2020 Annual Report

for the

Saskatchewan Ministry of Agriculture's

Agricultural Demonstration of Practices & Technologies (ADOPT) Program

and Fertilizer Canada

**Project Title:** Canola Seed Safety and Yield Response to Novel Phosphorus Sources in Saskatchewan Soils

(Project #20190469)

**Principal Applicant:** Chris Holzapfel, MSc, PAg
Indian Head Agricultural Research Foundation, PO BOX 156, Indian Head, SK, S0G 2K0

**Collaborators:** Jessica Enns (Weber), Bryan Nybo, and Michael Hall

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

## Project Identification

1. **Project Title:** Canola seed safety and yield response to novel phosphorus (P) fertilizer sources in Saskatchewan soils
2. **Project Number:** 20190469
3. **Producer Group Sponsoring the Project:** Indian Head Agricultural Research Foundation
4. **Project Location(s):** Field trials were located at Indian Head (#156), Scott (#380), Swift Current (#137), and Yorkton (#244), Saskatchewan
5. **Project start and end dates(s):** April-2020 to February-2021
6. **Project contact person & contact details:**

Chris Holzapfel, Research Manager
Indian Head Agricultural Research Foundation
PO BOX 156, Indian Head, SK, S0G 2K0
Phone: 306-695-7761
Email: cholzapfel@iharf.ca

**Collaborators:** Jessica Enns-Weber (WARC), Bryan Nybo (WCA), and Michael Hall (ECRF)

---

## Objectives and Rationale

7. **Project Objectives:**
The objective of this project was to demonstrate canola response to increasing rates of seed-placed phosphorus (P) fertilizer for various formulations. The focus was on stand establishment and yield. The formulations were monoammonium phosphate, MicroEssentials® S15, and struvite (CrystalGreen®) applied alone or in a blend.

8. **Project Rationale:**
Results varied by region, but approximately 75% of soil samples from Saskatchewan in 2020 had residual phosphorus (P) levels below 15 ppm (Olsen-P). For a large percentage of the major crop producing areas, well over half of the soils tested had pH values exceeding 7.3; however, this varied regionally with lower values in the more western and northern areas but much higher pH soils dominating the eastern half of the province (AGVISE Laboratories 2020). Higher pH soils result in reduced P fertilizer use-efficiency due to chemical reactions with calcium carbonate that reduce solubility and crop availability of applied P. While Saskatchewan farmers are increasingly aware of the long-term importance of P fertilization and many strive to maintain or build soil residual P over the long-term, P fertilizer use-efficiency in the year of application is notoriously low – generally below 30%. Consequently, many growers seek ways to improve this efficiency and premium formulations (i.e., MicroEssentials®, Alpine®, and CrystalGreen®) are possible solutions to this challenge. Of the growers who apply P fertilizer to canola, monoammonium phosphate (MAP; 11-52-0) continues to be the dominant form, holding 66% of the market by volume in 2019 with MicroEssentials® formulations accounting for 29% (Stratus Ag Research 2019).

While not exclusively a P product, MicroEssentials® S15 is a multi-nutrient fertilizer which is often recognized as having improved seed-safety (relative to MAP/ammonium sulfate (AS) blends) and providing season long sulfur (S) with the S consisting of equal parts sulfate and elemental forms. Promotional material and internal research on S15 (Mosaic Company 2016) shows a 2.7 bu/ac advantage over MAP applied alone and 1.4 bu/ac over blended MAP + AS (average of 56 trials over a 9-year period). University of Manitoba research (Grenkow et al. 2013) showed improved seed safety over MAP/AS but warned that S15 may not be as effective at providing plant available S compared to conventional MAP/AS 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 in plant available, soluble forms for a longer time allowing for better overall uptake. A previous ADOPT project at Indian Head in 2018 showed a 1 bu/ac yield advantage to MES15 over MAP when averaged across rates but, the response was not significant at the desired probability level (P = 0.063; Holzapfel 2019).

Struvite is marketed under the trade name CrystalGreen® (5-28-0 plus 10% Mg) and promotional material (Ostara CrystalGreen® 2019) claims superior crop safety with a salt index of 8 (compared to 27 in MAP and 21 in S15) along with improved season-long availability. Early University of Manitoba research found that struvite increased dry matter yields and P recovery over the control but not to the same extent as MAP. They suggested that this may have been due to the lower initial solubility of struvite in the high pH Manitoba soils (Ackerman et al. 2013). In later evaluations, with wheat and canola, Katanda et al (2016) saw similar early-season dry matter yield and uptake efficiency with struvite versus MAP and, at higher rates, greater biomass yields and P recovery with struvite during the later crop phases. They concluded that struvite could supply sufficient P to sustain yields with overall P use-efficiencies matching or exceeding those for MAP. Current recommendations for CrystalGreen® suggest blending with MAP so that struvite comprises 25% of the actual P in the blend for maximum P availability through the entire growing season (Ostara CrystalGreen® 2019).

Canola is a large user of P and relatively responsive to fertilizer applications. It is well documented that high rates of seed-placed P fertilizer can reduce seedling survival and establishment in sensitive crops such as canola; however, many farmers prefer to place at least a portion of their P in the seedrow to ensure it is not limiting early in the season. While P fertilization will typically increase canola yields when residual levels of this nutrient are low, the response is often most evident early in the season with more vigorous growth frequently observed. This is often referred to as a 'pop-up' effect and is primarily attributed to seed-placed P fertilizer but can also occur with side-banding. Advantages with seed-placement compared to other placement options are often observed under dry conditions (due to reduced mobility of P in solution) but this is also when the risk of seedling injury is highest. While side-banding is widely recognized as a safe and viable application method, the majority of P applied during seeding is placed in seed-row (45% by volume compared to 30% for side-banding, Stratus Ag Research 2019). Being both responsive to P fertilization and sensitive to injury with seed-placement of fertilizer products, canola is an ideal test crop for this project.

Literature Cited

**Ackerman, J., Zvomuya, F., Cicek, N., and D. Flaten. 2013.** Evaluation of manure-derived struvite as a phosphorus source for canola. Can. J. Plant Sci. **93:** 419-424.

**AGVISE Laboratories. 2020.** AGVISE Soil Test Summary: 2020 Manitoba, Saskatchewan. Online [Available] https://www.agvise.com/wp-content/uploads/2020/12/agvise-soil-test-summary-canada-2020.pdf (Feb. 11, 2021).

**Grenkow, L. 2013.** Effect of seed-placed phosphorus and sulphur fertilizers on canola plant stand, early season biomass and yield. M.Sc. Thesis. University of Manitoba, Winnipeg, MB. Online [Available]: https://mspace.lib.umanitoba.ca/xmlui/handle/1993/22150 (Feb. 11, 2020).

**Holzapfel, 2019.** Seed-placed phosphorus fertilizer forms and P. bilaii effects on canola emergence, phosphorus uptake, and yield. ADOPT #20170410 Project Report. Online [Available]: https://iharf.ca/wp-content/uploads/2019/05/Seed-placed-phosphorus-fertilizer-forms-and-P-bilaii-effect-on-canola.pdf (Feb. 11, 2020).

**Katanda, Y., Zvomuya, F., Flaten, D. and N. Cicek. 2016.** Hog-manure recovered struvite: effects on canola and wheat biomass yield and phosphorus use efficiencies. Soil Sci. Soc. Am. J. **80:** 135-146.

**Mosaic Company. 2016.** Mosaic AgriFacts: Long-term canola yield trials. Online [Available]: https://assets.ctfassets.net/3jf1t80tlft4/5GI6CYiTqRG9Rk1SxhrtB2/a4824a2f479e6a1de294b955cb3f47db/MicroEssentials-Canola-Yields-MES15-vs-MAP-Blend.pdf (Feb. 11, 2021).

**Ostara CrystalGreen®. 2019.** Ostara CrystalGreen® Spec Sheet. Online [Available]: https://241580-742494-raikfcquaxqncofqfm.stackpathdns.com/wp-content/uploads/2019/07/CG-General-Sell-Sheet_Web-1.pdf (Feb. 11, 2021).

**Stratus Ag Research. 2019.** Fertilizer Use Survey: 2019 Crop Year [Available]: https://fertilizercanada.ca/resources/cdn19-fertilizer-use/ (Feb. 12, 2021).

---

## Methodology and Results

**9. Methodology:**

Field trials with canola were conducted near Swift Current, Scott, Indian Head, and Yorkton in 2020. These locations vary in both their major soil characteristics (i.e., texture, organic matter, pH) and long-term climate. Swift Current, Scott, Indian Head, and Yorkton are in the dry Brown, Dark Brown, thin-Black, and Black soil climatic zones, respectively. The project aimed to evaluate responses to a range of seed-placed phosphorus (P) fertilizer rates and formulations with a focus on crop establishment and yield. In addition to a control where no P was applied, the rates were 25, 45, and 65 kg $P_2O_5$/ha. Only granular options could be evaluated due to equipment limitations. The forms included monoammonium phosphate (MAP), MicroEssentials® S15, CrystalGreen®, and a 50:50 blend (by mass of product) of MAP and CrystalGreen®. This blend resulted in actual $P_2O_5$ proportions of 35:65 from CrystalGreen® and MAP which is comparable to the industry recommended 25:75 blend. The total amount of nitrogen (N) applied was balanced across treatments within each location; however, the S15 treatments at Yorkton were discarded because a calculation error resulted in the supplemental urea rate with this form being too low. For simplicity, we did not necessarily attempt to balance total S rates across treatments but did require that S be not limiting with supplemental applications of ammonium sulfate. All P fertilizer was seed-placed while urea and ammonium sulfate were side-banded. Detailed treatment information is provided in Table 1.

**Table 1. Treatment descriptions for ADOPT Novel Phosphorus demonstrations completed at Swift Current, Scott, Indian Head, and Yorkton in 2020.**

| # | Phosphorus Form [Z] | Nutrient Analyses | Phosphorus Rate |
|---|---|---|---|
| 1 | Control | Not applicable | 0 kg $P_2O_5$/ha |
| 2 | Monoammonium phosphate | 11-52-0 | 25 kg $P_2O_5$/ha |
| 3 | Monoammonium phosphate | 11-52-0 | 45 kg $P_2O_5$/ha |
| 4 | Monoammonium phosphate | 11-52-0 | 65 kg $P_2O_5$/ha |
| 5 | MicroEssentials® S15 | 13-33-0-15 | 25 kg $P_2O_5$/ha |
| 6 | MicroEssentials® S15 | 13-33-0-15 | 45 kg $P_2O_5$/ha |
| 7 | MicroEssentials® S15 | 13-33-0-15 | 65 kg $P_2O_5$/ha |
| 8 | CrystalGreen® | 5-28-0 + 10% Mg | 25 kg $P_2O_5$/ha |
| 9 | CrystalGreen® | 5-28-0 + 10% Mg | 45 kg $P_2O_5$/ha |
| 10 | CrystalGreen® | 5-28-0 + 10% Mg | 65 kg $P_2O_5$/ha |
| 11 | 50:50 MAP:CrystalGreen®[Z] | 8-40-0 + 5% Mg | 25 kg $P_2O_5$/ha |
| 12 | 50:50 MAP:CrystalGreen® | 8-40-0 + 5% Mg | 45 kg $P_2O_5$/ha |
| 13 | 50:50 MAP:CrystalGreen® | 8-40-0 + 5% Mg | 65 kg $P_2O_5$/ha |

[Z] Expressed as actual $P_2O_5$ the ratio is 65:35 MAP:CrystalGreen®

Selected agronomic information and dates of operations are in Table A-1 of the Appendices. The specific canola hybrids varied across locations, but all used certified seed and a target rate of 105 viable seeds/$m^2$. The target seeding depth was approximately 2 cm at all locations. Weeds were controlled using registered pre-emergent and in-crop herbicides. Fungicides were applied at the discretion of individual site managers with applications at Indian Head and Scott but not Swift Current or Yorkton. Pre-harvest herbicides or desiccants were also utilized at the discretion of site-managers and the centre rows of each plot were straight-combined.

Various data were collected during the growing season and from the harvested seed. Residual nutrient levels and basic soil information were derived from spring composite samples from two depths, 0-15 cm and 15-60 cm. Spring plant densities were determined by counting seedlings in 4 x 1 m sections of crop row after emergence was complete. Plant densities were assessed again at the end of the season by counting stubble in 4 x 1 m sections of crop row after harvest, except at Swift Current where these counts were completed before combining. Grain yields were determined from the harvested seed and are corrected for dockage and to 10% seed moisture content. Daily temperatures and precipitation amounts were recorded from the nearest Environment and Climate Change Canada weather stations for each location.

Response data were analyzed using the Mixed procedure of SAS with the effects of P fertilizer treatment considered fixed and replicate effects treated as random. Data were analyzed separately for each location. Orthogonal contrasts were used to test whether P rate responses were linear, quadratic (curvilinear), or not significant both for individual formulations and on average. Additional contrasts compared forms when averaged across rates and the control to the combined fertilized treatments. Tukey's range test was used to separate individual treatment means and all treatment effects and differences between means were considered significant at $P \leq 0.05$.

**10. Results:**

*Growing season weather and residual soil nutrients*

Mean temperatures and total precipitation amounts for May through August are presented with the long-term averages for each location in Tables 2 and 3. Overall growing season temperatures were near average at Swift Current, Scott, and Indian Head, but above average at Yorkton (Table 2). At Yorkton, all months except May were warmer than average. All locations except Scott were drier than average when the full growing season was considered (Table 3). Swift Current received 157 mm from May through August, 83% of the long-term average. Indian Head was the driest location with only 113 mm from May-August, or 46% of average. Yorkton was also extremely dry with a total of 180 mm over the four-month season, 66% of average. Scott was the exception receiving 118% of its long-term average precipitation, or 258 mm, over the four-month period. July was the wettest month at Scott with 123 mm of precipitation during that month alone while August was the driest with approximately 25 mm, slightly below half of the long-term average.

**Table 2. Mean monthly temperatures with long-term (LT; 1981-2010) averages for the 2020 growing season at Swift Current (SW), Scott (SCT), Indian Head (IH), and Yorkton (YK), Saskatchewan.**

| Year | May | June | July | August | May-Aug |
|---|---|---|---|---|---|
| | -------------------------------------- Mean Temperature (°C) -------------------------------------- | | | | |
| SW-20 | 10.4 | 15.5 | 18.1 | 19.4 | 15.9 (100%) |
| SW-LT | 11.0 | 15.7 | 18.4 | 17.9 | 15.8 |
| SCT-20 | 9.9 | 14.8 | 17.2 | 16.3 | 14.6 (98%) |
| SCT-LT | 10.8 | 14.8 | 17.3 | 16.3 | 14.8 |
| IH-20 | 10.7 | 15.6 | 18.4 | 17.9 | 15.7 (101%) |
| IH-LT | 10.8 | 15.8 | 18.2 | 17.4 | 15.6 |
| YK-20 | 10.5 | 16.4 | 19.9 | 18.3 | 16.3 (107%) |
| YK-LT | 10.4 | 15.5 | 17.9 | 17.1 | 15.2 |

**Table 3. Mean monthly precipitation amounts with long-term (LT; 1981-2010) averages for the 2020 growing season at Swift Current (SW), Scott (SCT), Indian Head (IH), and Yorkton (YK), Saskatchewan.**

| Year | May | June | July | August | May-Aug |
|---|---|---|---|---|---|
| | -------------------------------------- Total Precipitation (mm) -------------------------------------- | | | | |
| SW-20 | 30.0 | 70.9 | 52.6 | 3.3 | 157 (83%) |
| SW-LT | 42.1 | 66.1 | 44.0 | 35.4 | 188 |
| SCT-20 | 51.9 | 55.9 | 123.0 | 27.0 | 258 (114%) |
| SCT-LT | 38.9 | 69.7 | 69.4 | 48.7 | 227 |
| IH-20 | 27.3 | 23.5 | 37.7 | 24.9 | 113 (46%) |
| IH-LT | 51.8 | 77.4 | 63.8 | 51.2 | 244 |
| YK-20 | 16.7 | 33.6 | 80.1 | 49.3 | 180 (66%) |
| YK-LT | 51.3 | 80.1 | 78.2 | 62.2 | 272 |

Soil test results for each location are provided in Table 4. Soil pH, organic matter, and C.E.C. values (where available) were typical for each location. The lowest soil pH values were observed at Scott and Swift Current (6.4-6.6) and these locations also had the coarsest soil texture and lower soil organic matter, especially at Swift Current for SOM. Indian Head and Yorkton had much higher pH (7.7-7.8) with moderate organic matter levels (4.3-4.8%) and, particularly at Indian Head, finer overall soil texture (i.e, CEC of 47 meq/100 g compared to 13 meq/100 g at Scott). Focussing on residual P, all sites were relatively deficient with 7-8 ppm Olsen-P at Indian Head and Yorkton and 10-12 ppm at Swift Current and Scott. Residual nitrogen, potassium, and sulfur levels are also provided; however, these nutrients were all intended to be non-limiting.

**Table 4. Soil test results for canola novel phosphorus formulation demonstrations at Swift Current (SW), Scott (SCT), Indian Head (IH), and Yorkton (YK), Saskatchewan.**

| Location / Depth | pH | SOM (%) | CEC (meq/100 g) | $NO_3$-N (kg/ha) | Olsen-P (ppm) | K (ppm) | S (kg/ha) |
|---|---|---|---|---|---|---|---|
| SW (0-15) | 6.6 | 2.8 | n/a | 21 | 10 | 338 | 47 |
| SW (15-60) | – | – | – | 34 | – | – | 54 |
| SCT (0-15) | 6.4 | 4.0 | 13.3 | 15 | 12 | 259 | 11 |
| SCT (15-60) | – | – | | 24 | – | – | 101 |
| IH (0-15) | 7.8 | 4.8 | 47.2 | 10 | 8 | 654 | 5 |
| IH (15-60) | – | – | – | 13 | – | – | 40 |
| YK (0-15) | 7.7 | 4.3 | 23.1 | 26 | 7 | 161 | 13 |
| YK (15-60) | – | – | – | 31 | – | – | 20 |

n/a – not available

Generally, the risk of seedling injury associated with seed-placed P fertilizer is expected to be highest in dry, coarse textured soils. The weather and soil conditions encountered provided a good range of environmental conditions to evaluate the P rate and formulation treatments.

*Canola Response to Seed-Placed Phosphorus Fertilizer Formulations and Rates*

Detailed results of the multiple comparisons tests and orthogonal contrasts are in the Appendices (Tables A-2 through A-9). Results from the contrasts comparing P forms (averaged across rates) and scatter plots depicting individual treatment means and significant linear or quadratic responses appear within the main body of the report.

The overall F-test for spring plant populations was significant at Scott ($P$ = 0.012; Table A-2) but no other locations and, even at Scott, no differences between individual treatment means were significant according to the multiple comparisons. The group comparisons, however, did show some differentiation between forms (Table 5), but there were inconsistencies across locations. At Swift Current, plant densities were low regardless of treatments but were reduced to a greater extent with S15 and the MAP:GC blend (≈26 plants/$m^2$) compared to MAP or CG applied alone (32-33 plants/$m^2$). At Scott, both MAP and S15 reduced plant stands compared to GC and the MAP:GC blend (47-48 plants/$m^2$ versus 56-59 plants/$m^2$). Furthermore, at Scott, average plant densities with CG and MAP:CG were like those observed in the control. At Indian Head, average plant densities were lowest with S15 (62 plants/$m^2$) and highest with CG (70 plants/$m^2$) but these values were similar to or higher than the control (61 plants/$m^2$). This indicated that none of the P forms had much of an adverse effect on emergence at Indian Head. At Yorkton, the lowest spring plant densities occurred with MAP (55 plants/$m^2$) while stands with CG and the MAP:CG blend (67 plants/$m^2$) were like the control (69 plants/$m^2$).

**Table 5. Phosphorus fertilizer form (averaged across rates) effects on canola spring plant densities. Means within a column followed by the same letter do not significantly differ ($P \leq 0.05$). Control (no P applied) values are provided as supplemental information.**

| P Form [Z] / Contrast | Swift Current | Scott | Indian Head | Yorkton |
|---|---|---|---|---|
| | ---------------------------- Spring Plant Density (plants/m$^2$) ---------------------------- | | | |
| Control | 30.5 | 57.1 | 60.7 | 69.3 |
| MAP | 32.4 A | 48.3 B | 64.4 AB | 54.6 B |
| S15 | 25.9 B | 46.9 B | 61.8 B | – |
| CG | 33.2 A | 59.9 A | 69.9 A | 67.0 A |
| MAP:CG | 26.1 B | 55.9 A | 66.2 AB | 67.1 A |
| | -------------------------------------- Pr > *F* (p-values) -------------------------------------- | | | |
| MAP vs S15 | 0.038 | 0.668 | 0.412 | – |
| MAP vs CG | 0.795 | 0.002 | 0.087 | 0.050 |
| MAP vs MAP:CG | 0.044 | 0.032 | 0.568 | 0.047 |
| S15 vs CG | 0.021 | 0.012 | 0.014 | – |
| S15 vs MAP:CG | 0.952 | 0.001 | 0.168 | – |
| CG vs MAP:CG | 0.024 | 0.243 | 0.245 | 0.982 |

[Z] MAP – monoammonium phosphate (11-52-0); S15 – MicroEssentials® S15 (13-33-0-15); CG – CrystalGreen® (5-28-0 + 10 Mg); MAP:CG – 50:50 blend (by mass of product) of MAP:CG (8-40-0 + 5 Mg)
[Y] Application rates were 25, 45, and 65 kg $P_2O_5$/ha

Figures 1-4 illustrate the effects of increasing application rates for each form on spring plant densities. At Swift Current (Fig. 1), only the linear response for S15 was significant. While the lack of stand reduction with seed-placed P was rather unexpected, especially considering the coarser soil texture and low organic matter at this location, we did expect S15 to be the hottest of the P forms due to the higher ammonium concentrations compared to MAP or, especially, CG. At Scott (Fig. 2), both MAP and S15 reduced spring plant counts with increasing application rates. CrystalGreen® (CG) had relatively little effect on emergence regardless of the rate or whether it was applied alone versus in a blend. At Indian Head, the response to S15 was quadratic, only appearing to negatively affect emergence at the highest rate (Fig. 3). The linear orthogonal contrast was also significant for CG, but, unexpectedly, the effect was positive with a subtle increase in plant populations observed with increasing rates of this form. This may have simply been due to variability. At Yorkton, spring plant densities were rather variable overall but there was no evidence of injury due to seed-placed P, regardless of the form (Fig. 4).

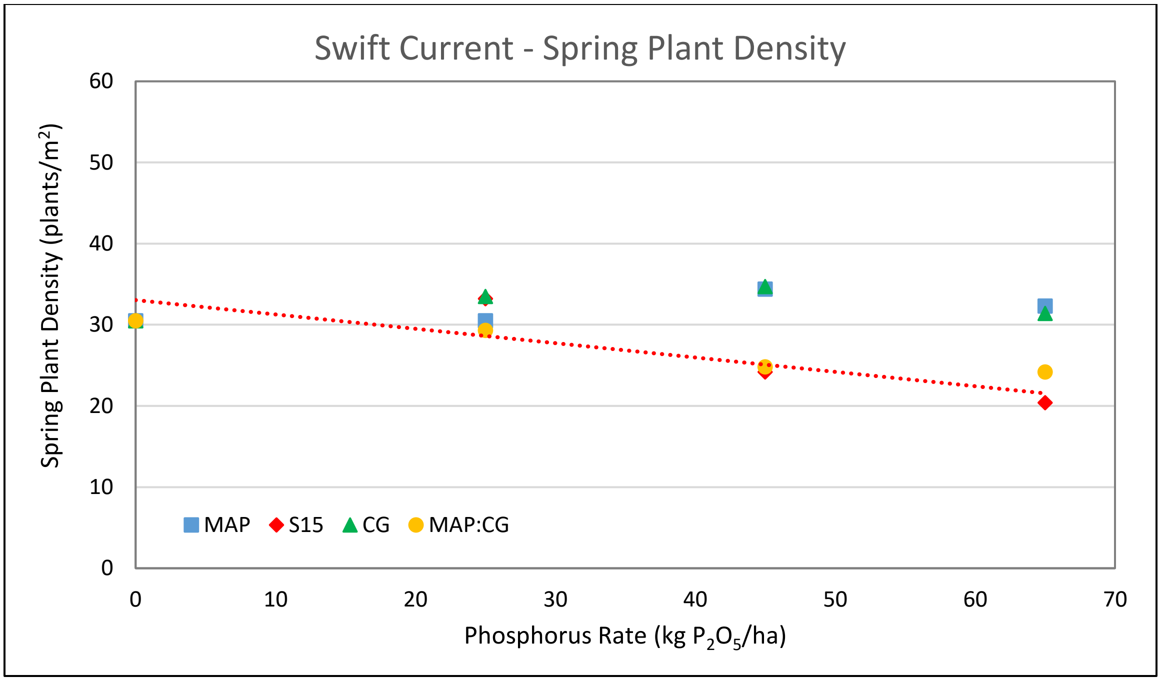


**Figure 1. Seed-placed phosphorus rate and form effects on canola spring plant densities at Swift Current. The least significant difference (Tukey-Kramer; $P \leq 0.05$) was 18.5 plants/$m^2$. The fertilizer forms were MAP (monoammonium phosphate), S15 (MicroEssentials® S15), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

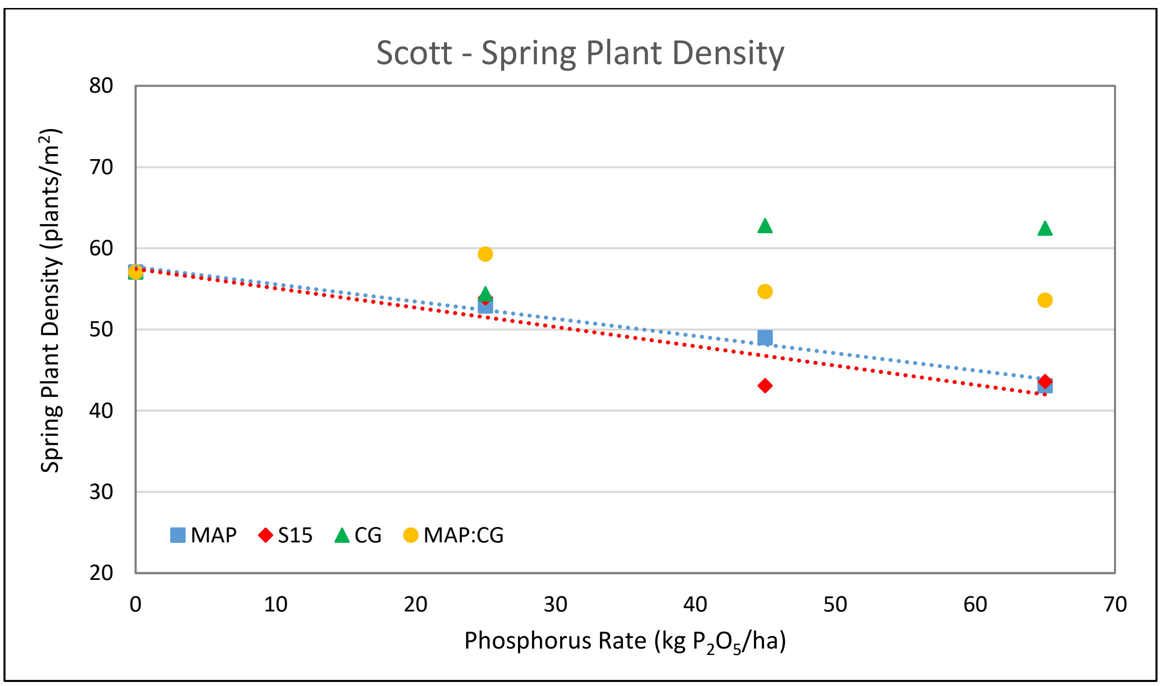


**Figure 2. Seed-placed phosphorus rate and form effects on canola spring plant densities at Scott. The least significant difference (Tukey-Kramer; $P \leq 0.05$) was 20.8 plants/$m^2$. The fertilizer forms were MAP (monoammonium phosphate), S15 (MicroEssentials® S15), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

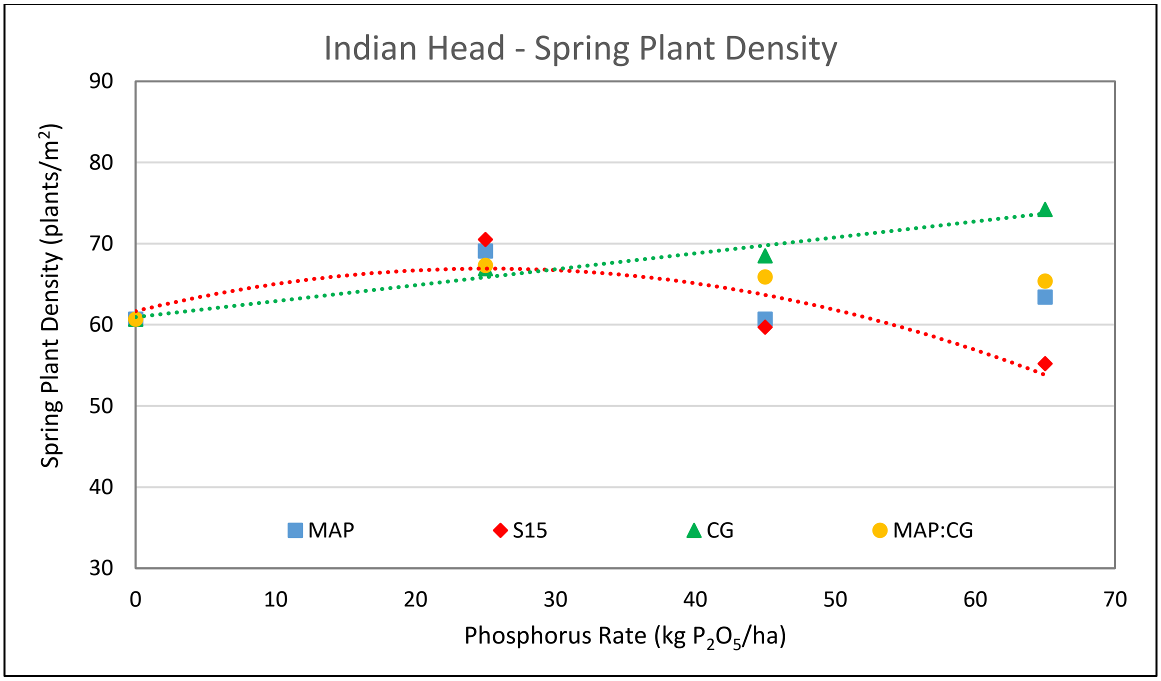


**Figure 3. Seed-placed phosphorus rate and form effects on canola spring plant densities at Indian Head. The least significant difference (Tukey-Kramer; $P \leq 0.05$) was 19.1 plants/$m^2$. The fertilizer forms were MAP (monoammonium phosphate), S15 (MicroEssentials® S15), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

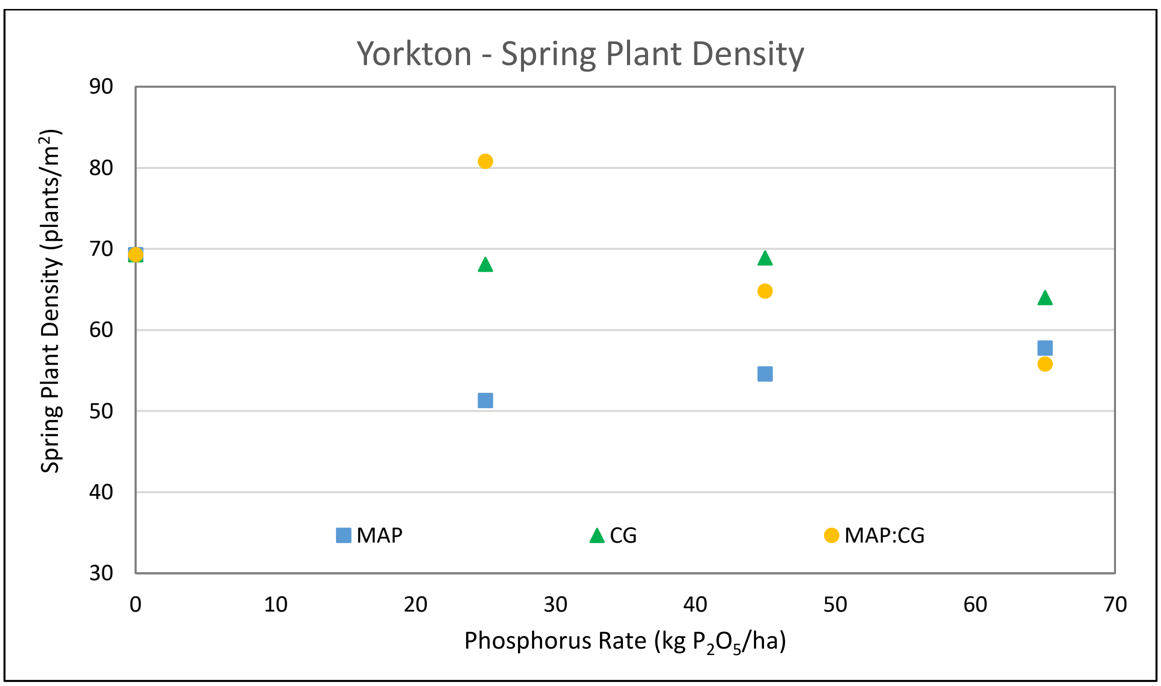


**Figure 4. Seed-placed phosphorus rate and form effects on canola spring plant densities at Yorkton. The least significant difference (Tukey-Kramer; $P \leq 0.05$) was 36.0 plants/$m^2$. The fertilizer forms were MAP (monoammonium phosphate), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

Due the importance of canola stand establishment as a response variable for this project and the potential for populations to change over the season; plant counts were completed again in the fall.

This occurred after harvest for all locations except Swift Current where the measurements were completed prior to combining. The overall F-test was only significant at Yorkton ($P$ = 0.047) for fall plant densities but, again, the effects were small enough that no differences between treatments were significant when considered individually (Table A-3). Notably, plant densities were much higher in the fall at Yorkton compared to what was observed in the spring. We attribute this primarily to incomplete emergence when the spring measurements completed but late-emerging volunteers could also have contributed to the discrepancy. When we compared P forms across rates, small but significant differences were detected for all locations (Table 6). At Swift Current, slightly lower fall plant populations occurred with S15 (28 plants/$m^2$) compared to both MAP and CG (34-35 plants/$m^2$) while values were intermediate with the MAP:CG blend (30 plant/$m^2$). At Scott, differences between forms were as expected with the lowest densities with S15, intermediate values with MAP, and the least effect with CG and the MAP:CG blend. At Indian Head, the lowest final plant densities occurred with S15 (52 plants/$m^2$) while values with MAP and CG were highest (59 plants/$m^2$) and the MAP:CG blend resulted in intermediate stands (54 plants/$m^2$). Like the spring results, these averaged densities did not generally differ from the control (54 plants/$m^2$). At Yorkton, these data were variable, but we observed the highest overall final densities with CG (123 plants/$m^2$), noticeably higher than in the control (103 plants/$m^2$).

**Table 6. Phosphorus fertilizer form (averaged across rates) effects on final (post-harvest) canola plant densities. Values within a column followed by the same letter do not significantly differ ($P \le 0.05$). Control (no P applied) values are provided as supplemental information.**

| P Form [Z] / Contrast | Swift Current | Scott | Indian Head | Yorkton |
|---|---|---|---|---|
| | ---------------------------- Fall Plant Density (plants/$m^2$) ---------------------------- | | | |
| | 31.4 | 65.4 | 53.8 | 103.0 |
| MAP | 34.1 A | 55.9 AB | 59.1 A | 99.9 B |
| S15 | 28.4 B | 51.4 B | 52.0 B | – |
| CG | 34.5 A | 62.4 A | 59.1 A | 122.9 A |
| MAP:CG | 29.5 AB | 60.2 A | 54.0 AB | 107.7 B |
| | ------------------------------------- Pr > $F$ (p-values) ------------------------------------- | | | |
| MAP vs S15 | 0.053 | 0.277 | 0.016 | – |
| MAP vs CG | 0.889 | 0.115 | 0.983 | 0.004 |
| MAP vs MAP:CG | 0.115 | 0.286 | 0.076 | 0.297 |
| S15 vs CG | 0.039 | 0.010 | 0.015 | – |
| S15 vs MAP:CG | 0.702 | 0.035 | 0.481 | – |
| CG vs MAP:CG | 0.088 | 0.598 | 0.072 | 0.048 |

[Z] MAP – monoammonium phosphate (11-52-0); S15 – MicroEssentials® S15 (13-33-0-15); CG – CrystalGreen® (5-28-0 + 10 Mg); MAP:CG – 50:50 blend (by mass of product) of MAP:CG (8-40-0 + 5 Mg)
[Y] Application rates were 25, 45, and 65 kg $P_2O_5$/ha

Individual treatment means and significant orthogonal contrasts for final plant densities are presented in Figs. 5-8. At Swift Current (Fig. 5), the overall fall plant densities were low but consistent with what was observed in the spring. The slight linear decline in plant densities observed with S15 in the spring was no longer evident in the fall and individual values were statistically similar regardless of the P form or rate. No orthogonal contrasts were significant for final plant density at Swift Current.

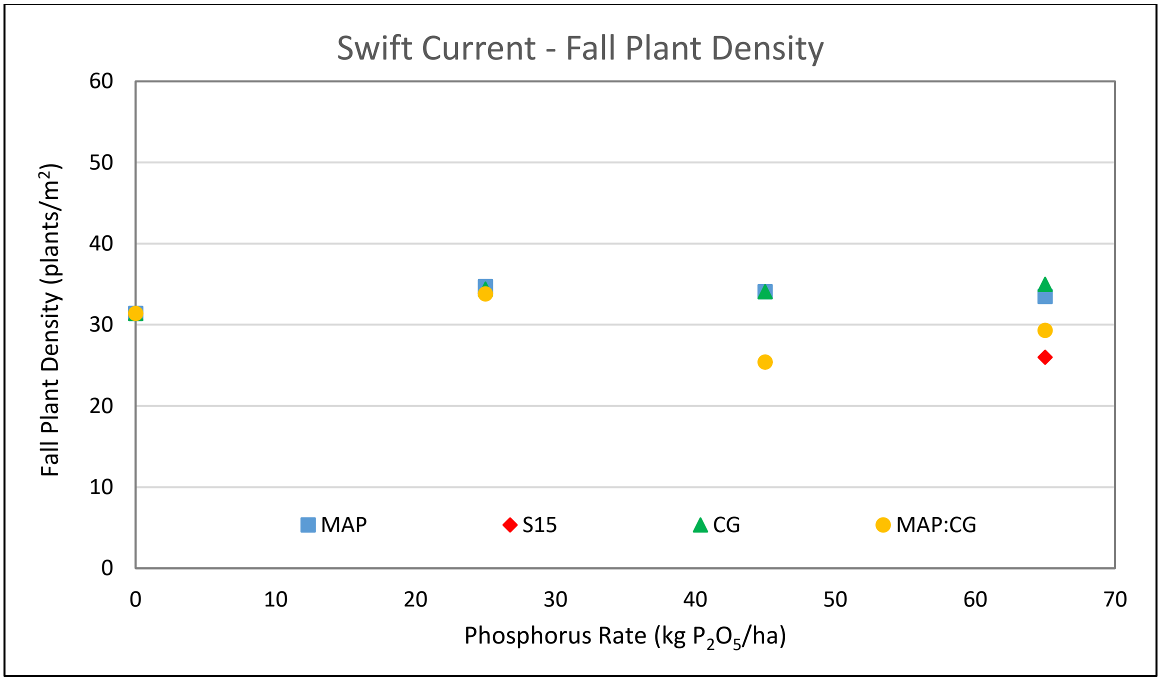


**Figure 5. Seed-placed phosphorus rate and form effects on canola fall plant densities at Swift Current. The least significant difference (Tukey-Kramer; $P \leq 0.05$) was 17.5 plants/m$^2$. The fertilizer forms were MAP (monoammonium phosphate), S15 (MicroEssentials® S15), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

Fall plant densities at Scott (Table A-4; Fig. 6) were slightly higher than those observed in the spring and the orthogonal contrast results differed subtly but, overall, the major trends were similar. Only the linear orthogonal contrast for S15 was significant ($P = 0.022$), compared to both MAP and S15 in the spring, but the trend with MAP was still similar ($P = 0.098$; Table A-5; Fig. 5). There was no reduction in final plant densities with seed-placed CG or the MAP:CG blend at Scott, regardless of the application rate.

At Indian Head, although we did detect small differences between forms when averaged across application rates, there was no evidence of final plant density reductions with seed-placed P according to the orthogonal contrast results, regardless of the form (Table A-5; Fig. 7).

At Yorkton, there was no evidence of final stand reductions with seed-placed P; however, the quadratic orthogonal contrast for the MAP:CG was significant (Table A-5; Fig. 8). This was primarily attributed to spatial variability with numerically higher values at the 25 kg $P_2O_5$/rate compared to both the control and the higher rates of this product. Again, fall plant density values were much higher than the spring values at Yorkton and, in some cases, higher than the target seeding rate, possibly due in part to volunteers.

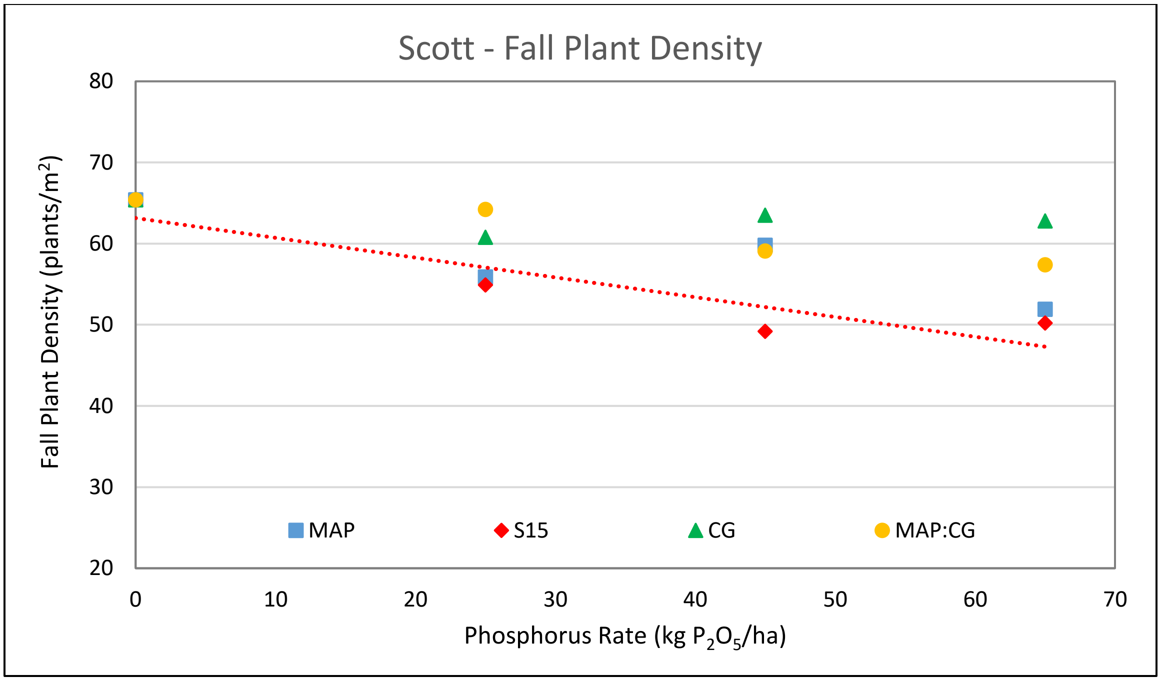


**Figure 6. Seed-placed phosphorus rate and form effects on canola fall plant densities at Scott. The least significant difference (Tukey-Kramer; $P \leq 0.05$) was 24.6 plants/m$^2$. The fertilizer forms were MAP (monoammonium phosphate), S15 (MicroEssentials® S15), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

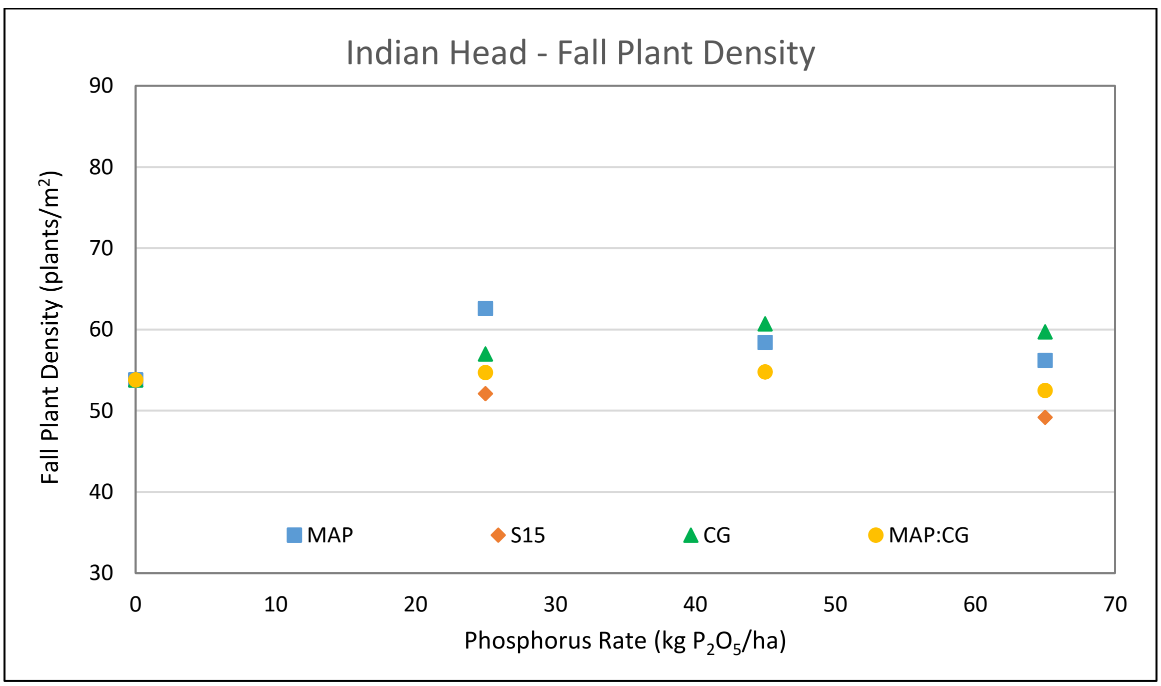


**Figure 7. Individual treatment means and orthogonal contrast results expressed graphically for seed-placed phosphorus rate and form effects on canola fall plant densities at Indian Head. The least significant difference (Tukey-Kramer; $P \leq 0.05$) was 17.0 plants/m$^2$. The fertilizer forms were MAP (monoammonium phosphate), S15 (MicroEssentials® S15), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

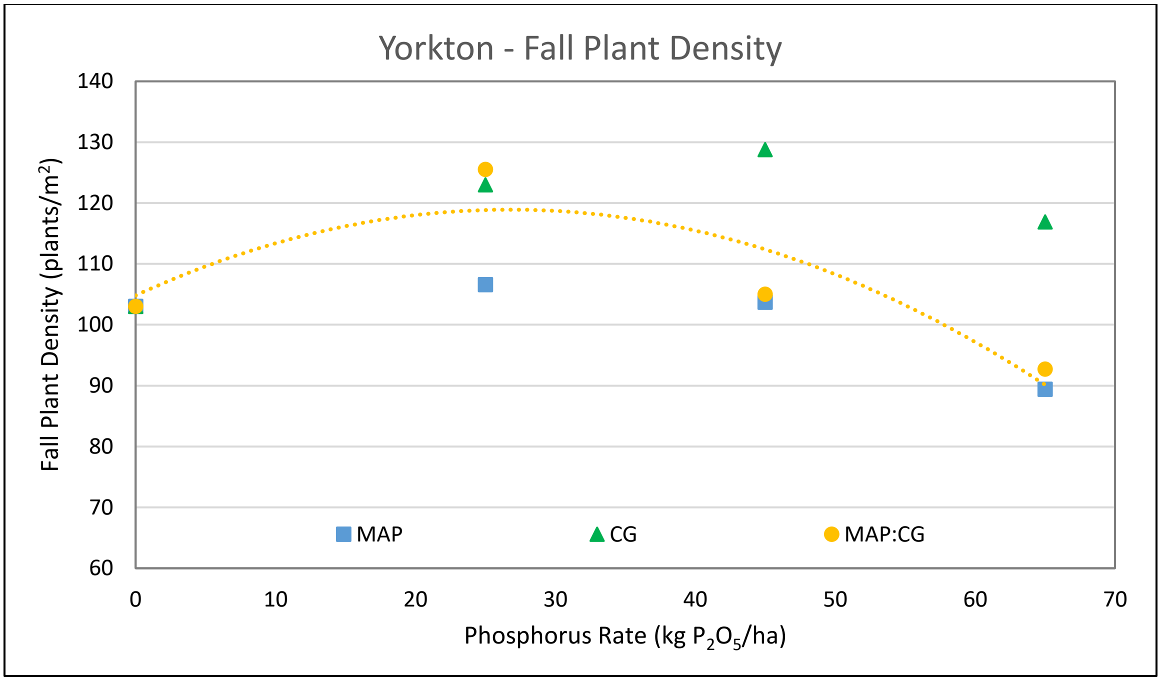


**Figure 8. Seed-placed phosphorus rate and form effects on canola fall plant densities at Yorkton. The least significant difference (Tukey-Kramer; P ≤ 0.05) was 43.6 plants/m$^2$. The fertilizer forms were MAP (monoammonium phosphate), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

Both P fertility status and plant densities could conceivably affect maturity in this project, but potentially in opposite ways. In addition to less vigorous early-season growth, crops that are deficient in P can also exhibit delayed maturity. In contrast, high rates of seed-placed P may reduce plant densities and, if large enough, these reductions lead to increased branched, prolonged flowering, and delayed maturity. In general, maturity was earliest at Swift Current (≈91-92 days), followed by Scott (≈97 days), Yorkton (≈100 days), and finally, Indian Head (≈103-104 days). As previously discussed, impacts on emergence were generally small and, similarly, the overall F-tests for canola maturity were not significant at any locations (Table A-6; *P* = 0.142-0.839). At Indian Head, the contrast comparing the control to the combined fertilized treatments was significant (*P* = 0.002), but the effect was small with an observed difference of only 0.8 days. The comparisons looking for maturity differences between P forms were not significant in any cases (Table 7; *P* = 0.077-0.863).

**Table 7. Phosphorus fertilizer form (averaged across rates) effects on canola maturity. Values within a column followed by the same letter do not significantly differ ($P \leq 0.05$). Control (no P applied) values are provided as supplemental information.**

| P Form [Z] / Contrast | Swift Current | Scott | Indian Head | Yorkton |
|---|---|---|---|---|
| | ---------------------------- Maturity (days from seeding) ---------------------------- | | | |
| Control | 91.8 | 96.5 | 104.1 | 101.3 |
| MAP | 91.4 A | 97.1 A | 103.5 A | 99.5 A |
| S15 | 91.7 A | 97.3 A | 103.3 A | – |
| CG | 91.5 A | 97.4 A | 103.4 A | 99.9 A |
| MAP:CG | 92.1 A | 97.2 A | 103.1 A | 100.7 A |
| | -------------------------------------- Pr > *F* (p-values) -------------------------------------- | | | |
| MAP vs S15 | 0.605 | 0.722 | 0.499 | – |
| MAP vs CG | 0.863 | 0.594 | 0.652 | 0.812 |
| MAP vs MAP:CG | 0.173 | 0.859 | 0.077 | 0.408 |
| S15 vs CG | 0.730 | 0.859 | 0.821 | – |
| S15 vs MAP:CG | 0.390 | 0.859 | 0.262 | – |
| CG vs MAP:CG | 0.232 | 0.722 | 0.180 | 0.554 |

[Z] MAP – monoammonium phosphate (11-52-0); S15 – MicroEssentials® S15 (13-33-0-15); CG – CrystalGreen® (5-28-0 + 10 Mg); MAP:CG – 50:50 blend (by mass of product) of MAP:CG (8-40-0 + 5 Mg)
[Y] Application rates were 25, 45, and 65 kg $P_2O_5$/ha

Individual treatment means and orthogonal contrast results (Table A-7) for maturity are presented in Figs. 9-13 below. At Swift Current (Fig. 9) and Scott (Fig. 10), individual treatment means were all within approximately two days of each other and no orthogonal contrasts were significant ($P$ = 0.078-0.863). At Indian Head (Fig. 11), the range in individual values was less than 2 days but the linear or quadratic contrast were significant for all formulations ($P$ = 0.004-0.044) with slightly earlier maturity when P fertilizer was applied. The greatest range in maturity across treatments was at Yorkton (Fig. 12), but overall variability was high and no orthogonal contrast for individual formulations were significant ($P$ = 0.072-0.895). Averaged across formulations, the quadratic response for maturity at Yorkton was significant ($P$ = 0.026) with the earliest maturity observed at 25 kg $P_2O_5$/ha (Table A-7). This may have been due to a combination P status and plant density effects; however, random variability may also have been a factor.

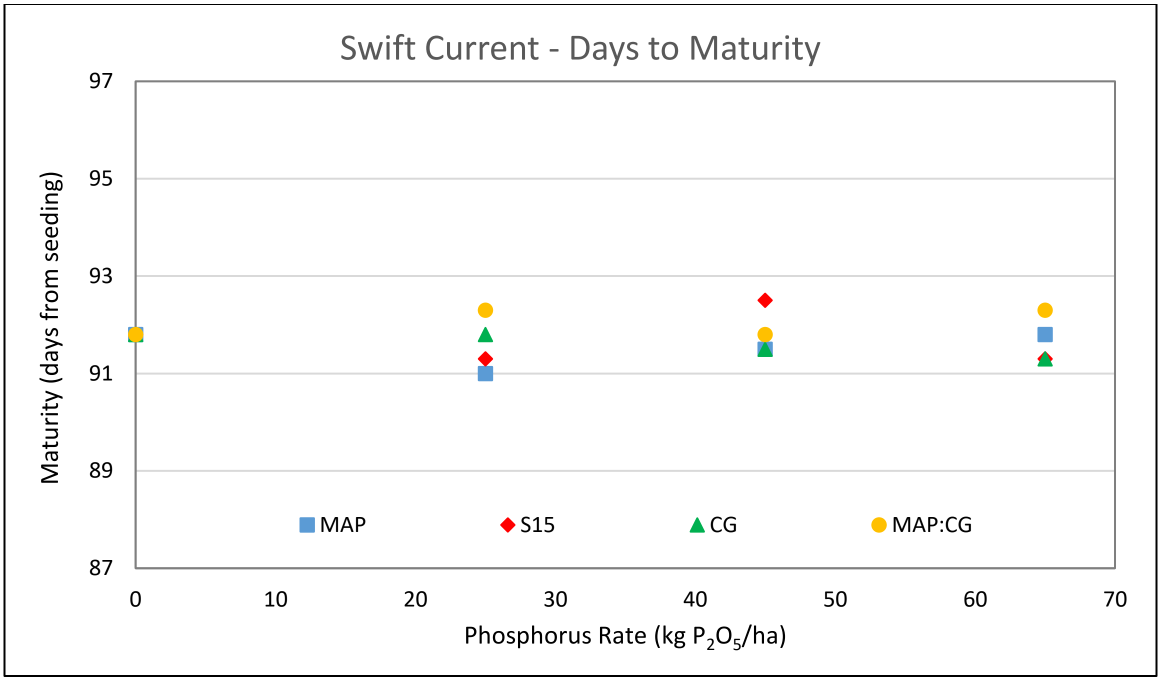


**Figure 9. Seed-placed phosphorus rate and form effects on canola maturity at Swift Current. The least significant difference (Tukey-Kramer; $P \leq 0.05$) was 2.9 days. The fertilizer forms were MAP (monoammonium phosphate), S15 (MicroEssentials® S15), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

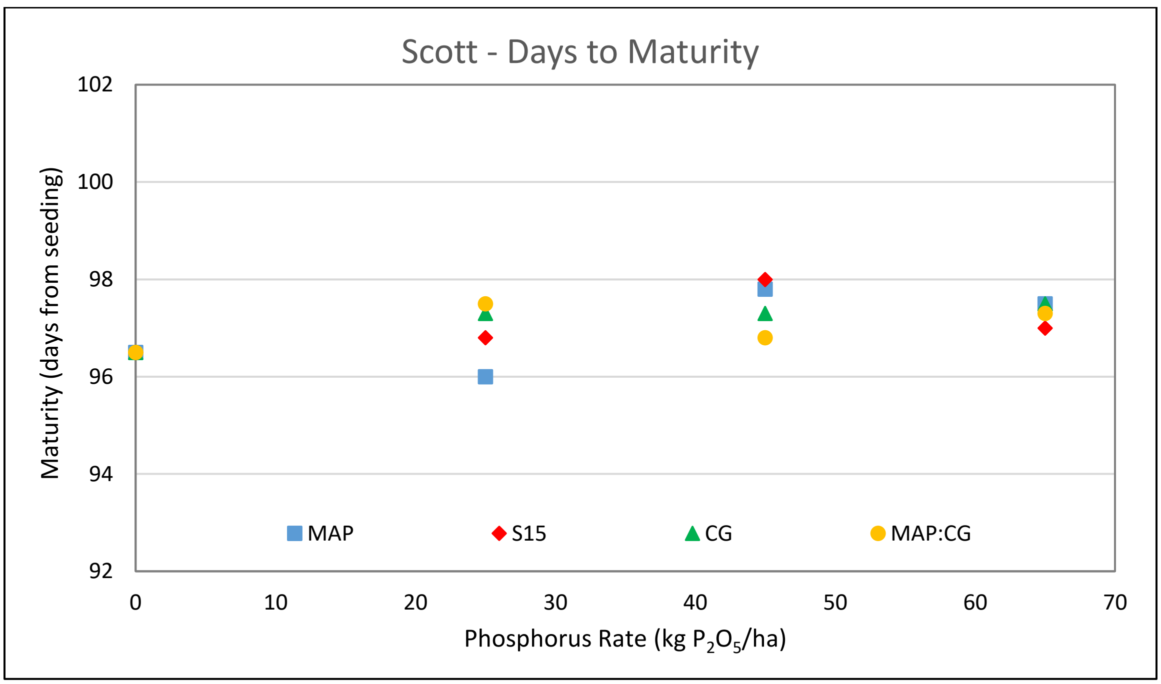


**Figure 10. Seed-placed phosphorus rate and form effects on canola maturity at Scott. The least significant difference (Tukey-Kramer; $P \leq 0.05$) was 2.9 days. The fertilizer forms were MAP (monoammonium phosphate), S15 (MicroEssentials® S15), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

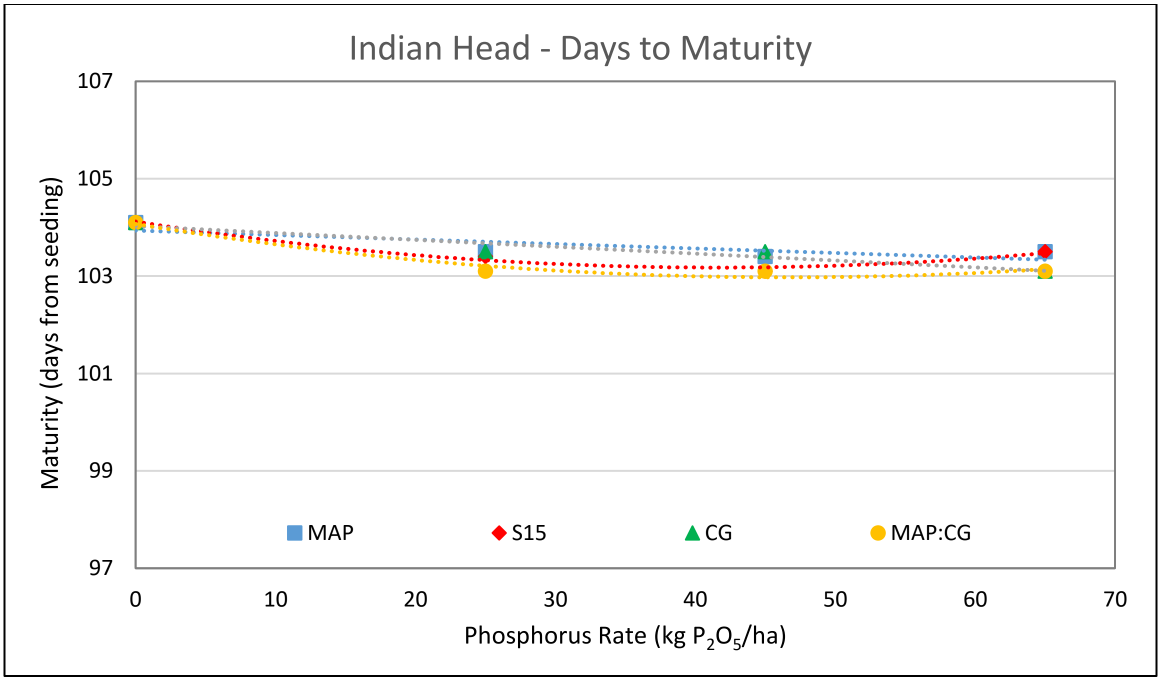


**Figure 11. Seed-placed phosphorus rate and form effects on canola fall plant densities at Indian Head. The least significant difference (Tukey-Kramer; *P* ≤ 0.05) was 1.1 days. The fertilizer forms were MAP (monoammonium phosphate), S15 (MicroEssentials® S15), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

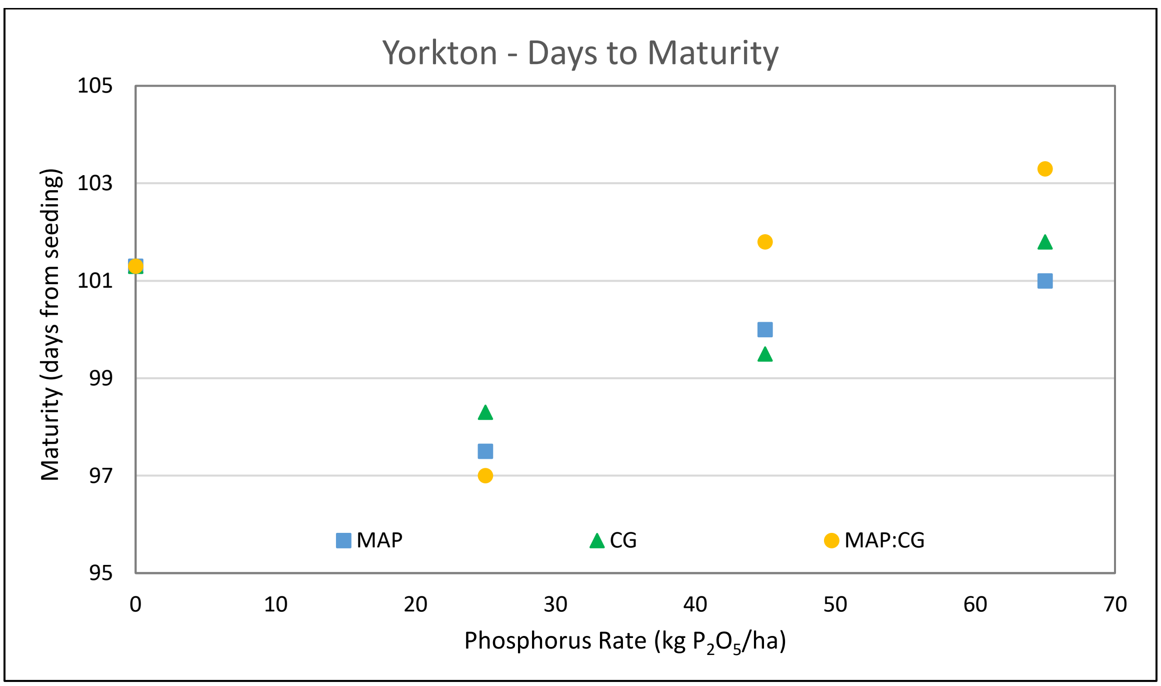


**Figure 12. Individual treatment means and orthogonal contrast results expressed graphically for seed-placed phosphorus rate and form effects on canola maturity at Yorkton. The least significant difference (Tukey-Kramer; P ≤ 0.05) was 8.3 days. The fertilizer forms were MAP (monoammonium phosphate), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

Average grain yields were highest at Scott and Indian Head (3306-3376 kg/ha), followed by Yorkton (3118 kg/ha), and then Swift Current (2166 kg/ha). The overall F-tests for treatment effects on yield (Table A-8) were significant at Scott ($P = 0.002$) and Yorkton ($P = 0.007$) but not Swift Current ($P = 0.200$) or Indian Head ($P = 0.111$). Additionally, the comparisons between the control and the combined fertilized treatments were significant for all locations ($P < 0.001$-0.015) except Indian Head ($P = 0.314$). Focussing on P formulations when averaged across rates, there were no differences at Swift Current ($P = 0.285$-0.836), Scott ($P = 0.313$-0.772), or Indian Head ($P = 0.065$-0.828). At Yorkton, the MAP:CG blend (3203 kg/ha) yielded higher than canola fertilized with CG on its own (3063 kg/ha; $P = 0.006$). Yields with MAP (3144 kg/ha) were intermediate and did not differ from those achieved with either CG ($P = 0.093$) or the blend ($P = 0.217$) at Yorkton.

**Table 8. Phosphorus fertilizer form (averaged across rates) effects on canola seed yield. Values within a column followed by the same letter do not significantly differ ($P \leq 0.05$). Control (no P applied) values are provided as supplemental information.**

| P Form [Z] / Contrast | Swift Current | Scott | Indian Head | Yorkton |
|---|---|---|---|---|
| | ------------------------------------- Seed Yield (kg/ha) ------------------------------------- | | | |
| Control | 1996 | 2973 | 3236 | 2951 |
| MAP | 2195 A | 3421 A | 3317 A | 3144 AB |
| S15 | 2151 A | 3369 A | 3367 A | – |
| CG | 2213 A | 3450 A | 3257 A | 3063 B |
| MAP:CG | 2163 A | 3398 A | 3305 A | 3203 A |
| | ------------------------------------- Pr > *F* (p-values) ------------------------------------- | | | |
| MAP vs S15 | 0.448 | 0.511 | 0.398 | – |
| MAP vs CG | 0.751 | 0.722 | 0.300 | 0.093 |
| MAP vs MAP:CG | 0.581 | 0.772 | 0.828 | 0.217 |
| S15 vs CG | 0.285 | 0.313 | 0.065 | – |
| S15 vs MAP:CG | 0.836 | 0.712 | 0.290 | – |
| CG vs MAP:CG | 0.386 | 0.520 | 0.411 | 0.006 |

[Z] MAP – monoammonium phosphate (11-52-0); S15 – MicroEssentials® S15 (13-33-0-15); CG – CrystalGreen® (5-28-0 + 10 Mg); MAP:CG – 50:50 blend (by mass of product) of MAP:CG (8-40-0 + 5 Mg)
[Y] Application rates were 25, 45, and 65 kg $P_2O_5$/ha

Orthogonal contrast results for canola yield response to P rate appear in Table A-9 and significant responses are presented graphically with the treatment means in Fig. 13-16 below. At Swift Current, despite the lack of a significant overall F-test, there was evidence of small yield responses with three out of four formulations (Fig. 13) and the linear response was significant when averaged across formulations ($P = 0.006$). For MAP and the MAP:CG blend, the response was linear while, for CG applied alone, it was quadratic with the highest yields at 25-45 kg/ha. Although the contrasts for S15 were not significant, yields with this product were in the range of those observed with the other forms at any given rate. When averaged across forms, the observed yield increase at 65 kg $P_2O_5$/ha was 214 kg/ha, or 11% at Swift Current.

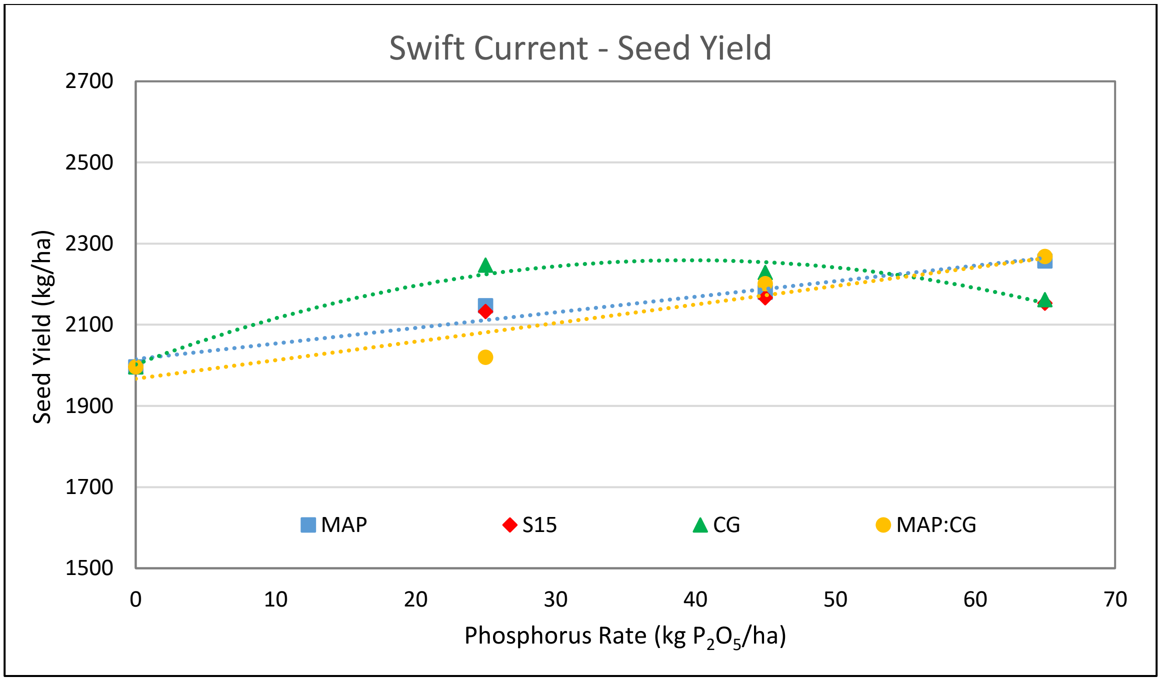


**Figure 13. Seed-placed phosphorus rate and form effects on canola seed yield at Swift Current. The least significant difference (Tukey-Kramer; *P* ≤ 0.05) was 347.4 kg/ha. The fertilizer forms were MAP (monoammonium phosphate), S15 (MicroEssentials® S15), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

The yield responses at Scott were the strongest and most consistent of all locations with linear yield increases as P rate increased for each individual fertilizer formulation (Fig. 14). When averaged across P formulations, yields with 65 kg $P_2O_5$/ha were 571 kg/ha, or 19%, higher than in the control. At the highest application rate, yields trended lower with S15, possibly due to the reduced plant populations observed with this treatment.

The weakest yield responses to P were observed at Indian Head, despite the relatively high yields and low residual soil P levels. Of the individual formulations, only S15 resulted in a small linear yield increase over the control (Fig. 15; *P* = 0.028). When averaged across formulations, the linear response was marginally significant (*P* = 0.063) but the magnitude of the increase was only 153 kg/ha, just under 5%.

Finally, the overall linear response to P rate at Yorkton was significant (*P* = 0.001) with a mean yield gain of 227 kg/ha, or 8%, at 65 kg $P_2O_5$/ha. The yield response was linear for MAP and the MAP:CG blend at Yorkton (Fig. 16; *P* ≤ 0.001), but not significant for CG applied alone (*P* = 0.176-0.376).

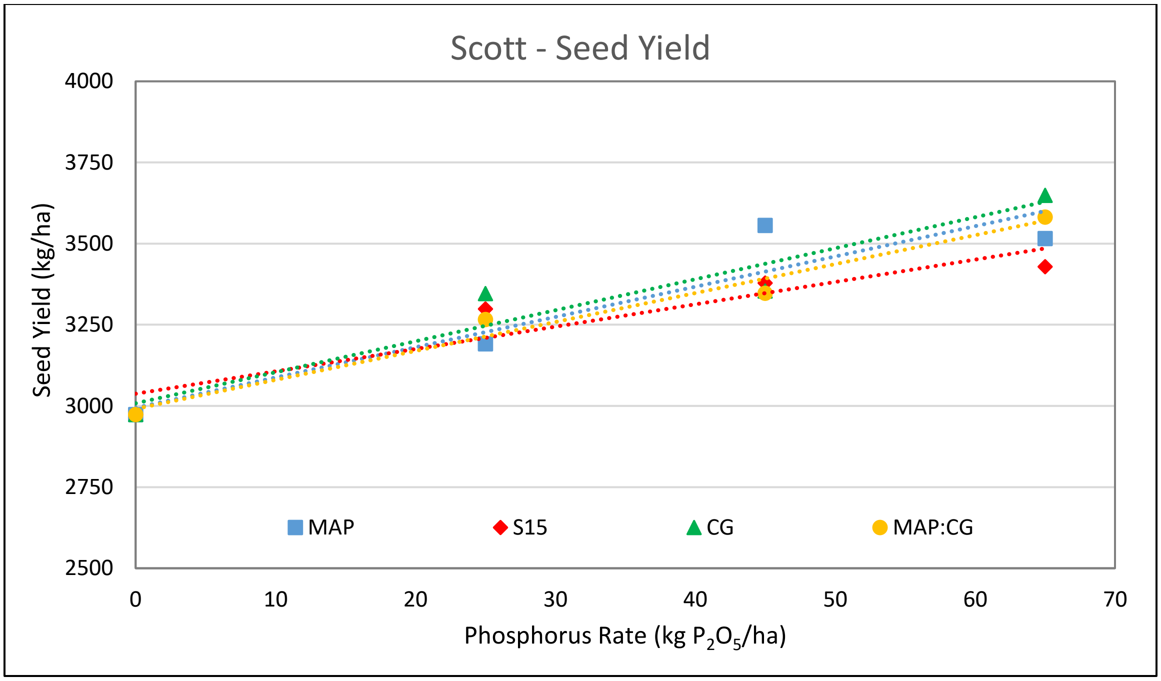


**Figure 14. Seed-placed phosphorus rate and form effects on canola seed yield at Scott. The least significant difference (Tukey-Kramer; $P \leq 0.05$) was 482.4 kg/ha. The fertilizer forms were MAP (monoammonium phosphate), S15 (MicroEssentials® S15), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

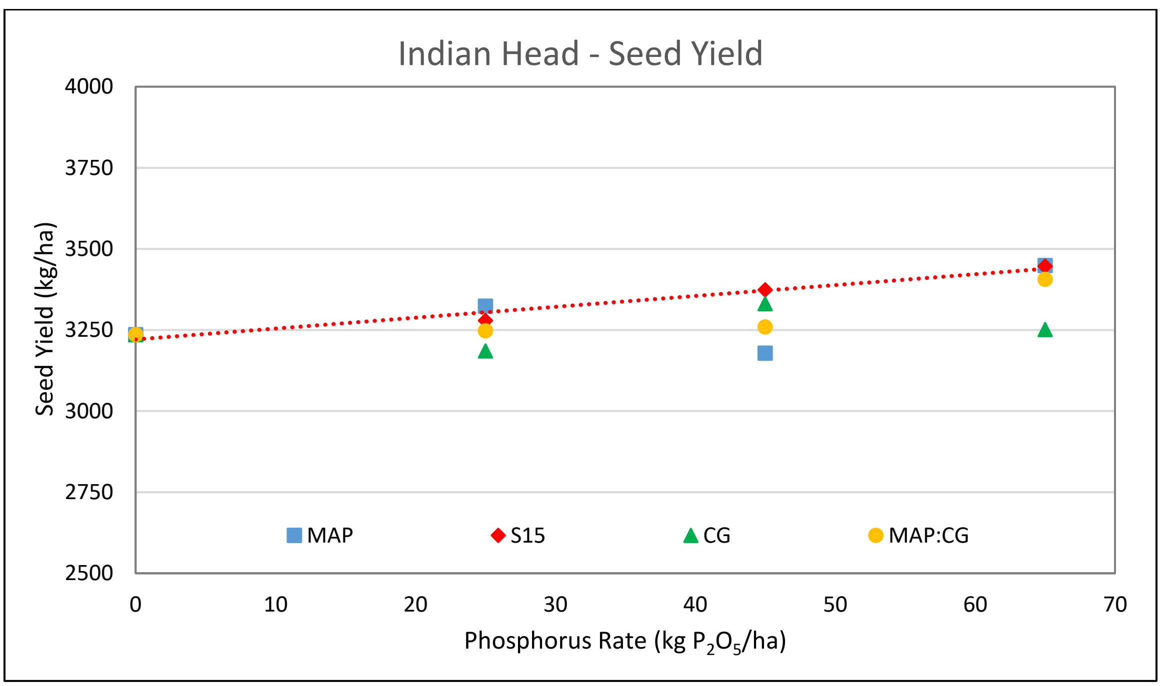


**Figure 15. Seed-placed phosphorus rate and form effects on canola seed yield at Indian Head. The least significant difference (Tukey-Kramer; $P \leq 0.05$) was 353.3 kg/ha. The fertilizer forms were MAP (monoammonium phosphate), S15 (MicroEssentials® S15), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

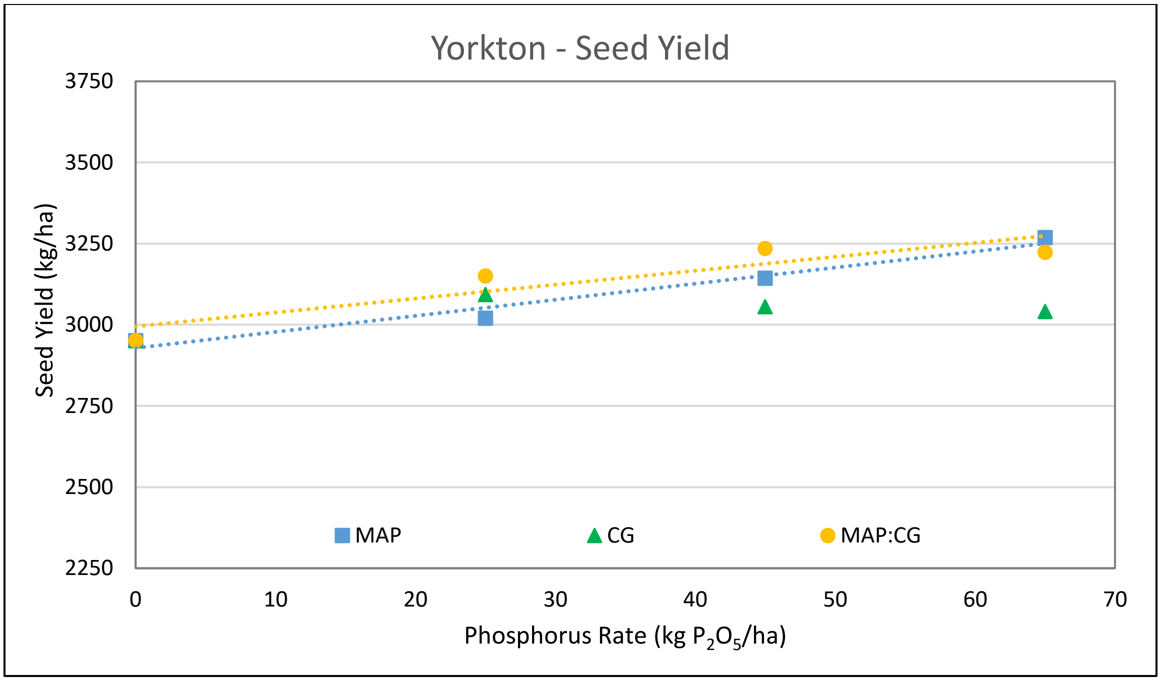


**Figure 16. Seed-placed phosphorus rate and form effects on canola seed yield at Yorkton. The least significant difference (Tukey-Kramer; P ≤ 0.05) was 275.4 kg/ha. The fertilizer forms were MAP (monoammonium phosphate), CG (CrystalGreen®), and a 50:50 blend of MAP:CG (by mass of product).**

*Extension Activities*

Due to COVID-19 restrictions, we were not able to show the field trials on any summer field tours or workshops during the 2020 season at Indian Head; however, highlights of this work will be shared where feasible going forward. Technical reports and extension materials will be available online through IHARF and/or Agri-ARM websites. Extension activities for the other locations are reported in separate individual site reports.

## 11. Conclusions and Recommendations

This project has demonstrated the effects of seed-placing various P fertilizer forms on canola establishment, maturity, and yield for a range of Saskatchewan soil and weather conditions. In addition to a control, the rates at which the products were applied ranged from safe for seed-row placement (25 kg $P_2O_5$/ha) to rates high enough to potentially cause serious seedling injury and stand reduction (i.e., 45-65 kg $P_2O_5$/ha). We expected the risks of seedling injury to be highest with S15, followed by MAP, the MAP:CG blend, and finally CG. This is generally what occurred; however, despite the dry conditions, there was little effect on establishment for all P formulations at Indian Head and Yorkton, the Black soil zone locations where the risks of stand reduction would be lower on average. Swift Current, the location where we expected the risk of seedling injury to be highest due to coarse soil texture, low organic matter and (on average) dry conditions, had high overall mortality but the effects of seed-placed P were negligible with only a slight reduction observed in the spring with S15 but not with any other formulations. When the counts were repeated in the fall, plant densities at Swift Current were similar regardless of P rate or formulation. Scott was the wettest of the locations in 2020 but this was atypical compared to the long-term averages and the risk of seedling injury with seed-placed fertilizer at Scott would normally be higher than Indian Head or Yorkton due coarser soil texture, and lower organic matter. We did, in fact, see the largest and most consistent reductions in plant densities at Scott, but only with MAP and S15 and, for the most part, not to the extent where much negative impact on yield would be expected. Focussing on maturity, effects were either not significant or too small to be of any practical importance. There was at least some evidence of yield response to P fertilizer at all locations, but the magnitude varied and there were inconsistencies for individual forms. The strongest responses, by far, were at Scott where yields increased by up to 19% with P fertilizer and the responses were reasonably consistent across forms. Yields with S15 and, to a lesser extent, MAP did trend lower for the highest rate at Scott, possibly due to lower plant populations. The second most responsive site was Swift Current where we saw an increase of up to nearly 11% at the highest P rate and similar responses regardless of form when averaged across rates. At Yorkton, the yield increase with P was 8% at the highest rate when averaged across forms and the greatest response occurred with the MAP:CG blend, followed by MAP, and finally CG. Despite low residual P and high yields, Indian Head had the weakest yield response at less than 5% and no differences amongst forms when averaged across rates; however, the response did appear to be most consistent with S15. The relative lack of response at Indian Head may suggest that soil test P levels do not necessarily account for the soil's ability to release P throughout the season. Farmers often base P rate decisions on yield expectations and crop removal rates, aiming to either maintain or build residual levels over their rotations. This is a reasonably sound and strategy. When it comes to choosing an optimal form, cost is certainly one important factor to consider but seed safety, equipment configurations, and overall availability should also play into this decision. Monoammonium phosphate is the least expensive, most readily available formulation and crops response well to it; however, MAP has moderately high potential to cause stand reductions when placed with the seed. Many growers prefer MicroEssentials® S15 for its ease of handling and sulfur content (i.e., it can eliminate to handle extra products or blends) but it can be more expensive and potentially cause greater seedling injury when seed-placed relative to MAP applied on its own. That said, MicroEssentials® S15 will generally be safer for seed row placement than a MAP plus ammonium sulfate blend. The greatest practical advantage to CrystalGreen® is its relative safety for seed row placement and potentially greater availability late in the season; however, applied alone it could be less available to crops early in the season than MAP may also be a more expensive option. Blending CrystalGreen® and MAP has the advantage reducing cost (relative to CG applied alone) and, perhaps, providing combination of early and late season available P. This option generally performed similar or better than MAP applied alone with respect to yield, in addition to being slightly safer for seed-row placement than MAP applied alone.

---

**Supporting Information**

**12. Acknowledgements:**

This project was supported by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canadian Agricultural Partnership bi-lateral agreement between the federal government and the Saskatchewan Ministry of Agriculture. Additional funding was provided by Fertilizer Canada. Canola seed and crop protection products used at Indian Head were provided in-kind by BASF. IHARF provided the land, equipment, and infrastructure required to complete this project at Indian Head and IHARF also has a strong working relationship and memorandum of understanding with Agriculture & Agri-Food Canada which helps to make work like this a possibility.

## 13. Appendices:

**Table A-1. Selected agronomic information and dates of operations from canola phosphorus fertilizer formulation demonstrations completed at Swift Current, Scott, Indian Head, and Yorkton, Saskatchewan in 2020.**

| Factor / Operation | Swift Current | Scott | Indian Head | Yorkton |
|---|---|---|---|---|
| Soil Climatic Zone | dry Brown | Dark Brown | thin-Black | Black |
| Previous Crop | Wheat | Wheat | Oat | Oat |
| Pre-emergent herbicide | 894 g glyphosate/ha (May 4) | 1334 g glyphosate/ha + 21 g carfentrazone-ethyl/ha (May 15) | 894 g glyphosate/ha (May 14) | None |
| Cultivar | L233P | L345PC | L345PC | 45CM39 |
| Seeding Date | May 14 | May 18 | May 15 | May 14 |
| Row Spacing | 21 cm | 25 cm | 30 cm | 30 cm |
| Spring Plant Density | June 8 | June 15 | June 10 | June 2 |
| Foliar Insecticide | None | None | None | 6 g deltamethrin/ha (May 29) |
| In-crop Herbicides | 500 g glufosinate ammonium/ha + 31 g clethodim/ha (June 2)<br>500 g glufosinate ammonium/ha + 31 g clethodim/ha (June 19) | 46 g clethodim/ha (June 18) | 593 g glufosinate ammonium/ha + 31 g clethodim/ha (June 16)<br>500 g glufosinate ammonium/ha (July 2) | 534 g glyphosate/ha (June 5)<br>93 g clethodim/ha (June 11) |
| Foliar Fungicide | None | 50 g fluxapyroxad/ha + 99 g pyraclostrobin | 242 g boscalid/ha + 82 g pyraclostrobin/ha (July 15) | None |
| Pre-harvest herbicide | None | 410 g diquat/ha | 894 g glyphosate/ha (August 29) | None |
| Harvest date | August 27 | September 10 | September 9-10 | September 2 |
| Post-Harvest Plant Counts | August 20 | September 11 | September 10 | September 4 |

**Table A-2. Mean spring plant densities and F-test results for phosphorus fertilizer formulation and rate treatments for canola at four Saskatchewan locations in 2020. Means within a column followed by the same letter do not significantly differ (Tukey's range test, *P* ≤ 0.05) and p-values ≤ 0.05 are considered significant.**

| Treatment [Z] | Swift Current | Scott | Indian Head | Yorkton |
|---|---|---|---|---|
| | Spring Emergence (plants/m$^2$) | | | |
| Control | 30.5 a | 57.1 a | 60.7 a | 69.3 a |
| MAP – 25[Y] | 30.5 a | 52.9 a | 69.1 a | 51.3 a |
| MAP – 45 | 34.4 a | 49.0 a | 60.7 a | 54.6 a |
| MAP – 65 | 32.3 a | 43.1 a | 63.4 a | 57.8 a |
| S15 – 25 | 33.2 a | 53.9 a | 70.5 a | – |
| S15 – 45 | 24.2 a | 43.1 a | 59.7 a | – |
| S15 – 65 | 20.4 a | 43.6 a | 55.2 a | – |
| CG – 25 | 33.5 a | 54.4 a | 66.9 a | 68.1 a |
| CG – 45 | 34.7 a | 62.8 a | 68.5 a | 68.9 a |
| CG – 65 | 31.4 a | 62.5 a | 74.2 a | 64.0 a |
| MAP:CG – 25 | 29.3 a | 59.3 a | 67.3 a | 80.8 a |
| MAP:CG – 45 | 24.8 a | 54.7 a | 65.9 a | 64.8 a |
| MAP:CG – 65 | 24.2 a | 53.6 a | 65.4 a | 55.8 a |
| S.E.M. | 3.77 | 4.16 | 3.90 | 10.30 |
| | Pr > *F* (p-values) | | | |
| Overall F-test | 0.147 | 0.012 | 0.081 | 0.225 |
| Check vs rest | 0.778 | 0.320 | 0.229 | 0.417 |

[Z] MAP – monoammonium phosphate (11-52-0); S15 – MicroEssentials® S15 (13-33-0-15); CG – CrystalGreen® (5-28-0 + 10 Mg); MAP:CG – 50:50 blend (by mass of product) of MAP:CG (8-40-0 + 5 Mg)
[Y] Application rates were 25, 45, and 65 kg $P_2O_5$/ha

**Table A-3. Orthogonal contrast results for canola spring plant density responses to phosphorus rates on average and for individual formulations. P-values ≤ 0.05 indicate that a response was significant.**

| Orthogonal Contrast [Z] | Swift Current | Scott | Indian Head | Yorkton |
|---|---|---|---|---|
| | Pr > *F* (p-values) | | | |
| All – linear | 0.365 | 0.143 | 0.555 | 0.216 |
| All – quadratic | 0.414 | 0.957 | 0.151 | 0.862 |
| MAP – linear | 0.578 | 0.019 | 0.960 | 0.312 |
| MAP – quadratic | 0.831 | 0.743 | 0.391 | 0.164 |
| S15 – linear | 0.027 | 0.009 | 0.150 | – |
| S15 – quadratic | 0.287 | 0.826 | 0.045 | – |
| CG – linear | 0.784 | 0.207 | 0.018 | 0.654 |
| CG – quadratic | 0.415 | 0.664 | 0.965 | 0.800 |
| MAP:CG – linear | 0.168 | 0.446 | 0.424 | 0.119 |
| MAP:CG – quadratic | 0.980 | 0.642 | 0.370 | 0.135 |

[Z] MAP – monoammonium phosphate (11-52-0); S15 – MicroEssentials® S15 (13-33-0-15); CG – CrystalGreen® (5-28-0 + 10 Mg); MAP:CG – 50:50 blend (by mass of product) of MAP:CG (8-40-0 + 5 Mg)
[Y] Application rates were 25, 45, and 65 kg $P_2O_5$/ha

**Table A-4. Mean final plant densities and F-test results for phosphorus fertilizer formulation and rate treatments for canola at four Saskatchewan locations in 2020. Means within a column followed by the same letter do not significantly differ (Tukey's range test, *P* ≤ 0.05) and p-values ≤ 0.05 are considered significant.**

| Treatment [Z] | Swift Current | Scott | Indian Head | Yorkton |
|---|---|---|---|---|
| | ---------- Fall Plant Densities (plants/$m^2$) ---------- | | | |
| Control | 31.4 a | 65.4 a | 53.8 a | 103.0 a |
| MAP – 25[Y] | 34.7 a | 55.9 a | 62.6 a | 106.6 a |
| MAP – 45 | 34.1 a | 59.8 a | 58.4 a | 103.7 a |
| MAP – 65 | 33.5 a | 51.9 a | 56.2 a | 89.4 a |
| S15 – 25 | 33.8 a | 54.9 a | 52.1 a | – |
| S15 – 45 | 25.4 a | 49.2 a | 54.8 a | – |
| S15 – 65 | 26.0 a | 50.2 a | 49.2 a | – |
| CG – 25 | 34.4 a | 60.8 a | 57.0 a | 123.0 a |
| CG – 45 | 34.1 a | 63.5 a | 60.7 a | 128.8 a |
| CG – 65 | 35.0 a | 62.8 a | 59.7 a | 116.9 a |
| MAP:CG – 25 | 33.8 a | 64.2 a | 54.7 a | 125.5 a |
| MAP:CG – 45 | 25.4 a | 59.1 a | 54.8 a | 105.0 a |
| MAP:CG – 65 | 29.3 a | 57.4 a | 52.5 a | 92.7 a |
| S.E.M. | 3.56 | 4.98 | 3.45 | 9.97 |
| | ---------- Pr > *F* (p-values) ---------- | | | |
| Overall F-test | 0.352 | 0.319 | 0.307 | 0.047 |
| Check vs rest | 0.951 | 0.128 | 0.518 | 0.451 |

[Z] MAP – monoammonium phosphate (11-52-0); S15 – MicroEssentials® S15 (13-33-0-15); CG – CrystalGreen® (5-28-0 + 10 Mg); MAP:CG – 50:50 blend (by mass of product) of MAP:CG (8-40-0 + 5 Mg)
[Y] Application rates are 25, 45, or 65 kg $P_2O_5$/ha

**Table A-5. Orthogonal contrast results for fall (post-harvest) canola plant density responses to phosphorus rates on average and for individual formulations. P-values ≤ 0.05 indicate that a response was significant.**

| Orthogonal Contrast [Z] | Swift Current | Scott | Indian Head | Yorkton |
|---|---|---|---|---|
| | ---------- Pr > *F* (p-values) ---------- | | | |
| All – linear | 0.669 | 0.079 | 0.793 | 0.714 |
| All – quadratic | 0.645 | 0.572 | 0.220 | 0.028 |
| MAP – linear | 0.692 | 0.098 | 0.751 | 0.311 |
| MAP – quadratic | 0.583 | 0.869 | 0.102 | 0.304 |
| S15 – linear | 0.135 | 0.022 | 0.483 | – |
| S15 – quadratic | 0.670 | 0.307 | 0.583 | – |
| CG – linear | 0.492 | 0.787 | 0.159 | 0.214 |
| CG – quadratic | 0.778 | 0.677 | 0.602 | 0.100 |
| MAP:CG – linear | 0.365 | 0.194 | 0.826 | 0.262 |
| MAP:CG – quadratic | 0.952 | 0.887 | 0.631 | 0.046 |

[Z] MAP – monoammonium phosphate (11-52-0); S15 – MicroEssentials® S15 (13-33-0-15); CG – CrystalGreen® (5-28-0 + 10 Mg); MAP:CG – 50:50 blend (by mass of product) of MAP:CG (8-40-0 + 5 Mg)
[Y] Application rates were 25, 45, and 65 kg $P_2O_5$/ha

**Table A-6. Mean days to maturity and F-test results for phosphorus fertilizer formulation and rate treatments for canola at four Saskatchewan locations in 2020. Means within a column followed by the same letter do not significantly differ (Tukey's range test, *P* ≤ 0.05) and p-values ≤ 0.05 are considered significant.**

| Treatment [Z] | Swift Current | Scott | Indian Head | Yorkton |
|---|---|---|---|---|
| | ------------------------------ Maturity (days from seeding) ------------------------------ | | | |
| Control | 91.8 a | 96.5 a | 104.1 a | 101.3 a |
| MAP – 25[Y] | 91.0 a | 96.0 a | 103.5 a | 97.5 a |
| MAP – 45 | 91.5 a | 97.8 a | 103.4 a | 100.0 a |
| MAP – 65 | 91.8 a | 97.5 a | 103.5 a | 101.0 a |
| S15 – 25 | 91.3 a | 96.8 a | 103.4 a | – |
| S15 – 45 | 92.5 a | 98.0 a | 103.1 a | – |
| S15 – 65 | 91.3 a | 97.0 a | 103.5 a | – |
| CG – 25 | 91.8 a | 97.3 a | 103.5 a | 98.3 a |
| CG – 45 | 91.5 a | 97.3 a | 103.5 a | 99.5 a |
| CG – 65 | 91.3 a | 97.5 a | 103.1 a | 101.8 a |
| MAP:CG – 25 | 92.3 a | 97.5 a | 103.1 a | 97.0 a |
| MAP:CG – 45 | 91.8 a | 96.8 a | 103.1 a | 101.8 a |
| MAP:CG – 65 | 92.3 a | 97.3 a | 103.1 a | 103.3 a |
| S.E.M. | 0.59 | 0.57 | 0.29 | 2.66 |
| | -------------------------------------- Pr > *F* (p-values) -------------------------------------- | | | |
| Overall F-test | 0.839 | 0.539 | 0.142 | 0.218 |
| Check vs rest | 0.892 | 0.240 | 0.002 | 0.492 |

[Z] MAP – monoammonium phosphate (11-52-0); S15 – MicroEssentials® S15 (13-33-0-15); CG – CrystalGreen® (5-28-0 + 10 Mg); MAP:CG – 50:50 blend (by mass of product) of MAP:CG (8-40-0 + 5 Mg)
[Y] Application rates are 25, 45, or 65 kg $P_2O_5$/ha

**Table A-7. Orthogonal contrast results for canola maturity responses to phosphorus rates on average and for individual formulations. P-values ≤ 0.05 indicate that a response was significant.**

| Orthogonal Contrast [Z] | Swift Current | Scott | Indian Head | Yorkton |
|---|---|---|---|---|
| | ------------------------------------- Pr > *F* (p-values) ------------------------------------- | | | |
| All – linear | 0.944 | 0.138 | 0.002 | 0.494 |
| All – quadratic | 0.975 | 0.592 | 0.016 | 0.026 |
| MAP – linear | 0.895 | 0.078 | 0.044 | 0.895 |
| MAP – quadratic | 0.375 | 0.666 | 0.123 | 0.152 |
| S15 – linear | 0.921 | 0.276 | 0.031 | – |
| S15 – quadratic | 0.600 | 0.350 | 0.023 | – |
| CG – linear | 0.518 | 0.235 | 0.004 | 0.789 |
| CG – quadratic | 0.801 | 0.690 | 0.645 | 0.124 |
| MAP:CG – linear | 0.693 | 0.527 | 0.004 | 0.209 |
| MAP:CG – quadratic | 0.974 | 0.628 | 0.040 | 0.072 |

[Z] MAP – monoammonium phosphate (11-52-0); S15 – MicroEssentials® S15 (13-33-0-15); CG – CrystalGreen® (5-28-0 + 10 Mg); MAP:CG – 50:50 blend (by mass of product) of MAP:CG (8-40-0 + 5 Mg)
[Y] Application rates were 25, 45, and 65 kg $P_2O_5$/ha

**Table A-8. Mean seed yields and F-test results for phosphorus fertilizer formulation and rate treatments for canola at four Saskatchewan locations in 2020. Means within a column followed by the same letter do not significantly differ (Tukey's range test, *P* ≤ 0.05) and p-values ≤ 0.05 are considered significant.**

| Treatment [Z] | Swift Current | Scott | Indian Head | Yorkton |
|---|---|---|---|---|
| | Seed Yield (kg/ha) | | | |
| Control | 1996 a | 2973 b | 3236 a | 2951 b |
| MAP – 25[Y] | 2147 a | 3191 ab | 3324 a | 3020 ab |
| MAP – 45 | 2180 a | 3556 a | 3179 a | 3143 ab |
| MAP – 65 | 2257 a | 3516 a | 3449 a | 3269 a |
| S15 – 25 | 2133 a | 3299 ab | 3279 a | – |
| S15 – 45 | 2167 a | 3379 ab | 3374 a | – |
| S15 – 65 | 2153 a | 3429 ab | 3447 a | – |
| CG – 25 | 2247 a | 3346 ab | 3186 a | 3093 ab |
| CG – 45 | 2229 a | 3354 ab | 3332 a | 3056 ab |
| CG – 65 | 2162 a | 3649 a | 3252 a | 3041 ab |
| MAP:CG – 25 | 2020 a | 3266 ab | 3248 a | 3150 ab |
| MAP:CG – 45 | 2201 a | 3347 ab | 3260 a | 3235 a |
| MAP:CG – 65 | 2268 a | 3582 a | 3407 a | 3223 ab |
| S.E.M. | 75.9 | 116.5 | 78.9 | 68.4 |
| | Pr > *F* (p-values) | | | |
| Overall F-test | 0.200 | 0.002 | 0.111 | 0.007 |
| Check vs rest | 0.015 | <0.001 | 0.314 | 0.004 |

[Z] MAP – monoammonium phosphate (11-52-0); S15 – MicroEssentials® S15 (13-33-0-15); CG – CrystalGreen® (5-28-0 + 10 Mg); MAP:CG – 50:50 blend (by mass of product) of MAP:CG (8-40-0 + 5 Mg)
[Y] Application rates are 25, 45, or 65 kg $P_2O_5$/ha

**Table A-9. Orthogonal contrast results for canola seed yield responses to phosphorus rates on average and for individual formulations. P-values ≤ 0.05 indicate that a response was significant.**

| Orthogonal Contrast [Z] | Swift Current | Scott | Indian Head | Yorkton |
|---|---|---|---|---|
| | Pr > *F* (p-values) | | | |
| All – linear | 0.006 | <0.001 | 0.063 | 0.001 |
| All – quadratic | 0.233 | 0.312 | 0.338 | 0.279 |
| MAP – linear | 0.011 | <0.001 | 0.132 | <0.001 |
| MAP – quadratic | 0.672 | 0.324 | 0.227 | 0.464 |
| S15 – linear | 0.100 | 0.002 | 0.028 | – |
| S15 – quadratic | 0.316 | 0.209 | 0.721 | – |
| CG – linear | 0.100 | <0.001 | 0.557 | 0.319 |
| CG – quadratic | 0.031 | 0.798 | 0.933 | 0.176 |
| MAP:CG – linear | 0.003 | <0.001 | 0.115 | 0.001 |
| MAP:CG – quadratic | 0.591 | 0.902 | 0.316 | 0.107 |

[Z] MAP – monoammonium phosphate (11-52-0); S15 – MicroEssentials® S15 (13-33-0-15); CG – CrystalGreen® (5-28-0 + 10 Mg); MAP:CG – 50:50 blend (by mass of product) of MAP:CG (8-40-0 + 5 Mg)
[Y] Application rates were 25, 45, and 65 kg $P_2O_5$/ha

**Abstract**

**14. Abstract/Summary**

Field trials were conducted at Swift Current, Scott, Indian Head, and Yorkton to demonstrate canola response to seed-placed phosphorus (P) fertilizer formulations, with a focus on establishment and yield. The P formulations were monoammonium phosphate (MAP, 11-52-0), MicroEssentials® S15 (13-33-0-15), CrystalGreen® (CG; 5-28-0 + 10% Mg), and 50:50 MAP:CG where 65% of the applied $P_2O_5$ came from MAP and 35% came from CG. In addition to a control where no P was applied, the application rates were 25, 45, and 65 kg $P_2O_5$/ha. All sites were reasonably low in P with 7-12 ppm residual Olsen P in the top 15 cm of soil. The response data included spring and fall plant densities, maturity, and yield. Treatment effects on plant densities were mostly small or not significant but, where responses occurred, S15 and MAP were the most likely to negatively affect emergence compared to CG. The most prominent reductions occurred at Swift Current and Scott, the latter where increasing rates of both seed-placed MAP and S15 reduced canola plant densities linearly. At Indian Head, only S15 at the highest application rate reduced plant populations while, at Yorkton, emergence was variable but not significantly affected by the treatments. Differences in plant densities tended to be less when the counts were repeated in the fall. Treatment effects on maturity were either not significant or too small to be of practical importance. The magnitude and consistency of yield responses varied with location. Scott was, by far, the most responsive location with linear yield increase detected for all formulations, by up to 19% at the highest P rate. At Swift Current, the average increase was at 11% at the highest P rate and, while there were subtle differences between forms, yields were statistically similar for all when averaged across rates. At Yorkton, the average yield increase was 8% and the best responses occurred with MAP and the MAP:CG blend compared to CG applied alone. The weakest response occurred at Indian Head despite high yields and low residual P. At this location, the average increase was less than 5% and, while the response was most consistent with S15, yields were statistically similar for all forms when averaged across rates. In conclusion, when choosing appropriate rates, considering removal rates with realistic yield targets continues be a reasonable strategy. In terms of choosing formulations, cost is important to consider but seed safety, equipment configurations, and overall product availability may also play into this decision.