2021 Annual Report

for the

Saskatchewan Ministry of Agriculture's

Agricultural Demonstration of Practices & Technologies (ADOPT) Program

Project Title: Lentil Response to Fertilizer Applications and Rhizobial Inoculation

(Project #20200528)

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Project Identification

1. **Project Title:** Lentil response to fertilizer applications and rhizobial inoculation
2. **Project Number:** 20200528 (SPG-AP2106a)
3. **Producer Group Sponsoring the Project:** Saskatchewan Pulse Crop Development Board
4. **Project Location(s):** Field trials were located near Indian Head (#156), Scott (#380), and Swift Current (#137), Saskatchewan
5. **Project start and end dates(s):** April-2020 to February-2021
6. **Project contact person & contact details:**

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Objectives and Rationale

7. **Project Objectives:**
   The objective of this project was to demonstrate the response of lentil to a wide range of fertility management treatments that focus on phosphorus rate, rhizobial inoculation, and nitrogen fertilization strategies.
8. **Project Rationale:**
   Lentils are one of the most important pulse crop options in Saskatchewan, especially in drier regions such as the Brown and Dark Brown soil zones but also in transitional areas of the Black soil zone. In

addition to seed and crop protection products which have been the focus recent research/demonstration activities for this crop, fertilizer and fertility related inputs comprise some of the greatest production costs for lentil and are critical for building yield potential. A 2000 kg/ha (~30 bu/ac) lentil crop requires a total of 82-101 kg N/ha, 22-27 kg P_2O_5/ha, 69-84 kg K_2O/ha, and 8-10 kg S/ha. As both potassium and sulfur are less likely to be limiting in most Saskatchewan soils, this demonstration focussed on nitrogen (N) and phosphorus (P) management.

As a pulse crop capable of meeting most of it's N requirements through biological fixation of dinitrogen (N_2) gas through symbiotic relationships with rhizobium bacteria, it is not generally recommended to apply N fertilizer to lentils beyond what is provided by P and/or S products. Alternatively, the recommended practice is to treat the seed or soil with *Rhizobium leguminosarum* inoculants to ensure that populations of this beneficial bacteria are sufficient to colonize the lentil roots and, through biological fixation, meet the N requirements of the crop. Because it can take several weeks for root nodules to form and start supplying N to the crop, low rates of starter N are sometimes recommended in coarse textured soils with low residual N. However, biomass and nutrient accumulation is relatively slow through this early period so crop demands prior to the late vegetative stages are also low (i.e. Mahli et al. 2007). Furthermore, high levels of mineral N can inhibit nodulation and N fixation and, as such, may even negatively impact total N availability and yield; thus, growers should be cautious with this approach. In the Brown soil zone, Yan et al. (2005) observed a 45% lentil yield increase with rhizobium inoculation and better responses with granular (versus seed-applied) products, regardless of placement; however, low rates of N fertilizer (15 kg N/ha) had inconsistent effects on yield. Their findings were consistent with work on field peas conducted by Clayton et al. (2004) where the highest yields were achieved with granular inoculant and no N fertilizer, but some benefit to N fertilization was observed when either no inoculant or a liquid inoculant was applied. Under relatively low yielding, drought conditions in Montana, Huang et al. (2016) did not increase yields with either inoculation (peat based, seed-applied) or starter N (urea or ESN) but were able to increase grain protein with both of these inputs. The fertilizer effect was much larger in the absence of inoculant. Bremer et al. (1989) observed the highest yields and N_2 fixation with inoculated lentils and inconsistent responses to N application (i.e., increased biomass production but no effect on yield, better yield responses in the absence of inoculant). Furthermore, they also showed that higher N rates significantly reduced the amount of atmospheric N in the grain due to substitution of fixed N with fertilizer N. At five locations over a four-year period in Alberta, Bowness et al. (2019) did not observe any yield benefits to either inoculation or N fertilization despite observing more nodules with inoculation and working in fields which had not been sown to peas, lentils, or faba beans for at least 5 years. They attributed the lack of response to adequate nodulation in all treatments, regardless of whether an inoculant was applied, even though there did appear to be more nodules in the inoculated plots. While examples of doing so are limited in the scientific literature, it is possible that in-season applications of N could provide yield or protein benefits without some of the negative impacts on nodulation and N_2 fixation that are frequently associated with high levels of mineral N.

While, depending on yields, lentil P requirements are typically fairly modest compared to other common crops, P is one of the most commonly limiting nutrients in Saskatchewan soils, second only to N. Pulse crops such as lentil are recognized as being good scavengers of residual soil nutrients and, as such, not especially responsive to fertilizer applications; however, actual results tend to vary with environment and responses to P application occasionally occur. Gan et al. (2005) looked at both 34 kg P_2O_5/ha and P-solubilizing microbes (*P. bilaii*) but did not observe any effects on lentil establishment, growth, or yield. With sites in the Brown, Dark Brown, and Black soil zones, Bremer et al. (1989) only increased lentil yields with P fertilizer application (30 kg P_2O_5/ha) in the Black soil

zone which had both the highest yields and lowest residual P levels. In field peas, Holzapfel et al. (2021) observed statistically significant yield increases with P fertilization at 64% (7/11) of their low P (<12 ppm Olsen-P) sites and an overall average of yield increase of 9% across 12 site-years, regardless of residual P levels or absolute yields.

This project was initiated to demonstrate some of the expected responses to rhizobial inoculation, start N applications, and P fertilization for a range of soil climatic zones in Saskatchewan while also exploring the potential merits of deferred N applications for increasing lentil yields and grain protein concentrations.

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Methodology and Results

9. Methodology:

Field trials with small red lentil were initiated near Indian Head (thin Black soil zone), Scott (Dark Brown soil zone), and Swift Current (Brown soil zone) in 2021. The treatments were combinations of P fertilizer rates, granular rhizobial inoculant, and supplementary N fertilizer applied either at the time of seeding (side-banded) or as an in-season broadcast application targeted for the bud formation stage prior to flowering (actual dates were June 23-July 5). The phosphorus source was monoammonium phosphate (MAP; 11-52-0), supplemental N was provided as urea (46-0-0), and the granular inoculant product was Nodulator Duo SCG (BASF; minimum of 8 x 107 CFU/g of *Rhizobium leguminosarum* biovar *viceae* STRAIN 1435 and 2 x 108 CFU/g of *Bacillus subtilis* STRAIN BU1814) at the label recommended rate, adjusted for row spacing. Where supplemental N was applied, the total N rate was 55 kg N/ha, adjusted for N provided by the MAP. Where supplemental N was not required by protocol, N was still balanced at 10 kg/ha across the P rates ranging from 0-45 kg

P_2O_5/ha to ensure that any observed responses were to P and not the N provided by the MAP. In total, 12 treatments were arranged in a four replicate RCBD (Table 1).

Table 1. Fertilizer and inoculant treatments evaluated in lentil fertility demonstrations conducted at Indian Head, Scott, and Swift Current in 2021.

#	P rate (side-banded MAP)	Granular Inoculant (label rate)	Extra N Fertilizer (adjusted for N from MAP but not residual NO_3-N)
1	0 kg P_2O_5/ha	No	None
2	0 kg P_2O_5/ha	Yes	None
3	22 kg P_2O_5/ha	No	None
4	22 kg P_2O_5/ha	Yes	None
5	45 kg P_2O_5/ha	No	None
6	45 kg P_2O_5/ha	Yes	None
7	45 kg P_2O_5/ha	No	55 kg N/ha sideband
8	45 kg P_2O_5/ha	No	55 kg N/ha in-season broadcast
9	45 kg P_2O_5/ha	Yes	55 kg N/ha sideband
10	45 kg P_2O_5/ha	Yes	55 kg N/ha in-season broadcast
11	67 kg P_2O_5/ha	Yes	None
12	67 kg P_2O_5/ha	Yes	55 kg N/ha sideband
- N balanced at 9.5 kg N/ha for treatments 1-4 to separate P from N responses - Both in-crop and side-band urea rates are adjusted for N provided by MAP (i.e., the total quantity of N applied in each of treatments 7, 8, 9, 10, and 12 was 55 kg N/ha			

Selected agronomic information is provided in Table 6 of the Appendices. Seeding was completed on May 4, May 10, and May 18 at Indian Head, Scott, and Swift Current, respectively. Certified seed was used in all cases and the variety was CDC Proclaim CL at Indian Head and CDC Impulse at Scott and Swift Current. All locations used a seed rate of 190 seeds/m^2. The seed was treated with fungicide products to suppress root diseases at all locations but the specific products varied. The plots were rolled after seeding but prior to emergence to break up soil lumps and push any stones down so that they would not interfere with combining. Weeds were controlled using registered pre-emergent and in-crop herbicides. Foliar fungicides were applied at the discretion of individual site managers. Pre-harvest herbicides were utilized as required to assist with crop drydown and provide late-season weed control. The lentils were straight-combined when it was fit to do so with outside crop rows excluded from the harvest area at Indian Head and Swift Current but not at Scott.

Various data were collected during the growing season and from the harvested seed. Residual nutrient levels were estimated from composite soil samples collected in the early spring. Soil was analyzed using two separate approaches with the sampling methods tailored to each method. For the conventional extractions, the sampling depths were 0-15 cm, and 15-60 cm and the samples were submitted to AgVise Laboratories. For the Plant Root Simulator analyses (Indian Head and Swift Current only), we focussed on the top 10 cm of soil and the samples were submitted fresh to Western Ag Laboratories. Spring plant densities were determined by counting seedlings in 2 x 1 m sections of crop row after emergence was complete and calculating plants/m^2. Seed yields were determined from the harvested grain samples, are adjusted for dockage and to a uniform seed

moisture content of 13%, and are expressed as kg/ha. Test weight was determined using standard CGC methodology for two sub-samples per plot and is expressed as g/0.5 l. Seed weight was determined by counting a minimum of 250 whole seeds per plot, weighing to the nearest 0.00 g, and calculating g/1000 seeds. Seed protein was determined using a FOSS NIR analyzer with two subsamples per plot analyzed and the same instrument used for all locations. Daily temperatures and precipitation amounts were recorded from the nearest Environment and Climate Change Canada weather station for each location.

Response data were analyzed separately for each location using the generalized linear mixed model (GLIMMIX) in SAS® Studio. Treatment effects were considered fixed and replicate effects were considered random. Individual treatment means were separated using the Tukey-Kramer test. Orthogonal contrasts were used to test whether any responses to P fertilizer rate were linear, quadratic, or not significant. Pre-determined contrast comparisons were used to compare specific groups of treatments which were considered to be of particular interest. These were un-inoculated versus inoculated (with and without extra N) and no extra N versus extra N (with and without inoculant). All treatment effects and differences between means were considered significant at $P \leq 0.05$; however, responses at $P \leq 0.100$ were also generally highlighted if they made agronomic sense and were deemed important.

10. Results:

Growing season weather and residual soil nutrients

Mean monthly temperatures and precipitation amounts for the 2021 growing seasons (May-August) are presented relative to the long-term (1981-2010) averages in Tables 2 and 3, respectively. Over the four-month period, temperatures were above-average at all three locations. May was slightly cooler than average while June and July were well above-average and August was closer to normal. Precipitation relative to the long-term average varied widely. At Indian Head, there were periods of drought throughout the season but, cumulatively, 295 mm of precipitation fell between May 1 and August 31. That said, much of the precipitation came in a few storm events and nearly 100 mm of this total came later in August after the lentils were harvested. At Scott, there was a total of 149 mm during the four-month period relative to a long-term average of 227 mm; however, similar to Indian Head, 48 mm (32%) of the precipitation reported for this period fell after the lentils were harvested in August. Swift Current received a total of 147 mm, 78% of average, but similar to the other two sites, 49 mm of this was received after the lentils had been harvested. Although lentils can tolerate heat and drought reasonably well compared to many crops, the conditions encountered did increase variability and reduce data quality at some locations, to a certain extent.

Table 2. Mean monthly temperatures along with long-term (1981-2010) averages for the 2021 growing seasons at Indian Head, Scott, and Swift Current, Saskatchewan.

Location	Year	May	June	July	August	Average
		---------- Mean Temperature (°C) ----------				
Indian Head	2021	9.0	17.7	20.3	17.1	16.0 (103%)
	Long-term	*10.8*	*15.8*	*18.2*	*17.4*	*15.6*
Scott	2021	8.9	17.3	19.6	17.2	15.8 (107%)
	Long-term	*10.8*	*14.8*	*17.3*	*16.3*	*14.8*
Swift Current	2021	9.5	18.3	21.6	17.9	16.8 (106%)
	Long-term	*11.0*	*15.7*	*18.4*	*17.9*	*15.8*

Table 3. Mean monthly precipitation along with long-term (1981-2010) averages for the 2021 growing seasons at Indian Head, Scott, and Swift Current, Saskatchewan.

Location	Year	May	June	July	August	Total
		---------- Cumulative Precipitation (mm) ----------				
Indian Head	2021	81.6	62.9	51.2	99.4	295 (121%)
	Long-term	*51.7*	*77.4*	*63.8*	*51.2*	*244*
Scott	2021	43.9	43.8	10.4	51.3	149 (66%)
	Long-term	*38.9*	*69.7*	*69.4*	*48.7*	*227*
Swift Current	2021	30.0	26.8	36.6	53.5	147 (78%)
	Long-term	*42.1*	*66.1*	*44.0*	*35.4*	*188*

Traditional soil test results for each location are provided in Table 4. The site near Indian Head had a pH of 8.1, 4.9% organic matter and cation exchange capacity (CEC) of 47 meq/100 g. Residual NO_3-N was 21 kg/ha and residual P was extremely low at only 2 ppm Olsen-P. Scott had more acidic soil (pH of 5.5) with 4.4% organic matter and coarser soil texture with a CEC of 16 meq/100 g. Residual NO_3-N was 32 kg/ha and there were 6 ppm Olsen-P. At Swift Current, the pH was 6.4, there was 2.6% organic matter, and the CEC was 18 meq/100 g. Residual NO_3-N was 30 kg/ha and Olsen-P was 11 ppm. It is difficult to compare the PRS probe results from Indian Head and Swift Current directly to the traditional soil tests, but they appeared to be reasonably consistent in that N and P were limiting and P supply was lower at Indian Head than at Swift Current (Table 5).

Table 4. Conventional soil test results (AgVise Laboratories) for lentil fertility demonstrations at Indian Head, Scott, and Swift Current, Saskatchewan in 2021.

Depth	pH	SOM (%)	CEC (meq/100g)	NO_3-N (kg/ha)	Olsen-P (ppm)	K (ppm)	S (kg/ha)
Indian Head 2021							
0-15	8.1	4.9	46.7	8	2	532	5
15-60	8.3	–	–	13	–	–	13
Scott 2021							
0-15	5.5	4.4	15.7	12	6	246	16
15-60	7.7	–	–	20	–	–	128
Swift Current 2021							
0-15	6.4	2.6	18.4	13	11	268	36
15-60	7.8	–	–	17	–	–	141

Table 5. Plant Root Simulator (PRS) probe nutrient supply estimates (Western Ag Laboratories) for lentil fertility demonstrations at Indian Head and Swift Current, Saskatchewan in 2021.

pH	Nitrogen (kg N/ha)	Phosphorus (kg P_2O_5/ha)	Potassium (kg K_2O/ha)	Sulfur (kg S/ha)
Indian Head 2021[Z]				
8.4	9	9	23	5
Swift Current 2021[Y]				
6.5	10	22	65	1

[Z] Supply values assume 250 mm total moisture availability (soil + precipitation and red lentil as the crop type
[Y] Supply values assume 228 mm total moisture availability (soil + precipitation and red lentil as the crop type

Plant Density

Detailed results for lentil plant density are provided in Tables 7-10 of the Appendices. Overall, plant densities were highest Indian Head (174 plants/m^2), intermediate at Scott (141 plants/m^2) and lowest at Swift Current (121 plants/m^2). We did not necessarily expect the treatments to affect emergence and, for the most part, this was the case. The overall F-test was significant at Scott (P = 0.017); however, the only difference between individual treatments occurred between the lowest and highest values with no meaningful trends identified (Table 7). The contrast comparing treatments which did not receive extra N to those that did (combined with inoculant) was also significant at Scott (P = 0.025); however, this did not occur in the absence of inoculant and is largely attributed to random variability/experimental error (Table 10). Again, all fertilizer applied during seeding was side-banded away from the seed-row and establishment was similar across the full range of P rates evaluated for all locations (Table 8).

Seed Yield

Individual treatment means for lentil seed yield and overall F-test results are provided in Table 11 of the Appendices while Tables 12-14 contain orthogonal contrast and group comparison results. For easier interpretation, the latter results are also provided in Figs. 1-3 below. The overall F-test indicated highly significant treatment effects at Indian Head (P < 0.001). Closer inspection of yields at this location showed a linear (P < 0.001) response to increasing P fertilizer rates (Table 12; Fig. 1).

There was no significant response to either inoculant (*P* = 0.099-0.603; Table 13; Fig. 2) or extra N fertilizer (*P* = 0.126-0.449; Table 14; Fig. 3). This lack of an inoculant response at Indian Head was somewhat unexpected considering that no peas, lentils, or faba beans had been grown on the site since 2007 and residual N was extremely low. At Scott, yields were variable with no significant overall F-test (*P* = 0.809), linear or quadratic responses to P rate (*P* = 0.862-0.916), or differences between groups of treatments due to inoculant (*P* = 0.277-0.394) or extra N fertilizer (*P* = 0.686-0.835). Numerically, yields did trend higher with inoculant at Scott; however, due to the high overall variability, this could not be attributed to an actual treatment effect. At Swift Current, the overall F-test was marginally significant (*P* = 0.083); however, the Tukey's multiple comparison test did not identify any significant differences between individual treatments. Neither the linear nor quadratic orthogonal contrasts for P rate were significant but, numerically, the highest yields occurred at 22 kg P_2O_5/ha. The group comparisons did not detect significant responses to either inoculant (*P* = 0.236-0.332) or extra N fertilizer (*P* 0.137-0.620) at Swift Current; however, the yields trended slightly higher with the extra inputs in both cases.

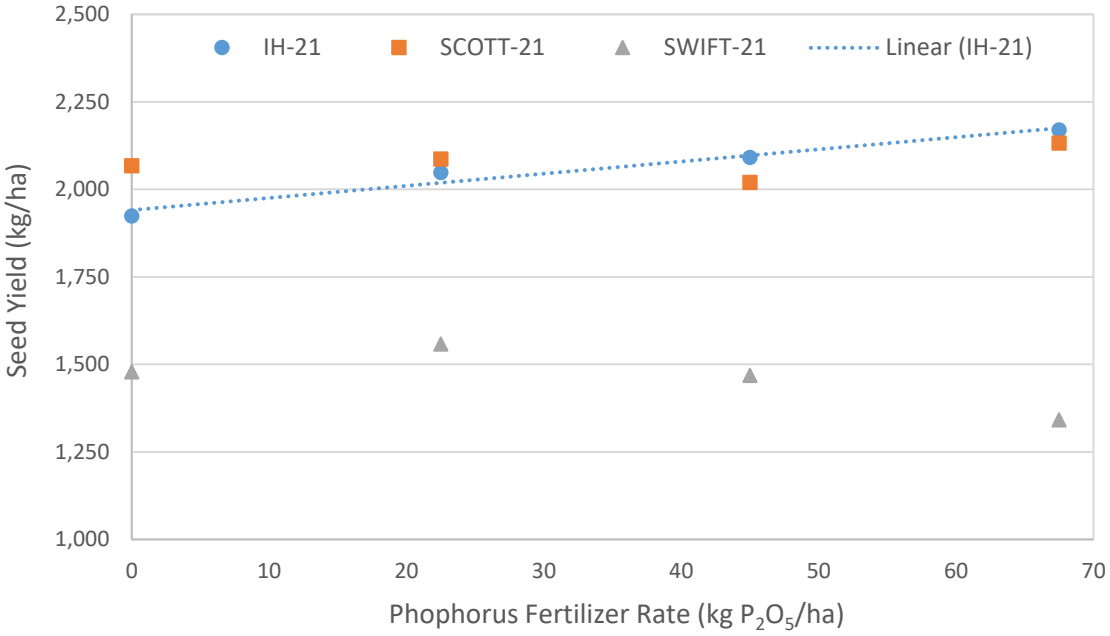

Figure 1. Lentil seed yield response to phosphorus (P) fertilizer rate at Indian Head, Scott, and Swift Current, Saskatchewan in 2021. Only the linear response at Indian Head was significant (*P* < 0.001).

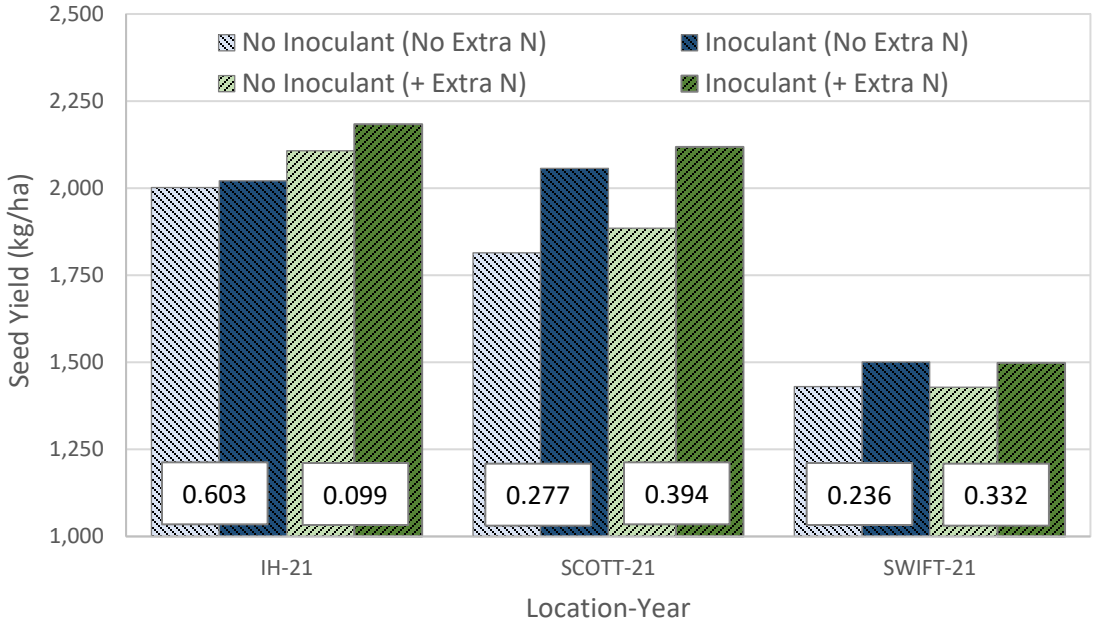

Figure 2. Group contrasts comparing granular inoculant effects on lentil seed yield, with and without the addition of extra nitrogen (N) fertilizer, at Indian Head, Scott, and Swift Current in 2021. P-values ≤ 0.05 are considered significant while P-values ≤ 0.10 may be considered marginally significant.

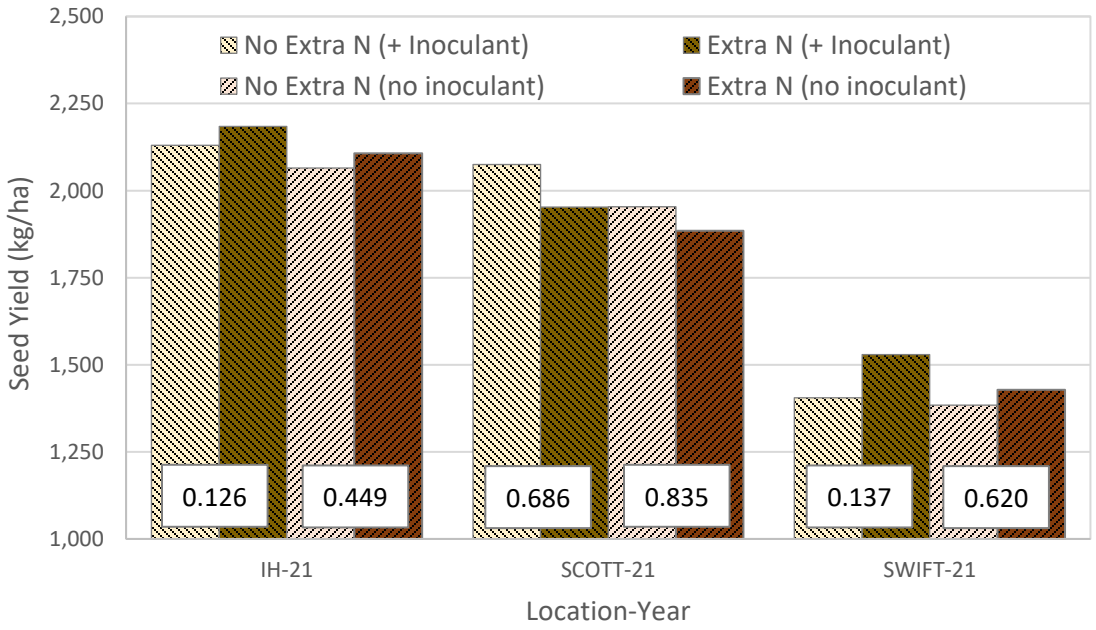

Figure 3. Group contrasts comparing extra nitrogen (N) fertilizer effects on lentil seed yield, with and without the addition of granular inoculant, at Indian Head, Scott, and Swift Current in 2021. P-values ≤ 0.05 are considered significant while P-values ≤ 0.10 may be considered marginally significant.

Test Weight

Individual treatment means for lentil test weight and overall F-test results are provided in Table 15 of the Appendices while orthogonal contrast and group comparison results are in Tables 16-18.

Again, the latter results are presented graphically in Figs. 4-6 below. The overall F-test for test weight was not significant at any locations (*P* = 0.229-0.730) and the multiple comparisons test did not detect any differences between individual treatment means (Table 15). There was no indication of any linear or quadratic responses to P fertilizer rate for this variable (*P* = 0.172-691; Table 16, Fig. 4) nor was there any evidence of granular inoculant (*P* = 0.278-0.630; Table 17; Fig. 5) or extra N (*P* = 0.115-0.725; Table 18; Fig. 6) effects.

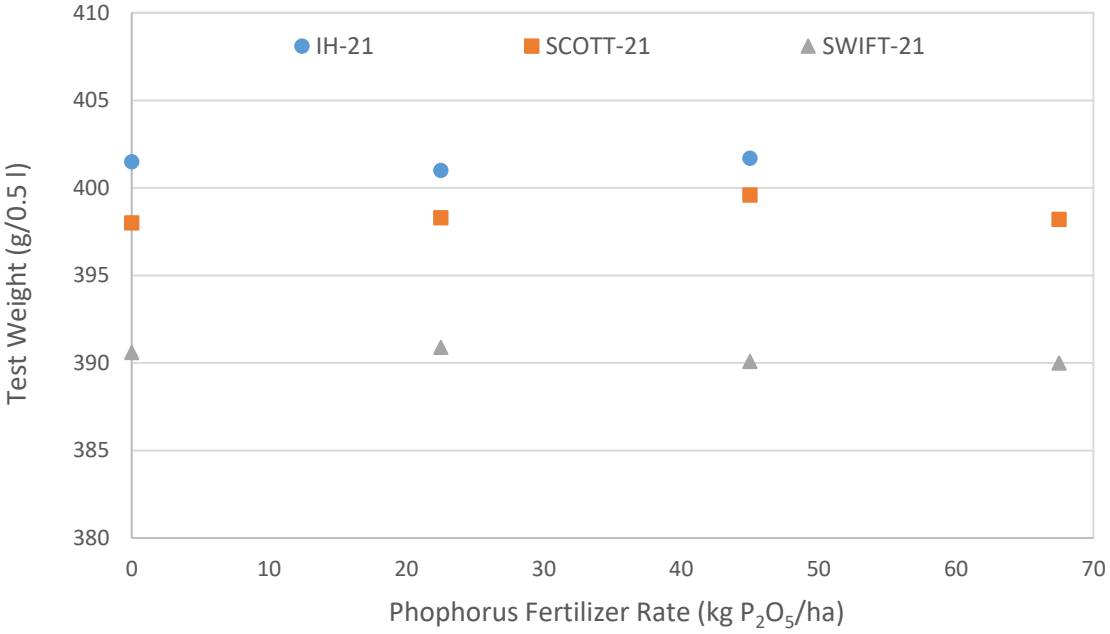

Figure 4. Lentil test weight response to phosphorus (P) fertilizer rate at Indian Head, Scott, and Swift Current, Saskatchewan in 2021. Neither the linear nor quadratic responses were significant at any locations (*P* = 0.172-0.691).

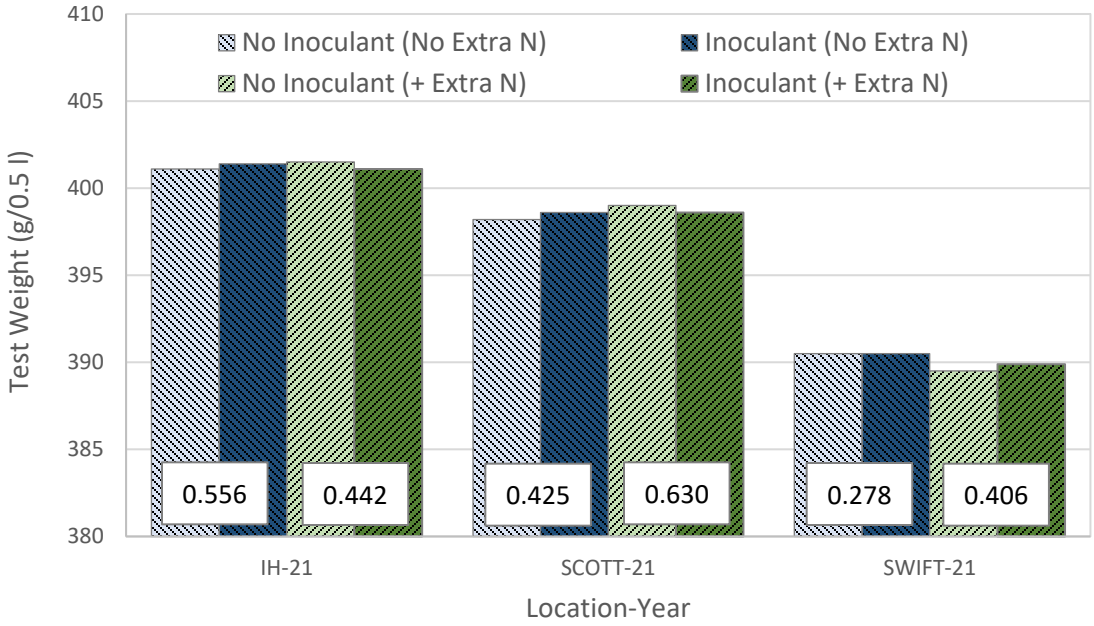

Figure 5. Group contrasts comparing granular inoculant effects on lentil test weight, with and without the addition of extra nitrogen (N) fertilizer, at Indian Head, Scott, and Swift Current in 2021. P-values ≤ 0.05 are considered significant while P-values ≤ 0.10 may be considered marginally significant.

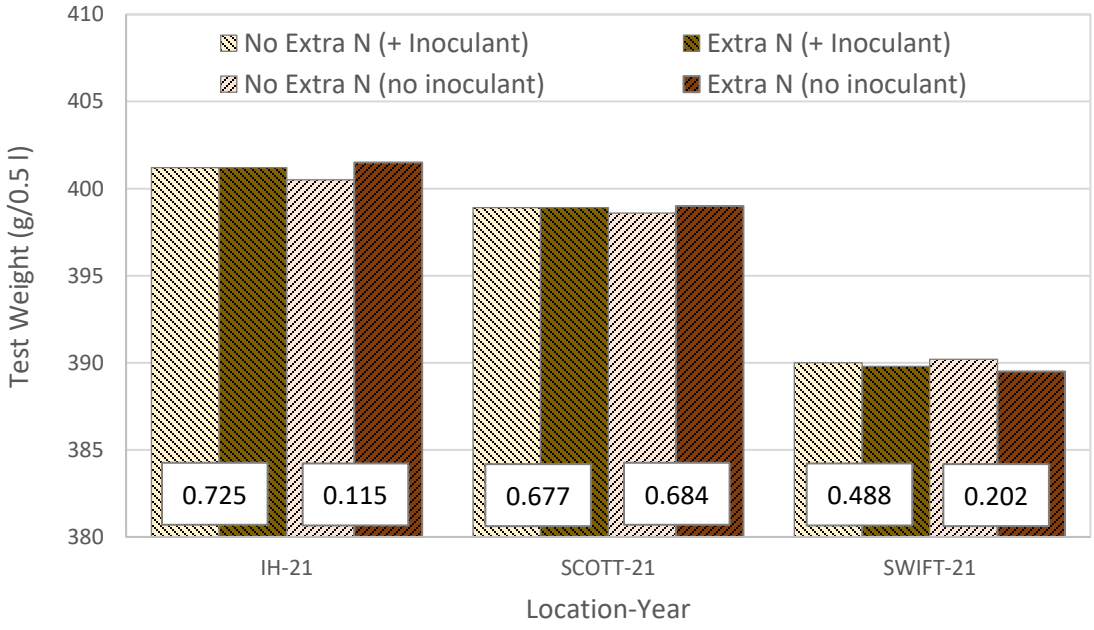

Figure 6. Group contrasts comparing extra nitrogen (N) fertilizer effects on lentil test weight, with and without the addition of granular inoculant, at Indian Head, Scott, and Swift Current in 2021. P-values ≤ 0.05 are considered significant while P-values ≤ 0.10 may be considered marginally significant.

Seed Weight

Individual treatment means for lentil seed weight (thousand kernel weight) and F-test results are in Table 19 of the Appendices while orthogonal contrast and group comparison results appear in

Tables 20-22 in addition to being presented graphically in Figs. 7-9 below. At Indian Head, the overall F-test was not significant (*P* = 0.857), the orthogonal contrasts did not indicate any linear or quadratic responses to increasing P rate (*P* = 0.511-0.922; Table 20; Fig. 7) and seed weights were consistent between inoculant (*P* = 0.511-0.976; Table 21; Fig. 8) and N fertilizer treatments (*P* = 0.373-0.624; Table 22; Fig. 9). At Scott, the overall F-test was not significant (*P* = 0.386) and there were no effects of either inoculant (*P* = 0.216-0.814; Table 21; Fig. 8) nor extra N (*P* = 0.542-0.748; Table 22; Fig. 9). The orthogonal contrasts did detect a quadratic response to P rate where the smallest seeds occurred at 22-45 kg P_2O_5/ha (*P* = 0.021; Table 20; Fig. 7); however, this result is difficult to explain and appeared somewhat inconsistent when the individual treatment means were inspected. At Swift Current, the overall F-test was significant (*P* = 0.043) but the only significant difference amongst individual treatments was between the lowest (45.7 g/1000 seeds) and highest (48.6 g/1000 seeds) values. There was some, albeit weak, evidence of larger seeds with inoculant at Swift Current, particularly when no extra N was applied (*P* = 0.096; Table 21; Fig. 8), but no effect of extra N (*P* = 0.454-0.780; Table 22; Fig. 9).

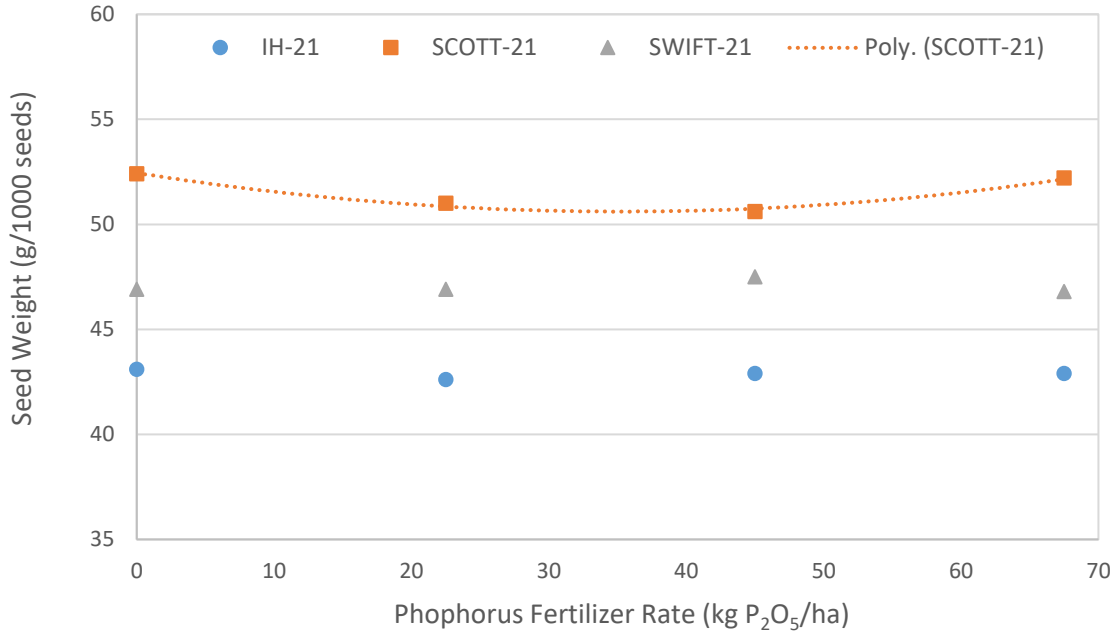

Figure 7. Lentil seed weight response to phosphorus (P) fertilizer rate at Indian Head, Scott, and Swift Current, Saskatchewan in 2021. Only the quadratic response at Scott was significant (*P* = 0.021).

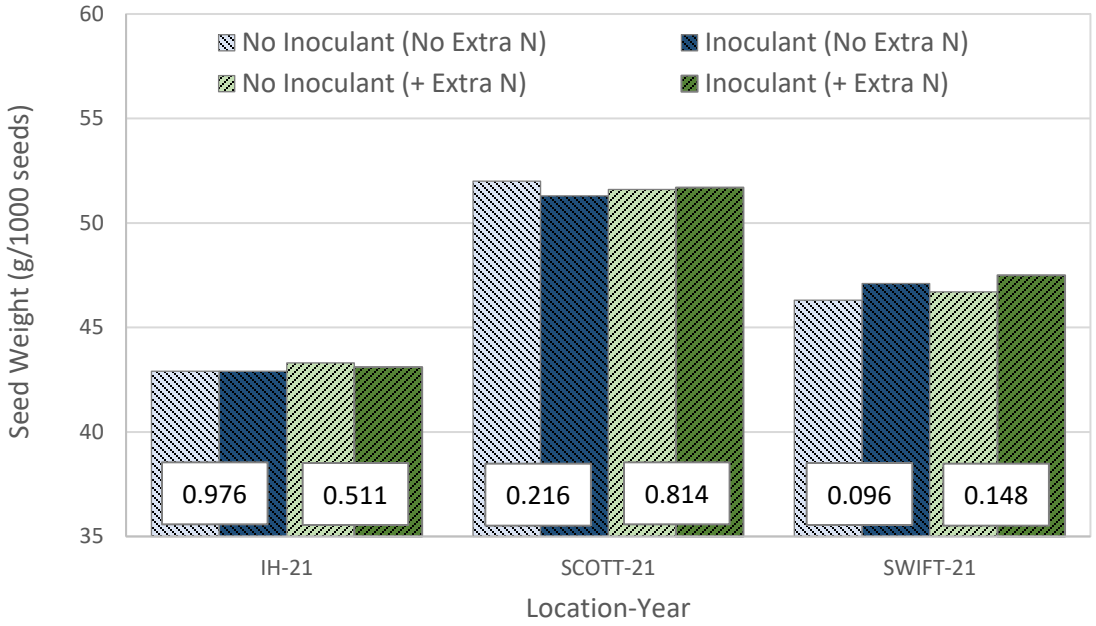

Figure 8. Group contrasts comparing granular inoculant effects on lentil seed weight, with and without the addition of extra nitrogen (N) fertilizer, at Indian Head, Scott, and Swift Current in 2021. P-values ≤ 0.05 are considered significant while P-values ≤ 0.10 may be considered marginally significant.

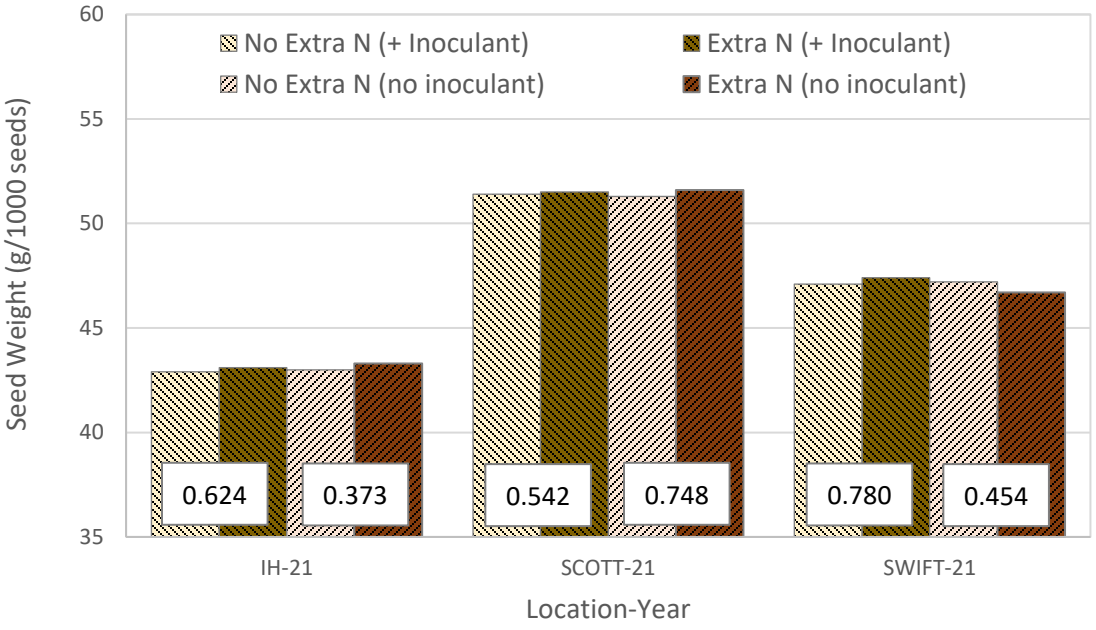

Figure 9. Group contrasts comparing extra nitrogen (N) fertilizer effects on lentil seed weight, with and without the addition of granular inoculant, at Indian Head, Scott, and Swift Current in 2021. P-values ≤ 0.05 are considered significant while P-values ≤ 0.10 may be considered marginally significant.

Seed Protein

Individual treatment means for lentil seed protein and overall F-test results are provided in Table 23 of the Appendices while the orthogonal contrast and group comparison results appear in Tables 24-

26 in addition to being presented graphically in Figs. 10-12 below. The overall F-test was not significant for seed protein at any of the three locations (*P* = 0.206-0.740). The orthogonal contrasts did not pick up any linear or quadratic responses to P rate (*P* = 0.181-0.729; Table 24; Fig. 10). Seed protein was not affected by inoculant at any locations (*P* = 0.574-0.832), regardless of whether supplemental N fertilizer was applied (Table 25; Fig. 11). Similarly, the addition of extra N fertilizer had no impact on lentil seed protein, regardless of location or whether granular inoculant was applied (*P* = 0.229-0.728; Table 26; Fig. 12).

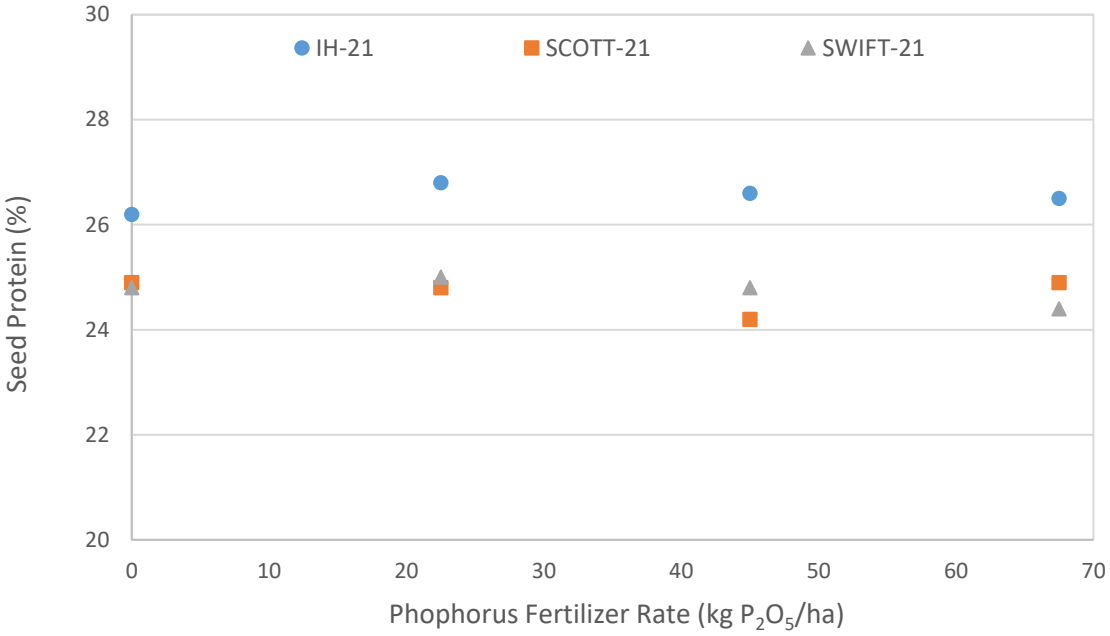

Figure 10. Lentil seed protein response to phosphorus (P) fertilizer rate at Indian Head, Scott, and Swift Current, Saskatchewan in 2021. Neither the linear nor quadratic responses were significant at any locations (*P* = 0.181-0.729).

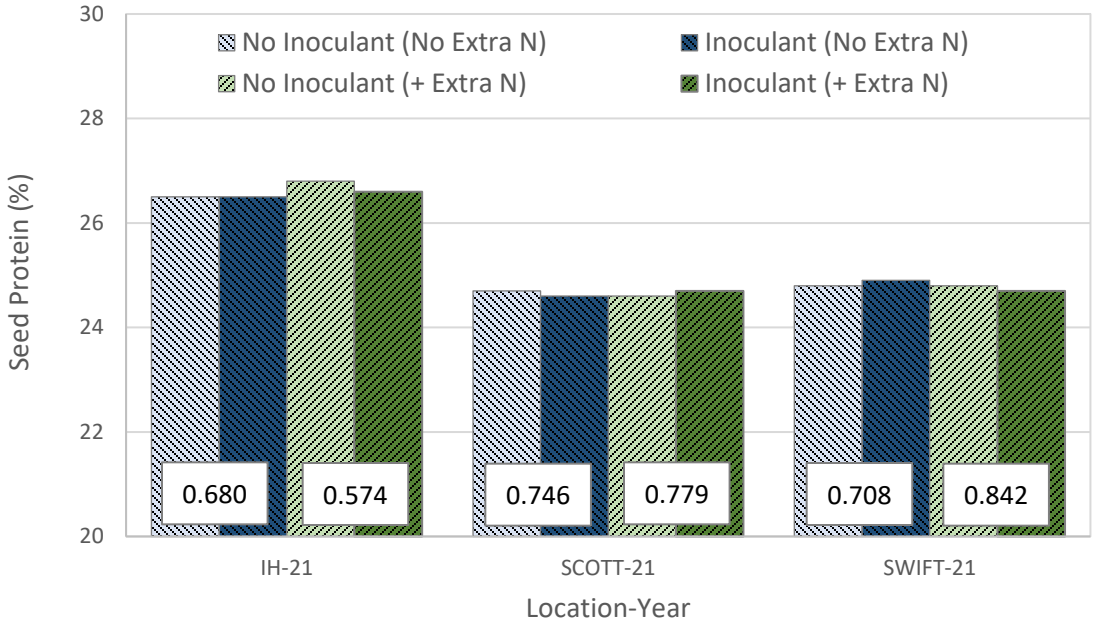

Figure 11. Group contrasts comparing granular inoculant effects on lentil seed protein, with and without the addition of extra nitrogen (N) fertilizer, at Indian Head, Scott, and Swift Current in 2021. P-values ≤ 0.05 are considered significant while P-values ≤ 0.10 may be considered marginally significant.

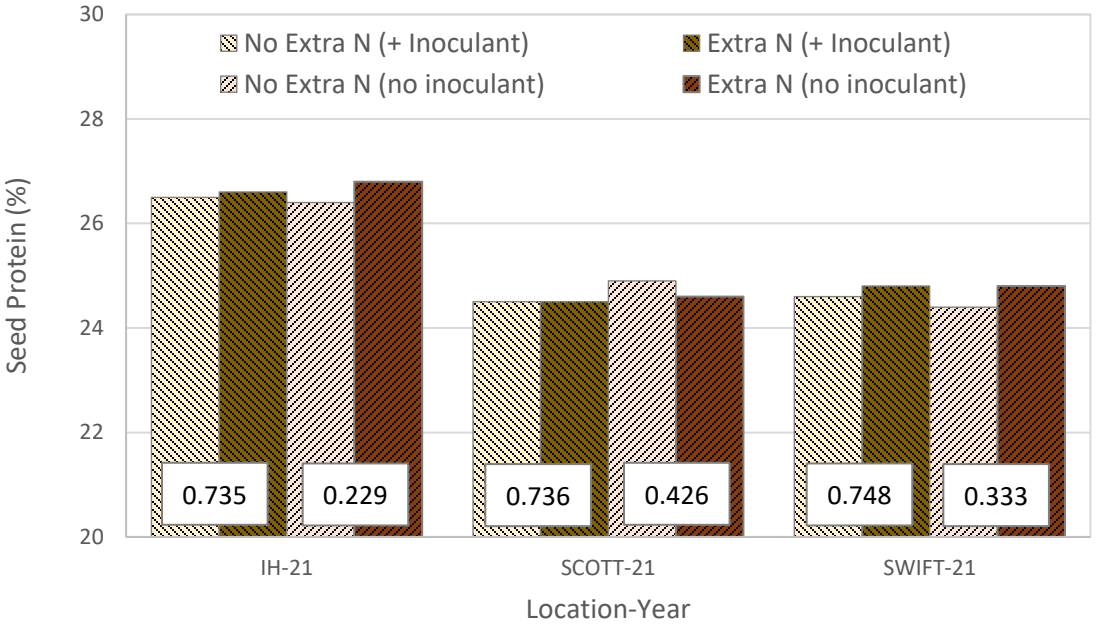

Figure 12. Group contrasts comparing extra nitrogen (N) fertilizer effects on lentil seed protein, with and without the addition of granular inoculant, at Indian Head, Scott, and Swift Current in 2021. P-values ≤ 0.05 are considered significant while P-values ≤ 0.10 may be considered marginally significant.

Extension Activities

While we did host a small field day on July 20, 2021 at Indian Head these plots could not be highlighted for logistic reasons; however, the plots were shown to an assortment of industry

representatives and producers during smaller, informal tours throughout the season. At Swift Current, the plots were shown during multiple tours throughout the season and also highlighted during a CKSW radio program entitled 'Walk the Plots' which is broadcast weekly throughout the growing season. At Scott, this demonstration was highlighted through social media platforms (Facebook and Twitter) during their Virtual Field Day on July 8, 2021.

This annual report will be available online through the IHARF website and results will be highlighted in other presentations and extension activities where appropriate opportunities arise. In addition Saskatchewan Pulse Growers will also incorporate results in their extension and resource materials.

11. Conclusions and Recommendations

While challenging environmental conditions limited yields and also reduced data quality in some cases, this project demonstrated lentil responses to P fertilization and N management strategies under relatively dry field conditions in Saskatchewan.

The lack of meaningful impacts on plant establishment indicated that side-band placement provided sufficient separation between the fertilizer products and the seed-row to prevent seedling toxicity and subsequent stand reduction.

Phosphorus application only increased yields at Indian Head, which had the lowest residual P levels and was also the highest yielding location. This is consistent with past research and supports the notion that lentils are good scavengers of residual nutrients, but can still respond to P fertilization when soil supply is limited and yields are sufficiently high. The observed response at Indian Head was linear; however, rates that would match removal (i.e. 20-40 kg/ha) are likely sufficient to ensure that yields are not limited in most cases. That being said, with only 2 ppm Olsen-P measured in the spring soil test at this site, the higher fertilizer rates could certainly be justified to ensure an adequate supply and help build soil fertility over the longer-term. For Swift Current and Scott, even though statistically significant yield increases with P were not detected, applying 22 kg P_2O_5/ha or more could still be warranted in order to at least maintain residual P levels. Furthermore, the high variability that occurred at Scott limited our ability to detect modest responses to P application. Phosphorus fertilization did not have any important effects on lentil seed quality, regardless of the location.

None of the three sites showed any benefit to rhizobial inoculation, regardless of yield potential or field history. Even though the site at Indian Head had not been seeded to peas, lentils, or faba beans for 13 years, the crop did not respond to inoculation and plants that were inspected during the season appeared to be well-nodulated. The greatest numerical differences in yield between un-inoculated and inoculated treatments occurred at Scott; however, variability was too high for the differences to be considered significant and, with peas on the site only two seasons prior, the probability of response to this input was potentially low. At Swift Current, there was some evidence of larger seeds with inoculant, but this response was only marginally significant at best. There was no protein response to rhizobial inoculation at any locations; thus, providing solid further evidence that N was not limiting in the un-inoculated treatments. Despite these results, we would be hesitant to recommend not applying a rhizobial inoculant due to the high importance of N_2 fixation; however, lentil growers looking to reduce input costs might consider utilizing less expensive formulations (i.e., seed-applied), particularly if the field has a history of pea/lentil productions and neither nodulation failures or N deficiencies have been observed in the past. Under such circumstances, it is unlikely that there would be any benefit to either dual inoculation (i.e., liquid plus granular) or exceeding label recommendations as we have seen with some legume crops such

as soybean where the associated rhizobium species is not native and there is limited history of the specific crop in rotation.

Similar to recent work with field peas and much of the previously published data, we did not see any benefit to N fertilizer applications in this project and, as such, have no reason to recommend this practice. While deferring N applications into the growing season may reduce the potential for negative impacts associated with reduced N fixation to occur, such N still relies on precipitation to be moved into the rooting zone and has failed to yield any benefits either in the current project or recent work with field peas where we evaluated similar practices. If nodulation failure and subsequent N deficiencies are confirmed early enough in the growing season, in-crop 'rescue' applications of N could have merit and may be the best option to correct such deficiencies, but are still unlikely to completely mitigate yield loss. In addition, applying a small amount of starter N may be justifiable to prevent early season deficiencies in coarse textured soils that are low in organic matter and residual NO_3-N; however, the N that is provided by modest rates of P and S (if applicable) can likely fulfill much of the crop's N demands before biological N_2 fixation takes over.

Due the challenging growing conditions and relatively small number of locations under which the treatments were evaluated, it would be beneficial to repeat this demonstration in order to document responses for a broader range of environments and generate more robust recommendations.

Supporting Information

12. Acknowledgements:

This project was financially supported by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canadian Agricultural Partnership bi-lateral agreement between the federal government and the Saskatchewan Ministry of Agriculture. The project was administrated in-kind by the Saskatchewan Pulse Crop Development Board. We would also like to acknowledge the Board of Directors from each of the participating organizations in addition to the many technical and professional staff without whom this project could not have been completed. IHARF, WARC, and WCA also have strong working relationships and memorandums of understanding with Agriculture and Agri-Food Canada which should be acknowledged and help make work like this possible.

13. Appendices:

Table 6. Selected agronomic information and dates of operations in 2021 for lentil trials at Indian Head, Scott, and Swift Current, Saskatchewan.

Activity	Indian Head	Scott	Swift Current
Previous Crop	Oat	Wheat	Barley
Most Recent Peas/Lentils	2007	2019	unknown, prior to 2016
Pre-seed Herbicide	890g glyphosate/ha (May 11)	1334 g glyphosate/ha + 21 g carfentrazone-ethyl (May 9)	890 g glyphosate/ha + 21 g carfentrazone-ethyl (May 3)
Seeding	May 4	May 10	May 18
Row Spacing	30 cm	25 cm	21 cm
Variety	CDC Proclaim CL	CDC Impulse CL	CDC Impulse CL
Seed Treatment	300 ml Insure Pulse + 39 ml INTEGO Solo/100 kg seed	100 ml Vibrance Maxx RFC/100 kg seed	100 ml Vibrance Maxx/100 kg seed
In-crop Herbicide	20g imazamox/ha + 9g imazapyr/ha (June 13)	20g imazamox/ha + 171g sethoxydim/ha (June 13)	211 g sethoxydim/ha (May 31) 20g imazamox/ha (June 16) 59g clethodim/ha (June 21)
Emergence Counts	June 18	June 14	June 11
In-Crop Nitrogen	June 23 (as per protocol)	June 24 (as per protocol)	July 5 (as per protocol)
Foliar Fungicide	99g fluxapyroxad/ha + 99g pryaclostrobin/ha (June 30)	99g fluxapyroxad/ha + 99g pryaclostrobin/ha (July 5)	no foliar fungicide applied
Pre-harvest Herbicide / Desiccant	890g glyphosate/ha (July 30) 410g diquat/ha (August 3)	410g diquat/ha (August 4)	410g diquat/ha (August 6)
Harvest	August 8	August 12	August 13

Table 7. Lentil fertility treatment effects on mean plant densities at Indian Head, Scott, and Swift Current, Saskatchewan in 2021. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, $P \leq 0.05$).

P_2O_5 Rate - Inoculant - Extra N	Indian Head	Scott	Swift Current
	---------- p-value ----------		
Overall F-test Results (Pr > *F*)	0.643	0.017	0.519
	---------- Plant Density (plants/m^2) ----------		
1) 0P - No - None	171.4 a	157.5 a	134.9 a
2) 0P - Yes - None	178.8 a	146.7 ab	120.5 a
3) 22P - No - None	150.1 a	139.3 ab	126.2 a
4) 22P - Yes - None	169.8 a	124.7 b	111.6 a
5) 45P - No - None	185.0 a	139.0 ab	121.1 a
6) 45P - Yes - None	172.3 a	151.9 ab	116.1 a
7) 45P - No - 55N sideband	175.1 a	130.2 ab	124.4 a
8) 45P - No - 55N in-crop	171.9 a	146.4 ab	120.5 a
9) 45P - Yes - 55N sideband	177.6 a	136.1 ab	119.6 a
10) 45P - Yes - 55N in-crop	168.6 a	130.2 ab	116.4 a
11) 67P - Yes - None	178.0 a	144.4 ab	114.0 a
12) 67P - Yes - 55N sideband	189.9 a	142.7 ab	126.8 a
S.E.M	11.09	5.92	6.63

Table 8. Linear and quadratic orthogonal contrast results for phosphorus fertilizer rate effects on lentil plant densities at Indian Head, Scott, and Swift Current (2021). Only treatments with granular inoculant and no additional N fertilizer were included.

Phosphorous Fertilizer Rate	Indian Head	Scott	Swift Current
	---------- Plant Density (plants/m^2) ----------		
0 kg P_2O_5/ha (2)	178.8	146.7	120.5
22 kg P_2O_5/ha (4)	169.8	124.7	111.6
45 kg P_2O_5/ha (6)	172.3	151.9	116.1
67 kg P_2O_5/ha (11)	178.0	144.4	114.0
Orthogonal Contrast	---------- Pr > *F* (p-value) ----------		
P Rate – Linear	0.999	0.445	0.612
P Rate – Quadratic	0.506	0.229	0.608

Table 9. Predetermined contrasts comparing un-inoculated to inoculated lentils, with and without extra nitrogen (N) fertilizer for plant density at Indian Head, Scott, and Swift Current (2021).

Inoculant Group Comparisons	Indian Head	Scott	Swift Current
	---------- Plant Density (plants/m^2) ----------		
No inoculant – No extra N (1,3,5) vs.	168.8 A	145.3 A	127.4 A
Inoculant – No extra N (2,4,6)	173.6 B	141.1 A	116.1 B
Pr > *F* (p-value)	0.598	0.392	0.044
No Inoculant + Extra N (7,8) vs.	173.5 A	138.3 A	122.5 A
Inoculant + Extra N (9,10)	173.1 A	133.1 A	118.0 A
Pr > *F* (p-value)	0.969	0.390	0.503

Table 10. Predetermined contrasts comparing lentils with no extra nitrogen (N) fertilizer to lentils with extra N fertilizer, with and without inoculant for plant density at Indian Head, Scott, and Swift Current (2021).

Extra N Group Comparisons	Indian Head	Scott	Swift Current
	---------- Plant Density (plants/m^2) ----------		
No Extra N + Inoculant (6,11) vs.	175.1 A	148.1 A	115.0 A
Extra N + Inoculant (9,10,12)	178.7 A	136.3 A	120.9 A
Pr > *F* (p-value)	0.667	0.025	0.379
No Extra N – No Inoculant (5) vs.	185.0 A	139.0 A	121.1 A
Extra N – No Inoculant (7,8)	173.5 A	138.3 A	122.5 A
Pr > *F* (p-value)	0.401	0.918	0.869

Table 11. Lentil fertility treatment effects on mean seed yield at Indian Head, Scott, and Swift Current, Saskatchewan in 2021. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, $P \leq 0.05$).

P_2O_5 Rate - Inoculant - Extra N	Indian Head	Scott	Swift Current
	---------- p-value ----------		
Overall F-test Results (Pr > *F*)	<0.001	0.809	0.083
	---------- Seed Yield (kg/ha) ----------		
1) 0P - No - None	1937 c	1668 a	1393 a
2) 0P - Yes - None	1923 c	2067 a	1478 a
3) 22P - No - None	2003 abc	1819 a	1515 a
4) 22P - Yes - None	2048 abc	2086 a	1558 a
5) 45P - No - None	2065 abc	1954 a	1384 a
6) 45P - Yes - None	2091 abc	2018 a	1468 a
7) 45P - No - 55N sideband	2208 a	1781 a	1324 a
8) 45P - No - 55N in-crop	2007 abc	1990 a	1531 a
9) 45P - Yes - 55N sideband	2219 a	1869 a	1610 a
10) 45P - Yes - 55N in-crop	2149 ab	2367 a	1387 a
11) 67P - Yes - None	2169 a	2132 a	1341 a
12) 67P - Yes - 55N sideband	2183 a	1622 a	1590 a
S.E.M	87.5	273.9	126.3

Table 12. Linear and quadratic orthogonal contrast results for phosphorus fertilizer rate effects on lentil seed yield at Indian Head, Scott, and Swift Current (2021). Only treatments with granular inoculant and no additional N fertilizer were included.

Phosphorous Fertilizer Rate	Indian Head	Scott	Swift Current
	---------- Seed Yield (kg/ha) ----------		
0 kg P_2O_5/ha (2)	1923	2067	1478
22 kg P_2O_5/ha (4)	2048	2086	1558
45 kg P_2O_5/ha (6)	2091	2019	1468
67 kg P_2O_5/ha (11)	2169	2132	1341
Orthogonal Contrast	---------- Pr > *F* (p-value) ----------		
P Rate – Linear	<0.001	0.916	0.129
P Rate – Quadratic	0.606	0.862	0.159

Table 13. Predetermined contrasts comparing un-inoculated to inoculated lentils, with and without extra nitrogen (N) fertilizer for seed yield at Indian Head, Scott, and Swift Current (2021).

Inoculant Group Comparisons	Indian Head	Scott	Swift Current
	---------- Seed Yield (kg/ha) ----------		
No inoculant – No extra N (1,3,5) vs.	2002 A	1814 A	1430 A
Inoculant – No extra N (2,4,6)	2021 A	2057 A	1501 A
Pr > *F* (p-value)	0.603	0.277	0.236
No Inoculant + Extra N (7,8) vs.	2107 A	1885 A	1428 A
Inoculant + Extra N (9,10)	2184 A	2118 A	1498 A
Pr > *F* (p-value)	0.099	0.394	0.332

Table 14. Predetermined contrasts comparing lentils with no extra nitrogen (N) fertilizer to lentils with extra N fertilizer, with and without inoculant for seed yield at Indian Head, Scott, and Swift Current (2021).

Extra N Group Comparisons	Indian Head	Scott	Swift Current
	---------- Seed Yield (kg/ha) ----------		
No Extra N + Inoculant (6,11) vs.	2130 A	2075 A	1405 A
Extra N + Inoculant (9,10,12)	2184 A	1953 A	1529 A
Pr > *F* (p-value)	0.126	0.686	0.137
No Extra N – No Inoculant (5) vs.	2065 A	1954 A	1384 A
Extra N – No Inoculant (7,8)	2107 A	1885 A	1428 A
Pr > *F* (p-value)	0.449	0.835	0.620

Table 15. Lentil fertility treatment effects on mean test weight at Indian Head, Scott, and Swift Current, Saskatchewan in 2021. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, $P \leq 0.05$).

P_2O_5 Rate - Inoculant - Extra N	Indian Head	Scott	Swift Current
	---------- p-value ----------		
Overall F-test (Pr > *F*)	0.730	0.658	0.229
	---------- Test Weight (g/0.5 l) ----------		
1) 0P - No - None	401.3 a	398.0 a	390.2 a
2) 0P - Yes - None	401.5 a	398.0 a	390.6 a
3) 22P - No - None	401.6 a	398.0 a	390.1 a
4) 22P - Yes - None	401.0 a	398.3 a	390.9 a
5) 45P - No - None	400.5 a	398.6 a	390.2 a
6) 45P - Yes - None	401.7 a	399.6 a	390.1 a
7) 45P - No - 55N sideband	401.4 a	398.5 a	389.3 a
8) 45P - No - 55N in-crop	401.6 a	399.5 a	389.7 a
9) 45P - Yes - 55N sideband	401.5 a	398.3 a	389.3 a
10) 45P - Yes - 55N in-crop	400.6 a	399.0 a	390.5 a
11) 67P - Yes - None	400.7 a	398.2 a	390.0 a
12) 67P - Yes - 55N sideband	401.4 a	399.4 a	389.6 a
S.E.M	0.53	0.93	0.56

Table 16. Linear and quadratic orthogonal contrast results for phosphorus fertilizer rate effects on lentil test weight at Indian Head, Scott, and Swift Current (2021). Only treatments with granular inoculant and no additional N fertilizer were included.

Phosphorous Fertilizer Rate	Indian Head	Scott	Swift Current
	---------- Test Weight (g/0.5 l) ----------		
0 kg P_2O_5/ha (2)	401.5	398.0	390.6
22 kg P_2O_5/ha (4)	401.0	398.3	390.9
45 kg P_2O_5/ha (6)	401.7	399.6	390.1
67 kg P_2O_5/ha (11)	400.7	398.2	390.0
Orthogonal Contrast	---------- Pr > *F* (p-value) ----------		
P Rate – Linear	0.451	0.535	0.172
P Rate – Quadratic	0.691	0.244	0.592

Table 17. Predetermined contrasts comparing un-inoculated to inoculated lentils, with and without extra nitrogen (N) fertilizer for test weight at Indian Head, Scott, and Swift Current (2021).

Inoculant Group Comparisons	Indian Head	Scott	Swift Current
	---------- Test Weight (g/0.5 l) ----------		
No inoculant – No extra N (1,3,5) vs.	401.1 A	398.2 A	390.5 A
Inoculant – No extra N (2,4,6)	401.4 A	398.6 A	390.5 A
Pr > *F* (p-value)	0.556	0.425	0.278
No Inoculant + Extra N (7,8) vs.	401.5 A	399.0 A	389.5 A
Inoculant + Extra N (9,10)	401.1 A	398.6 A	389.9 A
Pr > *F* (p-value)	0.442	0.630	0.406

Table 18. Predetermined contrasts comparing lentils with no extra nitrogen (N) fertilizer to lentils with extra N fertilizer, with and without inoculant for test weight at Indian Head, Scott, and Swift Current (2021).

Extra N Group Comparisons	Indian Head	Scott	Swift Current
	---------- Test Weight (g/0.5 l) ----------		
No Extra N + Inoculant (6,11) vs.	401.2 A	398.9 A	390.0 A
Extra N + Inoculant (9,10,12)	401.2 A	398.9 A	389.8 A
Pr > *F* (p-value)	0.725	0.677	0.488
No Extra N – No Inoculant (5) vs.	400.5 A	398.6 A	390.2 A
Extra N – No Inoculant (7,8)	401.5 A	399.0 A	389.5 A
Pr > *F* (p-value)	0.115	0.684	0.202

Table 19. Lentil fertility treatment effects on mean seed weight at Indian Head, Scott, and Swift Current, Saskatchewan in 2021. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, $P \leq 0.05$).

P_2O_5 Rate - Inoculant - Extra N	Indian Head	Scott	Swift Current
	---------- p-value ----------		
Overall F-test (Pr > *F*)	0.857	0.386	0.043
	---------- Seed Weight (g/1000 seeds) ----------		
1) 0P - No - None	42.9 a	52.2 a	45.9 ab
2) 0P - Yes - None	43.1 a	52.4 a	46.9 ab
3) 22P - No - None	42.7 a	52.4 a	45.8 ab
4) 22P - Yes - None	42.6 a	51.0 a	46.9 ab
5) 45P - No - None	43.0 a	51.3 a	47.2 ab
6) 45P - Yes - None	42.9 a	50.6 a	47.5 ab
7) 45P - No - 55N sideband	43.3 a	51.3 a	45.7 b
8) 45P - No - 55N in-crop	43.3 a	51.9 a	47.6 ab
9) 45P - Yes - 55N sideband	43.4 a	51.1 a	46.5 ab
10) 45P - Yes - 55N in-crop	42.8 a	52.3 a	48.6 a
11) 67P - Yes - None	42.9 a	52.2 a	46.8 ab
12) 67P - Yes - 55N sideband	43.0 a	51. 0 a	47.1 ab
S.E.M	0.39	0.66	0.57

Table 20. Linear and quadratic orthogonal contrast results for phosphorus fertilizer rate effects on lentil seed weight at Indian Head, Scott, and Swift Current (2021). Only treatments with granular inoculant and no additional N fertilizer were included.

Phosphorous Fertilizer Rate	Indian Head	Scott	Swift Current
	---------- Seed Weight (g/1000 seeds) ----------		
0 kg P_2O_5/ha (2)	43.1	52.4	46.9
22 kg P_2O_5/ha (4)	42.6	51.0	46.9
45 kg P_2O_5/ha (6)	42.9	50.6	47.5
67 kg P_2O_5/ha (11)	42.9	52.2	46.8
Orthogonal Contrast	---------- Pr > *F* (p-value) ----------		
P Rate – Linear	0.922	0.686	0.945
P Rate – Quadratic	0.511	0.021	0.498

Table 21. Predetermined contrasts comparing un-inoculated to inoculated lentils, with and without extra nitrogen (N) fertilizer for seed weight at Indian Head, Scott, and Swift Current (2021).

Inoculant Group Comparisons	Indian Head	Scott	Swift Current
	---------- Seed Weight (g/1000 seeds) ----------		
No inoculant – No extra N (1,3,5) vs.	42.9 A	52.0 A	46.3 A
Inoculant – No extra N (2,4,6)	42.9 A	51.3 A	47.1 A
Pr > *F* (p-value)	0.976	0.216	0.096
No Inoculant + Extra N (7,8) vs.	43.3 A	51.6 A	46.7 A
Inoculant + Extra N (9,10)	43.1 A	51.7 A	47.5 A
Pr > *F* (p-value)	0.511	0.814	0.148

Table 22. Predetermined contrasts comparing lentils with no extra nitrogen (N) fertilizer to lentils with extra N fertilizer, with and without inoculant for seed weight at Indian Head, Scott, and Swift Current (2021).

Extra N Group Comparisons	Indian Head	Scott	Swift Current
	---------- Seed Weight (g/1000 seeds) ----------		
No Extra N + Inoculant (6,11) vs.	42.9 A	51.4 A	47.1 A
Extra N + Inoculant (9,10,12)	43.1 A	51.5 A	47.4 A
Pr > *F* (p-value)	0.624	0.542	0.780
No Extra N – No Inoculant (5) vs.	43.0 A	51.3 A	47.2 A
Extra N – No Inoculant (7,8)	43.3 A	51.6 A	46.7 A
Pr > *F* (p-value)	0.373	0.748	0.454

Table 23. Lentil fertility treatment effects on mean seed protein at Indian Head, Scott, and Swift Current, Saskatchewan in 2021. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, $P \leq 0.05$).

P_2O_5 Rate - Inoculant - Extra N	Indian Head	Scott	Swift Current
	---------- p-value ----------		
Overall F-test (Pr > *F*)	0.658	0.206	0.740
	---------- Seed Protein (%) ----------		
1) 0P - No - None	26.5 a	24.7 a	25.2 a
2) 0P - Yes - None	26.2 a	24.9 a	24.8 a
3) 22P - No - None	26.5 a	24.4 a	24.7 a
4) 22P - Yes - None	26.8 a	24.8 a	25.0 a
5) 45P - No - None	26.4 a	24.9 a	24.4 a
6) 45P - Yes - None	26.6 a	24.2 a	24.8 a
7) 45P - No - 55N sideband	26.5 a	24.3 a	25.0 a
8) 45P - No - 55N in-crop	27.1 a	25.0 a	24.6 a
9) 45P - Yes - 55N sideband	26.4 a	24.6 a	24.7 a
10) 45P - Yes - 55N in-crop	26.9 a	24.8 a	24.7 a
11) 67P - Yes - None	26.5 a	24.9 a	24.4 a
12) 67P - Yes - 55N sideband	26.6 a	24.0 a	24.8 a
S.E.M	0.28	0.28	0.31

Table 24. Linear and quadratic orthogonal contrast results for phosphorus fertilizer rate effects on lentil seed protein at Indian Head, Scott, and Swift Current (2021). Only treatments with granular inoculant and no additional N fertilizer were included.

Phosphorous Fertilizer Rate	Indian Head	Scott	Swift Current
	---------- Seed Protein (%) ----------		
0 kg P_2O_5/ha (2)	26.2	24.9	24.8
22 kg P_2O_5/ha (4)	26.8	24.8	25.0
45 kg P_2O_5/ha (6)	26.6	24.2	24.8
67 kg P_2O_5/ha (11)	26.5	24.9	24.4
Orthogonal Contrast	---------- Pr > *F* (p-value) ----------		
P Rate – Linear	0.729	0.636	0.260
P Rate – Quadratic	0.221	0.181	0.300

Table 25. Predetermined contrasts comparing un-inoculated to inoculated lentils, with and without extra nitrogen (N) fertilizer for seed protein at Indian Head, Scott, and Swift Current (2021).

Inoculant Group Comparisons	Indian Head	Scott	Swift Current
	---------- Seed Protein (%) ----------		
No inoculant – No extra N (1,3,5) vs.	26.5 A	24.7 A	24.8 A
Inoculant – No extra N (2,4,6)	26.5 A	24.6 A	24.9 A
Pr > *F* (p-value)	0.680	0.746	0.708
No Inoculant + Extra N (7,8) vs.	26.8 A	24.6 A	24.8 A
Inoculant + Extra N (9,10)	26.6 A	24.7 A	24.7 A
Pr > *F* (p-value)	0.574	0.779	0.842

Table 26. Predetermined contrasts comparing lentils with no extra nitrogen (N) fertilizer to lentils with extra N fertilizer, with and without inoculant for seed protein at Indian Head, Scott, and Swift Current (2021).

Extra N Group Comparisons	Indian Head	Scott	Swift Current
	---------- Seed Protein (%) ----------		
No Extra N + Inoculant (6,11) vs.	26.5 A	24.5 A	24.6 A
Extra N + Inoculant (9,10,12)	26.6 A	24.5 A	24.8 A
Pr > *F* (p-value)	0.735	0.736	0.748
No Extra N – No Inoculant (5) vs.	26.4 A	24.9 A	24.4 A
Extra N – No Inoculant (7,8)	26.8 A	24.6 A	24.8 A
Pr > *F* (p-value)	0.229	0.426	0.333

Abstract

14. Abstract/Summary

Field trials were conducted at Indian Head, Scott, and Swift Current in 2021 to demonstrate lentil response to phosphorus (P) rate and nitrogen (N) management strategies that encompassed combinations of rhizobial inoculant, starter N, and in-crop N. The locations were representative of the Brown, Dark Brown, and thin Black soil zones of Saskatchewan. The variety was CDC Proclaim CL at Indian Head and CDC Impulse CL at Scott and Swift Current, the seed rate was 190 seeds/m^2, weeds were controlled using registered herbicides, and fungicides were applied at the discretion of site managers. The most recent pea or lentil crop ranged from only two years prior at Scott to 13 years at Indian Head. In addition to residual soil nutrients and weather, data collection included emergence, seed yield, test weight, seed weight, and seed protein. Emergence was not affected by the treatments in any cases, indicating that side-banding provided adequate separation between the fertilizer and seed-row. Yields were only increased with P fertilizer at Indian Head, the location with both the highest yields and the lowest residual P levels. No yield benefits to rhizobial inoculation were detected at any locations. Whether supplied as side-banded urea or an in-season broadcast application, extra N did not affect yield. Neither rhizobial inoculant nor N fertilizer impacted seed protein concentrations; thus, providing compelling evidence that N was not limiting in any treatments at any locations. In conclusion, we still recommend applying P fertilizer to prevent yield loss and maintain soil fertility with the sole exception potentially being fields where residual P is already high (i.e. manured fields). Similarly, we hesitate to suggest that growers may not need to apply inoculant as biological N fixation is critical for profitable lentil production. We do not recommend applying N fertilizer beyond what may be supplied by modest rates of P and sulfur products. Possible exceptions include rescue applications if nodulation failure is confirmed and, perhaps, coarse textured soils extremely low in both organic matter and residual N. Due to the unusually hot and dry weather in 2021, there may be value in repeating this project in 2022.
