2022 Final Report

for the

Saskatchewan Pulse Crop Development Board

Agronomic and Economic Response of Lentil to Seed Rate and Fungicides

(Project #AP-2207a)

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1. **Project Code (as is in contract):** AP2207a

2. **Project Title:** Agronomic and Economic Response of Lentil to Seed Rate and Fungicides

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

This project was initiated as a follow-up to a recently concluded ADF/SPG/WGRF research project led by Jessica Enns (Weber) in collaborations with multiple Agri-ARM sites and the University of Saskatchewan (Weber et al. 2019). That study evaluated multiple combinations of seeding rates, fungicide application strategies, and herbicide layering for improved weed control. Amongst other variables, data collection included relatively intensive weed measurements and disease ratings. Several key messages were derived from the work.

A pre-seed residual herbicide reduced early season annual weed populations by 66% compared to the traditional pre-seed burn-off strategy (i.e., glyphosate only). Weed issues were most severe at the commonly recommended seeding rate of 130 seeds/m^2 compared to higher rates. A seeding rate of 190 seeds/m^2 resulted in the highest yield and net returns compared to seeding rates of 130 or 260 seeds/m^2. Prior to this, under organic management and subsequently heavy weed pressure, Baird et al. (2009) achieved the highest yields and economic returns with a seeding rate of 235 seeds/m^2 and subsequent plant densities of approximately 150-160 plants/m^2; however, the closest seeding rate below this was only 94 seeds/m^2. As such, it is unclear whether intermediate seeding rates may have been sufficient under these weedy conditions.

In the Weber et al. (2019) study, disease severity tended to increase with seeding rate (260 seeds/m^2 > 190 seeds/m^2 > 130 seeds/ m^2). The work showed that a single fungicide application was more likely to be required when higher seeding rates were used and dual fungicide applications may be required under higher disease pressure; however, under the conditions encountered for that project, the cost of a fungicide typically reduced net returns compared to the unsprayed treatments. These specific field trials were generally conducted under dry conditions with low disease pressure; thus, may not have shown the economic benefits that were likely to have occurred under wetter conditions. For example, at Saskatoon in 2016, Kasper (2019) maximized red lentil yields with a combination of higher seeding rates (targeting 240 plants/m^2) and two fungicide applications (Headline® and Bravo®).

The Saskatchewan Pulse Growers specifically identified a need to expand on this recent work with a follow-up project to demonstrate the key findings, build upon the existing knowledge base (for a broader range of conditions) and create opportunities to share the information with farmers throughout the province. For this project, we chose to focus on seeding rates and fungicides in order to simplify field trial management and data collection while also reducing the number of treatments. Demonstrating the benefits of herbicide layering is challenging because results depend on the specific weed species and biotypes (i.e. herbicide resistance) along with environmental factors and timing of operations. Furthermore, natural weed populations are often inconsistent/patchy which exacerbates these challenges in small plot trials. When considered along with relevant preceding research, this project was intended to provide producers with information and extension material on the potential benefits of higher seeding rates to enhance lentil yields and their ability to compete with weeds while also illustrating potential drawbacks and implications for disease management.

Literature Cited

Baird, J. M., Shirtliffe, S. J., and Walley, F. L. 2009. Optimal seeding rate for organic production of lentil in the Northern Great Plains. Can. J. Plant Sci. **89:** 1089-1097.

Kasper, K. M. 2018. The effect of seeding rate and fungicide applications on lentil cultivars. University of Saskatchewan. MSc dissertation. Online [Available]: https://harvest.usask.ca/bitstream/handle/10388/11909/KASPER-THESIS-2019.pdf?sequence=1&isAllowed=y (January 20, 2022).

Weber, J. Holzapfel, C., Hall, M., Nybo, B, Hnatowich, G., Johnson, E., and Shirtliffe, S. 2019. Lentil Input Study: Final Report for the Saskatchewan Ministry of Agriculture (ADF Program), Saskatchewan Pulse Growers, and Western Grains Research Foundation. Online [Available]: https://applications.saskatchewan.ca/apps/AGR_Apps/adf/ADFAdminReport/20160010.pdf (January 20, 2022).

6. Objective(s) or purpose of the project

The objectives of this project are to:

1. Demonstrate the effects of lentil seeding rates and subsequent plant densities on competition with weeds, disease, yield, grain quality, and agronomic response to foliar fungicide applications.
2. Demonstrate the most profitable combinations of seeding rates and foliar fungicide application strategies for lentils under a range of Saskatchewan growing conditions.

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

Field trials with small red lentils were conducted at three locations (Swift Current – Brown Soil Zone; Scott – Dark Brown Soil Zone; Indian Head – thin Black Soil Zone) for two growing seasons (2021 and 2022). The treatments were a factorial combination of three seeding rates (130, 190, and 250 seeds/m^2) and three fungicide management treatments (no fungicide applied, single application at early flowering, single application at early flowering and a second application approximately 14 days after the first) for a total of 9 individual treatments. The fungicide products and rates were 395 ml/ha Dyax (250 g/l fluxapyroxad and 250 g/l pyraclostrobin) for the first application and 420 g/ha Lance WDG (70% boscalid) for the second. The treatments were replicated four times in an RCBD and are listed in Table 1.

Table 1. Seeding rate and fungicide treatments in lentil input demonstration trials conducted Indian Head, Scott, and Swift Current in 2021 and 2022.

Seeding Rate	T1 Fungicide (early bloom)	T2 Fungicide (≈14 days after T1)
130 seeds/m^2	None applied	None applied
130 seeds/m^2	395 ml Dyax/ha	None applied
130 seeds/m^2	395 ml Dyax/ha	420 g Lance WDG/ha
190 seeds/m^2	None applied	None applied
190 seeds/m^2	395 ml Dyax/ha	None applied
190 seeds/m^2	395 ml Dyax/ha	420 g Lance WDG/ha
250 seeds/m^2	None applied	None applied
250 seeds/m^2	395 ml Dyax/ha	None applied
250 seeds/m^2	395 ml Dyax/ha	420 g Lance WDG/ha

T1 - 100 g fluxapyroxad/ha + 100 g pyraclostrobin/ha applied 3-7 days after 1st flowers observed
T2 – 294 g boscalid/ha applied approximately 14 days after the first fungicide application

Selected agronomic information and dates of operations/data collection activities are provided in Table 4 of the Appendices. The lentils were direct seeded into cereal stubble and seeding equipment varied across locations. Fertilizer and granular inoculant were held constant across the study area within each site with fertility intended to be non-limiting in all cases. Seed treatment was used at all locations and the variety was either CDC Impulse CL (Swift Current and Scott) or CDC Proclaim CL (Indian Head). Weeds were controlled with registered pre-emergent and in-crop herbicide applications. Because we were interested in assessing the relative ability of the crop to compete with weeds at each seeding rate, no hand-weeding was permitted. Foliar fungicides were applied to individual plots as per protocol using hand booms or similar. Pre-harvest herbicides or desiccants were utilized at the discretion of individual site mangers, the plots were straight-combined when it was fit do so, and outside rows were excluded from the harvest area wherever possible.

Various data were collected during the growing season and from the harvested samples. Spring plant densities were estimated by counting 4 x 1 m sections of crop row after emergence was complete and converting the values to plants/m^2. Disease ratings were completed for all plots at two distinct times: prior to the first fungicide application and approximately 7 days after the 2nd fungicide application. At each time, five sections within each plot were rated on a scale of 0-100 (percent plant and stem area affected) and the values were averaged for each plot. At Indian Head in both years, plant samples were collected and submitted to the Saskatchewan Crop Protection Laboratory to confirm the presence of disease and identify the specific pathogens. At maturity, each plot was rated on a scale of 1-10 for the lentils ability to compete with weeds. A rating of 1 indicated that less than 10% of the plot area was affected by weeds while a rating of 10 indicated that >90% of the plot area was affected by weeds. Seed yields were determined from the harvested grain samples and are corrected for dockage and to 13% seed moisture content. Test weights were determined from the cleaned sub-samples using standard Canadian Grain Commission methods and are expressed as g/0.5 l. Seed weight was determined by counting and weighing a minimum of 250 seeds per plot and converting the values to g/1000 seeds. Growing season temperatures and precipitation amounts were compiled from the nearest Environment and Climate Change Canada weather stations, located within 3 km of each trial site.

Prior to analyses, data from Scott 2021 were removed due to extreme variability caused by drought and generally poor environmental conditions. Data from the remaining five sites were combined and analyzed using the generalized linear mixed model (GLIMMIX) in SAS® Studio. For most variables, the effects of site (S), seeding rate (SR), fungicide treatment (F), and all possible interactions were considered fixed while the effects of replicate (within site) were treated as random. Fungicide effects were excluded from the model for plant density. Disease and weed ratings were not statistically analyzed but are still summarized and utilized for explanatory purposes. Heterogeneity of variance components (by site) were tested for and permitted whenever significant differences in variance were detected and doing so improved the model fit. Individual treatment means were separated using Fisher's protected LSD test and sliced by site to produce F-tests for individual sites and to prevent means from being compared across sites. Orthogonal contrasts were utilized to test whether all possible responses to seeding rate (i.e., across sites, within sites, for individual fungicide treatments) were linear, quadratic, or not significant. All treatment effects and differences between means were considered significant at $P \leq 0.05$; however, responses at $P \leq 0.1$ were also generally highlighted if they made agronomic sense and were deemed important.

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.

Mean monthly temperatures and precipitation amounts for May-August of each site are presented relative to the long-term (1981-2010) averages in Tables 2 and 3, respectively. At Indian Head in 2021, it was initially dry, but timely precipitation events maintained a reasonable yield potential and the trial area was uniform and considered to be of good quality. While the total amount of precipitation was 121% of the long-term average, much of the rain fell in August which was too late to benefit the crop. In contrast, the 2022 growing season at Indian Head began wet and above-average (117%) precipitation from May through August helped to support well above-average yield potential at this site. While prolonged wet conditions can be quite detrimental to lentils, the site was well drained and dryer weather in June allowed the crop to root well and get off to a strong start. Temperatures at Indian Head were slightly above average in 2021 (103%) and approximately average in 2022 (101%). Both Scott (2022) and Swift Current (2021 and 2022) were warmer (105-106%) and drier (78-88%) than average; however, the overall variability at these sites was sufficiently low that the results were considered valid. Although lentils can tolerate heat and drought reasonably well compared to many crops, the conditions encountered at all sites except, potentially, Indian Head in 2022 were not conducive to disease and, as such, limited our ability to achieve the stated project objectives to a certain extent.

Table 2. Mean monthly temperatures along with long-term (1981-2010) averages for the growing seasons at Indian Head (2021 and 2022), Scott (2022), and Swift Current (2022).

Location	Year	May	June	July	August	Average
		--------------------------------- Mean Temperature (°C) ---------------------------------				
Indian Head	2021	9.0	17.7	20.3	17.1	16.0 (103%)
	2022	10.9	16.1	18.1	18.3	15.8 (101%)
	Long-term	*10.8*	*15.8*	*18.2*	*17.4*	*15.6*
Scott	2022	10.0	15.0	18.3	18.9	15.6 (105%)
	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%)
	2022	10.8	15.7	19.7	20.9	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 growing seasons at Indian Head (2021 and 2022), Scott (2022), and Swift Current (2022).

Location	Year	May	June	July	August	Total
		------------------------------ Cumulative Precipitation (mm) ------------------------------				
Indian Head	2021	81.6	62.9	51.2	99.4	295 (121%)
	2022	97.7	27.5	114.5	45.9	286 (117%)
	Long-term	*51.7*	*77.4*	*63.8*	*51.2*	*244*
Scott	2022	11.0	57.1	86.5	32.1	187 (83%)
	Long-term	*38.9*	*69.7*	*69.4*	*48.7*	*227*
Swift Current	2021	30.0	26.8	36.6	53.5	147 (78%)
	2022	43.2	31.2	83.5	6.7	165 (88%)
	Long-term	*42.1*	*66.1*	*44.0*	*35.4*	*188*

Detailed results tables are reserved for the Appendices (Section 14; Tables 5-23) with selected responses and basic observations illustrated graphically in the main body of the report.

For plant density, the simpler model with common variance estimates across site was used (Table 5), and the effects of site (S), seeding rate (SR), and their interaction were all significant (P < 0.001-0.004; Table 6). Across seeding rates, overall plant populations were highest at IH-22 and SC-22 (174-178 plants/m^2), and lower at the IH-22, SW-21, and SW-22 (139-141 plants/m^2; Table 7). With an average seeding rate of 190 live seeds/m^2, these establishment numbers represent survival rates of approximately 93% at the first two sites and 74% at the remaining three. Despite a significant S x SR interaction, the SR effects on plant densities were consistent across sites and were as expected. At all five sites and on average, plant densities increased linearly (P < 0.001) but not quadratically (P = 0.179-0.869) with increasing seeding rate (Table 8). Not unexpectedly, mortality increased with seeding rate. This was consistent at all five sites and, averaged across sites, the percentages of live seeds that established as plants were 89%, 82%, and 77% at seeding rates of 130, 190, and 250 seeds/m^2. The reason for the S x SR interaction is somewhat unclear, but likely due to subtle variation in differences between sites at each seeding rate. This could be interpreted as site effects differing depending on the seeding rate but, in any case, the interaction was not considered to be particularly important or interesting. In addition to Table 8, the S x SR and overall SR effects on plant densities are presented graphically in Fig. 1.

Based on the more in-depth project this demonstration was intended to build upon, along with past experience with lentils and other crops, we expected increased seeding rates to improve the crop's ability to compete with weeds. While we utilized a pre-seed burn-down and in-crop herbicides, no residual herbicides were applied and hand-weeding was prohibited. Detailed weed counts or biomass measurements were beyond the scope of this project; however, visual ratings on the overall weediness of each plot were completed in an attempt to document such effects and, while not statistically analyzed, these observations are summarized in Table 9 of the Appendices. Overall, the plots at all sites were relatively clean; however, the visual weediness rates did show a tendency for higher weed pressure at the lowest seeding rate at IH-21, SW-21, SC-22, and when averaged across sites. Across all sites, the overall weediness rating was 1.7/10 at 130 seeds/m2 and 1.4/10 for the 190-250 seeds/m^2 seeding rates. The IH-22 site had the highest overall values; however, these ratings are quite subjective and there was no apparent effect of seeding rate at this site. Most of the weeds observed at maturity at IH-22 were Canada thistles, a species which were not controlled by the in-crop herbicide options and tend to be quite patchy. In general, we know that higher seeding rates and narrow row spacing can help any crop compete with weeds; however, as previously alluded to, it is possible that the resulting denser canopy can also create conditions that result in heavier disease pressure.

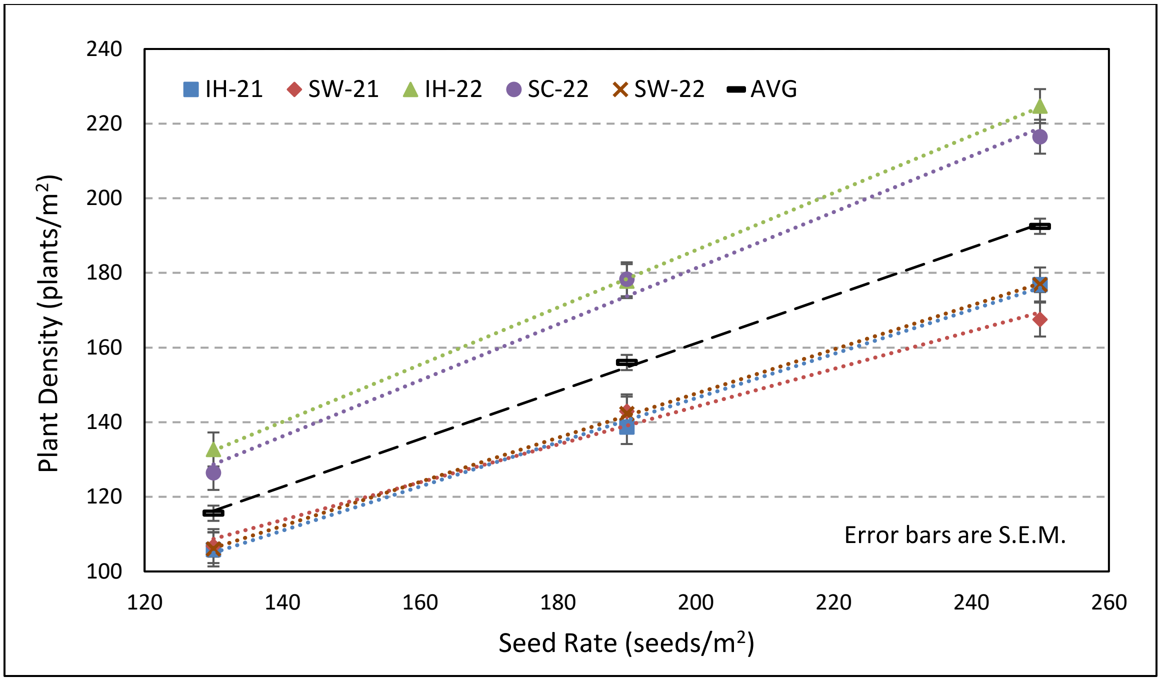

Figure 1. Seeding rate effects on lentil plant densities at Indian Head (2021 and 2022), Scott (2022), Swift Current (2021 and 2022), and averaged across all five sites. In all cases, the both the overall F-tests and linear response was highly significant (*P* < 0.001).

The initial disease ratings were completed at the start of flowering, immediately prior to the first fungicide treatment applications. The intent of these ratings was to provide information on the apparent disease pressure at the time when producers would need to decide whether or not to invest in a foliar fungicide application. Similar to the weediness rates, these data were not statistically analyzed. While ratings were completed for all plots, the values are only averaged across seeding rates since no fungicides had been applied at this time. The crop was rated on a scale of 0-100 (based on the percentage of stem and leaf area affected) in order to better allow us to document trace levels of disease relative to coarser rating scales. Disease pressure at the time of the first fungicide application was negligible at all five sites, ranging from 0.1-1.2% for individual sites when averaged across seeding rates (Table 10). The highest values were reported at IH-22 and the lowest were at SW-21, not unexpected since these were the wettest and driest of the sites, respectively. At the sites with the heaviest disease pressure, the lowest values did tend to coincide with the lowest seeding rate; however, the numbers were so small that they were not considered to be of much practical importance. Based specifically on these observations along with the weather/environmental conditions in late June/early July, it would have been difficult to recommend a fungicide application at all sites except IH-22, where disease pressure was low but symptoms were present and the weather/soil conditions were wetter than normal.

The final disease ratings, completed approximately 7 days after the second set of fungicide treatments were applied, are also presented in Table 10 for the main effects and in Table 11 for individual treatments. At this time, the rating values had increased at all locations except SW-21 where the ratings went from negligible (0.1-0.2%) prior to the first fungicide applications to non-existent (all ratings were zero) for the final ratings. The sites with the lowest disease pressure (i.e., IH-21, SW-21, and SW-22), did not exhibit any meaningful impacts of higher seeding rates on disease. At both IH-22 and SC-22, however, disease pressure did appear to increase with seeding rate as hypothesized. At IH-22, despite the wet weather, overall disease pressure remained quite low, averaging 2.3% at 130 seeds/m^2, 3.5% at 190 seeds/m^2, and 4.2% at 250 seeds/m^2. Unexpectedly given the dry conditions, values for the final disease ratings were highest at SC-22, averaging 2.4% at 130 seeds/m^2, 3.9% at 190 seeds/m^2, and 7.8% at 250 seeds/m^2. It is possible that these ratings at SC-22 were confounded by senescence to some extent. Across all five sites, the final disease ratings were 1.5%, 2.1%, and 3.1% at 130, 190, and 250 seeds/m^2, respectively. Averaged across seeding rates, fungicide, not unexpectedly, did not appear to have much impact on disease at the sites with the lowest pressure (i.e., IH-21, SW-21, or SW-22). At IH-22, the ratings averaged 4.8% in the control and 2.6% in the treated plots, with no difference between the single (1x) and dual (2x) applications. At Scott, the fungicide effects on final disease ratings appeared to be less prevalent, averaging 5.3% in the control and 4.3-4.6% in the treated plots. Averaged across all sites, the final disease rating values were 2.6% in the control and 2.1% in both 1x fungicide and 2x fungicide treatments. For those interested in more detailed results, mean final disease rating values for individual treatments are provided in Table 11. Again, plant samples from Indian Head were submitted to the Saskatchewan Crop Protection Laboratory in both years to confirm the presence of disease and identify the specific pathogens. In 2021, results were inconclusive with no disease identified in the sample (Fig. 8, Appendices). In 2022, the dominant disease was confirmed to be anthracnose (*Colletotrichum truncatum*) with infection levels on individual plants ranging from mild to severe. Alternaria was also identified on severely damaged pods but suspected to be saprophytic, specifically establishing on plants that had prematurely senesced as a result of the severe anthracnose infection.

For seed yield, the simpler model with common variance across sites performed well (Table 5) and the overall effects of site (S; $P < 0.001$) and fungicide treatment (F; $P = 0.012$) were highly significant while the overall seeding rate (SR) effects were marginally significant ($P = 0.056$; Table 6). Yields were highest at IH-22 (3498 kg/ha), followed by IH-21 and SC-22 (2221-2425 kg/ha), SW-22 (1868 kg/ha), and SW-21 (1498 kg/ha).

Detailed results tables for seeding rate and fungicide effects on lentil seed yield are presented in Tables 12-15 of the Appendices with basic summary graphs provided in Figs. 2 and 3 below. A highly significant S x SR interaction ($P = 0.001$) was due to seeding rate effects differing across sites. At IH-21, under dry but not extreme conditions, the seeding rate effect on lentil yield was positive with a significant overall F-test ($P = 0.002$) and yields increasing linearly ($P < 0.001$) from 2127 kg/ha to 2298 kg/ha as the seeding rate was increased from 130 to 250 seeds/m^2. At SW-21, under severe drought conditions, the overall F-test was not significant ($P = 0.163$) but there was a marginally significant linear decline in yields with increasing seeding rates (1529 kg/ha at 130 seeds/m^2 versus 1445 kg/ha at 250 seeds/m^2. At IH-22, under wet but high yielding conditions and in the presence of disease, the overall F-test was highly significant ($P = 0.021$). However, the response was opposite of what occurred at this location the previous year in that yields linearly ($P = 0.006$) declined from 3565 kg/ha to 3430 kg/ha as the seeding rate increased from 130 to 250 seeds/m^2. At SC-22, seeding rate had no impact on yield with no significant F-test ($P = 0.149$) or orthogonal contrasts ($P = 0.154$-181). Finally, SW-22, again under drought conditions, only had a marginally significant F-test ($P = 0.077$) but a linear decline ($P = 0.024$) in yield was detected as the seeding rate was increased from 130 seeds/m^2 (1924 kg/ha) to 250 seeds/m^2 (1814 kg/ha). When all five sites were averaged, the overall F-test was, again, only marginally significant ($P = 0.056$) but the orthogonal contrasts did suggest a slight linear ($P = 0.041$) decline in yield with increasing seeding rate. This was, however mostly due to yields being lower at the 250 seeds/m^2 rate as yields from 130-190 seeds/m^2 were essentially identical.

For fungicide treatment effects on yield, the overall F-test was only significant at IH-22 ($P = 0.024$) and when averaged across sites ($P = 0.012$); however, the lack of an S x F interaction suggests ($P = 0.692$) some level of consistency across sites. This can be explained by the facts that the significant response at IH-22 was relatively small in magnitude and, while frequently not significant for sites individually, there was a general trend for yields in the control plots to be slightly lower than in the treated plots at all sites. At IH-22, yields were 97-126 kg/ha (3-4%) higher than the control when fungicides were applied. Averaged across sites, the magnitude of the yield response to fungicide was 51-60 kg/ha (2-3%) over the control. The SC-22 site reported the highest levels of disease and there was a reasonably strong tendency ($P = 0.103$) for slightly higher yields when fungicide was applied (87-91 kg/ha or 4%). There were no cases where the dual fungicide application appeared to be beneficial over a single application at early bloom. It is conceivable that the observed responses may have been stronger if scaled up to whole fields where it takes longer for the canopy to dry out (i.e., due to edge effects) and where wetter of the field could serve as both a source from which disease could spread and would also be more likely to respond to the fungicide treatments.

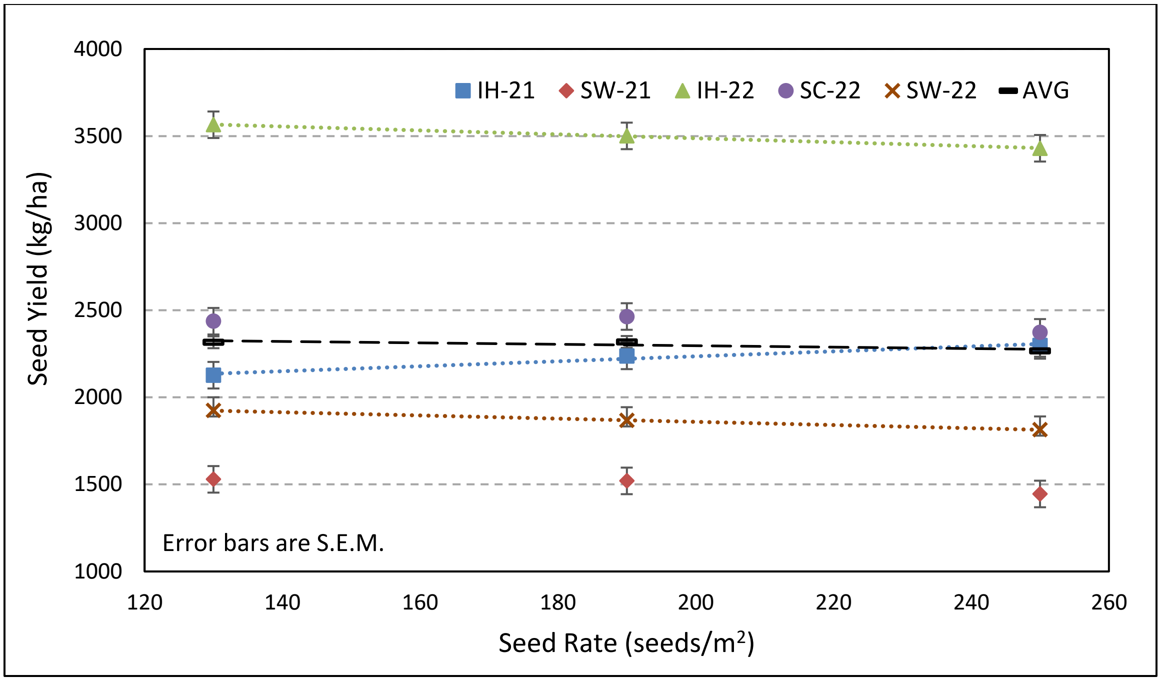

Figure 2. Seeding rate effects on lentil seed yield at Indian Head (2021 and 2022), Scott (2022), Swift Current (2021 and 2022), and averaged across all five sites. The overall F-test was highly significant at IH-21 (*P* = 0.002) and IH-22 (*P* = 0.006) and marginally significant at SW-22 (*P* = 0.077) and across sites (*P* = 0.056). The linear orthogonal contrasts were significant at IH-21, IH-22, SW-22, and across sites (*P* < 0.001-0.041) and marginally significant at SW-21 (*P* = 0.083).

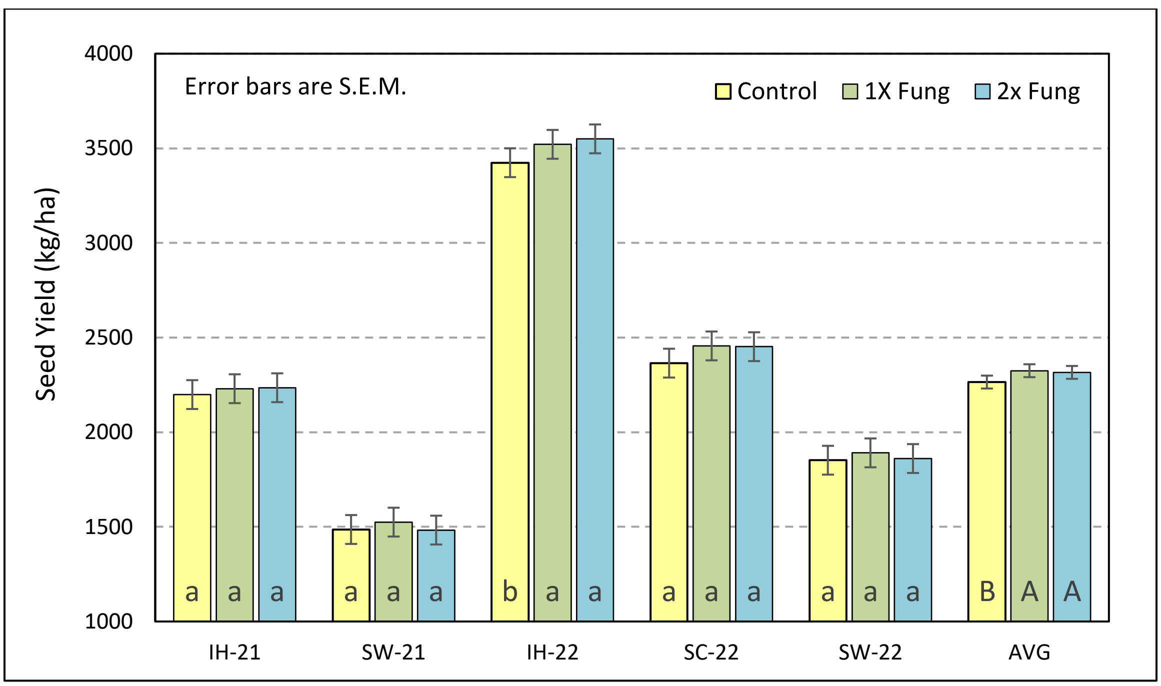

Figure 3. Fungicide treatment effects lentil seed yield at Indian Head (2021 and 2022), Scott (2022), Swift Current (2021 and 2022), and averaged across all five sites. The treatments were 1) untreated control, 2) fungicide applied at early bloom (1x), and 3) fungicide applied at early bloom and again ~14 day later (2x). The overall F-test was significant at IH-22 (*P* = 0.024) and across sites (*P* = 0.012).

Individual treatment means for seed yield and their corresponding orthogonal contrast results are presented in Tables 14-15. There was no overall SR x F interaction (*P* = 0.509), nor was the S x SR x F interaction significant (*P* = 0.866). This indicates that the responses to fungicide (or lack thereof) did not generally differ depending on the seeding rate. Alternatively, we could say that the response to seeding rate was reasonably consistent, regardless of whether a fungicide was applied. The greatest exception to this was IH-22, where both SR and F effects were detected; however, the response was not as expected. Rather than lentils at the highest seeding rate exhibiting a stronger yield response, it appeared that 130-190 seeds/m^2 treatments benefitted more from the foliar fungicide applications. Averaged across the 1x and 2x treatments at IH-22, the observed yield benefit was 4-5% at 130-190 seeds/m^2 and only 1% at 250 seeds/m^2 (Table 14). The higher yields at lower seeding rates, specifically when fungicide was applied, caused the seeding rate responses to vary at this location. In the absence of fungicide, the orthogonal contrasts showed no relationship between yield and seeding rate (*P* = 0.424-0.495) while, when fungicide was applied, yields linearly declined (*P* = 0.033-0.043) with seeding rate. It is possible that, at the 250 seeds/m^2 seeding rate and under the conditions encountered, other factors were limiting yield, constraining the potential benefit of the fungicide applications.

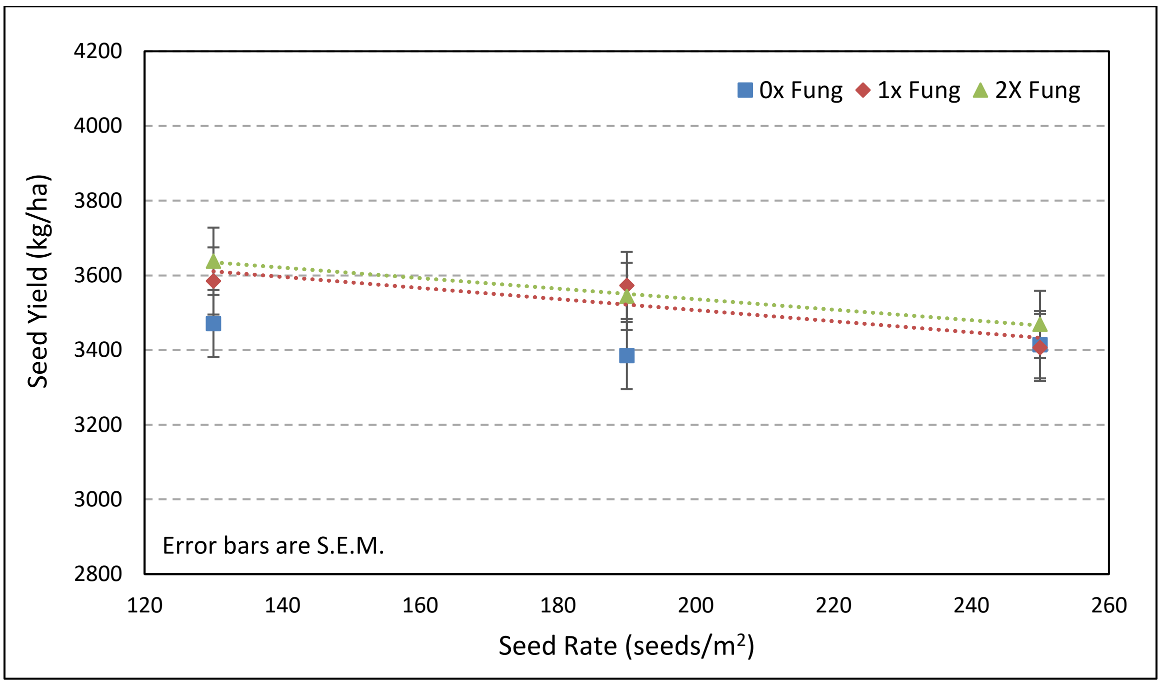

Figure 4. Seeding rate effects on lentil seed yield for individual fungicide treatments at Indian Head 2022 (IH-22). The overall F-test for SR x F for this site was significant (*P* = 0.022). The linear orthogonal contrasts were significant when fungicide was applied (*P* = 0.033-0.043) but there was no response in the control (*P* = 0.424-0.495).

For test weight, permitting heterogeneous variance estimates across sites improved the model fit and, therefore, the more complex procedure was utilized (Table 5). Based on the overall F-tests, test weight was affected by site (*P* < 0.001) with significant S x SR (*P* = 0.020) and S x F (*P* = 0.004) interactions. Averaged across treatments (Table 7), the highest test weights were observed at IH-22 (405 g/1000 seeds), followed by IH-21 (402 g/1000 seeds), SC-22 (393 g/1000 seeds), SW-21 (390 g/0.5 l), and SW-22 (387 g/0.5 l). It is possible that the higher test weights at Indian Head could be at least partly attributed to genetics since the variety at this location was CDC Proclaim and CDC Impulse was grown at Scott and Swift Current.

The S x SR interaction was due to seeding rated affecting test weight at SC-22 (*P* = 0.011), but no other sites (*P* = 0.145-0.401) or when averaged across sites (*P* = 0.882). At the responsive site, the relationship between seeding rate and test weight was mainly quadratic (*P* = 0.017) with higher test weights at the 130 seeds/m^2 seeding rate (394.3 g/0.5 l) compared to 190-250 seeds/m^2. At IH-22, the linear response was marginally significant (*P* = 0.059) and also negative; however, with the p-value for the contrast being greater than 0.05

and no significant F-test (*P* = 0.145), the response was considered weak. In addition to Table 16 of the Appendices, test weight responses to seeding rate for individual sites and across sites are presented graphically in Fig. 5 below.

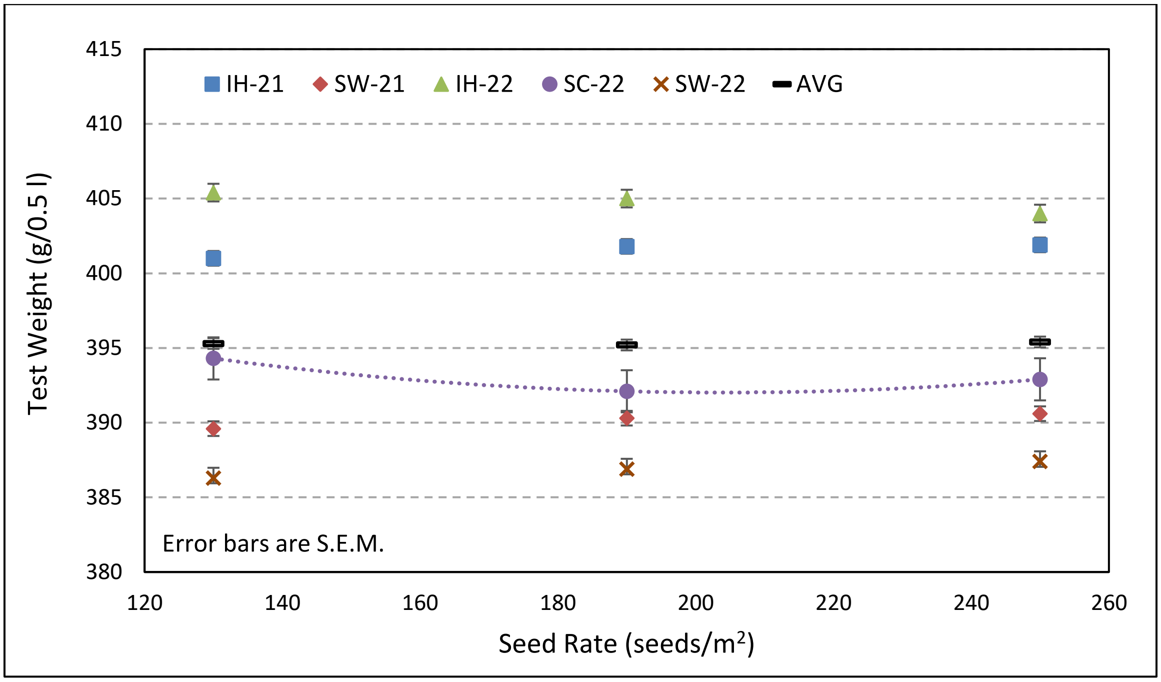

Figure 5. Seeding rate effects on lentil test weight at Indian Head (2021 and 2022), Scott (2022), Swift Current (2021 and 2022), and averaged across all five sites. The overall F-test was only significant at SC-22 (*P* = 0.011) The quadratic response was significant at SC-22 (*P* = 0.017) and the linear response was marginally significant at IH-22 (*P* = 0.059).

Moving on to fungicide effects (Table 17), the S x F interaction was due to responses occurring at SC-22 (*P* < 0.001) and SW-22 (*P* = 0.014), but no other sites individually (*P* = 0.429-0.942) or when averaged across sites (*P* = 0.148). At the two sites where they did occur, however, the fungicide effects on test weight were inconsistent. At SC-22, where disease was observed and there was tendency for higher yields with fungicide, the effect was positive. The observed test weight was 391.6 g/0.5 l in the control which increased to 393.1 g/0.5 l with a single fungicide application and 394.6 g/0.5 l with the dual application. In contrast, the highest test weights at SW-22 occurred in the control (388.0 g/0.5 l) while the lowest was observed with a single application of fungicide (859.9 g/0.5 l) and intermediate values were observed with the dual fungicide applications (386.6 g/0.5 l). Despite their statistical significance, the observed effects of both seeding rate and fungicide on test weight were agronomically unimportant and much smaller than those attributed to environment/genetics. Test weight is not specifically a grading factor for red lentils, so this variable is less important than it can be for some crops such as milling oat or malting barley. For interest sake, individual treatment means and orthogonal contrasts for test weight are presented in Tables 18 and 19, respectively.

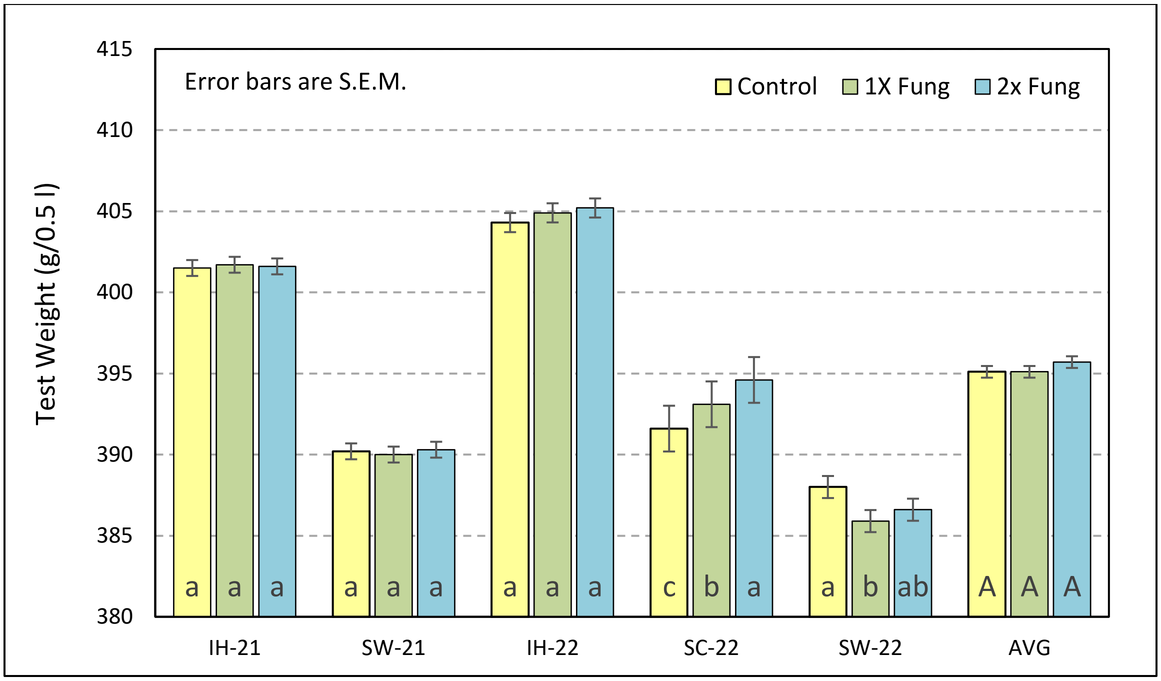

Figure 6. Fungicide treatment effects lentil test weight at Indian Head (2021 and 2022), Scott (2022), Swift Current (2021 and 2022), and averaged across all five sites. The treatments were 1) untreated control, 2) fungicide applied at early bloom (1x), and 3) fungicide applied at early bloom and again ~14 day later (2x). The overall F-test was significant at SC-22 ($P < 0.001$) and SW-22 ($P = 0.014$).

For lentil seed weight, variance was similar across sites; therefore, the simpler model was used (Table 5). The effects of site ($P < 0.001$), seed rate ($P = 0.003$), and fungicide ($P = 0.002$) were all significant (Table 6), but no interactions were detected ($P = 0.120$-0.356). Across treatments, seed weights were highest at SC-22 (49.0 g/1000 seeds), followed by SW-21 and SW-22 (46.8-47.0 g/1000 seeds), IH-21 (43.4 g/1000 seeds), and IH-22 (41.9 g/1000 seeds). Similar to test weight, the lower values at Indian Head may have been partly due to genetics. According to the 2022 Saskatchewan Seed Guide, the average seed weight is 40 g/1000 seeds for CDC Proclaim (used at Indian Head) and 44 g/1000 seeds for CDC Impulse (used at Scott and Swift Current).

The SR effect was small but such that seed weights declined linearly ($P = 0.002$), from 45.8 g/1000 seeds at 130 seeds/m^2 to 45.4 g/1000 seeds at the 250 seeds/m^2 seeding rate (Table 20; Fig. 7). While the S x SR interaction was not significant ($P = 0.120$), the main effect response was mostly due to IH-21 and SW-22, where both individual site F-tests ($P = 0.012$-0.030) and linear orthogonal contrasts ($P = 0.004$-0.009) were highly significant. At SW-22, the site-specific F-test was only marginally significant ($P = 0.057$), which prevented any treatment differences from being declared significant by the multiple comparisons test. However, the quadratic orthogonal contrast suggested a slight increase in seed weight going from 130 seeds/m^2 to 190 seeds/m^2, but a decline with further seeding rate increases to 250 seeds/m^2. While not a grading factor, seed size is an important yield component in that larger, heavier seeds contribute to higher yields. With that in mind, the observed decline in seed weight with increasing seeding rates likely contributed to the negative impacts of high seeding rates on yield observed at some sites and on average.

Focussing on fungicides (Table 21; Fig. 8), the effect on seed weight was small but positive. Averaged across sites, seed weights increased slightly but significantly from 45.35 g/1000 seeds in the control to an average of 45.77 g/1000 seeds when foliar fungicide was applied. While the S x F interaction was not significant, this effect was strongest at SW-21 and SC-22 where seed size was increased by up to 0.9-1.0 g/1000 seeds over the control with fungicide. The lack of S x F interaction was attributed to there being a trend for the control always having amongst the lowest seed weight and the responses being small at the sites where they did, definitively, occur. For interest sake, individual treatment means and more detailed orthogonal contrast results are provided in Tables 22-23 of the Appendices.

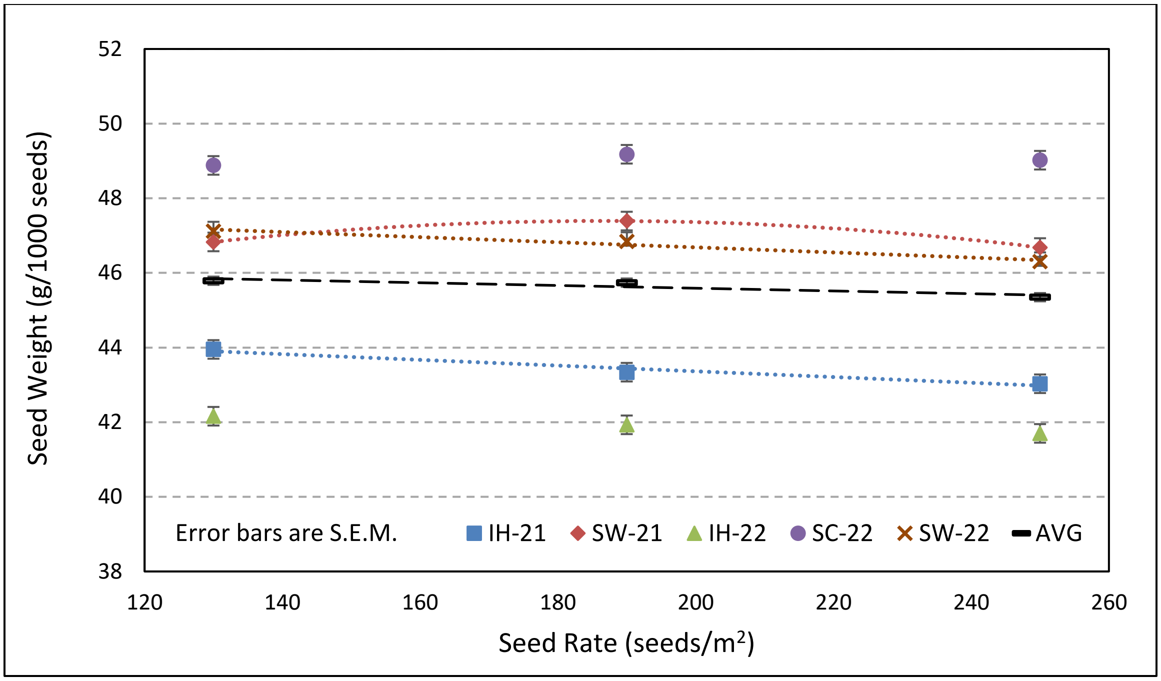

Figure 7. Seeding rate effects on lentil seed weight at Indian Head (2021 and 2022), Scott (2022), Swift Current (2021 and 2022), and averaged across all five sites. The overall F-test was significant at IH-21 (*P* = 0.012), SW-22 (*P* = 0.030), and across sites (*P* = 0.003) and marginally significant at SW-21 (*P* = 0.057). The linear response was significant at IH-21, SW-22, and across sites (*P* = 0.002-0.009) and the quadratic response significant at SW-21 (*P* = 0.012).

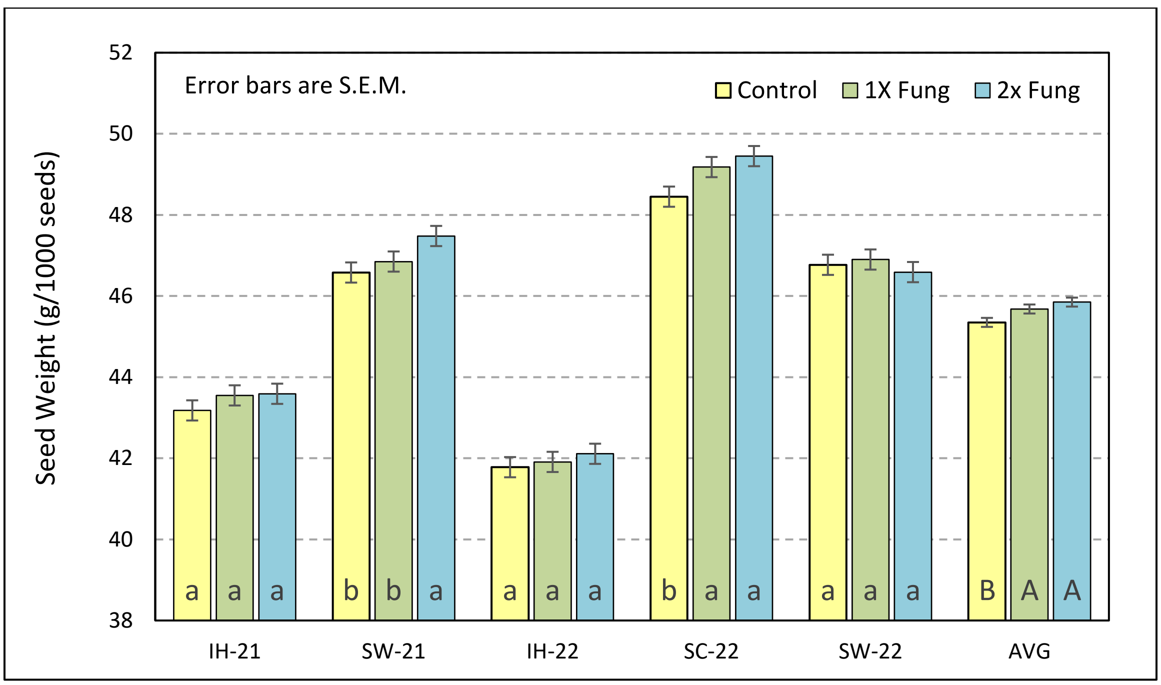

Figure 8. Fungicide treatment effects lentil seed weight at Indian Head (2021 and 2022), Scott (2022), Swift Current (2021 and 2022), and averaged across all five sites. The treatments were 1) untreated control, 2) fungicide applied at early bloom (1x), and 3) fungicide applied at early bloom and again ~14 day later (2x). The overall F-test was significant at SW-21 (*P* = 0.012), SC-22 (*P* = 0.005), and across sites (*P* = 0.002).

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

As is the case with most agronomic decisions, the actual economic returns associated with the treatments evaluated can vary widely with environmental conditions along with both commodity and input prices. Furthermore, absolute profits can also vary considerably, regardless of responses, depending on factors such as land cost, equipment, labour, and interest rates. With that in mind, using some basic assumptions, we calculated the relative marginal profits for each of the main factors evaluated in this project. Since interactions between seeding rate and fungicide for yield were rare, profits for individual treatments were not calculated. The specific assumptions are as follows. A small red lentil price of \$0.75/kg and a seed price of \$0.90/kg was based on 2022 SCIC base prices for both commercial and pedigreed red lentils (https://www.scic.ca/ci/prices/#commercialcrop). Seed treatment costs were estimated at \$11/ha, \$16/ha, and \$21.23/ha for the 130 seeds/m^2, 190 seeds/m^2, and 250 seeds/m^2 seeding rates, respectively. Fungicide prices were estimated at \$140.57/l for Dyax (\$55.58/ha) and \$140.34/kg for Lance WDG (\$58.94/ha). A fungicide application cost of \$14.35 was derived from the 2022-23 Farm Machinery Custom and Rental Rate Guide (https://publications.saskatchewan.ca/api/v1/products/76527/formats/85808/download) and is the average of all the high clearance sprayer options listed.

The most profitable seeding rate varied with location (Table 24). The sole site where yields increased with seeding rate was IH-21 and, with that, the 250 seeds/m^2 treatment was most profitable (\$87/ha higher than at 130 seeds/m^2). In all other cases, seeding rate effects on yield were either neutral or negative; therefore, with higher input costs associated with increasing seeding rates, relative marginal profits always declined as seeding rate was increased. Excluding IH-21, relative marginal profits at 190 seeds/m^2 ranged from \$1/ha to \$69/ha lower than at 130 seeds/m^2. At 250 seeds/m^2, relative marginal profits ranged from \$89/ha to \$142/ha less than at 130 seeds/m2 when IH-21 was excluded. When averaged across all five sites, relative marginal profits were \$19/ha lower at 190 seeds/m^2 than at 130 seeds/m^2 and \$78/ha lower when the seeding rate was increased to 250 seeds/m^2.

Despite the overall positive effect on yield, fungicide applications never resulted in higher marginal profits when averaged across seeding rates and compared to the untreated control (Table 25). The most responsive site was IH-22; however, the single application of foliar fungicide resulted in identical marginal profits to the control when both product and application costs were accounted for. The dual fungicide application resulted in a net reduction in marginal profits of \$52/ha relative to the control at IH-22. For the remaining sites, marginal profits ranged from \$1/ha to \$46/ha less than the control with a single fungicide application and from \$78-\$145/ha less than the control with the dual application. Averaged across all five sites, marginal profits were \$25/ha less with a single fungicide application and \$105/ha less with a dual application relative to the unsprayed control. While we know that lentils can be quite susceptible to disease and the impacts can be severe if it is not managed, these results reinforce the need to base fungicide applications on actual disease pressure and probability of response as much as possible to maximize profits. While it can be difficult to predict potential disease pressure and response to fungicide when such decisions must be made, if symptoms are negligible and environmental conditions are not conducive for disease to develop or spread, the likelihood of an economic benefit to the application is low. It would be particularly difficult to justify the dual fungicide applications under such conditions. That being said, we also recognise that disease can be spatially variable and pressure can potentially be less in small plots as opposed to whole fields due to edge effects (i.e., the canopy can dry out more readily in plots). Furthermore, research plots generally are not placed in the more poorly drained, wetter areas of the field where disease is often more severe and can spread into other areas of the field if not controlled.

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 results from this project were not always consistent with those from the previous, regionally relevant research which it was intended to expand upon, particularly with respect to seeding rate effects on seed yield. Establishment varied with environment in that the highest populations were achieved at IH-22 and SC-22 (174-18 plants/m^2 on average) and densities were lower at the remaining three sites (139-142 plants/m^2). Seedling mortality increased with seeding rate from 89% at 130 seeds/m^2 to 77% at 250 seeds/m^2.

While the plots were conventionally managed with respect to herbicide applications, we saw occasional, minor benefits in the crop's ability to compete with weeds as seeding rate was increased. However, the denser stands had potential to result in higher disease pressure. Yields were positively correlated with seeding at 1/5 sites (IH-21), not affected at 2/5 sites (SW-21 and SC-22), and negatively affected at 2/5 sites (IH-22 and SW-22), and when averaged across sites. The contrasting results at Indian Head may have been due to poorer overall establishment in 2021 and much wetter conditions in 2022. The magnitude of the yield response was small at the affected sites; however, with higher input costs and similar or lower yields, increasing seeding rates from 130 seeds/m^2 to 190 seeds/m^2 reduced profits at 3/5 sites. Rates of 250 seeds/m^2 were less profitable than 130 seeds/m^2 at 4/5 sites. In general, the higher seeding rates evaluated in this project appeared to have the greatest potential to be detrimental under either very dry conditions or wetter than normal conditions. The site where higher seeding rates were most beneficial (IH-21) had relatively high mortality and was dry but, with timely rainfall events and fine-textured soil, yields were still considered approximately average. In contrast, IH-22 had amongst the clearest negative responses to higher seeding rates and this site had excellent establishment, exceptionally high yields, and was wetter than normal most of the season. Seeding rate effects on test weight and seed weight were small, sometimes inconsistent, and not considered to be particularly important.

There was an overall benefit to applying a fungicide at early bloom, but not to following up with a second application, under the conditions encountered during this project. With generally low disease pressure, however, the yield responses were small, averaging only 3-4% at the most responsive sites and 2.5% across all five sites. The observed yield benefits to a single fungicide application were sufficient to cover the costs of the products and application at 2/5 sites, but did not increase profits. At 3/5 sites and when averaged across sites, relative profits were lower with a single fungicide application than in the control. The dual fungicide application was always less profitable than the control. Fungicide effects on test weight were rare, inconsistent, and generally unimportant and seed weight was, on average, increased slightly with fungicide. Importantly, we did not specifically have the grain graded or inspected for damage specifically associated with disease (i.e. ascochyta) and this can be an important grading issue. With respect to seed yield responses, there was no evidence that fungicide applications were more beneficial as higher plant densities. In contrast, at the sole site where there was evidence of an interaction (IH-22), fungicide appeared to be least beneficial at the highest seeding rate where we speculate that other factors may have been limiting to yield.

In conclusion, seeding rates of 130-190 seeds/m^2 should generally be relatively low risk and considered optimal. If low mortality is expected and/or there is risk of either extreme drought or wet conditions, the lower of these rates may be preferable. If seeding conditions are poor (i.e., high mortality is expected), weed pressure is high, or general weather conditions are more 'average', moving to the higher end of the 130-190 seeds/m^2 range may be beneficial. With the possible exception of organic production where there is potential for heavy weed pressure, seeding rates as high as 250 seeds/m^2 should be generally be avoided as such high seeding rates increase input costs and could even negatively affect yields. Disease should generally be managed independently of target plant populations. While it is reasonable to expect higher disease pressure in denser stands, even lower populations can compensate for the extra space with increased branching and prolonged flowering; thus, resulting in a dense canopy with strong potential to benefit from a fungicide application. With relatively weak responses to fungicide, our results support the recommendation to scout for disease and base management decisions on the actual disease pressure and weather conditions; however, we also recognize that results may be spatially variable in commercial fields with a higher general risk of disease relative to small plots. Experience has shown that lentils, particularly in wetter years or regions, can be quite prone to disease and failure to manage can be extremely costly – this must be considered in the decision making process.

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

To build upon the seeding rate findings with respect to both competition with weeds and implications for disease, updated research on row spacing and how it might affect seeding rate recommendations and/or response to fungicide applications in lentil production could have merit. While 20-30 cm is most common, commercial drills are available with row spacing approaching 40 cm. Wider row spacing could be beneficial from a disease management perspective; however, this comes with other drawbacks including a lessened ability to compete with weeds, which is already weak in lentils, and subsequently increased pressure on herbicides and potential for the development of resistant weeds. Furthermore, the ability of plants to compensate for wider rows through increased branching or extended flowering is limited and varies with crop type. Focussing more on fungicides, regular monitoring for disease resistance and/or insensitivity to available active ingredients and revisiting evaluations of contrasting active ingredients and modes of action could be beneficial. A wide range of products are available, and producers may benefit from frequent testing of their efficacy in a range of environments and also from rotating products on their fields in order to prevent insensitivity or resistance to existing products from developing. While in-depth trials are not always practical at this scale, validation of small plot trial results under larger, field-scale conditions using commercial sprayers and covering a variety of landscape positions may also have considerable merit.

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

This demonstration could not be highlighted during the 2021 Indian Head Crop Management Field Day for logistic reasons; however, the plots were shown to several industry representatives and producers during smaller, informal tours throughout the season. At Swift Current in 2021, the plots were shown by WCA staff during multiple tours throughout the season and also highlighted during a CKSW radio program entitled 'Walk the Plots'. At Scott in 2021, this demonstration was highlighted through social media platforms (Facebook and Twitter) during WARC's Virtual Field Day on July 8, 2021. In 2022, The demonstration was scheduled to be shown during the 2022 Indian Head Crop Management Field Day on July 19; however, this event was rained out and moved indoors. As a backup plan, Chris Holzapfel (IHARF) and Sara Anderson (SaskPulse) presented a general overview of the trial to approximately 120 people indoors. At Swift Current in 2022, the plots were toured by approximately 80 participants during WCA's annual field tour and featured Dale Risula (Ministry of Agriculture) as a guest speaker. Highlights from the project will be presented by Chris Holzapfel during the 2022 IHARF Winter Seminar and AGM on February 1, 2023 and by Amber Wall (WCA) during the SaskPulse Winter Meeting at Regina (February 2). This final report will be available online through the IHARF website and results will be highlighted in other presentations and extension activities where opportunities arise. In addition Saskatchewan Pulse Growers will also incorporate results in their extension and resource materials as they see fit.

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

Financial support for this project was provided exclusively 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.

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

Table 4. Selected agronomic information and dates of operations for 2021 and 2022 lentil trials at Indian Head (IH), Scott (SC), and Swift Current (SW), Saskatchewan.

Activity	IH-21	IH-22	SC-22	SW-21	SW-22
Previous Crop	Oat	Wheat	Wheat	Barley	
Pre-seed Herbicide	890 g glyphosate/ha (May 11)	890 g glyphosate/ha (May 12)	1334 g glyphosate/ha + 21 g carfentrazone - ethyl (May 12)	890 g glyphosate/ha + 21 g carfentrazone - ethyl (May 3)	890 g glyphosate/ha + 21 g carfentrazone - ethyl (May 2)
Seeding	May 4	May 9	May 9	May 17	May 6
Row Spacing	30 cm	30 cm	25 cm	21 cm	21 cm
Fertilizer Applied (kg N-P_2O_5-K_2O-S/ha)	7-35-0-0	7-35-0-0	7-33-0-0	9-41-0-0	9-41-0-0
Inoculant	3.0 kg/ha Nodulator Duo SCG	3.0 kg/ha Nodulator Duo SCG	3.7 kg/ha Nodulator Duo SCG	4.6 kg/ha Nodulator Duo SCG	4.6 kg/ha TagTeam Granular
Variety	CDC Proclaim CL	CDC Proclaim CL	CDC Impulse	CDC Impulse CL	CDC Impulse CL
Seed Treatment	300 ml Insure Pulse + 39 ml INTEGO Solo/100 kg seed	300 ml Insure Pulse + 39 ml INTEGO Solo/100 kg seed	100 ml Vibrance Maxx RFC/100 kg seed	100 ml Vibrance Maxx RFC/100 kg seed	100 ml Vibrance Maxx RFC/100 kg seed
In-crop Herbicide	20 g imazamox/ha + 9 g imazapyr/ha (June 13)	15 g imazamox + 15 g imazapyr + 167 ml sethoxydim/ha (June 7)	20 g imazamox/ha + 171 g sethoxydim/ha (June 7)	211 g sethoxydim /ha (May 31) 20 g imazamox/ha (June 16) 59 g clethodim/ha (June 21)	59 g clethodim/ha (June 7) 20 g imazamox/ha (June 16)
Emergence Counts	June 18	June 6	June 8	June 9	June 13
Foliar Fungicide	June 30 and July 13 (as per protocol)	June 30 and July 11 (as per protocol)	July 6 and July 19 (as per protocol)	July 5 and July 19 (as per protocol)	July 6 and July 20 (as per protocol)
Disease Ratings	June 29 & July 23	June 29 & July 26	July 5 and July 28	July 5 & July 27	July 5 and July 27
Weediness Ratings	August 1	July 28	August 3	July 27	July 27
Pre-harvest Herbicide / Desiccant	890 g glyphosate /ha (July 30) 410 g diquat/ha (August 3)	890 g glyphosate /ha (August 12) 410 g diquat/ha (August 19)	1334 g glyphosate/ha + 50 g saflufenacil/ha (August 15)	410 g diquat/ha (August 6)	297 g diquat/ha (August 8)
Harvest	August 8	August 23	August 23	August 13	August 10

Table 5. Model fit statistics and tests of common variance (between sites) for selected response variables. For plant density, seed yield, and seed weight, the simplified model (homogenous) performed better. For test weight, variance was found to be heterogeneous across sites and the more complex model was utilized.

Response Variable	Homogeneous	Heterogeneous	Pr > Chi Square [Y]
	-------------- AICc [Z] (smaller is better) --------------		-------- p-value --------
Plant Density (plants/m^2)	1397.23	1405.36	0.988
Seed Yield (kg/ha)	1774.07	1780.26	0.668
Test Weight (g/0.5 l)	630.41	626.39	0.014
Seed Weight (g/1000 seeds)	383.63	390.83	0.851

[Z] Akaike information criterion – used to determine the most appropriate model for each response variable
[Y] P-values greater than 0.05 indicate that variance estimates did not significantly differ across sites

Table 6. Tests of fixed effects for site (S), seeding rate (SR), fungicide (F), and all possible interactions for selected response variables in lentil fertility demonstrations conducted at four sites (Indian Head 2021 and 2022, Scott 2022, and Swift Current 2022).

Effect	Num DF	Den DF	F-Value	Pr > F
	-------------------------------- Plant Density --------------------------------			
Site (S)	4	15	41.89	<0.001
Seeding Rate (SR)	2	150	427.31	<0.001
S x SR	8	150	2.98	0.004
	--------------------------------- Seed Yield ---------------------------------			
Site (S)	4	15	113.21	<0.001
Seeding Rate (SR)	2	120	2.96	0.056
Fungicide (F)	2	120	4.59	0.012
SR x F	4	120	1.13	0.509
S x SR	8	120	3.69	0.001
S x F	8	120	0.72	0.692
S x SR x F	16	120	0.70	0.866
	-------------------------------- Test Weight --------------------------------			
Site (S)	4	15	434.66	<0.001
Seeding Rate (SR)	2	120	0.13	0.880
Fungicide (F)	2	120	1.94	0.148
SR x F	4	120	1.05	0.383
S x SR	8	120	2.40	0.020
S x F	8	120	3.07	0.004
S x SR x F	16	120	0.72	0.773
	------------------------------- Seed Weight -------------------------------			
Site (S)	4	15	273.11	<0.001
Seeding Rate (SR)	2	120	4.37	0.003
Fungicide (F)	2	120	7.41	0.002
SR x F	4	120	1.70	0.356
S x SR	8	120	1.98	0.120
S x F	8	120	1.79	0.194
S x SR x F	16	120	1.67	0.267

Table 7. Site effects on lentil plant density, seed yield, test weight, and seed weight. The sites are Indian Head (IH) in 2021 and 2022, Scott (SC) in 2022, and Swift Current (SW) in 2021 and 2022. For test weight, the values in parentheses are the standard error of the treatment mean (S.E.M.). Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD, $P \le 0.05$).

Site	Plant Density	Seed Yield	Test Weight	Seed Weight
	------ plants/m^2 ------	--------- kg/ha ---------	-------- g/0.5 l --------	---- g/1000 seeds ----
IH-2021	140.5 B	2221 B	401.6 B (0.26)	43.4 C
SW-2021	139.1 B	1498 D	390.2 D (0.25)	47.0 B
IH-2022	178.4 A	3498 A	404.8 A (0.41)	41.9 D
SC-2022	173.7 A	2425 B	393.1 C (1.35)	49.0 A
SW-2022	141.7 B	1868 C	386.8 E (0.53)	46.8 B
S.E.M.	3.03	71.1	–	0.17
Pr > F	<0.001	<0.001	<0.001	<0.001

Table 8. Main effect means for lentil seeding rate effects on plant density at five individual sites and averaged across sites. Values within a column followed by the same letter do not significantly differ (Fisher's Protected LSD, $P \le 0.05$). Linear and quadratic orthogonal contrast results for seeding rate (averaged across fungicide treatments) are also provided. According to the overall F-test, the S x SR interaction for plant density was highly significant ($P = 0.004$).

Main Effect	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
<u>Seeding Rate</u>	--------------------------------- Plant Density (plants/m^2) ---------------------------------					
130 seeds/m^2	105.9 c	106.8 c	132.7 c	126.4 c	106.0 c	115.6 C
190 seeds/m^2	138.7 b	142.9 b	177.8 b	178.3 b	142.3 b	156.0 B
250 seeds/m^2	176.9 a	167.5 a	224.7 a	216.5 a	176.9 a	192.5 A
S.E.M.	4.55	4.55	4.55	4.55	4.55	2.04
Pr > F	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
<u>Orthogonal Contrast</u>	-- Pr > *F* (p-value) --					
Seed Rate – Linear	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Seed Rate – Quadratic	0.598	0.264	0.853	0.179	0.869	0.391

Table 9. Main effect means for relative weediness ratings completed at physiological maturity. These ratings were not statistically analyzed and are solely provided as background, explanatory information.

Main Effect	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
<u>Seeding Rate</u>	-------------------------------- Weediness Ratings (0-10) --------------------------------					
130 seeds/m^2	1.4	1.8	2.8	1.3	1.0	1.7
190 seeds/m^2	0.9	1.5	2.5	1.0	1.0	1.4
250 seeds/m^2	0.8	1.3	2.7	1.0	1.1	1.4

Table 10. Main effect means for disease ratings completed prior to the first fungicide application and approximately 7 days after the final applications. These ratings were not statistically analyzed and are solely provided as background, explanatory information.

Main Effect	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
Seeding Rate	-------------------------------- T1 Disease Ratings (0-100%) --------------------------------					
130 seeds/m^2	0.5	0.1	1.0	0.7	0.5	0.6
190 seeds/m^2	0.5	0.2	1.1	0.9	0.4	0.6
250 seeds/m^2	0.5	0.1	1.4	0.9	0.6	0.7
Seeding Rate	---------------------------- T2 Final Disease Ratings (0-100%) ----------------------------					
130 seeds/m^2	1.9	0	2.3	2.4	1.3	1.5
190 seeds/m^2	1.6	0	3.5	3.9	1.4	2.1
250 seeds/m^2	1.9	0	4.2	7.8	1.5	3.1
Fungicide						
None (control)	1.8	0	4.8	5.3	1.3	2.6
1x (single application)	1.9	0	2.6	4.3	1.5	2.1
2x (dual application)	1.7	0	2.6	4.6	1.4	2.1

Table 11. Individual treatment means for disease ratings approximately 7 days after the final fungicide applications. These ratings were not statistically analyzed and are solely provided as background, explanatory information.

Main Effect	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
Seeding Rate	---------------------------- T2 Final Disease Ratings (0-100%) ----------------------------					
0X Fung-130 seeds/m^2	1.8	0	3.4	2.8	1.2	1.8
1x Fung-130 seeds/m^2	2. 0	0	1.9	2.5	1.3	1.4
2x Fung-130 seeds/m^2	1.9	0	1.8	2.0	1.3	1.4
0X Fung-190 seeds/m^2	1.7	0	6.1	2.8	1.3	2.4
1x Fung-190 seeds/m^2	1.6	0	2.0	3.5	1.6	1.7
2x Fung-190 seeds/m^2	1.6	0	2.3	5.5	1.4	2.2
0X Fung-250 seeds/m^2	2.0	0	4.9	10.3	1.5	3.7
1x Fung-250 seeds/m^2	2.0	0	3.9	6.8	1.6	2.9
2x Fung-250 seeds/m^2	1.7	0	3.8	6.3	1.6	2.7

Table 12. Main effect means for lentil seeding rate effects on seed yield at five individual sites and averaged across sites. Values within a column followed by the same letter do not significantly differ (Fisher's Protected LSD, *P* ≤ 0.05). Linear and quadratic orthogonal contrast results for seeding rate (averaged across fungicide treatments) are also provided. According to the overall F-test, the S x SR interaction for seed yield was highly significant (*P* = 0.001).

Main Effect	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
Seeding Rate	Seed Yield (kg/ha)					
130 seeds/m^2	2127 b	1529 a	3565 a	2437 a	1924 a	2316 A
190 seeds/m^2	2238 a	1520 a	3501 ab	2464 a	1867 a	2318 A
250 seeds/m^2	2298 a	1445 a	3430 b	2373 a	1814 a	2267 A
S.E.M.	76.2	76.2	76.2	76.2	76.2	34.1
Pr > F	0.002	0.163	0.021	0.149	0.077	0.056
Orthogonal Contrast	Pr > *F* (p-value)					
Seed Rate – Linear	<0.001	0.083	0.006	0.181	0.024	0.041
Seed Rate – Quadratic	0.543	0.434	0.939	0.154	0.962	0.204

Table 13. Main effect means for lentil fungicide treatment effects on seed yield at five individual sites and averaged across sites. Values within a column followed by the same letter do not significantly differ (Fisher's Protected LSD, *P* ≤ 0.05). According to the overall F-test, the S x F interaction for seed yield was not significant (*P* = 0.692).

Main Effect	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
Fungicide Treatment	Seed Yield (kg/ha)					
None (control)	2199 a	1486 a	3424 b	2365 a	1852 a	2265 B
1x (single application)	2230 a	1525 a	3521 a	2456 a	1891 a	2325 A
2x (dual application)	2235 a	1483 a	3550 a	2452 a	1861 a	2316 A
S.E.M.	76.2	76.2	76.2	76.2	76.2	34.1
Pr > F	0.716	0.610	0.024	0.103	0.693	0.012

Table 14. Seeding rate by fungicide treatment means for lentil seed yield at five individual sites and averaged across sites. Values within a column followed by the same letter do not significantly differ ($P \leq 0.05$); however, the experiment-wise error is not controlled in these letter groupings. According to the overall F-test, the S x SR x F interaction for seed yield was not significant ($P = 0.866$).

Treatment/Contrast	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
	------------------------------------- Seed Yield (kg/ha) -------------------------------------					
0X Fung-130 seeds/m^2	2098 c	1489 a	3471 bcd	2404 ab	1933 ab	2279 BCD
1x Fung-130 seeds/m^2	2149 abc	1552 a	3585 ab	2445 ab	1997 a	2346 AB
2x Fung-130 seeds/m^2	2135 bc	1547 a	3638 a	2461 ab	1841 abc	2324 A-D
0X Fung-190 seeds/m^2	2208 abc	1533 a	3385 d	2361 b	1800 bc	2257 D
1x Fung-190 seeds/m^2	2240 abc	1527 a	3572 abc	2541 a	1921 ab	2360 A
2x Fung-190 seeds/m^2	2266 ab	1499 a	3544 abcd	2491 ab	1880 abc	2336 ABC
0X Fung-250 seeds/m^2	2291 ab	1435 a	3414 cd	2331 b	1823 bc	2259 D
1x Fung-250 seeds/m^2	2300 a	1498 a	3407 d	2383 ab	1757 c	2269 CD
2x Fung-250 seeds/m^2	2303 a	1403 a	3469 bcd	2404 ab	1863 abc	2289 A-D
S.E.M.	89.9	89.9	89.9	89.9	89.9	40.2
Pr > F	0.091	0.653	0.022	0.259	0.135	0.509

Table 15. Linear and quadratic orthogonal contrasts results for lentil seed yield response to seeding rates increasing from 130-250 seeds/m^2. Results are presented for individual sites and averaged across sites. P-values ≤ 0.1 are considered marginally significant while values ≤ 0.05 are considered highly significant.

Orthogonal Contrast	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
Variable: Seed Yield	--------------------------------------- Pr > *F* (p-value) ---------------------------------------					
0x Fung – Linear	0.021	0.516	0.495	0.379	0.187	0.590
0x Fung – Quadratic	0.852	0.320	0.424	0.924	0.278	0.720
1x Fung – Linear	0.071	0.516	0.033	0.452	0.004	0.040
1x Fung – Quadratic	0.833	0.980	0.289	0.080	0.544	0.103
2x Fung – Linear	0.045	0.086	0.043	0.491	0.787	0.335
2x Fung – Quadratic	0.511	0.736	0.896	0.418	0.692	0.355

Table 16. Main effect means for lentil seeding rate effects on test weight at five individual sites and averaged across sites. Values within a column followed by the same letter do not significantly differ (Fisher's Protected LSD, *P* ≤ 0.05). Linear and quadratic orthogonal contrast results for seeding rate (averaged across fungicide treatments) are also provided. According to the overall F-test, the S x SR interaction for test weight was highly significant (*P* = 0.012).

Main Effect	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
Seeding Rate	------------------------------------ Test Weight (g/0.5 l) ------------------------------------					
130 seeds/m^2	401.0 a	389.6 a	405.4 a	394.3 a	386.3 a	395.3 A
190 seeds/m^2	401.8 a	390.3 a	405.0 a	392.1 b	386.9 a	395.2 A
250 seeds/m^2	401.9 a	390.6 a	404.0 a	392.9 b	387.4 a	395.4 A
S.E.M.	0.49	0.49	0.59	1.41	0.68	0.36
Pr > F	0.401	0.386	0.145	0.011	0.320	0.880
Orthogonal Contrast	--------------------------------------- Pr > *F* (p-value) ---------------------------------------					
Seed Rate – Linear	0.213	0.174	0.059	0.061	0.132	0.882
Seed Rate – Quadratic	0.601	0.817	0.588	0.017	0.968	0.630

Table 17. Main effect means for lentil fungicide treatment effects on test weight at five individual sites and averaged across sites. Values within a column followed by the same letter do not significantly differ (Fisher's Protected LSD, *P* ≤ 0.05). According to the overall F-test, the S x F interaction for test weight was highly significant (*P* = 0.004).

Main Effect	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
Fungicide Treatment	------------------------------------ Test Weight (g/0.5 l) ------------------------------------					
None (control)	401.5 a	390.2 a	404.3 a	391.6 c	388.0 a	395.1 A
1x (single application)	401.7 a	390.0 a	404.9 a	393.1 b	385.9 b	395.1 A
2x (dual application)	401.6 a	390.3 a	405.2 a	394.6 a	386.6 ab	395.7 A
S.E.M.	0.49	0.49	0.59	1.41	0.68	0.36
Pr > F	0.942	0.905	0.429	<0.001	0.014	0.148

Table 18. Seeding rate by fungicide treatment means for lentil test weight at five individual sites and averaged across sites. Values within a column followed by the same letter do not significantly differ (*P* ≤ 0.05); however, the experiment-wise error is not controlled in these letter groupings. According to the overall F-test, the S x SR x F interaction for seed yield was not significant (*P* = 0.773).

Treatment/Contrast	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
	------------------------------------- Test Weight (g/0.5 l) -------------------------------------					
0X Fung-130 seeds/m^2	400.9 a	389.7 a	404.5 ab	392.9 bc	386.9 ab	395.0 B
1x Fung-130 seeds/m^2	400.9 a	389.6 a	405.4 ab	392.7 bc	385.6 b	394.8 B
2x Fung-130 seeds/m^2	401.4 a	389.5 a	406.3 a	397.3 a	386.4 ab	396.2 A
0X Fung-190 seeds/m^2	401.3 a	390.8 a	404.6 ab	391.0 c	388.8 a	395.3 AB
1x Fung-190 seeds/m^2	402.2 a	389.8 a	405.3 ab	392.5 bc	385.1 b	395.0 B
2x Fung-190 seeds/m^2	402.0 a	390.2 a	405.2 ab	392.9 bc	386.7 ab	395.4 AB
0X Fung-250 seeds/m^2	402.3 a	390.2 a	403.7 b	390.9 c	388.4 a	395.1 AB
1x Fung-250 seeds/m^2	402.1 a	390.5 a	404.1 ab	394.2 b	386.9 ab	395.6 AB
2x Fung-250 seeds/m^2	401.5 a	391.2 a	404.2 ab	393.7 b	386.8 ab	395.5 AB
S.E.M.	0.88	0.88	0.93	1.59	0.99	0.49
Pr > F	0.926	0.921	0.611	<0.001	0.098	0.383

Table 19. Linear and quadratic orthogonal contrasts results for lentil test weight response to seeding rates increasing from 130-250 seeds/m^2. Results are presented for individual sites and averaged across sites. P-values ≤ 0.1 are considered marginally significant while values ≤ 0.05 are considered highly significant.

Orthogonal Contrast	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
Variable: Test Weight	-- Pr > *F* (p-value) --					
0x Fung – Linear	0.259	0.736	0.526	0.110	0.213	0.831
0x Fung – Quadratic	0.792	0.457	0.631	0.404	0.298	0.601
1x Fung – Linear	0.342	0.475	0.303	0.243	0.303	0.206
1x Fung – Quadratic	0.507	0.819	0.614	0.366	0.293	0.648
2x Fung – Linear	0.937	0.192	0.106	0.005	0.736	0.222
2x Fung – Quadratic	0.614	0.909	0.963	0.016	0.936	0.368

Table 20. Main effect means for lentil seeding rate effects on seed weight at five individual sites and averaged across sites. Values within a column followed by the same letter do not significantly differ (Fisher's Protected LSD, *P* ≤ 0.05). Linear and quadratic orthogonal contrast results for seeding rate (averaged across fungicide treatments) are also provided. According to the overall F-test, the S x SR interaction for seed weight was not significant (*P* = 0.120).

Main Effect	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
Seeding Rate	Seed Weight (g/1000 seeds)					
130 seeds/m^2	43.95 a	46.83 a	42.16 a	48.88 a	47.12 a	45.79 A
190 seeds/m^2	43.34 b	47.39 a	41.93 a	49.18 a	46.84 ab	45.74 A
250 seeds/m^2	43.03 b	46.68 a	41.70 a	49.02 a	46.30 b	45.35 B
S.E.M.	0.249	0.249	0.249	0.249	0.249	0.111
Pr > F	0.012	0.057	0.335	0.623	0.030	0.003
Orthogonal Contrast	Pr > *F* (p-value)					
Seed Rate – Linear	0.004	0.628	0.140	0.666	0.009	0.002
Seed Rate – Quadratic	0.576	0.019	0.988	0.384	0.619	0.155

Table 21. Main effect means for lentil fungicide treatment effects on seed weight at five individual sites and averaged across sites. Values within a column followed by the same letter do not significantly differ (Fisher's Protected LSD, *P* ≤ 0.05). According to the overall F-test, the S x F interaction for seed weight was not significant (*P* = 0.194).

Main Effect	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
Fungicide Treatment	Seed Weight (g/1000 seeds)					
None (control)	43.18 a	46.58 b	41.78 a	48.45 b	46.77 a	45.35 B
1x (single application)	43.55 a	46.85 b	41.91 a	49.18 a	46.90 a	45.68 A
2x (dual application)	43.59 a	47.48 a	42.11 a	49.45 a	46.59 a	45.85 A
S.E.M.	0.249	0.249	0.249	0.249	0.249	0.111
Pr > F	0.349	0.012	0.555	0.005	0.606	0.002

Table 22. Seeding rate by fungicide treatment means for lentil seed weight at five individual sites and averaged across sites. Values within a column followed by the same letter do not significantly differ (*P* ≤ 0.05); however, the experiment-wise error is not controlled in these letter groupings. According to the overall F-test, the S x SR x F interaction for seed yield was not significant (*P* = 0.267).

Treatment/Contrast	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
	------------------------------- Seed Weight (g/1000 seeds) -------------------------------					
0X Fung-130 seeds/m^2	43.78 a	46.23 b	41.95 a	47.40 b	47.15 ab	45.30 CD
1x Fung-130 seeds/m^2	43.98 a	47.05 ab	42.20 a	49.35 a	47.50 a	46.02 AB
2x Fung-130 seeds/m^2	44.10 a	47.23 ab	42.33 a	49.90 a	46.70 ab	46.05 A
0X Fung-190 seeds/m^2	43.08 ab	47.25 ab	41.53 a	49.00 a	47.03 ab	45.58 BCD
1x Fung-190 seeds/m^2	43.38 ab	46.88 b	42.20 a	49.25 a	47.08 ab	45.76 ABC
2x Fung-190 seeds/m^2	43.58 ab	48.05 a	42.08 a	49.30 a	46.43 b	45.89 AB
0X Fung-250 seeds/m^2	42.70 b	46.25 b	41.85 a	48.95 a	46.13 b	45.18 D
1x Fung-250 seeds/m^2	43.30 ab	46.63 b	41.33 a	48.95 a	46.13 b	45.27 D
2x Fung-250 seeds/m^2	43.10 ab	47.18 ab	41.93 a	49.15 a	46.65 ab	45.60 A-D
S.E.M.	0.397	0.397	0.397	0.397	0.397	0.177
Pr > F	0.177	0.029	0.645	0.002	0.138	0.356

Table 23. Linear and quadratic orthogonal contrasts results for lentil seed weight response to seeding rates increasing from 130-250 seeds/m^2. Results are presented for individual sites and averaged across sites. P-values ≤ 0.1 are considered marginally significant while values ≤ 0.05 are considered highly significant.

Orthogonal Contrast	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
Variable: Seed Weight	-------------------------------------- Pr > *F* (p-value) --------------------------------------					
0x Fung – Linear	0.046	0.963	0.852	0.004	0.057	0.602
0x Fung – Quadratic	0.726	0.031	0.419	0.077	0.404	0.106
1x Fung – Linear	0.209	0.428	0.104	0.456	0.011	0.002
1x Fung – Quadratic	0.572	0.936	0.346	0.829	0.572	0.579
2x Fung – Linear	0.064	0.926	0.456	0.163	0.926	0.062
2x Fung – Quadratic	0.957	0.069	0.914	0.628	0.590	0.772

Table 24. Basic economic analyses including estimated gross revenues and expenses associated with the seeding rate treatments. Basic assumptions include a grain price of $0.75/kg red lentils and seed costs (seed plus seed treatment) of $44, $65, and $85/ha at 130, 190, and 250 seeds/m² seeding rates, respectively.

Main Effect	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
Seeding Rate	------ Gross Revenue ($/ha) ------					
130 seeds/m²	$1,593	$1,145	$2,670	$1,825	$1,441	$1,735
190 seeds/m²	$1,676	$1,138	$2,622	$1,846	$1,398	$1,736
250 seeds/m²	$1,721	$1,082	$2,569	$1,777	$1,359	$1,698
	------ Seed Costs ($/ha) ------					
130 seeds/m²	$44	$44	$44	$44	$44	$44
190 seeds/m²	$65	$65	$65	$65	$65	$65
250 seeds/m²	$85	$85	$85	$85	$85	$85
	------ Relative Marginal Profits ($/ha) ------					
130 seeds/m²	$0	$0	$0	$0	$0	$0
190 seeds/m²	$62	($27)	($69)	($1)	($63)	($19)
250 seeds/m²	$87	($104)	($142)	($89)	($123)	($78)

Table 25. Basic economic analyses including estimated gross revenues and expenses associated with the fungicide treatments. The basic assumptions included a grain price of $0.75/kg red lentils and fungicide costs of approximately $58/ha for each product plus an application cost of $14 per pass.

Main Effect	IH-21	SW-21	IH-22	SC-22	SW-22	AVG
Seeding Rate	------ Gross Revenue ($/ha) ------					
No Fungicide	$1,647	$1,113	$2,565	$1,771	$1,387	$1,696
1x Fungicide	$1,670	$1,142	$2,637	$1,840	$1,416	$1,741
2x Fungicide	$1,674	$1,111	$2,659	$1,837	$1,394	$1,735
	------ Fungicide Costs ($/ha) ------					
No Fungicide	$0	$0	$0	$0	$0	$0
1x Fungicide	$70	$70	$70	$70	$70	$70
2x Fungicide	$143	$143	$143	$143	$143	$143
	------ Relative Marginal Profits ($/ha) ------					
No Fungicide	$0	$0	$0	$0	$0	$0
1x Fungicide	($47)	($41)	$3	($2)	($41)	($25)
2x Fungicide	($116)	($145)	($49)	($78)	($136)	($105)

Government of Saskatchewan

Crops and Irrigation Branch
Crop Protection Laboratory

Ministry of Agriculture
1610 Park St.
Regina, SK S4N 2G1

General Inquiries: 306-787-8130
Billing Inquiries: 306-787-7191
Email: cpl@gov.sk.ca

August 9, 2021

Lab ID: PD-296

Test Requested: Plant Disease

IHARF
Chris Holzapfel
Box 1568
INDIAN HEAD, SK, S0G 2K0
cholzapfel@iharf.ca

Field ID: 21-2502
Land Location: ----

Results:
Common Name: Inconclusive
Scientific Name: *N/A*

There was no disease identified in this sample.

For more information on crop protection please visit www.saskatchewan.ca, or contact the Agriculture Knowledge Centre at 1-866-457-2377, your Regional Crop Specialist, or a Crops and Irrigation Branch Provincial Specialist.

Sincerely,

Scott Hartley, P. Ag
Manager, Crop Protection Lab
Crops and Irrigation Branch

Figure 9. Saskatchewan Ministry of Agriculture Crop Protection Laboratory disease report for lentils grown at Indian Head, Saskatchewan in 2021.

Saskatchewan

Ministry of Agriculture
1610 Park Street
REGINA SK Canada S4N 2G1

General Inquiries: 306-787-8130
Billing inquiries: 306-787-7191
Email: cpl@gov.sk.ca

Crops and Irrigation Branch

Crop Protection Laboratory

Lab #: PD-000423

Report Date: August 08, 2022

IHARF
Chris Holzapfel
Box 156
Indian Head SK S0G 2K0

cholzapfel@iharf.ca

Plant Disease Testing

Land Description: NE-27-18-12-2
Result: Conclusive

Test Result
Common Name: Anthracnose
Scientific Name: *Colletotrichum truncatum*

Confirmed through observation of microsclerotia on stems and pods of severely affected "diseased" samples as well as acervuli with visible setae on stems of "healthy" plants (far less severe disease). Alternaria was present on severely damaged pods (likely saprophytic growth following premature senescence due to anthracnose infection).

For more information on crop protection, please visit www.saskatchewan.ca or contact the Agriculture Knowledge Centre at 1-866-457-2377, your Regional Crop Specialist or a Crops and Irrigation Branch Provincial Specialist.

Sincerely,

Faye Dokken

Faye Dokken, PAg, MSc
Director, Production Technology
Crops and Irrigation Branch

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Figure 10. Saskatchewan Ministry of Agriculture Crop Protection Laboratory disease report for lentils grown at Indian Head, Saskatchewan in 2022.

15. **Reference papers or articles –** as applicable

There are no reference papers or articles to refer to at this time.