2020 Final Report

for the

Saskatchewan Pulse Crop Development Board

Project Title: Enhanced Fertilizer Management for Optimizing Yield and Protein in Field Pea

(Project #AP-2003a-IHARF)

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1. **Project Code (as is in contract):**

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2. **Project Title:**

   Enhanced fertilizer management for optimizing yield and protein in field pea

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5. **Introduction** (background and rationale for project, include references to original research projects where necessary)

   Field peas are the most widely adapted pulse crop in Saskatchewan and are important to many growers for both the rotational benefits associated with legumes and as a key option for maintaining diversity in crop rotations. Furthermore, with increasing consumer demand for plant-based protein, there are emerging opportunities for growers to receive premiums for high protein pulse crops. Consequently, we anticipate increased interest in exploring potential management options to more consistently achieve high protein levels. Experience with non-legume crops suggests that N fertility is one of relatively few management decisions that can consistently affect grain protein concentrations.

   Field peas can benefit from N fixation whereby symbiotic relationships with *Rhizobium leguminosarum* bacteria allow atmospheric N_2 to be converted to plant available forms and utilized by the crop. The maximum benefit to this process is generally achieved when mineral N (soil + fertilizer) levels are low. Therefore, N fertilization in field pea production is not normally recommended unless soil residual levels are extremely low (i.e. < 11 kg NO_3-N/ha). In northwest Alberta, Clayton et al. (2004) found that, regardless of inoculant form, N fertilizer rates ranging from 0-80 kg N/ha (side-banded urea) increased vegetative growth but did not affect seed yield at 4/6 site-years and seed protein was not affected in any cases. At one site where there was a response, N fertilization increased grain yield with either no inoculant or seed-applied (peat or liquid) formulations but decreased yield when combined with granular inoculant. The highest yields, by a large margin, were achieved with no N fertilizer and granular inoculant. At the other site where there was an N fertilizer effect, increased yield with N fertilization only occurred when no inoculant (regardless of form) was applied. Another extensive study conducted in Alberta showed that application of

N fertilizer (20, 40, or 60 kg N/ha) increased pea yield in 24% of 58 trials by an average of 9% (McKenzie et al. 2001). When residual NO_3-N was less than 20 kg N/ha, increases occurred 33% of the time with an overall average benefit of 11%. Although protein was affected by the addition of N fertilizer at more than 36% of the sites, the response was more frequently negative than it was positive (21% versus 16%). In early work with a single site-year at Saskatoon, Sosuiski et al. (1974) were not able to measure yield but increased field pea seed protein by 2% over the control with 55 kg N/ha as ammonium-nitrate (33.5-0-0).

Focussing on P, field peas are not considered to be particularly responsive to fertilization; however, responses to modest rates have been documented in low P soils. Over a three-year period on low P soils (10-18 kg $NaHCO_3$ extractable P/ha) near Outlook, Melfort, and Saskatoon, Henry et al. (1994) increased pea yields by approximately 15% with 35 kg P_2O_5/ha as side-banded monoammonium phosphate at one of three locations while observing negative responses to seed-placed P rates exceeding 35 kg P_2O_5/ha at the other two locations. In a series of 21 trials using Triple Super Phosphate (0-45-0) as a P source, Karamanos et al. (2003) found that field peas responded to P when modified Kelowna extractable P was less than 10 ppm and added that the response was greater in loam versus clay soils and with side-banded versus seed-placed fertilizer. Many producers strive to apply P fertilizer rates that are sufficient to offset nutrients removed in the harvested grain. It is estimated that field peas removed approximately 0.6-0.8 lb P_2O_5/bu or 31-38 lb P_2O_5/ac (35-43 kg P_2O_5/ha) in a 50 bu/ac (3400 kg/ha) crop (Canadian Fertilizer Institute 1998).

Relatively few studies have evaluated field pea response to S fertilization. McKenzie et al. (2001) reported that yield increases with potassium and S fertilizer application occurred at only 3 of 44 trials in Alberta and found no correlation between the observed responses and soil test levels. Under low yielding, drought conditions at Swift Current in 2017, lentil yields were significantly increased with sulphate S fertilizer with the best results achieved using ammonium sulphate (21-0-0-24) at a rate of 20 kg S/ha (Nybo et al. 2017). While the treatments were also evaluated on field peas, yields were extremely low and no benefit was observed. A 50 bu/ac (3400 kg/ha) field pea crop will take up approximately 12-16 kg S/ha (Canadian Fertilizer Institute 1998). In general, S fertilizer responses are more likely to occur in coarse textured soils with low organic matter and low residual S.

Literature Cited

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6. Objective(s) or purpose of the project

The project objectives were to evaluate, across a range of Saskatchewan environments, the yield and protein response of yellow field pea to various rates and combinations of nitrogen (N), phosphorus (P) and sulfur (S) fertilizer. Specifically, the treatments were intended to allow us to measure the responses to varying rates of side-banded P and S fertilizer along with a few distinct N fertilization strategies.

7. Materials and Methods – experimental design, methods used, details of growing the crop(s), materials used, sites, etc. Statistical analysis used

In early 2019, Agri-ARM and Saskatchewan Pulse Growers agronomists designed and initiated a comprehensive field pea fertility study at multiple Saskatchewan locations. The locations were Swift Current (dry Brown), Outlook (Brown), Scott (Dark Brown), Indian Head (thin Black), Yorkton (Black), and Melfort (moist Black). Field trials were conducted at all six locations during both the 2019 and 2020 growing seasons. Again, the treatments were an assortment of fertilizer applications selected to test the yield and protein responses to varying P and S rates in addition to several N fertilization strategies. To represent both extremes we also included an unfertilized control and an ultra-high fertility treatment. The P and S sources were monoammonium phosphate (11-52-0) and ammonium sulphate (21-0-0-24), respectively. With the exception of treatments 12-13 where polymer coated urea (ESN; 44-0-0) was used, the N source was urea (46-0-0). All fertilizer was side-banded with the exception of the extra urea in Treatment 11 which was applied as a surface broadcast during the late vegetative crop stages. All treatments received the full, label-recommended rate of a granular (*Rhizobium leguminosarum*) inoculant. The fertilizer treatments are listed below in Table 1.

Table 1. Field pea fertilizer treatment descriptions.

#	kg N-P_2O_5-K_2O-S/ha
1	0-0-0-0 (no fertilizer)
2	17-0-0-10 (0 P)
3	17-20-0-10 (20 P)
4	17-40-0-10 (40 P / 10 S)
5	21-60-0-10 (60 P)
6	26-80-0-10 (80 P)
7	17-40-0-0 (0 S)
8	17-40-0-5 (5 S)
9	22-40-0-15 (15 S)
10	40-40-0-10 (40 N as MAP/AS/urea)
11[Z]	17.2-40-0-10 + 40 N in-crop broadcast urea
12[Y]	40-40-0-10 * (40 N as MAP/AS/ESN)
13[Y]	40-80-0-15 * (ultra high fertility / ESN)

[Z] In-crop N broadcast approximately 4-5 weeks after emergence, prior to canopy closure and 1st flowers

[Y] ESN (44-0-0) instead of urea as the supplemental N source in Trt #12 and 13

*All fertilizer side-banded except for the 40 kg N/ha as in-crop urea in Trt #11

Selected agronomic information is provided in Tables 7 and 8 of the Appendices for 2019 and 2020, respectively. Seeding equipment varied across locations but all sites utilized no-till drills with side-band capabilities and the field peas were always seeded directly into cereal stubble. All sites used the same seed source (variety CDC Spectrum) with a separate seed lot used each year and target seeding rates of 100

viable seeds/m^2, adjusted for seed size and percent germination. Seed treatments were used to mitigate the risk of root diseases and pea leaf weevil based on local risk levels as determined by individual site managers. Seeding dates ranged from May 7 to May 23 with seeding for the majority of location-years completed in the second week of May. Weeds were controlled using registered pre- and post-emergent herbicide options. Insecticides were not required at any locations. Foliar fungicides were applied preventatively at all sites except for Swift Current in 2019 and Outlook in 2020 where no foliar fungicide was applied but the risk of disease was low. Pre-harvest herbicides and/or desiccants were applied at the discretion of individual site managers and the plots were straight combined as soon as possible after it was fit to do so. Seed yields were corrected for dockage and to a uniform moisture content of 16%. Seed protein concentrations were determined for each plot using NIR instruments. To aid in the interpretation of results, composite soil samples were collected from each location prior to seeding to be analyzed for residual nutrients and other basic qualities. Similarly, precipitation amounts and temperatures for each location were compiled from the nearest Environment and Climate Change Canada weather stations.

The specific response data evaluated were seed yield and seed protein concentrations. Data were analyzed using the Mixed procedure of SAS 9.3 and two separate models. First, response data were combined across all 12 location-years with Fert effects treated as fixed and the effects of both location-year and replicate (within location-year) considered random. Next, in order to explore differences in responses across locations and years, data were analyzed separately for each location with the effects of year (Yr), fertilizer treatment (Fert), and the Yr x Fert interaction considered fixed and replicate effects (nested within years) treated as random. Heterogeneity in variance component estimates was permitted between years for the individual location analyses. In all cases, treatment means were separated using the Tukey-Kramer test which controls both pair-wise and experiment-wise error. Contrast statements were used to compare the unfertilized (1) to fertilized (2-13) treatments and normal fertility (4) to the treatments where extra N was applied (10, 11, and 12). Orthogonal contrasts were used to test whether the responses to increasing P and S rates were linear, quadratic, or not significant. All treatment effects and differences between means were considered significant at $P \leq 0.05$ but values ≤ 0.10 were frequently highlighted as noteworthy trends.

8. **Results & Discussion –** results presented and discussed in the context of existing knowledge and relevant literature or comparison to existing recommendations. Detail any major concerns or sources of error. Provide proper statistical significance.

Weather and Soil Characteristics

Mean monthly temperatures and precipitation amounts are presented relative to the long-term (1981-2010) averages for the 2019 and 2020 growing seasons (May-August) in Tables 2 and 3, respectively. Overall, temperatures were slightly below average in 2019 and approximately equal to the long-term average in 2020. Precipitation relative to the long-term average varied widely. At Indian Head, it was drier than normal both seasons. While the total growing season precipitation reached 213 mm (87% of the long-term average) in 2019, most of this came in August when it was of little benefit to the field peas which were approaching maturity at this time. In 2020, only 46% of the long-term precipitation was received but initial moisture reserves were reasonably high due to the wet previous fall. At Melfort, 89-93% (201-210 mm) of the long-term average precipitation was received over the two-year period while 84-91% (172-187) was received at Outlook. The growing seasons were approximately normal to slightly wetter than normal at Scott with 235-258 mm (104-114%) of precipitation received over the two-year period. At Swift Current, 2019 was relatively wet (223 mm or 119% of the long-term average) while 2020 was drier (157 mm or 83%). At Yorkton, it was drier than normal both seasons with 174-180 mm (64-66%) over the two-year period.

Table 2. Mean monthly temperatures along with long-term (1981-2010) averages for the 2019 and 2020 growing seasons at Indian Head, Melfort, Outlook, Scott, Swift Current, and Yorkton, Saskatchewan.

Location	Year	May	June	July	August	Average
		---------- Mean Temperature (°C) ----------				
Indian Head	2019	8.9	15.7	17.4	15.8	14.5 (93%)
	2020	10.7	15.6	18.4	17.9	15.7 (101%)
	Long-term	*10.8*	*15.8*	*18.2*	*17.4*	*15.6*
Melfort	2019	8.8	15.3	16.9	14.9	14.0 (92%)
	2020	10.1	14.3	18.2	17.6	15.1 (99%)
	Long-term	*10.7*	*15.9*	*17.5*	*16.8*	*15.2*
Outlook	2019	9.9	16.0	18.0	16.2	15.0 (93%)
	2020	11.3	15.8	19.1	18.8	16.3 (101%)
	Long-term	*11.5*	*16.1*	*18.9*	*18.0*	*16.1*
Scott	2019	9.1	14.9	16.1	14.4	13.6 (92%)
	2020	9.9	14.8	17.2	16.3	14.6 (98%)
	Long-term	*10.8*	*14.8*	*17.3*	*16.3*	*14.8*
Swift Current	2019	9.5	15.8	17.7	16.8	15.0 (95%)
	2020	10.4	15.5	18.1	19.4	15.9 (100%)
	Long-term	*11.0*	*15.7*	*18.4*	*17.9*	*15.8*
Yorkton	2019	8.6	16.0	18.3	16.1	14.8 (97%)
	2020	10.5	16.4	19.9	18.3	16.3 (107%)
	Long-term	*10.4*	*15.5*	*17.9*	*17.1*	*15.2*

Table 3. Mean monthly precipitation along with long-term (1981-2010) averages for the 2019 and 2020 growing seasons at Indian Head, Melfort, Outlook, Scott, Swift Current, and Yorkton, Saskatchewan.

Location	Year	May	June	July	August	Total
		---------- Cumulative Precipitation (mm) ----------				
Indian Head	2019	13.3	50.4	53.1	96.0	213 (87%)
	2020	27.3	23.5	37.7	24.9	113 (46%)
	Long-term	*51.7*	*77.4*	*63.8*	*51.2*	*244*
Melfort	2019	18.8	87.4	72.7	30.7	210 (93%)
	2020	26.7	103.7	52.4	18.5	201 (89%)
	Long-term	*42.9*	*54.3*	*76.7*	*52.4*	*226*
Outlook	2019	13.2	90.2	43.8	39.6	187 (91%)
	2020	30.1	92.3	31.5	18.3	172 (84%)
	Long-term	*42.6*	*63.9*	*56.1*	*42.8*	*205*
Scott	2019	12.7	97.7	107.8	18.0	236 (104%)
	2020	51.9	55.9	123.0	27.0	258 (114%)
	Long-term	*38.9*	*69.7*	*69.4*	*48.7*	*227*
Swift Current	2019	13.3	156	11.1	42.6	223 (119%)
	2020	30.0	70.9	52.6	3.3	157 (83%)
	Long-term	*42.1*	*66.1*	*44.0*	*35.4*	*188*
Yorkton	2019	11.1	81.6	49.1	32.2	174 (64%)
	2020	16.7	33.6	80.1	49.3	180 (66%)
	Long-term	*51.3*	*80.1*	*78.2*	*62.2*	*272*

Soil test results are provided in Table 4 below. Soil pH ranged from 5.9-8.1 and, although there was variation within locations, the lowest values generally occurred at Scott and Melfort while the highest values were observed at Indian Head and Outlook. Organic matter levels ranged from 2.3-11.7% and all values were considered reasonably representative of their corresponding regions. For example, OM was highest at Melfort (9.6-11.7%), lowest at Swift Current and Outlook (2.3-2.9%) and more intermediate at Scott (3.5-4%), Indian Head (4.1-4.7%), and Yorkton (4.3-6.5%). Residual nitrate was highly variable, below 50 kg NO_3-N/ha 8/12 location-years but with a range of 21-202 kg/ha and an overall mean of 54 kg/ha. Residual (Olsen) P levels were mostly low, below 10 ppm at 9/12 location-years and below 15 ppm at 11/12 location-years. Outlook 2020 was the sole site where residual P levels were considered high at 24 ppm. Residual S levels were variable and generally high enough that they were not expected to be limiting with the exception of Swift Current 2020 where only 9 kg S/ha was measured in the 0-30 cm soil profile. Although soil tests did not indicate that S deficiencies were likely in most cases, this nutrient can be difficult to sample for due to high spatial variability and the potential for 'hot spots' which can skew results from composite samples. Potassium (K) levels were relatively high at all locations and this nutrient was unlikely to be limiting. Potassium responses were not evaluated in this project.

Table 4. Selected soil test results for field pea fertility trials at Indian Head, Melfort, Outlook, Scott, Swift Current, and Yorkton Saskatchewan in 2019 and 2020. Values for NO_3-N and S are for 0-60 cm depth unless otherwise indicated. Values for all other attributes are for the 0-15 cm depth.

Location-Year	pH	S.O.M. (%)	NO_3-N (kg/ha)	Olsen-P (ppm)	K (ppm)	S (kg/ha)
Indian Head – 2019	7.7	4.7	27	4	573	60
Indian Head – 2020	8.0	4.1	32	3	502	34
Melfort – 2019	6.0	9.6	37 [Z]	9	473	85 [Z]
Melfort – 2020	6.0	11.7	58 [Z]	9	439	43 [Z]
Outlook – 2019	8.1	2.3	21	5	153	60 [Z]
Outlook – 2020	7.6	2.4	66	24	200	>182 [Z]
Scott – 2019	5.9	3.5	47	12	201	116
Scott – 2020	6.4	4.0	38	12	259	111
Swift Current – 2019	6.5	2.6	202	8	229	47
Swift Current – 2020	7.3	2.9	21 [Z]	9	359	9 [Z]
Yorkton – 2019	7.0	6.5	44	9	291	125
Yorkton – 2020	7.7	4.3	57	7	161	34 [Z]

[Z] Values are for the 0-30 cm soil depth for this attribute

Field Pea Yield and Protein Responses to Enhanced Fertility for Individual Locations

Detailed results tables and figures for individual locations are reserved for the Appendices but will referred to and discussed in the main body of the report. Before moving into the overall average results, responses at each location will be addressed.

At Indian Head, pea yields were affected by year (Yr; $P = 0.028$) and fertilizer treatment (Fert; $P < 0.001$) but the lack of a Yr x Fert interaction ($P = 0.246$) indicated that the fertilizer effects were reasonably consistent over the two seasons (Table 9). Across all treatments, yields at Indian Head were 4326 kg/ha in 2019 and 3966 kg/ha in 2020. The contrast results indicated that only phosphorus fertilizer rate affected yield with significant linear responses ($P < 0.001$-0.045) detected both years (Table 10; Fig. 5). Neither sulfur rate nor

additional N fertilizer affected seed yield at this location (Table 10; Fig. 5). For protein at Indian Head, only the Yr effect was significant ($P < 0.001$) with higher values in 2019 (24.0%) compared to 2020 (21.3%). The linear orthogonal contrast for S rate was significant in 2020 (Table 12; $P = 0.043$) with 20.9% protein without S and 22.0% at 15 kg S/ha; however, this response was small compared to the difference between years (Table 12; Fig. 8).

Overall yield variability was high at Melfort and, despite considerable variation amongst individual treatment means, only the effects of Year were significant ($P = 0.029$). On average, yields were higher in 2020 (4341 kg/ha) than 2019 (3802 kg/ha) at this location. Despite the lack of significant F-tests for Fert ($P = 0.272$) or Yr x Fert ($P = 0.398$), the contrast comparing the unfertilized control to the combined fertilized treatments was significant in 2020 (3884 versus 4379 kg/ha; $P < 0.001$). If this response was true and not a result of random variability, it can most reasonably be attributed to the small amounts of N that were provided to balance this nutrient across the majority of the fertilized treatments. The quadratic orthogonal contrast for P rate in 2019 was also significant (Table 14; Fig. 9) with higher yields at 40-60 kg P_2O_5/ha compared to 0, 20, or 80 kg P_2O_5/ha. For protein at Melfort, only the F-test for year was significant (Table 15; $P < 0.001$) with slightly higher values in 2020 (22.7%) compared to 2019 (21.0%). Of the contrasts, only the normal N versus extra N comparison was significant (Table 16; $P = 0.033$) and favoured the extra N (22.3% versus 22.9%); however, this benefit was relatively small compared to the difference between years.

At Outlook (Table 17), yields were affected by both year ($P = 0.049$) and fertilizer treatment ($P = 0.001$) with a significant Yr x Fert interaction ($P < 0.001$). The year effect was due to substantially higher yields in 2020 (5243 kg/ha) compared to 2019 (4198 kg/ha) while the interaction at Outlook was a result of there being no response to fertility in 2020 but some variation amongst treatments in 2019. In 2019, the unfertilized control treatment (3595 kg/ha) yielded significantly ($P < 0.001$) less than the combined fertilized treatments (Table 18; 5028 kg/ha). While not significant at the desired probability level, there was a marginal linear yield increase with P rate in 2019 ($P = 0.099$) and a marginal quadratic reduction in yields with S rate ($P = 0.069$). Focussing on the yield reduction observed in the unfertilized control relative to both the combined fertilized treatments and any of them individually, we can speculate that much of the initial yield increase was due to the small amounts of N that could generally be provided by modest rates of commonly used P and S fertilizer products (i.e. 11-52-0 and 21-0-0-24). The overall F-tests for protein at Outlook (Table 19) were significant for year ($P < 0.001$) but not quite significant for fertilizer treatment ($P = 0.060$) and there was no Yr x Fert interaction detected ($P = 0.157$). Despite the lack of an interaction, there was more variation amongst individual treatment means in 2019 (Table 19) and a small quadratic protein increase with P rate (Table 20; Fig. 15; $P = 0.021$). The quadratic (as opposed to linear) response in 2019 was due to the increase primarily being observed at the 80 kg P_2O_5/ha rate which also received slightly more N than the lower rates. The observed protein increase with high rates of P was small compared to the year-to-year variation (i.e. 19.9% in 2019 versus 24.4% in 2020) and was likely of little agronomic importance. Sulfur fertilization did not affect field pea protein ($P = 0.234$-0.903) at Outlook in either year (Table 20; Fig. 16).

At Scott, yields were affected by year ($P = 0.003$) and fertilizer treatment ($P < 0.001$) with a significant Yr x Fert interaction ($P = 0.027$). Yields were higher overall in 2019 (6022 kg/ha) than 2020 (5552 kg/ha) and the interaction was partly due to there being greater separation between treatments in 2019. The comparison of the unfertilized control to the combined fertilized plots was highly significant ($P < 0.001$) in 2019 (5546 kg/ha versus 6061 kg/ha) but only marginally significant ($P = 0.083$) in 2020 (5316 kg/ha versus 5572 kg/ha). In 2019, the effects of extra N on yield was significant (Table 22; $P = 0.002$) but the response was negative with a 305 kg/ha, or 5%, reduction associated with extra N. There was evidence of positive P responses in both years (Table 22; Fig. 17) with a strong quadratic yield increase in 2019 ($P = 0.008$) and a more modest

linear increase in 2020 (*P* = 0.030). There was no evidence of a yield response to S fertilization in either year at Scott (Table 22; Fig. 18). For protein, the year effect was significant (*P* < 0.001) while the fertilizer effect was not (*P* = 0.240); however, a Yr x Fert interaction was detected (Table 23; *P* = 0.025). Across treatments, protein concentrations averaged 23.7% in 2019 and 24.9% in 2020. The predetermined contrasts detected small N effects in both years (*P* = 0.025-0.030) but the responses were inconsistent. In 2019, there was a slight positive effect of extra N on protein (but a negative yield response) while, in 2020, there was a slight negative protein response observed with extra N. Phosphorus had no impact (*P* = 0.126-0.862) on protein at Scott (Table 24; Fig. 19). The quadratic response to S rate was significant in 2019 but only marginally so (*P* = 0.052) the effects were extremely small (Table 24; Fig. 20).

At Swift Current, pea yields were affected by Yr (*P* < 0.001) but the overall F-test for fertilizer treatment was not quite significant (*P* = 0.066) and there was no Yr x Fert interaction detected (Table 25; *P* = 0.317). Yields at this location were higher in 2020 (3645 kg/ha) than 2019 (2845 kg/ha). Despite the lack of a significant fertilizer effect or interaction, there were a few noteworthy yield responses identified through the contrasts (Table 26). Most notable was a significant (*P* = 0.034) quadratic yield increase with P rate in 2019 (Fig. 21) and a small but significant advantage to the combined fertilized treatments over the untreated control in 2020 (3431 kg/ha versus 3663 kg/ha). Seed protein at Swift Current (Table 27) was affected by year (*P* = 0.003) and fertilizer treatment (*P* = 0.016) with no Yr x Fert interaction (*P* = 0.294). In 2019, there was an overall protein increase (P < 0.001) amongst the combined fertilized treatments relative to the control (Table 28; 24.0% versus 24.8%). The trend was similar in 2020, but the increase was smaller (23.5% versus 24.1%) and not significant at the desired probability level (*P* = 0.058). Responses to specific nutrients varied with a small linear increase with P in 2019 (*P* = 0.001; Fig. 23) and a quadratic increase with S in 2020 (*P* = 0.045; Fig. 24). Despite their significance, both responses were small and likely of little importance.

At Yorkton (Table 29), the overall effects of both year and fertilizer treatment on yield were significant (*P* < 0.001) but the Yr x Fert interaction was not (*P* = 0.753). Yields were much higher in 2019, averaging 4883 kg/ha compared to 2840 kg/ha in 2020. In both years, the unfertilized control yielded significantly less than the combined fertilized treatments (*P* = 0.011-0.031) but responses to individual nutrients varied (Table 30). The effect of extra N on yield was not significant in either year (*P* = 0.364-0.509). In 2019, there was no evidence of a P response (*P* = 0.300-0.772) but we did detect a small linear yield increase (*P* < 0.001) with increasing S rates (Table 30; Fig. 26), despite soil samples from the site showing high residual levels of this nutrient. In 2020, there was a modest linear yield increase with P (*P* = 0.001; Table 30; Fig. 25) but no response to S (Fig. 25; *P* = 0.361-0.488). Focussing on protein at Yorkton (Table 31), the effects of year (*P* < 0.001) and fertilizer treatment (*P* = 0.039) were significant but the Yr x Fert interaction was not (*P* = 0.484). Similar to yield, protein levels were much higher in 2019 (21.8%) than in 2020 (17.2%). Despite the significant overall F-test, noteworthy nutrient effects on protein were both rare and small. The unfertilized versus fertilized comparison (Table 32) was never significant (*P* = 0.631-0.845). In 2019, there was a negative effect of extra N on protein (22.7% versus 21.7%; *P* = 0.040). In 2020, the quadratic response to P rate was significant (*P* = 0.046); however, the actual magnitude of the response was trivial, especially when compared to year-to-year variation (Fig. 27). The orthogonal contrasts did not detect any S rate effects on protein in either individual year at Yorkton (*P* = 0.104-0.411).

Overall Average Field Pea Yield and Protein Responses to Enhanced Fertility

Although the observed responses for individual site-years varied and were sometimes either inconsistent and/or difficult to explain, combining data from all location-years and treating site effects as random smoothed the results out substantially. Results from these analyses are presented in Table 5 and 6 below with responses to P and S rates for both yield and protein expressed graphically in Figs. 1-4.

Table 5. Results for tests of fertilizer effects on field pea seed yield and protein concentrations along with individual treatment means when averaged over 12 location-years in Saskatchewan. Means within a column followed by the same letter do not significantly differ from one another (Tukey-Kramer; $P \leq 0.05$).

Source / Treatment	Seed Yield	Seed Protein
Overall F-test	---------- p-value ----------	
Fertilizer Treatment (Fert)	<0.001	0.047
kg N-P_2O_5-K_2O-S/ha	---------- kg/ha ----------	---------- % ----------
1) 0-0-0-0 (no fertilizer)	4016 C	22.3 AB
2) 17-0-0-10 (0 P)	4155 BC	22.4 AB
3) 17-20-0-10 (20 P)	4303 AB	22.2 B
4) 17-40-0-10 (40 P / 10 S)	4468 A	22.6 AB
5) 21-60-0-10 (60 P)	4536 A	22.5 AB
6) 26-80-0-10 (80 P)	4456 A	22.6 AB
7) 17-40-0-0 (0 S)	4397 A	22.4 AB
8) 17-40-0-5 (5 S)	4310 AB	22.5 AB
9) 22-40-0-15 (15 S)	4405 A	22.5 AB
10) 40-40-0-10 (urea)	4367 AB	22.5 AB
11) 17-40-0-10 + 40 N in-crop	4431 A	22.7 A
12) 40-40-0-10 (ESN)	4382 AB	22.5 AB
13) 40-80-0-15 (ultra high fert)	4512 A	22.7 AB
S.E.M.	294.5	0.68
L.S.D.$^{0.05}$	236.6	0.56

Table 6. Results from field pea fertility treatment group comparisons and orthogonal contrast for seed yield and protein concentrations when averaged across 12 location-years in Saskatchewan.

Group comparison / Orthogonal Contrast	Seed Yield (kg/ha)	Seed Protein (%)
	---------- p-value ----------	
Unfertilized (1) vs Fertilized (2-13)	<0.001	0.065
(Group Means)	(4016 vs 4394)	(22.3 vs 22.5)
Normal N (4) vs Extra N (10,11,12)	0.202	0.959
(Group Means)	(4468 vs 4393)	(22.6 vs 22.6)
Phosphorus Rate – linear	<0.001	0.033
Phosphorus Rate – quadratic	0.004	0.731
Sulfur Rate – linear	0.422	0.549
Sulfur Rate – quadratic	0.812	0.259

The overall F-test for seed yield was highly significant ($P < 0.001$) while mean yields for the individual treatments were lowest in the unfertilized control (4016 kg/ha) and, numerically, highest with a combination of 60 kg P_2O_5/ha and 10 kg S/ha but no extra N (Trt. #4; 4536 kg/ha). Yields from essentially all

of the treatments that received modest rates of P were statistically similar (Table 5). The contrast comparisons showed an overall yield advantage of 378 kg/ha, or 9% ($P < 0.001$), for the combined fertilized treatments relative to the control (Table 6). Yields with normal versus extra N were statistically similar ($P = 0.202$) but, numerically, favoured the treatments that did not receive the additional N (4468 kg/ha versus 4393 kg/ha). Consistent with many of the sites individually, yields increased quadratically with P rate ($P = 0.002$), levelling off at roughly 40 kg P_2O_5/ha which is approximately what is required to match removal in a 3360 kg/ha (50 bu/ac) crop (Fig. 1). There was no yield increase ($P = 0.422$-0.812) associated with S fertilization (Fig. 2).

For protein, the overall F-test was significant when all locations were combined ($P = 0.047$) but there was only a 0.5% range and few significant differences amongst individual treatments (Table 5). The contrast comparisons (Table 6) did not detect any difference between the control and combined fertilized treatments ($P = 0.065$) or any benefit to extra N fertilizer ($P = 0.959$). Although there was a significant linear increase in protein with P rate ($P = 0.033$), the magnitude of the response was small with a spread of only 0.4% between 0 kg P_2O_5/ha and 80 kg P_2O_5/ha (Fig. 3). This effect might be attributable to generally healthier plants and root systems as the protein increase also came with a yield increase which was considerably larger in magnitude. Sulfur fertilization did not impact ($P = 0.259$-0.549) seed protein (Fig. 4).

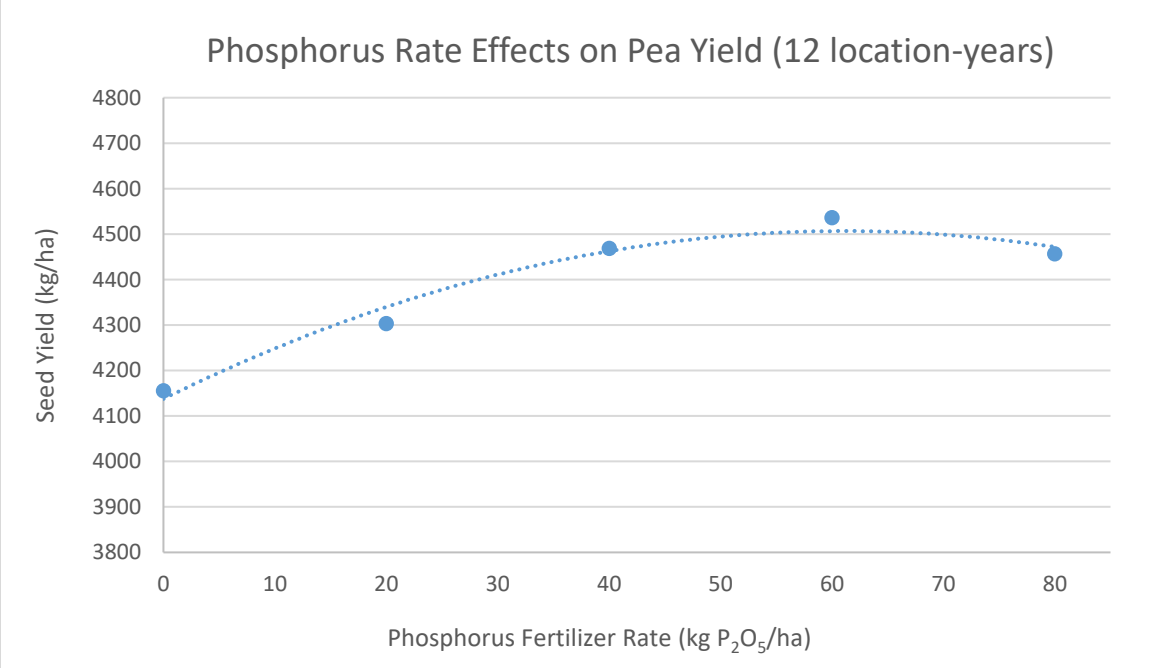

Figure 1. Field pea seed yield response to phosphorus fertilizer rate in Saskatchewan. The results are the overall average of 12 field trials comprised of six locations (Indian Head, Melfort, Outlook, Scott, Swift Current, and Yorkton) over a two-year period (2019-2020).

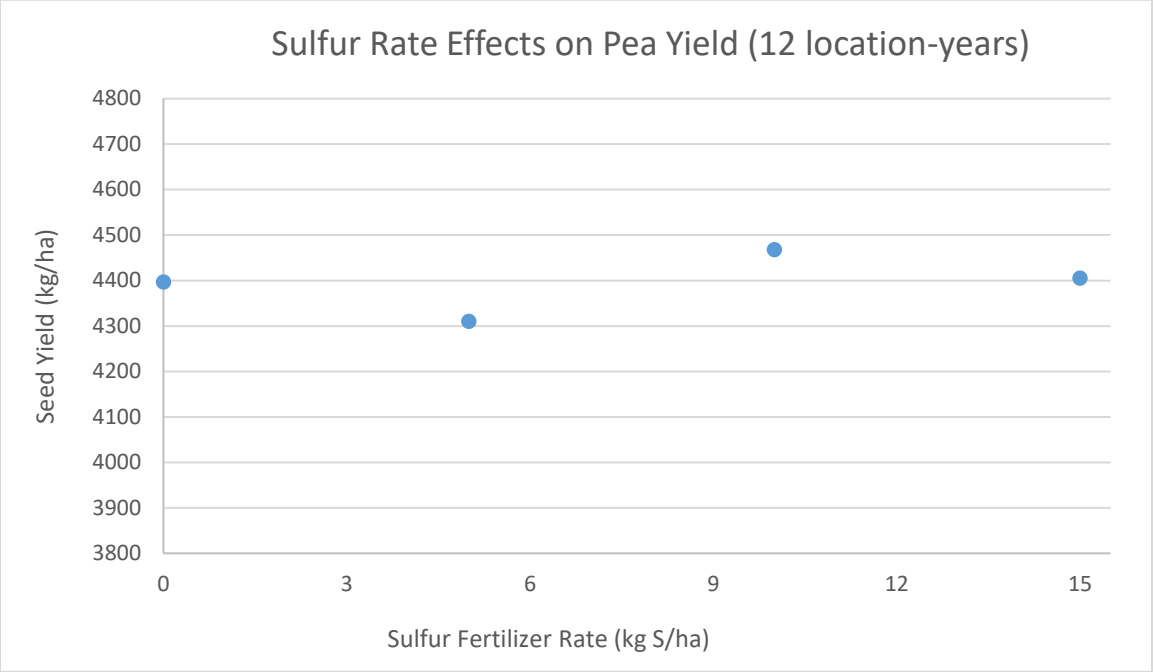

Figure 2. Field pea seed yield response to sulfur fertilizer rate in Saskatchewan. The results are the overall average of 12 field trials comprised of six locations (Indian Head, Melfort, Outlook, Scott, Swift Current, and Yorkton) over a two-year period (2019-2020).

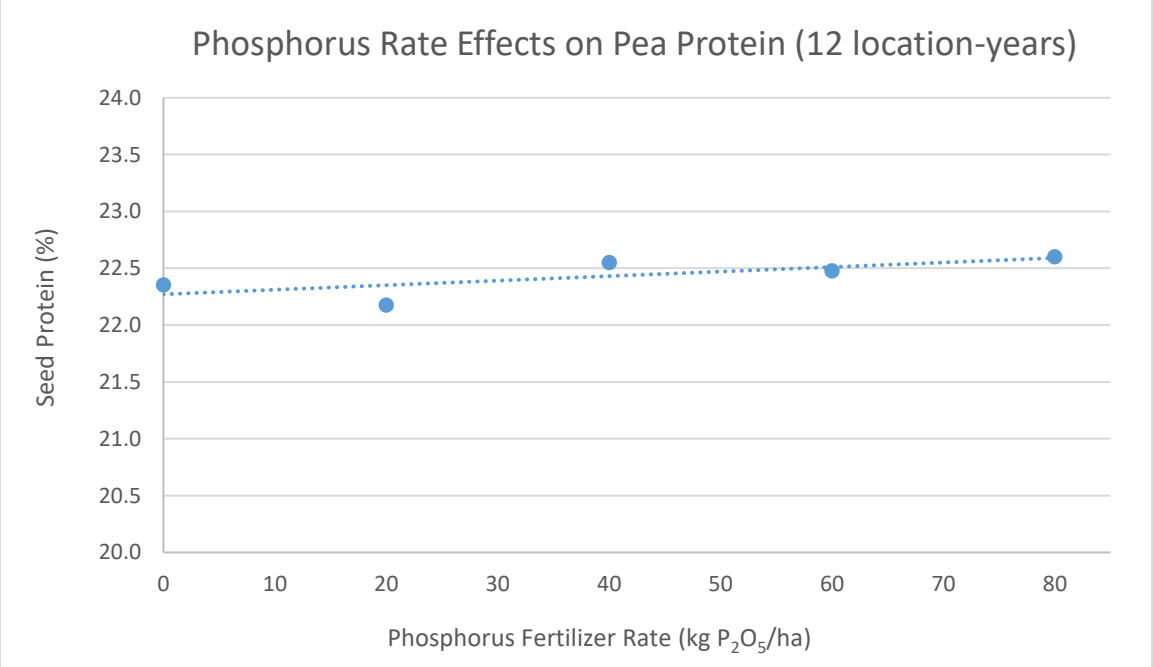

Figure 3. Field pea seed protein concentration response to phosphorus fertilizer rate in Saskatchewan. The results are the overall average of 12 field trials comprised of six locations (Indian Head, Melfort, Outlook, Scott, Swift Current, and Yorkton) over a two-year period (2019-2020).

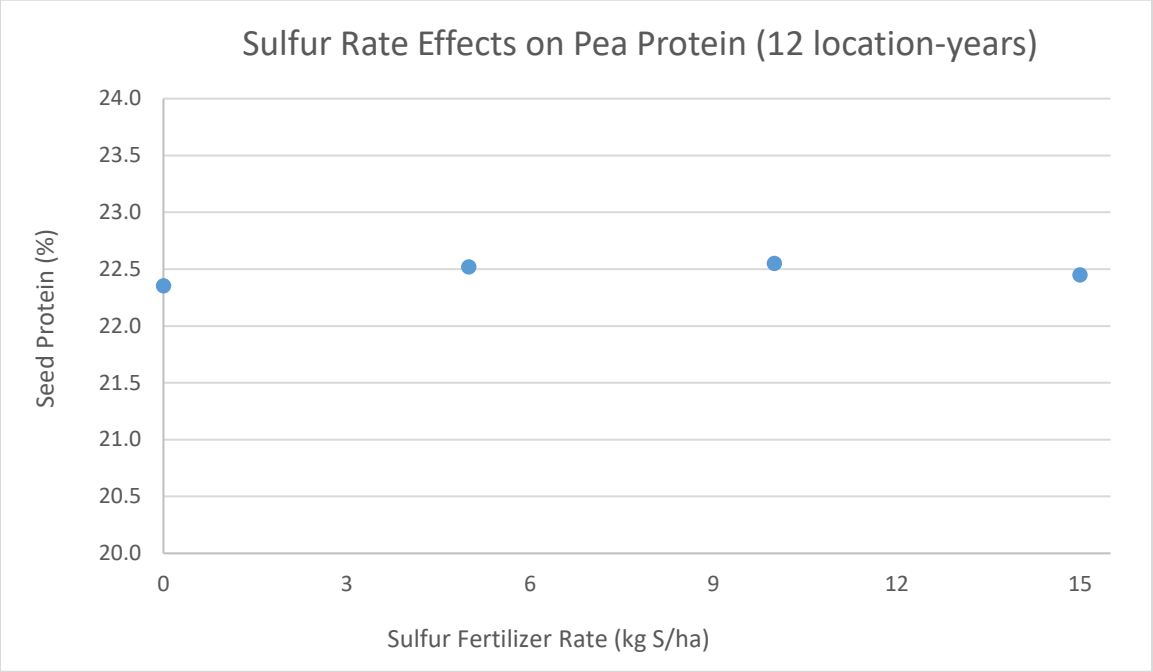

Figure 4. Field pea seed protein response to sulfur fertilizer rate in Saskatchewan. The results are the overall average of 12 field trials comprised of six locations (Indian Head, Melfort, Outlook, Scott, Swift Current, and Yorkton) over a two-year period (2019-2020).

9. **Economic and Practical Implications For growers** – is there any economic implications for growers

   While it is difficult to assign a specific monetary value to the work, the economic benefits associated with this research could conceivably arise from either enhanced yields through better fertilizer management or reduced fertilizer costs with no reduction in yield. The benefits will vary with environment and also as a function of the current practices of individual growers. For example, some growers may currently be under fertilizing their field peas, losing yield and further depleting soil reserves (i.e. phosphorus). The results from this work could help them justify the higher costs of enhanced fertility and ultimately realize higher profits and healthier soils over the longer term. In contrast, other producers may be fertilizing excessively and can potentially utilize these results to reduce their fertilizer investment (i.e. starter N, S in non-limiting soils) without negatively impacting yields.

   Since P fertilizer provided the most consistent responses, marginal economic returns were calculated for each P rate assuming $6.25/bu for yellow peas and two monoammonium phosphate (MAP) prices ($550 and 750/Mt). The results from this exercise are provided in Table 33 of the Appendices. Averaged across all locations, the most economical P rate was 40 kg P_2O_5/ha, regardless of the price of fertilizer. For individual locations, the most economical rate ranged from 0-60 kg/P_2O_5 with 3/6 locations having 20 kg P_2O_5/ha as the most profitable rate over the two seasons, regardless of the fertilizer price assumptions. Notably, the most profitable P rate for each individual location and on average was unchanged regardless of whether the P fertilizer price was $550/Mt or $750/Mt at 5/6 individual locations. The exception was Melfort, where there was substantial yield variability and the response to P was not statistically significant. At this location, the most profitable rate was 60 kg P_2O_5/ha at $550/Mt of MAP price but 0 kg P_2O_5/ha at $750/Mt of MAP.

10. **Conclusions & Recommendations –** how do results relate to origination objectives or original research that project is based on; is there a need to refine current recommendation based on the results from this project?

Overall, the locations provided a wide range of yield potentials and were representative of the major field pea producing regions of Saskatchewan. The observed fertilizer responses were largely consistent with past research and current recommendations for western Canada. Soil test P levels were considered low (≤ 12 ppm Olsen-P) for 11/12 location-years and there was evidence of a statistically significant ($P \leq 0.05$) response at 7/11 of the low P location-years (64%) and at least a marginally significant benefit ($P \leq 0.1$) at 8/11 low P sites (73%). When averaged across all twelve location-years, yields were increased by over 9% with P fertilization and the optimal rate was approximately 40 kg P_2O_5/ha. While responses were occasionally linear with top yields realized at the highest P rate, yield increases beyond the 20 kg P_2O_5/ha rate were rarely statistically significant and it is unlikely that rates exceeding approximately 40 kg P_2O_5/ha would be justified under most conditions. An exception could be when the objective of the producer is for long-term building of residual P and yields of 3500 kg/ha or more (> 50 bu/ac) are regularly achieved. Some of the literature cited in the introduction indicated yield increases of approximately 15% at responsive sites and suggested that responses were likely when soil test levels were below 10 ppm (modified Kelowna extractable P). Sulfur responses have been elusive in past research and this was also true in the current project. Past work has also shown that responses to S are poorly correlated with soil test results. Consequently, if deficiencies have been observed in the past for either field peas or other crops, applying a small amount of S may be justified; however, it is unlikely that S deficiency has been much of a yield limiting factor for the majority of field pea producers in Saskatchewan. Focussing on N, past research has found that N fertilization can frequently increase vegetative growth in field peas but positive yield responses are less likely, especially when combined with adequate rhizobial inoculation. Negative protein responses to N fertilization are at least as probable as positive responses. Our results did not show any benefits to N fertilization and, unless residual levels are extremely low or a nodulation failure is suspected, Saskatchewan field pea producers are advised to avoid applying any more N fertilizer than what is provided by the P and/or S fertilizer products being utilized. In most cases, this will be sufficient; however, in rare cases where neither P or S fertilizer is being applied and residual N is extremely low, side-banding a small amount of urea (or similar) might be beneficial.

11. **Future research –** did the project identify need for future research for further work?

This work would not specifically justify further research into N or S fertilization for field peas but there are certain areas of study that might build upon our understanding of this crop's response to P fertility and management effects on protein accumulation. Focussing on P fertility, several different fertilizer formulations are available, many of which provide varying proportions of N and/or differ in their solubility and suitability for seed-row placement or even foliar application. There may be value in exploring field pea responses to contrasting formulations and placement options for a range of soil environments. In addition, there would be merit in updated information on actual P uptake and removal by field peas utilizing modern varieties in no-till, continuously cropped systems. The values commonly referred to by industry are now 20 years old or more. Although work in underway to address this issue in Manitoba, there may be value in expanding this effort into Saskatchewan for field peas and other pulse crops. With regard to improving our understanding of protein accumulation in field pea, future research might focus more on inoculation, genetics, and/or other management practices as opposed to N fertilization. Finally, it could be beneficial to assess similar combinations of P, S, and N fertilizer rates and/or management strategies for other Saskatchewan pulse crops such as lentil, soybean, chickpeas, or faba beans in the specific regions where these crops can be successfully grown.

12. **Technology transfer activities –** include presentations, extension material, field days, articles published

Although extension opportunities were limited during the 2020 growing season, collaborators showed the plots and introduced the project during their annual field days and/or other formal and informal tours through the 2019 season. Wheatland Conservation Area promoted the project on a weekly CKSW radio program entitled 'Walk the Plots'. Sherrilyn Phelps (SPG) and Jessica Weber (WARC) acknowledged the project during a session entitled 'Maximizing Yield in Peas and Lentils by Optimizing Agronomy' at the 2020

CropSphere event (January 14, 2020). Chris Holzapfel shared results highlights at multiple meetings including an Independent Consulting Agronomists Network (ICAN) meeting (February 4, 2020), the IHARF Winter Meeting/AGM in both 2020 and 2021, the 2020 Manitoba Agronomists Conference (December 17, 2020), and the 2021 WARC Crop Opportunity Meeting (March 3, 2021). Garry Hnatowich of ICDC highlighted the project results in two separate videos on the ICDC YouTube Channel (https://www.youtube.com/channel/UCwhy-_unz11OVpHn31JoUmQ/videos). The videos were titled '2019 R&D: Improve Field Pea Nutrient Response Trial' and '2020 ICDC Virtual Field Day.' Bryan Nybo also presented results at the 2020 Swift Current winter pulse meeting in Swift Current (February 27, 2020). The 2019 Interim report has been publically available on the IHARF website (https://iharf.ca/wp-content/uploads/2020/05/Enhanced-fertilizer-management-for-optimizing-yield-and-protein-in-field-pea.pdf). We anticipate other opportunities for collaborators to utilize these results during future extension activities and this final report will also be available through IHARF (www.iharf.ca) and Agri-ARM (www.agriarm.ca) websites. Furthermore, the Saskatchewan Pulse Crop Development Board intends to incorporate these results into future extension materials and publications.

13. **Funding contributions –** acknowledge partners and contributors to the project

The Saskatchewan Pulse Growers Association were the sole financial supporters of this project. Many of the crop protection products utilized at the different locations were provided in-kind. Each of the participating organizations receives Agri-ARM base funding which is made available through the Canadian Agricultural Partnership bi-lateral agreement between the federal government and the Saskatchewan Ministry of Agriculture. Of the collaborating organizations, IHARF, WCA, ICDC, NARF, and WARC also have strong working relationships with Agriculture and Agri-Food Canada which should be acknowledged.

14. **Appendices:** detailed data tables, maps, photos, etc

Table 7. Selected agronomic information and dates of operations in 2019 for field pea fertility trials at Indian Head, Melfort, Outlook, Scott, Swift Current, and Yorkton, Saskatchewan.

Activity	Indian Head	Melfort	Outlook	Scott	Swift Current	Yorkton
Pre-seed Herbicide	890g glyphosate/ha (May 6)	667g glyphosate/ha + 18g saflufenacil/ha (May 21)	890g glyphosate/ha (May 6)	1134g glyphosate/ha + 21g carfentrazone/ha (May 19)	890g glyphosate/ha (May 4)	n/a
Seeding	May 9	May 22	May 9	May 12	May 14	May 7
Row Spacing	30 cm	30 cm	25 cm	25 cm	21 cm	30 cm
In-crop Herbicide	15g imazamox/ha + 15g imazethapyr/ha (June 12)	20g imazamox/ha + 424g bentazon/ha + 71g quizalofop/ha (July 5)	20g imazamox/ha + 424g bentazon/ha (June 5)	15g imazamox/ha + 15g imazethapyr/ha + 167g sethoxydim/ha (June 13)	20g imazamox/ha + 424g bentazon/ha (June 12)	20g imazamox/ha + 424g bentazon/ha (June 6) 89g clethodim/ha (June 6)
In-crop Nitrogen	June 28 (as per protocol)	July 11 (as per protocol)	June 27	June 10	May 14	June 27
Foliar Fungicide	74g fluxapyroxad/ha + 148g pyraclostrobin/ha (July 7)	201g picoxystrobin/ha (July 12)	74g fluxapyroxad/ha + 148g pyraclostrobin/ha (July 18)	74g fluxapyroxad/ha + 148g pyraclostrobin/ha (July 15)	n/a	201g picoxystrobin/ha (July 5)
Pre-harvest Herbicide / Desiccant	890g glyphosate/ha (August 8)	890g glyphosate/ha + 50g saflufenacil/ha (September 16)	410g diquat/ha (August 20)	410g diquat/ha (August 20)	n/a	n/a
Harvest	August 17	September 23	August 22	August 29	August 20	August 26

n/a – not applicable

Table 8. Selected agronomic information and dates of operations in 2020 for field pea fertility trials at Indian Head, Melfort, Outlook, Scott, Swift Current, and Yorkton, Saskatchewan.

Activity	Indian Head	Melfort	Outlook	Scott	Swift Current	Yorkton
Pre-seed Herbicide	890g glyphosate/ha (May 14)	890 g glyphosate/ha + 50g saflufenacil/ha (May 24)	852g ethalfluralin/ha (May 11)	1334g glyphosate/ha + 21g carfentrazone/ha (May 9)	890g glyphosate/ha + 21g carfentrazone/ha (May 4)	n/a
Seeding	May 7	May 23	May 16	May 11	May 11	May 14
Row Spacing	30 cm	30 cm	25 cm	25 cm	21 cm	30 cm
In-crop Herbicide	15g imazamox/ha + 15g imazethapyr/ha (June 5)	20g imazamox/ha + 424g bentazon/ha (June 23)	20g imazamox/ha + 424g bentazon/ha (June 16)	20g imazamox/ha + 424g bentazon/ha (June 11)	20g imazamox/ha + 424g bentazon/ha (May 26)	20g imazamox/ha + 424g bentazon/ha (June 11) 89g clethodim/ha (June 11)
In-crop Nitrogen	June 22 (as per protocol)	July 7 (as per protocol)	June 16 (as per protocol)	July 10 (as per protocol)	June 11 (as per protocol)	June 29
Foliar Fungicide	154g prothioconazole/ha + 132g trifloxystrobin/ha (July 2)	74g fluxapyroxad/ha + 148g pyraclostrobin/ha (July 20)	n/a	99g fluxapyroxad/ha + 99g pyraclostrobin/ha (July 9)	988 g chlorothalonil/ha (July 21)	149g pyraclostrobin/ha (July 6)
Pre-harvest Herbicide / Desiccant	890g glyphosate/ha (August 6)	409g diquat/ha (August 24)	492g diquat/ha (August 24)	410g diquat/ha (August 18)	n/a	409g diquat/ha (August 11)
Harvest	August 16	September 4	August 26	August 24	August 19	August 17

n/a – not applicable

Table 9. Results for tests of year and fertilizer effects on field pea yield and individual treatment means over a two-year period at Indian Head, Saskatchewan. Means within a column followed by the same letter do not significantly differ from one another (Tukey-Kramer; *P* ≤ 0.05).

Source / Treatment	2019	2020	2-Yr Average
Overall F-test	---------- p-value ----------		
Year (Yr)	–	–	0.028
Fertilizer Treatment (Fert)	<0.001	0.015	<0.001
Yr x Fert	–	–	0.246
kg N-P_2O_5-K_2O-S/ha	---------- Seed Yield (kg/ha) ----------		
1) 0-0-0-0 (no fertilizer)	4085 bc	3616 a	3850 B
2) 17-0-0-10 (0 P)	3994 c	3729 a	3861 B
3) 17-20-0-10 (20 P)	4287 abc	3761 a	4024 AB
4) 17-40-0-10 (40 P / 10 S)	4487 ab	3911 a	4199 AB
5) 21-60-0-10 (60 P)	4310 abc	4003 a	4156 AB
6) 26-80-0-10 (80 P)	4628 a	4046 a	4337 A
7) 17-40-0-0 (0 S)	4437 abc	3949 a	4193 AB
8) 17-40-0-5 (5 S)	4289 abc	3725 a	4007 AB
9) 22-40-0-15 (15 S)	4340 abc	4205 a	4272 A
10) 40-40-0-10 (urea)	4390 abc	4209 a	4299 A
11) 17-40-0-10 + 40 N in-crop	4186 abc	4117 a	4152 AB
12) 40-40-0-10 (ESN)	4374 abc	4051 a	4212 AB
13) 40-80-0-15 (ultra high fert)	4429 abc	4239 a	4334 A
S.E.M.	120.5	158.9	99.7
Year Average	4326 A	3966 B	–
S.E.M.	86.2	90.9	–

Table 10. Results from field pea fertility treatment group comparisons and orthogonal contrast for seed yield over a two-year period at Indian Head, Saskatchewan.

Group comparison / Orthogonal Contrast	2019	2020	2-Yr Average
	---------- p-value ----------		
Unfertilized (1) vs Fertilized (2-13)	0.006	0.009	<0.001
(Group Means)	(4085 vs 4346)	(3616 vs 3995)	(3850 vs 4171)
Normal N (4) vs Extra N (10,11,12)	0.097	0.175	0.814
(Group Means)	(4487 vs 4317)	(3911 vs 4125)	(4199 vs 4221)
Phosphorus Rate – linear	<0.001	0.045	<0.001
Phosphorus Rate – quadratic	0.322	0.944	0.550
Sulfur Rate – linear	0.815	0.121	0.238
Sulfur Rate – quadratic	0.994	0.060	0.113

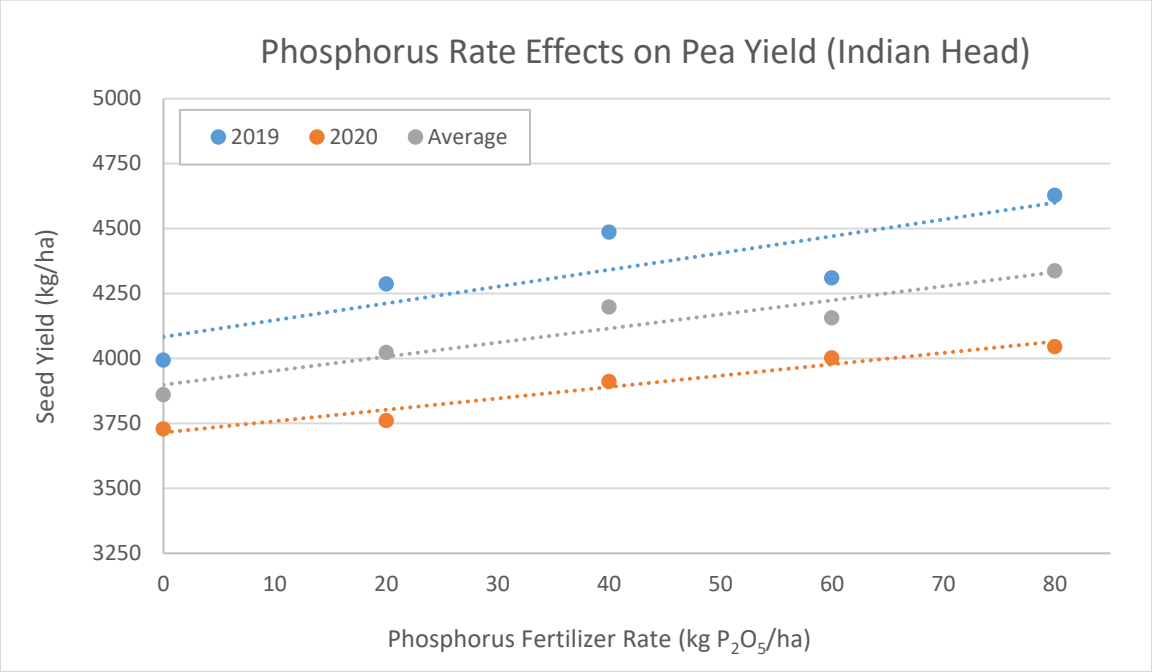

Figure 5. Field pea seed yield response to phosphorus fertilizer rate at Indian Head, Saskatchewan. Results are presented both for individual years and averaged across years.

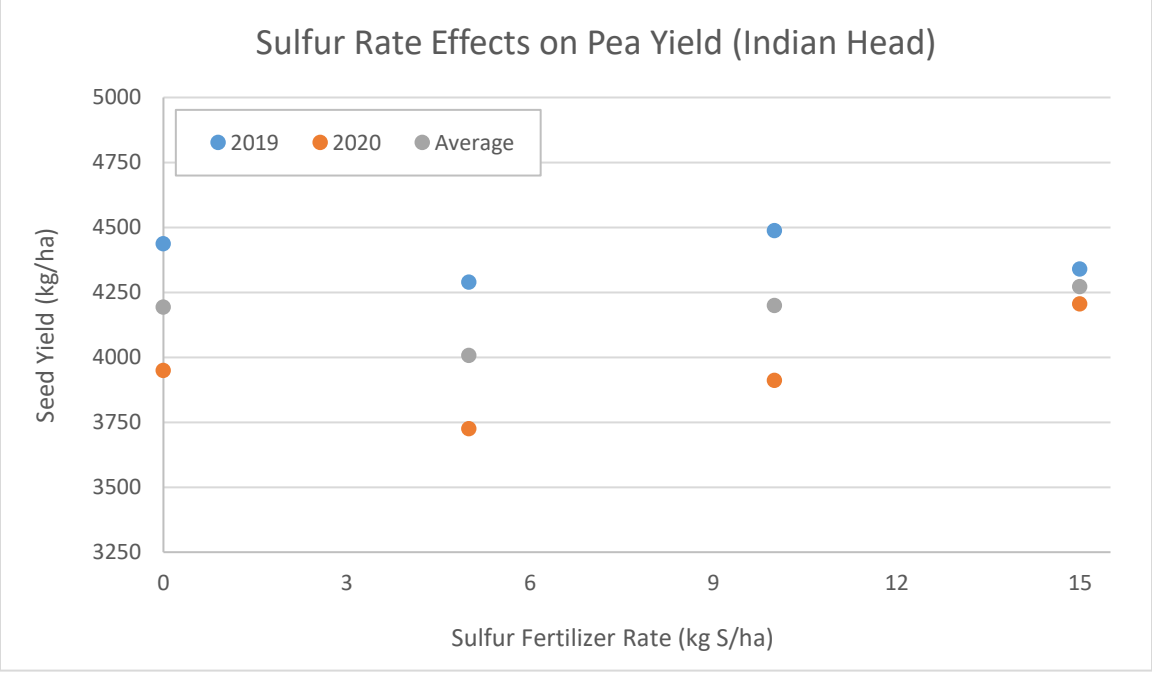

Figure 6. Field pea seed yield response to sulfur fertilizer rate at Indian Head, Saskatchewan. Results are presented both for individual years and averaged across years.

Table 11. Results for tests of year and fertilizer effects on field pea seed protein and individual treatment means over a two-year period at Indian Head, Saskatchewan. Means within a column followed by the same letter do not significantly differ from one another (Tukey-Kramer; $P \leq 0.05$).

Source / Treatment	2019	2020	2-Yr Average
Overall F-test	---------- p-value ----------		
Year (Yr)	–	–	<0.001
Fertilizer Treatment (Fert)	0.038	0.523	0.683
Yr x Fert	–	–	0.260
kg N-P_2O_5-K_2O-S/ha	---------- Seed Protein (%) ----------		
1) 0-0-0-0 (no fertilizer)	24.4 a	20.8 a	22.6 A
2) 17-0-0-10 (0 P)	23.8 ab	21.0 a	22.4 A
3) 17-20-0-10 (20 P)	24.1 ab	21.1 a	22.6 A
4) 17-40-0-10 (40 P / 10 S)	24.0 ab	21.4 a	22.7 A
5) 21-60-0-10 (60 P)	24.0 ab	21.1 a	22.5 A
6) 26-80-0-10 (80 P)	24.1 ab	21.0 a	22.5 A
7) 17-40-0-0 (0 S)	24.0 ab	20.9 a	22.5 A
8) 17-40-0-5 (5 S)	24.0 ab	21.5 a	22.8 A
9) 22-40-0-15 (15 S)	24.0 ab	22.0 a	23.0 A
10) 40-40-0-10 (urea)	23.8 b	21.3 a	22.5 A
11) 17-40-0-10 + 40 N in-crop	24.1 ab	21.5 a	22.8 A
12) 40-40-0-10 (ESN)	23.9 ab	21.6 a	22.7 A
13) 40-80-0-15 (ultra high fert)	24.1 ab	21.5 a	22.8 A
S.E.M.	0.16	0.37	0.20
Year Average	24.0 A	21.3 B	–
S.E.M.	0.13	0.156	–

Table 12. Results from field pea fertility treatment group comparisons and orthogonal contrast for seed protein over a two-year period at Indian Head, Saskatchewan.

Group comparison / Orthogonal Contrast	2019	2020	2-Yr Average
	---------- p-value ----------		
Unfertilized (1) vs Fertilized (2-13)	0.001	0.163	0.690
(Group Means)	(24.4 vs 24.0)	(20.8 vs 21.3)	(22.6 vs 22.7)
Normal N (4) vs Extra N (10,11,12)	0.487	0.967	0.875
(Group Means)	(24.0 vs 23.9)	(21.4 vs 21.4)	(22.7 vs 22.7)
Phosphorus Rate – linear	0.254	0.964	0.779
Phosphorus Rate – quadratic	0.403	0.493	0.372
Sulfur Rate – linear	0.706	0.043	0.065
Sulfur Rate – quadratic	0.904	0.972	0.946

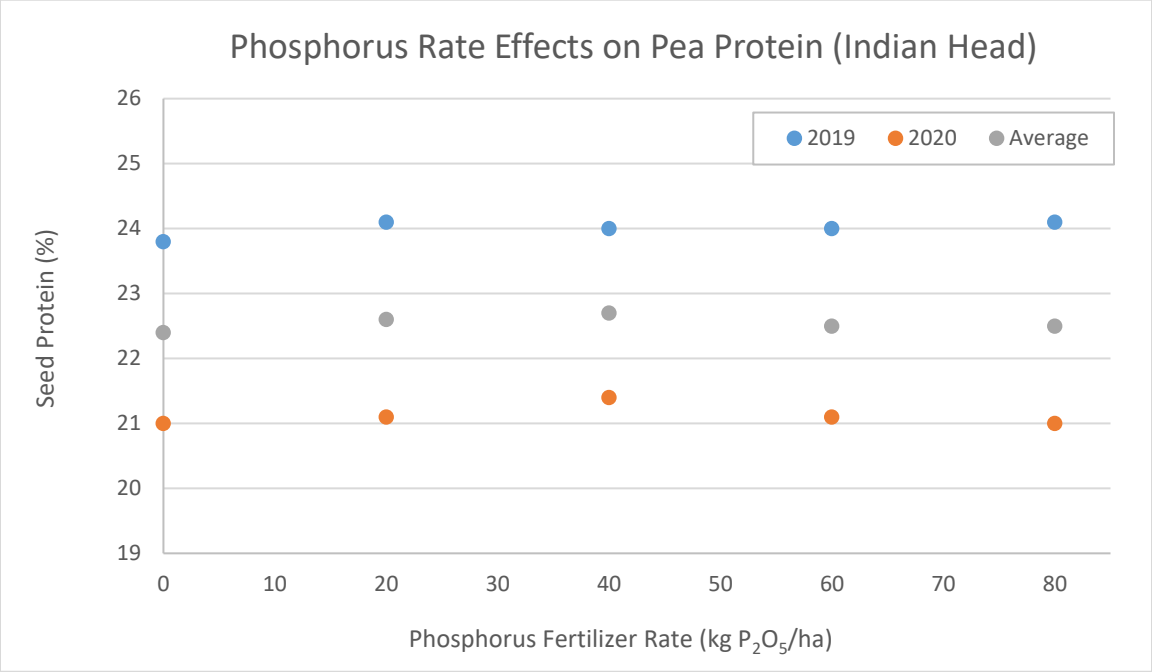

Figure 7. Field pea seed protein response to phosphorus fertilizer rate at Melfort, Saskatchewan. Results are presented both for individual years and averaged across years.

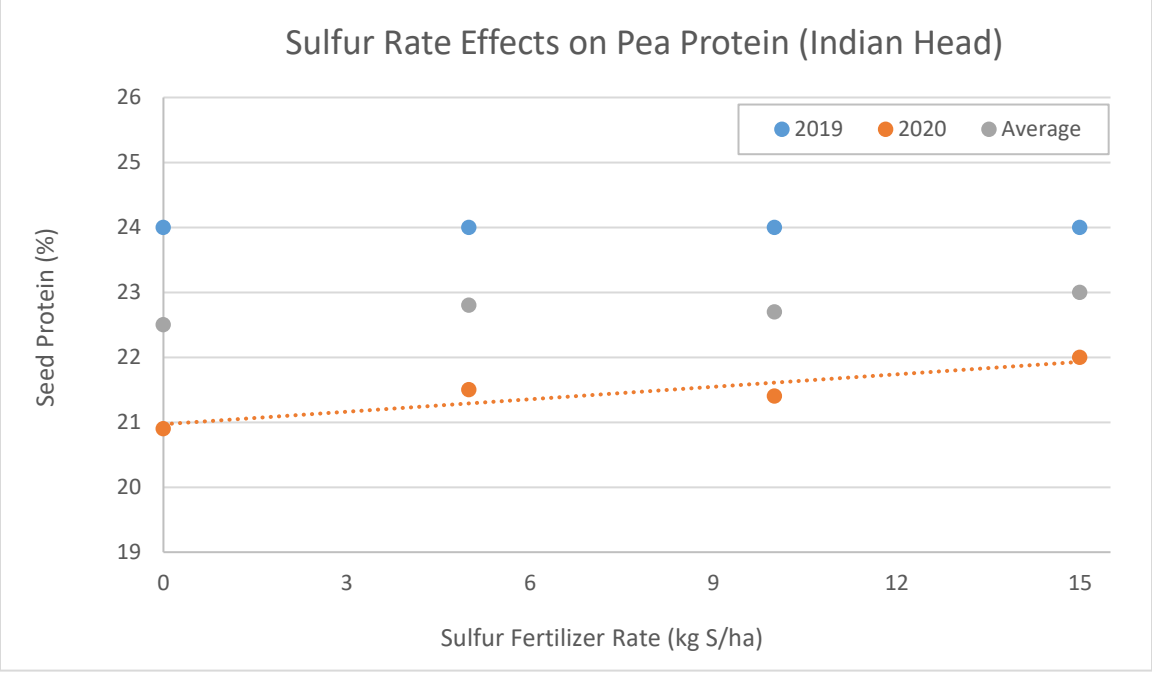

Figure 8. Field pea seed protein response to sulfur fertilizer rate at Indian Head, Saskatchewan. Results are presented both for individual years and averaged across years.

Table 13. Results for tests of year and fertilizer effects on field pea yield and individual treatment means over a two-year period at Melfort, Saskatchewan. Means within a column followed by the same letter do not significantly differ from one another (Tukey-Kramer; *P* ≤ 0.05).

Source / Treatment	2019	2020	2-Yr Average
Overall F-test	---------- p-value ----------		
Year (Yr)	–	–	0.029
Fertilizer Treatment (Fert)	0.497	0.083	0.272
Yr x Fert	–	–	0.398
kg N-P_2O_5-K_2O-S/ha	---------- Seed Yield (kg/ha) ----------		
1) 0-0-0-0 (no fertilizer)	3763 a	3884 a	3824 A
2) 17-0-0-10 (0 P)	3683 a	4365 a	4024 A
3) 17-20-0-10 (20 P)	3515 a	4314 a	3915 A
4) 17-40-0-10 (40 P / 10 S)	4210 a	4268 a	4239 A
5) 21-60-0-10 (60 P)	4157 a	4598 a	4378 A
6) 26-80-0-10 (80 P)	3484 a	4478 a	3981 A
7) 17-40-0-0 (0 S)	3548 a	4355 a	3951 A
8) 17-40-0-5 (5 S)	3742 a	4203 a	3972 A
9) 22-40-0-15 (15 S)	3838 a	4417 a	4127 A
10) 40-40-0-10 (urea)	3923 a	4389 a	4156 A
11) 17-40-0-10 + 40 N in-crop	3948 a	4339 a	4143 A
12) 40-40-0-10 (ESN)	3964 a	4382 a	4173 A
13) 40-80-0-15 (ultra high fert)	3644 a	4438 a	4041 A
S.E.M.	268.6	170.7	159.2
Year Average	3802 B	4341 A	–
S.E.M.	139.2	126.7	–

Table 14. Results from field pea fertility treatment group comparisons and orthogonal contrast for seed yield over a two-year period at Melfort, Saskatchewan.

Group comparison / Orthogonal Contrast	2019	2020	2-Yr Average
	---------- p-value ----------		
Unfertilized (1) vs Fertilized (2-13)	0.867	<0.001	0.061
(Group Means)	(3763 vs 3805)	(3884 vs 4379)	(3824 vs 4092)
Normal N (4) vs Extra N (10,11,12)	0.341	0.437	0.596
(Group Means)	(4210 vs 3945)	(4268 vs 4370)	(4239 vs 4157)
Phosphorus Rate – linear	0.744	0.195	0.373
Phosphorus Rate – quadratic	0.051	0.597	0.130
Sulfur Rate – linear	0.209	0.647	0.185
Sulfur Rate – quadratic	0.235	0.207	0.618

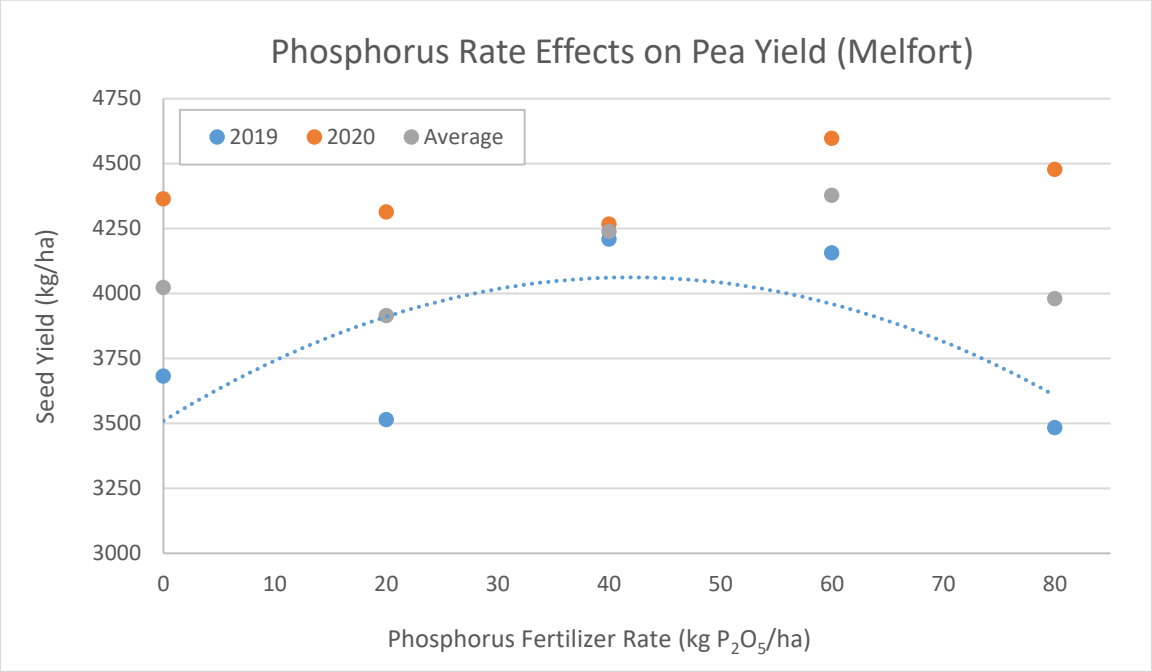

Figure 9. Field pea seed yield response to phosphorus fertilizer rate at Melfort, Saskatchewan. Results are presented both for individual years and averaged across years.

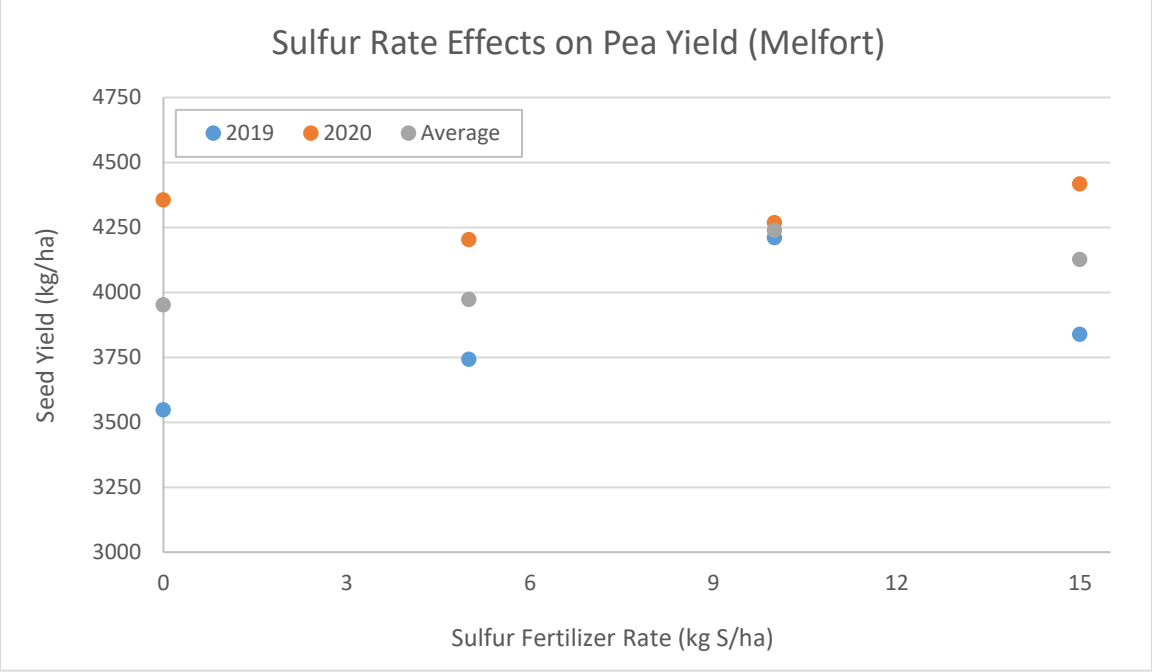

Figure 10. Field pea seed yield response to sulfur fertilizer rate at Melfort, Saskatchewan. Results are presented both for individual years and averaged across years.

Table 15. Results for tests of year and fertilizer effects on field pea seed protein and individual treatment means over a two-year period at Melfort, Saskatchewan. Means within a column followed by the same letter do not significantly differ from one another (Tukey-Kramer; *P* ≤ 0.05).

Source / Treatment	2019	2020	2-Yr Average
Overall F-test	---------- p-value ----------		
Year (Yr)	–	–	<0.001
Fertilizer Treatment (Fert)	0.978	0.192	0.600
Yr x Fert	–	–	0.817
kg N-P_2O_5-K_2O-S/ha	---------- Seed Protein (%) ----------		
1) 0-0-0-0 (no fertilizer)	20.9 a	22.4 a	21.6 A
2) 17-0-0-10 (0 P)	21.2 a	22.6 a	21.9 A
3) 17-20-0-10 (20 P)	21.1 a	23.1 a	22.1 A
4) 17-40-0-10 (40 P / 10 S)	20.7 a	22.3 a	21.5 A
5) 21-60-0-10 (60 P)	20.9 a	22.4 a	21.6 A
6) 26-80-0-10 (80 P)	20.9 a	22.6 a	21.8 A
7) 17-40-0-0 (0 S)	21.1 a	22.7 a	21.9 A
8) 17-40-0-5 (5 S)	20.7 a	22.9 a	21.8 A
9) 22-40-0-15 (15 S)	21.0 a	22.5 a	21.8 A
10) 40-40-0-10 (urea)	21.2 a	22.5 a	21.9 A
11) 17-40-0-10 + 40 N in-crop	21.2 a	23.1 a	22.1 A
12) 40-40-0-10 (ESN)	20.8 a	23.1 a	21.9 A
13) 40-80-0-15 (ultra high fert)	21.1 a	22.9 a	22.0 A
S.E.M.	0.33	0.26	0.21
Year Average	21.0 B	22.7 A	–
S.E.M.	0.13	0.12	–

Table 16. Results from field pea fertility treatment group comparisons and orthogonal contrast for seed protein over a two-year period at Melfort, Saskatchewan.

Group comparison / Orthogonal Contrast	2019	2020	2-Yr Average
	---------- p-value ----------		
Unfertilized (1) vs Fertilized (2-13)	0.840	0.152	0.298
(Group Means)	(20.9 vs 21.0)	(22.4 vs 22.7)	(21.6 vs 21.9)
Normal N (4) vs Extra N (10,11,12)	0.377	0.033	0.046
(Group Means)	(20.7 vs 21.1)	(22.3 vs 22.9)	(21.5 vs 22.0)
Phosphorus Rate – linear	0.399	0.323	0.204
Phosphorus Rate – quadratic	0.476	0.685	0.417
Sulfur Rate – linear	0.930	0.208	0.398
Sulfur Rate – quadratic	0.290	1.000	0.403

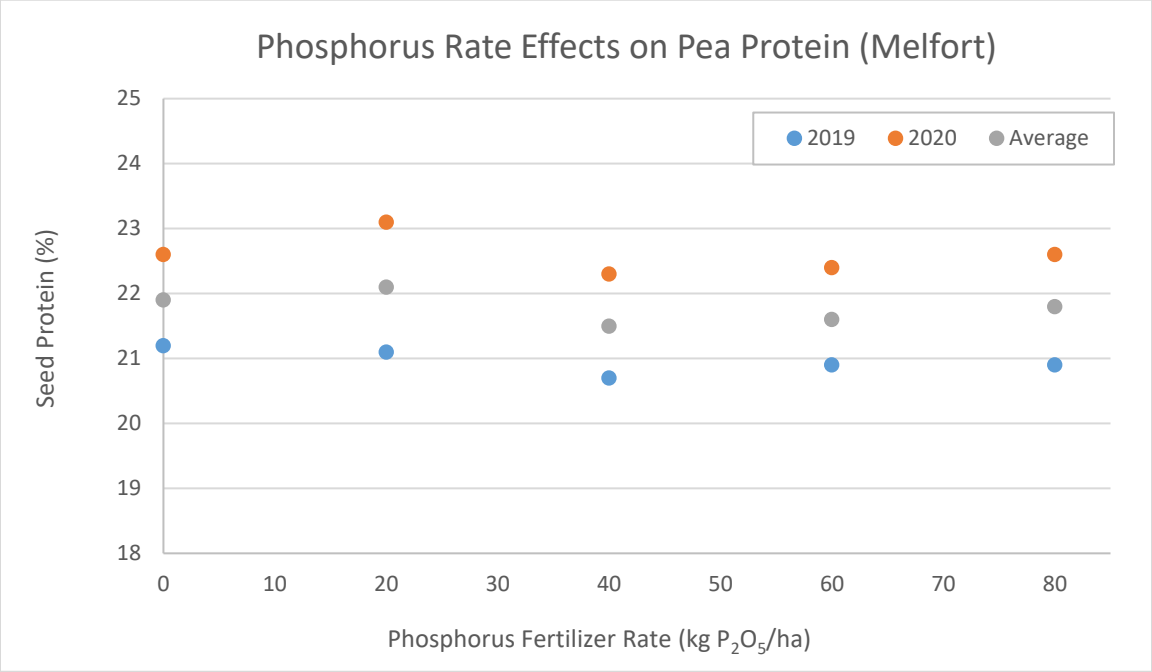

Figure 11. Field pea seed protein response to phosphorus fertilizer rate at Melfort, Saskatchewan. Results are presented both for individual years and averaged across years.

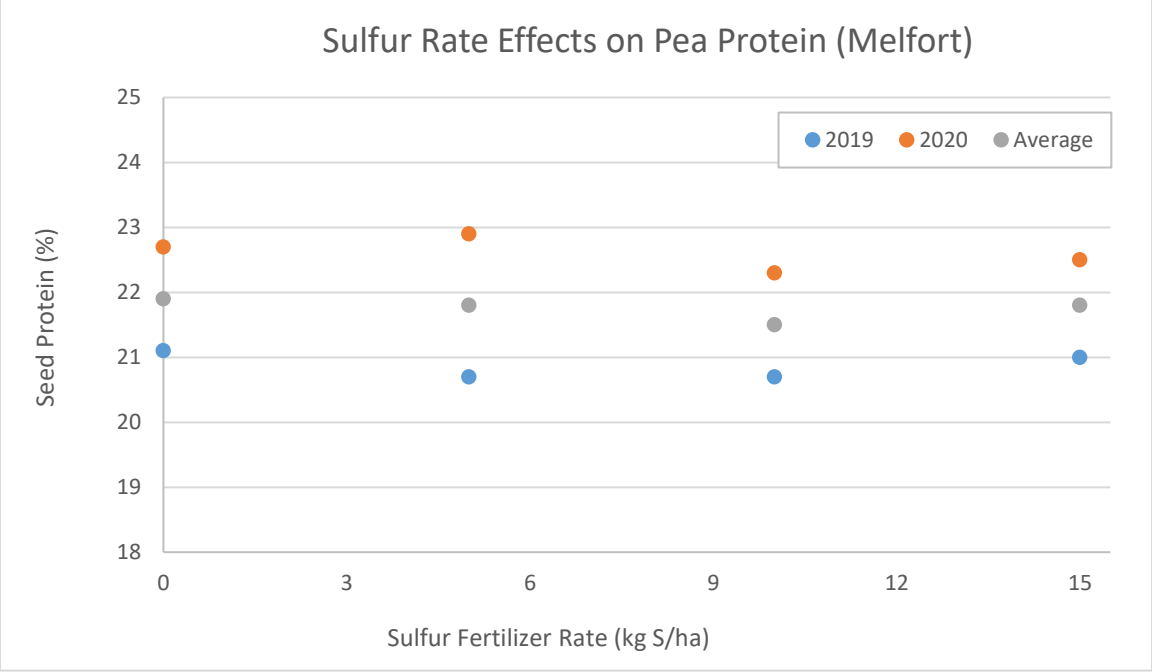

Figure 12. Field pea seed protein response to sulfur fertilizer rate at Melfort, Saskatchewan. Results are presented both for individual years and averaged across years.

Table 17. Results for tests of year and fertilizer effects on field pea yield and individual treatment means over a two-year period at Outlook, Saskatchewan. Means within a column followed by the same letter do not significantly differ from one another (Tukey-Kramer; *P* ≤ 0.05).

Source / Treatment	2019	2020	2-Yr Average
Overall F-test	---------- p-value ----------		
Year (Yr)	–	–	0.049
Fertilizer Treatment (Fert)	<0.001	0.233	0.001
Yr x Fert	–	–	<0.001
kg N-P_2O_5-K_2O-S/ha	---------- Seed Yield (kg/ha) ----------		
1) 0-0-0-0 (no fertilizer)	3595 b	5328 a	4461 B
2) 17-0-0-10 (0 P)	4377 ab	5312 a	4845 AB
3) 17-20-0-10 (20 P)	4912 ab	5268 a	5090 AB
4) 17-40-0-10 (40 P / 10 S)	4897 ab	5306 a	5101 AB
5) 21-60-0-10 (60 P)	5004 ab	5362 a	5183 A
6) 26-80-0-10 (80 P)	5054 ab	5065 a	5060 AB
7) 17-40-0-0 (0 S)	5472 a	5383 a	5427 A
8) 17-40-0-5 (5 S)	4782 ab	5271 a	5026 AB
9) 22-40-0-15 (15 S)	5218 a	5157 a	5187 A
10) 40-40-0-10 (urea)	5366 a	5135 a	5251 A
11) 17-40-0-10 + 40 N in-crop	5067 ab	5055 a	5061 AB
12) 40-40-0-10 (ESN)	4628 ab	5125 a	4876 AB
13) 40-80-0-15 (ultra high fert)	5558 a	5388 a	5473 A
S.E.M.	283.1	127.8	155.3
Year Average	4918 B	5243 A	–
S.E.M.	105.5	78.8	–

Table 18. Results from field pea fertility treatment group comparisons and orthogonal contrast for seed yield over a two-year period at Outlook, Saskatchewan.

Group comparison / Orthogonal Contrast	2019	2020	2-Yr Average
	---------- p-value ----------		
Unfertilized (1) vs Fertilized (2-13)	<0.001	0.401	<0.001
(Group Means)	(3595 vs 5028)	(5328 vs 5326)	(4461 vs 5131)
Normal N (4) vs Extra N (10,11,12)	0.700	0.101	0.819
(Group Means)	(4897 vs 5020)	(5306 vs 5105)	(5101 vs 5063)
Phosphorus Rate – linear	0.099	0.231	0.263
Phosphorus Rate – quadratic	0.410	0.218	0.228
Sulfur Rate – linear	0.598	0.175	0.329
Sulfur Rate – quadratic	0.069	0.863	0.101

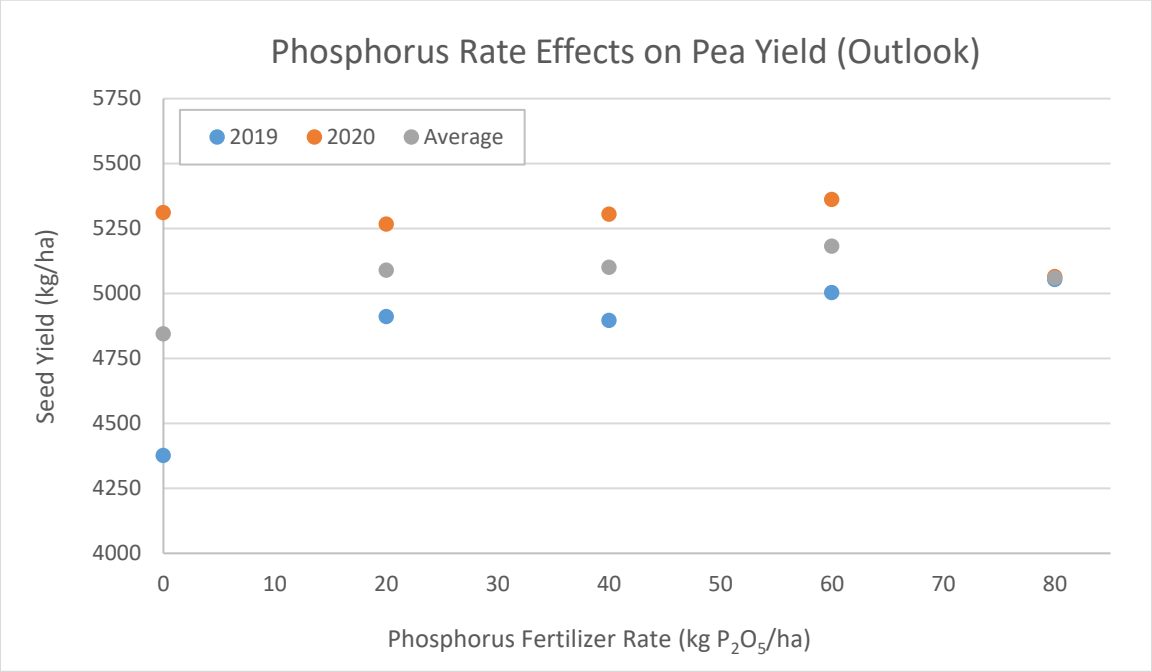

Figure 13. Field pea seed yield response to phosphorus fertilizer rate at Outlook, Saskatchewan. Results are presented both for individual years and averaged across years.

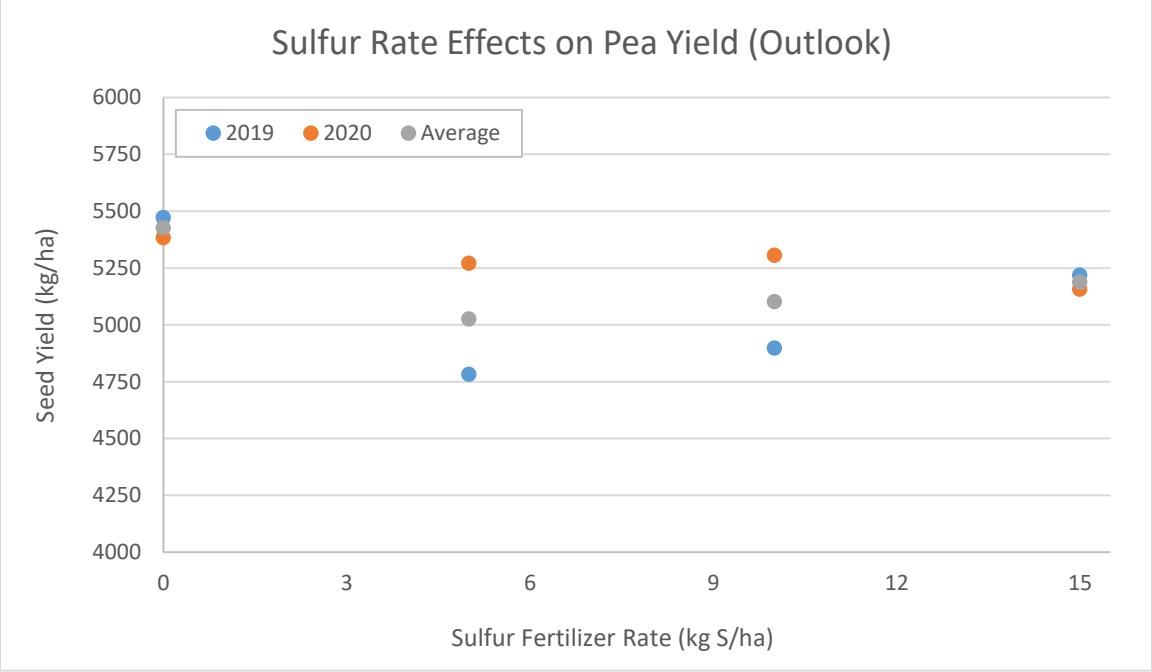

Figure 14. Field pea seed yield response to sulfur fertilizer rate at Outlook, Saskatchewan. Results are presented both for individual years and averaged across years.

Table 19. Results for tests of year and fertilizer effects on field pea seed protein and individual treatment means over a two-year period at Outlook, Saskatchewan. Means within a column followed by the same letter do not significantly differ from one another (Tukey-Kramer; *P* ≤ 0.05).

Source / Treatment	2019	2020	2-Yr Average
Overall F-test	---------- p-value ----------		
Year (Yr)	–	–	<0.001
Fertilizer Treatment (Fert)	0.029	0.204	0.060
Yr x Fert	–	–	0.157
kg N-P_2O_5-K_2O-S/ha	---------- Seed Protein (%) ----------		
1) 0-0-0-0 (no fertilizer)	19.7 ab	24.4 a	22.1 AB
2) 17-0-0-10 (0 P)	19.7 ab	24.0 a	21.8 AB
3) 17-20-0-10 (20 P)	19.5 ab	21.6 a	20.5 B
4) 17-40-0-10 (40 P / 10 S)	19.3 ab	24.7 a	22.0 AB
5) 21-60-0-10 (60 P)	19.9 ab	24.5 a	22.2 AB
6) 26-80-0-10 (80 P)	22.1 a	24.8 a	23.5 A
7) 17-40-0-0 (0 S)	20.1 ab	24.5 a	22.3 AB
8) 17-40-0-5 (5 S)	20.9 ab	24.6 a	22.7 AB
9) 22-40-0-15 (15 S)	19.5 ab	24.6 a	22.0 AB
10) 40-40-0-10 (urea)	18.8 ab	25.1 a	21.9 AB
11) 17-40-0-10 + 40 N in-crop	20.5 ab	25.0 a	22.8 AB
12) 40-40-0-10 (ESN)	18.7 b	24.8 a	21.8 AB
13) 40-80-0-15 (ultra high fert)	19.6 ab	24.9 a	22.3 AB
S.E.M.	0.70	0.84	0.55
Year Average	19.9 B	24.4 A	–
S.E.M.	0.39	0.37	–

Table 20. Results from field pea fertility treatment group comparisons and orthogonal contrast for seed protein over a two-year period at Outlook, Saskatchewan.

Group comparison / Orthogonal Contrast	2019	2020	2-Yr Average
	---------- p-value ----------		
Unfertilized (1) vs Fertilized (2-13)	0.763	0.988	0.860
(Group Means)	(19.7 vs 19.9)	(24.4 vs 24.4)	(22.1 vs 22.1)
Normal N (4) vs Extra N (10,11,12)	0.991	0.731	0.783
(Group Means)	(19.3 vs 19.3)	(24.7 vs 25.0)	(22.0 vs 22.1)
Phosphorus Rate – linear	0.010	0.069	0.003
Phosphorus Rate – quadratic	0.021	0.435	0.040
Sulfur Rate – linear	0.234	0.903	0.515
Sulfur Rate – quadratic	0.616	0.885	0.670

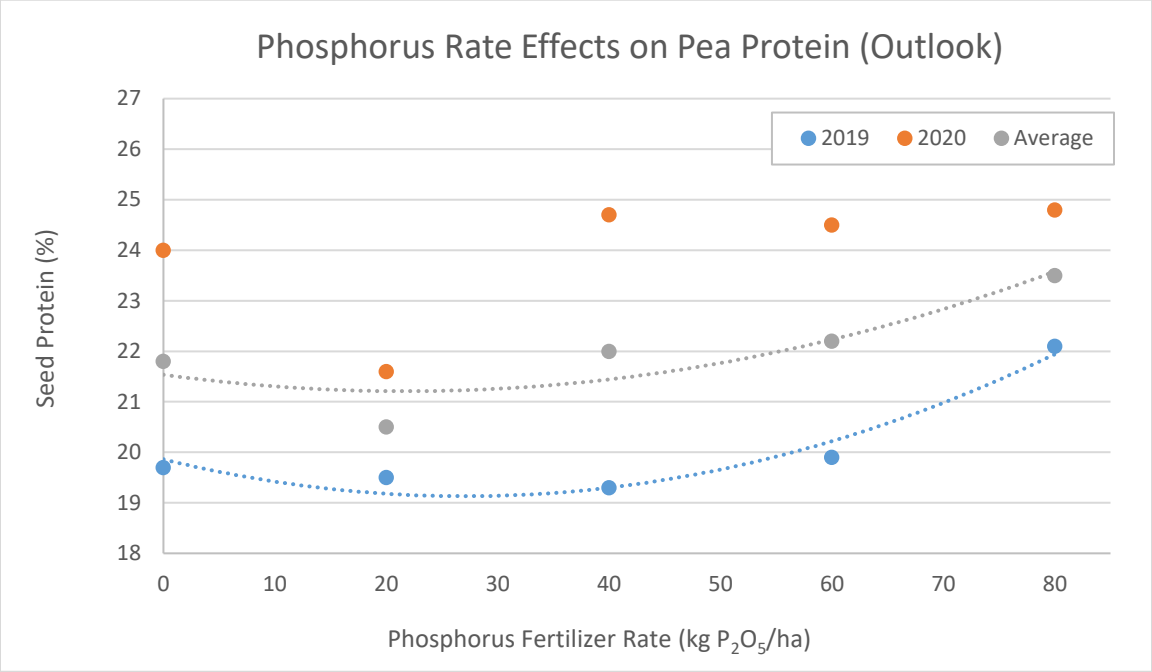

Figure 15. Field pea seed protein response to phosphorus fertilizer rate at Outlook, Saskatchewan. Results are presented both for individual years and averaged across years.

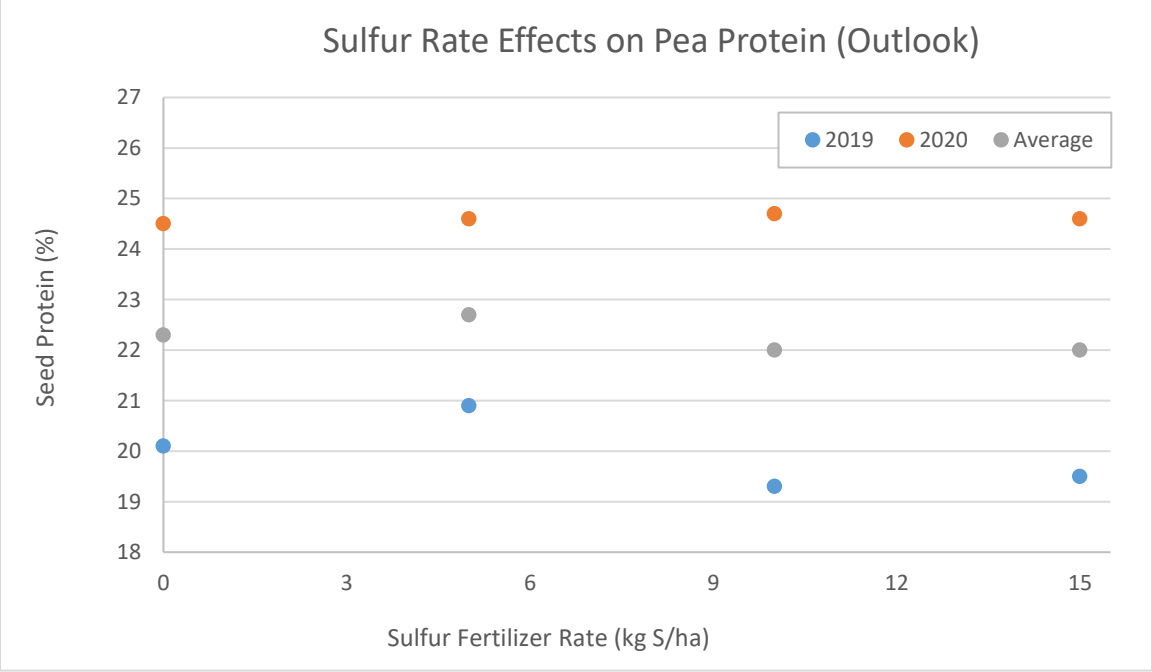

Figure 16. Field pea seed protein response to sulfur fertilizer rate at Outlook, Saskatchewan. Results are presented both for individual years and averaged across years.

Table 21. Results for tests of year and fertilizer effects on field pea yield and individual treatment means over a two-year period at Scott, Saskatchewan. Means within a column followed by the same letter do not significantly differ from one another (Tukey-Kramer; *P* ≤ 0.05).

Source / Treatment	2019	2020	2-Yr Average
Overall F-test	---------- p-value ----------		
Year (Yr)	–	–	0.003
Fertilizer Treatment (Fert)	<0.001	0.033	<0.001
Yr x Fert	–	–	0.027
kg N-P_2O_5-K_2O-S/ha	---------- Seed Yield (kg/ha) ----------		
1) 0-0-0-0 (no fertilizer)	5546 bc	5316 a	5431 cd
2) 17-0-0-10 (0 P)	5625 bc	5396 a	5510 bcd
3) 17-20-0-10 (20 P)	6202 a	5462 a	5832 ab
4) 17-40-0-10 (40 P / 10 S)	6137 a	5513 a	5825 abc
5) 21-60-0-10 (60 P)	6168 a	5807 a	5988 a
6) 26-80-0-10 (80 P)	6268 a	5714 a	5991 a
7) 17-40-0-0 (0 S)	6181 a	5694 a	5938 a
8) 17-40-0-5 (5 S)	6150 a	5559 a	5854 ab
9) 22-40-0-15 (15 S)	6244 a	5521 a	5882 ab
10) 40-40-0-10 (urea)	5340 c	5206 a	5273 d
11) 17-40-0-10 + 40 N in-crop	5953 ab	5837 a	5895 ab
12) 40-40-0-10 (ESN)	6204 a	5382 a	5793 abc
13) 40-80-0-15 (ultra high fert)	6266 a	5767 a	6017 a
S.E.M.	103.2	152.2	91.9
Year Average	6022 A	5552 B	–
S.E.M.	64.2	71.3	–

Table 22. Results from field pea fertility treatment group comparisons and orthogonal contrast for seed yield over a two-year period at Scott, Saskatchewan.

Group comparison / Orthogonal Contrast	2019	2020	2-Yr Average
	---------- p-value ----------		
Unfertilized (1) vs Fertilized (2-13)	<0.001	0.083	<0.001
(Group Means)	(5546 vs 6061)	(5316 vs 5572)	(5431 vs 5817)
Normal N (4) vs Extra N (10,11,12)	0.002	0.818	0.074
(Group Means)	(6137 vs 5832)	(5513 vs 5475)	(5825 vs 5654)
Phosphorus Rate – linear	<0.001	0.030	<0.001
Phosphorus Rate – quadratic	0.008	0.888	0.134
Sulfur Rate – linear	0.642	0.369	0.594
Sulfur Rate – quadratic	0.417	0.608	0.392

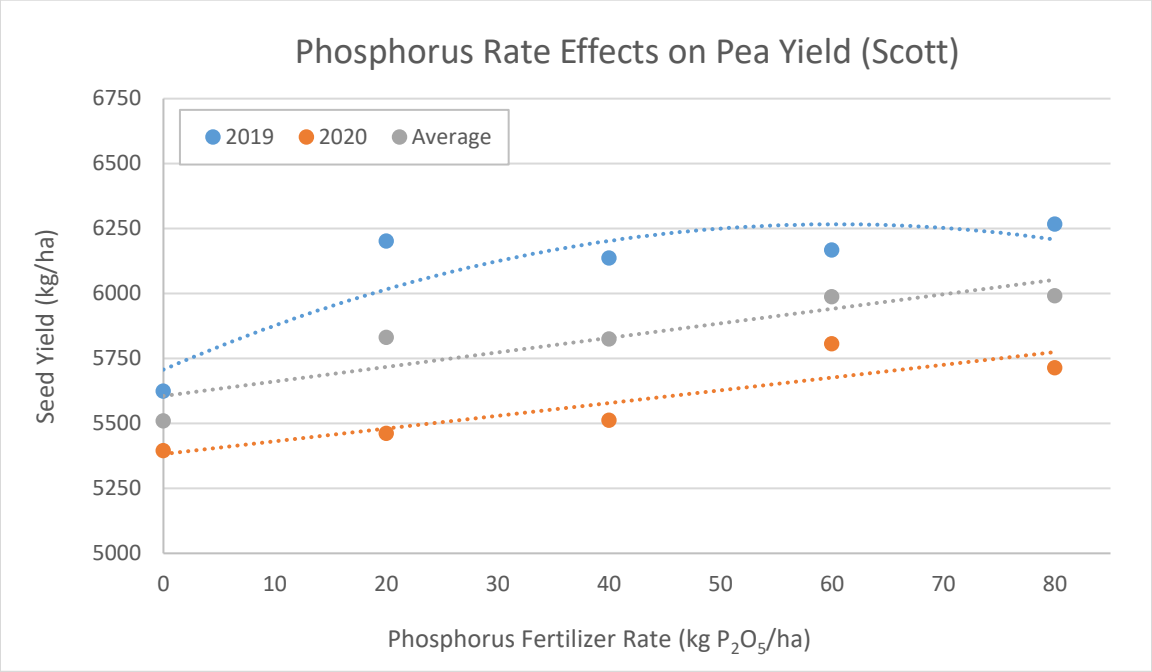

Figure 17. Field pea seed yield response to phosphorus fertilizer rate at Scott, Saskatchewan. Results are presented both for individual years and averaged across years.

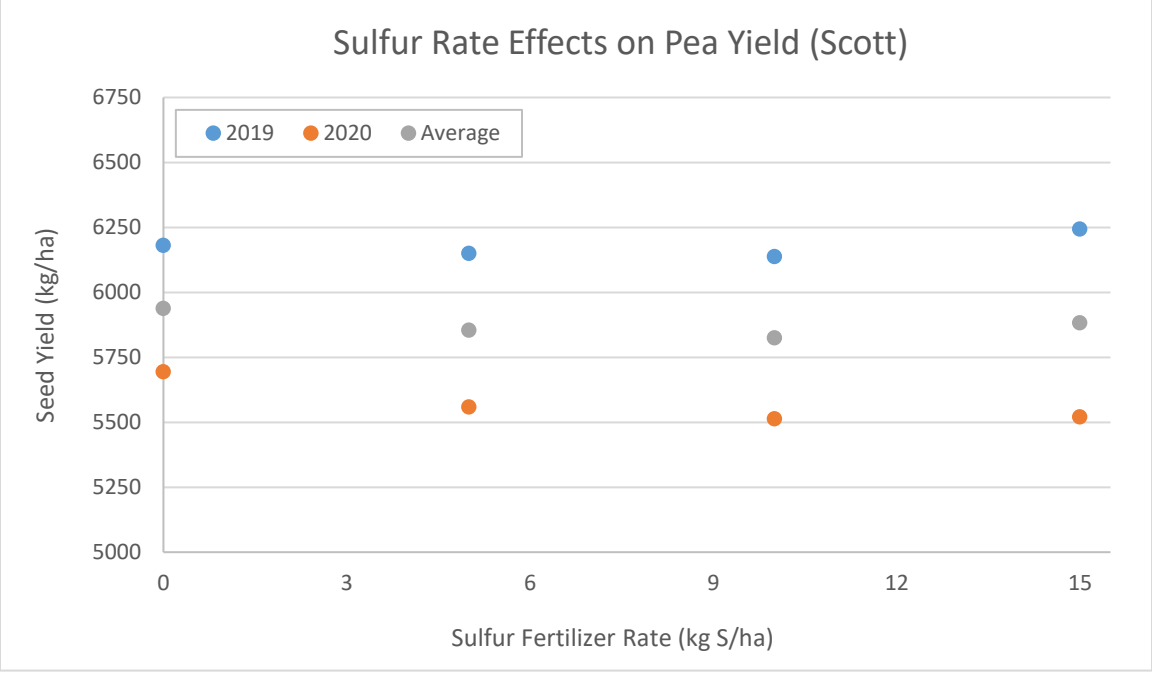

Figure 18. Field pea seed yield response to sulfur fertilizer rate at Scott, Saskatchewan. Results are presented both for individual years and averaged across years.

Table 23. Results for tests of year and fertilizer effects on field pea seed protein and individual treatment means over a two-year period at Scott, Saskatchewan. Means within a column followed by the same letter do not significantly differ from one another (Tukey-Kramer; $P \leq 0.05$).

Source / Treatment	2019	2020	2-Yr Average
Overall F-test	---------- p-value ----------		
Year (Yr)	–	–	<0.001
Fertilizer Treatment (Fert)	0.101	0.068	0.240
Yr x Fert	–	–	0.025
kg N-P_2O_5-K_2O-S/ha	---------- Seed Protein (%) ----------		
1) 0-0-0-0 (no fertilizer)	23.6 a	24.5 a	24.0 A
2) 17-0-0-10 (0 P)	23.9 a	24.8 a	24.3 A
3) 17-20-0-10 (20 P)	23.4 a	24.9 a	24.1 A
4) 17-40-0-10 (40 P / 10 S)	23.4 a	25.3 a	24.4 A
5) 21-60-0-10 (60 P)	23.8 a	25.1 a	24.4 A
6) 26-80-0-10 (80 P)	23.6 a	25.0 a	24.3 A
7) 17-40-0-0 (0 S)	23.8 a	25.0 a	24.4 A
8) 17-40-0-5 (5 S)	23.6 a	24.9 a	24.2 A
9) 22-40-0-15 (15 S)	23.8 a	24.9 a	24.3 A
10) 40-40-0-10 (urea)	24.1 a	24.8 a	24.4 A
11) 17-40-0-10 + 40 N in-crop	23.8 a	24.9 a	24.3 A
12) 40-40-0-10 (ESN)	23.6 a	25.0 a	24.3 A
13) 40-80-0-15 (ultra high fert)	23.6 a	25.3 a	24.5 A
S.E.M.	0.19	0.20	0.14
Year Average	23.7 B	24.9 A	–
S.E.M.	0.12	0.12	–

Table 24. Results from field pea fertility treatment group comparisons and orthogonal contrast for seed protein over a two-year period at Scott, Saskatchewan.

Group comparison / Orthogonal Contrast	2019	2020	2-Yr Average
	---------- p-value ----------		
Unfertilized (1) vs Fertilized (2-13)	0.455	0.006	0.010
(Group Means)	(23.6 vs 23.7)	(24.5 vs 25.0)	(24.0 vs 24.3)
Normal N (4) vs Extra N (10,11,12)	0.025	0.030	0.876
(Group Means)	(23.4 vs 23.8)	(25.3 vs 24.9)	(24.4 vs 24.3)
Phosphorus Rate – linear	0.836	0.203	0.412
Phosphorus Rate – quadratic	0.139	0.126	0.862
Sulfur Rate – linear	0.714	1.000	0.808
Sulfur Rate – quadratic	0.052	0.387	0.516

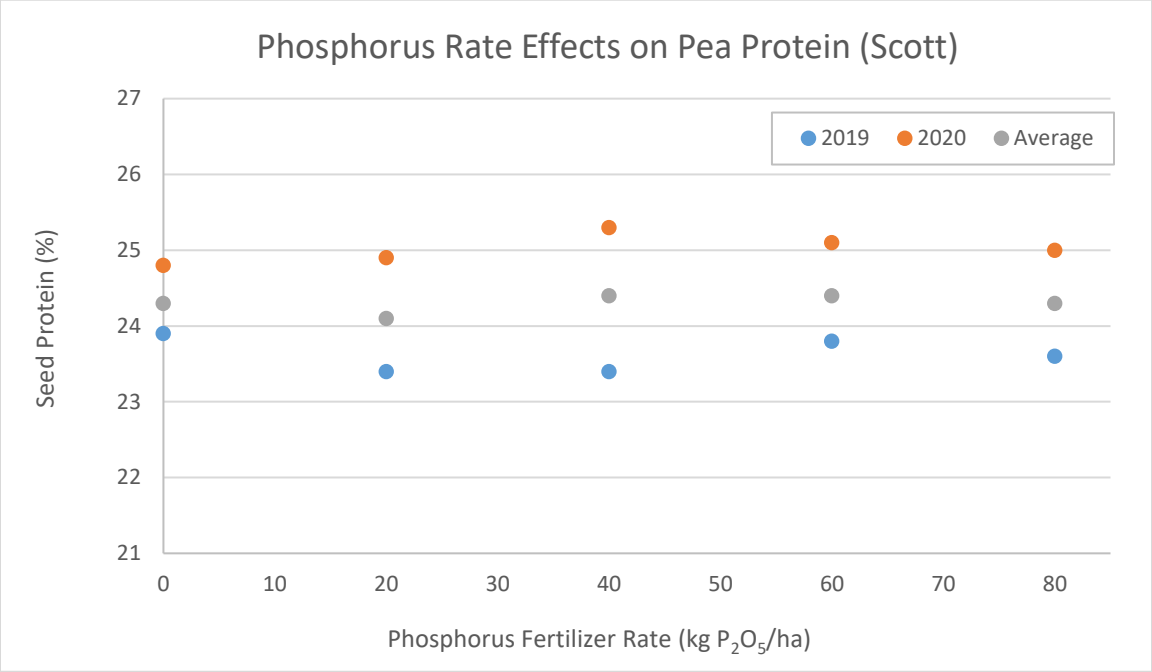

Figure 19. Field pea seed protein response to phosphorus fertilizer rate at Scott, Saskatchewan. Results are presented both for individual years and averaged across years.

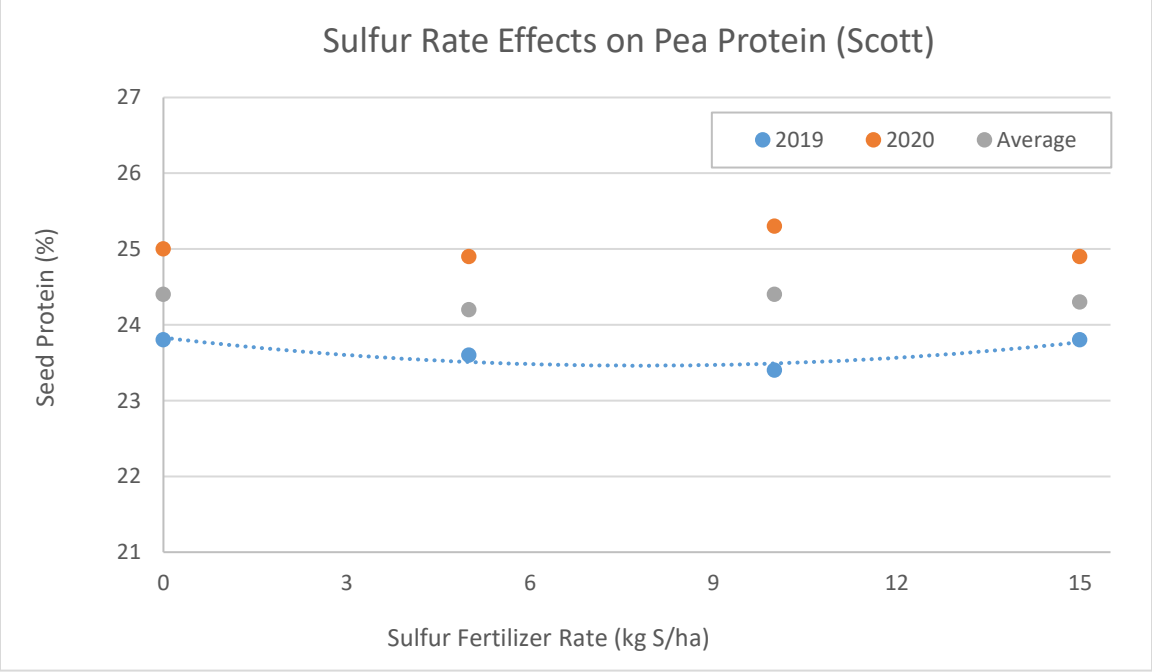

Figure 20. Field pea seed protein response to sulfur fertilizer rate at Scott, Saskatchewan. Results are presented both for individual years and averaged across years.

Table 25. Results for tests of year and fertilizer effects on field pea yield and individual treatment means over a two-year period at Swift Current, Saskatchewan. Means within a column followed by the same letter do not significantly differ from one another (Tukey-Kramer; *P* ≤ 0.05).

Source / Treatment	2019	2020	2-Yr Average
Overall F-test	---------- p-value ----------		
Year (Yr)	–	–	<0.001
Fertilizer Treatment (Fert)	0.090	0.394	0.066
Yr x Fert	–	–	0.317
kg N-P_2O_5-K_2O-S/ha	---------- Seed Yield (kg/ha) ----------		
1) 0-0-0-0 (no fertilizer)	2701 a	3431 a	3066 A
2) 17-0-0-10 (0 P)	2375 a	3642 a	3008 A
3) 17-20-0-10 (20 P)	3090 a	3689 a	3389 A
4) 17-40-0-10 (40 P / 10 S)	3111 a	3528 a	3320 A
5) 21-60-0-10 (60 P)	2855 a	3670 a	3262 A
6) 26-80-0-10 (80 P)	3078 a	3699 a	3388 A
7) 17-40-0-0 (0 S)	2806 a	3659 a	3233 A
8) 17-40-0-5 (5 S)	2908 a	3706 a	3307 A
9) 22-40-0-15 (15 S)	2611 a	3479 a	3045 A
10) 40-40-0-10 (urea)	2911 a	3666 a	3289 A
11) 17-40-0-10 + 40 N in-crop	2824 a	3800 a	3312 A
12) 40-40-0-10 (ESN)	2859 a	3806 a	3332 A
13) 40-80-0-15 (ultra high fert)	2861 a	3609 a	3235 A
S.E.M.	167.5	122.7	103.8
Year Average	2845 B	3645 A	–
S.E.M.	73.9	66.8	–

Table 26. Results from field pea fertility treatment group comparisons and orthogonal contrast over a two-year period for seed yield at Swift Current, Saskatchewan.

Group comparison / Orthogonal Contrast	2019	2020	2-Yr Average
	---------- p-value ----------		
Unfertilized (1) vs Fertilized (2-13)	0.341	0.041	0.053
(Group Means)	(2701 vs 2857)	(3431 vs 3663)	(3066 vs 3260)
Normal N (4) vs Extra N (10,11,12)	0.176	0.068	0.937
(Group Means)	(3111 vs 2865)	(3528 vs 3757)	(3320 vs 3311)
Phosphorus Rate – linear	0.021	0.779	0.038
Phosphorus Rate – quadratic	0.034	0.507	0.165
Sulfur Rate – linear	0.587	0.139	0.200
Sulfur Rate – quadratic	0.058	0.656	0.070

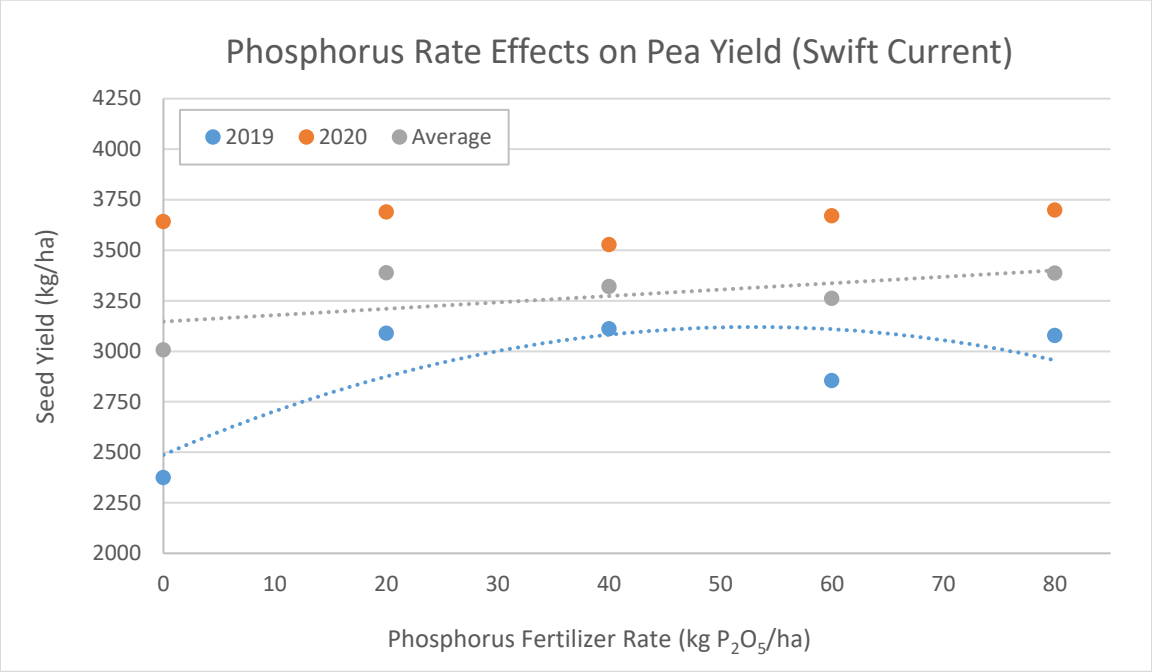

Figure 21. Field pea seed yield response to phosphorus fertilizer rate at Swift Current, Saskatchewan. Results are presented both for individual years and averaged across years.

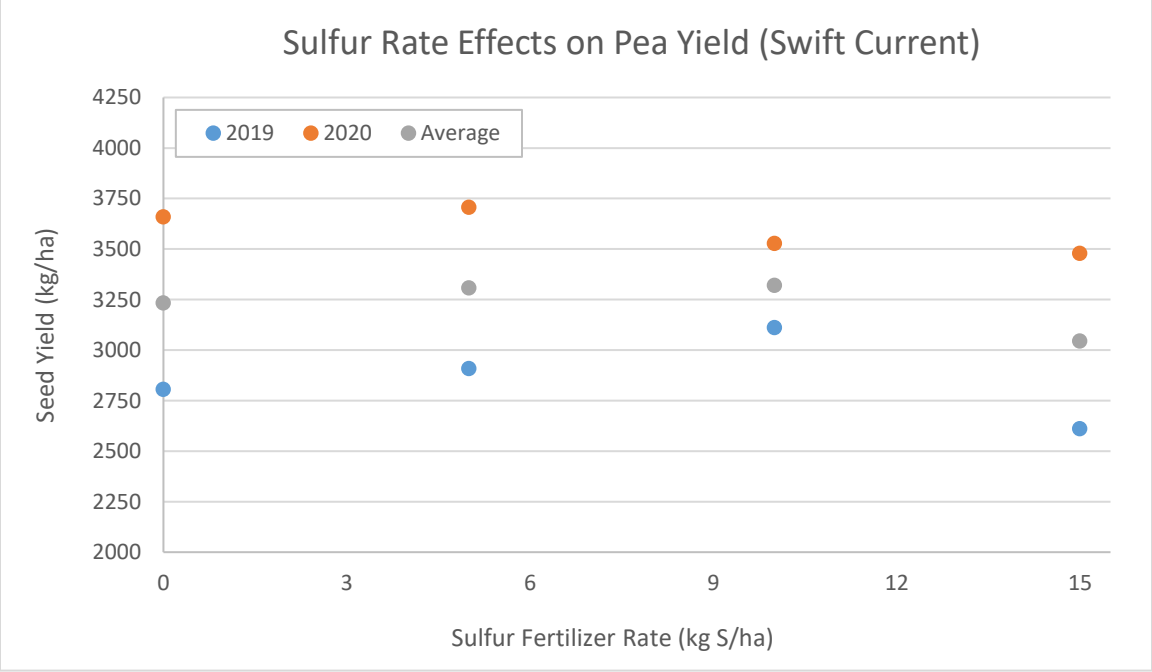

Figure 22. Field pea seed yield response to sulfur fertilizer rate at Swift Current, Saskatchewan. Results are presented both for individual years and averaged across years.

Table 27. Results for tests of year and fertilizer effects on field pea seed protein and individual treatment means over a two-year period at Swift Current, Saskatchewan. Means within a column followed by the same letter do not significantly differ from one another (Tukey-Kramer; $P \leq 0.05$).

Source / Treatment	2019	2020	2-Yr Average
Overall F-test	---------- p-value ----------		
Year (Yr)	–	–	0.003
Fertilizer Treatment (Fert)	<0.001	0.362	0.016
Yr x Fert	–	–	0.294
kg N-P_2O_5-K_2O-S/ha	---------- Seed Protein (%) ----------		
1) 0-0-0-0 (no fertilizer)	24.0 c	23.5 a	23.7 A
2) 17-0-0-10 (0 P)	24.1 bc	24.4 a	24.2 AB
3) 17-20-0-10 (20 P)	24.9 ab	23.6 a	24.2 AB
4) 17-40-0-10 (40 P / 10 S)	24.7 abc	24.6 a	24.7 A
5) 21-60-0-10 (60 P)	24.6 abc	24.0 a	24.3 AB
6) 26-80-0-10 (80 P)	25.1 a	24.2 a	24.6 AB
7) 17-40-0-0 (0 S)	24.8 abc	23.7 a	24.2 AB
8) 17-40-0-5 (5 S)	24.9 ab	24.5 a	24.7 A
9) 22-40-0-15 (15 S)	24.7 abc	24.1 a	24.4 AB
10) 40-40-0-10 (urea)	24.8 abc	23.9 a	24.3 AB
11) 17-40-0-10 + 40 N in-crop	24.6 abc	24.1 a	24.3 AB
12) 40-40-0-10 (ESN)	24.9 ab	24.3 a	24.6 AB
13) 40-80-0-15 (ultra high fert)	25.2 a	24.4 a	24.8 A
S.E.M.	0.16	0.35	0.19
Year Average	24.7 A	24.1 B	–
S.E.M.	0.067	0.108	–

Table 28. Results from field pea fertility treatment group comparisons and orthogonal contrast for seed protein over a two-year period at Swift Current, Saskatchewan.

Group comparison / Orthogonal Contrast	2019	2020	2-Yr Average
	---------- p-value ----------		
Unfertilized (1) vs Fertilized (2-13)	<0.001	0.058	<0.001
(Group Means)	(24.0 vs 24.8)	(23.5 vs 24.1)	(23.7 vs 24.5)
Normal N (4) vs Extra N (10,11,12)	0.963	0.181	0.229
(Group Means)	(24.7 vs 24.7)	(24.6 vs 24.1)	(24.7 vs 24.4)
Phosphorus Rate – linear	0.001	0.945	0.195
Phosphorus Rate – quadratic	0.279	0.861	0.776
Sulfur Rate – linear	0.425	0.398	0.656
Sulfur Rate – quadratic	0.626	0.045	0.042

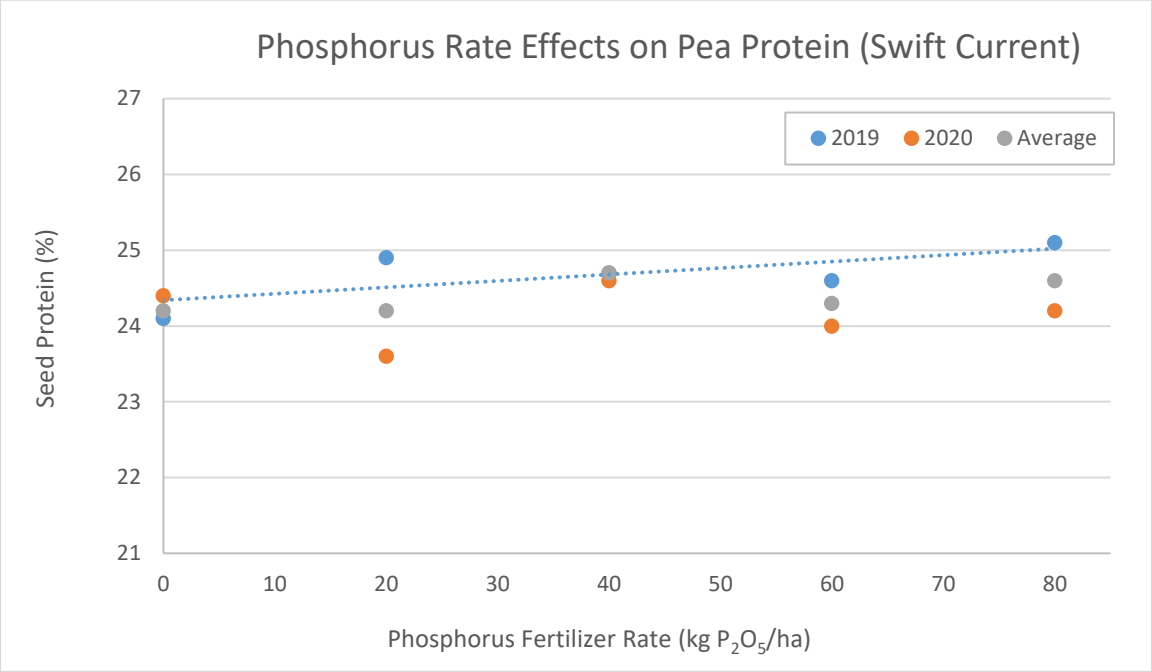

Figure 23. Field pea seed protein response to phosphorus fertilizer rate at Swift Current, Saskatchewan. Results are presented both for individual years and averaged across years.

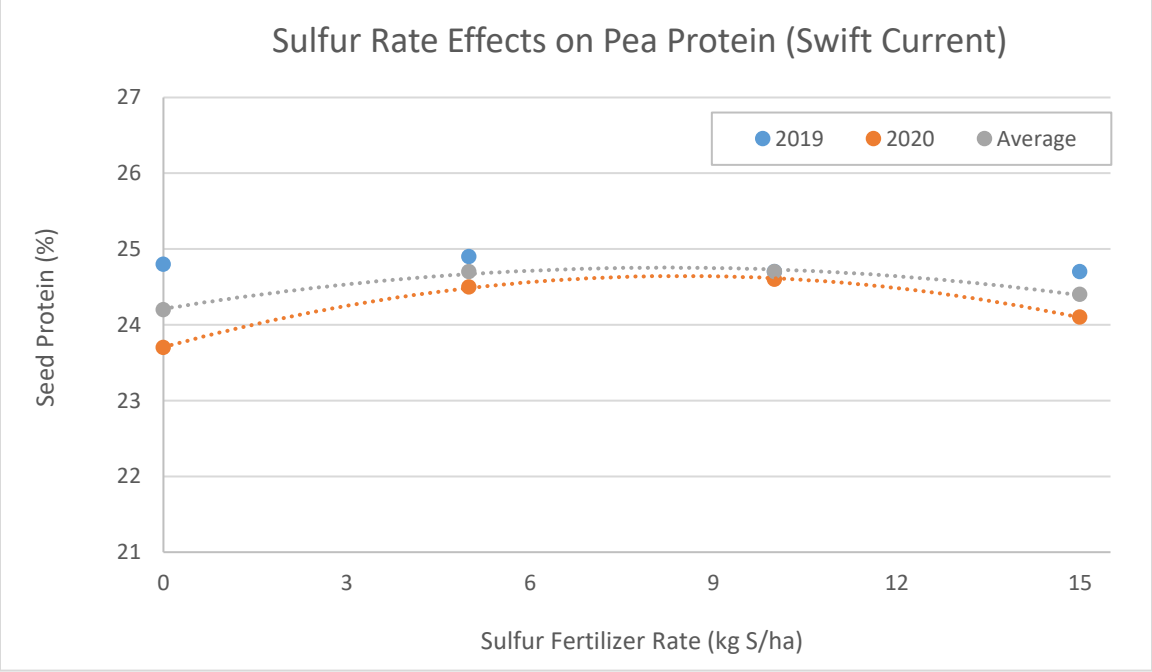

Figure 24. Field pea seed protein response to sulfur fertilizer rate at Swift Current, Saskatchewan. Results are presented both for individual years and averaged across years.

Table 29. Results for tests of year and fertilizer effects on field pea yield and individual treatment means over a two-year period at Yorkton, Saskatchewan. Means within a column followed by the same letter do not significantly differ from one another (Tukey-Kramer; *P* ≤ 0.05).

Source / Treatment	2019	2020	2-Yr Average
Overall F-test	---------- p-value ----------		
Year (Yr)	–	–	<0.001
Fertilizer Treatment (Fert)	0.081	0.011	<0.001
Yr x Fert	–	–	0.753
kg N-P_2O_5-K_2O-S/ha	---------- Seed Yield (kg/ha) ----------		
1) 0-0-0-0 (no fertilizer)	4422 a	2477 a	3450 C
2) 17-0-0-10 (0 P)	4973 a	2457 a	3715 ABC
3) 17-20-0-10 (20 P)	4751 a	2381 a	3566 BC
4) 17-40-0-10 (40 P / 10 S)	5082 a	3163 a	4122 AB
5) 21-60-0-10 (60 P)	5269 a	3241 a	4255 A
6) 26-80-0-10 (80 P)	5018 a	2943 a	3981 ABC
7) 17-40-0-0 (0 S)	4494 a	2786 a	3640 BC
8) 17-40-0-5 (5 S)	4641 a	2747 a	3694 ABC
9) 22-40-0-15 (15 S)	4952 a	2883 a	3918 ABC
10) 40-40-0-10 (urea)	4932 a	2942 a	3937 ABC
11) 17-40-0-10 + 40 N in-crop	4978 a	3064 a	4021 ABC
12) 40-40-0-10 (ESN)	4912 a	2938 a	3925 ABC
13) 40-80-0-15 (ultra high fert)	5049 a	2900 a	3974 ABC
S.E.M.	217.6	207.3	150.3
Year Average	4883 A	2840 B	–
S.E.M.	126.5	125.2	–

Table 30. Results from field pea fertility treatment group comparisons and orthogonal contrast for seed yield over a two-year period at Yorkton, Saskatchewan.

Group comparison / Orthogonal Contrast	2019	2020	2-Yr Average
	---------- p-value ----------		
Unfertilized (1) vs Fertilized (2-13)	0.011	0.031	0.001
(Group Means)	(4422 vs 4921)	(2477 vs 2870)	(3450 vs 3896)
Normal N (4) vs Extra N (10,11,12)	0.509	0.364	0.271
(Group Means)	(5082 vs 4941)	(3163 vs 2981)	(4122 vs 3961)
Phosphorus Rate – linear	0.300	0.001	0.003
Phosphorus Rate – quadratic	0.772	0.079	0.157
Sulfur Rate – linear	0.031	0.361	0.028
Sulfur Rate – quadratic	0.455	0.488	0.309

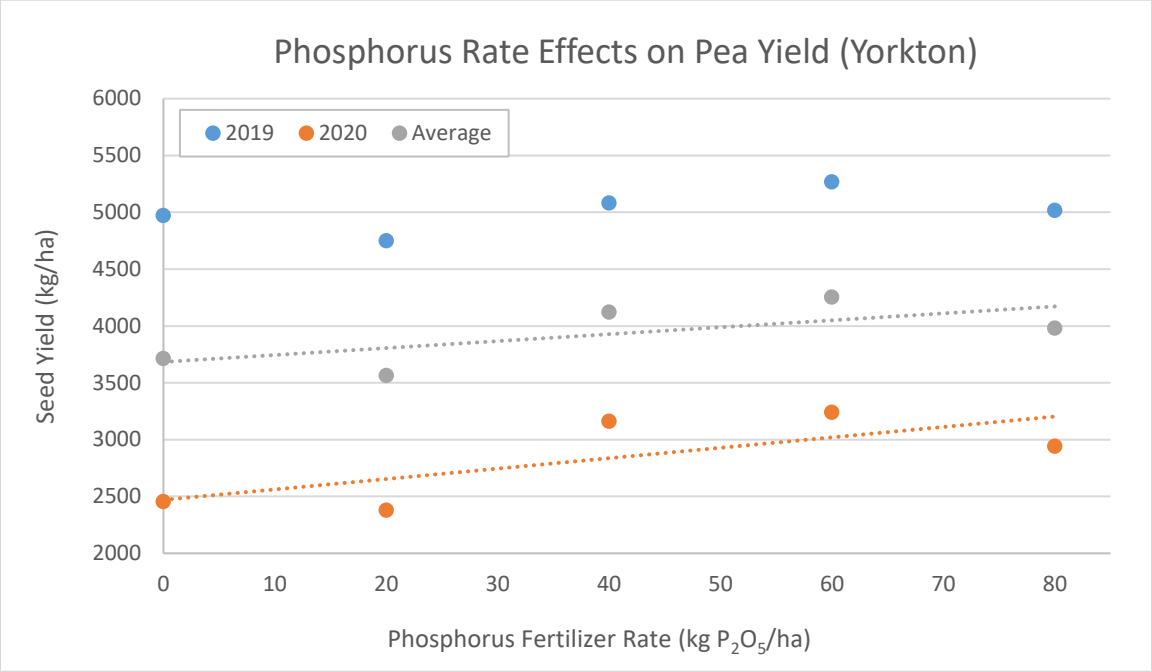

Figure 25. Field pea seed yield response to phosphorus fertilizer rate at Yorkton, Saskatchewan. Results are presented both for individual years and averaged across years.

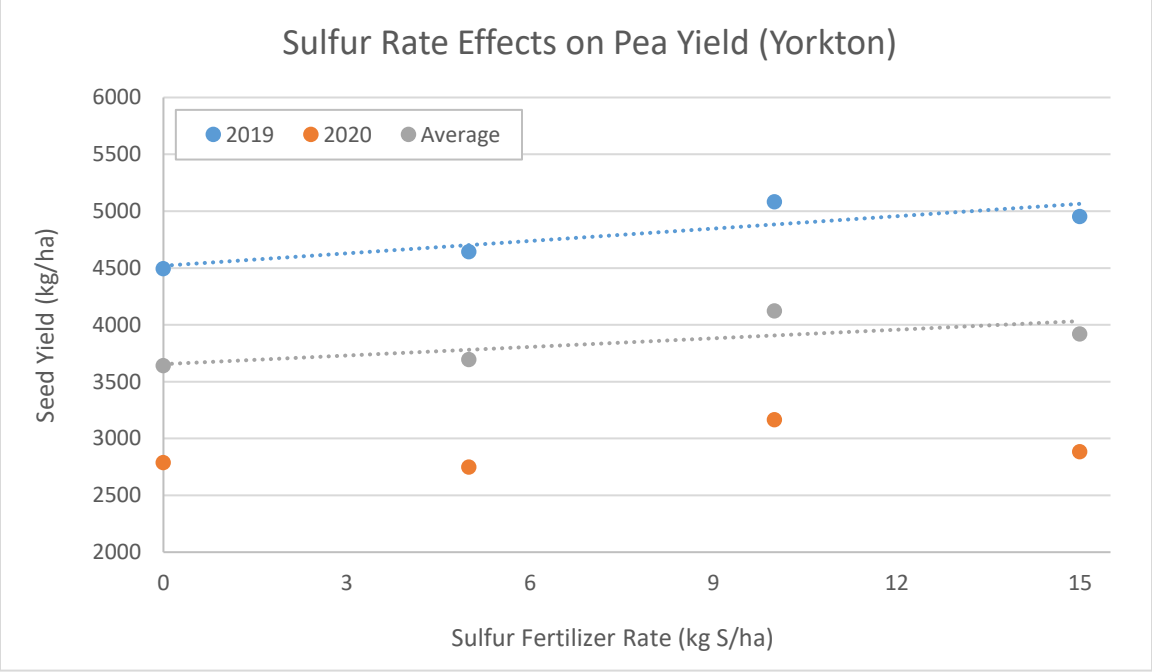

Figure 26. Field pea seed yield response to sulfur fertilizer rate at Yorkton, Saskatchewan. Results are presented both for individual years and averaged across years.

Table 31. Results for tests of year and fertilizer effects on field pea seed protein and individual treatment means over a two-year period at Yorkton, Saskatchewan. Means within a column followed by the same letter do not significantly differ from one another (Tukey-Kramer; *P* ≤ 0.05).

Source / Treatment	2019	2020	2-Yr Average
Overall F-test	---------- p-value ----------		
Year (Yr)	–	–	<0.001
Fertilizer Treatment (Fert)	0.538	0.031	0.039
Yr x Fert	–	–	0.484
kg N-P_2O_5-K_2O-S/ha	---------- Seed Protein (%) ----------		
1) 0-0-0-0 (no fertilizer)	22.0 a	17.1 a	19.6 A
2) 17-0-0-10 (0 P)	22.0 a	16.8 a	19.4 A
3) 17-20-0-10 (20 P)	21.8 a	17.2 a	19.5 A
4) 17-40-0-10 (40 P / 10 S)	22.7 a	17.5 a	20.1 A
5) 21-60-0-10 (60 P)	22.1 a	17.5 a	19.8 A
6) 26-80-0-10 (80 P)	21.5 a	16.5 a	19.0 A
7) 17-40-0-0 (0 S)	21.2 a	16.5 a	18.9 A
8) 17-40-0-5 (5 S)	21.4 a	16.4 a	18.9 A
9) 22-40-0-15 (15 S)	21.8 a	16.7 a	19.2 A
10) 40-40-0-10 (urea)	21.7 a	17.7 a	19.7 A
11) 17-40-0-10 + 40 N in-crop	22.0 a	18.1 a	20.1 A
12) 40-40-0-10 (ESN)	21.3 a	17.9 a	19.6 A
13) 40-80-0-15 (ultra high fert)	21.8 a	17.8 a	19.8 A
S.E.M.	0.43	0.43	0.30
Year Average	21.8 A	17.2 B	–
S.E.M.	0.17	0.16	–

Table 32. Results from field pea fertility treatment group comparisons and orthogonal contrast for seed protein over a two-year period at Yorkton, Saskatchewan.

Group comparison / Orthogonal Contrast	2019	2020	2-Yr Average
	---------- p-value ----------		
Unfertilized (1) vs Fertilized (2-13)	0.631	0.845	0.837
(Group Means)	(22.0 vs 21.8)	(17.1 vs 17.2)	(19.6 vs 19.5)
Normal N (4) vs Extra N (10,11,12)	0.040	0.334	0.423
(Group Means)	(22.7 vs 21.7)	(17.5 vs 17.9)	(20.1 vs 19.8)
Phosphorus Rate – linear	0.608	0.787	0.579
Phosphorus Rate – quadratic	0.147	0.046	0.016
Sulfur Rate – linear	0.104	0.378	0.078
Sulfur Rate – quadratic	0.209	0.411	0.143

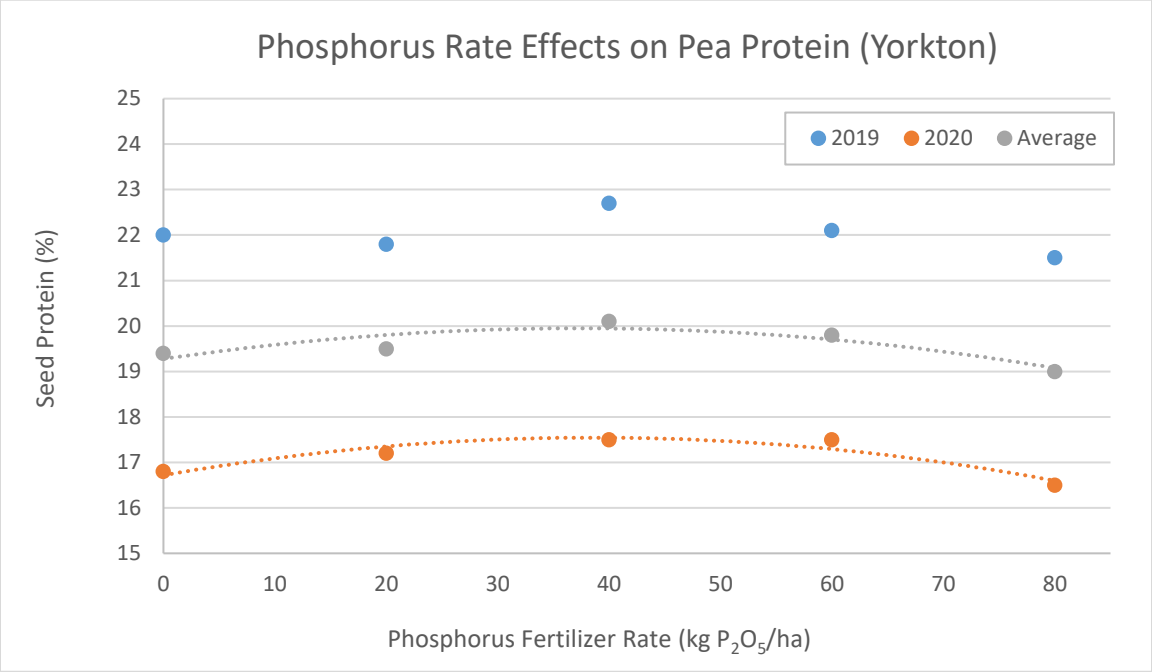

Figure 27. Field pea seed protein response to phosphorus fertilizer rate at Yorkton, Saskatchewan. Results are presented both for individual years and averaged across years.

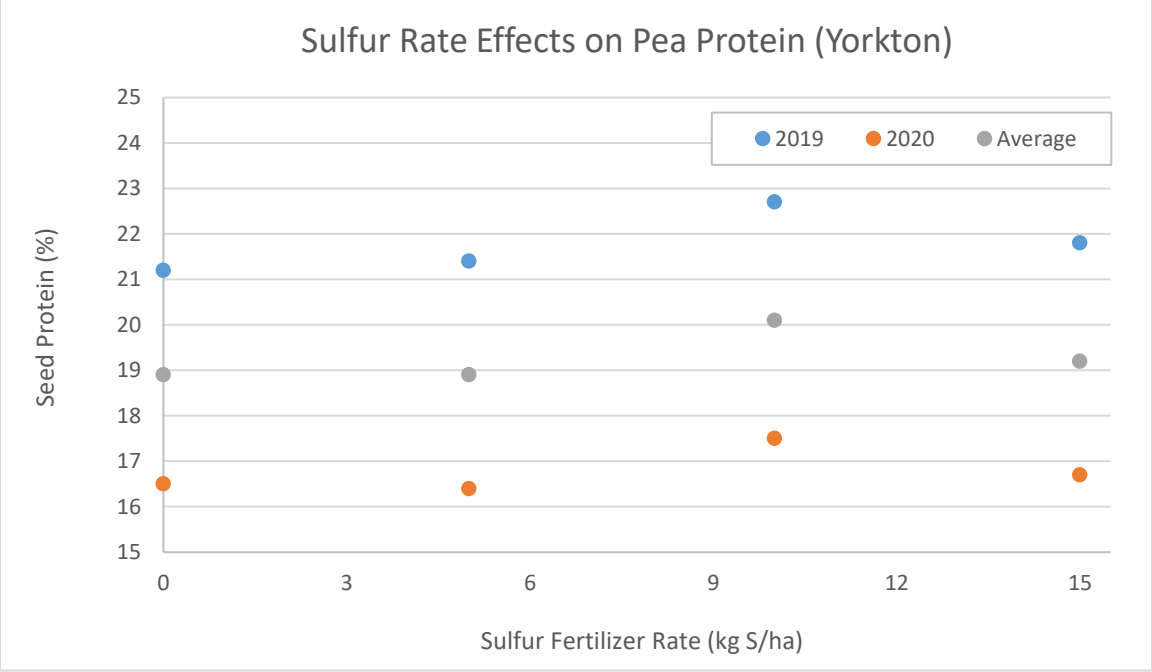

Figure 28. Field pea seed protein response to sulfur fertilizer rate at Yorkton, Saskatchewan. Results are presented both for individual years and averaged across years.

Table 33. Marginal economic returns at varying rates of monoammonium phosphate. A yellow field pea price of $230/Mt was assumed and fertilizer prices of both $550/Mt and $750/Mt were considered. For brevity, results are only presented for the two-year averages at each location and the overall 12 location-year average. The values presented do not take into account any production expenses other than P fertilizer or whether the P responses were statistically significant. Furthermore, these values do not take into account any longer term benefits associated with maintaining or building soil P over the long-term.

Location	0 kg P_2O_5/ha	20 kg P_2O_5/ha	40 kg P_2O_5/ha	60 kg P_2O_5/ha	80 kg P_2O_5/ha
	---------- $/ha with $550/Mt monoammonium phosphate ----------				
Indian Head	$884	$900	$919	$889	$909
Melfort (ns)	$922	$876	$928	$940	$828
Outlook (ns)	$1,110	$1,145	$1,126	$1,124	$1,075
Scott	$1,262	$1,315	$1,292	$1,309	$1,288
Swift Current	$689	$755	$718	$684	$692
Yorkton	$851	$796	$902	$912	$828
Avg	$952	$964	$981	$976	$937
	---------- $/ha with $750/Mt monoammonium phosphate ----------				
Indian Head	$884	$893	$904	$867	$879
Melfort	$922	$868	$913	$918	$798
Outlook	$1,110	$1,137	$1,111	$1,102	$1,045
Scott	$1,262	$1,307	$1,277	$1,287	$1,258
Swift Current	$689	$747	$703	$662	$662
Yorkton	$851	$788	$886	$890	$798
Avg	$952	$957	$966	$954	$907