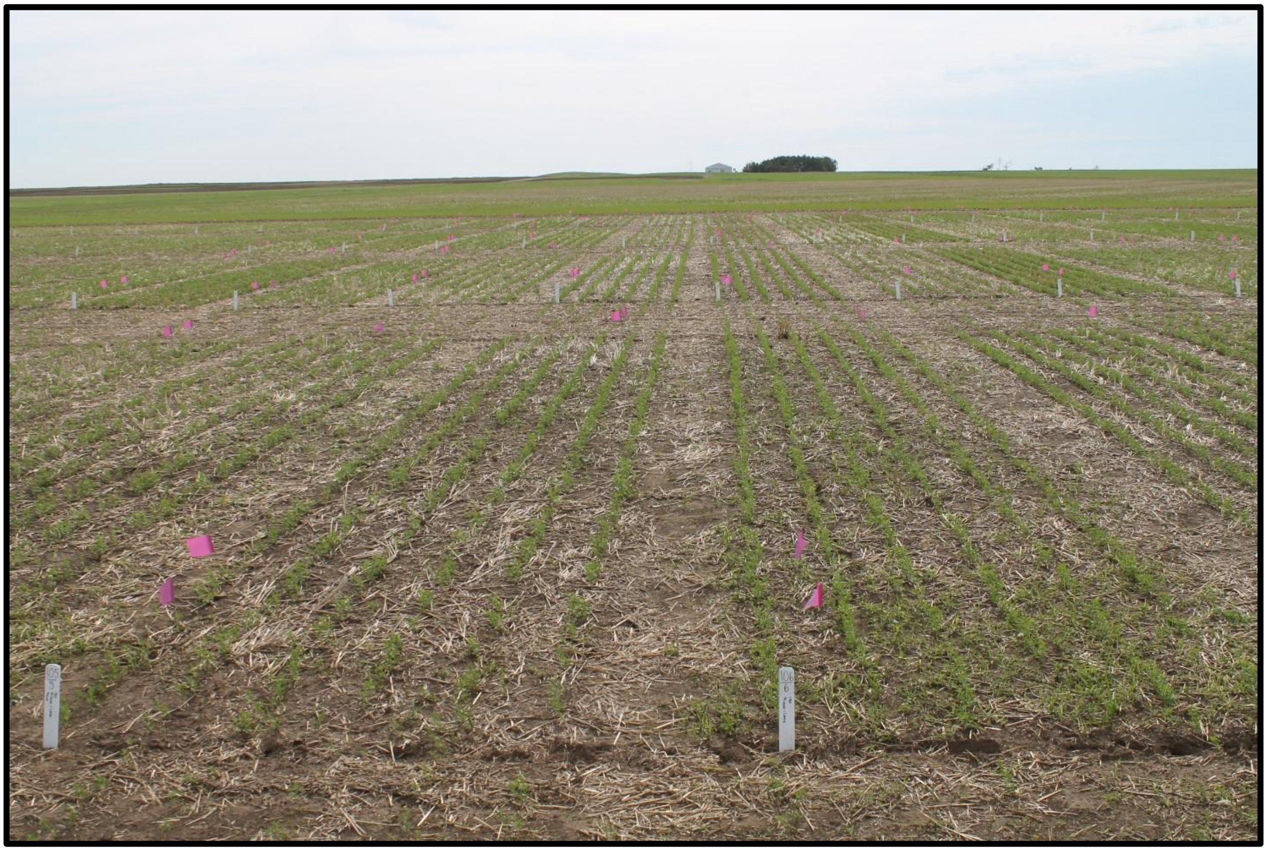
2018 Interim Report

for the

Saskatchewan Ministry of Agriculture (ADF Program), Saskatchewan Pulse Growers (SPG) & Western Grains Development Commission (WGRF)

Project Title: Lentil Input Study

(Project #AGR1721)



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1. Project Information

a. **Title:** Lentil Input Study
b. **WGRF File Number:** AGR1721
c. **Reporting Period:** January 01, 2019 to March 1, 2019

2. Special Project Activities Undertaken During this Reporting Period

Objective 1: To determine which combination of the common agronomic practices produce the greatest lentil yield

Methodology: The study was conducted at five locations in throughout Saskatchewan: Western Applied Research Corporation at Scott, Indian Head Agriculture Research Foundation at Indian Head, Irrigation Crop Diversification Centre at Outlook, Wheatland Conservation Area at Swift Current, East Central Research Foundation at Yorkton (2018) and University of Saskatchewan at Saskatoon (2018).

The experiment was conducted as a randomized complete block design (RBCD) with four replications. The trial consisted of a 3 x 3 x 2 factorial design with three seeding rates (130, 190 and 260 seeds/m^2), three fungicide treatments (no application, single application, two applications) and two herbicide management practices (pre-seed burn-off vs. pre-seed residual) to result in a total of 18 treatments. While certain aspects of the specific seeding equipment varied (i.e. row spacing, opener type) across locations, all plots were direct-seeded into cereal stubble and all fertilizer was side-banded during seeding. The single fungicide application consisted of Priaxor applied at beginning of flowering, while the dual fungicide application consisted of Priaxor followed by Lance WDG 10 to 14 DAA. The pre-seed burn off consisted of glyphosate and the pre-seed residual included glyphosate and Focus® co-formulated. Focus rates were applied based on soil type. The herbicide applications were applied three to five days prior to seeding. Post-emergent herbicide applications consisted of Ares and Centurion for all treatments. Fertilizer (N-P-K-S) was applied based on soil test recommendations to achieve a 30 bu per acre crop. Nodulator XL SCG pea and lentil inoculant was applied based on row spacing recommendations.

Pertinent agronomic information for each location is provided in Table 1 of the Appendices. Specific management practices and decisions were largely left to individual site managers and tailored to regional practices, available equipment and pests encountered; however, all controllable factors other than seeding rate, herbicides, and fungicides were intended to be non-limiting. Seeding dates ranged from May 9th to May 26th. Pre-harvest herbicides or desiccants were applied at or after the latest maturing plots reached physiological maturity if considered necessary or desirable. All plots were combined at maturity and, wherever possible, outside rows were excluded to minimize edge effects.

A composite soil sample (targeted depth intervals of 0-15 cm and 15-60 cm) was collected from each trial location in the early spring and submitted to laboratories of the individual sites choosing. The crop response data collected included crop and weed density, crop and weed biomass, disease ratings, days to flowering, days to maturity, seed yield, thousand kernel weights, and test weight.

Plant densities were determined by counting number of emerged plants on 2 x 1-meter row lengths per plot approximately two weeks after emergence (WAE). Weed densities were collected prior to canopy closure in the front and back of each plot using 0.25 m^2 quadrants. Disease ratings were taken prior to the first fungicide application, 7, 14 and 21 days after initial application (DAIA). Plots were rated based on % total disease ranging from zero to ten. Crop biomass was collected from the front and back using 0.25 m^2 quadrants at crop physiological maturity and weed biomass was collected and separated from the crop. Days to flowering was recorded at beginning of flowering and days to maturity were recorded when the bottom third of the pods turned yellow to brown and rattled when shaken. Yields were determined from cleaned harvested grain samples and corrected to 14% moisture content. Thousand kernel weights and test weights were recorded for seed quality. Mean monthly temperatures and precipitation amounts were estimated for each location from the nearest Environment Canada or private weather station.

Data were analysed on an individual and combined basis using the mixed model procedure of SAS software, with replicate, seed rate, fungicide application and herbicide application as random effects; location was considered fixed effect. Treatments were compared using the Tukey test and significance was declared at $P \leq 0.05$. In addition, contrast statements were used to compare the unsprayed check with fungicide treatment means.

Objective-2: To determine which integrated production system in the most economically feasible

Methodology: The economic analysis was conducted by calculating the cost and subsequent return of each agronomic practice. The economic equation took into consideration the yield (kg per hectare) per treatment and price per kilogram to determine gross income ($ per kg) minus the total cost [cost of seed ($ per kg), herbicide ($ per ha), fungicide ($ per ha), labor ($ per hour) and fuel ($ per ha)] to determine net grain ($ per ha).

a. Research accomplishments during the reporting period:

Objectives	**Progress**
1) To determine which combination of the common agronomic practices had the greatest effect on crop and weed growth, crop seed yield and overall seed quality	Year two of the study was conducted at five locations, disease levels were relatively low due to the drier conditions at some sites. However, a seeding rate effect was detected throughout the entirety of the disease rating period. Furthermore, a fungicide and seeding rate response was detected at 14 and 21 DAIA. Early season weed control and growth was significantly reduced with a pre-seed residual application compared to the pre-seed burn-off. Days to maturity were extended for increased seeding rates. A seeding rate of 190 seeds m^{-2} had the best yield.
2) To determine which integrated production system in the most economically feasible	A seeding rate of 190 seeds m^{-2} resulted in the greatest profit when all treatments were averaged amongst seeding rate. Overall, 190 seeds/m2 with a single fungicide application resulted in the highest gross profit.

In 2017, growing season temperatures and especially precipitation amounts were below-average at all 5 sites, therefore the lentils were limited by moisture and thus disease incidence was limited at most sites. Mean monthly temperatures and precipitation amounts are presented in Table 2 and 3 of the Appendices, respectively. The Outlook trial did apply irrigation sparingly with applications of 37.5 mm in June, and 12.5 mm in each of July and August for a total irrigation supplement to rainfall amounts listed of 62.5 mm. Amounts applied were judicial and only applied to relieve severe moisture stress.

In 2018, growing season temperatures were above the long-term average at all five locations. In contrast, total precipitation at all locations were below the long-term average at each respective location. The highest precipitation occurred at Scott> Indian Head> Swift Current > Outlook > Saskatoon. Mean monthly temperatures and precipitation amounts are presented in Table 2 and 3 of the Appendices, respectively.

Objectives: *To determine which combination of the common agronomic practices had the greatest effect on crop and weed growth, crop seed yield and overall seed quality*

Crop & Weed Densities

Indian Head

In 2017 & 2018 weed densities were significantly influenced by herbicide treatments (P= <0.001), indicating that pre-seed residual application was more effective in providing early season weed control compared to the pre-seed burn-off. Crop density was directly related to seeding rates and resulted in differences among all treatments (P < 0.0001). A seeding rate of 130 seeds m^{-2} had the lowest crop density and as seeding rate was increased the plant density followed similarly.

Outlook

Weed densities were relatively low at this location in 2017 & 2018 and no differences were detected between the herbicide treatments (P= 0.4791) or among the seeding rates (P= 0.2922). Differences were minimal and a trend was not observed. Crop densities were not affected by herbicide application (P= 0.2785). Differences among seeding rates were observed (P= 0.0001). A direct relationship between seeding rate and plant stand was observed.

Scott

In 2017 & 2018 weed densities were significantly influenced by herbicide treatments (P= <0.001) The pre-seed residual application was the most effective treatment, weed density was reduced by 71% compared to the pre-seed burn-off. Lentil establishment was also significantly influenced by seeding rates (P< 0.001). A direct relationship between seeding rate and crop density was observed.

Swift Current

Weed densities for 2017 & 2018 were significantly affected by herbicide treatment (P= 0.0001). Pre-seed residual applications had greater weed control than the pre-seed burn-off. Seeding rates resulted in differences in crop densities (P <0.001). A direct relationship between seeding rate and crop density was observed.

Yorkton (2017)

No differences were detected for weed densities for herbicide treatments (P= 0.6913) or seeding rates (P= 0.7596). However, there were several trends observed. The lowest seeding rate of 130 seeds m^{-2} resulted in the highest weed density. Weed densities tended to decline as seeding rate increased. Furthermore, weed densities were lower for the treatments sprayed with the pre-seed residual compared to treatments sprayed with the pre-seed burn-off. Seeding rate resulted in crop density differences (P <0.001). These results were similar to all the other locations were the higher seeding rates had the higher plant stands.

Saskatoon (2018)

Weed counts were not collected at this location. However, lentil establishment was significantly influenced by seeding rate (P=0.0001). A direct relationship between seeding rate and crop density was observed in which the highest seeding rate resulted in the greatest crop density.

All sites combined

A combined analysis of all 10 site-years indicated a significant effect of herbicides on weed densities (P=0.0263). There was a 57% reduction in weed density when a pre-seed residual was applied compared to the pre-seed burn-off. Seeding rate did not have an effect on weed densities and no differences were detected (P= 0.5955). However, a trend Seeding rate had a significant effect on crop density (P=0.0001). Seeding rate and crop density were positively correlated in which densities increased according to seeding rates.

Crop & Weed Dry Weight

Indian Head

Treatment effect for seeding rate (P=0.481) and herbicide (P= 0.9127) were not detected for weed biomass in 2017 & 2018. However, a trend indicated that with the lowest seeding rate resulted in the highest weed biomass and subsequently declined with increased seeding rates. Differences in crop biomass were detected for seeding rates (P= 0.0042) for 2017 & 2018. The seeding rate of 260 seeds m^{-2} had the highest crop biomass, followed by 190 seeds m^{-2} with a slight but not significant reduction and the lowest seeding rate had a significant reduction of crop biomass.

Outlook

In 2017, weed biomass was very low at this location and no difference between the herbicide treatments (P= 0.8767) or seeding rates (P= 0.7882) were detected. In contrast, herbicide was significant (P= 0.0069) in 2018 in which the pre-seed residual application resulted in a 68% reduction in weed biomass compared to the pre-seed burn-off. No effects of seeding rate (P= 0.1791) or herbicide treatments (P= 0.2867) were detected for crop biomass. A trend indicated that the highest biomass corresponded to a seeding rate of 260 seeds m^{-2}.

Scott

Weed biomass was strongly influenced by herbicide (P= 0.0008). The pre-seed residual application resulted in a weed biomass reduction of 65% compared to the pre-seed burn-off for 2017/2018. Crop biomass was not affected by herbicide treatments and no differences were observed (P= 0.5975). Seeding rate had an effect on crop biomass and differences among treatments were detected (P= 0.0313). A seeding rate of 190 seeds m^{-2} resulted in the highest crop biomass and a significant reduction was detected when a seeding rate of 130 seeds m^{-2} was used.

Swift Current

Weed biomass was not affected by seeding rate (P= 0.1882) or herbicide treatments (P= 0.2244) in 2017. However, when 2017 & 2018 were combined a seeding rate (P=0.0413) and herbicide (P=0.374) effect was significant. The lowest seeding rate had the highest weed biomass of 630 kg/ha compared to a seeding rate of 190 and 260 seeds m^{-2}. Crop biomass was not influenced by either seeding rate, fungicide, or herbicide.

Yorkton (2017)

Weed biomass differences were detected for seeding rate (P= 0.0461), as well as an interaction between seeding rate and herbicide treatments were observed (P= 0.0185). The interaction indicated that the highest seeding rates were the most effective at reducing weed biomass. Weed biomass reductions were greater at the highest seeding rates combined with a pre-seed residual application and were of equal efficacy to the highest seeding rate and a pre-seed burn-off. In contrast, pre-seed burn-off treatments combined with the lower seeding rates resulted in the highest weed biomass. Crop biomass did not have any differences in seeding rates (P= 0.7264) or herbicide treatments (P= 0.6670).

Saskatoon (2018)

Weed biomass was not affected by seeding rate (P= 0.1882) or herbicide treatments (P= 0.2244), however, weed biomass tended to decline with applications of a pre-seed residual herbicide. Crop biomass did not have any differences in seeding rates (P= 0.3358) or herbicide treatments (P= 0.8677).

All sites combined

Weed biomass was significantly influenced by herbicide applications (P=0.0001). There was a 52% reduction in biomass when a pre-seed residual herbicide was applied compared to the pre-seed burn-off. Weed biomass was also slightly influenced by seeding rate (P=0.0529) in which the lowest seeding rate had the greatest weed biomass. Seeding rates of 190 and 260 seeds m^{-2} had very similar weed biomass values, indicating minimal differences in crop-weed competition between the different seeding rates. In general, weed biomass was largely reduced when seeding rates were increased above 130 seeds m^{-2} and a residual herbicide was used (Fig. 1). Weed biomass continuously declined when glyphosate was applied alone at the highest seeding rate.

Disease Prevalence

Indian Head

Disease incidence levels were low in both 2017 & 2018 and similar trends were noted in both years. For this reason, disease ratings for 7, 14 and 21 DAIA were combined for 2017 & 2018. Disease ratings conducted prior to the first application indicated a very low presence of disease within the lentil canopy (<2.7%). However, a significant interaction of seeding rate by fungicide by herbicide was detected (P=0.0396). Disease ratings conducted 7 DAIA detected a significant difference among seeding rates (P= 0.002) and fungicide applications (P= <0.0001). The highest seeding rate resulted in the greatest prevalence of disease compared to the lowest seeding rate. The sprayed treatments had a lower disease prevalence compared to the unsprayed check. Disease ratings at 14 and 21 DAIA indicated a significant interaction between seeding rate and fungicide applications (P = 0.0008; 0.001), respectively. The trend indicated that the two highest seed rates (260 seeds m^{-2} > 190 seeds m^{-2}) resulted in the greatest disease prevalence when a fungicide was not applied. Disease pressure tended to decline with seeding rate when fungicides were applied. The lowest seeding rate had the least amount of disease present, particularly when fungicides were applied. In almost all cases, disease levels reduced with dual applications> single applications> no applications.

Scott

Disease incidence levels were low in both 2017 & 2018 and similar trends were noted in both years. For this reason, disease ratings prior to fungicide application, as well as 7, 14 and 21 DAIA were combined for 2017 & 2018. Disease ratings conducted prior to the first application and 7 DAIA indicated a very low presence of disease (<1.3%) and a significant response to seeding rate (P= <0.0001; 0.0065). Disease ratings conducted 14 DAIA were also significantly influenced by seeding rate (P= <0.0001) and fungicide (P= 0.0064), while at 21 DAIA an interaction between seeding rate and fungicide was observed (P=0.0284). Overall, the trend indicated that the two highest seed rates (260 seeds m^{-2} > 190 seeds m^{-2}) resulted in the greatest disease prevalence when a fungicide was not applied. Disease pressure tended to decline with seeding rate when fungicides were applied. The lowest seeding rate had the least amount of disease present, particularly when fungicides were applied. In almost all cases, disease levels reduced with dual applications> single applications> no applications. Furthermore, there was also a significant effect of herbicide at 21 DAIA (P=0.0357) in which treatments with pre-seed glyphosate had a slight increase of 9% in disease pressure compared to treatments with pre-seed residual.

Swift Current

In 2017, there were no detectable differences reported prior to application or at 7, 14, and 21 DAIA. In 2018, disease pressure prior to and 7 DAIA did not detect any differences among treatments. However, disease ratings at 14 and 21 DAIA indicated a significant interaction between seeding rate, fungicide and herbicide (P=0.0459; 0.0358). However, a general trend can not be determined for either 14 DAIA nor 21 DAIA and furthermore 14 DAIA and 21 DAIA do not follow in a similar pattern. Due to these challenges, further detections from this location in 2018 can not be made.

Outlook, Saskatoon & Yorkton

There were no detectable differences reported prior to application nor at 7, 14, and 21 DAIA for 2017 and 2018.

All sites combined

Disease ratings conducted prior to fungicide application indicated that disease pressure was low (<11%) across 10-site years. Although disease pressure was low, a seeding rate effect was still significant (P= 0.006) prior to fungicide application. The highest seeding rates (260 seeds m^{-2} > 190 seeds m^{-2}) had the greatest disease incidence compared to the current seeding rate recommendation of 130 seeds m^{-}2. A similar trend was noted across all disease ratings times (Fig. 2). However, at 14 and 21 DAIA a site effect was observed and therefore Indian Head (2017-2018), Scott (2017-2018) and Swift Current (2018) were analysed together. The 14 DAIA results indicated a seeding rate (P=<0.0001) and fungicide (P=<0.0001) effect in which the highest seeding rates (260 seeds m^{-2} > 190 seeds m^{-2} >130 seeds m^{-2}) had the greatest disease incidence, while disease pressure was greatest for unsprayed > dual ≥ single fungicide applications. A non-significant trend was also detected that corresponded with a significant seeding rate by fungicide interaction (P=0.0076) at 21 DAIA. This trend indicated that at unsprayed treatments at 260 seeds m^{-2} and 190 seeds m^{-2} had the greatest disease levels, followed by 260 seeds m^{-2} single> dual fungicide applications. Furthermore, 130 seeds m^{-2} unsprayed ≥ 190 seeds m^{-2} dual and single fungicide applications. The lowest disease incidence recorded occurred at 130 seeds m^{-2} single > dual fungicide application (Fig. 3). The remaining sites of Saskatoon, Outlook, Yorkton, and Swift Current (2017) were then analyzed together at 14 and 21 DAIA in which no significant differences were detected.

Maturity (DTF/DTM)

All sites combined

Days to flowering had a 46 day mean when averaged across 10 site-years. Individual sites were analysed but there were no significant differences were detected. A trend was noted when days to maturity was averaged across 10-site years. Maturity was delayed as seeding rates declined: (87 days) at 130 seeds m^{-2} > (86 days) at 190 seeds m^{-2} > (85 days) at 260 seeds m^{-2}.

Yield

Indian Head

Yield averaged across 2017 & 2018 was significantly influenced by seeding rate (P= 0.0002). There was no statistical difference detected between the two highest seeding rates, however, the highest seeding rate resulted in the greatest yield of 2595 kg/ha. Overall, yield increased by 6% and 3.6% at the highest seedings rates of 260 seeds m^{-2} and 190 seeds m^{-2} compared to the lowest seeding rate, respectively.

Scott

Seeding rate had a significant quadratic effect on yield ($P < 0.0001$) when averaged across 2017 & 2018. A maximum yield of 4306 kg/ha was obtained at 207 seeds m^{-2}. Yield decline when the seeding rate exceeded 207 seeds m^{-2}. Overall, yield increased by 8% when seedings rate exceeds 130 seeds m^{-2} followed by a 4% yield loss once seeding rates exceeded 207 seeds m^{-2}.

Swift Current

Yield averaged across 2017 & 2018 was significantly influenced by herbicide (P=0.0269). A yield gain of 7% occurred when a pre-seed residual was applied compared to the pre-seed burn-off. In contrast to the other sites, a seeding rate effect was not observed at this location.

Outlook, Yorkton, Saskatoon

There were no significant differences detected at all three locations. However, yield tended to increase when seeding rates exceeded 130 seeds m^{-2}.

All sites combined

The combined analysis indicated a significant seeding rate effect (P=0.0272). A seeding rate of 130 seeds m^{-2} had the lowest yield with 3355 kg ha^{-1}; a slight but significant yield increase to 3489 kg ha^{-1} was observed when a seeding rate of 190 seeds m^{-2} was used. Subsequently, yield declined slightly to 3423 kg ha^{-1} when a seeding rate of 260 seeds m^{-2} was used. Overall, maximum yield was achieved when seeding rates exceeded 190 seeds m^{-2} (Fig. 4). An additional trend that was noted amongst the higher weed density locations was an increase in yield at the highest seedings rates (190 seeds m^{-2}; 260 seeds m^{-}

^{2}) with pre-seed residual herbicide, followed by the highest seeding rates with pre-seed burn-off and lastly the lowest seeding rate with pre-seed residual > pre-seed burn-off.

Test Weights (TW) and Thousand Kernel Weights (TKW)

Indian Head

No treatment effect was observed for test weight when combined across 2017 & 2018. Test weight for all the treatments were very close and no trends were observed. Seeding rate had an effect on TKW (P= 0.0001) when combined across 2017 & 2018. The seeding rate of 130 seeds m^{-2} had the highest TKW of 41 g compared to 40 g at a seeding rate of 190 seeds m^{-2} and 260 seeds m^{-2}.

Outlook

No treatment effects or trends were observed for TW and TKW.

Scott

No differences were detected for TW and values were almost identical for all the treatments. Differences in TKW were detected among seeding rates (P= 0.0142) when analysed across years. As seeding rates increased TKW values decreased. The seeding rate of 130 seeds m^{-2} had the highest TKW of 38 g per 1000 seeds compared to 37 g per 1000 seeds at 190 seeds m^{-2} and 260 seeds m^{-2}.

Swift Current

No treatment effects were observed for TW and TKW. TKW values were nearly identical for all treatments and no differences were detected.

Yorkton

No treatment effects were observed for TW and TKW. A trend indicated that quality parameters are better with a lower seeding rate and tended to decrease as the seeding rate increased.

All sites combined

Thousand kernel weights and test weights averaged across 10 site- years did not result in any significant differences. TKW tended to decrease as seeding rates increased. Consequentially, maximum TKW were achieved at a seeding rate of 130 seeds m^{-2}. In general, for all locations, a trend indicated that the best quality parameters resulted from a seeding rate range from 130 seeds m^{-2} to 190 seeds m^{-2}.

Objective 2: *To determine which integrated production system in the most economically feasible*

In all economic scenarios the pre-seed burn-off treatment resulted in a higher net profit compared to the pre-seed residual treatment. Therefore, the cost of a pre-seed burn-off was used to determine the cost of production. The economic analysis was done with two market price scenarios. The low price was based on the market drop caused by the import tariff recently imposed by India and a high price that corresponds to a best-case market price scenario.

Basic management

This management includes no fungicide application. With the basic management strategy, average yield for a seeding rate of 130 seeds m^{-2} was 2483 kg ha^{-1}; 190 seeds m^{-2} was 2617 kg ha^{-1}; 260

seeds m^{-2} was 2685 kg ha^{-1}. The yield increases attributed to the two highest seedings rates returned a greater net profit than the lowest seeding rates. However, the highest seeding rate was the most profitable. A seeding rate of 260 seeds m^{-2} was the most balanced and returned the greatest net profit with \$940 ha^{-1} with a low market price scenario and \$1,530 ha^{-1} with a high market price (Table 4; 5).

Conventional management

This management included a single fungicide application. With this management strategy average yield for a seeding rate of 130 seeds m^{-2} was 2483 kg ha^{-1}; 190 seeds m^{-2} was 2752 kg ha^{-1}; 260 seeds m^{-2} 2617 kg ha^{-1}. For conventional management, a seeding rate of 190 seeds m^{-2} proved to be the most balanced and had the greatest net profit of \$928 per ha (Table 4; 5). Net profit was lowest for conventional management at a seeding rate of 130 seeds m^{-2} (\$835 per ha) compared to the highest seeding rate of 260 seeds m^{-2} (\$844 per ha).

Enhanced management

This management included a dual fungicide application. With this management strategy average yield for a seeding rate of 130 seeds m^{-2} was 2483 kg ha^{-1}; 190 seeds m^{-2} was 2617 kg ha^{-1}; 260 seeds m^{-2} 2617 kg ha^{-1}. At a seeding rate of 130 and 190 seeds m^{-2}, yield achieved for the enhanced management was similar to the basic management strategy. In contrast, the seeding rate of 260 seeds m^{-2} resulted in a yield that was similar to the conventional management. These results indicated that the net profits are lower for the enhanced management compared to basic and conventional due to the extra costs. As with the other management strategies, a seeding rate of 190 seeds m^{-2} returned the highest net profits with \$801 ha^{-1} for the low market price and \$1,377 ha^{-1} for the high market price (Table 4; 5).

b. Discussion:

The preliminary results indicated a relatively inconsistent response to the pre-seed residual application. However, all site- years were able to be combined and indicated a strong response of the pre-seed residual on early season weed control and overall weed growth. This was apparent as both weed populations and weed biomass declined by > 50% with applications of the residual herbicide. Seeding rate also played a role in reducing crop-weed competition as weed densities tended to decline with higher seeding rates. Increased seeding rates are an effective weed management strategy because it allows the crop to occupy the available space earlier in the growing season, which will reduce nutrient, space and light availability required for weed growth (Redlick 2015). These results coincide with previous studies (Baird et al. 2009; Redlick et al. 2017) in which increased seeding rate resulted in reduced weed biomass and improved crop competitive ability. In this study, enhanced crop competitive ability was apparent in the early growing season as weed biomass declined by 32% when seeding rates exceeded 130 seeds m^{-2}. Weed biomass was further hindered when an integrated management strategy was implemented.

An integrated weed management strategy of increased seeding rate (>130 seeds m^{-2}) combined with a pre-seed residual herbicide was highly effective in controlling early emerging weeds. Weed biomass continuously declined when a pre-seed burn-off was used at the highest seeding rate. Weed biomass further declined when high seeding rates and a pre-seed residual herbicide was used. These results indicated that seeding rate played a very large role in overall weed growth. Furthermore, these results indicated that a single pre-seed burn-off was not as effective as a residual herbicide at various seeding rates. The preliminary results coincide with several studies (Paolini et al. 2003; Blackshaw et al. 2005; Redlick et al. 2017) that indicated that an integrated approach including increased seeding rates combined with herbicides have proved to be the most effective approach in reducing crop-weed competition.

Increased seeding rates are an effective tool to manage crop-weed competition, however, it can also influence disease pressure within the canopy. A higher seeding rate results in a thicker canopy that is more prone to disease pressure (Davidson and Kimber 2007.) In contrast, lower plant densities typically result in lower disease pressure as there is less contact between plants and a lower moisture content within the canopy. Similarly, disease levels increased by 11% and 18% with seeding rates of 190 seeds m^{-2} and 260 seeds m^{-2} compared to 130 seeds m^{-2}, respectively (Fig. 2). To reduce disease pressure and improve overall plant health and seed yield, fungicides can be used preventatively and curatively throughout flowering. Fungicide treatments were effective in reducing disease levels, particularly when dual applications were used (Fig. 3). However, yield responses to fungicides were limited due to the dry environmental conditions that limited disease development (< 20%). As a result, single and dual fungicide applications resulted in a net loss of -$ 21 and -$ 60 compared to unsprayed across all seeding rates, respectively. In years where moisture is not a limiting factor, disease levels for seeding rates that exceed 130 seeds m^{-2} are expected to have exponentially higher disease levels and a greater response to fungicide applications. Therefore, under high disease pressure conditions, management strategies including fungicide applications are expected to return the highest profit. Fungicide applications should be considered as an insurance against yield losses caused by disease problems.

The current seeding rate recommendations of 130 seeds m^{-2} should be revalued based on our preliminary results. Yield tended to increase at a seeding rate of 190 seeds m^{-2} compared to the current recommendations. Furthermore, yield tended to increase at the higher seeding rates when a residual herbicide was utilized compared to the lowest seeding rates with a pre-seed burn-off under weedy conditions. Yield advantages were attributed to an enhanced crop competitive ability as a result of improved canopy closure, reduced weed biomass, and relatively low disease pressure. The preliminary results correspond with a similar study lead by Dr. Shirtliffe which indicated that the seeding rate of extra small and small red lentil should be doubled to 260 seeds m^{-2} (Barker, 2017). Although the current study found that 190 seeds m^{-2} was more beneficial than 260 seeds $m^{-2,}$ both studies indicate that a seeding rate exceeding 130 seeds m^{-2} is critical to enhance yields and reduce crop-weed competition.

Seeding rates had a consistent, positive effect on yield that resulted in profitable net gains. A seeding rate of 190 seeds m^{-2} also proved to be the most economically feasible, regardless of management strategy. The increase in seed costs associated with a seeding rate of 190 seeds m^{-2} were offset by the yield advantage; making this management strategy the most profitable. In contrast, the seed cost associated with a seeding rate of 260 seeds m^{-2} was unable to offset the input costs, making the highest seeding rate less profitable. Overall, preliminary results indicate that a seeding rate of 190 seeds m^{-2} could be utilized to limit disease pressure while simultaneously improving crop competitive ability to ensure a yield benefit.

c. Interim Conclusions:

The preliminary results of this study have highlighted several interesting trends. First of which, that the pre-seed residual herbicides tended to reduce early season weed populations and overall weed growth by > 50% in comparison to the traditional pre-seed burn-off strategy. Secondly, the preliminary results indicated that the highest seeding rates of 260 seeds m^{-2} will require multiple fungicide applications to reduce disease pressure. When seeding rates were dropped to 190 seeds m^{-2}, disease levels were similar to lentils unsprayed at the current seeding rate recommendation. This indicates that if seeding rates are to increase to 190 seeds m^{-2} then fungicide applications are likely required, particularly under moist conditions. Seeding rates that exceed the current recommendation will require a fungicide application to moderate disease pressure. However, as disease pressure were relatively low amongst all locations, the impact of multiple fungicide at high seeding rates on disease pressure and overall yield require further investigation. Lastly, the seeding rate of 190 seeds m^{-2} resulted in the highest yield and also provided enough canopy closure to compete with weeds. The seeding rate of 260 seeds m^{-2} did not substantially increase yield and resulted in higher input costs. Seed size had a slight, but not significant, reduction when seeding rates exceeded 130 seeds m^{-2}.

The economic analysis demonstrated that the best management practice is the conventional strategy with a seeding rate of 190 seeds m^{-2}. A high price market scenario indicated a net profit increase for the conventional management compared to the basic management. The high input costs associated with the enhanced management could be justified if a severe high disease pressure is present.

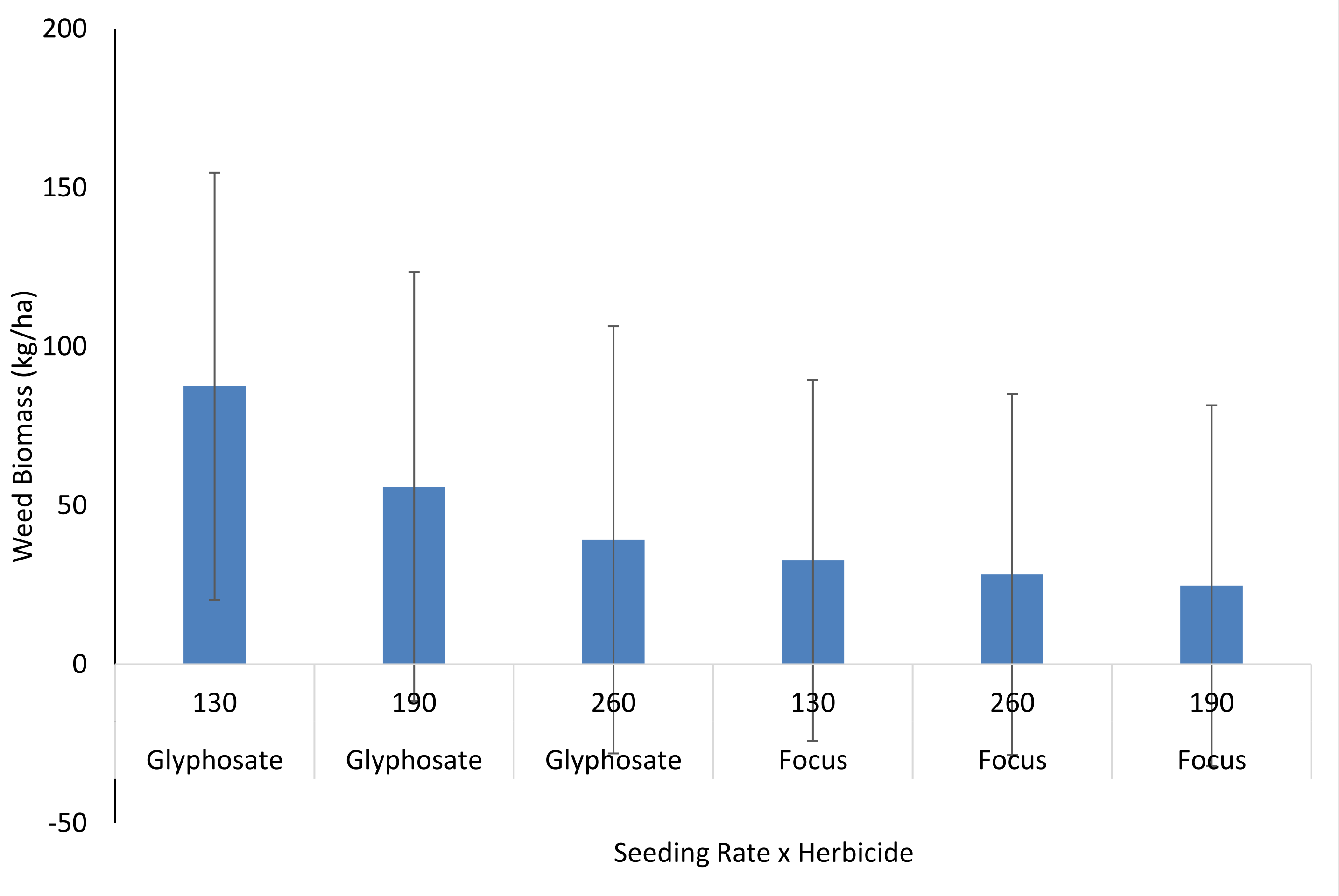

Figure 1. Weed biomass (kg/ha) response to lentil seeding rates (seeds m^{-2}) and herbicide treatments of pre-seed burn-off and pre-seed residual herbicides at ten site-years.

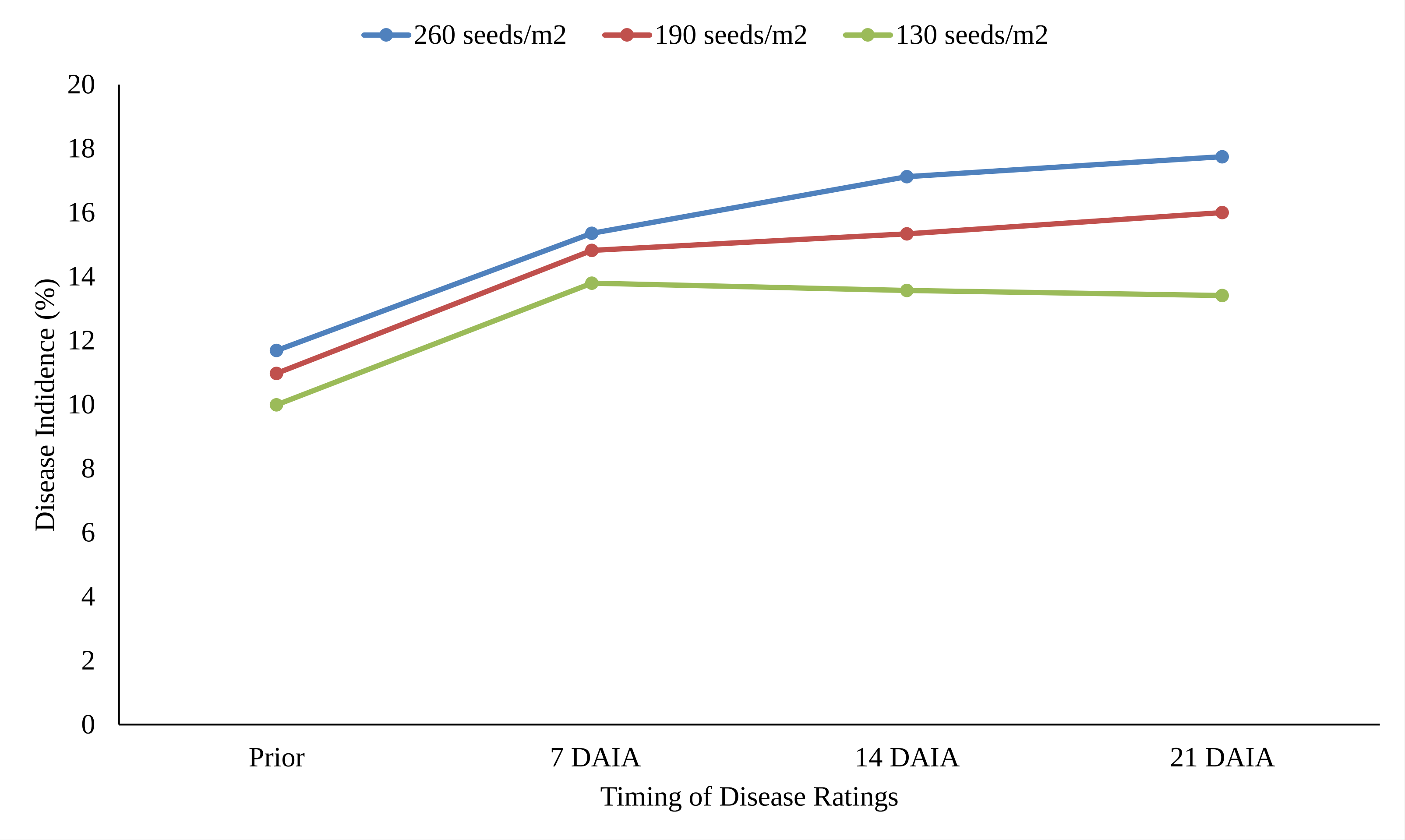

Figure 2. Disease response ratings prior to fungicide application and 7 DAIA, 14 DAIA, 21 DAIA to lentil seeding rates at ten locations across Saskatchewan, Canada (2017 & 2018).

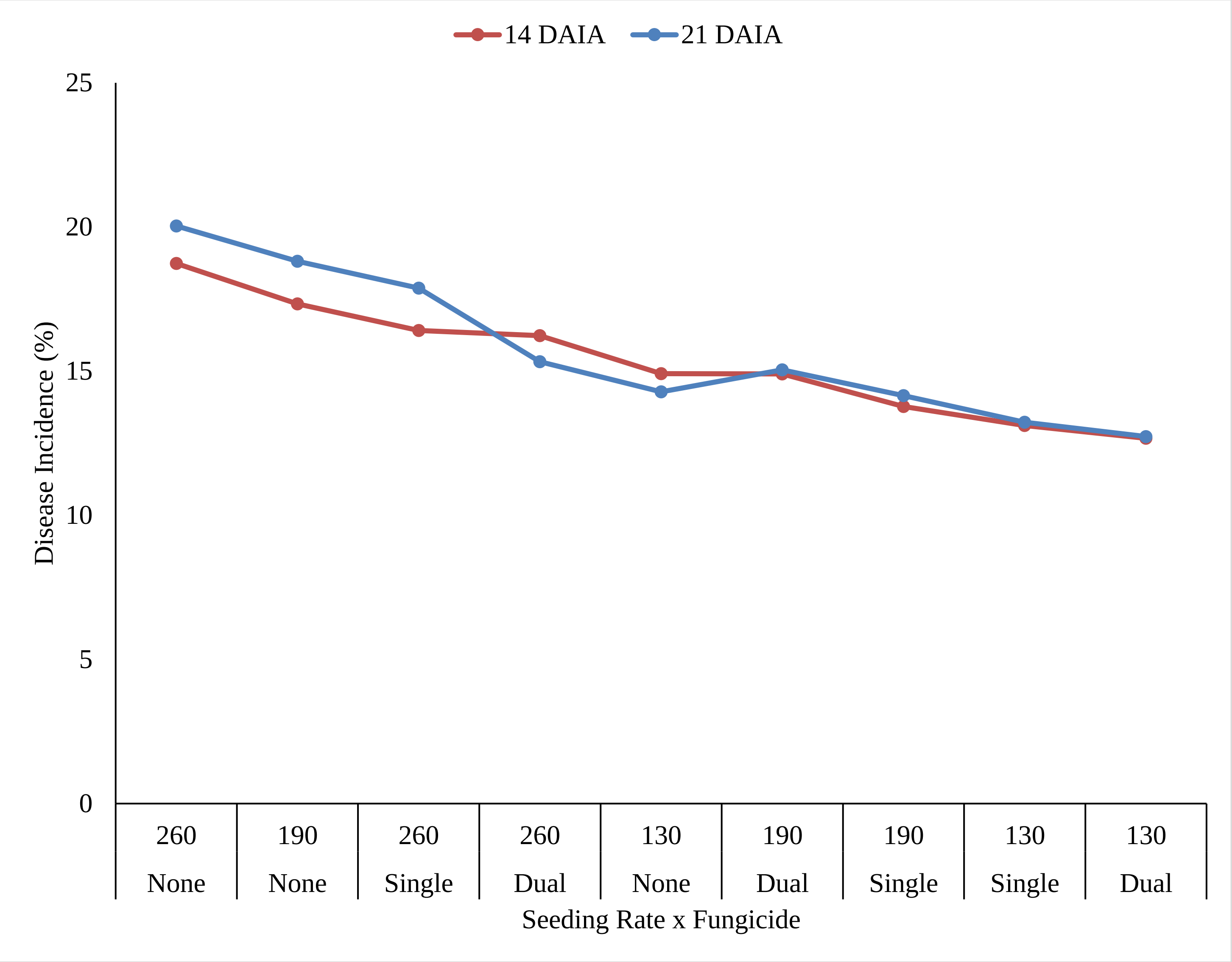

Figure 3. Disease response ratings at 14 DAIA and 21 DAIA to fungicide applications at three locations across Saskatchewan, Canada (2017 & 2018).

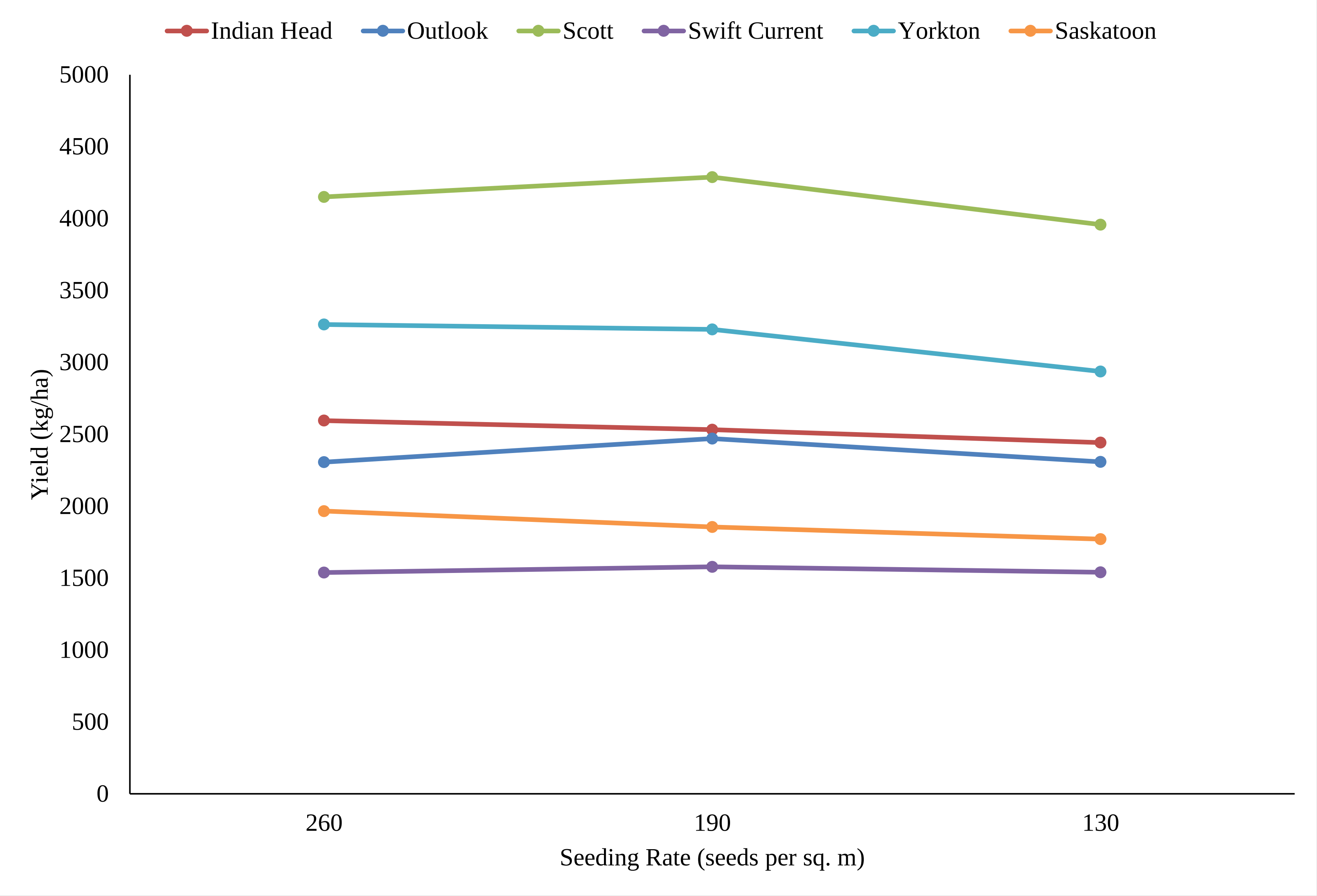

Figure 4. Lentil seed yield response to seeding rate (seeds per sq. m) at five locations across Saskatchewan, Canada (2017 & 2018).

3. Technology Transfer Activities in Relation to the Project

ICDC & Ministry Field Tour. Corn, Soybean and Field Bean. August 9th. Outlook, SK. Approx. 35 farmers and agronomists in attendance.

CSIDC Field Day and Trade Show, July 12th, 2018, Outlook, SK. Presentation on management strategies for lentil production. Approx. 100 farmers and agronomists in attendance.

Top Crop Manager Article. Donna Fleury. Higher seeding rates increase yields, improve crop competition and reduce weed biomass. December 2018.

Weber, Jessica. Lentils: which agronomic inputs provide the best return?. Dry Beans, Lentils, Chickpeas Please, Regina. February 19th, 2018. Approx. 10 farmers in attendance.

IHARF Field Day Tour, July 17th, 2018, Indian Head, SK. Presentation on management strategies for lentil production. Approx. 200 farmers and agronomists in attendance.

Weber, Jessica. An economic approach to lentil production. Crop Opportunity, North Battleford. March 13th, 2018. Approx. 100 farmers and agronomists in attendance.

WARC Field Day Tour, July 12th, 2017, Scott, SK. Presentation on management strategies for lentil production. Approx. 130 farmers and agronomists in attendance.

Farmer Writers of Saskatchewan Field Tour. June 3rd, 2017, Scott, SK. Presentation on management strategies for lentil production. 6 reporters in attendance.

FMC Agronomy Tour. July 19th, 2017, Scott, SK. Presentation on management strategies for lentil production. 10 agronomists in attendance.

Indian Head Richardson- Pioneer Agronomy Tour. July 21th, 2017. presentation on fungicide efficacy and the influence of seeding rates in lentils. in durum and stripe rust in winter wheat. Approx. 40 agronomists in attendance.

ECRF Field Day Tour, July 13th, 2017, Scott, SK. Presentation on management strategies for lentil production. Approx. 73 farmers and agronomists in attendance.

ICDC Field Day Tour, July 13th, 2017, Scott, SK. Presentation on management strategies for lentil production. Approx. 150 farmers and agronomists in attendance.

4. Changes Expected to Industry Contributions, In-Kind Support, Collaborations, Etc.

No changes to industry contributions or in-kind support occurred and none are expected going into the second year of the study. With regard to collaboration, the original site proposed at Yorkton (East Central Research Foundation) was dropped due to location restrictions and replaced with a site at Saskatoon under the supervision of Steve Shirtliffe. This revision is not expected to have any impacts on budget or the deliverables of the project.

5. Appendices

a. Resources / Literature Cited

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Redlick, C., Duddu, H.S., Syrovy, L.D., Willenborg, C.J., Johnson, E.N. and Shirtliffe, S.J., 2017. Effect of Seeding Rate on Dose Response of Wild Mustard (Sinapis arvensis) to Fluthiacet-Methyl. Weed Science, 65(4), pp.525-533.

Table 1. Selected agronomic information for the lentil input study at five locations in western Canada (2017).

	Location (2017)				
Factor / Field Operation	Indian Head	Scott	Swift Current	Outlook	Yorkton
Previous Crop	Barley	Wheat	Wheat	Barley	Wheat
Variety	CDC Maxim	CDC Maxim	CDC Maxim	CDC Maxim	CDC Maxim
Pre-emergent Herbicide	May 14- 15th	May-16th	May 16th	May 23rd	May 12th May 16th
Seeding Date	May 9th	May 19th	May 19th	May 26th	May 15th
Seeding Rate	-	-	-	-	-
Row spacing	30 cm	25 cm	23 cm	25 cm	25 cm
In-crop Herbicide	June 9th	June 15th June 23rd	Jun-27	June 23rd	June 12th
Fungicide	July 4th July 18th	July 8th July 17th	July 10th July 20th	July 10th July 27th	July 17th July 27th
Insecticide	n/a	n/a	n/a	n/a	July 27th
Pre-harvest herbicide	Aug 3rd	Aug 25th	Aug 16th	Aug 29th	Sept 7th
Harvest date	Aug 16th	Sept 1	Aug 23rd	Sept 5th	Sept 17th

Table 2. Selected agronomic information for the lentil input study at five locations in western Canada (2018).

	Location (2018)				
Factor / Field Operation	Indian Head	Scott	Swift Current	Outlook	Saskatoon
Previous Crop	Canary seed	Wheat	Durum	Potato	Canola
Variety	CDC Maxim	CDC Maxim	CDC Maxim	CDC Maxim	CDC Maxim
Pre-emergent Herbicide	May 11th	May 11th	May 7th	May 24th	May 4th
Seeding Date	May 13th	May 15th	May 9th	May 28th	May 9th
Seeding Rate	-	-	-	-	-
Row spacing	30 cm	25 cm	23 cm	25 cm	30cm
In-crop Herbicide	June 11th	June 18th	June 5th June 8th	July 3rd July 6th	June 4th
Fungicide	June 28th July 9h	July 6th July 17th	June 25th July 4th	July 16th July 25th	June 27th July 5th
Insecticide	n/a	n/a	June 22nd July 7th	n/a	n/a
Harvest date	Aug 11th	Aug 21	Aug 7th	Aug 31st	Aug 20th

Table 2. Mean monthly temperatures for the 2017 and 2018 growing season relative to the long-term averages (1981-2010) at five locations in western Canada.

		Mean Monthly Temperature (°C)				
Location	**Year**	**May**	**June**	**July**	**August**	**Average**
Indian Head	2018	13.9	16.5	17.5	17.6	16.4
	2017	11.6	15.5	18.4	16.7	15.5
	LT	10.8	15.8	18.2	17.4	15.6
Scott	2018	13.6	16.6	17.5	15.9	15.9
	2017	11.5	15.1	18.3	16.6	15.4
	LT	10.8	15.3	17.1	16.5	14.9
Swift Current	2018	14.6	17.1	18.8	18.7	17.3
	2017	12.3	15.7	20.6	18.3	16.7
	LT	10.9	15.4	18.5	18.2	15.8
Yorkton	2017	11.1	15.5	19	17.4	15.8
	LT	10.4	15.5	17.9	17.1	15.2
Outlook	2018	22.5	24.7	25.6	25.3	24.5
	2017	12.2	16.1	19.7	19.1	16.8
	LT	11.4	16.6	19.2	18.2	16.4
Saskatoon	2018	15	17.8	19.1	16.6	17.1
	LT	11	16.4	18.4	17.8	15.9

[Z] LT- Long-Term average (1981-2010)

Table 3. **Monthly precipitation amounts for the 2017 and 2018 growing season relative to the long-term averages (1981-2010) at 5 locations in western Canada.**

Total Monthly Precipitation (mm)

Location	**Year**	**April**	**May**	**June**	**July**	**August**	**Total**
Indian Head	2018	8.5	23.7	90.0	30.4	3.9	156.5
	2017	18.5	10.4	65.6	15.4	25.2	135.1
	LT [Z]	22.6	51.7	77.4	63.8	51.2	266.7
Scott	2018	8.5	35.6	58	85.8	20.2	208.1
	2017	30.9	69	34.3	22.4	53	209.6
	LT	24.4	38.9	69.7	69.4	48.7	251.1
Swift Current	2018	9.9	25.6	16.9	51.2	31	134.6
	2017	8.6	21	35.3	11	28	103.9
	LT	23	50	80	53	47	254
Yorkton	2017	28.8	74.9	62.8	141.7	59.1	367.3
	LT	22	51.3	80.1	78.2	62.2	272
Outlook	2018	6.0	25	13	36	17	97.0
	2017	32.0	29.0	60.4	7.4	128.8	257.6
	LT	21	46	67	57	46	237
Saskatoon	2018	6.4	23.3	19.1	5.7	12.5	67
	LT	11.4	16.9	32	31.2	18.9	110.4

[Z] LT- Long-Term average (1981-2010)

Table 4. Economic analysis of a basic, conventional and enhanced management strategy at three seeding rates at a high market price of CDC Maxim lentil at five locations in Saskatchewan (2017-2018).

Seeding Rate (seeds per sq. m)	**Management Strategy**	**Yield (kg/ha)**	**$/kg**	**Net Revenue**	**Production Expenses ($/ha)**	**Gross Revenue** ($/ ha)	**Gross Revenue** ($/ ac)
130	Basic	2483	$ 0.66	$ 1,638.93	$ 190.99	$ 1,448	$ 585.96
	Conventional	2483	$ 0.66	$ 1,638.93	$ 257.21	$ 1,382	$ 559.16
	Enhanced	2483	$ 0.66	$ 1,638.93	$ 325.12	$ 1,314	$ 531.68
190	Basic	2617	$ 0.66	$ 1,727.52	$ 216.19	$ 1,511	$ 611.61
	Conventional	2752	$ 0.66	$ 1,816.11	$ 282.41	$ 1,534	$ 620.67
	Enhanced	2617	$ 0.66	$ 1,727.52	$ 350.32	$ 1,377	$ 557.33
260	Basic	2685	$ 0.66	$ 1,771.81	$ 241.39	$ 1,530	$ 619.34
	Conventional	2617	$ 0.66	$ 1,727.52	$ 307.62	$ 1,420	$ 574.61
	Enhanced	2617	$ 0.66	$ 1,727.52	$ 375.53	$ 1,352	$ 547.13

Table 5. Economic analysis of a basic, conventional and enhanced management strategy at three seeding rates at a low market price of CDC Maxim lentil at five locations in Saskatchewan (2017-2018).

Seeding Rate (seeds per sq. m)	**Management Strategy**	**Yield (kg/ha)**	**$/kg**	**Net Revenue**	**Production Expenses ($/ha)**	**Gross Revenue** ($/ ha)	**Gross Revenue** ($/ ac)
130	Basic	2483	$ 0.44	$ 1,092.62	$ 190.99	$ 902	$ 364.88
	Conventional	2483	$ 0.44	$ 1,092.62	$ 257.21	$ 835	$ 338.08
	Enhanced	2483	$ 0.44	$ 1,092.62	$ 325.12	$ 767	$ 310.60
190	Basic	2617	$ 0.44	$ 1,151.68	$ 216.19	$ 935	$ 378.58
	Conventional	2752	$ 0.44	$ 1,210.74	$ 282.41	$ 928	$ 375.68
	Enhanced	2617	$ 0.44	$ 1,151.68	$ 350.32	$ 801	$ 324.30
260	Basic	2685	$ 0.44	$ 1,181.21	$ 241.39	$ 940	$ 380.33
	Conventional	2617	$ 0.44	$ 1,151.68	$ 307.62	$ 844	$ 341.58
	Enhanced	2617	$ 0.44	$ 1,151.68	$ 375.53	$ 776	$ 314.10

Table 6. Cost of CDC Maxim seed for economic analysis production costs

Seeding Rate (seeds /m^2)	Seeding Rate (kg/ha)	Cost of CDC Maxim ($ / kg)	Total of CDC Maxim
130	44.8	1.12	$20.40
190	67.2	1.12	$30.60
260	89.6	1.12	$40.80

Table 7. Input costs for the economic analysis based on management strategies and seeding rates 2018 growing season

	@ 130 seeds per sq. meter			@ 190 seeds per sq. meter			@ 260 seeds per sq. meter		
	Basic	Conventional	Enhanced	Basic	Conventional	Enhanced	Basic	Conventional	Enhanced
Seed ($/ha)	50.41	50.41	50.41	75.61	75.61	75.61	100.82	100.82	100.82
Fertilizer ($/ha)	39.54	39.54	39.54	39.54	39.54	39.54	39.54	39.54	39.54
Herbicide ($/ha)[Y]	68.92	68.92	68.92	68.92	68.92	68.92	68.92	68.92	68.92
Inoculants ($/ha[X]	32.12	32.12	32.12	32.12	32.12	32.12	32.12	32.12	32.12
Fungicides ($/ha)[W]	0.00	56.34	114.41	0.00	56.34	114.41	0.00	56.34	114.41
Labour ($/hr)[V]	0.00	9.88	19.77	0.00	9.88	19.77	0.00	9.88	19.77
Total Cost ($/ha)	190.99	257.21	325.17	216.19	282.42	350.37	241.40	307.62	375.58

[Y] Herbicide costs were based on glyphosate, Ares, and Centurion. As there was no significant difference of herbicide on yield, the cost of Focus was excluded for the economic analysis

[X] Inoculant costs were based on granular product for the 2017 – 2018 growing season

[W] Fungicide costs we based on the product cost for Priaxor sprayed at 180 ml/ac and Lance WDG at 170 g/ ac for the 2017-2018 growing season

[V] Labour costs were assessed for cost of spraying based on three independent quotes from customer sprayer operations