2021 Final Report

for the

Saskatchewan Ministry of Agriculture's

Agricultural Demonstration of Practices & Technologies (ADOPT) Program

and Fertilizer Canada

Project Title: Fall Rye Cover Crop Effects on Canola Establishment and Response to Nitrogen

(Project #20200437)

Principal Applicant: Chris Holzapfel, MSc, PAg

Indian Head Agricultural Research Foundation, PO BOX 156, Indian Head, SK, S0G 2K0

Correspondence: cholzapfel@iharf.ca or (306) 695-7761

Project Identification

1. **Project Title:** Fall rye cover crop effects on canola establishment and response to nitrogen
2. **Project Number:** 20200437
3. **Producer Group Sponsoring the Project:** Indian Head Agricultural Research Foundation
4. **Project Location(s):** Indian Head, Saskatchewan, R.M. #156
5. **Project start and end dates(s):** September-2020 to February-2022
6. **Project contact person & contact details:**

Chris Holzapfel, Research Manager
Indian Head Agricultural Research Foundation
PO BOX 156, Indian Head, SK, S0G 2K0
Mobile: 306-695-7761
Office: 306-695-4200
Email: cholzapfel@iharf.ca

Objectives and Rationale

7. **Project Objectives:**
The broader objectives of this project were to gain experience and expertise with cover crops while providing a forum for discussion on how they might be successfully incorporated into annual cropping systems under Saskatchewan conditions. Specifically, we aimed to demonstrate the effects of a preceding cereal rye cover crop on 1) the overall establishment and yield of canola in addition to early-season weed densities and 2) the nitrogen (N) fertilizer requirements of canola.

8. **Project Rationale:**
Cover crops are not a new concept and have been used in many annual cropping/mixed farming operations throughout the world, at least on regional basis, for a variety of reasons. Some of the potential benefits of cover crops include building soil organic matter, N fixation, boosting soil biology, erosion prevention, protecting nutrients from environmental loss, suppressing weeds, improving water infiltration, breaking pest cycles, and more. There are innumerable species that can potentially be used as cover crops and specifically how they are established and where they fit in rotations can also vary. The precise manner in which cover crops are integrated into agricultural systems will depend on the intended purposes (i.e. erosion protection versus reducing salinity versus weed suppression, etc.), in addition to climate and crop rotation considerations. Published, regionally relevant research on the practical benefits and drawbacks of cover crops is limited; however, an appreciable number of producers are seeking ways to integrate them into their operations and there is growing interest in this practice from both farmers and consumers due to their potential positive impacts on soil health and environmental sustainability. One of the challenges in conducting research and demonstration activities with cover crops is that there are so many species to choose from and ways in which they might be utilized. Much of the innovation and evaluation of cover crops in Saskatchewan cropping systems has been led by farmers and other industry professionals as opposed to by researchers and the academic community; however, both have a role to play in further developing this practice.

Despite the high level of interest and many potential benefits, there is a steep learning curve to integrating cover crops into existing crop rotations. In many cases, our short growing season and unpredictable/extreme weather can make doing so difficult and creates unique challenges with respect to successful establishment and mitigating the potential negative impacts on subsequent crops. The current project was initiated to demonstrate a potential application of cover cropping (fall rye preceding canola), provide insights towards some of the potential benefits and challenges associated with this practice, and how it might affect other management considerations (i.e. N fertility). The rationale for choosing fall rye for a cover crop was that it establishes well under cool conditions (i.e. late fall), resumes growth earlier in the spring than most other winter cereals, and has allelopathic effects (particularly on other grassy plants such as volunteer cereals or wild oats). Canola was chosen as a test crop because it is economically important in Saskatchewan, benefits from early weed removal, is responsive to N fertility, and can be seeded later than other regionally well-adapted broadleaf options (i.e. peas or lentils); thus, giving more time for cover crop growth in the early spring. The potential longer term benefits to the fall rye cover are many, but some short-term effects might include more biologically active soil, early-spring weed suppression, and increased crop residues to help protect canola seedlings from extreme weather and reduce evaporation of soil moisture. That said, the rye may also potentially have negative impacts. If establishment is successful and enough growth occurs, it will likely tie up some nutrients early in the season which could result in increased fertilizer demands; however, it is also feasible that these nutrients will become available to the canola later on and the overall impacts on fertilizer demands will be negligible in the end. Under dry spring conditions, the fall rye may also utilize much of the initially available soil moisture and could potentially either negatively impact canola establishment (due to there being insufficient initial moisture for germination) and/or reduce the overall yield potential if dry conditions persist. Furthermore, it is also possible that the allelopathic effects of rye, which have the potential benefit of providing weed control benefits, could also impede canola emergence and/or establishment.

Methodology and Results

9. Methodology:

A field trial was initiated near Indian Head, Saskatchewan in the fall of 2020. The treatments were a factorial combination of two cover crop scenarios (either no cover crop or a fall rye cover crop) and five N fertilizer rates (25, 60, 105, 140, and 175 kg N/ha). The N fertilizer rates were not adjusted for residual soil NO_3-N because of the possible impacts of cover crops on this parameter. The 10 treatments were arranged in a four replicate RCBD.

The previous crop was canaryseed and, for perennial weed control, the site was sprayed with 894 g/ha on September 29 (2020), prior to emergence of the cover crops. The fall rye cover was seeded as per protocol on September 19, 2020 at a target rate of 250 seeds/m^2. The following spring, the fall rye was terminated with 894 g glyphosate/ha on the evening of May 13 and the plots were seeded the next day. Seeding was completed using an eight opener SeedMaster® drill at a target depth of approximately 2 cm. A blend of monoammonium phosphate, potassium chloride, and ammonium sulfate was side-banded to supply 36 kg P_2O_5/ha, 18 kg K_2O/ha, and 18 kg S/ha. Additional urea was side-banded to vary the total amount of N applied as per protocol. The canola was seeded at a target rate of 105 seeds/m^2 and the variety was InVigor® L345PC. In addition to the glyphosate applications prior to seeding, weeds were controlled using registered in-crop herbicides applications. Foliar fungicide was applied preventatively on July 2 (early bloom) to suppress sclerotinia, even though the risk of this disease was low. Foliar insecticide was applied over the entire study area and select areas of the surrounding fill crop on July 27 to control grasshoppers. After all treatments had reached physiological maturity (August 15), 894 g glyphosate/ha was applied for pre-harvest weed control and to terminate the crop. The centre five rows of each plot were straight-combined on September 2 using a plot combine.

Various data were collected through the season and from the harvested grain samples. To assess overall fertility on the site and any impacts of the fall rye cover crop, soil samples were collected just prior to seeding with separate composites for the plots with and without the fall rye cover crop. The composites consisted of a minimum of 12 samples per treatment and were collected using two separate methods, depending on the instructions of the labs for which they were destined. Conventional samples were collected for two separate depths (0-15 cm, 15-60 cm), dried at 30-35 °C, ground, and submitted to AgVise Laboratories (Northwood, ND, USA) for various analyses. The Plant Root Simulator (PRS®) probe analyses samples were collected from the same plots for two depths (0-10 cm, 10-30 cm), sealed into plastic bags, refrigerated until they could be shipped, and submitted to Western Ag Laboratories (Saskatoon, SK) for analyses. Plant densities were measured on two separate occasions, in the late spring and again after harvest, by recording the number of plants/stubble in 4 x 1 m sections of crop row and calculating plants/m^2. Yields were determined from the mass of the harvested grain samples and are corrected for both dockage and to a uniform moisture content of 10%. Seed oil and protein concentrations were determined simultaneously by running two cleaned sub-samples of canola per plot through a FOSS NIR analyzer. Mean monthly precipitation amounts were estimated from the nearby Environment and Climate Change Canada weather station, located approximately 3 km from the trial site. Selected agronomic information, dates of field operations and data collection activities are summarized in Table 4 of the Appendices.

Response data were analyzed using the generalized linear mixed model (GLIMMIX) procedure in SAS® Studio. The effects of cover crop (CC), N rate (NR), and the CC x NR interaction were treated as fixed while replicate effects were considered random. Orthogonal contrasts were used to test whether responses to NR were linear, quadratic (curvilinear), or not significant. Treatment effects and differences between means were considered significant at $P \leq 0.05$ and the conservative Tukey-Kramer test was used to separate treatment means.

10. Results:

Growing season weather and residual soil nutrients

Weather data for the fall of 2020 and the 2021 growing season are presented alongside the long-term averages in Table 1 below. The fall months of September and October (2020) were extremely dry with 15 mm of total precipitation in September and less than 4 mm in October. For the two months combined, this amounted to 31% of the long-term average. Furthermore, this dry fall followed an unusually dry growing season (May-August 2020) where only 46% of the long-term average precipitation was received. Temperatures were average in September 2020 but below average in October. Consequently, there was essentially no germination of the fall rye cover crop in the fall of 2020. For following growing season, temperatures were 103% of the long-term average overall but May was cool. The hottest months were June and July, both of which were approximately 2 °C warmer than normal (11-12%). Total growing season precipitation was 121% of the average; however, 30% of this (~90 mm) came in the last two weeks of August, after the canola was terminated and too late to be of any benefit to the crop. Given the timing of precipitation, extremely dry start to the season, and above-normal summer temperatures, the season as a whole was still considered dry. Coming back to the fall rye establishment, many plants emerged in the early spring but, at the time of termination, individual plants remained small, ranging from only 1-3 leaves. Although plant counts on the fall rye were not completed, the numbers were clearly well below the target of approximately 200 plants/m^2. In terms of growing season effects on the canola, the crop fared quite well overall. Initial establishment was excellent with a large precipitation event in the latter half of May, after the canola was seeded. The extreme heat in June and July did result in some pod abortion and general stress; however, timely rain in early June and mid-July helped sustain the crop through the season. The plots were exposed to light hail and high winds in July; however, damage to the canola was negligible and, in the end, yields were approximately average.

Table 1. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2021 growing seasons at Indian Head, SK. Data for the fall period (September through October) were also reported.

Year	Prev. Sep	Prev. Oct	May	June	July	August	May-Aug
	------- Mean Temperature (°C) -------						
2021	11.5	1.4	9.0	17.7	20.3	17.1	16.0 (103%)
LT	11.5	4.0	10.8	15.8	18.2	17.4	15.6
	------- Total Precipitation (mm) -------						
2021	15.0	3.8	81.6	62.9	51.2	99.4	295 (121%)
LT	35.3	24.9	51.8	77.4	63.8	51.2	244

Again, soil sampling was completed just prior to terminating the rye and seeding the canola with separate composites for each cover crop treatment and samples submitted to two separate labs which use contrasting approaches to assessing nutrient supply. The results from the conventional soil test analyses are presented below in Table 2. The PRS® probe analyses results are deferred to Table 5 of the Appendices due to suspected sample contamination and unusual results that were inconsistent with both the conventional soil test results and other samples collected from the broader trial site. The soil pH, cation exchange capacity (C.E.C.), and organic matter were typical for the site, averaging 7.9, 43.3 meq/100 g, and 4.9%, respectively. With respect to overall fertility, the 'No Cover Crop' treatments trended higher relative to the "Fall Rye Cover Crop" treatments for NO_3-N (28 kg N/ha versus 20 kg N/ha), phosphorus (9 ppm versus 4 ppm), and sulfur (43 kg S/ha versus 27 kg S/ha). The opposite trend was observed for potassium (563 ppm versus 572 ppm); however, given the high values of this nutrient, this amount of variation was considered negligible. Considering the inherent variability of soil nutrients and samples, it cannot be stated with certainty that the observed differences were due to the cover crop effects as opposed to natural variability. The results from the PRS® probe analyses showed the opposite trend and much larger differences between samples (Table 5) but, again, these results are suspect. With poor establishment of the fall rye and small plants at the time of soil sampling, effects on soil fertility were expected to be small.

Table 2. Conventional soil test results (AgVise Laboratories) from Indian Head (2020-21) collected from plots with and without a fall rye cover crop, just prior to cover crop termination and seeding.

Treatment	Depth (cm)	pH	C.E.C. (meq)	S.O.M. (%)	NO_3-N (kg/ha)	Olsen-P (ppm)	K (ppm)	S (kg/ha)
No Cover Crop	0-15	7.9	44.1	4.8	8	9	563	9
	15-60	8.1	-	-	20	-	-	34
	0-60	-	-	-	28	-	-	43
Fall Rye Cover Crop	0-15	7.9	42.5	5.0	7	4	572	7
	15-60	8.1	-	-	13	-	-	20
	0-60	-	-	-	20	-	-	27

Crop Responses to Cover Crop Treatments and Nitrogen Fertility

Results from the overall tests of fixed effects are presented for each response variable in Table 3 below. The effects of cover crop (CC) were significant for final plant density ($P < 0.001$), grassy weed and total weed densities ($P = 0.011$-0.026), seed yield ($P = 0.008$), and seed protein ($P = 0.043$). The N rate (NR) effects were significant for seed yield ($P < 0.001$), seed oil ($P < 0.001$), and seed protein ($P < 0.001$). The CC x NR interaction was not significant for any of the response variables evaluated. A more detailed discussion of results for individual variables follows.

Table 3. Tests of fixed effects of cover crop and nitrogen rate for canola establishment, weed densities, yield, oil content, and protein at Indian Head in 2021. P-values below 0.05 indicate that an effect was significant for the corresponding response variable.

Response Variable	Cover Crop (CC)	N Rate (NR)	CC x NR
	--------------------------	Pr > *F* (p-values)	--------------------------
Spring Plant Density (plants/m^2)	0.157	0.173	0.603
Final Plant Density (plants/m^2)	<0.001	0.580	0.590
Broadleaf Weeds (weeds/m^2)	0.284	0.372	0.177
Grassy Weeds (weeds/m^2)	0.011	0.785	0.254
Total Weeds (weeds/m^2)	0.026	0.723	0.244
Seed Yield (kg/ha)	0.008	<0.001	0.477
Oil (%)	0.118	<0.001	0.511
Protein (%)	0.043	<0.001	0.896

Results for cover crop effects on plant density are presented in Fig. 1 below, while main effect means for both cover crop and N rate are also provided in Table 6 of the Appendices. When measured in the spring, approximately one month after seeding, plant densities averaged 76 plants/m^2 and were similar across cover crop treatments ($P = 0.157$) and N rates ($P = 0.173$). With a seeding rate of 105 live seeds/m^2, initial mortality was estimated at 28%. The dry conditions during seeding followed by over 80 mm of precipitation starting one week afterwards were ideal for establishment and any initial moisture differences caused by the cover crop were unlikely to have affected spring plant densities under these conditions. When plant populations were assessed again post-harvest, the numbers were slightly lower, averaging 68 plants/m^2; thus, a final mortality of 35%. Similar to the spring densities, there was no effect of N rate detected post-harvest ($P = 0.580$).

At this time, however, there was a small but significant cover crop effect ($P < 0.001$) whereby we measured 72 plants/m^2 with no cover crop and 65 plants/m^2 with the fall rye cover. This was a relative reduction of 10%; however, neither of these populations were likely to be limiting to yield and it is not entirely clear why negative cover crop impacts were detected post-harvest, but not in the spring. Rye is known to have allelopathic effects on other plants both during emergence and also when its residues are decomposing. It is possible that the extremely dry conditions in the fall and early-spring, prior to the rain in late May, left many rye seeds un-germinated. Some of these may have germinated with or even after (due to less optimal placement) the canola, having a slight negative effect on plant numbers that was not fully realized at the time of the spring plant counts. Alternatively, the fall rye that was established was likely only dying while or after the canola was emerging. If this was the case, decomposition of this plant material may have only begun to occur after the canola was established; hence delaying any associated allelopathic effects until after the spring measurements were completed. In any case, overall establishment was sufficiently high and the negative effects of the rye were small enough that we did not expect any adverse consequences for the canola crop due to this reduction in final plant populations.

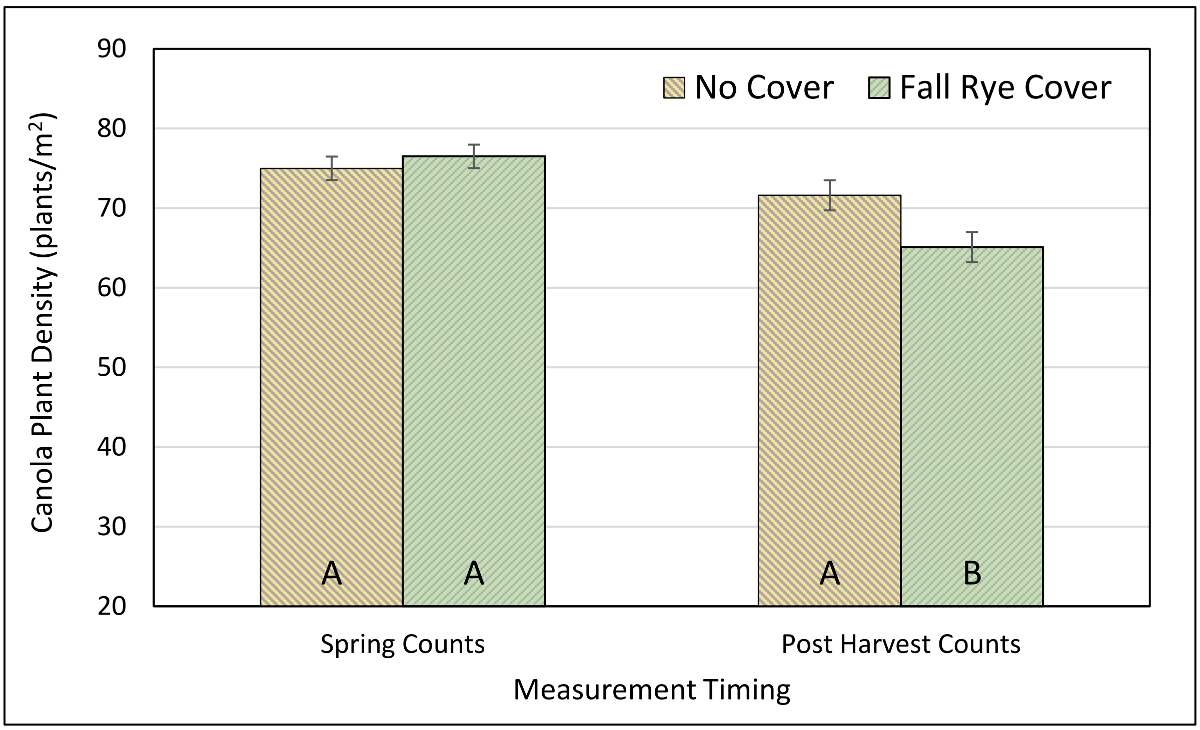

Figure 1. Fall rye cover crop effects on canola establishment at Indian Head in 2021. Measurements were completed in the spring, approximately 4 weeks after seeding, and in the fall, post-harvest. Error bars are the standard error of the treatment means and means within a group (timing of measurement) denoted by the same letter do not significantly differ (Tukey-Kramer, $P \leq 0.05$).

For the weed assessments, we waited until just prior to the in-crop herbicide applications in order to give as much time as possible for weeds to emerge and be counted. Main effect means and results of the multiple comparisons tests are provided in Table 7 of Appendices while cover crop effects are also illustrated in Fig. 2 below. Overall, the plots were relatively clean with few broadleaf weed species observed and a modest number of grassy weed species. The dominant grassy weed was volunteer canaryseed but, again, we did not record individual weed species beyond classifying them as broadleaf or grassy types. As previously alluded to, N rate had no effect on weed populations, regardless of how they were classified (*P* = 0.372-0.785). While the fall rye cover crop had no effect on broadleaf species (*P* = 0.284), both the grassy weed densities and total (broadleaf plus grassy) numbers were higher with the cover crop (*P* = 0.011-0.026). This result was not expected but can likely be reasonably explained. Again, it is feasible that, under the dry conditions, some of the fall rye seeds had not yet germinated when the cover crop was terminated and the canola was seeded. Any such seeds that were still viable would have surely germinated after the major precipitation event in late May and would have had plenty of time to emerge prior to completing the plant counts. This would explain why we observed higher numbers in the cover cropped treatments for the grassy weed species but no effect for broadleaf weeds. The absolute average numbers of grassy weeds were 14/m^2 with no cover crop and 19/m^2 where the cover crop was utilized, an increase of 33%. For total weeds, the numbers were 19/m^2 with no cover crop and 23.5/m^2 with the cover crop, an increase of 21%. Despite the statistically significant treatment effects, overall weed populations were, again, low overall and all were easily controlled with the in-crop herbicide application.

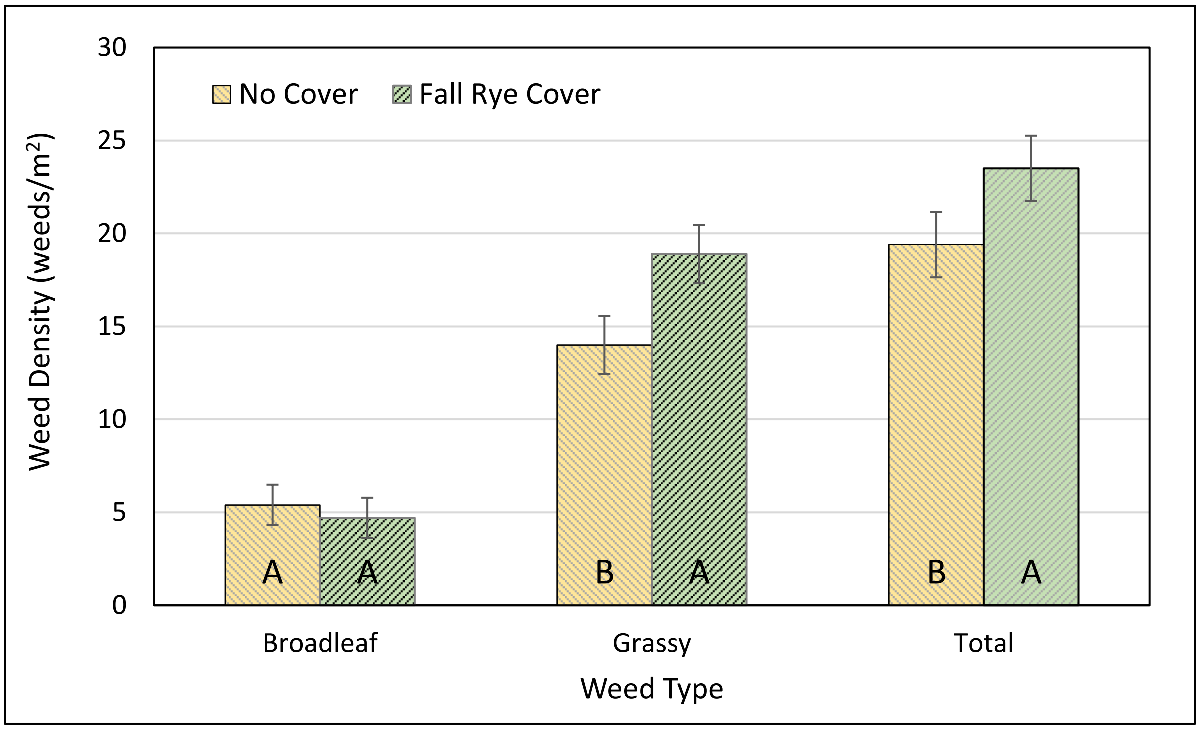

Figure 2. Fall rye cover crop effects on weed densities at Indian Head in 2021. Measurements were completed just prior to the in-crop herbicide applications and, in addition to the total numbers, weeds were categorized as either broadleaf or grassy types. Error bars are the standard error of the treatment means and means within a group (measurement time) denoted by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Both the main effect and individual treatment means for canola seed yield, oil content, and protein concentrations are presented in Tables 8 and 9 of the Appendices. Since the CC x NR interactions were not significant, individual treatment means are provided for interest sake only.

The treatment effects on yield are illustrated graphically in Fig. 3 below. Unlike the previously discussed variables, but as expected, canola seed yield responded strongly to N fertilizer rate (*P* < 0.001). Averaged across cover crop treatments, yields ranged from only 1050 kg/ha at 25 kg N/ha to 2917 kg/ha at 175 kg N/ha. While the orthogonal contrasts showed a quadratic response (*P* < 0.001) and inspection of the means revealed diminishing returns at the higher rates compared to the low end of the range, the yield response to N was still remarkably strong with significant increases observed with each incremental increase in the amount of N applied. The CC effect was due to a small reduction in yield where the cover crop was utilized. The reduction was only 61 kg/ha, or 3%, when averaged across N rates; however, due to the uniform trial area and high statistical power of the factorial design and analyses, it was significant (P = 0.008) nonetheless. Figure 3 shows that this difference was reasonably consistent across the full range of N rates evaluated, hence the lack of a CC x NR interaction.

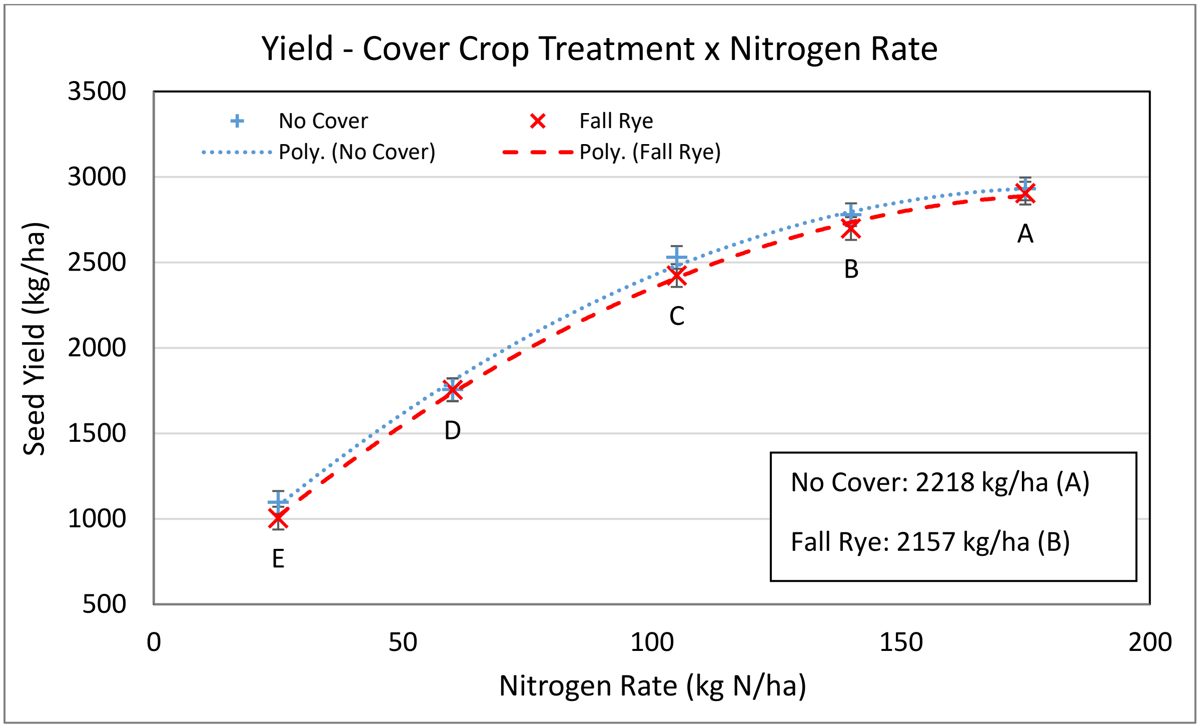

Figure 3. Canola seed yield response to nitrogen rate (NR) when grown without and with a fall rye cover crop (CC) at Indian Head in 2021. Error bars are the standard error of the treatment means. The effects of both cover crop (*P* = 0.008) and N rate (*P* < 0.001) were significant; however, the CC x NR interaction was not (*P* = 0.477). Values denoted by the same letter do not significantly differ. Letter groupings for N rate are for the main effect means (averaged across cover crop treatments).

While canola seed oil content was not affected by cover crop (P = 0.118), the N response was highly significant (P < 0.001) and the opposite to what was observed for yield. At the lowest N rate, seed oil was 44.6% and did not begin to decline until the N rates exceeded 60 kg N/ha (Fig. 4; Table 8). At this point, seed oil content declined significantly with each incremental increase in N and the rate of decline accelerated at the highest N rates, which were also where yield gains with increasing N were beginning to taper off. This was an expected response as canola oil content is known to be inversely related to protein and to decline with increasing N rate.

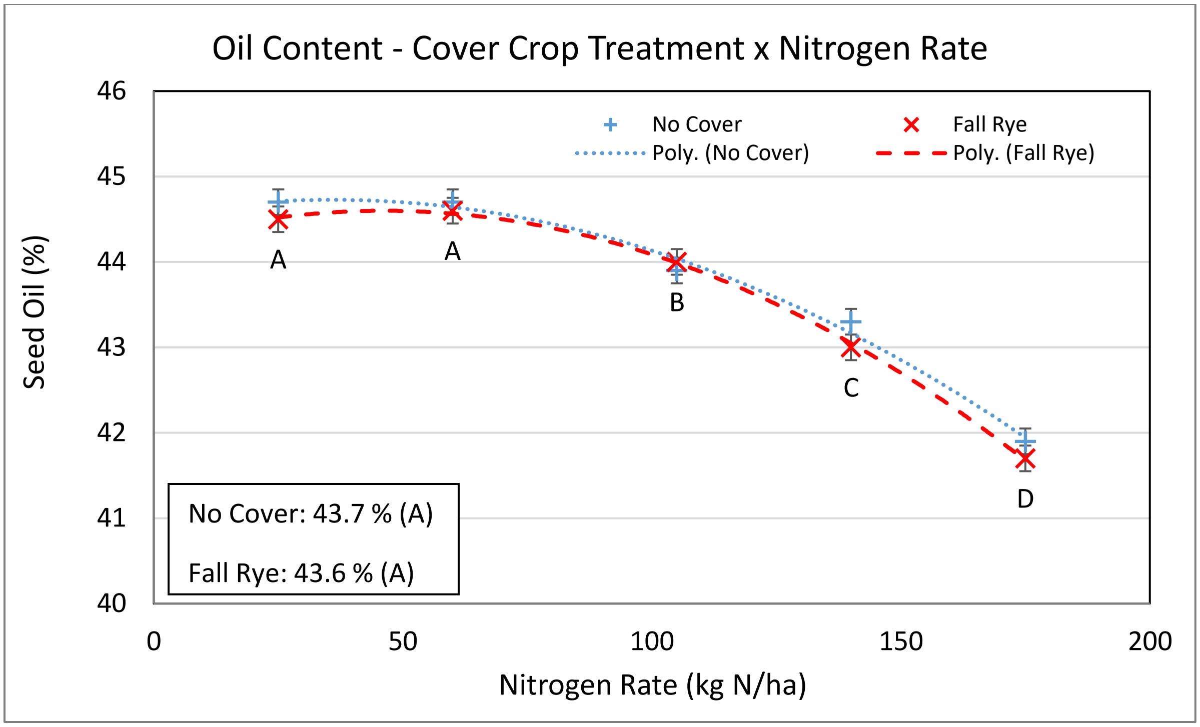

Figure 4. Canola seed oil response to nitrogen rate (NR) when grown without and with a fall rye cover crop (CC) at Indian Head in 2021. Error bars are the standard error of the treatment means. The effect of N rate was significant (P < 0.001), but the effects of cover crop (P = 0.118) and the CC x NR interaction (P = 0.511) were not. Values denoted by the same letter do not significantly differ. Letter groupings for N rate are for the main effect means (averaged across cover crop treatments).

Results for canola seed protein are presented in Fig. 5 below and in Table 8 of the Appendices. While significant (P = 0.043), the effect of the fall rye cover was small with an average protein concentration of 19% in the absence of a cover crop and 19.2% with the fall rye cover when averaged across N rates. This may have been a function of dilution, due to the slightly but significantly lower seed yields observed with the cover crop. One could also speculate that nutrients tied up by the cover crop earlier in the season were released later and contributed to protein. With the poor establishment and limited growth of the fall rye, the latter explanation may have been somewhat unlikely; however, neither of these explanations can be ruled out and it is possible that it was a combination of the two. In any case, the effect was small and of relatively little practical importance. In contrast, N fertilizer rate had a strong effect on seed protein (P < 0.001). Similar to oil content, seed protein did not begin to increase until the N rates exceeded 60 kg/ha at which point each incremental increase in N rate resulted in significantly higher protein. Similar to yield, the difference between the two cover crop treatments appeared to be reasonably consistent across the range of N rates; hence the lack of a CC x NR interaction (P = 0.896).

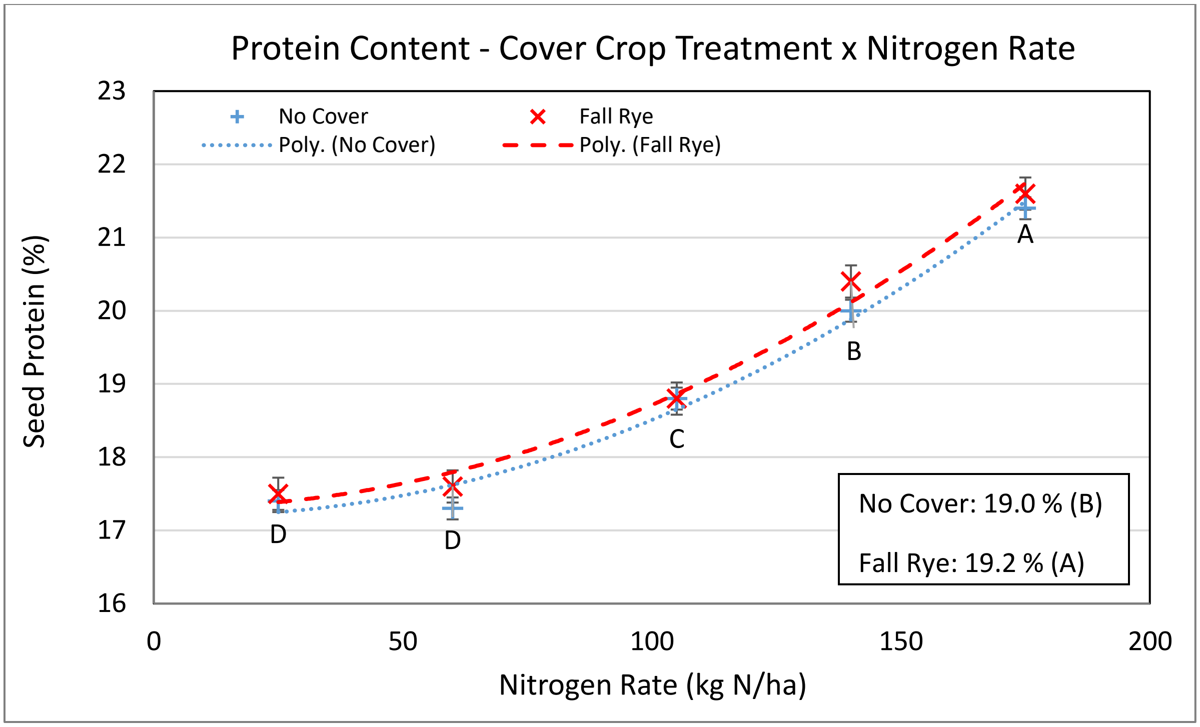

Figure 5. Canola seed protein response to nitrogen rate (NR) when grown without and with a fall rye cover crop (CC) at Indian Head in 2021. Error bars are the standard error of the treatment means. The effects of both cover crop ($P = 0.043$) and N rate ($P < 0.001$) were significant; however, the CC x NR interaction was not ($P = 0.896$). Values denoted by the same letter do not significantly differ. Letter groupings for N rate are for the main effect means (averaged across cover crop treatments).

Extension Activities

In 2020-21, this demonstration was shown to approximately 70 participants on July 20 during a scaled back IHARF Crop Management Field Day. There was discussion of the potential merits and challenges of incorporating cover crops into annual cropping systems in the short, frequently dry, Saskatchewan growing seasons. Final results will continue to be presented where appropriate through oral presentations and other extension materials in the winter of 2020-21 and beyond. This final technical report and other extension materials derived from the project will be available online through IHARF and/or Agri-ARM websites.

11. Conclusions and Recommendations

Due to the extremely dry fall and early-spring, the 2020-21 growing season at Indian Head was not particularly favourable for the establishment of a fall rye cover crop. Nonetheless, the project demonstrated some of the challenges that can occur with incorporating cover crops into annual cropping systems with our short growing seasons and frequently dry weather. While the fall rye was seeded in the third week of September and there was sufficient time for germination and some fall growth, it was too dry for the seed to germinate in the fall and initial establishment was negligible. The snow melt provided enough moisture for some germination in the early spring; however, with extremely low soil initial moisture reserves and below average snow-pack, some seeds remained ungerminated and the plants that did establish never got past the 1-3 leaf stage. With the exception of slightly higher seed protein without negatively affecting oil content, any significant cover crop effects on the canola were negative. For example, final plant densities were reduced by 15%, total weed populations were increased by 21% (presumably due to delayed germination of rye plants), and yields were reduced by 3%. That being said, this was only one example of how cover crops might be incorporated into annual cropping systems and the 2020-21 environmental conditions were far from typical. If this same set of treatments were evaluated in a fall where we were able to achieve successful establishment and a reasonable amount of fall growth followed by a wet spring, the overall results might have looked quite different.

Cover crop effects on initial soil fertility and subsequent crop response to N fertility were somewhat inconclusive and considered to generally be negligible. The trends observed for soil test results were contradictory and the observed responses to N fertilizer were consistent with and without a cover crop, with no significant interactions detected. The responses to N were strong, highly consistent, and as expected for yield, seed oil, and seed protein.

This project was established again in the fall of 2021 and will be repeated this coming growing season in order to build upon these results.

Supporting Information

12. Acknowledgements:

This project was jointly funded by Fertilizer Canada and the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canadian Agricultural Partnership bi-lateral agreement between the federal government and the Saskatchewan Ministry of Agriculture. IHARF has a strong working relationship and a memorandum of understanding with Agriculture and Agri-Food Canada which should be acknowledged and IHARF provided the land, equipment, and infrastructure required to complete this project. Special thanks are extended to all of the IHARF staff who worked on the project and to Danny Petty for administering the project.

13. Appendices:

Table 4. Selected agronomic information and dates of operations for canola cover crop and nitrogen response demonstration at Indian Head in 2020-21.

Factor / Field Operation	2020-21
Previous Crop	Canaryseed
Cover Crop Seeding Date	Sep-19-2020
Cover Crop Seed Rate	250 seeds/m^2 (98 kg/ha)
Soil Sampling Date	May-13-2021
Pre-emergent Herbicide	894 g glyphosate/ha May-13-2021
Canola Seeding Date	May-14-2021
Canola Seed Rate	105 seeds/m^2 (5.3 kg/ha)
kg P_2O_5-K_2O-S ha^{-1}	36-18-18
Spring Plant Density	Jun-18-2021
Weed Counts	Jun-16-2021
In-crop Herbicide	593 g glufosinate-ammonium/ha + 30 g clethodim/ha Jun-19-2021
Foliar Fungicide	242 g boscalid/ha + 86 g pyraclostrobin/ha Jul-2-2021
Foliar Insecticide	872 g malathion/ha (grasshoppers) Jul-27-2021
Pre-harvest herbicide	894 g glyphosate/ha Aug-15-2021
Harvest date	Sep-2-2021
Fall Plant Density	Sep-7-2021

Table 5. Plant Root Simulator (PRS) soil test results (Western Ag Laboratories) from Indian Head (2020-21) collected from plots with and without a fall rye cover crop, just prior to cover crop termination and seeding.

Treatment	pH	N	P_2O_5	K_2O	S
		-------------------- kg/ha --------------------			
No Cover	8.3	21	26	48	15
Fall Rye Cover	8.2	54	66	55	78

Notes: Nutrient release values are based on 250 mm of total moisture and canola as the crop type. The sample depth is 10 cm for pH, P_2O_5, and K_2O and 30 cm for N and S. The high fertility observed in the fall rye cover treatments was unexpected and inconsistent with other soil samples from the broader research site.

Table 6. Main effect means for cover crop (CC) and nitrogen rate (NR) effects on canola plant densities at Indian Head in 2021, as measured in the spring and fall (post-harvest). Main effect means followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Main Effect	Spring Plant Density	Final Plant Density
Cover Crop	------------------------------ plants/m^2	------------------------------
None	75.0 A	76.5 A
Fall Rye	71.6 A	65.1 B
S.E.M.	1.47	1.89
Nitrogen Rate		
25 kg N/ha	75.1 A	67.0 A
60 kg N/ha	72.0 A	71.0 A
105 kg N/ha	68.2 A	70.0 A
140 kg N/ha	73.8 A	72.8 A
175 kg N/ha	77.2 A	73.2 A
S.E.M.	2.49	2.96

Table 7. Main effect means for cover crop (CC) and nitrogen rate (NR) effects on weed densities at Indian Head in 2021, as measured just prior to the in-crop herbicide applications. In addition to the total populations, weeds were broadly categorized into broadleaves and grassy types. Main effect means followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Main Effect	Broadleaf Weeds	Grassy Weeds	Total Weeds
Cover Crop	--------------------------------------	weeds/m^2	--------------------------------------
None	5.4 A	14.0 B	19.4 B
Fall Rye	4.7 A	18.9 A	23.5 A
S.E.M.	1.09	1.55	1.76
Nitrogen Rate			
25 kg N/ha	6.0 A	17.1 A	23.1 A
60 kg N/ha	4.8 A	14.7 A	19.6 A
105 kg N/ha	5.0 A	17.6 A	22.6 A
140 kg N/ha	3.9 A	17.4 A	21.3 A
175 kg N/ha	5.4 A	15.3 A	20.7 A
S.E.M.	1.23	2.18	2.33

Table 8. Main effect means for cover crop (CC) and nitrogen rate (NR) effects on canola yield, oil content, and protein content at Indian Head in 2021. Results from the orthogonal contrasts which test whether N rate responses are linear, quadratic (curvilinear), or not significant are also included. Main effect means followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Main Effect	Seed Yield	Oil Content	Protein Content
Cover Crop	---------- kg/ha ----------	------------------------------ % ------------------------------	
None	2218 A	43.7 A	19.0 B
Fall Rye	2157 B	43.6 A	19.2 A
S.E.M.	59.1	0.10	0.17
Nitrogen Rate			
25 kg N/ha	1050 E	44.6 A	17.5 D
60 kg N/ha	1755 D	44.7 A	17.4 D
105 kg N/ha	2476 C	43.9 B	18.8 C
140 kg N/ha	2739 B	43.1 C	20.2 B
175 kg N/ha	2917 A	41.8 D	21.5 A
S.E.M.	62.0	0.12	0.19
Orthogonal Contrast	------------------------------------ Pr > *F* (p-values) ------------------------------------		
NR - linear	<0.001	<0.001	<0.001
NR - quadratic	<0.001	<0.001	<0.001

Table 9. Individual treatment means for cover crop (CC) by nitrogen rate (NR) effects on canola yield, oil content, and protein content at Indian Head in 2021. Results from the orthogonal contrasts which test whether N rate responses (within cover crop treatments) are linear, quadratic (curvilinear), or not significant are also included. Means followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05). These means are presented for interest sake only as no CC x NR interactions were detected.

Treatment	Seed Yield	Oil Content	Protein Content
CC x NR	---------- kg/ha ----------	------------------------------ %	------------------------------
None - 25 kg N/ha	1096 e	44.7 a	17.4 d
None - 60 kg N/ha	1756 d	44.7 a	17.3 d
None - 105 kg N/ha	2529 c	43.9 b	18.8 c
None - 140 kg N/ha	2779 ab	43.3 d	20.0 b
None - 175 kg N/ha	2930 a	41.9 e	21.4 a
NR - linear (p-value)	<0.001	<0.001	<0.001
NR - quad (p-value)	<0.002	<0.001	<0.001
Fall Rye - 25 kg N/ha	1004 e	44.5 ab	17.5 d
Fall Rye - 60 kg N/ha	1754 d	44.6 a	17.6 d
Fall Rye - 105 kg N/ha	2423 c	44.0 bc	18.8 c
Fall Rye - 140 kg N/ha	2698 b	43.0 d	20.4 b
Fall Rye - 175 kg N/ha	2905 a	41.7 e	21.6 a
NR - linear (p-value)	<0.001	<0.001	<0.001
NR - quad (p-value)	<0.001	<0.001	<0.001
S.E.M.	66.5	0.15	0.22

Abstract

14. Abstract/Summary

With funding from the Saskatchewan Ministry of Agriculture's ADOPT program and Fertilizer Canada, a project was initiated to demonstrate potential benefits and challenges associated with incorporating cover crops into annual cropping systems and implications for nitrogen (N) fertilizer requirements. The field trial was located near Indian Head, Saskatchewan, and the test crop was canola. The treatments were a factorial combination of two cover crop treatments (no cover versus fall rye cover) and five N rates (25, 60, 105, 140, and 175 kg N/ha). The N rates were not adjusted for residual soil N as we anticipated that this could be affected by the cover crops and hoped to measure any impacts on N fertilizer requirements. Data collection included separate soil test analyses for each of the two cover crop treatments, canola plant density, weed counts, canola seed yield, seed oil content, and seed protein. With the extremely dry fall, cover crop establishment was poor; however, limited emergence and growth occurred in the spring. Fall rye plant populations were below what was targeted and the plants that did establish only reached 1-3 leaves. As such, impacts on residual soil nutrients were likely negligible, but the soil test results were inconsistent. Nitrogen had no impact on canola emergence, but final plant populations were 15% lower with the cover crop. The cover crop also increased populations of grassy weed species, presumably a result of ungerminated rye seeds emerging after the cover crop was terminated and the canola was seeded. Canola yield, seed oil, and protein all responded strongly and as expected to N rate with the effects on yield and protein being positive and negative effects on oil content. The fall rye cover resulted in slightly but significantly lower yields and higher protein content but had no impact on oil content. Overall, the project illustrated some of the potential challenges with incorporating cover crops into annual cropping systems under the short, frequently dry, Saskatchewan growing seasons; however, our results may have been quite different with better fall rye establishment and a wet spring. This project is being repeated for the 2021-22 growing season in order to build upon these results.