analysis along with harvested flaxseed from the trial. Results showed large variation in MAP Cd levels (ranging from 9-39 ppm), but soil Cd levels were found to be relatively low (<0.1-2 ppm) among all sites. None of the treatments of zinc or gypsum had a significant effect on any of the measured parameters at any site. Since seed Cd level and yield had no apparent improvement upon the application of treatments, they were deemed economically inefficient compared to the untreated control.

Sustainable Canadian Agricultural Partnership

Saskatchewan

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This project was highlighted on field days of ECRF, IHARF, and SERF with 280 people in attendance. In February 2024, WARC presented the project at Top Notch Farming extension meetings in St. Walburg and Unity, SK.

Project Objectives

This project was set up at four sites across Saskatchewan to demonstrate the efficacy of zinc and calcium fertilization for reducing cadmium levels in flaxseed. Varying rates of zinc sulphate and gypsum were applied and evaluated for their effect on cadmium accumulation in harvested flaxseed. Toxicity effect on plants during the growing season was also assessed. Lastly, an economic analysis was done to compare the economic feasibility of products. This was the second year of this demonstration.

Project Rationale

Cadmium is a toxic, non-essential heavy metal which is found naturally in Saskatchewan soils (1). Flax can accumulate high levels of cadmium in seeds, thereby introducing cadmium into the food chain (2). Cadmium accumulation has been an emerging trade concern for Canadian flax farmers after the European Union in 2021 established new regulations on maximum allowable levels of cadmium in linseed of 0.5 mg/kg or 0.5 parts per million (Official document, 3).

There is ongoing research at Agriculture and Agri-Food Canada and the University of Saskatchewan to breed for low cadmium-accumulating flax varieties (4); however, with the recent new regulations on flax imports in emerging markets, it is important to look for interim solutions and assess their economic viability. Using zinc and calcium has shown potential in pot studies in reducing cadmium accumulation in plants. Fertilizing with zinc reduced cadmium accumulation in flaxseed by 20% (5), and other studies involving durum wheat show similar effects (6, 7). Calcium/gypsum ($CaSO4$) application also reportedly reduced cadmium accumulation and content in lentil, faba bean, wheat, and canola (8, 9), likely due to the physiochemical similarities between calcium and cadmium ions. Using zinc sulphate and gypsum could thus prove to be viable and economically feasible interim solutions in addressing the pressing issue of cadmium accumulation in flax.

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Methodology

The project was carried out at four locations in Saskatchewan – WARC (Scott), ECRF (Yorkton), IHARF (Indian Head), and SERF (Redvers) in 2023. Prior to seeding, soil tests were conducted at each site to determine the level of cadmium in the soil. Additionally, since commercial phosphate fertilizers naturally contain cadmium and can be a major source of cadmium addition to the soil, a sample of the fertilizer MAP (Monoammonium phosphate) used at each site was sent to the lab for cadmium testing. The flax variety used for this project was CDC Rowland, a medium-high cadmium-accumulating variety. Seeding rate at all locations was approximately 45 lb/ac, targeting a plant stand of approximately 593 plants per square metre after accounting for germination, thousand seed weight, and 10% mortality. The field trials were set up as randomized complete block design with four replicates and seven treatments. The treatments were: 1) Untreated control, 2) Zn at 1X rate, 3) Zn at 0.5X (low) rate, 4) Zn at 2X (high) rate, 5) Gypsum at 1X rate, 6) Gypsum at 0.5X (low) rate, and 7) Gypsum at 2X (high) rate. The Zn product used was Zinc Sulphate Granular from Nexus BioAg, and the gypsum product used was GypRich Prill from Diverge Business Development Inc. Table 1 shows the treatments and rates of applied products. To ensure that other nutrients were not limiting, N, P, and S fertilizers were applied across all treatments at a constant rate of approximately 90 kg/ha, 30 kg/ha, and 20 kg/ha respectively. All fertilizers, including the treatments, were side banded at seeding.

During the growing season, data were collected on plant density and plant height post flowering to determine any adverse effects of the treatments on plant growth. Pest management varied across locations; however, weeds, disease, and insects were intended to be non-limiting in all cases. After harvest, yield was calculated (adjusted for dockage and to a uniform seed moisture content of 10%), and the harvested flaxseed samples were sent to the lab for quantification of accumulated cadmium. Table A1 in the Appendix provides temperature and precipitation data for the 2023 growing season, and Table A2 has the dates for operations at each site.

Table 1. Treatments and rates used for the project.

Trt #	Trt Description	Rate of Trt	Rate of product applied*
1	Untreated control - no zinc, no gypsum	-	-
2	Zn - 1X rate	2.5 kg/ha Zn	7.04 kg/ha $ZnSO_4$ product
3	Zn - low rate (0.5X rate)	1.25 kg/ha Zn	3.52 kg/ha $ZnSO_4$ product
4	Zn - high rate (2X rate)	5 kg/ha Zn	14.08 kg/ha $ZnSO_4$ product
5	Gypsum - 1x rate	107 kg/ha gypsum	133.75 kg/ha gypsum product
6	Gypsum - low rate (0.5X rate)	53.5 kg/ha gypsum	66.88 kg/ha gypsum product
7	Gypsum - high rate (2X rate)	214 kg/ha gypsum	267.5 kg/ha gypsum product

*Amount of product was calculated based on information from the product suppliers that the zinc sulphate product contained 35.5% zinc and the gypsum product contained 80% gypsum. The gypsum product contained 20% calcium.

Data were analysed using Statistix 10.0. One-way ANOVA was performed and post-hoc testing was done using Tukey's HSD with alpha = 0.10.

Results *(you must provide the following information)*

All locations were around 1.5°C warmer and 68-125 mm drier compared to their long-term average (Table A1 in the Appendix).

Soil and MAP fertilizer tests revealed variation in Cadmium (Cd) levels between sites (Table 2). While soil Cd levels were ≤ 0.2 ppm at all sites, Cd levels in the MAP fertilizer ranged from 9.1 ppm at WARC to 39 ppm at IHARF. Depending on the rate of application of MAP at each site, the amount of Cd inadvertently applied to the soil via MAP fertilizer ranged from 0.001 lb/ac at WARC to 0.007 lb/ac at IHARF. Full soil and fertilizer analysis reports are included in Appendix tables A3 and A4, and the fertility information for each site is included in Appendix table A5.

Table 2. Lab analysis of Cadmium content in MAP fertilizer and soil at different sites and their soil types in 2023.

Site	**WARC (Scott)**	**ECRF (Yorkton)**	**IHARF (Indian Head)**	**SERF (Redvers)**
Soil type	Dark brown, loam	Moist black, clay loam	Black, clay	Black, loam
Cd in MAP fertilizer (ppm)[†]	9.1	31.8	39	32
Cd applied to soil*	0.001 lb/ac	0.004 lb/ac	0.007 lb/ac	0.004 lb/ac
	(0.0009% of applied MAP)	(0.003% of applied MAP)	(0.004% of applied MAP)	(0.003% of applied MAP)
Cd in soil (ppm) [†]	<0.1	0.2	0.2	<0.1

[†]Analysis from Agvise Laboratories Inc, USA.
*Calculated based on lab results for cadmium (ppm) in MAP and the rate of MAP application at each site.

Mean values of parameters for each treatment along with site averages and p-values from ANOVA are shown in Table 3.

Table 3. Means of parameters and results after ANOVA analysis for each site in 2023. Different letters beside values within a column indicate statistically significant difference between site averages for that column at 90% confidence level. Same letters imply no statistically significant difference between sites averages.

Site		**Treatment**	**Plant density (plants/m^2)**	**Plant height (cm)**	**Seed Cd (ppm)**	**Yield (kg/ha)**
WARC	1	Untreated control	330	58	0.46	1893
	2	Zn - 1X rate	348	59	0.41	1967
	3	Zn - low rate (0.5X rate)	338	59	0.50	1921
	4	Zn - high rate (2X rate)	339	59	0.50	1883
	5	Gypsum - 1x rate	356	58	0.44	1836
	6	Gypsum - low rate (0.5X rate)	332	61	0.45	1893
	7	Gypsum - high rate (2X rate)	356	59	0.53	1858
		Site average	343[c]	59[b]	0.47[b]	1893[b]
		p-value	0.60	0.64	0.18	0.30
ECRF	1	Untreated control	536	59	0.21	2047
	2	Zn - 1X rate	506	59	0.15	2009
	3	Zn - low rate (0.5X rate)	564	59	0.15	2251
	4	Zn - high rate (2X rate)	636	61	0.15	2386
	5	Gypsum - 1x rate	619	59	0.19	2248
	6	Gypsum - low rate (0.5X rate)	584	60	0.16	2340
	7	Gypsum - high rate (2X rate)	537	59	0.16	1982
		Site average	569[a]	59[b]	0.16[c]	2180[a]
		p-value	0.41	0.93	0.82	0.74
IHARF	1	Untreated control	458	55	0.74	2198
	2	Zn - 1X rate	520	55	0.71	2164
	3	Zn - low rate (0.5X rate)	499	56	0.71	2189
	4	Zn - high rate (2X rate)	576	56	0.69	2143
	5	Gypsum - 1x rate	479	56	0.70	2127
	6	Gypsum - low rate (0.5X rate)	502	57	0.70	2131
	7	Gypsum - high rate (2X rate)	516	54	0.69	2125
		Site average	507[b]	55[c]	0.70[a]	2154[a]
		p-value	0.31	0.12	0.88	0.77
SERF	1	Untreated control	446	68	0.50	1754

2	Zn - 1X rate	449	65	0.37	1619
3	Zn - low rate (0.5X rate)	432	67	0.31	1586
4	Zn - high rate (2X rate)	558	67	0.45	1690
5	Gypsum - 1x rate	461	70	0.47	1815
6	Gypsum - low rate (0.5X rate)	526	66	0.49	1455
7	Gypsum - high rate (2X rate)	417	68	0.31	1611
	Site average	470[b]	67[a]	0.41[b]	1647[c]
	p-value	0.17	0.62	0.11	0.38

ANOVA on combined data showed that only the effect of Site was statistically significant on measured parameters. The effect of Treatment was not statistically significant. ECRF had the highest average plant density (567 plants/m^2) and ECRF and IHARF had the highest yields (2154-2180 kg/ha) out of all sites. SERF had the lowest yield of 1647 kg/ha averaged across treatments. The average height of plants was highest at SERF and lowest at IHARF. Cd seed content in harvested flaxseed was highest at IHARF (0.70 ppm) and lowest at ECRF (0.16 ppm).

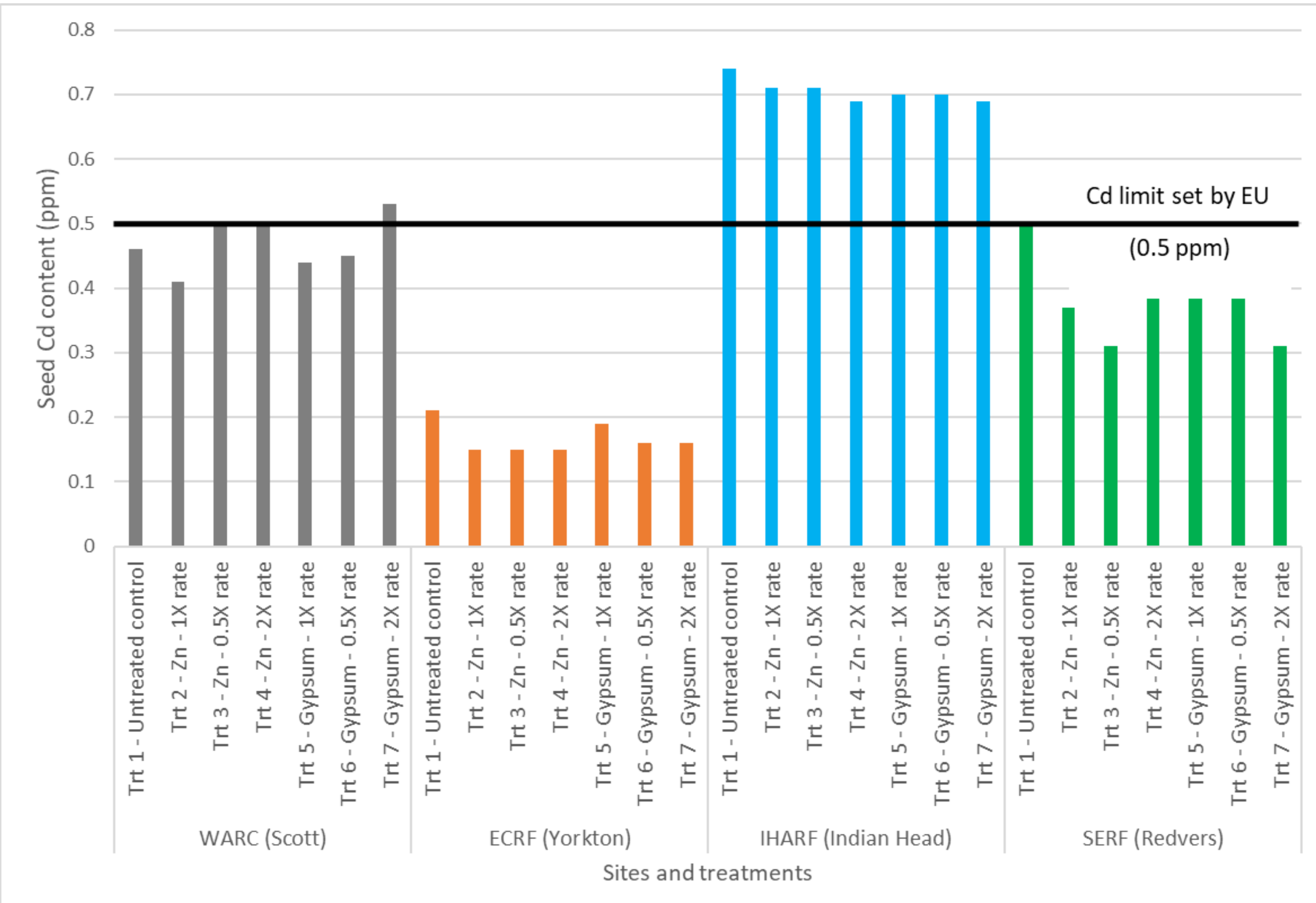

Figure 1. Cadmium accumulation in harvested flaxseed for various treatments at four different sites in the trial in 2023. Thick black line indicates maximum limit for cadmium in linseed set by the European Union (0.5 ppm).

When each site was analyzed separately, no statistically significant differences in parameters were found between treatments, implying that treatment of neither zinc nor calcium/gypsum affected plant density, plant height, yield, or seed Cd content at any of the sites (Table 3). Seed Cd content for all treatments at ECRF and SERF was below the limit of 0.5 ppm set by the European Union (Figure 1). All treatments at IHARF had seed Cd content above 0.5 ppm.

Table 4. Means of parameters and results after ANOVA analysis for each site and year. Different letters beside values, where present, indicate statistically significant differences in means for that column at 90% confidence level for that site. Same letters indicate no statistically significant difference between means for that site.

Site	Year	Plant density (plants/m²)	Average height (cm)	Yield (kg/ha)	Seed Cd (ppm)
WARC	2022	234^{g}	51^{d}	2204^{c}	0.56^{bc}
	2023	343^{f}	59^{b}	1893^{d}	0.47^{de}
ECRF	2022	583^{b}	67^{a}	3053^{a}	0.52^{cd}
	2023	569^{bc}	59^{b}	2180^{c}	0.16^{f}
IHARF	2022	526^{cd}	52^{d}	3112^{a}	0.64^{ab}
	2023	507^{de}	55^{c}	2154^{c}	0.70^{a}
SERF	2022	940^{a}	55^{c}	2486^{b}	0.20^{f}
	2023	470^{e}	67^{a}	1647^{e}	0.41^{e}

Compared to last year (2022) of this trial, a significant reduction in yield was observed at all sites this year (2023) (Table 4). Cd accumulation in harvested seed was also reduced in 2023 at all sites except IHARF. These could be due to a multitude of factors such as weather, switching flax variety to CDC Rowland in 2023 from Prairie Thunder in 2022, slightly reduced seeding rate in 2023 compared to 2022, or differences in fertility. Table 5 provides ANOVA summary of the effects of site, treatment, year, and their interaction after combining data from 2022 and 2023. Only the effects of site, year, and their interaction were significant for all parameters (Table 5). A complete set of results from the 2022 year can be found in Table A6 and A7 of the Appendix.

Table 5. ANOVA summary of effects of Site, Year, Treatment, and their interaction on measured parameters after combining data from 2022 and 2023. Values where P≤0.10 are bolded.

Factor	Plant density (plants/m²)		Average height (cm)		Yield (kg/ha)		Seed Cd (ppm)	
	F-value	Pr > F	F-value	Pr > F	F-value	Pr > F	F-value	Pr > F
Site	332.54	**0.00**	162.82	**0.00**	70.58	**0.00**	133.00	**0.00**
Year	107.15	**0.00**	106.13	**0.00**	364.98	**0.00**	8.00	**0.00**
Treatment	1.64	0.14	1.05	0.39	0.23	0.97	0.18	0.98
Site x Year	177.92	**0.00**	134.89	**0.00**	14.20	**0.00**	68.33	**0.00**
Site x Treatment	0.82	0.67	0.45	0.97	0.25	1.00	0.87	0.61
Year x Treatment	1.43	0.20	0.19	0.98	0.69	0.66	1.39	0.22
Site x Year x Treatment	0.73	0.78	0.50	0.96	0.66	0.85	0.54	0.93

<u>Economic analysis</u>

The suppliers for zinc and gypsum products used in this project quoted the cost of the zinc product to be \$5.95/kg and the cost of the gypsum product to be \$0.45/kg. The price of flax was assumed to be \$15.00/bu (2024 Saskatchewan Crop Planning Guide), or \$0.59/kg assuming a flax bushel weight of 56 lb/bu. Yield revenue was calculated for each site by multiplying the price of flax with average yield at that site.

Since yield was not statistically different between treatments at any of the sites, there was not a significant change in revenue from yield. However, the additional cost of zinc and gypsum applications would affect net returns. Table 4 shows the cost of each treatment application as a percent of yield revenue for all sites. Treatment costs ranged from 1% of yield revenue to as high as 8% of yield revenue, which was observed when gypsum was applied at 2X rate at SERF. Since the application of zinc or gypsum did not lead to significant reduction in seed cadmium levels compared to the untreated control at any of the sites, investing in these treatments does not seem economically beneficial based on the data.

Table 4. Cost of treatment application as a % of yield revenue at each site in 2023.

Treatment		Treatment cost† ($/ha)	Treatment cost as % of yield revenue			
			WARC	ECRF	IHARF	SERF
1	Untreated control	0	0	0	0	0
2	Zn - 1X rate	42	3	3	3	3
3	Zn - low rate (0.5X rate)	21	2	1	1	2
4	Zn - high rate (2X rate)	84	6	5	5	7
5	Gypsum - 1x rate	60	3	3	3	4
6	Gypsum - low rate (0.5X rate)	30	2	1	2	2
7	Gypsum - high rate (2X rate)	120	7	6	6	8

†Calculated based on the rate of products applied. Refer to Table 1 for more information.

Extension

This project was highlighted on field days of ECRF, IHARF, and SERF to a total attendance of 280 industry personnel. In February 2024, the employees of WARC, Koralie Mack and Kayla Slind, presented the project at Top Notch Farming extension meetings in St. Walburg and Unity, SK, respectively.

Conclusions and Recommendations

Despite all locations being drier and warmer than their long-term average, the trial was conducted successfully at all sites.

Soil samples analyzed for cadmium (Cd) content showed low Cd in all 4 sites, ranging from <0.1 ppm to 0.2 ppm. Cd levels were more varied in MAP fertilizer samples collected from each site and ranged from 9.1 ppm at WARC to 39 ppm at IHARF. While a causal relationship could not be established between MAP or soil Cd content and Cd content of harvested flaxseed, the location at Indian Head (IHARF), with the highest seed and MAP Cd content, produced flaxseed with highest Cd levels (averaging 0.7 ppm, 0.2 ppm higher than the MRL of 0.5 ppm set by the EU). Average Cd content of seed harvested at all other sites was within the 0.5 ppm limit.

Individual site analysis showed no significant effect of any of the treatments of zinc or gypsum on plant density, height, yield, or seed Cd content. Treatment of flax with varying rates of zinc and gypsum produced similar results as the untreated control, thus rendering the treatments economically inefficient.

Compared to 2022, flax yield was significantly reduced at all sites in 2023. Cd levels in harvested flaxseed were also lower in 2023 at all sites except IHARF. However, none of the treatments of zinc or calcium in either year at any of the sites led to a significant reduction in seed Cd levels compared to the untreated control. Findings from two years of this project suggest that at the rates and formulations used in this project, the application of neither zinc nor calcium is effective at reducing Cd accumulation in medium-high to high Cd-accumulating flax varieties.

Sustainable Canadian Agricultural Partnership (Sustainable CAP) Performance Indicators

a) List of performance indicators

Sustainable CAP Indicator	Total Number
Scientific publications from this project (List the publications under section b)	
• Published	0
• Accepted for publication	0
HQPs trained during this project	
• Master's students	0
• PhD students	0
• Post docs	0
Knowledge transfer products developed based on this project (presentations, brochures, factsheets, flyers, guides, extension articles, podcasts, videos). List the knowledge transfer products under section (c)	5

[1] Please only include the number of unique knowledge transfer products.

b) List of scientific journal articles published/accepted for publication from this project.

Title	Author(s)	Journal	Date Published or Accepted for Publication	Link (if available)

c) List of knowledge transfer products/activities developed from this project.

Knowledge Transfer Product or Activity	Event/Location Where Knowledge Transfer Was Conducted	Estimated Number of Producers Participated In Knowledge Transfer	Link (if available)
SERF Field Day (July 28, 2023)	Redvers, SK	40	
ECRF Field Day (July 21, 2023)	Yorkton, SK	80	
Top Notch Farming Extension Meeting	St. Walburg, SK	Unknown	
Top Notch Farming Extension Meeting	Unity, SK	Unknown	
IHARF Field Day (July 18, 2023)	Indian Head, SK	160	

Acknowledgements

Signage was put beside the trial for SaskFlax, and Ministry of Agriculture and ADOPT were acknowledged when giving an overview of the trial at field days at each location.

CDC Rowland seed was arranged by SaskCanola. Zinc Sulfate product for the trial was provided as in-kind support by Nexus BioAg. The gypsum product, GypRich prill, was donated by DBD Inc.

Appendices

Table A1. Mean long-term and 2022 temperature and precipitation over the growing season at the 4 sites.

Location	Year	May	June	July	August	Avg. / Total
		--------------------*Mean Temperature (°C)* -------------------				
Indian Head	2023	14.0	19.4	16.7	17.7	17.0
	Long-term	***10.8***	***15.8***	***18.2***	***17.4***	***15.6***
Scott	2023	14.9	17.2	17.1	17.4	16.7
	Long-term	***10.8***	***14.8***	***17.3***	***16.3***	***14.8***
Redvers	2023	14.5	19.7	17.6	17.8	17.4
	Long-term	***11.1***	***16.2***	***18.7***	***18.0***	***16.0***
Yorkton	2023	14.1	19.4	16.8	17.8	17
	Long-term	***10.4***	***15.5***	***17.9***	***17.1***	***15.2***
		--------------------------- *Precipitation (mm)* -------------------				
Indian Head	2023	12.9	49.6	15.9	40.8	119.2
	Long-term	***51.7***	***77.4***	***63.8***	***51.2***	244.1
Scott	2023	16.6	81.1	29.7	31.7	159.1
	Long-term	**38.9**	**69.7**	**69.4**	**48.7**	**226.7**
Redvers	2023	84.1	33.0	10.8	37.6	165.5
	Long-term	***60.0***	***85.2***	***65.5***	***46.6***	***272***
Yorkton	2023	20	83.4	17.4	72.6	193.4
	Long-term	***51***	***80***	***78***	***62***	***272***

Table A2. Dates of key operations at all sites.

Activity	---**Date**---			
	Indian Head	**Scott**	**Redvers**	**Yorkton**
Pre-seed/pre-emergent Herbicide Application	Authority 480 @ 118 ml/ac on May 19 & Roundup Weathermax @ 0.67 L/ac on May 20	Glyphosate 540 @ 1L/ac & AIM @35 ml/ac on May 16	Roundup @ 0.7 L/ac on May 9 and May 20	None
Seeding	16-May	18-May	19-May	24-May
Emergence Counts	6-Jun	15-Jun	31-May	5-Jun
In-crop Herbicide Application	Buctril M @ 0.405 L/ac + 300 ml/ac IPCO Contender (Assure 2) + 1% IPCO MSO adjuvant on June 10	Buctril M @ 0.4 L/ac, Centurion @ 150 ml/ac & Amigo @ 0.5L/100L (225mL/ac) on Jun 8	Buctril M @ 0.4 L/ac on Jun 6, Yuma @ 0.2L/ac on Jun 9, & Arrow All In @ 150 ml/ac on Jun 19	Centurion + Amigo + AMS according to label on June 19

In-crop Insecticide	None	Decis @ 60 mL/ac on July 7	None	None
Fungicide	Dyax @ 0.16 L/ac (plus 0.125% Agrol 90) on July 5	Dyax @160ml/ac on July 11	None	Dyax @160ml/ac on July 7
Plant height measurements	28-July	17-Jul	21-July	24-July
Desiccation	25-August	05-Sep	None	31-Aug
Harvest	8-Sep	12-Sep	3-Sep	5-Sep

Table A3. Soil test results from all sites.

Property/Element	**Unit**	**IHARF**		**WARC**		**SERF**		**ECRF**	
Depth	**cm**	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
CEC	**meq/100 g**	49.1	.	14.3	.	26.9	.	20.2	.
O.M.	**%**	5.8	.	3.6	.	4.7	.	6.1	.
Carbonates	**%**	1.5	.	0.3	.	0.7	.	0.5	.
ph		7.8	8.1	5.5	.	7.7	8.0	6.4	7.7
NO3-N	**ppm**	4.0	1.5	11	15.5	9.0	3.5	8.5	7.0
Olsen-P	**ppm**	8	.	21		7	.	21	
Sol Salts	**mmhos/cm**	0.50	0.51	0.17	0.45	1.1	1.78	0.23	0.29
Sulphur	**ppm**	5	6	9	10	60+	60+	8	7
Zn	**ppm**	2.45	.	1.69	.	1.11	.	1.43	.
Fe	**ppm**	20.9	.	109.2	.	18.7	.	54.8	.
Cu	**ppm**	2.0	.	0.70	.	0.76	.	0.66	.
Mn	**ppm**	3.0	.	22.2	.	3.4	.	10.2	.
Chloride	**ppm**	6.0	5.0	1.5	1.5	2.0	3.5	4.5	6.0
B	**ppm**	1.95	.	0.56	.	1.3	.	0.73	.
Cd-Total	**ppm**	0.2	.	<0.1	.	<0.1	.	0.2	.
K	**ppm**	590	.	268	.	328	.	247	.
Ca	**ppm**	7348	.	1540	.	3714	.	3118	.
Mg	**ppm**	1282	.	287	.	873	.	467	.
Na	**ppm**	39	.	14	.	53	.	15	.

Table A4. Fertilizer analysis report from all sites. All values are after analysing the dried sample.

Parameter	**Units**	**IHARF**	**WARC**	**SERF**	**ECRF**
Total Phosphate (P2O5)	%	49.95	53.29	53.49	51.67
Cadmium	ppm	39	9.1	32	31.8
Total Nitrogen	%	12	11	11	13

Table A5. Flax seeding rate and applied fertilizers and their rates at seeding for all sites.

	Seeding/Application rate (lb/ac)			
	WARC	ECRF	IHARF	SERF
Flax – CDC Rowland	45	45	44.6	45
Urea	140	165	194	128
MAP	0	58	77	51
AMS	74	21	83	74

Table A6. Lab analysis of Cadmium content in MAP fertilizer and soil at different sites in trial year 2022.

Site	WARC (Scott)	ECRF (Yorkton)	IHARF (Indian Head)	SERF (Redvers)
Soil type	Dark brown, loam	Moist black, clay loam	Black, clay	Black, loam
Cd in MAP fertilizer (ppm)†	26.2	43.3	41.3	29.7
Cd applied to soil*	0.003 lb/ac (0.006% of applied MAP)	0.003 lb/ac (0.004% of applied MAP)	0.006 lb/ac (0.01% of applied MAP)	0.004 lb/ac (0.007% of applied MAP)
Cd in soil (ppm) †	0.3	0.5	0.2	<0.1

†Analysis from Agvise Laboratories Inc, North Dakota, USA.
*Calculated based on lab results for cadmium (ppm) in MAP and the rate of MAP application at each site.

Table A7. Means of parameters and results after ANOVA analysis for each site for trial year 2022. Different letters beside values, where present, indicate statistically significant differences in means for that column at 90% confidence level for that site. Absence of letters indicate no statistically significant difference between means for that site.

Site		Treatment	Plant density (plants/m²)	Plant height (cm)	Seed Cd (ppm)	Yield (kg/ha)
WARC	1	Untreated control	246	51	0.56	2176
	2	Zn - 1X rate	223	51	0.57	2207
	3	Zn - low rate (0.5X rate)	229	51	0.58	2241
	4	Zn - high rate (2X rate)	233	52	0.51	2186
	5	Gypsum - 1x rate	242	52	0.57	2234
	6	Gypsum - low rate (0.5X rate)	236	53	0.57	2238
	7	Gypsum - high rate (2X rate)	232	52	0.59	2146
		Site average	234	52	0.56	2204
		p-value	0.98	0.71	0.74	0.69
ECRF	1	Untreated control	593	65	0.51ab	2841
	2	Zn - 1X rate	603	67	0.61a	3262
	3	Zn - low rate (0.5X rate)	591	68	0.49ab	3023
	4	Zn - high rate (2X rate)	636	69	0.41b	3075
	5	Gypsum - 1x rate	598	67	0.47ab	3013
	6	Gypsum - low rate (0.5X rate)	547	68	0.52ab	2887
	7	Gypsum - high rate (2X rate)	515	68	0.62a	3272
		Site average	583	67	0.52	3053
		p-value	0.15	0.16	0.07	0.14
IHARF	1	Untreated control	485	52	0.60	3083
	2	Zn - 1X rate	580	51	0.65	3160

	3	Zn - low rate (0.5X rate)	477	52	0.68	3137
	4	Zn - high rate (2X rate)	502	53	0.62	3096
	5	Gypsum - 1x rate	549	53	0.66	3079
	6	Gypsum - low rate (0.5X rate)	552	50	0.61	3097
	7	Gypsum - high rate (2X rate)	537	52	0.65	3135
		Site average	526	52	0.64	3112
		p-value	0.24	0.20	0.90	0.66
SERF	1	Untreated control	940	55	0.18	2423
	2	Zn - 1X rate	969	55	0.22	2574
	3	Zn - low rate (0.5X rate)	951	57	0.23	2458
	4	Zn - high rate (2X rate)	914	56	0.24	2474
	5	Gypsum - 1x rate	935	55	0.18	2427
	6	Gypsum - low rate (0.5X rate)	938	56	0.23	2560
	7	Gypsum - high rate (2X rate)	935	54	0.17	2489
		Site average	940	55	0.20	2486
		p-value	0.97	0.43	0.63	0.38

Expenditure Statement

You must provide an expenditure statement showing how ADOPT funds were used. Expenditures must be reported using the budget categories shown in Appendix B of your contract. We recommend that you report your expenditures using the Excel spreadsheet we have developed for this purpose (ADOPT Expenditure Statement.xls). That spreadsheet is available from the research branch project manager or the evaluation coordinator.

Note that the ADOPT contract requires you to retain all receipts and financial records relating to the project for at least six years after the project is completed.