Agriculture Demonstration of Practices and Technologies (ADOPT)

Project Final Report

The final project report should be made available electronically (MS Word). Additional data tables and or graphs may be submitted in spreadsheet format. Due to formatting, printing and distribution requirements, final reports will not be accepted as PDF documents. Completed reports must be returned by email to Evaluation.Coordinator@gov.sk.ca.

Project Title: Spring Cereal Re-seeding Options for Poor Stands of Winter Wheat (Final Report)

Project Number: 20220367

Producer Group Sponsoring the Project: Indian Head Agricultural Research Foundation

Project Location(s): *Provide the name or number of the rural municipality, nearest town or legal land location if possible. Provide the name of any cooperating landowner(s).* Indian Head, Saskatchewan (R.M. #156)

Project start date *(month & year)*: 9/1/2021

Project end date *(month & year)*: 3/31/2024

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Abstract *(maximum 200 words)*

Detail key elements from the project objectives, methodology, results and conclusions to provide a short concise summary of the project. List extension activities such as field days or workshops and include the number of people who visited the project.

A demonstration with winter wheat was first established in the fall of 2021 and repeated in 2022. The objective was to demonstrate winter wheat viability under a wide range of plant densities and evaluate potential re-seeding options. The treatments were seeding rates ranging from 50-500 seeds/m^2 and additional treatments which were seeded to winter wheat but terminated in late-May and re-seeded to barley, oat, or canary seed. Data collection included winter wheat plant densities and yields plus relative profits for all treatments. Winter wheat establishment was excellent both years with actual densities of 46-333 plants/m^2 in 2022 and 55-362 plants/m^2 in 2023. Our results were broadly consistent with past research in that winter wheat stands of 100 plants/m^2, or even less, yielded remarkably well. When populations fell below this level, yields in 2022 declined substantially and delayed maturity and weed issues were observed; however, this did not occur to the same extent in 2023. Re-seeding was consistently successful with the

spring cereals establishing and yielding well. Oats were the most profitable option, followed by canary seed, and finally barley. Re-seeding to barley produced slightly lower returns than the most profitable winter wheat stands. Oats and, to a lesser degree, canary seed were more profitable than all winter wheat treatments, even after re-seeding costs were accounted for.

Project Objectives

Provide a short statement outlining the project objectives. Identify the key concept this project was designed to demonstrate. For example, you might use a statement such as *"This project was intended to demonstrate and compare the benefits of……" or "The objective of this project was to demonstrate the impact of…."*

The objective of this project was to demonstrate the agronomic and economic performance of a wide range of winter wheat stands relative to a selection of agronomically suitable spring cereal re-seeding options. More specifically, we intended to demonstrate the minimum plant populations were where winter wheat yields were likely to be compromised and to look at the economics of reseeding to either barley, oat, or canary seed.

Project Rationale

Briefly describe why this project is of interest to local producers. Why is it important to have this project? What are the potential beneficial outcomes? What is the perceived need?

There are numerous advantages to growing winter wheat and other fall-seeded cereals, especially from longer-term agronomic and environmental perspectives; however, unfavorable conditions for fall establishment have taken a toll on this crop in recent years. In some years and regions, wet weather has created challenges with harvesting the preceding crops in a timely manner, thus greatly diminishing the window for fall seeding. Alternatively, many regions have experienced severe drought and, extremely dry soil conditions in the fall have either created doubt regarding the viability of winter cereals or led to poor fall establishment and subsequently delayed crops or suboptimal stands. When poor establishment does occur, producers must make the difficult decision of whether to nurture the existing crop and hope that it is profitable or terminate it and reseed to a suitable spring crop, taking on additional and often seeding late in May or early June, past the ideal seeding window.

In addition to the fact that spring crops seeded in late May or June do not usually perform as well as with earlier seeding, the decision to re-seed is especially challenging because poor stands of winter wheat can often still be viable if weed control and fertility is adequate. Detailed information on assessing overwinter survival and spring stands is provided by Manitoba Agri-Food and Rural Development (https://www.gov.mb.ca/agriculture/crops/crop-management/pubs/assessing-winter-wheat-survival.pdf). According to this resource, the optimum plant stand is 20-25 plants/square foot (213-269 plants/m^2); however, stands of 5-8 plants/square foot (54-86 plants/m^2) can still yield up to 80% of the maximum. If the decision to reseed is made, options are frequently limited either by disease considerations (i.e., spring wheat is not recommended due to wheat streak mosaic virus) or herbicide issues (i.e., fall 2,4-D or florasulam can negatively impact many broadleaf options). With these potential issues, along with basic rotational considerations, this project focussed on barley, oat, and canary seed as the most viable options to re-seed to after termination of the winter wheat.

This project was initiated to benefit producers by demonstrating winter wheat response to a wide range of plant densities, intended to simulate preferred versus poor stand establishment, along with the relative economic and agronomic performance of taking a sub-optimal stand of winter wheat to harvest versus reseeding to either barley, oat, or canary seed.

Methodology

Fully describe how the project was set up and run. You should provide enough information so that any reader can understand what you did, and where and when you did it. From that they can determine if your report has any relevance to their own operation. For example, your description should include all relevant items such as 1) the number and size of any field plots, 2) what was seeded, 3) what treatments were applied to the plots, 4) the schedule or timing of any relevant activities such as seeding, treatment application or harvest, and 5) what was measured to evaluate the success of any treatment. If your project dealt with animals, you should be sure to include 1) the number of animals in each trial group, 2) the treatment or procedure applied to each group, and 3) what was measured to evaluate the success of each treatment.

A field demonstration with winter wheat was initiated in the fall of 2021 and repeated the following growing season. The treatments were arranged in a four replicate RCBD and were simply six different winter wheat seeding rates (50, 100, 200, 300, 400, and 500 seeds/m^2). Three additional treatments were seeded at a rate of 100 seeds/m^2 and destined to be terminated and re-seeded to spring cereal options.

Selected agronomic details and dates of operations are provided in Table 5 of the Appendices. Winter wheat seeding was completed on September 15 in 2022 and September 30 in 2023. The variety was AAC Goldrush, and seed was treated with Raxil Pro in both years. The applied fertility was 125-40-20-20 kg N-P_2O_5-K_2O-S/ha across all treatments and both years, with all fertilizer side-banded and urea, monoammonium phosphate, potash, and ammonium sulphate as sources. In both years, the entire trial sites were sprayed prior to winter wheat emergence and each spring, the three treatments slated for re-seeding were terminated with glyphosate and re-seeded to either barley, oat, or canary seed. The re-seeding operations were completed on May 23 in both years and termination of the winter wheat occurred on May 21-22. This was thought to be late enough to provide time for a thorough evaluation of winter wheat establishment and winter kill, yet still early enough to re-seed with a high probably of success for the spring seeded crops. The target seeding rates and varieties of the spring seed crops were AAC Synergy barley (300 seeds/m^2), CDC Arborg oat (350 seeds/m^2), and Keet canaryseed (45 kg/ha). No additional fertilizer was applied with the spring seeded crops. For all crops, weeds and disease were kept non-limiting using registered herbicide and fungicide options. Insecticides were utilized as required and included applications to control grasshoppers in both years and aphids on the canaryseed in 2022. In both years, pre-harvest glyphosate was applied on the winter wheat and canary seed, but not in the barley or oats. For yield determination, the centre rows of each plot were straight combined using Wintersteiger plot combines.

Data collection included assessments of winter wheat plant densities and grain yield. In 2022, winter wheat plant densities were estimated from destructive counts where plants in 2 x 1 m sections of crop row were dug up, separated at the roots, and counted. In 2023, the winter wheat primarily emerged in the spring; therefore, non-destructive counts could be completed accurately, and we did not need to dig up the plants. All values were averaged for each plot and converted to plants/m^2. Grain yields for all crops were adjusted for dockage and to uniform seed moisture contents of 14.5% for winter wheat, 13.5% for barley and oat, and 13% for canary seed.

The winter wheat establishment and yield data were analyzed using the GLIMMIX procedure of SAS Studio with the effects of year (YR), seeding rate (SR) and the Yr × SR interaction treated as fixed and replicate effects (nested within year) treated as random. Individual treatment means were separated using Fisher's protected L.S.D. test and orthogonal contrasts were utilized to test whether responses to seeding rate were linear or quadratic (curvilinear). Additionally, non-linear regression analyses were completed using SigmaPlot 14.5 to establish the relationship between actual winter wheat plant densities and grain yield. Treatment effects and differences between means were considered significant at $P \leq 0.05$; however, p-values ≤ 0.1 may also be acknowledged as marginally significant. Spring cereal yield data were analyzed separately with the effects of Yr, crop type (CROP), and the Yr × CROP interaction considered fixed and replicate effects (within year) random. Again, mean yields were separated using Fisher's protected L.S.D. test.

A marginal economic analysis was completed to demonstrate the relative economic ramifications of re-seeding to a spring cereal crop as opposed to nurturing the winter wheat, regardless of establishment, and taking it to harvest. For this analyses, several assumptions had to be made and only the expenses that were assumed to vary between treatments were considered Grain prices and costs of operations were primarily estimated using the 2022-23 Saskatchewan Crop Planning Guide and the 2022-23 Farm Machinery Custom Rental Rate Guide (https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/crops-and-irrigation/crop-guides-and-publications). The assumed grain prices were $315, $281, $389, and $771/Mt for winter wheat, barley, oat, and canary seed, respectively. Gross revenues were estimated using these price assumptions and the observed grain yields. The expenses associated with terminating the poor stands of winter wheat included both the cost of the application and 894 g glyphosate/ha and was assumed to be $30/ha in total (approximately $15/ha each for the product and application cost). Re-seeding costs for all crops were set to $58/ha while the cost of the seed itself was assumed to be $100/ha, $120/ha, and $60/ha for barley, oats, and canary seed, respectively. For simplicity, crop protection costs were assumed to be similar for all crops except for oat herbicide costs being $45/ha less than winter wheat, barley, or canary seed due to the lack of wild oat herbicide options. Marginal net income was estimated by subtracting all applicable expenses from the gross revenues. We recognize that actual revenues and expenses will vary from farm-to-farm or year-to-year and, as such, encourage readers to substitute these numbers with their own if they see value in doing so.

Results *(you must provide the following information)*

Present and discuss any project results, including any data or measurements taken to evaluate the demonstration. Include things that didn't appear to work. These results are just as important to share. List extension activities such as field days or workshops. List the activity, the date it occurred, and the number of people who attended.

Growing Season Weather Conditions

Mean monthly temperatures and total precipitation amounts for the 2021 and 2022 growing seasons (May-August) at Indian Head are presented alongside the long-term (1981-2010) averages in Table 1. Information from the preceding fall months is also provided to coincide with establishment of the winter wheat and aid in interpretation of results. In the fall of 2021, essentially no rain fell in September; however, October was wetter and warmer than average. Winter snowfall was abundant, and the spring 2022 melt was later than normal. Precipitation for the month of May was nearly twice the long-term average and, overall, conditions were suitable for both the successful establishment and early-season growth of winter cereals. While soil moisture was higher than ideal for seeding the spring cereal options in 2022, the crops were seeded in the last week of May and established by early June. With abundant moisture and approximately normal temperatures, yields for all crops, regardless of when they were seeded, were quite high.

Moving on to the second season, winter wheat seeding in the fall of 2022 was delayed due to harvest being late, and the months of September and October were dry. The winter wheat did not emerge in the fall of 2022; however, with good initial soil moisture (largely due to a late April snowstorm), came up quite well in the early spring. Soil moisture and overall conditions were ideal for re-seeding to spring cereals in late May; however, the 2023 growing season was warm and dry. May and June were especially hot and only 119 mm of rain was received over the four-month period, 49% of average and 42% of the previous season. Consequently, yields were considerably lower than 2022 and, for the winter wheat in particular, moisture was quite limiting during the grain filling stages.

Table 1. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2021 and 2022 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) ----------						
2022	14.5	6.8	10.9	16.1	18.1	18.3	15.8 (+0.2)
2023	13.7	5.6	14.0	19.4	16.7	17.7	17.0 (+1.4)
LT	11.5	4.0	10.8	15.8	18.2	17.4	15.6
	---------- Total Precipitation (mm) ----------						
2022	0.4	43.0	97.7	27.5	114.5	45.9	286 (117%)
2023	14.5	18.8	12.9	49.6	15.9	40.8	119 (49%)
LT	35.3	24.9	51.8	77.4	63.8	51.2	244

Winter Wheat Establishment and Yield

Results of the overall tests of fixed effects for winter wheat establishment and yield are presented in Table 6 of the Appendices. Despite the stark contrast in environmental conditions, actual plant densities were similar between years (P = 0.120) and there was no year Yr × SR interaction (P = 0.883), indicating that the seeding rate response was also similar between years. The SR response was as expected, with plant populations increasing quadratically from 46-55 seeds/m^2 at 50 seeds/m^2 to 347-362 plants/m^2 at 500 seeds/m^2. The quadratic nature of the plant density response was due to increasing seedling mortality at the higher seeding rates. For example, averaged over the two years, the estimated seedling mortality at 50 seeds/m^2 was 0% while, at 500 seeds/m^2, it was over 40%. Increasing seedling mortality with increasing seeding rates is commonly observed and generally attributed to higher competition amongst seedlings for resources and space.

Winter wheat grain yield was affected by year (Yr; P < 0.001), seeding rate (SR; P < 0.001), and the Yr x SR interaction (P < 0.001; Table 6). Due to the differences in moisture availability, yields were much higher overall in 2022 (5338 kg/ha) than 2023 (3993 kg/ha). The seeding rate responses were not entirely as expected. In 2023, we saw the lowest yields, by a substantial margin, at 50 seeds/m^2; however, yields peaked at the relatively low seeding rates of 100-200 seeds/m^2 and were significantly lower at the highest seeding rate of 500 seeds/m^2 (Table 3). In 2023, yields also peaked at 100-200 seeds/m^2; however, yields at only 50 seeds/m^2 were surprisingly high and did not significantly differ from the top yielding treatments. Furthermore, yields fell quite dramatically at the highest seeding rate. This difference in response between the two years was apparent in the orthogonal contrasts whereby the yield response to seeding rate was quadratic in 2022, but more linear in 2023. The more dramatic decline in yield at high plant populations in 2023 was attributed to the much drier conditions, which did improve slightly late in the season with cooler temperatures prevailing and a relatively small but timely precipitation event in mid-July. It is probable that the lower plant populations used less soil moisture early on and, due to delayed maturity, benefited more from any latter season precipitation. While not specifically assessed, the low plant populations matured noticeably later than the denser stands, particularly in 2022 (i.e., Fig. 5 of the Appendices)

Table 2. Treatment means and orthogonal contrast results for seeding rate effects on winter wheat plant densities at Indian Head (2021-22). The percentage of viable seed that established as plants are provided in parentheses for interest's sake. Means followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05). The overall averaged plant densities did not differ between years and were 196 plants/m^2 in 2022 and 214 plants/m^2 in 2023.

Seeding Rate	2022	2022	AVG
viable seeds/m^2		---------- plants/m^2 ----------	
50	46 f (92)	55 f (110)	50 F (100)
100	96 e (96)	105 e (105)	101 E (101)
200	168 d (84)	180 d (90)	174 D (87)
300	244 c (81)	258 c (86)	251 C (84)
400	291 b (73)	324 b (81)	307 B (77)
500	333 a (67)	362 a (72)	347 A (69)
S.E.M.	13.7	13.7	9.7
Pr > F (p-value)	<0.001	<0.001	<0.001
		---------- p-value ----------	
SR - linear	<0.001	<0.001	<0.001
SR - quadratic	0.017	0.026	0.002

Table 3. Treatment means and orthogonal contrast results for seeding rate effects on winter wheat grain yields at Indian Head (2021-22). Means followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05). The overall averaged yields were significantly higher in 2022 (5338 kg/ha) than in 2023 (3993 kg/ha).

Seeding Rate	2022	2022	AVG
viable seeds/m^2		---------- kg/ha ----------	
50	4623 c	4033 ab	4328 E
100	5641 a	4257 a	4949 A
200	5619 a	4133 ab	4876 AB
300	5392 ab	3902 bc	4647 CD
400	5487 ab	3963 b	4725 BC
500	5268 b	3670 c	4469 DE
S.E.M.	141.7	141.7	100.2
Pr > F (p-value)	<0.001	0.008	<0.001
		---------- p-value ----------	
SR - linear	0.030	0.001	0.351
SR - quadratic	<0.001	0.163	<0.001

Figures 1-2 illustrate the winter wheat yield response as a direct function of the actual plant observed populations, as opposed to seeding rates. Due to the different responses, data were not combined across years for this part of the analyses; however, the response in 2023 did become significantly quadratic as opposed to linear when the data was looked at in this manner. The regression analyses suggested that, in 2022, maximum winter wheat yields were achieved at 215-220 plants/m^2 but yields at 50 plants/m^2 were still 88% of maximum (Fig. 1). In 2023, winter wheat yields peaked at only 135-145 plants/m^2 and were still 98% of maximum at 50 plants/m^2. On the other end of the spectrum, yields at 350 plants/m^2 were 92% of maximum in 2022 and 90% of maximum in 2023.

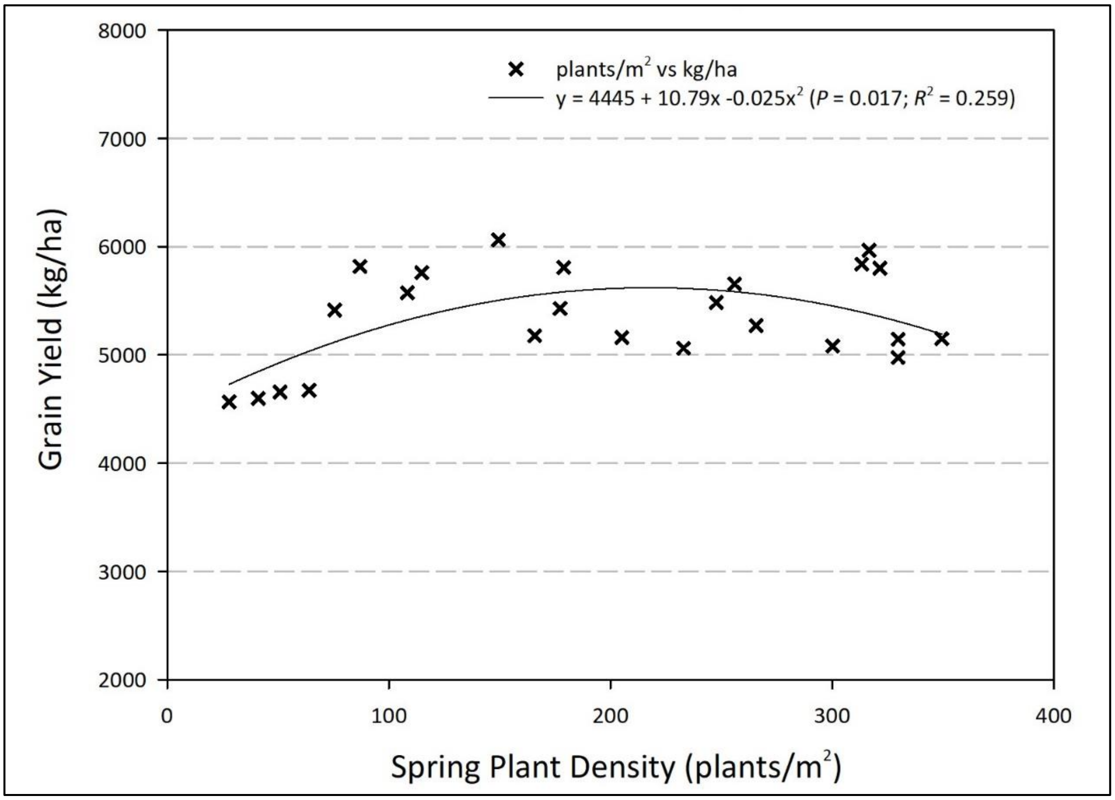

Figure 1. Relationship between plant density (plants/m^2) and grain yield for individual winter wheat plots at Indian Head in 2022. Data were analyzed using a non-linear regression in SigmaPlot 14.5.

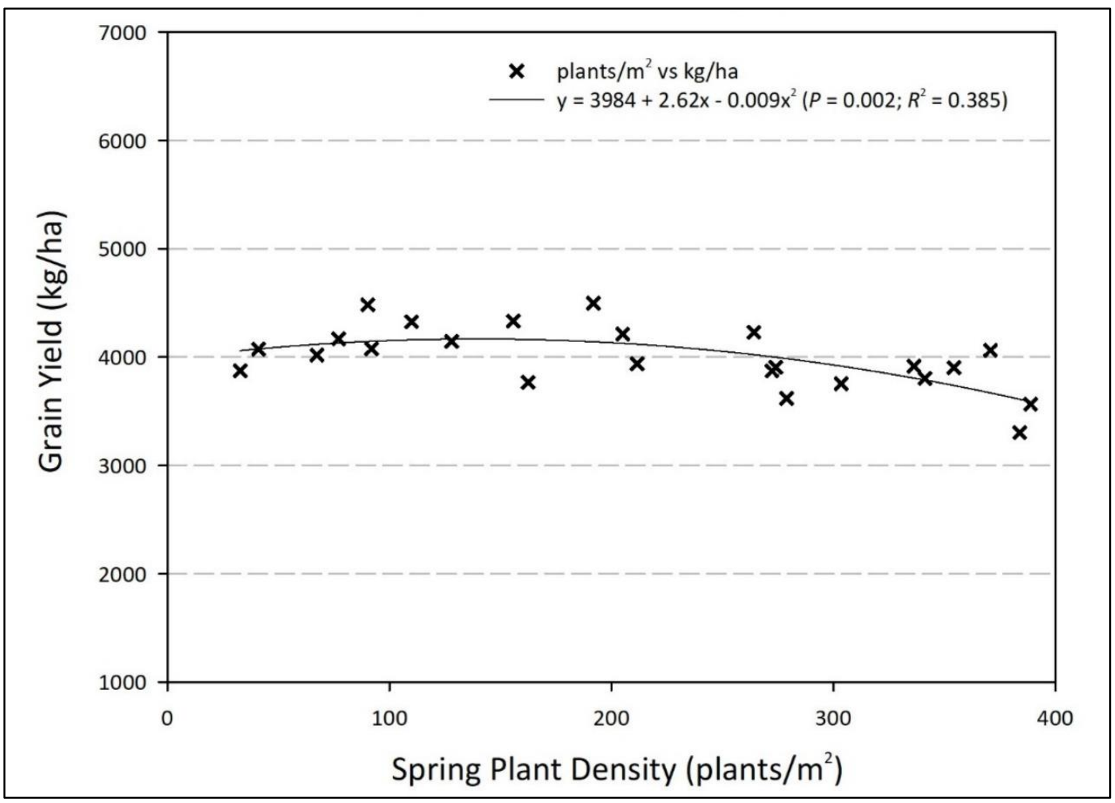

Figure 2. Relationship between plant density (plants/m^2) and grain yield for individual winter wheat plots at Indian Head in 2023. Data were analyzed using a non-linear regression in SigmaPlot 14.5.

Feasibility of Re-seeding to Spring Cereals

The spring cereal options evaluated as options for re-seeding all performed quite well. Mean yields for each crop type in both years and averaged across years are presented in Table 4 below. Like the winter wheat, yields were higher overall in 2022 than in 2023, attributable to the dry weather. In both years, yields were highest for barley, followed by oat, and then canary seed; however, this is not necessarily a reflection of the relative profitability of each crop which was our primary interest for this project.

Table 4. Mean yields for various spring cereal options when re-seeded into poor stands of winter wheat. Values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test; *P* ≤ 0.05).

Crop Type	2021	2022	AVG
	------------------------------------ kg/ha	--------------------------------------	
Barley	6702 a	5326 a	6014 A
Oat	5977 b	4813 b	5395 B
Canary seed	2712 c	2069 c	2391 C
S.E.M.	49.1	49.1	34.7

Detailed assumptions and outcomes of the marginal economic analyses are presented in Tables 8 and 9 of the Appendices; however, the results are also illustrated in Figs. 3 and 4 below for 2022 and 2023, respectively. Even after considering the costs of terminating the winter wheat and re-seeding, the spring seeded cereal options performed reasonably well economically. Despite high yields, barley was consistently the least profitable of the three spring cereals and, in both years, generally resulted in similar profits as all but the lowest yielding winter wheat treatments. Oats were the most profitable option and, under the conditions encountered, were $368-385/ha more profitable than even the best performing winter wheat treatments, regardless of year. Despite much lower absolute yields with canary seed, the estimated marginal profits of this crop were intermediate to the barley and oats and generally slightly more profitable than the best winter wheat treatments. Importantly, these results could vary dramatically in years better suited to winter wheat production, with later re-seeding, or with less favorable conditions for re-seeding.

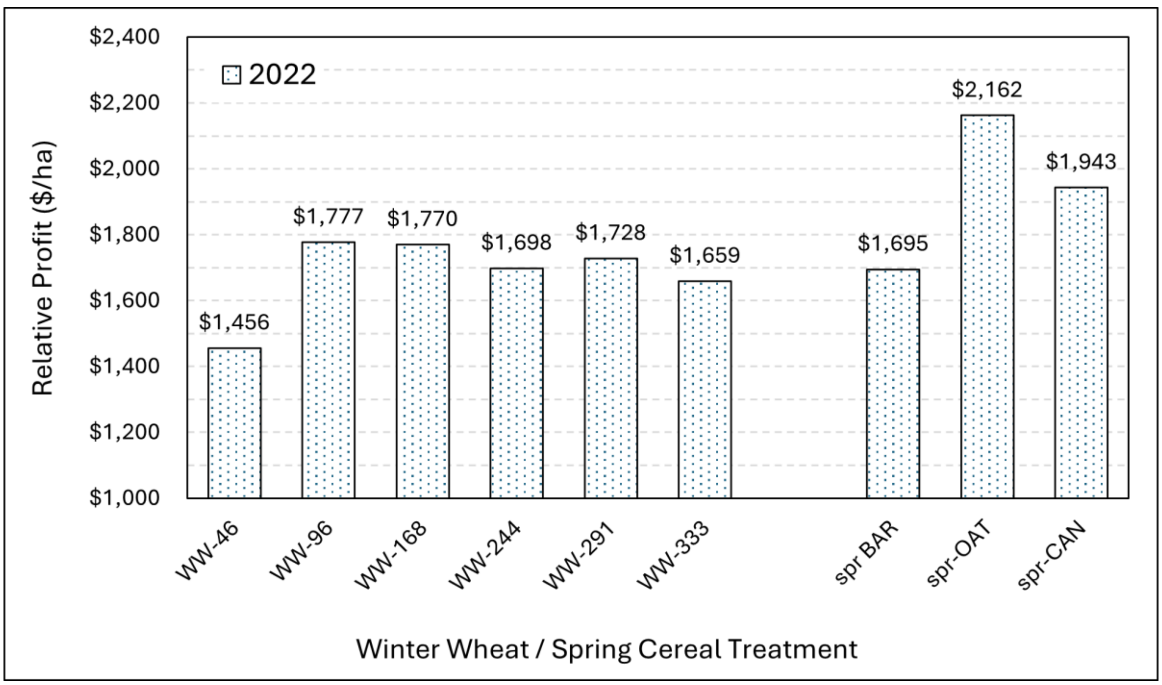

Figure 3. Relative profitability ($/ha) of winter wheat (WW) growing at a wide range of plant densities (46-333 plants/m²) versus with spring (spr) re-seeding to barley (BAR), oat (OAT), or canary seed (CAN) in 2022 at Indian Head. Detailed information on the assumptions used are provided in the Appendices (Table 8).

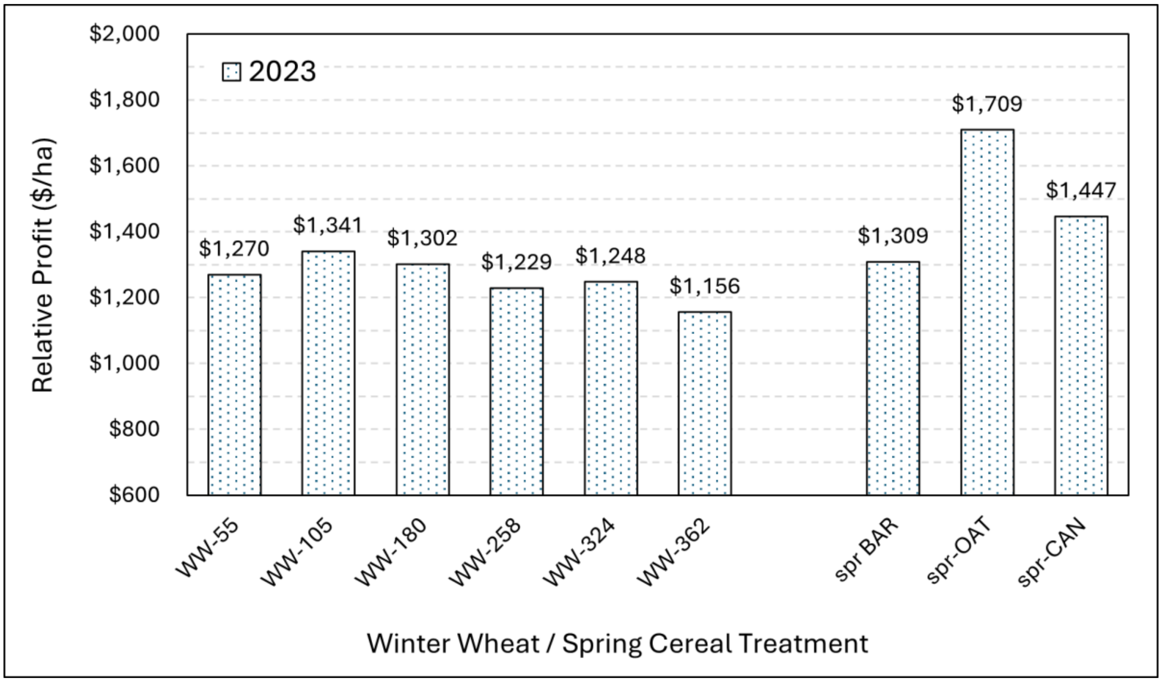

Figure 4. Relative profitability ($/ha) of winter wheat (WW) growing at a wide range of plant densities (55-62 plants/m²) versus with spring (spr) re-seeding to barley (BAR), oat (OAT), or canary seed (CAN) in 2023 at Indian Head. Detailed information on the assumptions used are provided in the Appendices (Table 9).

Extension Activities

This demonstration was scheduled to be shown during the 2022 Indian Head Crop Management Field Day on July 19; however, the event was rained out and moved indoors. Nonetheless, Chris Holzapfel (IHARF) presented a general overview of the trial to approximately 120 people indoors. In 2023, the project was shown to approximately 160 participants during the field day (July 18, 2023), with Chris Holzapfel providing a detailed discussion of the previous year's results and a general overview on agronomy and recent challenges in winter cereal production. The 2022 interim report has been available for download on the IHARF website (www.iharf.ca) and the current, final report will also be posted. Results will continue to be presented through oral presentations and other extension materials.

Conclusions and Recommendations

Describe what was learned from the demonstration. Highlight any significant conclusions and provide recommendations for the application and adoption of the project results. Be sure that you have presented the relevant data to support your conclusions. Identify any further research, development and communication needs, if applicable.

This project has demonstrated the tremendous ability of winter wheat to compensate for sub-optimal plant populations if fertility, moisture, and the length of the growing season are not limiting. Overall mortality of the winter wheat was better than expected with essentially 100% of the live seeds planted becoming established plants at the lowest seeding rates and 69-77% survival at the highest rates. Unexpectedly, some of the highest winter wheat yields and economic returns were achieved with plant populations as low as approximately 100-175 plants/m². When populations fell below this level in 2022, yields declined substantially and serious issues with maturity and weeds began to materialize. This was less evident under the drought conditions of 2023 where weed pressure was low, maturity was earlier, and yields at the lowest populations were still 98% of maximum.

Focussing on the re-seeding options, all performed reasonably well in terms of the yields achieved and their relative profitability. Yields for all the spring re-seeding options were well above average in 2022 and slightly below average in 2023. In both years, all easily reached maturity despite being seeded somewhat later than optimal. Even with having the highest absolute yields, barley was the least profitable option and, when costs of terminating the winter wheat and re-seeding were accounted for, resulted in slightly lower profits than the most profitable winter wheat treatments. That said, terminating the winter wheat and re-seeding to barley was considerably more profitable than the poorest winter wheat stands of less than 50 plants/m^2 in 2022. This was not the case in 2023 where even the poorest winter wheat stands yielded relatively well. Oats were consistently the most profitable re-seeding option and re-seeding to this crop was always substantially more profitable than the best winter wheat treatments – even after the costs associated with terminating the winter wheat and re-seeding were accounted for. With intermediate net returns, canary seed also proved to be a viable re-seeding option under the conditions encountered. Again, one drawback of canary seed relative to the other options is that it is considerably later maturing; however, this was not problematic in the current demonstration and re-seeding to canary seed resulted in slightly higher profits than all winter wheat treatments.

While this project has demonstrated that terminating and re-seeding poor stands of winter wheat to other, spring seeded, cereal options can be quite viable, several factors should be considered before committing to do so. First, while winter wheat stands as low as 100 plants/m^2 performed well under the conditions encountered, the uniformity of stands must also be considered when assessing the crop. For example, it is likely that a field with consistently marginal stands will be easier to manage and more successful than a crop where the overall average population is marginal, but high variability exists. This variability could result in sizeable portions of the field suffering substantial yield loss in addition to wide ranges in maturity within the field. Furthermore, it should be recognized that plant densities as low as 100 plants/m^2 will not always perform as well as they did in the current demonstration, particularly under heavy weed pressure. The other factor to consider is the actual calendar date by which re-seeding could be completed and soil moisture conditions at this time. In the current project, re-seeding was completed on May 23, not unreasonable from a practical perspective but not especially late. Our results could have been quite different if re-seeding have been postponed until the second week of June. Furthermore, conditions were always favourable for rapid establishment of the re-seeded crops. In a dry spring, re-seeding into an established, albeit poor, winter cereal stand could be extremely risky with successful establishment being dependant upon timely and sufficient precipitation after re-seeding is completed.

In conclusion, growers faced with a sub-optimal stand of winter wheat need to consider the viability of the existing crop, costs associated with terminating and re-seeding, the probability of successfully establishing a spring seeded option, and the likelihood of the re-seeded crop reaching maturity in a timely manner.

Sustainable Canadian Agricultural Partnership (Sustainable CAP) Performance Indicators

a) List of performance indicators

Sustainable CAP Indicator	Total Number
Scientific publications from this project (List the publications under section b)	
• Published	0
• Accepted for publication	0
HQPs trained during this project	
• Master's students	0
• PhD students	0
• Post docs	0
Knowledge transfer products developed based on this project (presentations, brochures, factsheets, flyers, guides, extension articles, podcasts, videos). List the knowledge transfer products under section (c)	4

[1] Please only include the number of unique knowledge transfer products.

b) List of scientific journal articles published/accepted for publication from this project.

Title	Author(s)	Journal	Date Published or Accepted for Publication	Link (if available)
n/a	n/a	n/a	n/a	n/a

c) List of knowledge transfer products/activities developed from this project.

Knowledge Transfer Product or Activity	Event/Location Where Knowledge Transfer Was Conducted	Estimated Number of Producers Participated in Knowledge Transfer	Link (if available)
C. Holzapfel (IHARF) Plot Tour	Crop Mgt Field Day, Indian Head (Jul-19-2022)	110	https://iharf.ca/indian-head-crop-management-field-day/
Year 1 – Interim Report	IHARF Website	unknown	https://iharf.ca/full-reports/
C. Holzapfel (IHARF) Plot Tour	Crop Mgt Field Day, Indian Head (Jul-18-2023)	160	https://iharf.ca/indian-head-crop-management-field-day/
Year 2 – Final Report	IHARF Website	unknown	https://iharf.ca/full-reports/

Acknowledgements

Include actions taken to acknowledge support by the Ministry of Agriculture, the Canadian Agriculture Partnership (for projects approved between 2017 and 2023) and the Sustainable Canadian Agriculture Partnership (for projects approved between 2023 and 2028).

Financial support was provided under the Sustainable Canadian Agricultural Partnership, a federal-provincial-territorial initiative. Fertilizer Canada also contributed financially to the project. We would like to acknowledge the IHARF Board of Directors in addition to the many technical and support staff who worked on the project. IHARF has a strong working relationships and memorandum of understanding with Agriculture and Agri-Food Canada which should also be acknowledged and helps to make work such as this possible.

Appendices

Identify any changes expected to industry contributions, in-kind support, collaborations or other resources.

Table 5. Selected agronomic information and dates of operations for winter wheat establishment / re-seeding demonstration at Indian Head in 2022 and 2023.

Factor / Operation	2021-22	2022-23
Previous Crop	Canola	Canola
Fall Seeding Date	Sep-15-2021	Sep-30-2022
Winter Wheat Variety	AAC Goldrush	AAC Goldrush
Winter Wheat Seed Treatment	1 g tebuconazole + 5 g prothioconazole + 2 g metalaxyl / 100 kg seed	1 g tebuconazole + 5 g prothioconazole + 2 g metalaxyl / 100 kg seed
Fertility	125-40-20-20 kg N-P_2O_5-K_2O-S/ha	125-40-20-20 kg N-P_2O_5-K_2O-S/ha
Fall Herbicide	894 g glyphosate + 5 g flurasulam/ha (Sep-19-2021)	894 g glyphosate (Oct-9-2022)
Winter Wheat Termination	894 g glyphosate (May-21-2022)	894 g glyphosate (May-22-2023)
Spring Seeding Date	May-23-2022	May-23-2023
Spring Cereal Varieties and Rates	Barley (AAC Synergy – 300 seeds/m^2) Oat (CDC Arborg – 350 seeds/m^2) Canary seed (Keet – 40 kg/ha)	Barley (AAC Synergy – 300 seeds/m^2) Oat (CDC Arborg – 350 seeds/m^2) Canary seed (Keet – 40 kg/ha)
Spring Plant Density	May-26-2022	May-17-2023
In-Crop Herbicides	145 g fluroxypyr + 100 clopyralid + 560 g MCPA ester + 15 pyroxsulam/ha (winter wheat; Jun-6-2022) 145 g fluroxypyr + 100 g clopyralid + 560 g MCPA ester/ha (all spring cereals; Jun-19-2022) 62 g pinoxaden/ha (barley; Jun-20-2022) 92 g penoxaprop p-ethyl/ha (canary; Jun-20-22)	5 g halauxifen + 77 g fluroxypyr + 348 g MCPA ester + 15 g pyroxsulam/ha (winter wheat; May-29-2023) 145 g fluroxypyr + 100 g clopyralid + 560 g MCPA ester/ha (all spring cereals; Jun-13-2023)
Foliar Fungicide	100 g prothioconazole + 100 g tebuconazole/ha (winter wheat; Jul-1-2022) 74 g azoxystrobin + 124 g propiconazole + 30 g benzovindiflupyr/ha (all spring cereals; Jul-10-2022)	151 g prothioconazole + 75 g tebuconazole + 75 g fluopyram/ha (winter wheat; Jul-1-2022) 74 g azoxystrobin + 124 g propiconazole + 30 g benzovindiflupyr/ha (all spring cereals; Jun-30-2023)
Foliar Insecticide	7.4 g deltamethrin/ha (all crops; Jul-9-2022) 240 g dimethoate/ha (canary; Aug-2-2022)	7.4 g deltamethrin/ha (all crops; Jun-16-2023)
Pre-harvest herbicide	894 g glyphosate/ha (winter wheat; Aug-15-2022) 894 g glyphosate/ha (canary; Sep-16-2022)	894 g glyphosate/ha (winter wheat; Aug-9-2023) 894 g glyphosate/ha (canary; Aug-28-2023)
Harvest Dates	Aug-22-2022 (winter wheat); Sep-6-2022 (barley) Sep-15-2022 (oat); Sep-16-2022 (canary)	Aug-17-2023 (winter wheat); Aug-28-2023 (barley) Aug-28-2023 (oat); Sep-8-2023 (canary)

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Table 6. Tests of fixed effects of year (Yr), seeding rate (SR), and the Yr x SR interaction on winter wheat establishment and grain yield over two growing seasons at Indian Head. Data were analysed using the GLIMMIX procedure of SAS Studio.

Effect	Num DF	Den DF	F-Value	Pr > F (p-value)
	---------- Plant Density ----------			
Year (Yr)	1	6	3.28	0.120
Seed Rate (SR)	5	30	162.81	<0.001
Yr × SR	5	30	0.34	0.883
	---------- Grain Yield ----------			
Year (Yr)	1	6	79.62	<0.001
Seed Rate (SR)	5	30	10.77	<0.001
Yr × SR	5	30	6.79	<0.001

Table 7. Tests of fixed effects of year (Yr), crop type (CROP), and the Yr x CROP interaction on spring cereal crop grain yields over two growing seasons at Indian Head. Data were analysed using the GLIMMIX procedure of SAS Studio.

Effect	Num DF	Den DF	F-Value	Pr > F (p-value)
Year (Yr)	1	6	519.32	<0.001
Crop Type (CROP)	2	12	3780.9	<0.001
Yr × CROP	2	12	35.84	<0.001

Figure 5. Delayed maturity and poor canopy closure of winter wheat at less than 50 established plants/m^2 (Jul-29-2022).

Figure 6. Oat (left), canary seed (centre), and barley (right) reseeded into poor stands of winter wheat (Jul-29-22).

Table 8. Estimated economic returns associated with winter wheat at varying plant populations relative to terminating the winter wheat and re-seeding to various spring cereal options in 2022. Only the expenses that were explicitly assumed to differ between treatments were included and actual expenses will vary for individual operations and years. Winter wheat seeding rates were not accounted for in this economic analysis since they were only varied to simulate varying levels of establishment resulting from adverse conditions during seeding and/or winter kill.

Treatment [Z]	Grain Price [Y]	Gross Income [X]	Termination Cost [W]	Re-Seeding Cost [V]	Seed Cost [U]	Crop Protection [T]	Marginal Net Income [S]
	---- $/Mt ----	---- $/ha ----					
Winter Wheat: 46 plants/m^2	$315	$1,456	–	–	–	–	$1,456
Winter Wheat: 96 plants/m^2	$315	$1,777	–	–	–	–	$1,777
Winter Wheat: 168 plants/m^2	$315	$1,770	–	–	–	–	$1,770
Winter Wheat: 244 plants/m^2	$315	$1,698	–	–	–	–	$1,698
Winter Wheat: 291 plants/m^2	$315	$1,728	–	–	–	–	$1,728
Winter Wheat: 333 plants/m^2	$315	$1,659	–	–	–	–	$1,659
Re-seeded to Barley	$281	$1,883	$30	$58	$100	–	$1,695
Re-seeded to Oat	$389	$2,325	$30	$58	$120	($45)	$2,162
Re-seeded to Canary seed	$771	$2,091	$30	$58	$60	–	$1,943

[Z] Treatments are crop type and plant populations based on the observed winter wheat densities and spring cereals include costs of seeding and terminating winter wheat

[Y] Grain prices are approximated from the 2022 Saskatchewan Crop Planning Guide

[X] Gross incomes are based on actual yields and the assumed grain prices

[W] Termination cost is associated with killing the winter wheat prior to re-seeding and estimated from the average custom rate for a high clearance sprayer in the 2022-23 Farm Machinery Custom and Rental Rate Guide (approximately $15/ha each for the product and application cost)

[V] Re-seeding cost is estimated from the average custom rate for a high clearance sprayer in the 2022-23 Farm Machinery Custom and Rental Rate Guide

[U] Seed costs are estimated from the 2022 Saskatchewan Crop Planning Guide

[T] Crop Protection Costs may vary widely but assume similar costs for all crops except oats where no grassy weed herbicide options are available

[S] Marginal Net Income estimates only include the input costs that were assumed to vary between treatments, actual net income will always be lower

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Table 9. Estimated economic returns associated with winter wheat at varying plant populations relative to terminating the winter wheat and re-seeding to various spring cereal options in 2023. Only the expenses that were explicitly assumed to differ between treatments were included and actual expenses will vary for individual operations and years. Winter wheat seeding rates were not accounted for in this economic analysis since they were only varied to simulate varying levels of establishment resulting from adverse conditions during seeding and/or winter kill.

Treatment [Z]	Grain Price [Y]	Gross Income [X]	Termination Cost [W]	Re-Seeding Cost [V]	Seed Cost [U]	Crop Protection [T]	Marginal Net Income [S]
	---- $/Mt ----	-- $/ha --					
Winter Wheat: 55 plants/m^2	$315	$1270	–	–	–	–	$1270
Winter Wheat: 105 plants/m^2	$315	$1341	–	–	–	–	$1341
Winter Wheat: 180 plants/m^2	$315	$1302	–	–	–	–	$1302
Winter Wheat: 258 plants/m^2	$315	$1229	–	–	–	–	$1229
Winter Wheat: 324 plants/m^2	$315	$1248	–	–	–	–	$1248
Winter Wheat: 362 plants/m^2	$315	$1156	–	–	–	–	$1156
Re-seeded to Barley	$281	$1497	$30	$58	$100	–	$1309
Re-seeded to Oat	$389	$1872	$30	$58	$120	($45)	$1709
Re-seeded to Canary seed	$771	$1595	$30	$58	$60	–	$1447

[Z] Treatments are crop type and plant populations based on the observed winter wheat densities and spring cereals include costs of seeding and terminating winter wheat
[Y] Grain prices are approximated from the 2022 Saskatchewan Crop Planning Guide
[X] Gross incomes are based on actual yields and the assumed grain prices
[W] Termination cost is associated with killing the winter wheat prior to re-seeding and estimated from the average custom rate for a high clearance sprayer in the 2022-23 Farm Machinery Custom and Rental Rate Guide (approximately $15/ha each for the product and application cost)
[V] Re-seeding cost is estimated from the average custom rate for a high clearance sprayer in the 2022-23 Farm Machinery Custom and Rental Rate Guide
[U] Seed costs are estimated from the 2022 Saskatchewan Crop Planning Guide
[T] Crop Protection Costs may vary widely but assume similar costs for all crops except oats where no grassy weed herbicide options are available
[S] Marginal Net Income estimates only include the input costs that were assumed to vary between treatments, actual net income will always be lower

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Expenditure Statement

You must provide an expenditure statement showing how ADOPT funds were used. Expenditures must be reported using the budget categories shown in Appendix B of your contract. We recommend that you report your expenditures using the Excel spreadsheet we have developed for this purpose (ADOPT Expenditure Statement.xls). That spreadsheet is available from the research branch project manager or the evaluation coordinator.
Note that the ADOPT contract requires you to retain all receipts and financial records relating to the project for at least six years after the project is completed.

The expenditure statement was submitted in a separate document and is available upon request.