2017 Project Report

for the

Saskatchewan Pulse Crop Development Board

Project Title: Seed-Placed vs Side-Banded Phosphorus Effects on Faba Bean Establishment and Yield (Project #AP-17-08)

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1. **Project Code:** AP-17-08

2. **Project Title:** Seed-placed versus side-banded phosphorus fertilizer (11-52-0) effects on faba bean establishment and yield

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5. **Introduction**
Faba beans have been grown in limited acres on the Prairies for decades and have long been considered well adapted to the moister, cooler regions of Saskatchewan, including much of the Black soil zone. While the seeded acreage is relatively small, interest in this crop continues to be strong due to its high yield potential, improved resistance to root diseases and ability to withstand prolonged wet periods much better than field peas and lentils. With the potential for increased production of this crop, farmers need exposure to the management factors that should be considered when growing faba beans. While published research on faba bean response to phosphorus (P) fertilizer is limited, the basic principles of P management in crop production are generally understood. At three Saskatchewan locations (Outlook, Melfort and Saskatoon – 8 site-years in total), Henry et al. (1995) compared side-band and seedrow placement at six rates up to 100 kg P_2O_5/ha. They found that faba beans were more responsive to P than field pea or lentil and also concluded that the yield response was more consistent with side-banding, especially when all three crops were considered. Field trials at 2 locations in Alberta over a three year period (6 site-years) did not show a significant response to P, K or S fertilization when all sites were combined, but there was an overall tendency for higher yields with P fertilizer and the response to P was significant at two sites when looked at individually (Olsen and Bowness 2016). While obviously under different environmental conditions, research in the Ethiopian highlands showed yield responses of up to 53% (averaged over six site-years) with P application in deficient soils and found that yields continued to increase right through the highest rate (69 kg P_2O_5/ha) evaluated in the trial (Agegnehu and Fessehaie, 2006). In Western Australia, Bolland et al. (2000) saw large yield increases (50-100%) with P fertilization at 2/3 locations but could not explain the variation in response with soil test P levels. They recorded the strongest response at the site with the highest residual P and no response where the lowest P levels were detected. While the response to P fertilizer applications may vary and be difficult to predict, it is known that high yielding faba beans export large amounts of P in the grain. For example, a relatively modest 3360 kg/ha (50 bu/ac) crop removes 49-60 kg P_2O_5/ha (55-67 lb/ac) and takes up a total of 79-96 kg P_2O_5/ha (89-108 lb/ac).

While most research suggests that crops respond similarly to safe rates of side-banded versus seed-placed P fertilizer, many growers prefer seed-placement and the early-season (pop-up) response can be superior under cool, dry conditions or extremely low residual P levels for some crops. Henry et al. (1995) found that faba beans were considerably less prone to injury from seed-placed P than field peas or, to a lesser extent, lentils but did see slightly lower plant populations (9%) at Outlook when averaged across rates. Notably, there was no effect of seed placed P at rates up to 100 kg P_2O_5 at Melfort or Saskatoon despite 45% and 16-27% reductions relative to side-banding (averaged across rates) for field peas and lentils, respectively. Nonetheless, there are limits to how much P fertilizer can be placed in the seedrow before the risk of crop injury becomes unacceptably high. Currently, the Saskatchewan Ministry of Agriculture recommends that no more than 25 kg/ha P_2O_5 (22 lb P_2O_5/ac) be applied when using narrow openers while the Saskatchewan Pulse Grower suggest the safe rate is up to 45 kg P_2O_5/ha assuming 10-15% seedbed utilization.

6. Objective(s) or purpose of the project

A project was initiated in 2016 through the ADOPT Program (SK Ministry of Agriculture / AAFC) and continued in 2017 with funding from the Saskatchewan Pulse Growers. The specific objectives of the project were to: 1) Demonstrate and gather information on faba bean response to phosphorus fertilization in low P soils, 2) Compare the overall response to seed-placed (in-furrow) versus side-band placement of P fertilizer, and 3) Demonstrate the maximum safe rates of seed-placed monoammonium phosphate and provide information on faba bean sensitivity to seed-placed P fertilizer when seeded into clay soils using a hoe drill with low seed-bed utilization.

7. Materials and Methods

Field trials with faba beans were established near Indian Head on spring wheat stubble in 2016 (50.556° N, -103.608° W) and barley stubble in 2017 (50.546° N, -103.602° W). The treatments were arranged in a four replicate Randomized Complete Block Design (RCBD) and included two placement methods, four rates of monoammonium phosphate and an unfertilized control:

1. Control – 0 P_2O_5
2. Seed-Placed – 20 kg 0 P_2O_5/ha (18 lb P_2O_5/ac)
3. Seed-Placed – 40 kg P_2O_5/ha (36 lb P_2O_5/ac)
4. Seed-Placed – 60 kg P_2O_5/ha (53 lb P_2O_5/ac)
5. Seed-Placed – 80 kg P_2O_5/ha (71 lb P_2O_5/ac)
6. Side-Banded – 20 kg P_2O_5/ha (18 lb P_2O_5/ac)
7. Side-Banded – 40 kg P_2O_5/ha (36 lb P_2O_5/ac)
8. Side-Banded – 60 kg P_2O_5/ha (53 lb P_2O_5/ac)
9. Seed-Banded – 80 kg P_2O_5/ha (71 lb P_2O_5/ac)

Selected agronomic information for the field trials over the two year period is provided in Table 1. Snowbird (zero-tannin) faba beans were direct-seeded into standing cereal stubble in early May using a SeedMaster plot drill equipped with eight openers on 30 cm row spacing. With an opener width of 16 mm (5/8"), the theoretical seed-bed utilization with this drill is less than 6%. The seed was inoculated with Nodulator self-adhering peat based inoculant (BASF Canada) applied at twice the label recommended rate to ensure nodulation was not limiting. No supplemental nitrogen was applied (i.e. N was not balanced across P treatments) and monoammonium phosphate (11-52-0) was applied as per protocol. For the side-band treatments, fertilizer was placed 38 mm (1.5") beside and 19 mm (3/4") below the seed. The target seeding depth was approximately 38 mm (1.5") and, although both springs were relatively dry, the seed was always placed into moisture. Weeds were controlled using registered pre-emergent and in-crop herbicide applications and fungicide was applied at mid-bloom to minimize the potential for disease. Pre-harvest glyphosate was applied for weed control at physiological maturity and the centre five rows of each plot were straight-combined when it was fit to do so.

Emergence was measured at two pre-determined intervals (targeted 15 and 30 days after seeding) by counting the number of seedlings in two separate 1 m sections of crop row per plot. On the first measurement date, the sample areas were marked so that the same sections of crop could be reassessed at the later date. Yields were determined from the harvested grain samples which were corrected for dockage and to 16% seed moisture content. Seed size was determined by counting and weighing a minimum of 200 seeds and calculating g 1000/seeds (TKW). Weather data were estimated from a private weather station located approximately 2 km from the field trial site in 2016 and from an Environment Canada station approximately 3 km from the site in 2017.

All response data were analysed using the Mixed procedure of SAS with the effects of year (Y), P treatment (P) and their interaction (Y × P) considered fixed while replicate effects were considered random. Tukey's studentized range test, which controls experiment-wise error and tends to be relatively conservative, was used to compare all possible combinations of individual treatments. Contrast comparisons were used to evaluate the control against all fertilized plots and seed-placed versus side-banded P. Orthogonal contrasts were used to determine whether the responses to seed-placed and side-banded P were insignificant, linear or curvilinear (quadratic). All treatment effects and comparisons were considered significant at $P \leq 0.05$.

Table 1. Selected agronomic information for faba bean P rate and placement trials at Indian Head, Saskatchewan in 2016 and 2017.

Factor / Field Operation	2015	2016
Pre-emergent herbicide	894 g glyphosate/ha + 140 g sulfentrazone/ha (7-May)	894 g glyphosate/ha (15-May) 140 g sulfentrazone/ha (10-May)
Fertility	N as provided w/11-52-0 (not balanced across treatments), 164 g Nodulator seed-applied inoculant/100 kg seed	N as provided w/11-52-0 (not balanced across treatments), 164 g Nodulator seed-applied inoculant/100 kg seed
Seeding Date	1-May	6-May
Cultivar	Snowbird (zero tannin)	Snowbird (zero tannin)
Seeding Rate	50 viable seeds/m^2	50 viable seeds/m^2
Row spacing	30 cm	30 cm
In-crop herbicide	15 g imazomox/ha + 15 g imazethapyr/ha + 40 g tepraloxydim (4-Jun)	15 g imazomox/ha + 15 g imazethapyr/ha + 40 g tepraloxydim (7-Jun) 1079 g bentazon/ac (12-Jun)
Fungicide	74 g fluxapyroxad/ha + 140 g pyraclostrobin /ha (28-Jun)	74 g fluxapyroxad/ha + 140 g pyraclostrobin /ha (6-Jul)
Insecticide	none applied	none applied
Pre-harvest	890 g glyphosate/ha (28-Aug)	890 g glyphosate/ha (25-Aug)
Harvest date	19-Sep	7-Sep

8. Results & Discussion

Growing Season Weather & Soil Test Information

Mean monthly temperatures and precipitation amounts for the 2016 and 2017 growing seasons at Indian Head are presented along with the long-term (1981-2000) averages in Table 2. Overall, the early spring of 2016 was relatively dry but soil conditions were excellent for seeding and the faba beans were seeded early and into good moisture. While May was initially warm and dry, precipitation late in the month amounted to 140% of the long-term average. The total precipitation amount for June was 81% of normal while July was wet (177%) and August was comparatively dry (58%). Total precipitation from April 1 through August 31 in 2016 was 292 mm (11.7"), approximately 9% above the long-term average. Temperatures were higher than normal in May and June then approximately normal in July and August. Unfortunately, the 2016 plots were severely damaged by hail on July 18 (mid-late bloom) resulting in most upper stems being broken off, many damaged pods and premature termination of flowering. Although severe, the damage was considered uniform across the study area and all data was considered viable despite the negative impacts on yield. The 2017 season started with an early snowmelt but abundant sub-soil moisture; however, conditions were unusually warm and dry through most of the spring and summer. Despite the initial moisture, the conditions that followed seeding were hot, windy and dry; therefore, emergence tended to be somewhat variable early on. The first major precipitation event in 2017 occurred in mid-June and, from April through August, the cumulative precipitation received was 135 mm or 52% of the long-term average. Temperatures in 2017 were average overall but above normal in May and below normal in August. In general, the overall faba bean yield potential was much lower in 2017 than the previous season as this crop prefers cool temperatures and abundant moisture.

Table 2. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 15-2016 and 2016-17 growing season at Indian Head, SK.

Year	April	May	June	July	August	Avg. / Total
	Mean Temperature (°C)					
2016	3.8	13.9	17.5	18.5	17.1	14.2
2017	4.2	11.6	15.5	18.4	16.7	13.3
LT	4.2	10.8	15.8	18.2	17.4	13.3
	Precipitation (mm)					
2016	13.9	72.6	63.0	112.8	29.8	292
2017	18.5	10.4	65.6	15.4	25.2	135
LT	17.1	51.8	77.4	63.8	51.2	261

Composite soil samples were collected from the study area each spring and submitted to AgVise Laboratories for analyses (Table 3). Soil pH for the upper 15 cm was 7.4-7.8 with 5-6% organic matter and a relative high cation exchange capacity of 39-47 Meq. The soil is classified as an Indian Head heavy clay with clay-loam to clay surface textures. Residual NO_3-N concentrations were moderately low (19-24 kg/ha) while S and K were considered unlikely to be limiting at 47-78 kg/ha and 606-725 ppm, respectively. Residual soil P was quite low at 4-9 ppm (Olsen-P), or approximately 7-16 kg/ha extractable P.

Table 3. Residual soil nutrient levels in faba bean phosphorus response trials conducted over a two-year period at Indian Head, Saskatchewan (2016-17).

Soil Property / Nutrient	2016	2017
pH (0-15 cm)	7.4	7.8
O.M.	6.0%	5.0%
C.E.C.	39.1 Meq	46.7
NO_3-N (0-60 cm)	24 kg/ha	19 kg/ha
Olsen-P (0-15 cm)	9 ppm	4 ppm
K (0-15 cm)	725 ppm	606 ppm
SO_4-S (0-60 cm)	47 kg/ha	78 kg/ha

Crop Response to Phosphorus Rate & Placement

Faba bean emergence was assessed at two separate times, once at approximately 15 days after seeding (part way through emergence) and again approximately 30 days after seeding when it was assumed that emergence was complete. Results for the initial measurements are presented for 2016, 2017 and averaged across years in Figs. 1-3 and also in the Appendices (Table 5). At this time, plant densities were similar between the two years (25-30 plants/m^2 on average) and, according to both the tests of fixed effects (Table 4) and orthogonal contrasts (Table 5), not affected by P treatment in either year alone or when averaged across years. At 30 days after planting, the average values were higher in 2016 than under the drier conditions of 2017 but the tests of fixed effects did not show either a P treatment effect or Y × P interactions (Table 4). The orthogonal contrasts detected a quadratic relationship between seed-placed P rate and plant density in both 2016 (Fig. 4, Table 6) and when averaged across years (Fig. 6, Table 6); however this was likely due to random variability as the results were not indicative of seedling toxicity. For example, in both 2016 and when averaged across years, final plant populations were numerically higher with 80 kg/ha seed-placed P_2O_5 than in the control (Figs. 4 and 6, Table 6). In 2017, there were no indications of a P effect on final plant populations regardless of application rate or placement method (Fig. 5).

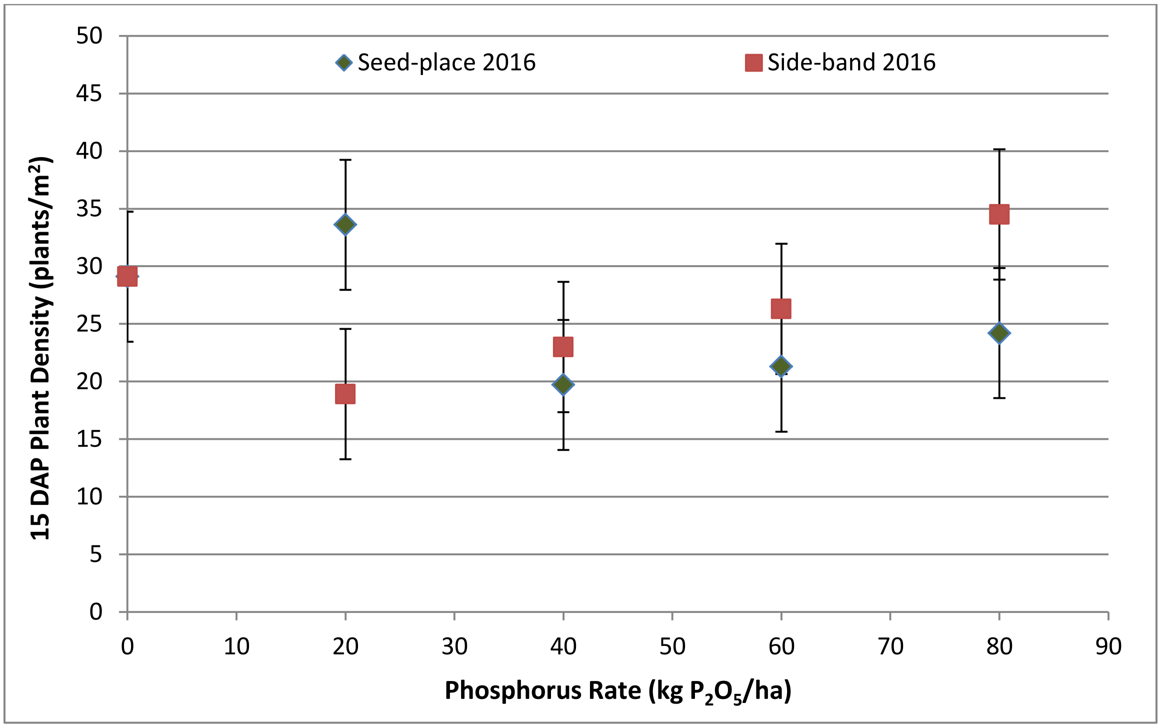

Figure 1. Phosphorus rate and placement effects on early (15 days after planting) faba bean emergence at Indian Head, Saskatchewan in 2016.

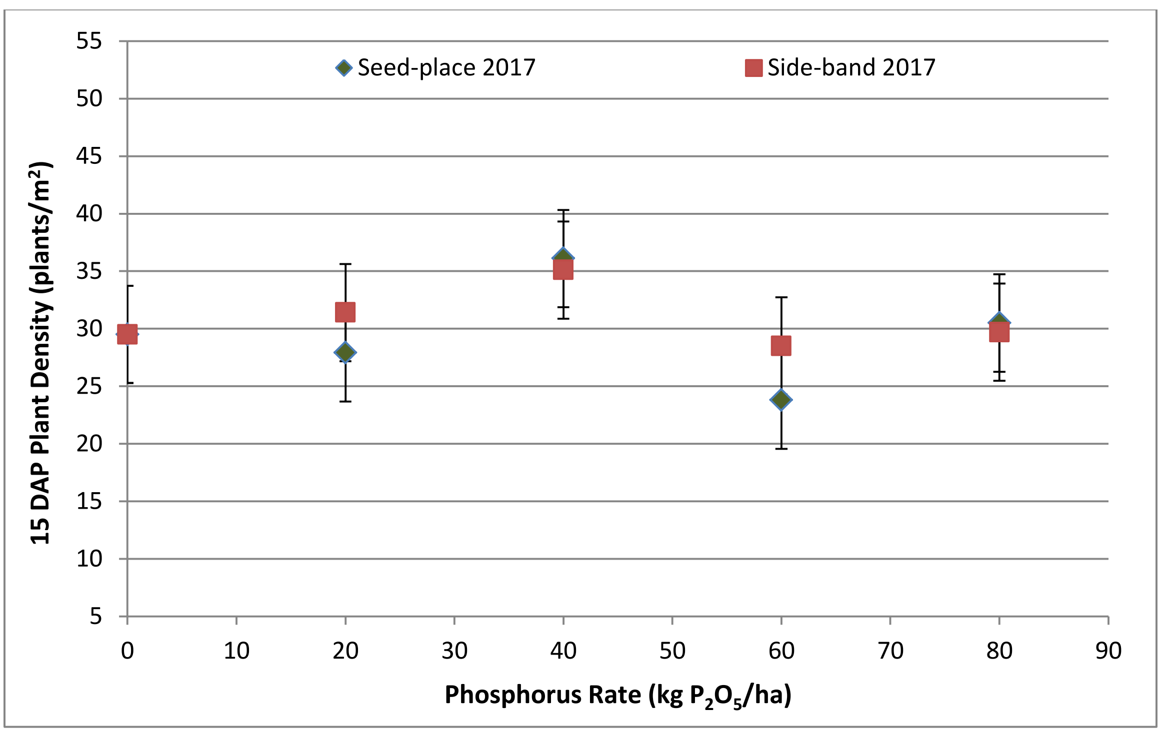

Figure 2. Phosphorus rate and placement effects on early (15 days after planting) faba bean emergence at Indian Head, Saskatchewan in 2017.

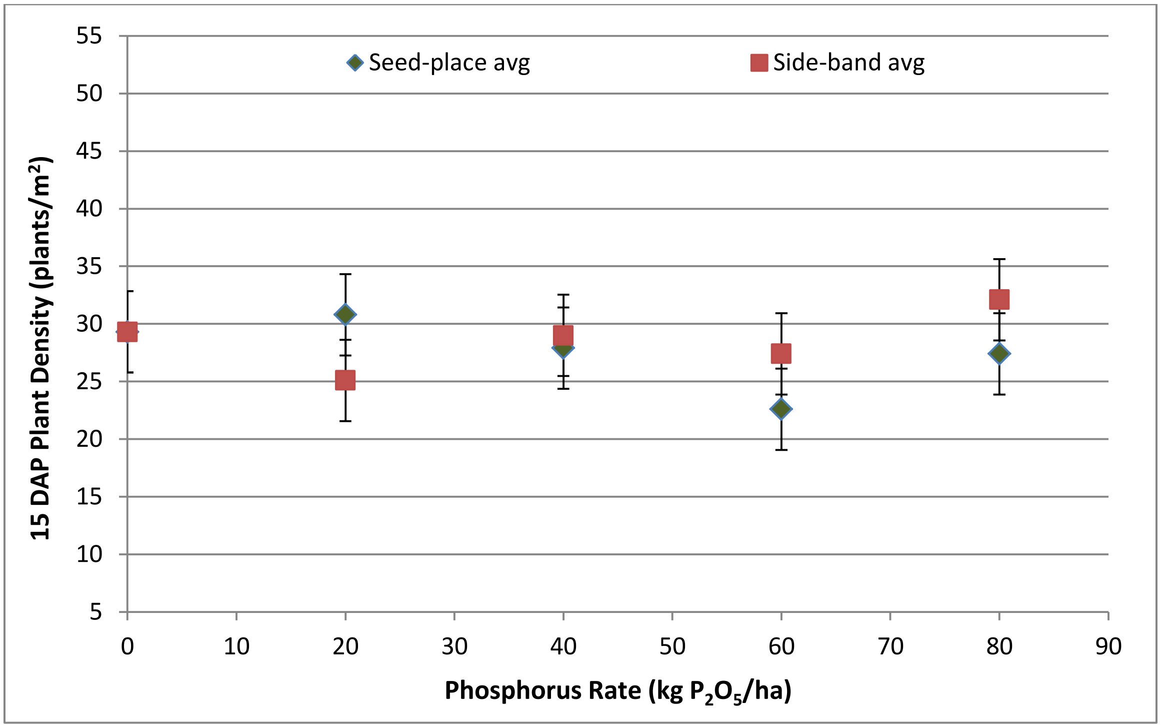

Figure 3. Phosphorus rate and placement effects on early (15 days after planting) faba bean emergence averaged over a two-year period (2016-17) at Indian Head.

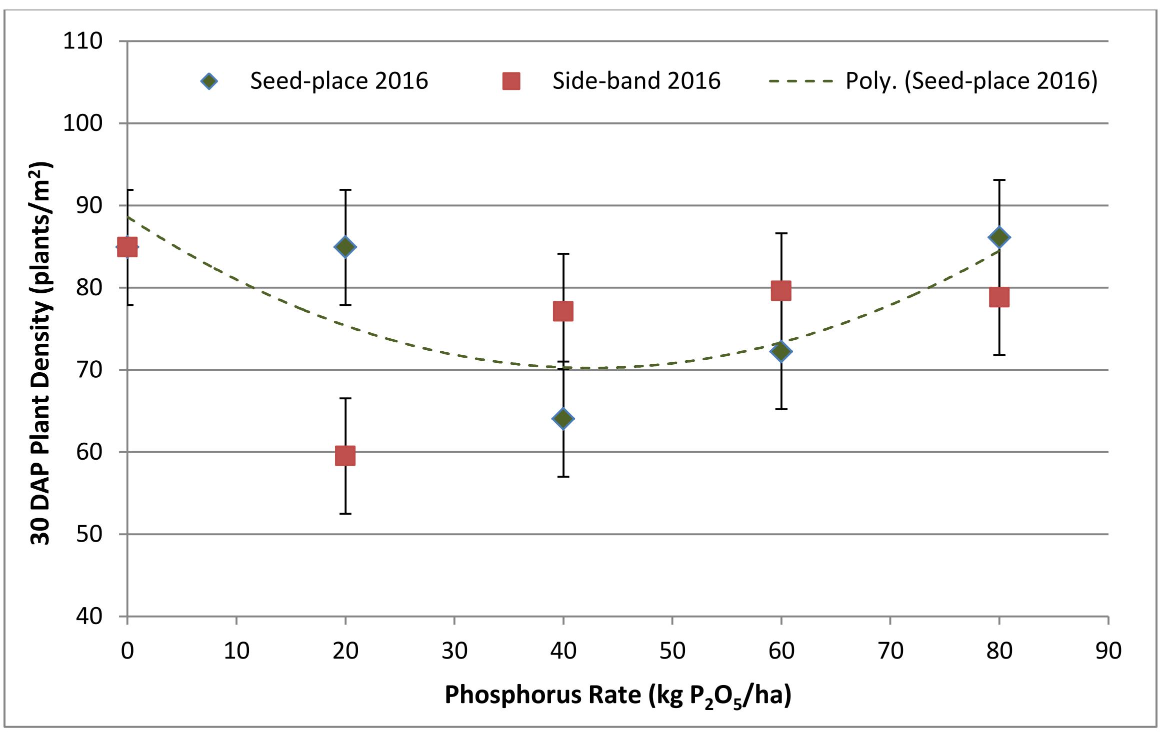

Figure 4. Phosphorus rate and placement effects on final (30 days after planting) faba bean emergence at Indian Head, Saskatchewan in 2016.

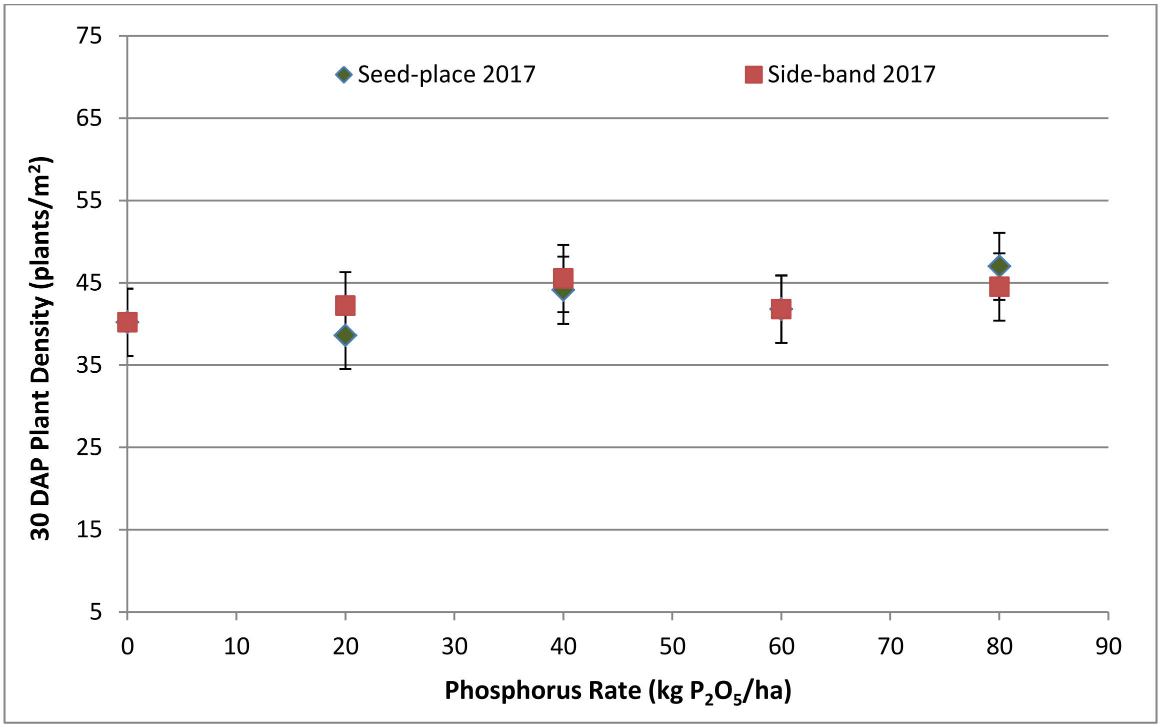

Figure 5. Phosphorus rate and placement effects on final (30 days after planting) faba bean emergence at Indian Head, Saskatchewan in 2017.

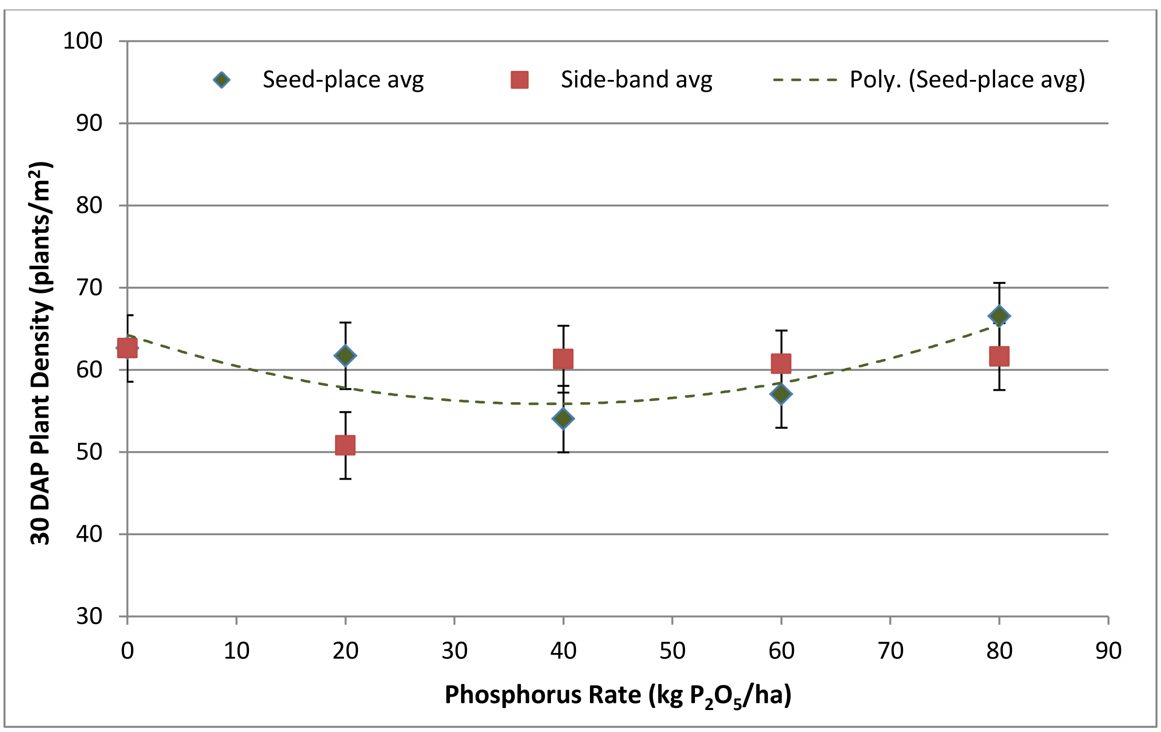

Figure 6. Phosphorus rate and placement effects on final (30 days after planting) faba bean emergence averaged over a two-year period (2016-17) at Indian Head, Saskatchewan.

Phosphorus rate and placement effects on faba bean seed yield are presented in Figs. 7-9 and Table 7 of the Appendices. Seed yields were affected by year and by P treatment but with no Y × P interaction, thereby suggesting that the P response was consistent despite the contrast in weather between the two seasons. Even after the hail damage in 2016, the overall yield (across P treatments) this season was 4213 kg/ha compared to 2571 kg/ha under the much drier conditions of 2017. Within individual years, Tukey's studentized range test did not detect any significant differences amongst the treatments; however, for both years and placement methods the orthogonal contrasts showed significant linear yield increases with increasing P rate (Figs 7-8, Table 7). Averaged over the two years, yields increased linearly by 440 kg/ha (14%) as the P rate was increased from 0 to 80 kg/ha. There were no apparent yield differences associated with P placement either for individual years or when averaged across years. Overall, the slope of the linear yield increase with P rates was steeper under the high yielding conditions of 2016; however, the strong response in 2017 was not necessarily unexpected either as P mobility and mineralization throughout the season are reduced under dry soil conditions.

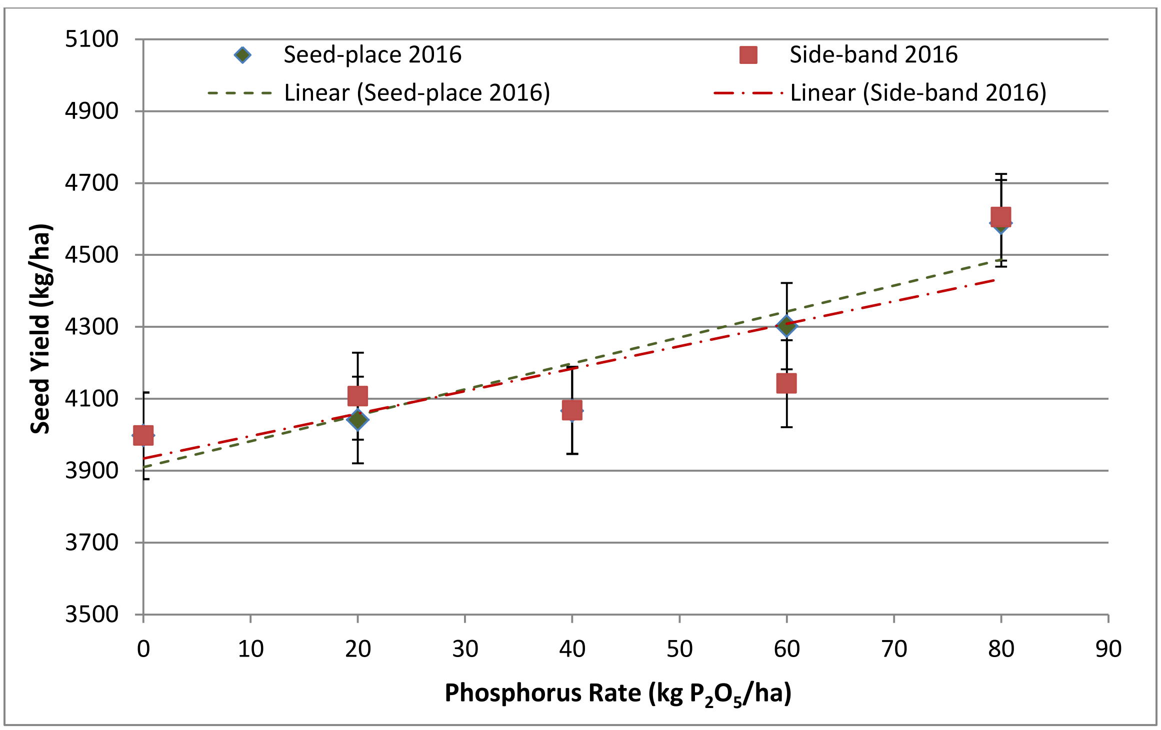

Figure 7. Phosphorus rate and placement effects on faba bean seed yield at Indian Head, Saskatchewan in 2016.

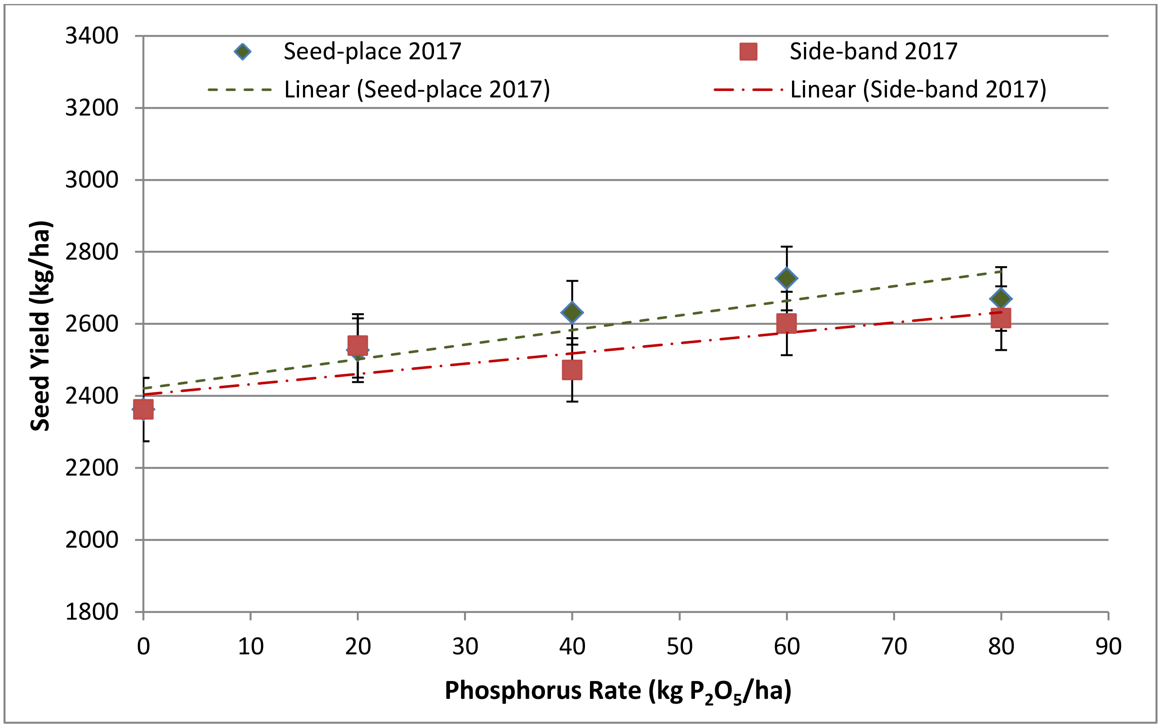

Figure 8. Phosphorus rate and placement effects on faba bean seed yield at Indian Head, Saskatchewan in 2017.

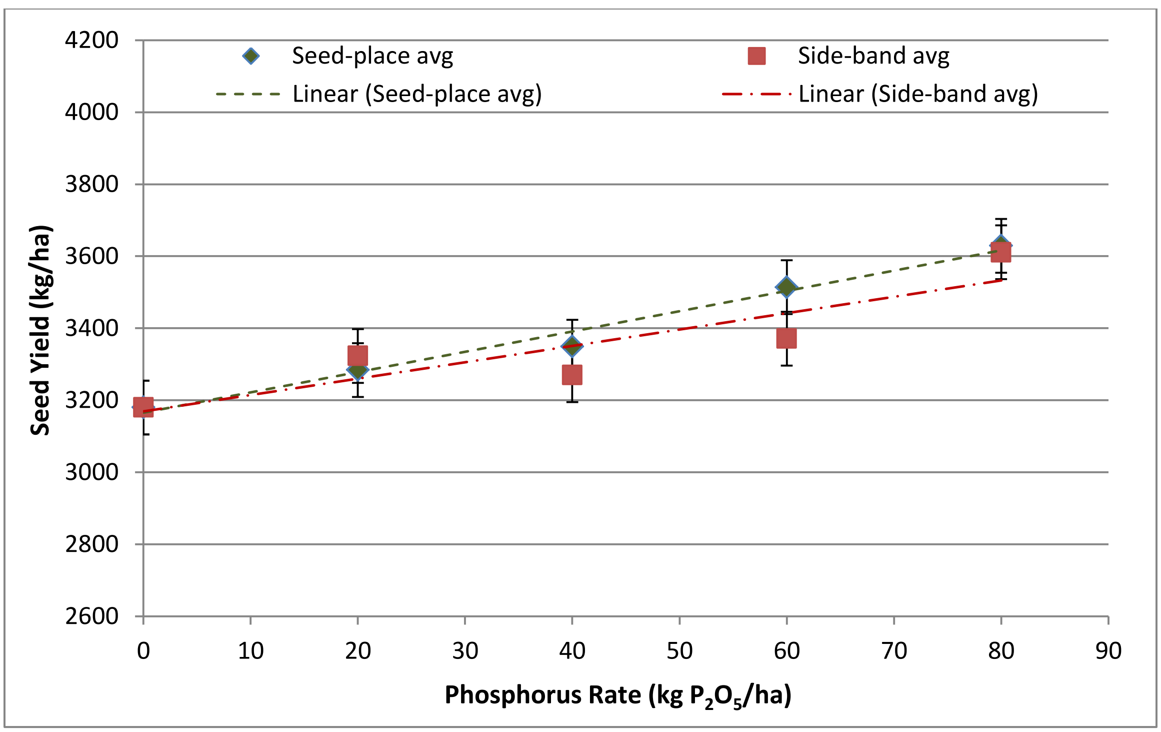

Figure 9. Phosphorus rate and placement effects on faba bean seed yield averaged over a two-year period (2016-17) at Indian Head, Saskatchewan.

Results for P treatment effects on faba bean seed weight (g/1000 seeds) are presented in Figs. 10-12 and Table 8. For this variable, the overall F-test was significant for year and P treatment but there was no Y × P interaction suggesting that the treatment effects were reasonably consistent over the two years (Table 4). Despite the significant F-tests, no individual treatment differences were detected by the multiple comparisons test for either year individually or averaged across years. However, the contrasts suggested larger seeds in the unfertilized control (compared to the average of all fertilized treatments) in 2016 and when averaged over the two years and the orthogonal contrasts also showed somewhat inconsistent responses. In any case, the observed effects were small, of little agronomic consequence and indicate that the observed yield increases with P fertilization were not due to larger seed size but, rather, were attributable to some other factor (i.e. more pods per plant or more seeds per pod).

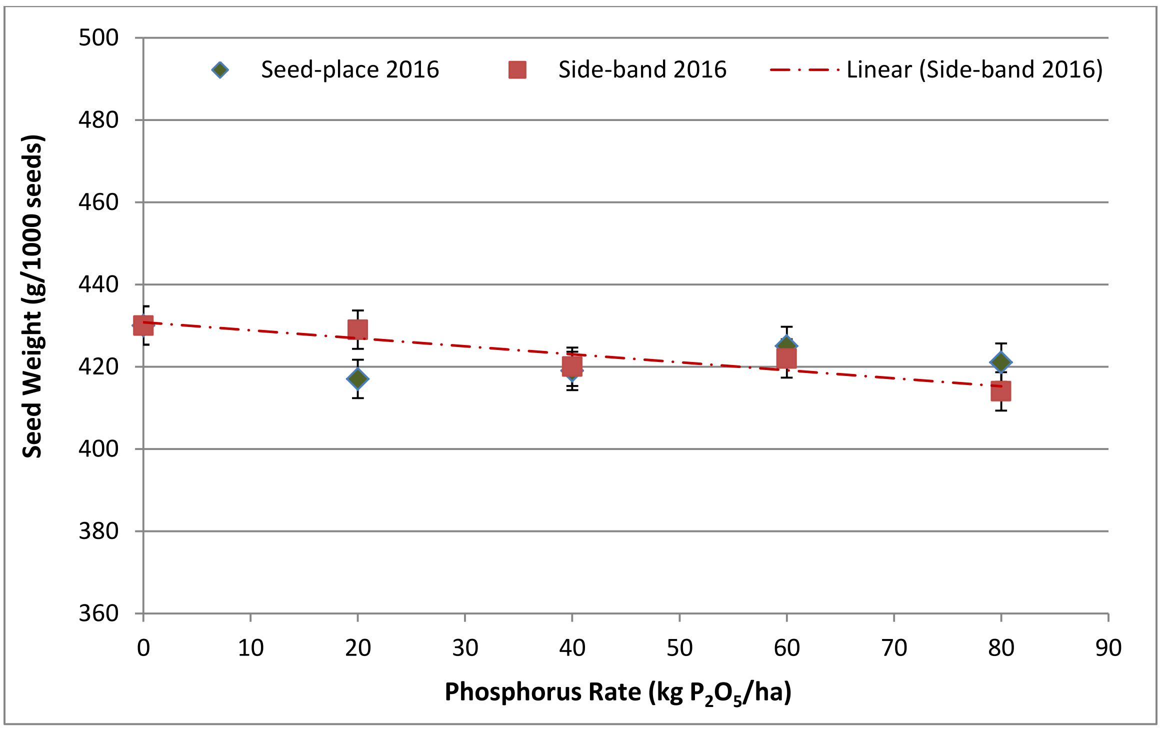

Figure 10. Phosphorus rate and placement effects on faba bean seed weight at Indian Head, Saskatchewan in 2016.

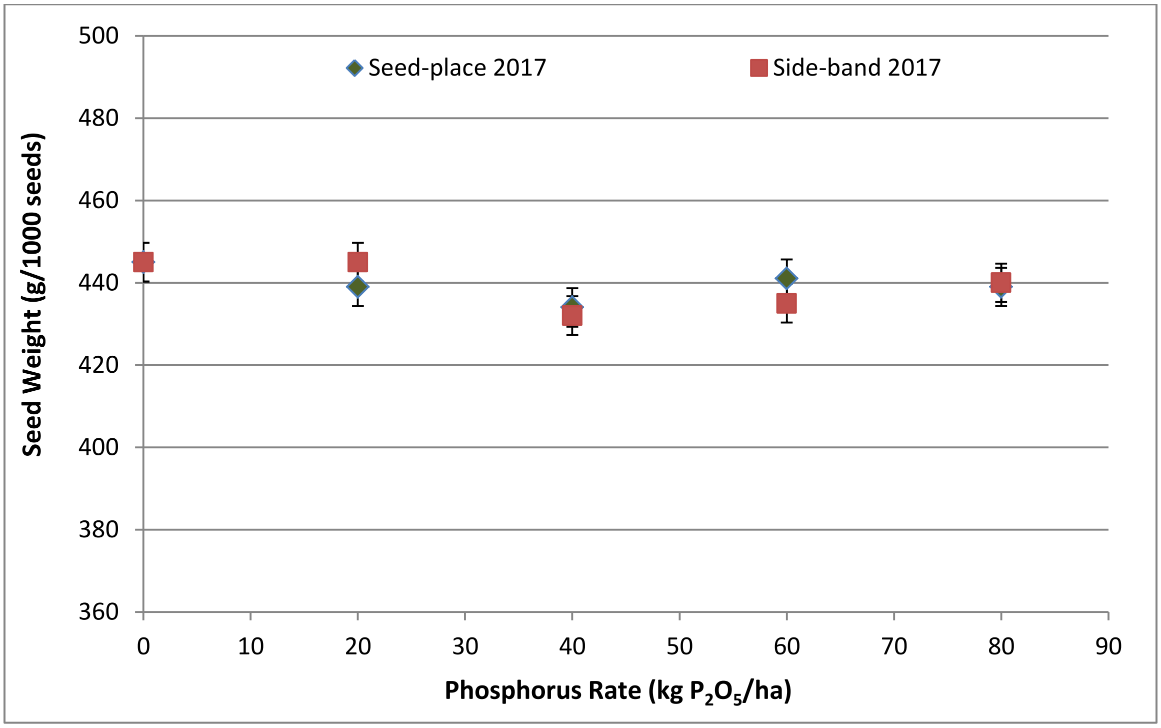

Figure 11. Phosphorus rate and placement effects on faba bean seed weight at Indian Head, Saskatchewan in 2017.

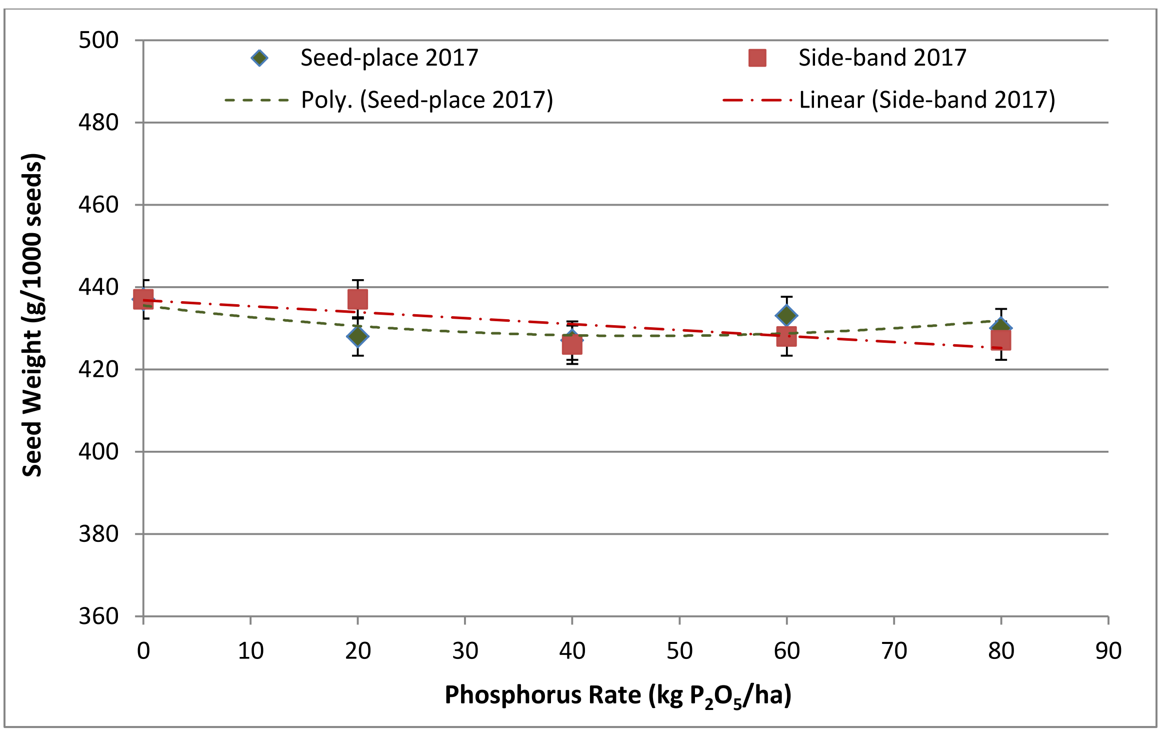

Figure 12. Phosphorus rate and placement effects on faba bean seed weight averaged over a two-year period at Indian Head, Saskatchewan.

9. Economic and Practical Implications For growers

Overall, the results from this project suggest that P fertility is important for growing faba beans and, in low P soils, yield responses to P fertilizer application are likely to occur. The yield increases that were realized with P fertilization in the current study were as high as 14% but the actual response will vary from year-to-year and field-to-field. Although the observed response was linear and the highest yields were achieved at the highest application rates, it will not necessarily be practical or economical to use rates this high; however, the results do demonstrate the high potential requirements of this crop. There were no noteworthy differences in response across the two placement methods indicating that either seed-placement or side-banding P fertilizer is effective; however, these results should not be taken to suggest that high rates of seed-placed P (i.e. > 40 kg P_2O_5/ha) will be safe under broader circumstances.

10. Conclusions & Recommendations

This project evaluated the response of faba beans to varying rates of seed-placed versus side-banded monoammonium phosphate (11-52-0) with a focus on crop establishment, yield and, to a lesser extent, seed weight. The results were generally consistent with past research which has shown that faba beans are less sensitive to seed-placed fertilizer but, with respect to yield, relatively responsive to P fertilizer application compared to other traditional pulse crops. While published research on P management for faba beans is limited, this crop removes approximately 1.3 kg P_2O_5/ha per bushel of grain produced – this equates to 67 kg P_2O_5/ha for a 3360 kg/ha (50 bu/ac) crop. Assuming the objective is to maintain or build residual soil P, such high rates are not likely practical or economical; however, thinking about it in this manner illustrates the importance of P fertility for this crop. The observed yield response in the current project and some of the cited past research supports this assertion. In terms of safe rates of seed-placed P, the Saskatchewan Ministry of Agriculture suggests that rates should not exceed 25 kg/ha with narrow openers. The Saskatchewan Pulse Growers suggest a maximum safe seed-placed rate of 45 kg/ha assuming seedbed utilization of 10-15%. Despite the lack of injury observed at higher rates in the current project and previous Saskatchewan research, growers are not advised to exceed the current recommendations when seed-placing P. Regardless of the inherent crop sensitivity, seedling injury associated with P fertilizer toxicity is affected by several environmental factors and, as such, can vary dramatically from year-to-year and also across spatially variable landscapes. There is also the potential for antagonistic effects of high rates of seed-placed fertilizer on rhizobial inoculants with pulse crops; however, this is not something that was specifically assessed in the current project or cited research. In both years, residual P levels were very low and the subsequent responses suggest that soil testing was reasonably effective for predicting whether short-term yield benefits to fertilization were likely.

Future research

The greatest limitation of the current project is that it was conducted over a relatively short period, a single geographic location, using a single drill configuration and always on fields with low residual P. Broadening the scope of the work would provide insights into the potential for seedling injury (with high rates of seed-placed P) in coarser textured, lower organic matter or low pH soils. Field sites with a broader range of residual P levels (i.e. including fields with moderate and high concentrations of extractable P) would provide more information on the ability of soil tests to predict the likelihood of yield responses to fertilization; however, many growers are shifting towards managing P from a long-term perspective seeking to maintain or build overall fertility over extended periods of time.

11. Technology transfer activities

This project was highlighted as part of the Crop Management Field Day in 2016 (July 19, 219 registered guests) where Chris Holzapfel (IHARF) and Corey Loessin (Saskatchewan Pulse Growers Association/Pulse Canada) led attendees through the plots and discussed research objectives and activities of SPG for faba beans and soybeans. The faba bean segment of the tour focussed on P fertility, inoculation, establishment (i.e. seeding dates and rates) and disease management for this relatively new crop. The trial was also highlighted on tours co-hosted with Arysta Lifesciences (July 26, 2016, 45 guests) and for Richardson-Pioneer (July 27, 33 guests). In 2017, the project could not be shown as part of the IHARF Crop Management Field Day for logistic reasons; however, the trial was shown on smaller tours hosted for agronomists from FCL (July 13) and Richardson-Pioneer (July 21). In addition to these more formal tours, the sites were visited by numerous growers, agronomists and researchers over the two seasons. The full detailed summary of this work from 2016 is available online (www.iharf.ca) and updated results will be posted in the winter of 2016-17. Results have also been presented in numerous oral presentations including the 2017 IHARF Winter Seminar & AGM (Feb. 1, 2017, Weyburn, SK), Crop Command Agronomy Meeting (March 16, 2017, Southey, SK) and the SPG 2017 Pulse Agronomy Workshop (Nov. 7-8, 2017, Saskatoon, SK). This work was also featured in Top Crop Manager in the spring of 2017 (https://www.topcropmanager.com/fertility-nutrients/effects-of-phosphorus-on-fababean-establishment-and-yield-19983) Results will continue to be disseminated through a variety of other media (i.e. oral presentations, popular agriculture press, social media, fact sheets, etc.) as opportunities arise.

12. Funding contributions

This project was initially funded (in 2016) through the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement. Acknowledgement of the Saskatchewan Ministry of Agriculture's support for this demonstration will be included as part of all written reports and oral presentations that arise from this work. In 2017, funding for the project was secured through the Saskatchewan Pulse Crop Development Board (Sask Pulse Growers) in order to build on the previously completed work. Acknowledgement of the Saskatchewan Ministry of Agriculture and Saskatchewan Pulse Growers' support for this work will be included as part of all written reports, oral presentations and other extension materials that arise from this work. The crop protection products evaluated in this demonstration were provided in-kind by BASF and FMC of Canada. The many contributions of Danny Petty, Christiane Catellier, Dan Walker, Karter Kattler, Carly Miller, Shaelyn Stadnyk and Andrea De Roo are greatly appreciated.

13. Appendices:

Table 4. Test of fixed effects year (Y), phosphorus treatment (P) and their interaction (Y × P) on selected response variables at Indian Head over a two-year period.

Effect	Plant Density (15 DAP)	Plant Density (30 DAP)	Seed Yield	Seed Weight
	-------------	------------- p-values	-------------	-------------
Year (Y)	0.279	< 0.001	< 0.001	0.007
Phosphorus Treatment (P)	0.564	0.168	< 0.001	0.014
Y × Trt	0.163	0.126	0.153	0.750

Table 5. Treatment means for monoammonium phosphate (11-52-0) rate and placement effects on faba bean emergence at approximately 2 weeks after planting for individual years and averaged across years. Means within a group followed by the same letter do not significantly differ (*P* ≤ 0.05) and contrast p-values below 0.05 are considered significant.

	2016		2017		Average	
Phosphorus Rate	Seed-Place (SP)	Side-Band (SB)	Seed-Place (SP)	Side-Band (SB)	Seed-Place (SP)	Side-Band (SB)
kg P_2O_5/ha	---------- plants/m^2 ----------					
0	29.1 a		29.5 a		29.3 a	
20	33.6 a	18.9 a	27.9 a	31.4 a	30.8 a	25.1 a
40	19.7 a	23.0 a	36.1 a	35.1 a	27.9 a	29.0 a
60	21.3 a	26.3 a	23.8 a	28.5 a	22.6 a	27.4 a
80	24.2 a	34.5 a	30.5 a	29.7 a	27.4 a	32.1 a
S.E.M.	5.65		4.23		3.53	
	---------- p-value ----------					
Check vs rest	0.471		0.817		0.642	
SP vs SB	0.796		0.530		0.570	
P-Rate – lin	0.178	0.271	0.855	0.827	0.224	0.432
P-Rate – quad	0.524	0.067	0.772	0.387	0.718	0.297

Table 6. Treatment means for monoammonium phosphate (11-52-0) rate and placement effects on faba bean emergence at approximately 4 weeks after planting for individual years and averaged across years. Means within a group followed by the same letter do not significantly differ ($P \leq 0.05$) and contrast p-values below 0.05 are considered significant.

	2016		2017		Average	
Phosphorus Rate	Seed-Place (SP)	Side-Band (SB)	Seed-Place (SP)	Side-Band (SB)	Seed-Place (SP)	Side-Band (SB)
kg P_2O_5/ha	---------- plants/m^2 ----------					
0	84.9 a		40.2 a		62.6 a	
20	84.9 a	59.5 a	38.6 a	42.2 a	61.7 a	50.8 a
40	64.0 a	77.1 a	44.1 a	45.5 a	54.0 a	61.3 a
60	72.2 a	79.6 a	41.8 a	41.8 a	57.0 a	60.7 a
80	86.1 a	78.8 a	47.0 a	44.5 a	66.5 a	61.6 a
S.E.M.	7.01		4.08		4.06	
	---------- p-value ----------					
Check vs rest	0.187		0.448		0.420	
SP vs SB	0.524		0.800		0.660	
P-Rate – lin	0.634	0.717	0.156	0.485	0.791	0.515
P-Rate – quad	0.029	0.186	0.680	0.681	0.035	0.330

Table 7. Treatment means for monoammonium phosphate (11-52-0) rate and placement effects on faba bean seed yield for individual years and averaged across years. Means within a group followed by the same letter do not significantly differ (*P* ≤ 0.05) and contrast p-values below 0.05 are considered significant.

	2016		2017		Average	
Phosphorus Rate	Seed-Place (SP)	Side-Band (SB)	Seed-Place (SP)	Side-Band (SB)	Seed-Place (SP)	Side-Band (SB)
kg P_2O_5/ha	----------	----------	---------- kg/ha	----------	----------	----------
0	3997 a		2362 a		3180 c	
20	4041 a	4107 a	2527 a	2539 a	3284 bc	3323 abc
40	4066 a	4068 a	2631 a	2472 a	3349 abc	3270 c
60	4302 a	4142 a	2726 a	2601 a	3514 abc	3371 abc
80	4588 a	4605 a	2669 a	2616 a	3629 a	3611 ab
S.E.M.	120.8		88.3		74.8	
	----------	----------	---------- p-value	----------	----------	----------
Check vs rest	0.062		0.014		0.004	
SP vs SB	0.827		0.192		0.344	
P-Rate – lin	< 0.001	0.002	0.005	0.044	< 0.001	< 0.001
P-Rate – quad	0.127	0.074	0.171	0.697	0.663	0.218

Table 8. Treatment means for monoammonium phosphate (11-52-0) rate and placement effects on faba bean seed weight for individual years and averaged across years. Means within a group followed by the same letter do not significantly differ (*P* ≤ 0.05) and contrast p-values below 0.05 are considered significant.

	2016		2017		Average	
Phosphorus Rate	Seed-Place (SP)	Side-Band (SB)	Seed-Place (SP)	Side-Band (SB)	Seed-Place (SP)	Side-Band (SB)
kg P_2O_5/ha	---------- g/1000 seeds ----------					
0	430 a		445		437 a	
20	417 a	429 a	439 a	445 a	428 a	437 a
40	419 a	420 a	434 a	432 a	427 a	426 a
60	425 a	422 a	441 a	435 a	433 a	428 a
80	421 a	414 a	439 a	440 a	430 a	427 a
S.E.M.	4.68		4.68		3.31	
	---------- p-value ----------					
Check vs rest	0.024		0.130		0.009	
SP vs SB	0.832		0.887		0.961	
P-Rate – lin	0.422	0.002	0.440	0.103	0.267	0.001
P-Rate – quad	0.099	0.903	0.231	0.107	0.046	0.288

14. Reference papers or articles:

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