

2025 Project Report

for the

Agricultural Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Enhanced Phosphorus Uptake in Flax through Novel Fertilizer Formulations and Biological Inoculants

Project #: 202401051



Principal Investigator: Chris Holzapfel¹

¹Indian Head Agricultural Research Foundation, Indian Head, SK, S0G 2K0

Collaborators: Kaeley Kindrachuk², Kade Kettenbach², Ishita Patel³, Brianne McInnes³, Mike Hall⁴, and Greg Tomcala⁴

² Saskatchewan Oilseed Development Commission, Saskatoon, SK, S7T 0J1

³ Northeast Agriculture Research Foundation, Melfort, SK, S0E 1A0

⁴ East Central Research Foundation, Yorkton, SK, S3N 3X3

Correspondence: cholzapfel@iharf.ca or (306) 695-7761

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: Enhanced phosphorus uptake in flax through novel fertilizer formulations and biological inoculants

Project Number: 20241051

Producer Group Sponsoring the Project: Saskatchewan Oilseed 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).* Indian Head (RM #156), Melfort (RM #428), and Yorkton (RM #244), Saskatchewan

Project start date (month & year): 4/1/2025

Project end date (month & year): 3/31/2026

Project Manager Contact

Full Name: Kaeley Kindrachuk, Agronomy Extension Specialist (Chris Holzapfel, IHARF, Project Lead)

Organization: Saskatchewan Oilseed Development Commission (SaskOilseeds)

Mailing Address: 225-415 Wellman Crescent, Saskatoon, SK, S7T 0J1

Phone Number: 306-975-0273

E-mail: kkindrachuk@saskoilseeds.com

Abstract *(maximum 200 words)*

Detail key elements from the project objectives, methodology, results and conclusions to provide a short concise summary of the project. List extension activities such as field days or workshops and include the number of people who visited the project.

Field trials with flax were established at three Saskatchewan locations (Indian Head, Melfort, and Yorkton) in the spring of 2025. The objective was to demonstrate options for improving phosphorus (P) uptake in flax production and the treatments were a factorial combination of three biological and four P fertilizer treatments. The biological treatments were an untreated control (UTC), granular *Penicillium bilaiae* (PB), and granular arbuscular mycorrhizal fungi (AMF) inoculants. The P treatments were a control with no P fertilizer (0P), monoammonium phosphate (MAP; 11-52-0), MicroEssentials® S15 (13-33-0-15), and Smart Nutrition™ MAP + MST (9-43-0-16). Where applicable, the P rate was 40 kg P₂O₅/ha, and all fertilizer was side-banded. Inoculant products were placed in-furrow. Data collection included residual soil qualities, emergence, early-season biomass yields, tissue P, P-uptake, seed yield, and test weights. While environment affected essentially all response variables, only seed yield and test weight were affected by the biological or P treatments. The seed yield response was unexpected, revealing a 4.5% reduction with AMF inoculant relative to

UTC when averaged across locations and P treatments. Test weight was also highest in the UTC biological treatment; however, interactions revealed that this was inconsistent across P treatments and mostly driven by high and potentially random variability at Yorkton. The trials were shown at multiple field days during the growing season and results highlights were shared during winter agronomy meetings.

Project Objectives

Provide a short statement outlining the project objectives. Identify the key concept this project was designed to demonstrate. For example, you might use a statement such as *“This project was intended to demonstrate and compare the benefits of.....”* or *“The objective of this project was to demonstrate the impact of....”*

The overall project objectives were to demonstrate the ability of contrasting phosphorus (P) fertilizer formulations and biological inoculants to improve P uptake in flax. More specifically, we wished to explore whether flax P uptake and the corresponding seed yields might vary with the specific fertilizer formulation and whether biological inoculants intended to enhance P solubility and/or uptake were utilized. Additional questions we wished to address were whether the responses differed with environment and whether the combination of novel P fertilizer forms and biological inoculants might increase flax P uptake and seed yield beyond what could be achieved with either of these inputs applied alone.

Project Rationale

Briefly describe why this project is of interest to local producers. Why is it important to have this project? What are the potential beneficial outcomes? What is the perceived need?

Although flax (*Linum usitatissimum*) has been shown to respond modestly to phosphorus (P) fertilizer applications (i.e., Holzapfel et al. 2018), the response can be unpredictable and is often less pronounced than for other common crops (i.e., Grant et al., 2009). That said, flax does have relatively high P requirements with a 2200 kg/ha crop (35 bu/ac) removing approximately 28 kg P₂O₅/ha in the seed (<https://prairienutrientcalculator.info/>) and total uptake likely being as high as 35 kg P₂O₅/ha. Monoammonium phosphate (11-52-0) has long been considered the standard with respect to granular P fertilizer options in western Canada; however, other formulations are available. While not exclusively a P product, MicroEssentials® S15 (13-33-0-15) is a multi-nutrient fertilizer which has the benefits of improved seed-safety (relative to MAP/AMS blends) and providing sulfur (S), with the S consisting of equal parts sulfate and elemental forms. Promotional material for S15 showed significantly higher canola plant populations and a 2.6 bu/ac yield advantage (average of 24 trials over a three-year period) over MAP plus ammonium sulphate (AMS) blends (Mosaic Company 2014). For wheat, when averaged over 39 sites throughout the U.S. and Canada, Mosaic (2019) reported a more modest 1.6 bu/ac advantage over MAP + AMS. University of Manitoba research with canola (Grenkow et al. 2013) showed improved seed safety over MAP/AMS but also warned that S15 may not be as effective for providing available S as sulfate-based products (i.e. MAP/AMS blends). That aside, the claim specific to P is that the combination of nutrients in S15 creates a more acidic environment which helps keep the P soluble and available for longer; thus, leading to better uptake of this nutrient. As a relatively new product, publicly available information on crop response to MAP + MST® is limited. The nutrient analysis for MAP + MST® is 9-43-0-16 and it is essentially MAP homogenized with micronized (mean particle size of 15 microns) elemental S particles (Nutrien Ltd. 2025). While this formulation is largely marketed as an improved option for delivering elemental S to crops, like MicroEssentials® formulations, the solubility and crop uptake of P with MAP + MST® may be enhanced relative to MAP due to the acidifying effect of the elemental S. While third-party research looking at the relative uptake and yield response to P is scarce for MAP + MST®, preliminary results from the Discovery Research Farm near Langham, Saskatchewan showed favorable crop responses to this product and enhanced solubility (i.e., Discovery Farm 2023; Blake Weiseth, personal communication). As of 2024, MAP accounted for 69% of the P market for canola in western Canada while approximately 14% was MicoEssentials® products and all other formulations accounted for 13%, up from 10% in 2023 (Stratus Ag Research 2024). For wheat, MAP, MicroEssentials®, and other P sources accounted for 75%, 10%, and 9%, respectively, with novel sources up from less than 5% in 2023 (Stratus Ag Research 2024).

Flax is dependent on arbuscular mycorrhizal fungi (AMF) for uptake of immobile nutrients like P. As such, high

frequencies of canola in the rotation and/or conventional tillage systems can have a negative impact (i.e., Grant et al. 2009; Monreal et al., 2011). Consequently, flax may be a particularly good candidate for biological inoculants with potential to improve P uptake. Focusing on AMF, we know that many crops benefit tremendously from their symbiotic relationship with plant roots and established AMF networks can effectively function as an extension of the crop's root system. Premier-Tech is a company with a long history of manufacturing soil amendments and biological inoculants and AGTIV® REACH G is their current AMF granular inoculant product for non-legume crops (<https://www.ptagtiv.com/en/products/aktiv-field-crops-granular/>). A meta-analysis of field studies from 1975-2013 found that AMF colonization of wheat roots was frequently improved with inoculation and that successful colonization significantly improved grain yield, harvest index, and nutrient uptake (Pellegrino et al. 2015); however, these results were not specific to no-till management and/or western Canada. In field pea and lentil, Biswaray (2015) saw some benefits of AMF inoculation to legume nutrient uptake and other growth parameters; however, responses varied across environments and seed yield increases were not observed. Islam et al. (2021) found that the long-term success of introduced AMF species varied regionally with the introduced AMF being most persistent in coarser, lower organic matter soils where there were less natural abundance and diversity of indigenous AMF (i.e., Swift Current and Outlook) as opposed to fine texture, higher organic matter soils (Scott and Melfort). This suggests that introduced AMF species may have difficulty competing with indigenous species when the latter are abundant and/or diverse. Another biological product with potential to influence P uptake of crops is *Penicillium bilaiae*, a soil fungus commonly used as a plant growth-promoting microorganism that solubilizes soil P and forms symbiotic relationships with many plant species, enhancing P uptake while feeding off plant waste products. Although the ability of these fungi to solubilize soil P is reasonably well-accepted, the benefits of inoculation under field conditions have been more elusive. When combined with different rates and sources of P fertilizer, Grant et al. (2002) reported little effect of seed inoculation with *P. bilaiae* on durum yields or grain nutrient concentrations. While seed yields were not measured, Vessy and Heisinger (2001), reported that, although P fertilization improved root growth at both sites, measurable benefits to inoculation with *P. bilaiae* only occurred at one location and in the absence of P fertilizer application. In a meta-analysis considering results from 47 wheat experiments conducted in the Canadian Prairies between 1989 and 1995, Karamanos et al. (2010) reported a response to P fertilization in 70% of the trials (33/47) and to *P. bilaiae* in 30% (14/47). The responses to *P. bilaiae*, however, were only positive at 5/14 response sites and were negative at 9/14 sites. Since these responses could not be attributed to soil properties or weather, they were essentially considered random events. No research looking at response to *P. bilaiae* inoculation specifically for flax was found in this literature review; however, this was likely because flax is a relatively minor crop both in western Canada and globally.

This project was initiated to benefit Saskatchewan farmers by demonstrating flax response to novel P formulations, alone or in combination with either AMF or P solubilizing biological inoculants. In addition to increasing awareness and generating discussion around the potential benefits and limitations of these products, we hoped to identify how flax responses to them may differ as a function of soil characteristics and/or weather conditions.

Methodology

Fully describe how the project was set up and run. You should provide enough information so that any reader can understand what you did, and where and when you did it. From that they can determine if your report has any relevance to their own operation. For example, your description should include all relevant items such as 1) the number and size of any field plots, 2) what was seeded, 3) what treatments were applied to the plots, 4) the schedule or timing of any relevant activities such as seeding, treatment application or harvest, and 5) what was measured to evaluate the success of any treatment. If your project dealt with animals, you should be sure to include 1) the number of animals in each trial group, 2) the treatment or procedure applied to each group, and 3) what was measured to evaluate the success of each treatment.

In the spring of 2025, field trials with flax (*Linum usitatissimum*) were established near Indian Head, Melfort, and Yorkton, Saskatchewan. An additional site at Scott was abandoned early in the season due to a herbicide application error. The treatments were a factorial combination of three inoculant treatments and four phosphorus (P) fertilizer treatments. The inoculant treatments were 1) an untreated control (UTC), 2), a P solubilizing *Penicillium bilaiae*

inoculant (Jumpstart® G; PB), and 3) a mycorrhizal inoculant (AGTIV® REACH G; MYC). The P treatments were 1) an unfertilized control (OP), 2) monoammonium phosphate (11-52-0; MAP), MicroEssentials® S15 (13-33-0-15; MES15), and Smart Nutrition™ MAP+MST (9-43-0-16). Where applicable, P was applied at 40 kg P₂O₅/ha. Sulfur was applied at 15-18 kg S/ha, depending on the P treatment; however, the form of S (sulfate versus elemental) varied. While the urea nitrogen (N) rate varied across locations, it was always balanced across treatments within a site and intended to be non-limiting. Fertilizer products were always side-banded, and the inoculant products were always seed-placed. The twelve treatments were arranged in a four replicate randomized complete block design (RCDB) and are described in Table 1.

Table 1. Treatment descriptions in 2025 SaskOilseeds Flax Phosphorus Uptake Demonstration.

#	Biological Inoculant ^Z	#	P Fertilizer Treatment ^Y	Sulfur Notes
1	No inoculant (UTC)	1	No P applied (OP)	16.6 kg S/ha as ammonium sulfate (AMS; 100% sulfate)
2	Jumpstart® G (PB)	2	40 kg P ₂ O ₅ /ha as MAP	16.6 kg S/ha as ammonium sulfate (AMS; 100% sulfate)
3	AGTIV® REACH G (AMF)	3	40 kg P ₂ O ₅ /ha as MES15	18.2 kg S/ha (50% sulfate 50% elemental)
		4	40 kg P ₂ O ₅ /ha as MAP+MST	14.9 kg S/ha (100% elemental)

^Z Jumpstart® G is a granular phosphorus solubilizing inoculant (1.3 x 10⁶ cfu/g *Penicillium bilaiae*)

AGTIV® REACH G is a granular mycorrhizal inoculant (178 viable *Rhizophagus irregularis* per gram)

^Y MAP (monoammonium phosphate; 11-52-0) at 77 kg/ha along with 69 kg/ha ammonium sulphate (21-0-0-24)

MES15 (MicroEssentials® S15; 13-33-0-15) at 121 kg/ha; MAP+MST (Smart Nutrition™ MAP + MST; 9-43-0-16) at 93 kg/ha

Pertinent agronomic details and dates of operations are provided in Table 13 of the Appendices. Flax was direct seeded into cereal stubble, and the variety was CDC Glas at all locations. The seeding rate was 667 seeds/m² to target 400 plants/m² at 40% mortality. Weeds were controlled using registered pre-emergent and in-crop herbicides and a preventative foliar fungicide was applied during bloom to prevent pasmo or other diseases from limiting yields. At Melfort, the plots were accidentally sprayed with imazamox and showed initial injury but recovered well; therefore, the data from this location was retained. While this incident may have impacted yields, the effects were uniform across the trial area and Melfort was our highest yielding location; thus, it was not considered to be a greater issue than many other environmental factors that could limit productivity. Preharvest herbicides or desiccants were applied at the discretion of site managers, and the centre rows of each plot were straight-combined after they were mature and sufficiently dried.

Various data were collected through the growing season and from the harvested grain samples. Emergence for each variety was estimated by counting the number of seedlings in 2 x 1 m sections of crop row) and converting the averaged values to plants/m². At Indian Head and Melfort, the above-ground biomass from 2 x 1 m sections of crop-row was harvested at the early reproductive stages, dried, and weighed to determine early-season biomass yields (kg/ha). The entire dried sub-sample was ground and submitted to Agvise Laboratories for percent total P determination. In addition to being treated as a dependant variable, the percent total P values were converted to P₂O₅ and used in conjunction with the dry matter yields to estimate early-season P-uptake (kg P₂O₅/ha). The rationale for converting these values to kg P₂O₅/ha was to make them consistent with the units we typically use when thinking about P fertilizer rates; however, doing so had no impact on relative treatment differences or statistical significance. Maturity was monitored but not affected by the treatments in any cases. Seed yields were determined from the harvested grain samples and are adjusted for dockage and to 10% seed moisture content. Test weights are expressed in g/0.5 l and were determined using standard CGC methods, a cleaned grain subsample, and two measurements per plot. Due to unusual variability that did not appear to be related to the treatments, one full replicate was discarded at both Indian Head and Yorkton. Weather data was from the nearest ECCC weather station and mean monthly temperatures and precipitation totals are expressed relative to the long-term (1981-2010) average.

Response data were analysed using the generalized linear mixed model (GLIMMIX) procedure of SAS® Studio with, unless otherwise indicated, the effects of site (S), biological inoculant (INOC), P treatment (PHOS), and all possible interactions considered fixed and replicate effects (nested within site) considered random. Heterogeneity amongst variance component estimates (by site) was tested for and permitted when significant and doing so improved model convergence. Where justified by the overall tests of fixed effects, Fisher's protected LSD test was used to separate

treatment means. All comparisons were contained within sites and the slicediff statement was used to help identify differences in responses when interactions with site were detected. All treatment effects and differences between means were considered significant at $P \leq 0.05$; however, meaningful trends or p-values ≤ 0.10 were also acknowledged.

Results (you must provide the following information)

Present and discuss any project results, including any data or measurements taken to evaluate the demonstration. Include things that didn't appear to work. These results are just as important to share. List extension activities such as field days or workshops. List the activity, the date it occurred, and the number of people who attended.

Soil characteristics for each location are provided in Table 2. The basic properties (i.e., pH, organic matter, cation exchange capacity) of the soil at each location were considered representative of the growing regions with which they corresponded. The pH was slightly alkali at Indian Head (8.0), neutral at Yorkton (7.1), and slightly acidic at Melfort (6.2). Due to the high clay content and organic matter, cation exchange capacity was highest at Indian Head and Melfort (38-48 meq) but more moderate at Yorkton which, compared to Indian Head, had a loamier texture. Organic matter was relatively high all locations, but less at Indian Head and Yorkton (5.0-5.4%) than Melfort (8.4%). Bicarbonate-extractable (Olsen) P levels were 7 ppm at Indian Head and 14 ppm at Melfort and Yorkton. Residual S was 29-74 kg S/ha, unlikely to be limiting for flax even if the elemental S in some treatments was potentially not oxidized early enough to be utilized by the current crop. Due to the potential importance of crop rotation, the previous three crops are reported in Table 13 with the most recent canola crop occurring in 2021 at Indian Head where a four year rotation is followed, but 2023 at Melfort and Yorkton.

Table 2. Selected soil test results for flax phosphorus (P) uptake demonstration conducted at Indian Head (IH), Melfort (ME), and Yorkton (YK) in 2025. Unless otherwise indicated, all measurements are representative of the 0-15 cm soil profile.

Parameter	IH-25	ME-25	YK-25
pH	8.0	6.2	7.1
Organic Matter (%)	5.0	8.4	5.4
CEC (meq)	48.1	38.4	23.9
CCE (%)	2.4	0.4	0.2
NO ₃ -N (kg/ha) ^z	27	41	72 ^y
Olsen-P (ppm)	7	14	14
K (ppm)	641	416	267
kg S/ha (kg/ha) ^z	29	52	74 ^y

^z Values for residual NO₃-N and S are for the 0-60 cm soil profile

^y Estimated by multiplying 0-30 cm values by a conversion factor of 1.5

Mean monthly temperatures and precipitation totals for the four-month (May through August) growing season are in Tables 3 and 4, respectively. Over the four-month growing season, temperature trends varied widely by site being about average at Indian Head and above-average at Melfort and Yorkton. Despite these discrepancies, May and August were warmer than average at all locations while June and July were cooler, but to a much greater extent at the more northern locations. Looking at precipitation, Indian Head was the driest location with only 136 mm over the season (56% of average) while Yorkton was intermediate (195 mm or 72% of average), and Melfort was the wettest (237 mm or 105%). The precipitation patterns differed in that at Indian Head, the season started wetter but became progressively drier, while at Melfort and Yorkton, conditions were initially dry but wetter later in the season.

Table 3. Mean monthly temperatures along with long-term (LT; 1981-2010) averages for the 2025 growing season at Indian Head (IH), Melfort (ME), and Yorkton (YK), Saskatchewan.

Year	May	June	July	August	May-Aug
----- Mean Temperature (°C) -----					
IH-25	12.7	15.3	17.0	17.8	15.7 (+0.1)
IH-LT	10.8	15.8	18.2	17.4	15.6
ME-25	13.8	15.0	17.0	18.0	16.0 (+0.8)
ME-LT	10.7	15.9	17.5	16.8	15.2
YK-25	12.4	15.7	17.5	18.3	16.0 (+0.8)
YK-LT	10.4	15.5	17.9	17.1	15.2

Table 4. Total monthly precipitation amounts along with long-term (LT; 1981-2010) averages for the 2025 growing season at Indian Head (IH), Melfort (ME), and Yorkton (YK), Saskatchewan.

Year	May	June	July	August	May-Aug
----- Total Precipitation (mm) -----					
IH-25	42.6	39.4	27.1	26.9	136 (56%)
IH-LT	51.7	77.4	63.8	51.2	244
ME-25	4.8	93.2	25.9	113.5	237 (105%)
ME-LT	42.9	54.3	76.7	52.4	226
YK-25	23.6	63.4	36.8	71.2	195 (72%)
YK-LT	51.0	80.0	78.0	62.0	272.0

The overall tests of fixed effects are presented in Table 5 which will be referred to throughout the discussion. Heterogeneity (across sites) in variance component estimates was never significant ($P = 0.349-1.000$); therefore, the simpler statistical model was always used.

Table 5. Overall tests of fixed effects for selected response variables in flax P uptake demonstrations conducted in 2025 at Indian Head (IH-25), Melfort (ME-25), and Yorkton (YK-25). Data were analyzed using the generalized linear mixed model (GLIMMIX) procedure of SAS® Studio with the effects of site (S), inoculant (INOC), phosphorus (PHOS), and all possible interactions considered fixed. Replicate effects (within site) were considered random. Heterogeneity of variance components was tested for and permitted when significant at $P \leq 0.05$.

Source	Plant Density	Biomass Yield ^z	Tissue P Conc. ^z	P ₂ O ₅ Uptake ^z	Seed Yield	Test Weight
----- Pr > F (p-values) -----						
S	<0.001	0.357	0.005	0.036	0.008	<0.001
INOC	0.303	0.472	0.972	0.425	0.039	0.006
S x INOC	0.378	0.102	0.369	0.226	0.996	0.579
PHOS	0.199	0.630	0.441	0.484	0.333	0.313
S x PHOS	0.264	0.811	0.175	0.687	0.548	0.547
INOC x PHOS	0.640	0.209	0.672	0.162	0.299	0.039
S x INOC x PHOS	0.529	0.348	0.620	0.195	0.301	0.082
Common Var.	0.349	0.795	0.356	1.000	0.494	0.816

^z Early-season biomass yields, tissue-P, and P₂O₅ Uptake were only measured at Indian Head and Melfort

The effects of location, or site, were significant ($P < 0.001-0.038$) for all response variables except early-season biomass yields ($P = 0.357$). This variation was not unexpected and is indicative of flax's sensitivity to environmental conditions with respect to establishment and overall productivity. The overall site means for each variable are presented in Table 6 which we will refer to while discussing each response variable individually.

Table 6. Overall location means for selected flax response variables. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test; $P \leq 0.05$) and values in parentheses are the standard error of the treatment mean (S.E.M.).

Location	Plant Density	Biomass Yield	Tissue P Concentration	Early-Season P-Uptake	Seed Yield	Test Weight
	--- plants/m ² ---	----- kg/ha -----	----- % -----	--- kg/P ₂ O ₅ /ha ---	----- kg/ha -----	----- g/0.5 L -----
IH-25	632 A (12.4)	958 A (30.9)	0.28 B (0.008)	6.0 B (0.23)	1960 B (113.3)	331 C (0.5)
ME-25	141 C (10.9)	916 A (26.8)	0.33 A (0.007)	6.9 A (0.20)	2643 A (98.1)	339 B (0.5)
YK-25	514 B (12.4)	–	–	–	2331 AB (113.3)	343 A (0.5)

Flax establishment was affected by site ($P < 0.001$), but no other main effects or interactions ($P = 0.199-0.640$). The site effects showed the highest populations at Indian Head (632 plants/m² or ~5% mortality), followed by Yorkton (514 plants/m² or ~23% mortality), and finally Melfort, where initial establishment was much poorer (141 plants/m² or ~79% mortality). While it is likely that the crop at Melfort filled in with the rains later in June, the high mortality at this site illustrates the sensitivity of this crop to environmental conditions during seeding and drill settings. The lack of any other treatment effects suggests that neither the side-banded P fertilizer products nor in-furrow inoculant products affected emergence. This does not necessarily mean that fertilizer injury with side-band placement could not have affected emergence in the case of Melfort, only that the urea was more important than the P/S products if this did, in fact occur. Individual treatment means for flax plant densities are presented in Table 14 of the Appendices.

Table 7. Inoculant (INOC) and phosphorus (P) treatment (PHOS) effects on flax emergence for individual sites and across sites. The inoculant treatments were an untreated control (UTC), a granular *Penicillium bilaiae* inoculant (PB), and a granular mycorrhizal inoculant (AMF). The P treatments were an unfertilized control (OP), monoammonium phosphate (MAP), MicroEssentials® S15 (MES15), and Smart Nutrition™ MAP + MST. Because neither the main effects of INOC, PHOS, nor their interactions with site, were significant, these means are presented solely for the sake of interest and transparency. Letter groupings are only provided when justified by the overall tests of fixed effects.

Main Effect	Indian Head	Melfort	Yorkton	Average
<u>INOC</u> ----- Emergence (plants/m ²) -----				
UTC	637	148	537	441
PB	615	139	517	423
AMF	645	136	486	422
S.E.M	18.7	16.7	18.7	10.4
----- Pr > F (p-value) -----				
Effect Slice ²	–	–	–	–
<u>PHOS</u> ----- Emergence (plants/m ²) -----				
OP	658	149	495	441
MAP	621	143	540	423
MES15	641	134	542	422
MAP+MST	610	138	477	441
S.E.M.	21.1	18.3	21.1	11.7
----- Pr > F (p-value) -----				
Effect Slice ²	–	–	–	–

² Effect slices are only presented when doing so is justified by a corresponding interaction with site

Again, due to infrastructure capacity differences and budget limitations, early-season biomass yields, tissue P concentrations, and P uptake were only measured at Indian Head and Melfort. Notably, early-season biomass yields were consistent ($P = 0.357$; Table 5) between the two locations (916-952 kg/ha; Table 6), but also not affected by any other main effects nor interactions ($P = 0.102-0.811$). There were differing trends for the INOC effects at Indian Head and Melfort, but without the S x INOC response being significant at the desired probability ($P = 0.102$) or any reason to expect such a response, they were likely random (Table 8). Averaged across sites, there was no evidence of any early season pop-up response to P, with 934 kg dry matter/ha in the OP control and an overall of 938 kg/ha in the plots that received P and there were no apparent trends at either site when looked at alone. Individual treatment means for early-season biomass yield are deferred to Table 15 of the Appendices, solely for interest's sake, as neither the INOC x PHOS nor S x INOC x PHOS interactions were significant.

Table 8. Inoculant (INOC) and phosphorus (P) treatment (PHOS) effects on early-season (start of flowering) biomass yield in flax for individual sites and across sites. The inoculant treatments were an untreated control (UTC), granular *Penicillium bilaiae* inoculant (PB), and granular mycorrhizal inoculant (AMF). The P treatments were an unfertilized control (OP), monoammonium phosphate (MAP), MicroEssentials® S15 (MES15), and Smart Nutrition™ MAP + MST. Because neither the main effects of INOC, PHOS, nor their interactions with site, were significant, these means are presented solely for the sake of interest and transparency. Letter groupings are only provided when justified by the overall tests of fixed effects.

Main Effect	Indian Head	Melfort	Yorkton	Average
<u>INOC</u> ----- Early-Season Biomass Yield (kg/ha) -----				
UTC	939	1007	–	972
PB	939	896	–	918
AMF	996	846	–	921
S.E.M	53.6	46.4	–	35.4
----- Pr > F (p-value) -----				
Effect Slice ^z	–	–	–	–
<u>PHOS</u> ----- Early-Season Biomass Yield (kg/ha) -----				
OP	934	934	–	934
MAP	973	969	–	971
MES15	983	912	–	947
MAP+MST	942	851	–	896
S.E.M.	61.9	53.6	–	40.9
----- Pr > F (p-value) -----				
Effect Slice ^z	–	–	–	–

^z Effect slices are only presented when doing so is justified by a corresponding interaction with site

Tissue P concentrations were affected by site ($P = 0.005$), but no other main effects nor interactions ($P = 0.175-0.972$; Table 5). Despite similar dry matter yields, tissue P concentrations were slightly higher at Melfort (0.33%) versus Indian Head (0.28%; Table 6). No other meaningful treatment effects were noted other than, perhaps, a slight trend for higher tissue P concentrations with the application of P fertilizer at Indian Head (Table 9). This response was marginally significant when the data from Indian Head was analyzed alone (not shown), but not when it was combined with Melfort. While neither the INOC x PHOS nor S x INOC x PHOS interactions were significant ($P = 0.620-0.670$), individual treatment means for this variable are provided in Table 16 of the Appendices.

Like the biomass yields and tissue P concentrations, early-season P uptake was affected by site ($P = 0.036$; Table 5), but no other main effects or interactions ($P = 0.162-0.687$). Due to the higher tissue P concentrations, early-season P uptake was slightly greater at Melfort (6.9 kg P₂O₅/ha) than at Indian Head (6.0 kg P₂O₅/ha; Table 6). Main effect means for this variable are in Table 10 while the individual treatment means are deferred to the Appendices (Table 17); however, no trends were strong enough to warrant further discussion. Importantly, these values do not reflect the total P requirements of flax since they only account for the above-ground accumulation and most of the crop's dry matter accumulation occurs later, during boll formation and filling. We chose to collect these measurements earlier in the season because this is often when P fertilizer effects on crop growth are most apparent. Early-season pop-up responses to P fertilizer frequently diminish later in the season as the root system develops and soil P becomes more available. While additional measurements at maturity may have provided additional insights towards the total P requirements of flax, budget limitations prevented us from doing these measurements at both stages. As such, we chose to focus on seed yield as the final indicator of P uptake and overall treatment performance.

Table 9. Inoculant (INOC) and phosphorus (P) treatment (PHOS) effects on flax whole plant tissue P concentrations (start of flowering) for individual sites and across sites. The inoculant treatments were an untreated control (UTC), granular *Penicillium bilaiae* inoculant (PB), and granular mycorrhizal inoculant (AMF). The P treatments were an unfertilized control (OP), monoammonium phosphate (MAP), MicroEssentials® S15 (MES15), and Smart Nutrition™ MAP + MST. Because neither the main effects of INOC, PHOS, nor their interactions with site, were significant, these means are presented solely for the sake of interest and transparency. Letter groupings are only provided when justified by the overall tests of fixed effects.

Main Effect	Indian Head	Melfort	Yorkton	Average
<u>INOC</u> ----- Tissue P Concentrations (% Total P) -----				
UTC	0.28	0.32	–	0.30
PB	0.28	0.33	–	0.30
AMF	0.27	0.33	–	0.30
S.E.M	0.010	0.009	–	0.007
----- Pr > F (p-value) -----				
Effect Slice ^z	–	–	–	–
<u>PHOS</u> ----- Tissue P Concentrations (% Total P) -----				
OP	0.26	0.33	–	0.29
MAP	0.29	0.32	–	0.31
MES15	0.28	0.33	–	0.30
MAP+MST	0.27	0.33	–	0.30
S.E.M.	0.011	0.009	–	0.007
----- Pr > F (p-value) -----				
Effect Slice ^z	–	–	–	–

^z Effect slices are only presented when doing so is justified by a corresponding interaction with site

Table 10. Inoculant (INOC) and phosphorus (P) treatment (PHOS) effects on early-season (start of flowering) P uptake in flax for individual sites and across sites. The inoculant treatments were an untreated control (UTC), granular *Penicillium bilaiae* inoculant (PB), and granular mycorrhizal inoculant (AMF). The P treatments were an unfertilized control (OP), monoammonium phosphate (MAP), MicroEssentials® S15 (MES15), and Smart Nutrition™ MAP + MST. Because neither the main effects of INOC, PHOS, nor their interactions with site, were significant, these means are presented solely for the sake of interest and transparency. Letter groupings are only provided when justified by the overall tests of fixed effects.

Main Effect	Indian Head	Melfort	Yorkton	Average
<u>INOC</u> ----- Early-Season P Uptake (kg P ₂ O ₅ /ha) -----				
UTC	6.0	7.5	–	6.7
PB	5.9	6.7	–	6.3
AMF	6.2	6.4	–	6.3
S.E.M	0.39	0.34	–	0.26
----- Pr > F (p-value) -----				
Effect Slice ^z	–	–	–	–
<u>PHOS</u> ----- Early-Season P Uptake (kg P ₂ O ₅ /ha) -----				
OP	5.6	7.0	–	6.3
MAP	6.4	7.1	–	6.7
MES15	6.2	6.9	–	6.6
MAP+MST	5.9	6.4	–	6.2
S.E.M.	0.46	0.39	–	0.30
----- Pr > F (p-value) -----				
Effect Slice ^z	–	–	–	–

^z Effect slices are only presented when doing so is justified by a corresponding interaction with site

Flax seed yield was measured at all three locations and affected by site ($P = 0.008$) and inoculant treatment ($P = 0.039$) but not P treatment ($P = 0.333$) nor any interactions ($P = 0.299-0.996$; Table 5). The site effects revealed that flax yields appeared to be largely influenced by precipitation in 2025 with the highest yields at Melfort (2643 kg/ha), intermediate yields at Yorkton (2331 kg/ha), and the lowest yields at Indian Head (1960 kg/ha; Table 6). Notably, most crops had

above average yields at Indian Head in 2025; however, the flax appeared to be adversely affected by the late-season heat and drought. The inoculant response was unexpected, showing a small (4.5%) but significant yield reduction with the AMF inoculant relative to the UTC and intermediate yields with the addition of *Penicillium bilaiae* (Table 11). While unexpected, the lack of an S x INOC treatment ($P = 0.996$) and inspection of individual site means confirms that this response was consistent. Possible explanations could be that the introduced AMF strains competed with native populations or increased carbon drain on the plants due to AMF feeding on photosynthates without providing sufficient improvements in water or nutrient uptake in return (i.e., Dai et al. 2014; Ryan and Graham. 2002). Examples where no benefit to AMF inoculation was observed under field conditions are not uncommon in the literature, particularly under field conditions with no-till management and following host crops. However, a negative response was considered unlikely with an AMF dependent crop like flax and under management where native populations may already be abundant. Seed yields with P fertilizer application trended higher at Yorkton (7%) and, to a lesser extent, Indian Head (3%), but without even marginally significant PHOS or S x PHOS effects ($P = 0.333-0.548$) we cannot suggest that this was a genuine response. Across locations and inoculant treatments, yields in the OP control (2257 kg/ha) were 97% of what was achieved with P fertilizer (2329 kg/ha). With no INOC x PHOS or S x INOC x PHOS effects detected ($P = 0.299-0.301$), the individual treatment means (Table 18; Appendices) are only presented for interest's sake. In general, we can see that yields were still quite variable at Yorkton, despite having removed what appeared to be the worst affected replicate.

Table 11. Inoculant (INOC) and phosphorus treatment (PHOS) effects on flax seed yield for individual sites and across sites. The inoculant treatments were an untreated control (UTC), granular *Penicillium bilaiae* inoculant (PB), and granular mycorrhizal inoculant (AMF). The P treatments are an unfertilized control (OP), monoammonium phosphate (MAP), MicroEssentials® S15 (MES15), and Smart Nutrition™ MAP + MST. Because neither the main effects of PHOS, S x INOC nor S x PHOS effects were significant, these means are presented solely for the sake of interest and transparency. Letter groupings are only provided when justified by the overall tests of fixed effects, in which case values within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test; $P \leq 0.05$).

Main Effect	Indian Head	Melfort	Yorkton	Average
<u>INOC</u> ----- Seed Yield (kg/ha) -----				
UTC	2017	2711	2390	2373 A
PB	1955	2626	2304	2295 AB
AMF	1908	2591	2298	2266 B
S.E.M	121.7	105.4	121.7	42.5
----- Pr > F (p-value) -----				
Effect Slice ^z	–	–	–	–
<u>PHOS</u> ----- Seed Yield (kg/ha) -----				
OP	1916	2638	2218	2257
MAP	1939	2649	2398	2329
MES15	1975	2699	2351	2342
MAP+MST	2010	2585	2356	2317
S.E.M.	125.6	108.8	125.6	69.4
----- Pr > F (p-value) -----				
Effect Slice ^z	–	–	–	–

^z Effect slices are only presented when doing so is justified by a corresponding interaction with site

Test weights of the harvested flax seed were affected by site (<0.001), and inoculant ($P = 0.006$) with a significant INOC x PHOS interaction ($P = 0.039$) also detected (Table 5). The site response (Table 6) was such that test weight was lightest at Indian Head (331 g/0.5 L), highest at Yorkton (343 g/0.5 L), and intermediate at Melfort (339 g/0.5 L). The overall INOC effect was due to the UTC (339 g/0.5 L) having slightly lower test weight on average than either the PB or AMF inoculant treatments; however, the response was too small to be of much importance and somewhat variable within individual sites (Table 12). The INOC x PHOS interaction revealed inconsistencies in the P responses, depending on the inoculant treatment. In the UTC (no inoculant) control, test weights with OP and MAP were higher than all other treatments while, with AMF, test weights tended to be lower in the OP control (Table 19). While only marginally significant ($P = 0.082$), the S x INOC x PHOS interaction revealed that most of the discrepancy was driven by the results

at Yorkton, our most variable site, and could be largely random.

Table 12. Inoculant (INOC) and phosphorus (P) treatment (PHOS) effects on the test weight of harvested flax seed for individual sites and across sites. The inoculant treatments were an untreated control (UTC), granular *Penicillium bilaiae* inoculant (PB), and granular mycorrhizal inoculant (AMF). The P treatments were an unfertilized control (OP), monoammonium phosphate (MAP), MicroEssentials® S15 (MES15), and Smart Nutrition™ MAP + MST. Because neither the main effects of PHOS, S x INOC nor S x PHOS effects were significant, these means are presented solely for the sake of interest and transparency. Letter groupings are only provided when justified by the overall tests of fixed effects, in which case values within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test; $P \leq 0.05$).

Main Effect	Indian Head	Melfort	Yorkton	Average
----- Test Weight (g 0.5/L) -----				
INOC				
UTC	332	340	343	339 A
PB	330	340	342	337 B
AMF	331	339	342	337 B
S.E.M	0.71	0.62	0.71	0.39
----- Pr > F (p-value) -----				
Effect Slice ²	–	–	–	–
----- Test Weight (g 0.5/L) -----				
PHOS				
OP	331	340	342	338
MAP	331	340	344	338
MES15	331	339	342	337
MAP+MST	332	339	343	338
S.E.M.	0.8	0.7	0.8	0.44
----- Pr > F (p-value) -----				
Effect Slice ²	–	–	–	–

² Effect slices are only presented when doing so is justified by a corresponding interaction with site

Extension Activities

This project was featured at the Indian Hed Crop Management Field Day (July 15, 2025; 157 attendees), Kade Kettenbach (SaskOilseeds) and Chris Holzapfel (IHARF) introduced the project and objectives along with results from past complimentary projects. At Melfort, the trial was not a formal stop but was outfitted with treatment and sponsor signs and acknowledged during NARF/AAFC Joint Annual Field Day (July 23, 2025; 126 attendees), while Kade Kettenbach (SaskOilseeds) gave a more formal presentation during the NARF/AAFC Minor/Niche Crops Field Day (July 24, 2025; 36 attendees). Chris Holzapfel presented preliminary results during a phosphorus presentation at the Manitoba Agronomists Conference (Dec-10, 2025) which was recorded to be posted online later but viewed live by 410 participants. Results may be incorporated into future Fact Sheets prepared by IHARF, SaskOilseeds, and/or AgriARM and the final technical report will be available online through IHARF and AgriARM websites. We will continue to incorporate results highlights into future presentations where appropriate opportunities arise.

Conclusions and Recommendations

Describe what was learned from the demonstration. Highlight any significant conclusions and provide recommendations for the application and adoption of the project results. Be sure that you have presented the relevant data to support your conclusions. Identify any further research, development and communication needs, if applicable.

Overall, the results from this project did not demonstrate any significant responses to phosphorus (P) fertilizer application, regardless of the formulation. In terms of the lack of a P response, past research has shown flax to be a good scavenger of soil P and relatively unresponsive to fertilizer; however, more extensive trials have shown that modest yield gains can be expected with this crop when averaged over fields and years. Furthermore, an important goal of P fertilization is to maintain or build residual soil fertility; therefore, applying some P will be recommended under most circumstances to ensure optimum yields in the current flax crop while achieving longer-term soil fertility objectives. With no differences between formulations in terms of crop response, the most economical P fertilizer option

would be that which is the least expensive, most likely monoammonium phosphate (MAP; 11-52-0); however, MicroEssentials® S15 and Smart Nutrition™ MAP + MST may still be attractive to farmers seeking alternatives to ammonium sulfate as an S source. Regarding responses to biological inoculant products, our results were not necessarily inconsistent with past work since significant responses to both *Penicillium bilaiae* and mycorrhizal (AMF) inoculants have been rather elusive under field conditions in western Canada. While the observed seed yield reduction with AMF can potentially be rationalized, it was unexpected and conducting this work over additional years and/or locations is recommended to see if is repeatable or simply disappears with a larger data set. That said, our control treatments always performed at least as well as the treated plots; therefore, neither of these inoculant products would specifically be recommended for no-till, dryland flax production based on the current results.

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
Highly Qualified Personnel (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) ¹ . 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. Please ensure that each line includes the following: **Title, Author(s), Journal, Date Published or Accepted for Publication and Link to Article (if available)**. Add additional lines as needed.

1. Not Applicable – no scientific articles associated with this project have been submitted for peer-review or publication.

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)
C. Holzapfel (IHARF) and K. Kettenbach (SaskOilseeds) plot tour / presentation	Indian Head Crop Management Field Day (Indian Head, Jul-15-2025)	157	https://iharf.ca/indian-head-crop-management-field-day/
C. Holzapfel (IHARF) Presentation	Manitoba Agronomists Conference (Winnipeg, Dec-10-2025)	410	https://umanitoba.ca/agricultural-food-sciences/manitoba-agronomists-conference

I. Patel (NARF) Plot Tour	NARF/AAFC Join Annual Field Day (Jul-23-2025)	126	https://neag.ca/events/
K. Kettenbach (SaskOilseeds) Presentation / Plot Tour	NARF/AAFC Minor/Niche Crops field Day (Melfort, July 24, 2025)	36	https://neag.ca/events/
Final Project Report	IHARF Website (online)	not known	https://iharf.ca/full-reports/

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Appendices

Include any additional materials supporting the previous sections, e.g. detailed data tables, maps, graphs, specifications, literature cited (Use a consistent reference style throughout).

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Supplemental Tables

Table 13. Pertinent agronomic information for 2025 flax phosphorus (P) uptake demonstrations conducted at Indian Head, Melfort, and Yorkton, Saskatchewan in 2025.

Operation / Activity	Indian Head	Melfort	Yorkton
Previous Three Crops	Canary (24) Field Pea (23) Wheat (22)	Wheat (24) Canola (23) Cereal Plots (22)	Wheat (24) Canola (23) Wheat (22)
Row Spacing	30.5 cm	30.5 cm	30.5 cm
Nitrogen Rate	115 kg N/ha	100 kg N/ha	72 kg N/ha
Seeding Date	May-9-2025	May-14-2025	May-22-2025
Plant Density	Jun-3-2025	Jun-10-2025	Jun-4-2025
Biomass Date	Jul-2-2025	Jul-7-2025	n/a
Fungicide Date	Jul-5-2025	Jul-11-25	Jul-14-2025
Desiccation	Sep-8-2025 (glyphosate)	Sep-23-2025 (glyphosate)	Sep-8-2025 (diquat)
Harvest Date	Sep-21-2025	Oct-7-2025	Sep-22-2025

Table 14. Biological inoculant (INOC) by phosphorus (P) treatment (PHOS) effects on flax emergence for individual sites (S) and averaged across sites. The inoculant treatments were an untreated control (UTC), granular *Penicillium bilaiae* inoculant (PB), and granular mycorrhizal inoculant (AMF). The P treatments were an unfertilized control (OP), monoammonium phosphate (MAP), MicroEssentials® S15 (MES15), and Smart Nutrition™ MAP + MST. With no significant INOC x PHOS or S x INOC x PHOS interactions, these means are presented solely for the sake of interest and transparency.

INOC	PHOS	Indian Head	Melfort	Yorkton	Average
----- Emergence (plants/m ²) -----					
UTC	OP	687	160	496	448
	MAP	611	147	626	461
	MES15	630	139	562	444
	MAP+MST	621	146	466	411
PB	OP	627	135	476	413
	MAP	599	166	532	432
	MES15	655	125	562	447
	MAP+MST	578	129	497	401
AMF	OP	659	152	515	442
	MAP	652	116	461	410
	MES15	638	136	502	425
	MAP+MST	639	140	469	413
S.E.M		35.0	30.7	35.0	19.4
Effect Slice ^z (p-value)		–	–	–	–

^z Effect slices are only presented when doing so is justified by a corresponding interaction with site

Table 15. Biological inoculant (INOC) by phosphorus (P) treatment (PHOS) effects on early-season biomass yields in flax for individual sites (S) and averaged across sites. The inoculant treatments were an untreated control (UTC), granular *Penicillium bilaiae* inoculant (PB), and granular mycorrhizal inoculant (AMF). The P treatments were an unfertilized control (OP), monoammonium phosphate (MAP), MicroEssentials® S15 (MES15), and Smart Nutrition™ MAP + MST. With no significant INOC x PHOS or S x INOC x PHOS interactions, these means are presented solely for the sake of interest and transparency.

INOC	PHOS	Indian Head	Melfort	Yorkton	Average
----- Early-Season Biomass Yield (kg/ha) -----					
UTC	OP	951	1134	–	1042
	MAP	960	1194	–	1077
	MES15	862	874	–	868
	MAP+MST	982	826	–	904
PB	OP	872	984	–	928
	MAP	967	837	–	902
	MES15	1036	935	–	984
	MAP+MST	882	829	–	856
AMF	OP	979	686	–	832
	MAP	992	874	–	933
	MES15	1053	926	–	989
	MAP+MST	961	897	–	929
S.E.M		107.2	92.8	–	70.9
Effect Slice ^z (p-value)		–	–	–	–

^z Effect slices are only presented when doing so is justified by a corresponding interaction with site

Table 16. Biological inoculant (INOC) by phosphorus (P) treatment (PHOS) effects on flax whole plant tissue P concentrations (start of flowering) for individual sites (S) and averaged across sites. The inoculant treatments were an untreated control (UTC), granular *Penicillium bilaiae* inoculant (PB), and granular mycorrhizal inoculant (AMF). The P treatments were an unfertilized control (OP), monoammonium phosphate (MAP), MicroEssentials® S15 (MES15), and Smart Nutrition™ MAP + MST. With no significant INOC x PHOS or S x INOC x PHOS interactions, these means are presented solely for the sake of interest and transparency.

INOC	PHOS	Indian Head	Melfort	Yorkton	Average
----- Tissue P Concentrations (% Total P) -----					
UTC	OP	0.25	0.33	–	0.29
	MAP	0.30	0.33	–	0.31
	MES15	0.28	0.33	–	0.31
	MAP+MST	0.28	0.31	–	0.29
PB	OP	0.27	0.33	–	0.30
	MAP	0.29	0.32	–	0.30
	MES15	0.28	0.32	–	0.30
	MAP+MST	0.27	0.36	–	0.31
AMF	OP	0.26	0.33	–	0.30
	MAP	0.28	0.33	–	0.30
	MES15	0.27	0.34	–	0.31
	MAP+MST	0.27	0.33	–	0.30
S.E.M		0.016	0.014	–	0.2917
Effect Slice ^z (p-value)		–	–	–	–

^z Effect slices are only presented when doing so is justified by a corresponding interaction with site

Table 17. Biological inoculant (INOC) by phosphorus (P) treatment (PHOS) effects on early-season (start of flowering) P uptake in flax for individual sites (S) and averaged across sites. The inoculant treatments were an untreated control (UTC), granular *Penicillium bilaiae* inoculant (PB), and granular mycorrhizal inoculant (AMF). The P treatments were an unfertilized control (OP), monoammonium phosphate (MAP), MicroEssentials® S15 (MES15), and Smart Nutrition™ MAP + MST. With no significant INOC x PHOS or S x INOC x PHOS interactions, these means are presented solely for the sake of interest and transparency.

INOC	PHOS	Indian Head	Melfort	Yorkton	Average
----- Early-Season P Uptake (kg P ₂ O ₅ /ha) -----					
UTC	OP	5.5	8.6	–	7.1
	MAP	6.6	9.0	–	7.8
	MES15	5.6	6.6	–	6.1
	MAP+MST	6.2	5.8	–	6.0
PB	OP	5.3	7.3	–	6.3
	MAP	6.3	6.0	–	6.1
	MES15	6.6	6.8	–	6.7
	MAP+MST	5.5	6.7	–	6.1
AMF	OP	5.8	5.2	–	5.5
	MAP	6.3	6.5	–	6.4
	MES15	6.5	7.2	–	6.9
	MAP+MST	5.9	6.7	–	6.3
S.E.M		0.79	0.68	–	0.52
Effect Slice ^z (p-value)		–	–	–	–

^z Effect slices are only presented when doing so is justified by a corresponding interaction with site

Table 18. Biological inoculant (INOC) by phosphorus (P) treatment (PHOS) effects on flax seed yield for individual sites (S) and averaged across sites. The inoculant treatments were an untreated control (UTC), granular *Penicillium bilaiae* inoculant (PB), and granular mycorrhizal inoculant (AMF). The P treatments are an unfertilized control (OP), monoammonium phosphate (MAP), MicroEssentials® S15 (MES15), and Smart Nutrition™ MAP + MST. With no significant INOC x PHOS or S x INOC x PHOS interactions, these means are presented solely for the sake of interest and transparency.

INOC	PHOS	Indian Head	Melfort	Yorkton	Average
----- Seed Yield (kg/ha) -----					
UTC	OP	1924	2693	2493	2370
	MAP	2067	2760	2476	2434
	MES15	2036	2783	2286	2368
	MAP+MST	2042	2610	2305	2319
PB	OP	1971	2704	2101	2259
	MAP	1894	2583	2214	2230
	MES15	1930	2643	2539	2371
	MAP+MST	2023	2575	2362	2320
AMF	OP	1853	2519	2059	2143
	MAP	1857	2605	2505	2322
	MES15	1957	2673	2227	2286
	MAP+MST	1964	2570	2400	2311
S.E.M		153.8	133.2	153.8	85.0
Effect Slice ^z (p-value)		–	–	–	–

^z Effect slices are only presented when doing so is justified by a corresponding interaction with site

Table 19. Biological inoculant (INOC) by phosphorus (P) treatment (PHOS) effects on the test weight of harvested flax seed for individual sites (S) and averaged across sites. The inoculant treatments were an untreated control (UTC), granular *Penicillium bilaiae* inoculant (PB), and granular mycorrhizal inoculant (AMF). The P treatments were an unfertilized control (OP), monoammonium phosphate (MAP), MicroEssentials® S15 (MES15), and Smart Nutrition™ MAP + MST. Values within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test; $P \leq 0.05$).

INOC	PHOS	Indian Head	Melfort	Yorkton	Average
----- Test Weight (g 0.5/L) -----					
UTC	OP	332 a	341 a	346 a	340 A
	MAP	331 a	342 a	345 a	340 A
	MES15	332 a	339 a	341 bc	337 BC
	MAP+MST	332 a	340 a	341 bc	338 B
PB	OP	330 a	340 a	341 bc	337 BC
	MAP	330 a	340 a	341 ab	337 BC
	MES15	330 a	338 a	344 ab	338 B
	MAP+MST	331 a	340 a	343 abc	338 B
AMF	OP	331 a	339 a	340 c	336 C
	MAP	330 a	339 a	344 ab	338 B
	MES15	331 a	339 a	341 bc	337 BC
	MAP+MST	332 a	338 a	344 ab	338 B
S.E.M		1.2	1.1	1.23	0.68
Effect Slice ^z (p-value)		0.630	0.300	0.002	—

^z The S x INOC x PHOS interaction was only marginally significant ($P = 0.082$); interpret discrepancies between sites cautiously

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.

Provided in a separate Excel workbook and available upon request.