2018 Annual Report
for the

Agricultural Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Seed-Placed Phosphorus Fertilizer Forms and *P. bilaii* Effects on Canola Emergence, Phosphorus Uptake, and Yield

(Project #20170410)

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Project Identification

1. **Project Title:** Seed-placed phosphorus fertilizer forms and *P. bilaii* effects on canola emergence, phosphorus uptake, and yield
2. **Project Number:** 20170410
3. **Producer Group Sponsoring the Project:** Indian Head Agricultural Research Foundation
4. **Project Location(s):** Indian Head, Saskatchewan, R.M. #156
5. **Project start and end dates (month & year):** April-2018 to February-2019
6. **Project contact person & contact details:**

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Objectives and Rationale

7. **Project objectives:**

The objective of this project was to demonstrate the relative crop safety and agronomic performance of seed-placed granular phosphorus (P) fertilizer forms when applied in the seed-row with and without the P solubilizing inoculant *Penicillium bilaii* (Jumpstart®).

8. **Project Rationale:**

As of 2015, 81% of soil samples evaluated from Saskatchewan had P levels that were considered to be below critical levels and the average pH was 7.4. Higher pH soils, common throughout much of eastern Saskatchewan, also lead to reduced P fertilizer use-efficiency. Saskatchewan farmers are becoming increasingly aware of the long-term importance of P fertilization and many would like to maintain or build P levels over the long-term; however, P fertilizer use-efficiency in the year of application is notoriously low – generally below 30%. Consequently, many growers are seeking means of improving this efficiency and alternative formulations (i.e. MES15, Alpine P) or biological products (i.e. *P. bilaii*, mycorrhizal inoculants, humic acids) are seen as possible solutions to this challenge.

Canola is known to be a large user of P and, compared to many crops, quite responsive to fertilizer applications. It is also well documented that high rates of seed-placed P fertilizer have potential to reduce seedling survival and establishment in canola. At the same time, many growers and agronomists prefer to place at least some P in the seed-row to ensure it is not limiting early in the season, especially in soils with high pH or very extremely low residual P levels. While P fertilizer application will typically result in higher canola seed yields when soil residual levels are low, the response is often most apparent early in the season when more vigorous growth with P fertilization is frequently observed. This is commonly referred to as a 'pop-up' effect and is primarily attributed to seed-placed P fertilizer but can also be observed with side-banded P under most conditions. The greatest advantages to seed-placed P compared to other placement options with respect to early-season growth and P uptake are often observed under dry conditions but, unfortunately, this is also when the risk of seedling injury is highest. While side-banding is widely recognized as a viable, safe application method, most P applied during seeding is seed-placed (51% compared to 36% for side-banding, Stratus Ag Research 2015).

With regard to P fertilizer forms, most research has shown that the fate of different products along with potential crop response is similar, regardless of initial differences in their chemical composition. Of the growers who apply P fertilizer to canola, monoammonium phosphate (11-52-0) holds 73% of the market for canola production (Stratus Ag Research, 2015). While not exclusively a P product, MES15 is a premium, multi-nutrient fertilizer which is often perceived as having the benefit of improved seed-safety (compared to MAP/AS blends) and providing season-long sulphur with the S consisting of equal parts SO_4-S and elemental forms. Promotional material and internal research on MES15 from Mosaic showed significantly higher plant populations and a 2.6 bu/ac advantage (3-year average, 24 trials) over MAP plus ammonium sulphate (AS) blends. Independent research completed at the University of Manitoba (Grenkow et al. 2013) also showed improved seed safety over MAP/AS but warned that MES15 may not be as effective at providing plant available S as the conventional products under more severely limiting conditions. That aside, the claim specific to phosphorus is that the combination of nutrients and elemental S in MES15 creates a more acidic environment which helps keep the P in soluble forms for a longer period of time leading to better crop uptake. There is relatively little previous research with MES15 that is focussed specifically on P as opposed to MAP/AS blends.

Penicillium bilaii, a P solubilizing bacterium which is the active ingredient found in products such as Jumpstart® and TagTeam® has been available for 15-20 years and is utilized by an appreciable number of farmers; however, independent research has generally shown limited and inconsistent agronomic responses. A three-year, multi-location trial with sites in Manitoba and Saskatchewan showed a significant yield response in two out of nine site-years but the response was positive at one and negative at the other (Mohr et. al. 2013). The observed responses to *P. bilaii* inoculation were consistent regardless of P fertilizer management. Karamonos et al. (2010) summarized results from forty-seven spring wheat field trials conducted from 1989-1995 and found that 70% of the sites were responsive to P and 30% were response to *P. bilaii*; however, of the fourteen sites responsive to *P. bilaii*, only five showed a significant yield increase while nine had lower yields with inoculation. The authors suggested that the responses could not be attributed to extractable P, soil organic matter, soil texture, or weather and concluded that they were random events. Internal testing and promotional material from Acceleron BioAg shows an average 6% yield increase with Jumpstart® on canola (71 trials) but notes that individual results may vary (https://www.acceleronsas.ca/products/jumpstart).

The current project was initiated to demonstrate (in the year of application and in a deficient soil) the potential P supply benefits (or lack thereof) of contrasting P fertilizer formulations (MAP and MES15) with and without the addition of a P solubilizing inoculant (*P. bilaii*).

Grenkow, L., Flaten, D., Grant, C. and J. Heard. 2013. Seed-placed phosphorus and sulphur fertilizers: Effect on canola plant stand and yield. Soils and Crops. March 5-6, Saskatoon, Saskatchewan. Online [Available]: http://www.usask.ca/soilsncrops/conference-proceedings/2013-proceedings/2013%20Oral%20Presentations.php (January 31, 2019)

Karamanos, R., Flore, N. and J. Harapiak. 2010. Re-visiting use of *Penicillium bilaii* with phosphorus fertilization of hard red spring wheat. Can. J. Plant Sci. **90:**265-277.

Mohr, R., Irvine, B, Grant, C., Holzapfel, C., Hogg, T. and A. Kirk. 2013. Response of canola to the application of phosphorus fertilizer and *Penicillium bilaii* (Jumpstart®). Final Report. SaskCanola

Project Code: CARP SCDC 2010-18. Online [Available]: http://www.saskcanola.com/research/response-of-canola-to-the-application-of-phosphorus-fertilizer-and-penicillium-bilaii-jumpstart (January 31, 2019)

Methodology and Results

9. Methodology:

A field trial was initiated in the spring of 2018 near Indian Head, Saskatchewan (50.546 N, 103.606 W) to evaluate canola response to contrasting rates of two P fertility forms, with and without the addition of a *P. bilaii* inoculant. Indian Head is situated in the thin-Black soil zone of southeast Saskatchewan and the soil is classified as an Indian Head clay with typical organic matter concentrations of 4.5-5.5%. Ten treatments were replicated four times in an RCBD with specific treatment details provided in Table 1.

Table 1. Canola phosphorus fertility treatments evaluated at Indian Head in 2018. All phosphorus fertilizer was placed in the seed-row.

#	Phosphorus Form	Phosphorus Rate	P. bilaii Inoculant
1	n/a	0 kg P_2O_5/ha	No
2	MAP [Z]	25 kg P_2O_5/ha	No
3	MES15 [Y]	25 kg P_2O_5/ha	No
4	MAP	50 kg P_2O_5/ha	No
5	MES15	50 kg P_2O_5/ha	No
6	n/a	0 kg P_2O_5/ha	Yes [X]
7	MAP	25 kg P_2O_5/ha	Yes
8	MES15	25 kg P_2O_5/ha	Yes
9	MAP	50 kg P_2O_5/ha	Yes
10	MES15	50 kg P_2O_5/ha	Yes

[Z] MAP: 11-52-0 [Y] MES15: 13-33-0-15

Selected agronomic information and dates of measurements are provided in Table 2. The glufosinate ammonium tolerant variety InVigor L233P was direct-seeded deep into wheat stubble on May 14 using a SeedMaster with eight openers on 30 cm row spacing. The target seed rate was 110 seeds/m^2 and the target depth was just slightly below 2.5 cm (1"). The seed was treated with Prosper and Lumiderm to protect against flea beetles, cutworms, and various seed/soil borne diseases. Phosphorus rates and forms were varied as per protocol but P fertilizer was always placed in the seed-row. Urea and potassium sulphate were side-banded and (pre-seed) broadcast to provide 135-0-53-19 kg N-P_2O_5-K_2O-S/ha as background fertility in all plots. Weeds were controlled using registered pre-emergent and in-crop herbicides. No foliar insecticides were required. Pre-harvest glyphosate was applied at approximately

70-80% seed colour change and the centre five rows of each plot were straight-combined on August 22.

Various data were collected over the growing season and from the harvested grain samples. Plant densities were measured by counting the number of individual plants in 4 x 1 m sections of crop row per plot (May 31) and converting the mean values to plant per square meter. At early bud formation (June 19; GS51), the above-ground plant material was harvested from 2 x 1 m sections of crop row per plot. The material was dried and weighed to determine early-season dry matter yield, expressed in kg/ha. The samples were subsequently ground and submitted to a third party (Agvise Laboratories) for percent total P determination. This information was used to calculate early-season P uptake, expressed as kg P_2O_5/ha. Grain yields were determined by weighing the harvested grain samples and are corrected for dockage and to a uniform moisture content of 14.5%. Percent distinctly green seed was determined from one crushed, 500 seed subsample per plot.

Table 2. Selected agronomic information for the canola phosphorus demonstration at Indian Head in 2018.

Factor / Field Operation	**Indian Head 2018**
Previous Crop	CWRS Wheat
Pre-emergent herbicide	894 g glyphosate/ha May 14, 2018
Seeding Date	May 14, 2018
Emergence Counts	May 31, 2018
In-crop Herbicide	593 g glufonsinate ammonium/ha + 44 g clethodim/ha June 13, 2018
Biomass / P-Uptake	June19, 2018
Foliar Fungicide	242 g bosalid/ha + 82 g pyraclostrobin/ha July 5, 2018 (as per protocol)
Preharvest Herbicide	894 g glyphosate/ha August 8, 2018
Harvest date	August 22, 2018

All response data were analysed using the Mixed procedure of SAS with treatment effects considered fixed and replicate effects treated as random. Least significant difference (LSD) values were calculated and are presented regardless of the F-test results; however, in cases where the overall F-test was not significant these values should be used cautiously. Orthogonal contrasts were used to the describe the responses to P fertilizer rate (i.e. across all forms/inoculant treatments, for each form separately, and with/without *P. bilaii* inoculant). Additional contrasts were used to compare 1) unfertilized treatments to all those that received P fertilizer, all treatments where MAP was the P source to all MES15 treatments, and all treatments that were inoculated with *P. bilaii* to all that were not. All treatment effects and differences between means were considered significant at $P \leq 0.05$.

10. Results:

Growing season weather and residual soil nutrients

Weather data for the 2018 growing season at Indian Head is provided along with the long-term (1981-2010) averages in Table 3. Although there was less initial sub-soil moisture than previous seasons, the canola was seeded into adequate soil moisture for germination and, in general, timely late-May/early-June rains got spring seeded crops in the area off to a strong start. For May and June combined, precipitation was 88% of the long-term (1981-2010) average; however, July and August were much drier with only 34 mm of total precipitation, or 30% of the long-term average. Consequently, late-season drought stress resulted in relatively early maturity; however, canola yields were still relatively high considering the conditions. Temperatures for the 2018 growing season were well-above average in May and, to a lesser extent, June but below average in July and approximately average in August. Over the four-month period, the mean temperature in 2018 was 16.4 °C while the long-term average is 15.6 °C.

Table 3. Mean monthly temperatures and precipitation amounts along with long-term (LT; 1981-2010) averages for the 2018 growing season (May through August) at Indian Head, SK.

Year	May	June	July	August	Avg. / Total
	------------ Mean Temperature (°C) ------------				
IH-2018	13.9	16.5	17.5	17.6	16.4
IH-LT	10.8	15.8	18.2	17.4	15.6
	------------ Precipitation (mm) ------------				
IH-2018	23.7	90.0	30.4	3.9	148
IH-LT	51.8	77.4	63.8	51.2	244

A composite soil sample was collected on May 7 (0-15 cm, 15-60 cm) and analyzed for basic chemical properties and residual nutrient levels (Table 4). The site had a pH of 7.5 and organic matter content of 5.9% in the upper 15 cm profile. Residual N and P levels were considered low and likely to be limiting while K and S levels were considerably higher.

Table 4. Selected soil test results for canola P fertility demonstration at Indian Head, Saskatchewan (2018).

Attribute / Nutrient	0-15 cm	15-60 cm	0-60 cm
pH	7.5	7.9	–
C.E.C. (meq/100g)	46.2	–	–
S.O.M. (%)	5.9	–	–
NO_3-N (kg/ha)[Z]	10	9	19
Olsen-P (ppm)	7	–	–
K (ppm)	633	–	–
S (kg/ha)	14	174	188

Field Trial Results

Individual treatment means are deferred to Table 9 of the Appendices while the orthogonal contrast results are presented below in Table 5 and the remaining contrasts follow in Tables 6, 7, and 8. Contrast results for maturity are not presented as treatment effects were either not significant or of little practical relevance. Percent green seed was excluded from the analyses as essentially all values were zero with an overall mean of 0.1% and maximum of 0.4% amongst individual plots.

Table 5. Orthogonal contrasts for canola P rate responses to different fertilizer forms and as affected by P. bilaii inoculation. Probability values greater than 0.05 indicate that a response was not significant.

P Form	0 kg P_2O_5/ha	25 kg P_2O_5/ha	50 kg P_2O_5/ha	Pr > F (linear)	Pr > F (quad)
	---------- Plant Density (plants/m^2) ----------				
All	72.5	64.8	60.6	0.005	0.575
MAP	72.5	67.7	65.4	0.122	0.744
MES15	72.5	62.0	55.8	<0.001	0.595
No P bilaii	69.3	65.9	58.5	0.058	0.631
P bilaii	75.7	63.8	62.6	0.024	0.208
	---------- Early Season Biomass (kg dry matter/ha) ----------				
All	1006	1293	1268	0.003	0.019
MAP	1006	1326	1288	0.006	0.039
MES15	1006	1261	1249	0.016	0.114
No P bilaii	910	1281	1222	0.011	0.022
P bilaii	1102	1304	1314	0.077	0.286
	---------- Early Season P Concentration (% P) ----------				
All	0.39	0.40	0.43	<0.001	0.056
MAP	0.39	0.41	0.42	0.003	0.747
MES15	0.39	0.39	0.44	<0.001	0.011
No P bilaii	0.40	0.40	0.43	0.015	0.075
P bilaii	0.39	0.40	0.43	<0.001	0.341
	---------- Early Season P Uptake (kg P_2O_5/ha) ----------				
All	9.1	11.8	12.5	<0.001	0.078
MAP	9.1	12.3	12.5	<0.001	0.053
MES15	9.1	11.4	12.4	<0.001	0.449
No P bilaii	8.4	11.8	12.0	0.002	0.074
P bilaii	9.7	11.9	12.9	0.008	0.472
	---------- Seed Yield (kg/ha) ----------				
All	3002	3063	3163	<0.001	0.470
MAP	3002	3045	3126	0.005	0.587
MES15	3002	3082	3199	<0.001	0.575
No P bilaii	2958	3063	3135	0.001	0.669
P bilaii	3046	3063	3190	0.007	0.154

The overall F-test for canola plant density was significant (*P* = 0.040) with a range of 55-76 plants/m^2 amongst individual treatments (Table 9). Closer inspection of the means reveals that only the highest P rate resulted in plant densities significantly lower than the controls, particularly for MES15. According to the orthogonal contrasts (Table 5), plant populations declined linearly with increasing P rate for MES15 ($P < 0.001$) but not for MAP ($P = 0.122$). The linear response was also significant when averaged across both P forms ($P = 0.005$). For MES15 at the 50 kg P_2O_5/ha rate, spring canola densities were 23% low than the treatments that did not receive P fertilizer while for MAP the observed plant numbers were 10% lower but the difference was not significant. Averaged across rates, forms, and *P. bilaii* treatments, canola plant populations were 13.5% lower with seed-placed P relative to the control ($P = 0.010$; Table 6). Of the fertilized treatments, plant densities were 11% lower with MES15 versus MAP when averaged across rates and inoculant treatments ($P = 0.022$; Table 7). The increased seedling mortality with MES15 was not necessarily unexpected as the total product rates for this form were higher (recall that no S was seed-placed in the MAP treatments). Recent research at multiple Agri-ARM locations is showing, not unexpectedly, that the risk of seedling injury is considerably higher when MAP is seed-placed in combination with ammonium sulphate as opposed to at modest rates on its own. Inoculation with *P. bilaii* did not affect canola plant densities ($P = 0.472$; Table 8).

Table 6. Contrast results for selected canola response variables comparing the control treatments where no P fertilizer was applied to all treatments that received P fertilizer. Means within a row followed by the same letter do not significantly differ ($P \leq 0.05$).

Response Variable	Control	P Fertilizer	Pr > F
Plant Density (plants/m^2)	72.5 a	62.7 b	0.010
Early Season Biomass (kg dry matter/ha)	1006 b	1280 a	0.001
Tissue P Concentration (% P)	0.39 b	0.42 a	0.006
P Uptake (kg P_2O_5/ha)	9.1 b	12.1 a	<0.001
Seed Yield (kg/ha)	3002 b	3113 a	0.002

Without a significant overall *F*-test ($P = 0.087$), no differences between individual treatments were declared significant for early-season biomass yields (Table 9); however, the contrasts revealed several broader responses. Biomass yields increased linearly and/or quadratically with P rate regardless of the fertilizer form (Table 5). Across forms and rates, the mean early-season biomass yields were 27% higher with P fertilizer ($P = 0.001$; Table 6) but similar for MAP versus MES15 ($P = 0.444$; Table 7). Although the dry matter yields did not differ between the treatments that received *P. bilaii* inoculation versus those that did not when averaged across P rates and forms (Table 8; $P = 0.166$), the orthogonal contrast results differed (Table 5) with a significant P rate response in the uninoculated treatments (*P* = 0.011-0.022) but not in those that received *P. bilaii* (*P* = 0.077-0.286). This appeared to be mainly due to slightly higher biomass yields with inoculation when no P fertilizer was applied but not amongst the fertilized treatments (Table 5). Furthermore, although the linear contrast for P rate response with *P. bilaii* was not quite significant at the desired probability ($P = 0.077$), there was a fairly distinct trend showing a slight increase in biomass with increasing P rate.

The overall *F*-test for early season tissue P concentrations was highly significant ($P < 0.001$); however, the absolute differences were small ranging only from 0.39-0.45% (Table 9). Regardless of the fertilizer form or whether *P. bilaii* was applied, tissue P concentrations increased linearly ($P < 0.001$-0.015) from 0.39% to 0.43% (on average) as the P fertilizer rate was increased from 0 to 50 kg P_2O_5/ha. (Table 5). In some cases, the response was also quadratic with the greatest increases occurring when the P rate was increased from 25 to 50 kg P_2O_5/ha. As expected, the contrasts showed that P concentrations were higher with P fertilizer than without ($P = 0.006$); however, no differences between forms ($P = 1.000$) or due to *P. bilaii* inoculation ($P = 0.346$) were detected.

Table 7. Contrast results for selected canola response variables comparing all treatments that received MAP (11-52-0) as the P source to those that received MES15 (13-33-0-15). Means within a row followed by the same letter do not significantly differ ($P \leq 0.05$).

Response Variable	MAP	MES15	Pr > F
Plant Density (plants/m^2)	66.5 a	58.9 b	0.022
Early Season Biomass (kg dry matter/ha)	1306 a	1254 a	0.444
Tissue P Concentration (% P)	0.42 a	0.42 a	1.000
P Uptake (kg P_2O_5/ha)	12.4 a	11.9 a	0.435
Seed Yield (kg/ha)	3085 a	3140 a	0.063

Table 8. Contrast results for selected canola response variables comparing all treatments that did not receive *P. bilaii* inoculant to all those that did. Means within a row followed by the same letter do not significantly differ ($P \leq 0.05$).

Response Variable	Control	P. bilaii	Pr > F
Plant Density (plants/m^2)	63.6 a	65.7 a	0.472
Early Season Biomass (kg dry matter/ha)	1183 a	1268 a	0.166
Tissue P Concentration (% P)	0.41 a	0.41 a	0.346
P Uptake (kg P_2O_5/ha)	11.2 a	11.9 a	0.246
Seed Yield (kg/ha)	3071 a	3111 a	0.128

Early-season P uptake was calculated from the observed biomass yields and tissue P concentrations with values converted to kg P_2O5/ha. The treatments affected early-season P-uptake ($P = 0.025$) with individual means ranging from 8.4-13.1 kg P_2O_5 (Table 9). Similar to the results for tissue P concentration, P uptake increased linearly with fertilizer rate ($P < 0.001$-0.008; Table 5) and was 33% higher overall with P fertilizer than without ($P < 0.001$; Table 6). Also consistent with variables it was calculated from, there were no differences in early-season canola P-uptake between fertilizer forms (P = 0.435) or due to *P. bilaii* inoculation (P = 0.246).

Maturity (60% seed colour change) was recorded for each plot and was significantly affected by the treatments (P = 0.005); however, the range between the earliest and latest maturing treatments was only 0.6 days (Table 9) and of little practical importance. Sometimes, under severe P deficiencies, crop development and maturity can be delayed; however, there was no indication of that being the case for any treatments in the current field trial.

Seed yield was affected by the P treatments with a significant overall F-test (P = 0.003) but relatively narrow range of individual treatment means (2958-3203 kg/ha; Table 9). While yields in the unfertilized control plots were amongst the lowest, they did not significantly differ from several individual fertilized treatments. Nonetheless, the orthogonal contrasts showed a linear yield increase with P fertilizer rate regardless of the form or whether *P. bilaii* inoculant was applied (P < 0.001-0.007) and the plots that received P yielded slightly but significantly higher than those that did not (P = 0.002). Although significant, the yield response associated with P fertilization was modest – less than 4% when averaged across all fertilized treatments and approximately 7% in the highest yielding individual treatments. While the overall mean yield with MES15 tended to be slightly (55 kg/ha or 2%) higher than with MAP (Table 7), the difference was worth noting but not quite significant at the desired probability level (P = 0.063). Mean seed yields of canola in the treatments that were inoculated with *P. bilaii* were similar to those that did not (P = 0.128; Table 8).

Extension Activities and Dissemination of Results

Unfortunately, this project could not be showcased during the main Indian Head Crop Management Field Day; however, the site was visited on numerous other smaller and/or informal tours throughout the season. The full project report will be made available online on the IHARF website (www.iharf.ca) and potentially elsewhere in the winter of 2018-19. Results may also be made available through a variety of other media (i.e. oral presentations, popular agriculture press, fact sheets, etc.) as opportunities arise and where appropriate.

Conclusions and Recommendations

Even though conditions were dry, the overall canola yield potential was relatively high and modest but significant responses to P fertilization were achieved for most of the variables measured. The most important effect on plant establishment was that the higher rates of P, particularly MES15 significantly increased seedling mortality relative to the control with observed reductions as high as 23% in the worst affected treatments. The higher mortality with MES15 was attributed to the additional N and S in this product and the subsequently higher overall product rates required to balance P relative to MAP. No additional fertilizer was seed-placed in the treatments where the P form was MAP. Nonetheless, under the conditions encountered and with the seeding rates used, plant populations were always considered high enough to optimize yield despite higher mortality in certain treatments. Early-season biomass production, P tissue concentrations, and P-uptake were all significantly higher with P fertilization and increased with P rate but none of these factors were affected by either the form of P or *P. bilaii* inoculation. The yield response to P was modest but significant and linear in all cases, regardless of P form or inoculation. There was a tendency for higher yields with MES15 that was worth noting but the difference was small at only 2% or 55 kg/ha (1 bu/ac). Any significant effects on maturity were of little practical significance and percent green seed was negligible in all plots regardless of treatment. Broadly speaking, the project showed that both MAP and MES15 performed similarly as P sources for canola in a low P soil. When applied alone as opposed to in a blend with ammonium sulphate, MAP resulted in less seeding injury at the highest rate but this did not translate into a yield advantage. In fact, the tendency was for slightly higher yields with MES15 but not by quite enough to be considered statistically significant. The strongest indication of a benefit to *P. bilaii* inoculation was evidence of higher early-season biomass yields in the absence of P fertilizer but the statistical significance of this response was relatively weak and it did not translate into a yield benefit. Importantly, inoculation with *P. bilaii* was not a substitute for P fertilizer as responses to P fertilizer were significant regardless of inoculation for most variables, including seed yield. Although little benefit was detected in the current project, the potential merits of *P. bilaii* inoculation may vary with crop type and environmental conditions. Overall, producers are advised to consider soil tests, crop removal rates and long-term fertility objectives when deciding on appropriate P fertilizer rates. Caution should be exercised when considering higher rates of seed-placed P (especially with multi-nutrient products like MES15 or similar blends). Growers specifically interested in *P. bilaii* inoculation are advised to utilize check strips to determine whether economic benefits are being realized under their specific conditions and to utilize this input in combination with P fertilizer as opposed to as a substitute for adequate fertilization.

Supporting Information

11. Acknowledgements:

This project was supported by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement. Crop protection products used for both plot maintenance and treatments were provided in-kind by Bayer CropScience, BASF, and Acceleron BioAg. IHARF also has a strong working relationship and memorandum of understanding with Agriculture & Agri-Food Canada.

12. Appendices

Table 9. Treatment means, overall F-tests, and measures of variability for selected canola response variables. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, $P \leq 0.05$).

#	Treatment	Emergence	Biomass	Tissue P	P Uptake	Maturity	Seed Yield
		plants/m^2	kg/ha	%	kg P_2O_5/ha	days	kg/ha
1	0P – no P. bilaii	69 ab	910 a	0.40 cde	8.4 c	85.1 bc	2958 e
2	25P MAP – no P. bilaii	72 ab	1320 a	0.41 b-e	12.2 ab	84.9 c	3042 de
3	25P MES – no P. bilaii	60 bc	1242 a	0.40 de	11.3 ab	84.9 c	3085 bcd
4	50P MAP – no P. bilaii	61 bc	1245 a	0.42 bcd	11.8 ab	85.5 ab	3074 cde
5	50P MES – no P. bilaii	56 c	1200 a	0.45 a	12.3 ab	85.6 a	3196 ab
6	0P – 3 kg P. bilaii/ha	76 a	1102 a	0.39 e	9.7 bc	85.1 bc	3046 de
7	25P MAP 3 kg P. bilaii/ha	64 abc	1329 a	0.41 b-e	12.4 a	85.3 abc	3049 de
8	25P MES – 3 kg P. bilaii/ha	64 abc	1279 a	0.39 e	11.4 ab	85.1 bc	3078 cd
9	50P MAP – 3 kg P. bilaii/ha	70 ab	1331 a	0.43 ab	13.1 a	85.4 ab	3177 abc
10	50P MES – 3 kg P. bilaii/ha	55 c	1297 a	0.43 abc	12.6 a	85.5 ab	3203 a
	$LSD_{0.05}$	12.9	272.5	0.011	2.58	0.40	116.5
	S.E.M.	4.7	93.9	0.026	0.91	0.15	63.0
	Pr > F (p-value)	0.040	0.087	<0.001	0.025	0.005	0.003

Abstract

13. Abstract/Summary:

A field trial with canola was established near Indian Head to demonstrate crop response to varying application rates of contrasting P fertilizer products with and without *P. bilaii* inoculation. The rates were 0, 25, or 50 kg P_2O_5/ha (seed-placed), the forms were MAP (11-52-0) or MES15 (13-33-0-15), and the inoculant product was in-furrow granular JumpStart. The soil at this location is a heavy clay and the site was low in residual P with a high pH and organic matter content of 5.9%. Initial moisture conditions were good for establishment but became dry later on; however, yields were remarkably high given the conditions. There was a significant overall stand reduction with increasing P fertilizer rates, particularly for MES15 and presumably due to the higher product rates and additional nutrients with this form. Plant populations were 13.5% lower with seed-placed P on average but up to 23% lower at the 50 kg P_2O_5/ha rate of MES15. Despite these effects, populations were sufficiently high to not limit yields in all treatments. Both P forms resulted in modest but significant increases in early-season biomass yield, P tissue concentrations, and P-uptake. There was evidence that *P. bilaii* inoculation increased biomass yields in the absence of P fertilizer but this did not translate into higher tissue concentrations, uptake or seed yield. The response was relatively small at only 4% when averaged across all fertilized treatments and less than 7% in the highest yielding treatments; however, canola yields increased linearly with P rate in a similar manner regardless of form or *P. bilaii* inoculation. Maturity was similar regardless of treatment with only 0.6 days between the earliest and latest treatments and there was essentially no green seed. Overall, producers are advised to consider soil tests, crop removal and long-term fertility objectives when deciding on appropriate P rates. Caution should be exercised when considering higher rates of seed-placed fertilizer, especially with multi-nutrient products like MES15 or similar blends. Regarding *P. bilaii* inoculation, growers are advised to utilize check strips to determine whether economic benefits are being realized and to utilize this input in combination with as opposed to as a substitute for adequate fertilization.