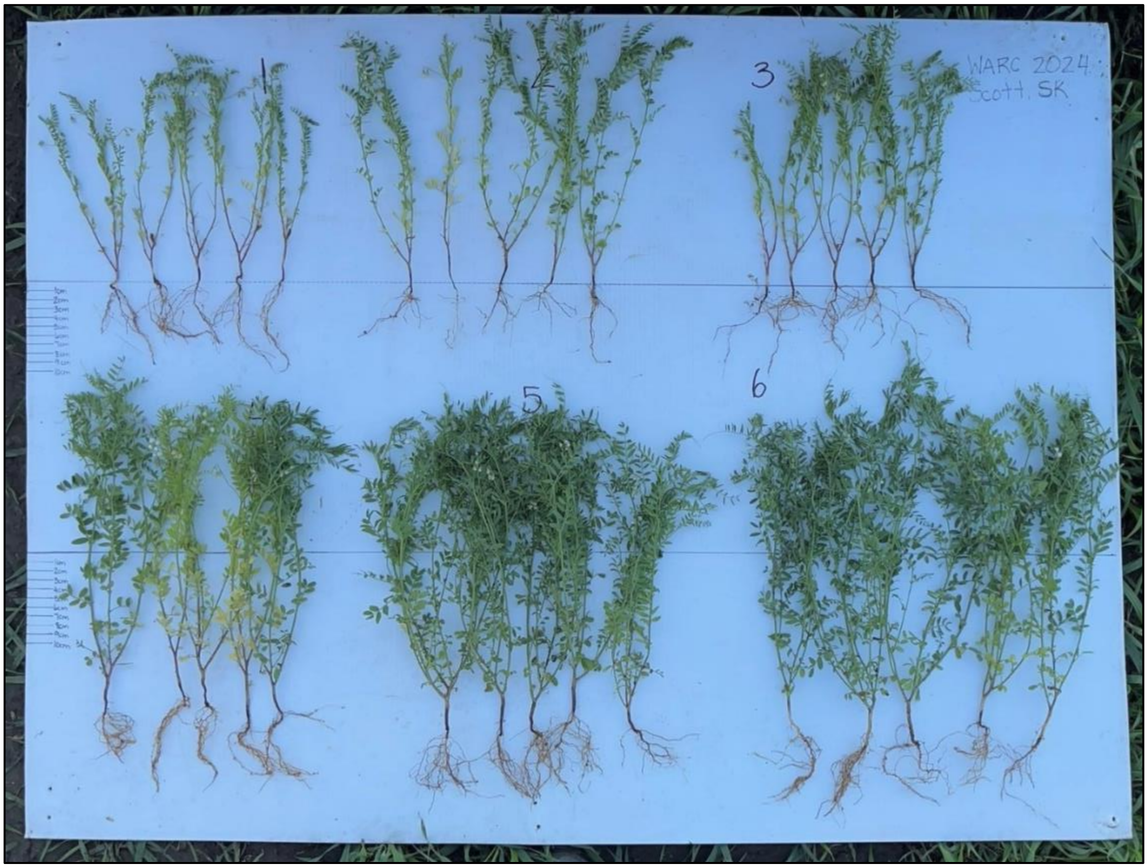
2024 Interim Report
for the
Saskatchewan Pulse Crop Development Board

Project Title: Integrated Pest Management (IPM) for Lentils in Aphanomyces Soil
(Project #AP-2407a)



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1. **Project Code (as is in contract):** AP-2407a

2. **Project Title:** Integrated Pest Management (IPM) for Lentils in Aphanomyces Soil

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5. **Abstract/Summary**

A study evaluated nitrogen rates (0, 50, and 100 lbs N/ac), seed treatment (Rancona Trio), and seed dates (early versus late) as management strategies to reduce root rot in lentils at four locations, Scott, Swift Current, Outlook, and Redvers in Saskatchewan in 2024. Plant establishment was generally stable, though excessive nitrogen reduced plant densities in some cases. Seed treatment and early seeding improved establishment at most locations. NDVI and chlorophyll measurements suggested that late seeding and moderate to high nitrogen rates enhanced plant vigor. Shoot and root disease responses varied by site, with higher nitrogen rates and early seeding reducing disease, although seed treatment had no significant impact. Root pathogen analysis revealed that *Aphanomyces euteiches* was present at all sites, but not in all treatments, while Fusarium species (*F. redolans, F. solani, F. avenaceum*) exhibited high infection rates at all sites. Nodulation was generally reduced with higher nitrogen rates, particularly at Swift Current. Yield responses to nitrogen showed that low to moderate nitrogen rates led to greater yields than high nitrogen rates, likely due to other limiting factors. Early seeding consistently increased yields and net returns across sites. Protein content increased with higher nitrogen rates and later seeding, while seed quality remained high with minimal disease. Overall, moderate nitrogen rates and early seeding showed promise as management strategies for reducing root rot disease in lentils, although additional years of research will be crucial to provide reliable recommendations for producers.

6. Introduction

Lentil (*Lens culinaris* L.), a member of the legume family (*Leguminosae*), is an important pulse crop in Western Canada (Saskatchewan Ministry of Agriculture, 2023). Originally domesticated in Southwest Asia around 7,000 B.C., lentils are now widely grown to reduce nitrogen fertilizer requirements, diversify and lengthen crop rotations, and improve economic returns. When inoculated with the appropriate *Rhizobium* bacteria, lentils can fix atmospheric nitrogen, supplying a significant portion of their nitrogen needs. In 2022, lentil production in Saskatchewan was estimated at 2.3 million tons, a 43.3% increase from 2021, which had been affected by drought conditions. Saskatchewan accounts for 85.4% of Western Canada's lentil production, making it a key region for pulse crop research and management.

Aphanomyces root rot, caused by *Aphanomyces euteiches*, is a major threat to lentil and pea production. This pathogen, classified as an oomycete, produces thick-walled resting spores (oospores) that enable it to persist in the soil during winter conditions. While its development is strongly influenced by high soil moisture, the pathogen can also survive in drier conditions. Once above-ground symptoms become visible, no treatment is available to save the crop. The primary method of detection involves digging up roots, which, when infected, become soft, water-soaked, and take on a honey-brown or caramel color. Infection also negatively impacts nodulation, and as the disease progresses, above-ground symptoms such as yellowing and plant decline appear.

Due to the severity of Aphanomyces root rot and the limited management options available, many producers in Saskatchewan are reassessing their pulse acreage. Given the high economic importance of lentils in Saskatchewan, identifying and demonstrating alternative management strategies to mitigate Aphanomyces damage is critical. This project was developed in collaboration with Dr. Syama Chatterton and Dr. Michelle Hubbard and builds upon their ongoing research. It is supported by the Saskatchewan Pulse Growers in response to the growing impact of Aphanomyces on lentil and pea production across the province.

7. Objective(s) or purpose of the project

The overall objective of this project is to evaluate the impact of different management techniques on Aphanomyces disease in lentils. These management strategies include:

a) Assessing whether the application of starter nitrogen at seeding influences the severity of Aphanomyces root rot.
b) Demonstrating the effectiveness of the seed treatment Rancona Trio in managing root disease.
c) Evaluating the impact of early versus late seeding dates on disease severity in lentils.

8. Materials and Methods

Field trials were established at four locations across Saskatchewan, representing different soil zones: two sites in the Brown soil zone (Swift Current and Outlook), one site in the Dark Brown soil zone (Scott), and one site in the Black soil zone (Redvers). The Outlook site was irrigated, receiving a total of 18.7 mm of irrigated precipitation from May to September. All other locations were managed under dryland conditions.

Each trial followed a three-way factorial design within a randomized complete block design (RCBD) with four replications. The twelve treatments were based on three factors: nitrogen rate, seed treatment, and seeding date (Table 1). Nitrogen was applied at three rates—0, 50, and 100 lbs N/ac—using urea fertilizer

(46-0-0). Lentil seed was either treated with Rancona Trio at a rate of 500 mL/100 kg seed or left untreated. Seeding dates were classified as either early (targeting early May) or late (targeting mid-May).

Table 1. Treatment list for AP-2407a "Integrated Pest Management (IPM) for Lentils in Aphanomyces Soil" including Nitrogen rate (lbs/ac), seed treatment, and seed date.

TRT #	Nitrogen Rate (lbs/ac)	Seed Treatment	Seeding Date
1	0	Yes	Early
2	0	Yes	Late
3	0	No	Early
4	0	No	Late
5	50	Yes	Early
6	50	Yes	Late
7	50	No	Early
8	50	No	Late
9	100	Yes	Early
10	100	Yes	Late
11	100	No	Early
12	100	No	Late

Seeding equipment and general crop management varied by location, with specific agronomic details and operation dates outlined in Table 1 of the Appendix. Early seeding occurred between April 29 – May 12, while late seeding took place between May 13 – May 23, depending on location. The lentil variety used in the study was CDC Impulse, and all sites were seeded at a target density of 190 seeds/m². In addition to nitrogen treatments, supplemental fertilizers were applied as per soil test recommendations. Rhizobial inoculant was applied at seeding across all locations. Weed control was managed using pre-seed and in-crop herbicides, while some sites received preventative fungicide applications. No insecticides were used during the study. Pre-harvest desiccants were applied at some locations to aid in harvest management. Trials were harvested between July 31 – September 6 for early seed treatments, and August 6 – September 14 for late seeded treatments.

Data Collection

Dates for data collection at each site are provided in Table 3 of the Appendix. To determine soil fertility requirements and site characteristics, composite soil samples were collected from each trial location in the spring of 2024 at two depth increments, 0–15 cm and 15–60 cm. Soil samples were also sent to Discovery Seed Labs for confirmation of Aphanomyces oospore levels. Plant density assessments were conducted at the 3–6 node stage by counting plants within four 1-meter row lengths per plot. At sites equipped with NDVI sensors, NDVI measurements were collected at this stage. Plant height was recorded for five plants per plot at three growth stages: the 3–6 node stage, early to full flower (R1–R2), and full pod (R6). Nodulation and root disease severity were assessed at the 3–6 node stage and again at the R1–R2 stage. Five plants per plot were evaluated for above-ground disease symptoms using a severity scale from 0 to 5, while root disease was rated on a scale from 1 to 5 (Table 2). Nodulation was assessed based on placement, color, and the number of nodules, following a standardized assessment guide (Figure 1). Additionally, at the R1-R2 stage, one plant was randomly selected per plot in the first replicate of the trial and the most severely diseased plant submitted to Discovery Seed Labs for root rot pathogen identification. Yields were determined from cleaned harvested grain samples and corrected to 13% moisture content. Cleaned grain samples were analyzed for protein content using an NIR machine. Composite samples per treatment were submitted to Discovery Seed Labs for germination, vigour, and seed disease. An economic analysis was conducted to assess the cost-effectiveness of treatments by calculating net return based on seed treatment and urea costs, as well as gross revenue per treatment. Seed treatment and urea costs were obtained from the Rack Petroleum retail on February 21, 2025. Gross revenue was determined using the average yield per treatment at each site and across all sites, combined with the lentil market price from AGT Foods on February 21, 2025. Daily weather data was collected from on-site weather stations, while long-term climate data (1981–2010) was obtained from Environment Canada.

Table 2. Rating Scale for shoot symptoms (1-5) and root symptoms (0-5) of Aphanomyces.

Rating Value	Shoot Symptoms	Root Symptoms
0		No root discoloration
1	Healthy plant	1-25% discoloration
2	Slight yellowing of lower leaves	25-50% discoloration
3	Yellowing of the lower leaves up to the 3rd or 4th nodes, some stunting	50-75% discoloration
4	Necrosis of at least half or more of the leaves with some stunting	75-100% discoloration
5	Plant dead or nearly so	Dead plant

ASSESSMENT CODES

1. PLANT AND GROWTH VIGOUR

Plants green and vigourous....................5
Plants green and relatively small....................3
Plants slightly chlorotic....................2
Plants very chlorotic....................1

Poor nitrogen fixation can cause nitrogen deficiency symptoms such as yellowing of the leaves at the base of the plant prior to flowering, and poor plant development.

2. NODULE COLOUR / NUMBER

Greater than 5 clusters or groups of pink pigmented nodules....................5
3 – 5 clusters / groups of predominantly pink nodules....................3
Less than 3 groups of nodules OR nodules whitish or greenish in colour ...1
No nodules OR nodules white or green in colour....................0

Determination of the efficiency of nitrogen fixation via nodule colour and the number of nodule clusters present. Carefully slice open the nodules. The strong pink colour of the nodules is caused by the presence of leghemoglobin, which must be present for active nitrogen fixation. If a nodule is brown, white or green, it is considered non-effective.

3. NODULE POSITION

Crown and lateral nodulation....................3
Generally crown nodulation....................2
Generally lateral nodulation....................1

Predominantly crown nodulation is observed when seed is inoculated. Lateral nodulation is prevalent when native *Rhizobia* species exist in the soil or when granular inoculants are used. The crown region of a plant is generally the area of soil surrounding the seed. The approximate size of this region varies according to the crop. For example, the crown region for peas can be visualized as a cylinder extending approximately 8-10 cm deep from the soil surface with an 8 cm diameter.

TOTAL SCORE

11 – 13	**Effective nodulation.** Good nitrogen fixation potential.
7 – 10	**Nodulation less effective.** Fixation potential reduced. Were inoculation or growing conditions less than optimum?
1 – 6	**Generally unsatisfactory nodulation.** Requires evaluation of inoculants used, inoculation methods and of growing conditions on site.

Figure 1. Nodulation Assessment Guide including plant vigour (1-5), nodule colour/number (0-5), and nodule position (1-3) for a total score out of 13.

Statistical Analysis

The data were analyzed using R (ver. 2023.12.0+369; RStudio Team, 2023) to assess the effects of different management strategies such as nitrogen fertilizer, seed treatment, and seed date on Aphanomyces in lentils. Other variables measured included plant density, NDVI, plant height, yield, and protein. For the combined analysis, a linear mixed effects model was used with nitrogen rate, seed treatment, and seed date as fixed effects and replicate nested within site as the random effects. For individual sites, a linear mixed-effects model was applied with N rate, seed treatment, and seed date as the fixed effect and replicate as the random effect. All models were evaluated for assumptions of normality and homogeneity of variance. When these assumptions were not met, data were log-transformed. Analysis of variance (ANOVA) was performed to identify significant differences at $p < 0.05$. Post-hoc pairwise comparisons of means were conducted using estimated marginal means (EMMs) via the emmeans package in R, with the Sidak adjustment for multiple comparisons. Root and seed samples submitted to Discovery Seed Labs were not statistically analyzed due to the low number of data points, as only one sample was collected per treatment at each site.

Certain data collection parameters were not recorded at specific sites and were excluded from the analysis, as outlined in Table 2 in the Appendix. The early seeding date treatments at Redvers were cancelled under the advisement of SPG on July 3rd due to a mechanical issue with the cone on the new seeder that resulted in the seed and fertilizer being sown over a shorter length than intended. Additionally, at the Swift Current site, root samples for the late-seeded treatments were not submitted due to poor root quality, following SPG's advisement.

9. Results & Discussion

Weather

The environmental conditions during the 2024 growing season were generally favorable for root rot disease development across all sites. Temperatures were above the long-term average at all locations (Table 3), with April, July, August, and September being particularly warm. July stood out as an especially hot month across most sites. In contrast, May was cooler than the long-term average at all locations.

Precipitation levels were above average for most of the growing season (Table 3), with a particularly wet spring (April and May) compared to historical climate norms. All sites received more precipitation than their respective long-term averages in April, with Swift Current receiving nearly twice its usual amount. This trend continued into May, where all sites saw substantially higher-than-normal rainfall, creating persistently wet spring conditions conducive to root rot development. By June, precipitation remained above average at most locations except Swift Current. However, July brought a shift, with all sites experiencing drier-than-average conditions alongside elevated temperatures. August remained relatively dry, while September saw slightly above-average or near-normal moisture levels.

Overall, most sites experienced a cool, wet spring, followed by rising temperatures in June and July and drier conditions toward the end of the growing season. These environmental conditions were ideal for root rot disease development, as soil moisture plays a crucial role in allowing oospores to infect plant roots.

Table 3. Mean monthly temperature (°C) and cumulative monthly precipitation (mm) for Scott, Swift Current, Outlook, and Redvers from April to September, 2024.

Site	Year	April	May	June	July	August	Sept.	Average/ Sum	% of Long-term Average
		Temperature (°C)							
Scott	2024	5.7	9.8	13.3	18.9	17.4	14.7	13.3	108%
	Long-term[z]	3.8	10.8	15.3	17.1	16.5	10.4	12.3	
Swift Current	2024	6.8	10.6	14.3	21.3	19.4	16.7	14.9	111%
	Long-term	5.2	10.9	15.4	18.5	18.2	12.0	13.4	
Outlook	2024	7.0	11.2	14.2	20.4	18.1	16.2	14.5	106%
	Long-term	5.3	11.5	16.1	18.9	18.0	12.3	13.7	
Redvers	2024	5.4	10.9	14.7	20.0	17.7	15.8	14.1	104%
	Long-term	4.4	11.1	16.2	18.7	18.0	12.5	13.5	
		Precipitation (mm)							
Scott	2024	22.1	74.2	112.0	26.7	42.8	39.5	317.3	116%

	Long-term[z]	21.6	36.3	61.8	72.1	45.7	36.0	273.5	
Swift Current	2024	22.2	73.6	52.1	18.6	18.2	47.8	232.5	91%
	Long-term	12.1	43.8	72.8	52.6	41.5	31.5	254.3	
Outlook	2024	22.4	65.7	122.0	19.1	3.8	52.7	285.7	114%
	Long-term	16.1	39.0	63.9	56.1	42.8	32.8	250.7	
Redvers	2024	19.5	92.0	156.2	13.4	39.0	70.6	390.7	127%
	Long-term	13.3	53.2	95.2	65.5	46.6	32.7	306.5	

[z]Long-term average for all sites (1981-2010); Environment Canada

Soil Test Results

Soil was sampled at approximately 15 cm depth and submitted to Discovery Seed Labs for Aphanomyces confirmation. At the Scott location, the direct soil extraction method detected 100 spores/gram. Additionally, the bait test method identified Aphanomyces in replicated samples. Thus, confirming that the location at Scott where the trial was placed had Aphanomyces infected soil. However, soil samples for Aphanomyces confirmation were not submitted from Swift Current, Outlook, or Redvers.

Soil samples were also taken at depths of 0-15 cm and 15-60 cm at each location, with composite samples representing the trial area to assess residual nutrient levels and soil characteristics (Table 4). At Scott, residual nitrogen levels were relatively high, measuring 54 lbs/ac at the 0-15 cm depth and 75 lbs/ac at the 15-60 cm depth. In contrast, nitrogen levels were much lower at the other sites: Swift Current (12 lbs/ac), Outlook (6 lbs/ac), and Redvers (9 lbs/ac) at the 0-15 cm depth. Phosphorus levels were low across all sites, ranging from 4-12 ppm. Potassium levels were relatively high at each site, ranging from 172-394 ppm, which is typical for Saskatchewan soils. Sulphur levels were high at the 0-15 cm depth at Scott (30 ppm), Outlook (40 ppm), and Redvers (24 ppm), but were low at Swift Current (8 ppm). A similar trend for sulphur was observed at the 15-60 cm depth across the sites. Organic matter levels ranged from 2.4% to 4.8%, with Scott having the highest levels. The pH level was slightly acidic at Swift Current (6.5), near neutral at Scott (7.1), and alkaline at Outlook (8.2). The cation exchange capacity was highest at Outlook (22.2 meq), followed by Scott (21.3 meq), and lowest at Swift Current (17.3 meq), giving a general indication of soil texture at each site. Organic matter, pH, and cation exchange capacity were not measured at Redvers.

Table 4. Soil nutrients and characteristics for each site, 2024. NA indicates information not available.

		Scott	**Swift Current**	**Outlook**	**Redvers**
Soil Zone		dark brown	brown	brown	black
Nitrate (NO3)- 0-15 cm depth	lbs/ac	54	12	6	9
Nitrate (NO3)- 15-60 cm depth	lbs/ac	75	69	15	30
Phosphorus (Olsen)	ppm	10	12	4	8
Potassium	ppm	394	211	172	203
Sulphur- 0-15 cm depth	lbs/ac	30	8	40	24
Sulphur- 15-60 cm depth	lbs/ac	>360	18	>120	>360
Organic Matter	%	4.8	2.5	2.4	NA
pH- 0-15 cm depth		7.1	6.5	8.2	NA
Cation Exchange Capacity	meq	21.3	17.3	22.2	NA

Plant Establishment

Lentil plant establishment was largely unaffected by the management strategies implemented in this study; however, some site-specific differences were observed. There were no significant treatment effects or interactions detected at Scott or Outlook. But, at Swift Current, plant establishment varied significantly with nitrogen (N) rate ($p < 0.001$) and seeding date ($p < 0.001$), while at Redvers, seed treatment had a significant effect ($p = 0.013$). Anova results and treatment means are provided for each site in the Appendix.

At Swift Current, the highest N rate (100 lbs N/ac) resulted in significantly lower plant densities (117 plants/m²) compared to the 0N (131 plants/m²) and 50N (130 plants/m²) treatments. While over-fertilization in dry conditions can lead to seedling mortality, the spring conditions at Swift Current in 2024 were exceptionally wet compared to climate norms. Similar, though non-significant, trends were observed at other sites, where higher N rates tended to be associated with slightly lower plant densities. Despite favorable spring moisture conditions across all sites, these results suggest that excessive N fertilization at seeding may contribute to seedling mortality.

At Redvers, seed treatment significantly improved plant establishment, with treated seed producing 142 plants/m² compared to 122 plants/m² for untreated seed. This response was expected, as the cool and wet spring conditions at Redvers likely increased the risk of seedling diseases. Scott and Swift Current also observed slightly higher plant densities with treated seed versus untreated seed, although not significant.

Early seeding at Swift Current resulted in greater plant establishment (139 plants/m²) compared to late seeding (113 plants/m²). Trends between other sites were inconsistent and non-significant. Early seeding can improve access to early-season moisture, but can also delay germination and increase disease risk depending on soil conditions. A significant N rate × seeding date interaction at Swift Current ($p = 0.007$) indicated that the highest plant density occurred with early seeding and no N fertilization, which was significantly greater than plant densities observed with late seeding at all N rates.

Overall, plant establishment varied by site and management strategy, with environmental conditions playing a key role in determining outcomes. The results suggest potential benefits of low to moderate N rates, seed treatment, and early seeding for improving plant establishment, though responses may be site-specific and influenced by environmental conditions.

Plant Height

Plant height was measured to assess overall lentil health and vigor across treatments. Plant height was recorded at three growth stages (3–6 node, R1–R2, R6) at Scott and Swift Current, while at Outlook, measurements were taken only at 3-6 node stage. No height data was collected at Redvers.

Nitrogen (N) rate had a marginal effect on plant height at Scott ($p = 0.070$) and a significant effect at Swift Current ($p = 0.019$), but was not significant at Outlook ($p = 0.741$). The 50 lbs N/ac rate generally resulted in the tallest plants, suggesting improved growth and vigor. At Scott and Outlook, the 100 lbs N/ac rate produced the second-tallest plants, while at Swift Current, it resulted in the shortest. At Swift Current, plant height followed the order of 50 > 0 > 100 lbs N/ac, indicating that moderate N additions at seeding may benefit lentil growth.

Seed treatment had no significant effect on plant height at any site. However, seeding date influenced plant height at Scott and Swift Current ($p < 0.001$). At Scott, late-seeded treatments were 0.9 cm taller than early-seeded treatments, while at Swift Current, late-seeded treatments were 4.8 cm taller. Outlook followed a similar, though non-significant trend.

Overall, nitrogen rate had a marginal to significant effect at Scott and Swift Current, with the 50 lbs N/ac rate generally producing the tallest plants, while seed treatment had no impact. Late seeding resulted in taller plants at Scott and Swift Current, with a greater difference at Swift Current.

NDVI & Chlorophyll Content

NDVI at Scott and Outlook was measured at the 3-6 node stage. At Swift Current, chlorophyll content was used as an alternative indicator of plant health. NDVI data, collected at Scott and Outlook, followed similar trends to plant height. The 100 lbs N/ac rate resulted in the highest NDVI values, though significance was observed only at Scott. Late-seeded lentils had significantly greater NDVI values at Scott ($p = 0.002$) and Outlook ($p < 0.001$), while seed treatment had no effect. The combination of 100 lbs N/ac and late seeding resulted in the highest NDVI values at both sites. At Swift Current, where NDVI was not measured, chlorophyll content was used as an alternative indicator of plant health, showing significantly higher values for late-seeded lentils ($p = 0.012$). These results suggest that later seeding, particularly when combined with nitrogen additions, may enhance lentil growth and vigour.

Shoot Disease Symptoms

Above-ground plant material was assessed for disease symptoms at multiple growth stages across locations. At Scott, Swift Current, and Outlook, ratings were conducted at the 3–6 node stage and R1–R2 stage. At Redvers, plants were rated only at the R1–R2 stage.

Nitrogen rate had a significant effect on shoot disease symptoms at Scott ($p = 0.002$) and Outlook ($p = 0.043$), with a marginal effect at Redvers ($p = 0.055$). At Scott, the 0 and 50 lbs N/ac rates resulted in significantly higher disease ratings compared to the 100 lbs N/ac rate. A similar trend was observed at Outlook, where the 50 lbs N/ac rate had significantly higher disease ratings than both the 0 and 100 lbs N/ac rates. In contrast, at Redvers, the highest nitrogen rate (100 lbs/ac) resulted in significantly higher disease ratings than the no-nitrogen treatment. However, Aphanomyces was not confirmed at this site, so any visible disease symptoms cannot be definitively attributed to Aphanomyces.

Seed treatment had no significant effect on shoot disease ratings at any location. However, seeding date had a significant effect at Scott ($p = 0.007$), Swift Current ($p = 0.005$), and Outlook ($p < 0.001$). The Redvers site did not have both seeding date treatments and were not included in this analysis. At Swift Current and Outlook, late seeding resulted in significantly higher disease ratings than early seeding. At Scott, the opposite trend was observed, with early seeding leading to significantly higher disease ratings than late seeding.

Altogether, nitrogen rate significantly affected shoot disease symptoms at Scott and Outlook, with lower disease ratings at the highest N rate (100 lbs/ac). Seeding date also influenced disease ratings, with late seeding increasing disease at Swift Current and Outlook but decreasing it at Scott, while seed treatment had no effect.

Root Disease Symptoms

Root disease symptoms were assessed on a 0–5 scale at all sites alongside shoot disease ratings. Nitrogen rate significantly affected root disease at Scott ($p = 0.002$), where the lowest rate (0 lbs/ac) had the highest disease ratings, and the highest rate (100 lbs/ac) had the lowest. A similar trend was observed at Redvers, while the opposite occurred at Swift Current and Outlook, where higher nitrogen rates increased disease.

Consistent with shoot disease ratings, seed treatment had no significant effect on root disease. However, early seeding resulted in significantly lower root disease ratings at Scott ($p < 0.001$) and Swift Current ($p = 0.001$), with a similar but non-significant trend at Outlook ($p=0.507$). Seeding earlier may allow roots to establish before Aphanomyces oospores have a chance to infect roots and cause severe damage.

Overall, higher nitrogen rates reduced root disease at some sites but increased it at others, while early seeding consistently lowered root disease, likely by allowing root establishment before Aphanomyces infection.

Nodulation

Nodulation of roots were assessed at the same timing as disease assessments at all sites. A rating scale determined that an overall score of 11-13 indicates effective nodulation, 7-10 indicates less effective nodulation, and 1-6 indicates unsatisfactory nodulation.

Lower N rates tended to result in greater nodulation scores; with the 0N rate ranging from 6.85-10.80 across sites, 50N ranging from 6.76-10.90, and 100 N ranging from 5.67-10.60. These scores indicate less than effective nodulation across N rates and sites, with unsatisfactory nodulation occurring for all rates at Scott and the 50 and 100 N rates at Swift Current. Swift Current was the only site where differences between N rates were significant ($p<0.001$). These results are congruent with general knowledge that higher rates of N can hinder nodulation of pulses.

Seed treatment did not have a significant effect on nodulation at any site. Early seeding improved nodulation at Outlook ($p < 0.001$) and showed a similar, though non-significant, trend at Scott ($p = 0.382$). In contrast, Swift Current showed significantly greater nodulation with late seeding ($p = 0.038$).

Overall, nodulation was generally below effective levels across sites, with higher nitrogen rates reducing nodulation at Swift Current, and seeding date effects varying by location.

Root Disease Pathogens

Roots were submitted to Discovery Seed Labs for identification of disease pathogens. Root samples were collected at the R1-R2 growth stage from Scott, Swift Current, and Outlook. At Swift Current, samples were submitted only for the early seeding date treatments. Redvers did not submit root samples for pathogen identification.

At Scott, *F. redolans* and *F. solani* were detected in 100% of the treatments, while *Aphanomyces* was found in 92% of the treatments. The only treatment where *Aphanomyces* was not detected was the 0N – treated – early seeding treatment. *F. avenaceum* was present in 75% of the treatments, whereas *F. oxysporum* was not detected in any treatment.

At Outlook, *Aphanomyces* and *F. avenaceum* were detected in 75% of the treatments. The only treatment that did not test positive for *Aphanomyces* was 0N – untreated – late treatment. *F. solani* had the highest infection rate at 83%, *F. redolens* at 67% infection, and *F. oxysporum* had the lowest infection rate at 17% of treatments.

At Swift Current, all submitted treatments (early seeding date only) tested positive for *Aphanomyces*, *F. oxysporum*, *F. redolens*, and *F. solani*. *F. avenaceum* had the lowest infection rate at 33% of treatments.

Overall, these results give an indication as to which pathogens may be causing the disease responses at each site. The Aphanomyces pathogen was present at all sites, but not present in all treatments. It's important to note the small sample size; however, as only one plant per plot in the first replicate. Therefore, actual infection rates may vary.

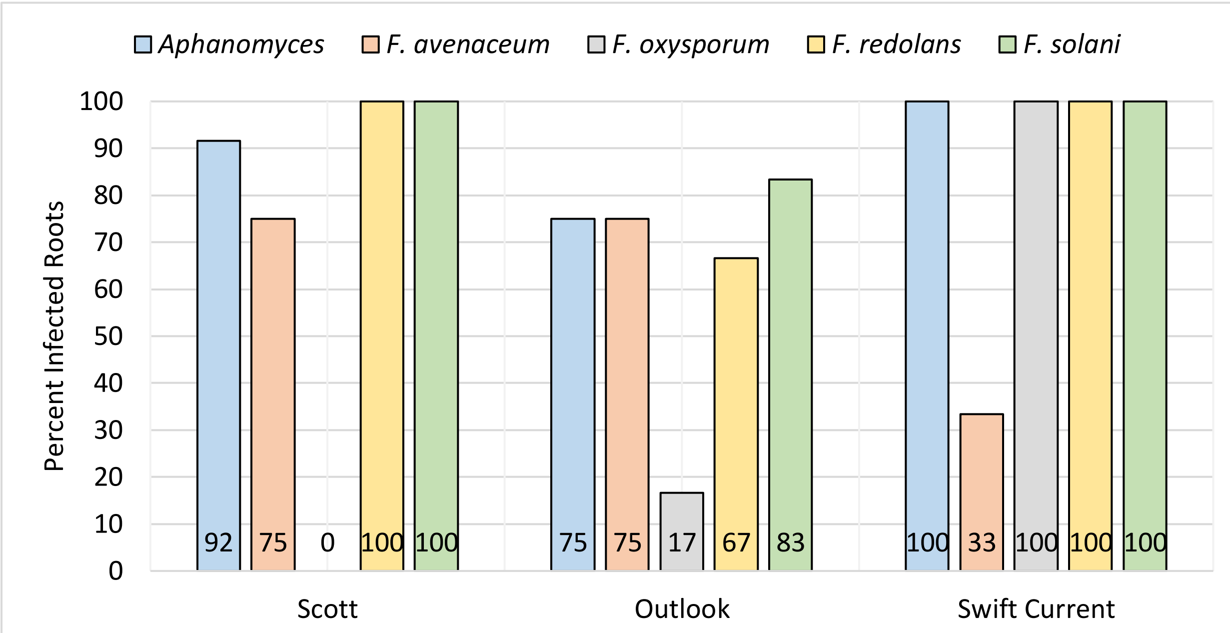

Figure 2. Percentage of lentil roots infected with root rot pathogens (*Aphanomyces, F. avenaceum, F. oxysporum, F. redolans, F. solani*) at Scott, Outlook, and Swift Current, 2024.

<u>*Yield*</u>

Lentil yield responded significantly to nitrogen rate at Outlook ($p = 0.036$) but not at Scott ($p = 0.840$), Swift Current ($p = 0.759$), or Redvers ($p = 0.352$). Generally, lower N rates (0 and 50 lbs N/ac) resulted in higher lentil yields than 100 lbs N/ac. At Outlook, where the response was significant, yields were 3.4 bu/ac higher for the 0N treatment and 3.0 bu/ac higher for the 50N treatment compared to 100N. This suggests that applying high rates of N at seeding may not improve lentil yield, especially if other factors are limiting yield potential.

Seeding date had a relatively consistent impact on yield across sites. At Swift Current, early seeding increased yield by 2.2 bu/ac compared to late seeding, while at Outlook, early seeding resulted in a 2.8 bu/ac yield advantage. Although early seeding also produced higher yields at Scott, the difference was not statistically significant. These findings suggest a potential yield benefit from seeding lentils in early May.

A significant three-way interaction (N rate × seed treatment × seeding date) at Swift Current showed the highest yield for the combination of 100N – untreated – early, which was significantly greater than multiple other treatment combinations, including the lowest-yielding 100N – untreated – late treatment. No other sites exhibited a significant three-way interaction.

These results suggest that, at most sites, the combination of N rate, seed treatment, and seed date does not provide a consistent yield benefit. Instead, early seeding combined with low to moderate N rates may have the greatest potential to improve lentil yields, though responses may vary by site.

Protein

Nitrogen rate and seeding date showed consistent trends across sites, whereas seed treatment had no effect on overall protein levels. Protein content was significantly higher with the 100 lbs N/ac rate compared to no nitrogen at Scott ($p = 0.016$) and Redvers ($p = 0.033$). Although similar trends were observed at Swift Current and Outlook, the differences were not statistically significant.

Seeding date also had a significant effect on protein levels, with late seeding resulting in higher protein content at Scott ($p < 0.001$), Swift Current ($p < 0.001$), and Outlook ($p < 0.001$). The greatest difference was observed at Outlook, where late-seeded lentils had 0.6% higher protein than early-seeded ones. At Scott and Swift Current, the differences were 0.4% and 0.3%, respectively.

Overall, protein content consistently increased with higher nitrogen rates and later seeding across all sites. Given that nitrogen is known to enhance protein levels, these results align with expectations. Additionally, the effect of seeding date on protein levels is consistent with findings in research on seeding dates of wheat, where later seeding typically results in higher protein content (Collier et al., 2021).

Seed Quality

Seed testing results from Discovery Seed Labs indicated good seed quality across all treatments and locations. Germination ranged from 81% to 99%, vigor from 77% to 98%, and thousand kernel weight from 33 to 42 g per 1,000 seeds. Levels of seed-borne disease were low across all samples.

No *Ascochyta* was detected in any of the submitted seed samples. The highest *Anthracnose* infection observed was 0.5%, occurring in the 50N – untreated – late treatment at Outlook. However, there are no established guidelines for safe levels of *Anthracnose* in seed, as it is not considered highly seed-borne (Sask Ag, n.d.). *Botrytis* and *Sclerotinia* infections were also minimal, with a maximum detected level of 0.3% for both pathogens. *Botrytis* infection was found in three samples from Redvers: 0N – untreated – early, 50N – treated – early, and 100N – untreated – early. It is important to note that only early-seeded samples were submitted from Redvers. *Sclerotinia* infection was detected in just one sample, occurring in the 100N – treated – late-seeded treatment at Outlook.

According to Saskatchewan Agriculture guidelines, seed with *Botrytis* or *Sclerotinia* infection levels exceeding 10% should not be planted (Sask Ag, n.d.). The infection levels observed in this study were well below this threshold, indicating no concerns regarding seed quality.

Economics

An economic analysis was conducted to evaluate net returns between treatments. Net returns varied slightly by site due to differences in yield. Redvers had the highest net returns, ranging from $573.64 to $687.48, but also had the highest yields between all sites. Scott and Outlook had comparable net returns, with Outlook ranging from $303.94 to $528.36 and Scott from $279.89 to $575.28. Swift Current had the lowest net returns, ranging from $287.62 to $391.66, which corresponds to lower yields at this site.

At most sites, lower nitrogen (N) rates and untreated seed resulted in greater net returns due to reduced input costs. The exception was the Scott site, where the 50 lbs N/ac rate had a lower net return than the 100 lbs N/ac rate. Although not statistically significant, the 100N treatment yielded 1.6 bu/ac more than the 50N treatment. Similarly, untreated seed generally resulted in higher net returns, except at Outlook, where treated seed netted $6.54 more than untreated. The treated seed yielded 0.8 bu/ac more than untreated, though this difference was not significant. When averaged across all sites, lower N rates and untreated seed provided the highest net returns. However, as no statistically significant yield differences were observed, these findings may not be consistently replicable, and should not advise management decisions.

While seeding dates do not typically influence input costs, the large yield differences between seeding dates at each site make net return comparisons valuable. At Scott, Swift Current, and Outlook, early seeding resulted in higher net returns than late seeding, aligning with significantly higher yields at these sites. When averaged across sites, early seeding led to an increased net return of $42.50/ac compared to late seeding.

Overall, the economic analysis indicates that lower N rates and untreated seed generally provide the highest net returns due to reduced input costs, though site-specific variations exist. Given the lack of statistically significant yield differences between N rates and seed treatments, these findings do not definitively establish that low N rates and untreated seed will always be the most economical choice. However, early seeding consistently resulted in greater net returns, aligning with significantly higher yields at all sites, suggesting both agronomic and economic benefits to early May seeding.

Table 4. Net revenue ($/ac) for each treatment and averaged for nitrogen rates (0, 50, 100 lbs/ac), seed treatment (treated vs. untreated), and seed date (early vs. late) for all sites, Scott, Swift Current, Outlook, and Redvers, 2024.

	All Sites	Scott	Swift Current	Outlook	Redvers
Treatments		------------------net revenue ($/ac)---------------			
0N-Treated-Early	$430.85	$451.25	$385.97	$453.29	--
0N-Treated-Late	$432.89	$279.89	$351.29	$449.21	$653.21
0N-Untreated-Early	$442.68	$450.84	$348.84	$528.36	--
0N-Untreated-Late	$512.04	$575.28	$361.08	$422.28	$687.48
50N-Treated-Early	$418.61	$394.13	$381.89	$477.77	--
50N-Treated-Late	$406.37	$322.73	$312.53	$377.81	$612.41
50N-Untreated-Early	$450.83	$479.39	$371.27	$503.87	--
50N-Untreated-Late	$438.59	$403.91	$324.35	$373.31	$650.75
100N-Treated-Early	$379.84	$418.60	$320.68	$402.28	--
100N-Treated-Late	$410.44	$416.56	$292.12	$357.40	$573.64
100N-Untreated-Early	$361.06	$387.58	$391.66	$303.94	--
100N-Untreated-Late	$410.02	$432.46	$287.62	$346.78	$577.30
N Rate					
0N	$454.62	$439.32	$361.80	$463.29	$670.35
50N	$428.60	$400.04	$347.51	$433.19	$631.58
100N	$390.34	$413.80	$323.02	$352.60	$575.47
Seed Treatment					
Treated	$413.17	$380.53	$340.75	$419.63	$613.09
Untreated	$435.87	$454.91	$347.47	$413.09	$638.51
Seed Date					
Early	$413.98	$430.30	$366.72	$444.92	--
Late	$371.48	$405.14	$321.50	$387.80	$625.80

10. Conclusions & Recommendations

This study evaluated the effects of nitrogen rate, seed treatment, and seeding date on lentil establishment, disease incidence, yield, quality, and economic returns across multiple sites. Results showed that plant establishment was generally stable across treatments, although excessive nitrogen reduced plant densities in some cases. Seed treatment and early seeding improved establishment at most locations. NDVI and chlorophyll measurements indicated that late seeding and moderate to high nitrogen rates enhanced plant vigor.

Shoot and root disease responses varied by site, with higher nitrogen rates and early seeding reducing disease at most locations. Seed treatment did not significantly impact disease suppression. Root pathogen analysis revealed that *Aphanomyces* was present at all sites, but not in all treatments, and Fusarium species such as *F. redolans, F. solani*, and *F. avenaceum* had high infection rates at Scott, Outlook, and Swift Current. These findings provide insight into the pathogens contributing to disease responses under different management conditions. Nodulation was generally below effective levels, with higher nitrogen rates further reducing nodulation, particularly at Swift Current.

Yield responses to nitrogen indicated that low to moderate N rates produced greater yields than high N rates, likely due to other yield limiting factors. Early seeding consistently increased yield across sites, which was also reflected in higher net returns. Protein content increased with higher nitrogen rates and later seeding. Seed quality remained high across all treatments with minimal disease presence. Economic analysis revealed that lower nitrogen rates and untreated seed generally resulted in higher net returns due to reduced input costs, although site-specific variations existed. Early seeding consistently improved profitability, making it the most promising strategy for maximizing returns.

Overall, these findings highlight the importance of site-specific management and suggest that moderate nitrogen rates and early seeding show promise as management strategies for reducing root rot disease in lentils. Additional years of research will be crucial to confirm the consistency of these results and provide reliable recommendations for producers.

11. Technology transfer activities

This project was showcased during the growing season at the annual field days for WARC on July 10th, WCA on July 18th, SERF on July 24th. At the WARC field day, Jessica Enns highlighted the trial to an audience of approximately 100 people by showing root samples from different plots. At the WCA field day, Mike Brown and Meagan Reed, SPG representatives, presented the trial to around 75 attendees. At the SERF field day, the trial was showcased to 28 attendees. Amber Wall (WCA) presented the project at the Winter Pulse Days in Swift Current on February 11, 2025 to approximately 120 attendees. Alex Waldner (WARC) is scheduled to present the project in the "Agri-ARM Research Update" webinar on March 27th. In addition to these presentations, a fact sheet and full report will be made available for public access on the websites of WARC, WCA, ISASK, and SERF.

12. Funding contributions & Acknowledgements

Financial support was provided by the Saskatchewan Pulse Growers. The Scott site was managed by Jessica Enns and Alex Waldner. The Swift Current was managed by Bryan Nybo and Amber Wall. The Outlook site was managed by Gursahib Singh. And the Redvers site was managed by Lana Shaw. Each site would like to recognize the support of technical and summer staff for conducting this project. Statistical analysis and report were written by project lead, Alex Waldner.

13. Appendix

Table 1. Crop management and dates of lentils at each location, 2024.

Operation	Scott	Swift Current	Outlook	Redvers
Previous Crop	peas	durum	NA	Canola
Pre-seed Herbicide	May 4/May 21* (Glyphosate & Aim)	April 23 (Glyphosate & Aim)	None	May 13 (Glyphosate)
Seeding Dates	May 5/May 22	April 29/May 13	May 9/May 23	May 12/May 21
lbs P2O5-K2O-S/ac	16-0-0	50-29-10	25-0-0	28-0-0
Inoculant	Nodulator Duo	Tagteam BioniQ	NA	Launcher
In-Crop Herbicide	June 2/June 19 (Solo Ultra Q)	June 20 (Solo ADV & Assure II)	June 24 (Centurion)	June 15 (Solo)
Fungicide	July 11 (Dyax)	July 23 (Voliam Express)	None	None
Insecticide	none	none	August 12 (Coragen)	None
Pre-harvest Herbicide	Aug 14/Aug 20 & 22 (Reglone ION)	none	August 30 (Glyphosate)	Sept 5 (Diquat)
Harvest Date	Aug 20/Aug 27	July 31/Aug 6	September 6	Sept 14

*early/late seed date treatments

Table 2. Dates of data collection for all sites, 2024. NA indicates data was not collected.

	Scott		**Swift Current**		**Outlook**		**Redvers****	
	Early	Late	Early	Late	Early	Late	Early	Late
soil test to confirm oospore levels	01-May		NA		NA		NA	
Agvise soil test	09-May		16-Apr		25-Apr		14-Nov	
plant density @ 3-6 node	30-May	18-Jun	24-May	06-Jun	20-Jun	04-Jul	07-Jun	07-Jun
heights @ 3-6 node	11-Jun	24-Jun	11-Jun	20-Jun	20-Jun	04-Jul	NA	NA
heights @ R1-R2	08-Jul	16-Jul	27-Jun	11-Jul	NA	NA	NA	NA
heights @ R6	25-Jul	25-Jul	11-Jul	30-Jul	NA	NA	NA	NA
root assessments	11-Jun	24-Jun	11-Jun	20-Jun	18-Jun	03-Jul	NA	NA
shoot assessments	11-Jun	24-Jun	11-Jun	20-Jun	18-Jun	03-Jul	NA	NA
nodule assessments	11-Jun	24-Jun	11-Jun	20-Jun	18-Jun	03-Jul	NA	NA
root assessments	08-Jul	16-Jul	04-Jul	11-Jul	18-Jul	23-Jul	NA	19-Jul
shoot assessments	08-Jul	16-Jul	04-Jul	11-Jul	18-Jul	23-Jul	NA	19-Jul
nodule assessments	08-Jul	16-Jul	04-Jul	11-Jul	18-Jul	23-Jul	NA	19-Jul
NDVI	11-Jun	24-Jun	06-Jun	19-Jun	20-Jun	04-Jul	NA	NA
DSL root samples (date received)	11-Jul	19-Jul	08-Jul	NA*	19-Jul	29-Jul	NA	NA
yield	20-Aug	27-Aug	31-Jul	06-Aug	06-Sept	06-Sept	NA	14-Sep
protein	20-Nov	20-Nov	10-Dec	10-Dec	10-Jan	10-Jan	NA	12-Dec
DSL seed test	01-Nov	01-Nov	02-Dec	02-Dec	20-Jan	20-Jan	NA	14-Jan

*****Late seed date treatments at Swift Current not submitted to Discovery Seed Labs for root rot pathogen identification under advisement of SPG due to poor root quality.

**Early seed date treatments at Redvers cancelled on July 3rd due to seeding error under the advisement of SPG.

Table 3. Overall results of ANOVA to assess the effects of nitrogen rate (0, 50, 100 lbs N/ac), seed treatment (treated vs. untreated), and seed date (early vs. late) on response variables of lentils at Scott, 2024. Bold p-values denote significance at p<0.05. Different letters within columns are significantly different at p<0.05 using estimated marginal means comparison.

	Plant Density plants/m²		**Height** cm		**NDVI** 0-1		**Shoot Ratings** 1-5		**Root Ratings** 0-5		**Nodule Ratings** 1-13		**Yield** bu/ac		**Protein** %	
	----		----		----		----	p-value	----		----		----		----	
N Rate (R)	0.560		0.070		**0.013**		**0.002**		**0.002**		0.952		0.840		**0.016**	
Seed Trt (S)	0.764		0.696		0.731		0.334		0.195		0.086		0.177		0.386	
Seed Date (D)	0.988		**<0.001**		**0.002**		**0.007**		**<0.001**		0.382		0.591		**<0.001**	
R x S	0.151		0.234		0.143		0.317		0.489		0.509		0.401		0.375	
R x D	0.458		0.106		0.116		0.902		0.114		0.894		0.711		0.464	
S x D	0.810		0.850		0.450		0.334		0.642		0.344		0.231		0.066	
R x S x D	0.936		0.981		0.176		0.985		0.633		0.594		0.384		0.995	
N Rate																
0N	149	*a*	26.5	*a*	0.202	*b*	1.46	*a*	2.90	*b*	6.85	*a*	21.8	*a*	10.5	*b*
50N	143	*a*	27.8	*a*	0.214	*ab*	1.26	*ab*	2.73	*ab*	6.82	*a*	20.9	*a*	10.6	*ab*
100N	142	*a*	27.8	*a*	0.225	*a*	1.16	*b*	2.49	*a*	6.76	*a*	22.5	*a*	10.7	*a*
Seed Treatment																
Treated	146	*a*	27.4	*a*	0.212	*a*	1.26	*a*	2.65	*a*	7.01	*a*	20.1	*a*	10.5	*a*
Untreated	144	*a*	27.3	*a*	0.215	*a*	1.33	*a*	2.77	*a*	6.61	*a*	23.3	*a*	10.6	*a*
Seed Date																
Early	145	*a*	26.9	*b*	0.203	*b*	1.39	*a*	2.54	*a*	6.91	*a*	22.3	*a*	10.4	*b*
Late	145	*a*	27.8	*a*	0.224	*a*	1.20	*b*	2.88	*b*	6.71	*a*	21.1	*a*	10.8	*a*
R x S																
0N - Treated	157	*a*	27.0	*a*	0.198	*a*	1.38	*a*	2.77	*a*	7.21	*a*	18.4	*a*	10.4	*a*
50N - Treated	141	*a*	27.4	*a*	0.207	*a*	1.30	*a*	2.74	*a*	6.85	*a*	19.1	*a*	10.6	*a*
100N - Treated	139	*a*	27.9	*a*	0.233	*a*	1.11	*a*	2.44	*a*	6.97	*a*	23.0	*a*	10.6	*a*
0N - Untreated	141	*a*	26.0	*a*	0.206	*a*	1.55	*a*	3.02	*a*	6.49	*a*	25.1	*a*	10.5	*a*
50N - Untreated	146	*a*	28.2	*a*	0.220	*a*	1.23	*a*	2.73	*a*	6.79	*a*	22.7	*a*	10.6	*a*
100N - Untreated	146	*a*	27.6	*a*	0.217	*a*	1.21	*a*	2.55	*a*	6.55	*a*	22.1	*a*	10.8	*a*
R x D																

0N - Early	152	*a*	26.5	*a*	0.200	*a*	1.54	*a*	2.86	*a*	7.00	*a*	22.3	*a*	10.2	*a*
50N - Early	144	*a*	27.6	*a*	0.196	*a*	1.38	*a*	2.50	*a*	6.95	*a*	22.7	*a*	10.4	*a*
100N - Early	138	*a*	26.6	*a*	0.214	*a*	1.26	*a*	2.25	*a*	6.79	*a*	22.0	*a*	10.4	*a*
0N - Late	145	*a*	26.5	*a*	0.204	*a*	1.39	*a*	2.94	*a*	6.70	*a*	21.2	*a*	10.7	*a*
50N - Late	142	*a*	28.0	*a*	0.231	*a*	1.15	*a*	2.96	*a*	6.69	*a*	19.1	*a*	10.7	*a*
100N - Late	147	*a*	28.9	*a*	0.236	*a*	1.06	*a*	2.74	*a*	6.74	*a*	23.0	*a*	10.9	*a*
S x D																
Treated - Early	146	*a*	27.1	*a*	0.200	*a*	1.32	*a*	2.46	*a*	7.22	*a*	22.1	*a*	10.4	*a*
Untreated - Early	143	*a*	26.7	*a*	0.207	*a*	1.46	*a*	2.62	*a*	6.60	*a*	22.5	*a*	10.3	*a*
Treated - Late	145	*a*	27.8	*a*	0.225	*a*	1.20	*a*	2.84	*a*	6.80	*a*	18.1	*a*	10.7	*a*
Untreated - Late	145	*a*	27.8	*a*	0.222	*a*	1.20	*a*	2.92	*a*	6.62	*a*	24.1	*a*	10.8	*a*
R x S x D																
0N-Treated-Early	162	*a*	27.1	*a*	0.195	*a*	1.42	*a*	2.75	*a*	7.58	*a*	22.6	*a*	10.3	*a*
0N-Treated-Late	153	*a*	26.9	*a*	0.200	*a*	1.32	*a*	2.80	*a*	6.85	*a*	14.2	*a*	10.6	*a*
0N-Untreated-Early	143	*a*	25.8	*a*	0.205	*a*	1.65	*a*	2.98	*a*	6.42	*a*	22.1	*a*	10.2	*a*
0N-Untreated-Late	138	*a*	26.1	*a*	0.207	*a*	1.45	*a*	3.08	*a*	6.55	*a*	28.2	*a*	10.8	*a*
50N-Treated-Early	141	*a*	27.2	*a*	0.180	*a*	1.38	*a*	2.42	*a*	6.92	*a*	20.8	*a*	10.5	*a*
50N-Treated-Late	140	*a*	27.6	*a*	0.235	*a*	1.23	*a*	3.05	*a*	6.78	*a*	17.3	*a*	10.7	*a*
50N-Untreated-Early	147	*a*	28.1	*a*	0.212	*a*	1.38	*a*	2.58	*a*	6.97	*a*	24.5	*a*	10.4	*a*
50N-Untreated-Late	144	*a*	28.4	*a*	0.228	*a*	1.07	*a*	2.88	*a*	6.60	*a*	20.8	*a*	10.8	*a*
100N-Treated-Early	136	*a*	26.9	*a*	0.225	*a*	1.18	*a*	2.20	*a*	7.17	*a*	23.0	*a*	10.4	*a*
100N-Treated-Late	141	*a*	29.0	*a*	0.240	*a*	1.05	*a*	2.67	*a*	6.78	*a*	22.9	*a*	10.8	*a*
100N-Untreated-Early	140	*a*	26.3	*a*	0.203	*a*	1.35	*a*	2.30	*a*	6.40	*a*	21.0	*a*	10.5	*a*
100N-Untreated-Late	152	*a*	28.9	*a*	0.233	*a*	1.07	*a*	2.80	*a*	6.70	*a*	23.2	*a*	11.0	*a*

Table 4. Overall results of ANOVA to assess the effects of nitrogen rate (0, 50, 100 lbs N/ac), seed treatment (treated vs. untreated), and seed date (early vs. late) on response variables of lentils at Swift Current, 2024. Bold p-values denote significance at $p<0.05$. Different letters within columns are significantly different at $p<0.05$ using estimated marginal means comparison.

	Plant Density		**Height**		**Chlorophyll Meter**		**Shoot Ratings**		**Root Ratings**		**Nodule Ratings**		**Yield**		**Protein**	
	plants/m^2		cm		CCI		1-5		0-5		1-13		bu/ac		%	
	--------------------------------						p-value								--------------------------------	
N Rate (R)	**<0.001**		**0.019**		0.538		0.314		0.983		**<0.001**		0.759		0.144	
Seed Trt (S)	0.603		0.663		0.353		0.138		0.403		0.354		0.700		0.956	
Seed Date (D)	**<0.001**		**<0.001**		**0.012**		**0.005**		**0.001**		**0.038**		**<0.001**		**<0.001**	
R x S	0.695		0.146		0.699		0.570		0.653		0.178		**0.039**		0.673	
R x D	**0.007**		0.141		0.574		0.795		**0.009**		0.880		**0.007**		0.857	
S x D	0.983		0.761		0.965		0.184		0.350		0.343		0.866		0.470	
R x S x D	0.875		0.789		0.299		0.192		0.590		0.266		**0.003**		0.426	
N Rate																
0N	131	*a*	22.4	*ab*	2.7	*a*	1.32	*a*	1.66	*a*	8.23	*a*	18.0	*a*	12.2	*a*
50N	130	*a*	22.5	*a*	2.7	*a*	1.40	*a*	1.68	*a*	6.76	*b*	18.3	*a*	12.2	*a*
100N	117	*b*	21.8	*b*	2.5	*a*	1.31	*a*	1.68	*a*	5.67	*b*	18.1	*a*	12.4	*a*
Seed Treatment																
Treated	126	*a*	22.4	*a*	2.5	*a*	1.38	*a*	1.71	*a*	7.08	*a*	18.2	*a*	12.3	*a*
Untreated	125	*a*	22.1	*a*	2.8	*a*	1.30	*a*	1.64	*a*	6.70	*a*	18.0	*a*	12.3	*a*
Seed Date																
Early	139	*a*	19.8	*b*	2.4	*b*	1.27	*b*	1.52	*a*	6.45	*a*	19.2	*a*	12.1	*b*
Late	113	*b*	24.6	*a*	2.8	*a*	1.42	*a*	1.82	*b*	7.32	*b*	17.0	*b*	12.4	*a*
R x S																
0N - Treated	131	*a*	22.8	*a*	2.7	*a*	1.40	*a*	1.69	*a*	8.96	*a*	18.5	*ab*	12.2	*a*
50N - Treated	129	*a*	22.7	*a*	2.4	*a*	1.44	*a*	1.76	*a*	6.75	*a*	18.5	*ab*	12.2	*a*
100N - Treated	119	*a*	21.6	*a*	2.4	*a*	1.31	*a*	1.68	*a*	5.53	*a*	17.5	*bc*	12.4	*a*
0N - Untreated	130	*a*	22.0	*a*	2.7	*a*	1.25	*a*	1.64	*a*	7.50	*a*	17.4	*bc*	12.2	*a*
50N - Untreated	130	*a*	22.3	*a*	3.0	*a*	1.36	*a*	1.59	*a*	6.76	*a*	18.1	*abc*	12.3	*a*
100N - Untreated	115	*a*	22.0	*a*	2.5	*a*	1.30	*a*	1.69	*a*	5.83	*a*	18.6	*a*	12.3	*a*
R x D																

0N - Early	145	*a*	19.8	*a*	2.6	*a*	1.25	*a*	1.70	*abc*	7.94	*a*	18.2	*ab*	12.0	*a*
50N - Early	137	*a*	19.9	*a*	2.5	*a*	1.30	*a*	1.46	*bc*	6.21	*a*	19.7	*a*	12.1	*a*
100N - Early	135	*ab*	19.8	*a*	2.1	*a*	1.25	*a*	1.41	*c*	5.21	*a*	19.7	*a*	12.2	*a*
0N - Late	116	*c*	25.0	*a*	2.8	*a*	1.40	*a*	1.62	*abc*	8.53	*a*	17.7	*b*	12.4	*a*
50N - Late	122	*bc*	25.1	*a*	2.9	*a*	1.50	*a*	1.89	*ab*	7.30	*a*	16.8	*b*	12.4	*a*
100N - Late	100	*d*	23.8	*a*	2.8	*a*	1.36	*a*	1.95	*a*	6.14	*a*	16.5	*b*	12.5	*a*
S x D																
Treated - Early	140	*a*	19.9	*a*	2.3	*a*	1.34	*a*	1.60	*a*	6.84	*a*	19.3	*a*	12.1	*a*
Untreated - Early	138	*a*	19.8	*a*	2.5	*a*	1.19	*a*	1.45	*a*	6.07	*a*	19.2	*a*	12.1	*a*
Treated - Late	113	*a*	24.8	*a*	2.7	*a*	1.42	*a*	1.82	*a*	7.32	*a*	17.1	*a*	12.4	*a*
Untreated - Late	112	*a*	24.4	*a*	3.0	*a*	1.42	*a*	1.82	*a*	7.33	*a*	16.9	*a*	12.4	*a*
R x S x D																
0N-Treated-Early	145	*a*	20.1	*a*	2.9	*a*	1.30	*a*	1.73	*a*	8.80	*a*	19.4	*abc*	12.0	*a*
0N-Treated-Late	117	*a*	25.6	*a*	2.5	*a*	1.50	*a*	1.65	*a*	9.12	*a*	17.7	*bcd*	12.4	*a*
0N-Untreated-Early	145	*a*	19.6	*a*	2.3	*a*	1.20	*a*	1.68	*a*	7.08	*a*	17.1	*bcd*	12.1	*a*
0N-Untreated-Late	116	*a*	24.4	*a*	3.2	*a*	1.30	*a*	1.60	*a*	7.92	*a*	17.7	*bcd*	12.3	*a*
50N-Treated-Early	136	*a*	20.1	*a*	2.0	*a*	1.38	*a*	1.65	*a*	6.03	*a*	20.2	*ab*	12.1	*a*
50N-Treated-Late	122	*a*	25.4	*a*	2.8	*a*	1.50	*a*	1.88	*a*	7.47	*a*	16.8	*cd*	12.2	*a*
50N-Untreated-Early	138	*a*	19.8	*a*	3.0	*a*	1.23	*a*	1.27	*a*	6.40	*a*	19.2	*abcd*	12.0	*a*
50N-Untreated-Late	122	*a*	24.8	*a*	3.0	*a*	1.50	*a*	1.90	*a*	7.12	*a*	16.9	*cd*	12.5	*a*
100N-Treated-Early	138	*a*	19.6	*a*	2.0	*a*	1.35	*a*	1.42	*a*	5.70	*a*	18.2	*abcd*	12.3	*a*
100N-Treated-Late	101	*a*	23.5	*a*	2.8	*a*	1.27	*a*	1.92	*a*	5.35	*a*	16.8	*cd*	12.5	*a*
100N-Untreated-Early	132	*a*	19.9	*a*	2.3	*a*	1.15	*a*	1.40	*a*	4.72	*a*	21.2	*a*	12.2	*a*
100N-Untreated-Late	99	*a*	24.0	*a*	2.8	*a*	1.45	*a*	1.98	*a*	6.92	*a*	16.1	*d*	12.5	*a*

Table 5. Overall results of ANOVA to assess the effects of nitrogen rate (0, 50, 100 lbs N/ac), seed treatment (treated vs. untreated), and seed date (early vs. late) on response variables of lentils at Outlook, 2024. Bold p-values denote significance at p<0.05. Different letters within columns are significantly different at p<0.05 using estimated marginal means comparison.

	Plant Density plants/m^2		Height cm		NDVI 0-1		Shoot Ratings 1-5		Root Ratings 0-5		Nodule Ratings 1-13		Yield bu/ac		Protein %	
	--------------------								p-value						--------------------	
N Rate (R)	0.740		0.741		0.078		**0.043**		0.387		0.635		**0.036**		0.923	
Seed Trt (S)	0.878		0.881		0.830		0.336		0.310		0.906		0.479		0.830	
Seed Date (D)	0.209		0.211		**<0.001**		**<0.001**		0.507		**<0.001**		**0.016**		**<0.001**	
R x S	0.760		0.759		0.799		0.694		0.311		0.288		0.336		0.748	
R x D	0.353		0.354		**0.043**		0.941		0.628		0.329		0.137		0.465	
S x D	1.000		0.997		0.176		0.397		0.757		1.000		0.748		0.966	
R x S x D	0.973		0.969		0.728		0.549		0.761		0.519		0.236		0.864	
N Rate																
0N	111	*a*	14.6	*a*	0.436	*a*	1.31	*b*	2.06	*a*	10.80	*a*	22.9	*a*	11.7	*a*
50N	119	*a*	15.6	*a*	0.474	*a*	1.45	*a*	2.20	*a*	10.90	*a*	22.5	*ab*	11.8	*a*
100N	114	*a*	14.9	*a*	0.489	*a*	1.31	*b*	2.19	*a*	10.60	*a*	19.5	*b*	11.8	*a*
Seed Treatment																
Treated	114	*a*	14.9	*a*	0.468	*a*	1.33	*a*	2.20	*a*	10.80	*a*	22.0	*a*	11.8	*a*
Untreated	116	*a*	15.1	*a*	0.464	*a*	1.38	*a*	2.10	*a*	10.70	*a*	21.2	*a*	11.8	*a*
Seed Date																
Early	110	*a*	14.3	*a*	0.301	*b*	1.24	*b*	2.12	*a*	11.60	*b*	23.0	*a*	11.5	*b*
Late	120	*a*	15.7	*a*	0.631	*a*	1.47	*a*	2.18	*a*	9.92	*a*	20.2	*b*	12.1	*a*
R x S																
0N - Treated	114	*a*	14.9	*a*	0.447	*a*	1.30	*a*	2.05	*a*	10.60	*a*	22.6	*a*	11.7	*a*
50N - Treated	119	*a*	15.6	*a*	0.471	*a*	1.44	*a*	2.35	*a*	10.90	*a*	22.4	*a*	11.8	*a*
100N - Treated	109	*a*	14.3	*a*	0.487	*a*	1.25	*a*	2.19	*a*	10.80	*a*	21.1	*a*	11.8	*a*
0N - Untreated	109	*a*	14.2	*a*	0.424	*a*	1.31	*a*	2.06	*a*	11.00	*a*	23.3	*a*	11.8	*a*
50N - Untreated	119	*a*	15.6	*a*	0.476	*a*	1.46	*a*	2.05	*a*	10.80	*a*	22.5	*a*	11.8	*a*
100N - Untreated	119	*a*	15.5	*a*	0.492	*a*	1.36	*a*	2.19	*a*	10.40	*a*	17.9	*a*	11.7	*a*
R x D																

0N - Early	111	*a*	14.5	*a*	0.305	*c*	1.23	*a*	2.09	*a*	11.57	*a*	24.3	*a*	11.5	*a*
50N - Early	118	*a*	15.4	*a*	0.300	*c*	1.31	*a*	2.15	*a*	11.54	*a*	25.3	*a*	11.5	*a*
100N - Early	100	*a*	13.1	*a*	0.299	*c*	1.19	*a*	2.11	*a*	11.68	*a*	19.5	*a*	11.4	*a*
0N - Late	112	*a*	14.6	*a*	0.566	*b*	1.39	*a*	2.02	*a*	10.03	*a*	21.6	*a*	12.0	*a*
50N - Late	121	*a*	15.8	*a*	0.647	*ab*	1.59	*a*	2.25	*a*	10.18	*a*	19.6	*a*	12.0	*a*
100N - Late	128	*a*	16.7	*a*	0.680	*a*	1.42	*a*	2.26	*a*	9.56	*a*	19.5	*a*	12.2	*a*
S x D																
Treated - Early	109	*a*	14.3	*a*	0.317	*a*	1.24	*a*	2.15	*a*	11.61	*a*	23.3	*a*	11.5	*a*
Untreated - Early	110	*a*	14.4	*a*	0.286	*a*	1.24	*a*	2.08	*a*	11.58	*a*	22.8	*a*	11.5	*a*
Treated - Late	120	*a*	15.6	*a*	0.620	*a*	1.42	*a*	2.24	*a*	9.93	*a*	20.8	*a*	12.1	*a*
Untreated - Late	121	*a*	15.8	*a*	0.642	*a*	1.52	*a*	2.12	*a*	9.91	*a*	19.6	*a*	12.0	*a*
R x S x D																
0N-Treated-Early	114	*a*	14.9	*a*	0.336	*a*	1.27	*a*	2.10	*a*	11.20	*a*	22.7	*a*	11.5	*a*
0N-Treated-Late	114	*a*	14.9	*a*	0.557	*a*	1.32	*a*	2.00	*a*	9.97	*a*	22.5	*a*	11.9	*a*
0N-Untreated-Early	108	*a*	14.1	*a*	0.274	*a*	1.18	*a*	2.08	*a*	11.95	*a*	25.9	*a*	11.5	*a*
0N-Untreated-Late	109	*a*	14.3	*a*	0.575	*a*	1.45	*a*	2.05	*a*	10.07	*a*	20.7	*a*	12.0	*a*
50N-Treated-Early	119	*a*	15.5	*a*	0.300	*a*	1.30	*a*	2.30	*a*	11.72	*a*	24.9	*a*	11.5	*a*
50N-Treated-Late	120	*a*	15.6	*a*	0.642	*a*	1.57	*a*	2.40	*a*	10.10	*a*	20.0	*a*	12.0	*a*
50N-Untreated-Early	117	*a*	15.2	*a*	0.300	*a*	1.32	*a*	2.00	*a*	11.35	*a*	25.7	*a*	11.6	*a*
50N-Untreated-Late	122	*a*	15.9	*a*	0.652	*a*	1.60	*a*	2.10	*a*	10.25	*a*	19.3	*a*	12.1	*a*
100N-Treated-Early	94	*a*	12.3	*a*	0.314	*a*	1.15	*a*	2.05	*a*	11.90	*a*	22.2	*a*	11.4	*a*
100N-Treated-Late	125	*a*	16.3	*a*	0.660	*a*	1.35	*a*	2.33	*a*	9.72	*a*	20.0	*a*	12.2	*a*
100N-Untreated-Early	106	*a*	13.9	*a*	0.284	*a*	1.23	*a*	2.17	*a*	11.45	*a*	16.9	*a*	11.4	*a*
100N-Untreated-Late	132	*a*	17.1	*a*	0.700	*a*	1.50	*a*	2.20	*a*	9.40	*a*	19.0	*a*	12.1	*a*

Table 6. Overall results of ANOVA to assess the effects of nitrogen rate (0, 50, 100 lbs N/ac) and seed treatment (treated vs. untreated) on response variables of lentils at Redvers, 2024. Bold p-values denote significance at p<0.05. Different letters within columns are significantly different at p<0.05 using estimated marginal means comparison.

	Plant Density plants/m²		**Shoot Ratings** 1-5		**Root Ratings** 0-5		**Nodule Ratings** 1-13		**Yield** bu/ac		**Protein** %	
	-----		-----		-----		p-value		-----		-----	
N Rate (R)	0.101		**0.055**		0.688		0.108		0.352		**0.033**	
Seed Trt (S)	**0.013**		0.316		0.267		0.417		0.609		0.076	
R x S	0.950		0.543		0.670		0.753		0.880		0.927	
N Rate												
0N	134	*a*	1.11	*b*	1.69	*a*	9.74	*a*	33.1	*a*	11.9	*b*
50N	141	*a*	1.29	*ab*	1.68	*a*	8.75	*a*	32.2	*a*	12.2	*ab*
100N	121	*a*	1.34	*a*	1.52	*a*	8.85	*a*	30.5	*a*	12.3	*a*
Seed Treatment												
Treated	142	*a*	1.21	*a*	1.68	*a*	9.28	*a*	31.6	*a*	12.2	*a*
Untreated	122	*b*	1.28	*a*	1.57	*a*	8.95	*a*	32.3	*a*	12.0	*a*
R x S												
0N - Treated	145	*a*	1.02	*a*	1.75	*a*	9.72	*a*	32.5	*a*	12.0	*a*
50N - Treated	151	*a*	1.25	*a*	1.80	*a*	9.10	*a*	31.5	*a*	12.3	*a*
100N - Treated	130	*a*	1.35	*a*	1.50	*a*	9.00	*a*	30.6	*a*	12.4	*a*
0N - Untreated	122	*a*	1.20	*a*	1.62	*a*	9.75	*a*	33.7	*a*	11.8	*a*
50N - Untreated	131	*a*	1.32	*a*	1.55	*a*	8.40	*a*	32.9	*a*	12.0	*a*
100N - Untreated	112	*a*	1.32	*a*	1.55		8.70	*a*	30.3	*a*	12.2	*a*

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