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:	Demonstrating the Efficacy of Foliar-Applied Nitrogen Fixing Bacteria for Wheat
Project Number:	20230018
Producer Group Sponsoring the Project:	Saskatchewan Wheat Development Commission
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, R.M. #156 (Indian Head Agricultural Research Foundation); Melfort, R.M. #428 (Northeast Agriculture Research Foundation); Outlook, R.M. #284 (Irrigation Crop Diversification Corporation); Prince Albert, R.M. #481 (Conservation Learning Centre); Redvers, R.M. #61 (Southeast Research Farm); Scott, R.M. #380 (Western Applied Research Corporation); Swift Current, R.M. #137 (Wheatland Conservation Area Inc.); Yorkton, R.M. #244 (East Central Research Foundation)
Project start date *(month & year):*	4/1/2023
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.

In 2023, field trials were conducted at eight Saskatchewan locations to evaluate and demonstrate the potential ability of commercially-available, foliar-applied biological products to aid in nitrogen (N) nutrition and improve yield and quality in wheat. The locations were Indian Head, Melfort, Outlook (irrigated), Prince Albert, Redvers, Scott, Swift Current, and Yorkton. The treatments were a factorial combination of three N fertility levels (50, 100, or 150 kg N/ha) and three foliar

treatments (untreated control, Envita®, or Utrisha™-N). The N levels included residual soil nitrate and the foliar treatments were applied at the 4-6 leaf stage and label recommended rates. Except for one location, we observed consistent yield and grain protein concentration responses to increasing N fertilizer rates. There were, however, no indications of improved N status associated with the foliar treatments for either grain yield or protein concentrations, regardless of N fertilizer level or location. As such, we recommend that farmers do not back off on their N fertilizer rates if using such products and include check strips to evaluate efficacy on their own farms. Many of the Agri-ARM sites featured this demonstration during their annual field days and dissemination of results during winter extension meetings is ongoing.

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 effects of commercially-available, foliar-applied nitrogen (N) fixing bacteria products on the yield and seed quality of CWRS wheat grown under a range of N fertility levels and contrasting environmental conditions.

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?

Nitrogen is the most commonly limiting nutrient in the production of non-legume crops in Saskatchewan and, in many cases, the most expensive input. This is especially true in recent years as fertilizer prices have reached record high levels. Further to the economic considerations, national and international targets for reducing greenhouse gas emissions associated with N fertilization in agriculture are putting pressure on producers to maximize the efficiency of N fertilization and, potentially, reduce overall N inputs. Consequently, products that have potential to reduce N fertilizer requirements in crop production have received substantial attention and interest from Saskatchewan grain producers and commodity groups. Furthermore, many in the agricultural industry expect biological products to play an increasingly important role in the efficient and sustainable production of crops. The proposed project aims to demonstrate, under field conditions and a wide-range of soil/climatic environments, the agronomic performance of new biological products such as Envita® (Azotic Technologies; 1 x 107 CFU/ml *Gluconacetobacter diazotrophicus*) and Utrisha™-N (Corteva Agriscience; 3 x 107 CFU/ml *Methylobacterium symbioticum* SB23). These products may have the ability to facilitate biological N fixation in crops that would otherwise be unable to do so; thus, potentially subsidizing soil and fertilizer N and improving the overall fertilizer N-use efficiency in Saskatchewan crop production. While others exist, these two biological N-fixing technologies are expected to have the greatest market share in western Canada and are likely the most familiar to Saskatchewan producers. As one of the most economically important crops in Saskatchewan and largest users of N, particularly when high protein is also desired, CWRS wheat is an excellent test crop for this project. This topic was specifically identified as a research and extension priority by SaskWheat directors and members.

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.

Field trials with CWRS wheat were initiated at eight Saskatchewan locations in the spring of 2023. The locations were representative of a broad range of Saskatchewan growing regions and, in alphabet order, included Indian Head (thin-Black soil zone), Melfort (Black soil zone), Outlook (Brown soil zone, irrigated), Prince Albert (Black soil zone), Redvers (Black soil zone), Scott (Dark Brown soil zone), Swift Current (Brown soil zone), and Yorkton (Black soil zone). The treatments were a factorial combination of three N fertilizer levels and three foliar-applied, N fixing biological products, arranged in a Randomized Complete Block Design (RCBD) and replicated four times at each location. The target N levels, adjusted for residual soil NO_3-N (0-60 cm), were 50 (low), 100 (medium), and 150 kg N/ha (high). It was our expectation for N to be limiting at both the low and medium levels while, at the high level, the N rates would be more typical for CWRS wheat but still not excessive for most regions. The foliar-applied biological treatments were either an untreated control (none applied), Envita® (95 ml/ac plus 0.1% Agrol 90), and Utrisha™-N (135 g/ac). These treatments were applied at the 4-6 leaf stage, in a minimum water volume of 93 l/ha (10 US gal/ac), and we used distilled water to minimize any potential negative impacts of chlorine or other additives on the biological products being demonstrated. We also did our best to apply the treatments either early in the morning or on relatively cool days. While prolonged humid conditions may have also been ideal, this was not necessarily possible as we had to hit the target crop stages and have limited windows that were suitable for the treatment applications. Furthermore, farmers do not generally have the luxury of waiting for ideal conditions to apply crop protection products or biologicals such as those evaluated in the current project.

Selected agronomic information and dates of operations are provided in Table 5 of the Appendices. Plot size varied across locations to accommodate the specific seeding and spraying equipment. Weeds were controlled using registered pre-emergent and in-crop herbicides and preventative fungicide applications were recommended to ensure that disease would not be a yield limiting factor. Although not all sites applied a fungicide, the risk of disease was generally low and it is highly unlikely that this had any impact on yields or the observed responses. Pre-harvest herbicides or desiccants were used at the discretion of individual site managers and, wherever possible, only the centre rows of each plot were harvested to avoid potentially confounding edge effects.

Various data were collected to evaluate the treatments and help explain the results. Composite soil samples were collected for the specific study areas and analyzed by Agvise Laboratories for residual nutrients and other basic properties. To provide information on the overall establishment at each site and test for potential N fertilizer rate effects, plant counts were completed after emergence was complete and the average number of plants/m^2 for each plot was calculated. Yields were determined by weighing the grain harvested from a known plot area, adjusting the weights for dockage and to a uniform moisture content of 14.5%, and converting the values to kg/ha. Grain protein concentrations were determined using NIR grain analyzers. Weather data for each site were recorded using either Environment Canada or privately owned weather stations and are summarized for the May-August, inclusive, period.

All response data was analyzed using the generalized linear mixed model (GLIMMIX) of SAS. For grain yield and protein concentrations, the effects of site (S), N fertilizer level (N), foliar treatment (F), and all possible interactions were considered fixed while replicate effects (nested within site) were considered random. For plant density, foliar treatment was excluded from the model since these treatments had not yet been applied when the measurements were completed. We permitted and tested for heterogeneity in variance estimates across locations for all response variables; however, the more complex model was only used when doing so significantly improved convergence. Treatment means were separated using Tukey's test and orthogonal contrasts were used to test whether the overall N-rate responses were linear, quadratic, or not significant. All treatment effects and differences between means were considered significant at $P \leq 0.05$; however, p-values of 0.05-0.1 may also be acknowledged. Data from three sites, Prince Albert, Swift Current, and Yorkton were excluded from the combined analyses due to either there being no response to N whatsoever (Prince Albert), severe hail damage (Swift Current), or unusually high variability that may have reduced our ability to detect treatment effects at other individual sites or when averaged across sites (Yorkton); however, data from these sites were still analyzed individually using simplified models and are reported on and discussed as appropriate.

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.

Soil Test Results and Growing Season Weather Conditions

Soil test results for all eight sites are provided in Table 1 below. While our intention was to have initially low residual N at all sites, this was not always possible with the actual amounts ranging from 16-72 kg NO_3-N/ha (0-60 cm). Nitrogen fertilizer rates were adjusted for residual NO_3-N, with the lowest N level targeting 50 kg N/ha (soil plus fertilizer); however, this could not be achieved at Melfort, Prince Albert, Swift Current and Yorkton where the low N level ended up with 59, 76, 56, and 62 kg N/ha, respectively, after the N from any phosphorus and sulfur fertilizer products were accounted for. Soil pH, organic matter, and C.E.C. values ranged widely but were all considered typical for their corresponding locations. Nutrients other than N were intended to be non-limiting and were not specifically of interest for this project.

Table 1. Selected soil test analyses results for biological N fixation product demonstrations conducted for CWRS wheat at Indian Head (IH), Melfort (ME), Outlook (OL), Prince Albert (PA), Redvers (PA), Scott (SC), Swift Current (SW), and Yorkton (YK) in 2023. Unless otherwise indicated, all measurements are representative of the 0-15 cm soil profile.

Parameter	IH-23	ME-23	OL-23	PA-23	RV-23	SC-23	SW-23	YK-23
pH	7.8	6.2	7.7	5.7	7.9	5.7	6.7	6.8
Organic Matter (%)	5.5	8.7	2.7	3.5	3.4	3.8	2.9	7.8
CEC (meq)	45.6	37.0	15.3	n/a	33	14.7	16.7	27.4
NO_3-N (kg/ha) [Z]	16	41	24	72[Y]	29	21	19	55[Y]
Olsen-P (ppm)	7	16	8	21	6	17	8	16
K (ppm)	590	619	345	152	199	394	298	353
kg S/ha (kg/ha) [Z]	56	87	54	64	484+	105	49	77

[Z] Values for residual NO_3-N and S are for the 0-60 cm soil profile

[Y] Corresponding values were reported for 0-30 cm and estimated for the 0-60 cm depth by multiplying by 1.5

n/a – data not available

Mean monthly temperatures for each location are presented along with the long-term (1981-2010) averages in Table 2 while precipitation amounts are in Table 3. All locations were considerably warmer than average, with May and June being particularly hot. July was slightly cooler than average to approximately average while August temperatures were approximately average to slightly above average. Over the four-month period from May through August, growing season temperatures ranged from 1.4-1.9 °C above average. Turning our attention to precipitation, all locations but one were much drier than average. Swift Current was the exception, with 95% of average precipitation and, with 179 mm in total, this location was also the wettest in absolute terms, despite typically being the most arid of the Agri-ARM locations. Unfortunately, the plots at Swift Current were also damaged by a hail storm that resulted in an estimated 50% yield loss. Outlook was the driest of the sites with only 95 mm of precipitation (46% of average); however, this location is irrigated and received an additional 246 mm of irrigation water in June through August. The remaining locations received 49-70% of the long-term average precipitation amounts, or 111-179 mm. Excluding Outlook, which was irrigated, Indian Head, Melfort, and Yorkton were the driest in both absolute terms and as a percentage of the long-term average.

Table 2. Mean monthly temperatures along with long-term (LT; 1981-2010) averages for the 2023 growing season at Indian Head (IH), Melfort (ME), Outlook (OL), Prince Albert (PA), Redvers (RV), Scott (SC), Swift Current (SW), and Yorkton (YK), Saskatchewan.

Year	May	June	July	August	May-Aug
	---------- Mean Temperature (°C) ----------				
IH-23	14.0	19.4	16.7	17.7	17.0 (+1.4)
IH-LT	10.8	15.8	18.2	17.4	15.6
ME-23	14.1	19.2	16.9	17.3	16.9 (+1.7)
ME-LT	10.7	15.9	17.5	16.8	15.2
OL-23	15.2	19.5	18.5	18.7	18.0 (+1.9)
OL-LT	11.5	16.1	18.9	18.0	16.1
PA-23	14.4	18.8	16.6	17.1	16.7 (+1.6)
PA-LT	10.4	15.3	18.0	16.7	15.1
RV-23	14.5	19.7	17.6	17.9	17.4 (+1.4)
RV-LT	11.1	16.2	18.7	18.0	16.0
SC-23	14.9	17.2	17.1	17.4	16.7 (+1.9)
SC-LT	10.8	14.8	17.3	16.3	14.8
SW-23	14.8	17.7	18.4	18.8	17.4 (1.6)
SW-LT	11.0	15.7	18.4	17.9	15.8
YK-23	13.8	19.7	16.7	17.8	17.0 (+1.8)
YK-LT	10.4	15.5	17.9	17.1	15.2

Table 3. Mean monthly precipitation amounts along with long-term (LT; 1981-2010) averages for the 2023 growing season at Indian Head (IH), Melfort (ME), Outlook (OL), Prince Albert (PA), Redvers (RV), Scott (SC), Swift Current (SW), and Yorkton (YK), Saskatchewan.

Year	May	June	July	August	May-Aug
	---------- Total Precipitation (mm) ----------				
IH-23	12.9	49.6	15.9	40.8	119 (49%)
IH-LT	51.8	77.4	63.8	51.2	244
ME-23	17.9	26.4	16.4	50.0	111 (49%)
ME-LT	42.9	54.3	76.7	52.4	226
OL-23	17.2	15.3 (117)	15.5 (86)	46.6 (43)	95 (46%)
OL-LT	42.6	63.9	56.1	42.8	205
PA-23	22.8	52.8	40.8	51.2	168 (67%)
PA-LT	44.7	68.6	76.6	61.6	252
RV-23	84.1	33.0	10.8	37.6	166 (62%)
RV-LT	60.0	95.2	65.5	46.6	267
SC-23	16.6	81.1	29.7	31.7	159 (70%)
SC-LT	38.9	69.7	69.4	48.7	227
SW-23	41.0	32.9	63.3*	42.1	179 (95%)
SW-LT	42.1	66.1	44.0	35.4	188
YK-23	16.8	67.9	18.0	33.3	136 (50%)
YK-LT	51.3	80.1	78.2	62.2	272

[Z] Values in parentheses Outlook are irrigation water

[Y] Hailstorm at Swift Current on July 22/2023 resulted in an estimated 50% seed yield loss

Wheat Establishment, Yield, and Grain Quality

To give a sense of the overall environmental conditions and productivity at each site, location means for each response variable are presented in Table 4 below. Again, Prince Albert, Swift Current, and Yorkton were excluded from the combined analyses so neither letter groupings nor standard error values are provided for these locations. Not unexpectedly given the wide range of environmental conditions, the site effects were highly significant ($P < 0.001$) for all response variables (Table 6). Overall differences between sites will be referred back to where appropriate while discussing treatment effects and individual response variables.

Table 4. Main effect means for location, or site effects on spring wheat plant density, grain yield, and grain protein concentration. Values within a column followed by the same letter do not significantly differ (Tukey-Kramer, $P \leq 0.05$).

Location	Plant Density	Grain Yield	Grain Protein
	---------- plants/m^2 ----------	---------- kg/ha ----------	---------- % ----------
Indian Head [Z]	326.9 A (8.73)	4494 B (60.2)	9.6 D (0.18)
Melfort [Z]	243.0 C (8.73)	3418 C (76.2)	9.9 CD (0.18)
Outlook [Z]	224.7 C (8.73	5243 A (66.4)	10.7 BC (0.18)
Prince Albert [Y]	189.6	3746	14.7
Redvers [Z]	286.3 B (8.73)	4369 B (221.1)	10.8 B (0.19)
Scott [Z]	308.5 AB (8.73)	4480 AB (286)	12.6 A (0.18)
Swift Current [Y]	182.1	1333	17.7
Yorkton [Y]	275.9	4314	12.4
	---------- p-value ----------		
Pr > F	<0.001	<0.001	<0.001

[Z] Data combined for analyses across sites with SITE (S), Nitrogen (N), and the S x N interaction as fixed effects

[Y] Data excluded from the combined analyses and, therefore, cannot be compared to other sites

Plant densities were primarily measured to provide insights into the overall establishment at each location in addition to any potential impacts of the N fertility treatments. According to the overall tests of fixed effects in the combined analysis (Table 6), emergence was affected by site ($P < 0.001$) and N rate ($P = 0.006$) but no S x N interaction was detected ($P = 0.556$). The highest plant populations were achieved at Indian Head and Scott (309-327 plants/m^2), followed by Redvers (286 plants/m^2), then Melfort and Outlook (225-243 plants/m^2). Plant populations at Prince Albert and Swift Current were relatively low (182-189 plants/m^2) while those at Yorkton were intermediate (276 plants/m^2). Detailed results for N effects on emergence are deferred to the Appendices (Table 8); however, the response may have been due more to sampling error than actual differences in plant populations. The N effect on plant density showed populations increasing from 269 plants/m^2 to 281-284 plants/m^2 at the higher N rates. We speculate that the wheat may have been tillering earlier and to a greater extent when N was less limiting. While we aimed to distinguish between tillers and plants, doing so can be difficult, particularly if emergence counts are delayed or with less experienced staff. In any case, plant populations at all locations, including Prince Albert and Swift Current, were sufficiently high that we did not expect them to limit yields or impede our ability to detect treatment effects on grain yield or protein concentrations.

Detailed results for spring wheat grain yields are provided in Tables 9-10 of the Appendices and summarized graphically in Figs. 1-3 below. Yield was affected by site ($P < 0.001$) and N level ($P < 0.001$) with an S x N interaction ($P < 0.001$) indicating that the yield response to N varied across sites. There was no effect of foliar treatment on yield ($P = 0.793$) and the S x F ($P = 0.995$) and S x N ($P = 0.637$) interactions indicated that this lack of response was consistent,

regardless of environment or N fertilizer rate. Despite the lack of responses to the foliar treatments, all treatment means are presented in the interest of full transparency and because this was a key objective of the project.

Averaged across treatments, yields ranged from 1333 kg/ha at Swift Current to 5243 kg/ha at Outlook (Table 4). Again, yields of all eight locations cannot be directly compared since not all were included in the combined analyses. Of those that were, and averaged across them, yields increased with each incremental addition of N fertilizer, from 3529 kg/ha at 50 kg N/ha to 5189 kg/ha at 150 kg N/ha (Fig. 1; Table 9). The S x N interaction was due to subtle variation in the response at individual sites. For example, yields at Melfort were statistically similar at the low and medium N levels but substantially higher at 150 kg N/ha. At Scott, there was a more typical quadratic response with yields increasing from the low to medium N rates but no further gains going from 100 kg N/ha to 150 kg N/ha. For the other three sites included in the combined analyses (Indian Head, Outlook, and Redvers), grain yields increased with each incremental addition of N fertilizer, similar to the averaged results. Of the sites that were not included in the combined analyses, there was no response to N whatsoever at Prince Albert and the responses were relatively weak at Swift Current and Yorkton, but still significant and generally peaking at the medium (100 kg total N/ha) rate.

Averaged across the five sites included in the combined analyses, foliar treatment had no impact on wheat yields with the overall average yields for the control, Envita®, and Utrisha™-N ranging from 4375-4415 kg/ha (Fig. 2). Consistent with the lack of an S x F interaction, there were no trends to suggest that the yield response to foliar treatment differed at individual sites when averaged across N levels. Individual treatment means are presented for individual sites (Table 10) and averaged across sites (Fig. 3, Table 10). While some sites had considerable yield variation between foliar treatments at any given N level, the trends were inconsistent within and across sites and were not indicative of any meaningful responses to any of the foliar treatments. Across the five sites included in the combined analyses, we see that the yields for the different foliar treatments were quite similar for any given N rate (Fig. 3, Table 10) and, again, none of the overall F-tests associated with the foliar treatments were significant (Tables 6-7).

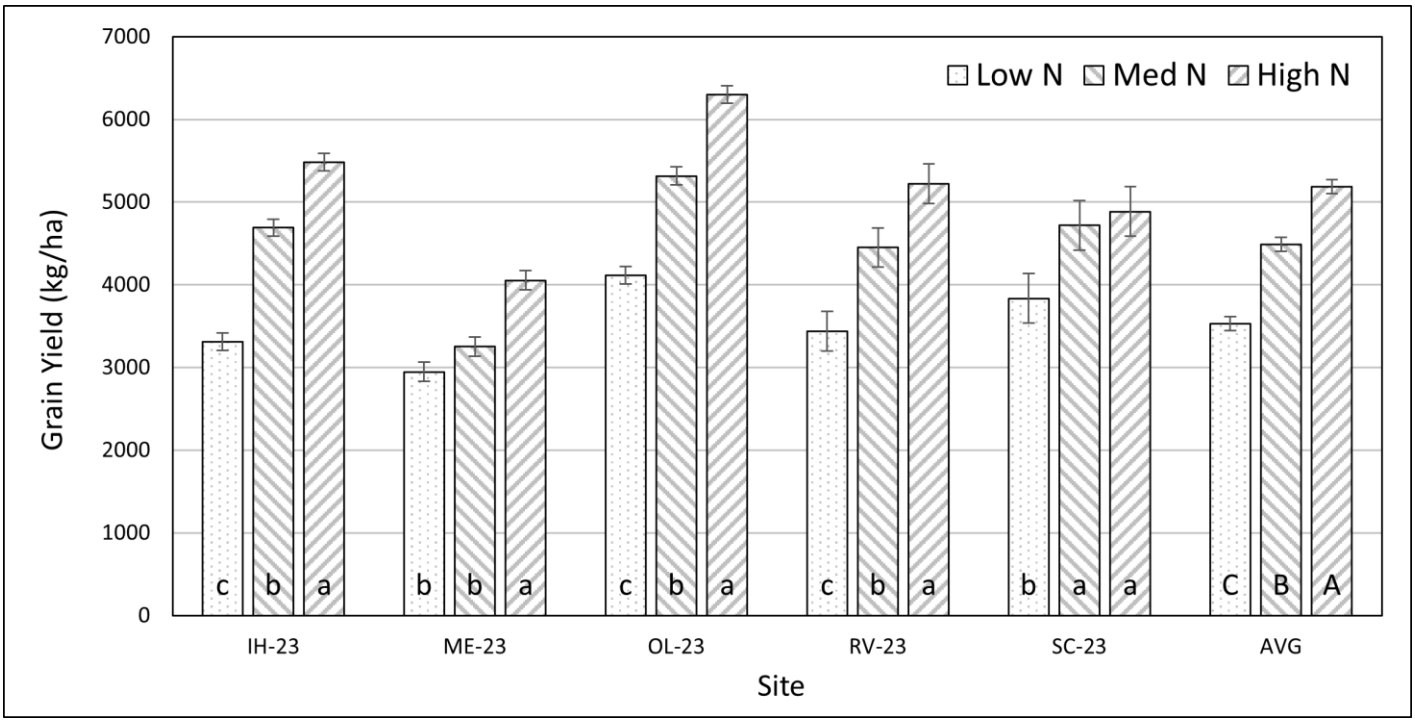

Figure 1. Nitrogen (N) fertility level effects on wheat grain yields for individual sites and averaged across sites. The N fertility levels were Low (50 kg N/ha), medium (100 kg N/ha), and high (150 kg N/ha), including residual soil N. The locations were Indian Head (IH-23), Melfort (ME-23), Outlook (OL-23), Redvers (RV-23), and Scott (SC), while AVG denotes the overall, 5-site average. Error bars are S.E.M. and values within a site denoted by the same letter do not significantly differ (Tukey's, $P \leq 0.05$).

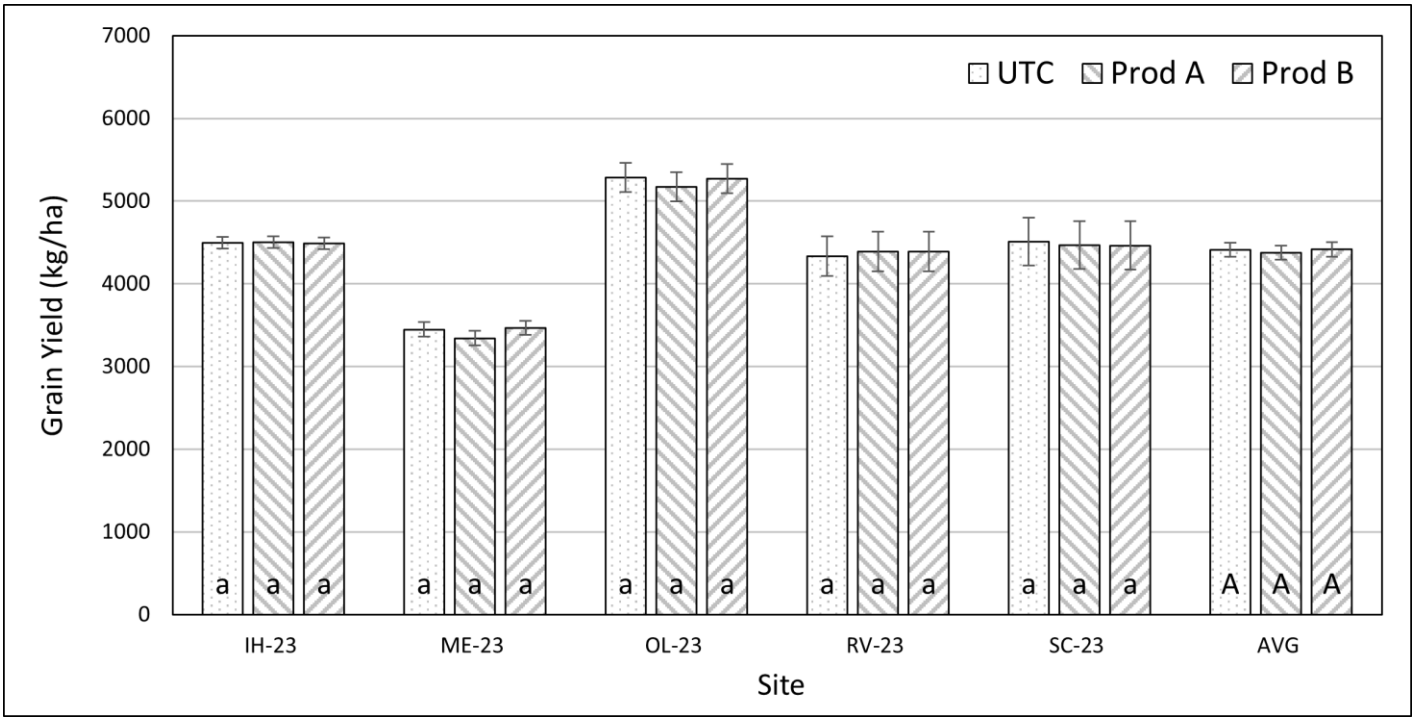

Figure 2. Foliar-applied nitrogen (N) fixing bacteria treatment effects on wheat grain yields for individual sites and averaged across sites. The foliar treatments were UTC (untreated check), Prod A (95 ml/ac Envita + 0.1% Agrol 90), and Prod B (135 g/ac Utrisha-N), applied at the 4-6 leaf stage. The locations were Indian Head (IH-23), Melfort (ME-23), Outlook (OL-23), Redvers (RV-23), and Scott (SC), while AVG denotes the overall, 5-site average. Error bars are S.E.M. and values within a site denoted by the same letter do not significantly differ (Tukey's, $P \leq 0.05$).

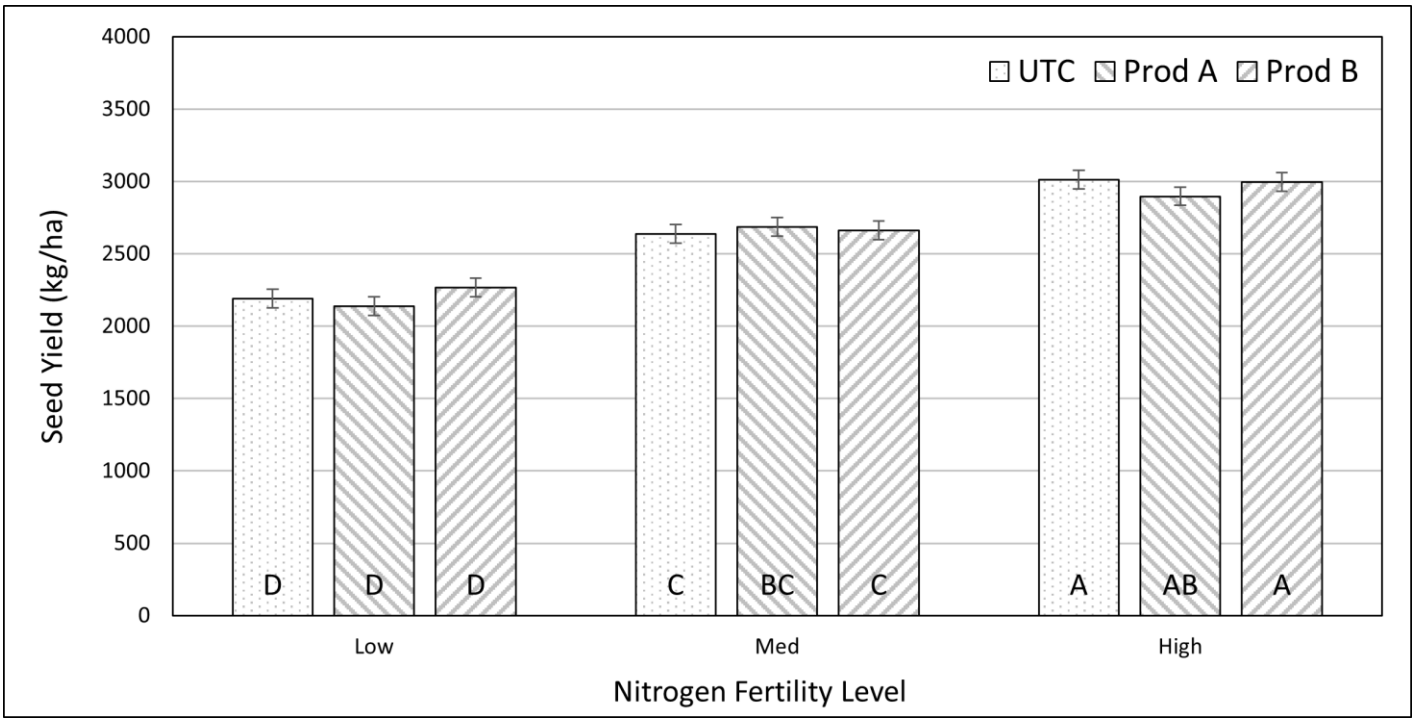

Figure 3. Nitrogen (N) fertility level by foliar-applied N fixing bacteria treatment effects on wheat grain yields, averaged across 5 sites. The N fertility levels were Low (50 kg N/ha), medium (100 kg N/ha), and high (150 kg N/ha), including residual soil N. The foliar treatments were UTC (untreated check), Prod A (95 ml/ac Envita + 0.1% Agrol 90), and Prod B (135 g/ac Utrisha-N), applied at the 4-6 leaf stage. Error bars are S.E.M. and values within a site denoted by the same letter do not significantly differ (Tukey's, $P \leq 0.05$).

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Moving on to protein, results from the overall tests of fixed effects in the combined analysis were similar to those reported for yield with significant site ($P < 0.001$), N level ($P < 0.001$), and S x N ($P < 0.001$) effects, but no effect of foliar treatment ($P = 0.256$), or S x F, S x N, or S x F x N interactions detected (Table 6; $P = 0.456$-0.901). For the sites excluded from the combined analyses, the N effect for protein was significant at Swift Current and Yorkton ($P < 0.001$) but not Prince Albert ($P = 0.264$) while neither the F nor N x F interactions were significant at any locations ($P = 0.088$-0.941).

Treatment means for the overall N fertilizer level effects on wheat protein are presented for individual sites and averaged across sites in Fig. 4 below and Table 11 of the Appendices. Across sites, grain protein increased significantly with each incremental addition of N fertilizer; however, the response was quadratic ($P < 0.001$) with a much larger increase going from 100 kg N/ha to 150 kg N/ha versus from 50 kg N/ha to 100 kg N/ha. This response was as expected since grain protein often begins to increase more rapidly at the point where yield increases with additional N inputs begin to diminish. The individual site responses were consistent with this pattern and the significant S x N interaction was due to subtle variation in whether there was a significant protein increase going from 50 kg N/ha to 100 kg N/ha. Again, grain protein also increased with N rate at Swift Current and Scott, but not at Prince Albert (Table 11).

Consistent with the lack of significant overall tests of fixed effects, protein concentrations were always quite similar for the different foliar treatments, regardless of whether we looked at sites individually or averaged across them (Fig. 5, Table 11). With respect to individual treatments, the values were quite similar for different foliar treatments at any given N rate when averaged across sites (Fig. 6; Table 13). While variability was quite high for some of the sites individually, there were never any trends that were sufficiently consistent to suggest that the foliar treatments were improving grain protein with any confidence Table 13).

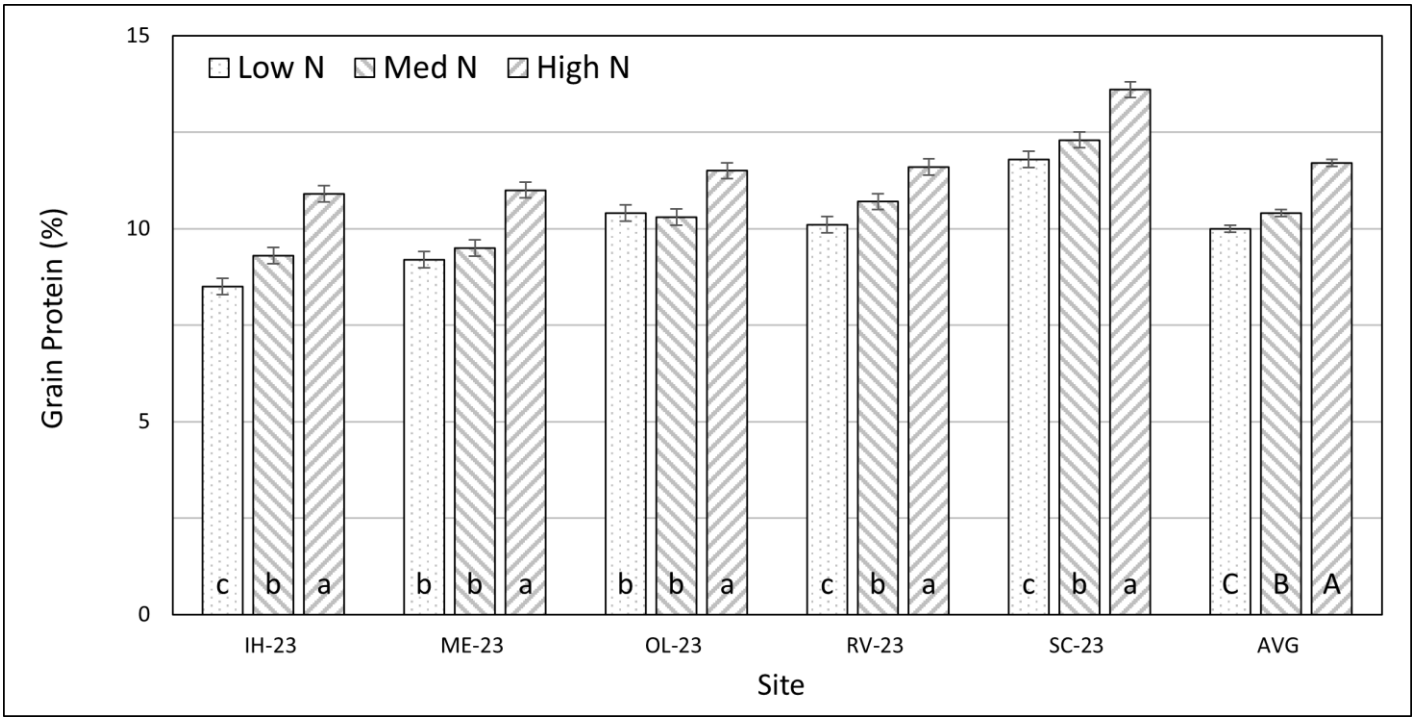

Figure 4. Nitrogen (N) fertility level effects on wheat grain protein concentrations for individual sites and averaged across sites. The N fertility levels were Low (50 kg N/ha), medium (100 kg N/ha), and high (150 kg N/ha), including residual soil N. The locations were Indian Head (IH-23), Melfort (ME-23), Outlook (OL-23), Redvers (RV-23), and Yorkton (YK), while AVG denotes the overall, 5-site average. Error bars are S.E.M. and values within a site denoted by the same letter do not significantly differ (Tukey's, $P \leq 0.05$).

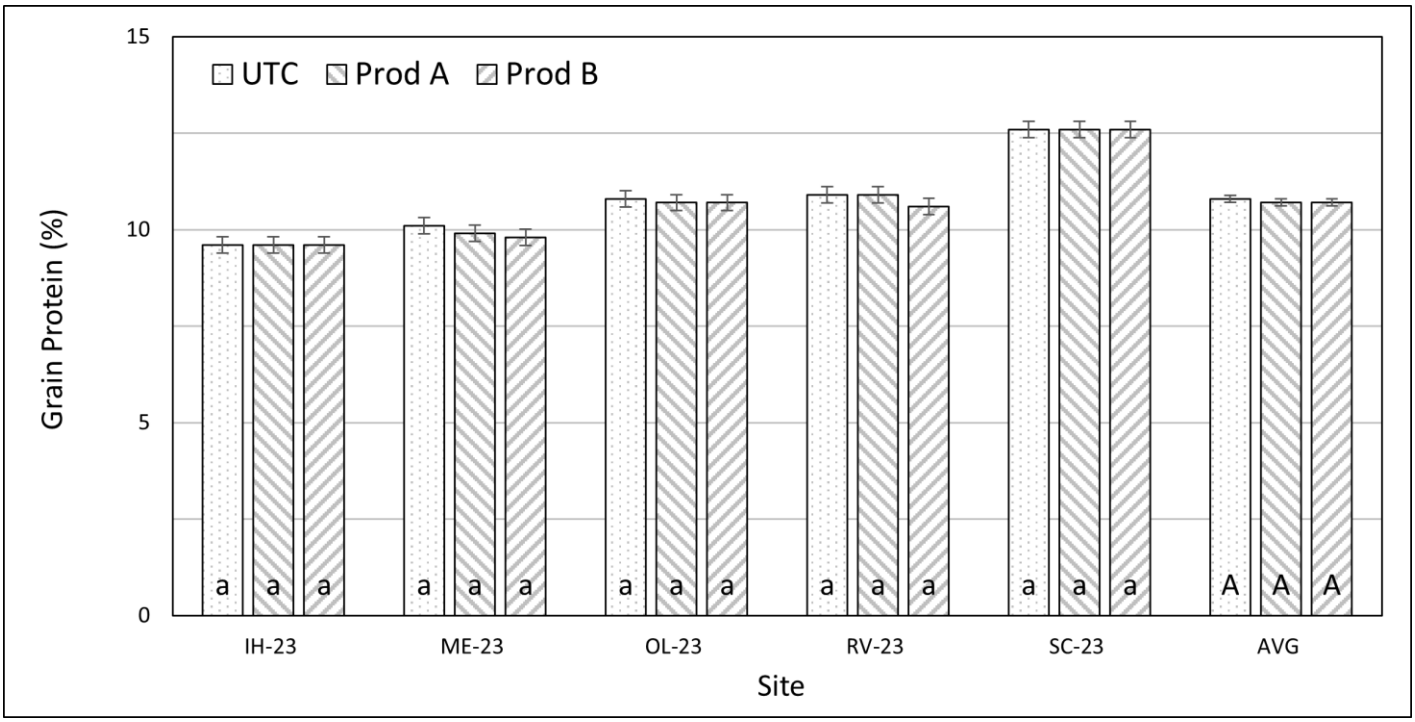

Figure 5. Foliar-applied nitrogen (N) fixing bacteria treatment effects on wheat grain protein concentrations for individual sites and averaged across sites. The foliar treatments were UTC (untreated check), Prod A (95 ml/ac Envita + 0.1% Agrol 90), and Prod B (135 g/ac Utrisha-N), applied at the 4-6 leaf stage. The locations were Indian Head (IH-23), Melfort (ME-23), Outlook (OL-23), Redvers (RV-23), and Scott (SC), while AVG denotes the overall, 5-site average. Error bars are S.E.M. and values within a site denoted by the same letter do not significantly differ (Tukey's, $P \leq 0.05$).

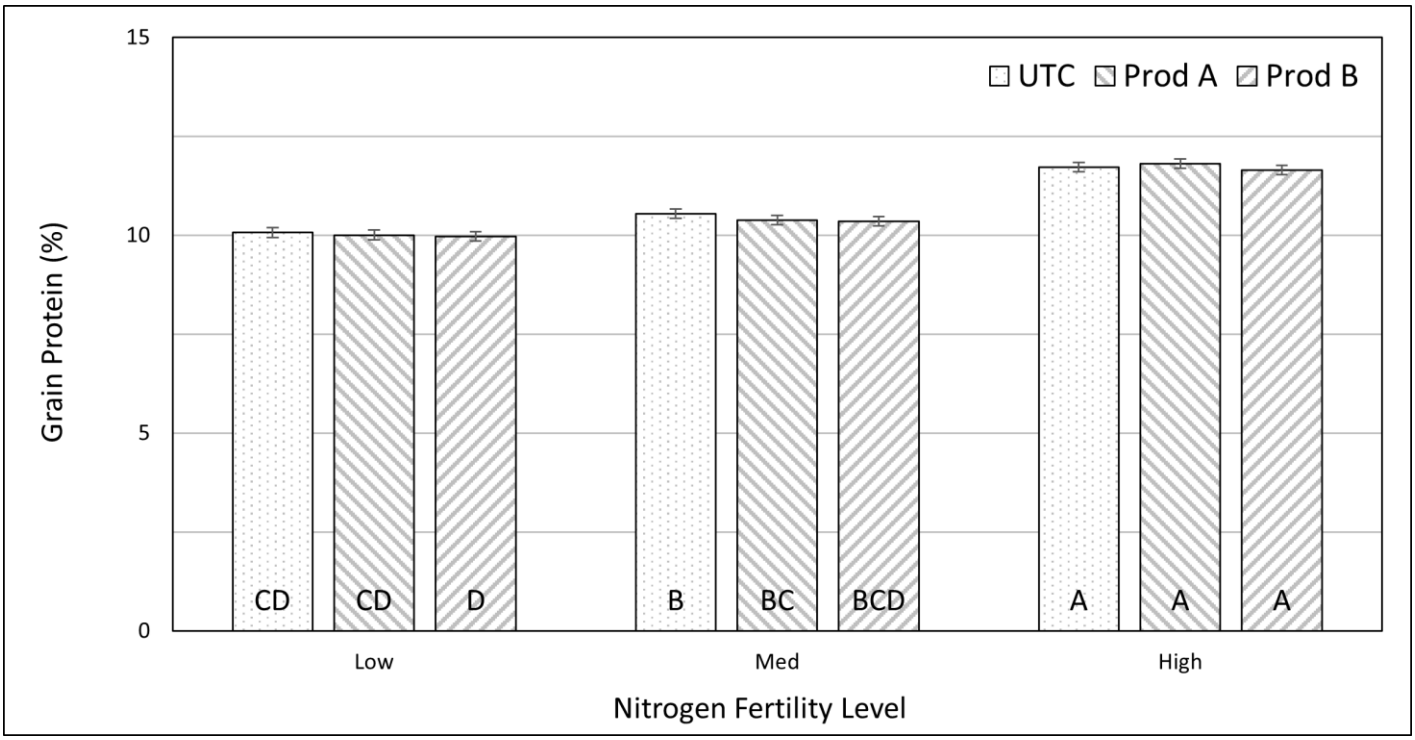

Figure 6. Nitrogen (N) fertility level by foliar-applied N fixing bacteria treatment effects on spring wheat grain protein concentrations, averaged across 5 sites. The N fertility levels were Low (50 kg N/ha), medium (100 kg N/ha), and high (150 kg N/ha), including residual soil N. The foliar treatments were UTC (untreated check), Prod A (95 ml/ac Envita + 0.1% Agrol 90), and Prod B (135 g/ac Utrisha-N), applied at the 4-6 leaf stage. Error bars are S.E.M. and values within a site denoted by the same letter do not significantly differ (Tukey's, $P \leq 0.05$).

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Extension Activities

At Indian Head, this project was highlighted by Chris Holzapfel during the 2023 Indian Head Crop Management Field Day, held on July 18 (160 participants). Kayla Slind showed the trials during the Scott Field Day on July 12 (120 participants) and Lana Shaw toured the Redvers trial during the SERF Field Day on July 27 (50 participants). Mike Hall acknowledged the trial during then ECRF farm tour on July 20 (80 participants) and the trial was signed and acknowledged during the during the NARF/AAFC Joint Annual Field Day on July 26, 2023 (70 participants) where Dale Leftwich (SCDC) discussed the project in detail at a complementary canola trial. Carmen Prang (SWDC) discussed the project during the ICDC field day held on July 13, 2023 and attended by more than 200 participants. Gursahib Singh presented results from Outlook during the 2023 Irrigation Saskatchewan Conference, held Dec. 5-7 in Saskatoon with approximately 300 participants. Chris Holzapfel presented results from the project at the IHARF Winter Meeting and AGM at Balgonie on February 7 (150 participants) and during the 2024 ICAN Conference on February 8 at Moose Jaw (40 participants). Jessica Enns will be presenting results at both the Crop Opportunities Meeting in North Battleford on March 7 and the Agri-ARM Research update on March 19. This final project report will also be available online at the IHARF website (www.iharf.ca) and the websites of several other Agri-ARM collaborators.

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.

With the exception of 1/8 sites which was excluded from the combined statistical analyses, we observed the expected increases in both seed yield and protein concentrations with the addition of N fertilizer in the form of the side-banded urea. We did not, however, observe any effects on these variables that could indicate improved N status or biological N_2 fixation associated with the foliar applications of the biological products demonstrated in this project. This was the case, regardless of the environmental conditions encountered (i.e., site) or overall N fertility level (i.e., N fertilizer rate). For some sites, individual treatment means were somewhat variable; however, there were no trends that were consistent enough to suggest positive responses to the biological treatments with any confidence. While we cannot rule out that positive responses might occur with either different crop types or under environmental conditions that were not met in the current project, we did our best to allow the foliar products to succeed. This included careful storage of the products, using distilled water as a carrier, ensuring adequate water volumes, attempting to apply the biological products during cooler conditions, and testing the them under N limiting conditions. These results are generally consistent with a similar project conducted with canola, field-scale trials funded by SaskWheat and SaskCanola, and complementary, ongoing research at the University of Saskatchewan. With all this in mind, we recommend that farmers avoid reducing their N fertilizer rates when using biological products intended to improve N nutrition in crop production and utilize untreated check strips (preferably replicated) to confirm whether or not they are realizing any benefits on their own farms.

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)	13

[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 # of Producers Participated In Knowledge Transfer	Link (if available)
C. Holzapfel (IHARF) Plot Tour	Crop Management Field Day, Indian Head (July 18, 2023)	160	https://iharf.ca/indian-head-crop-management-field-day/
K. Slind (WARC) Plot Tour	Scott Field Day, Scott (July 12, 2023)	120	https://www.westernapplied research.com/events/
L. Shaw (SERF) Plot Tour	SERF Field, Redvers (July 27)	50	https://southeastresearchfarm.org /resources-events/
B. McInnes (NARF) Plot Tour	NARF/AAFC Joint Annual Field Day, Melfort (July 26, 2023)	70	https://neag.ca/events/
M. Hall (ECRF) Plot Tour	ECRF Annual Field Day, Yorkton (July 20, 2023)	80	http://www.ecrf.ca/?page=tour
C. Prang (SWDC) Plot Tour	ICDC Annual Irrigation Field Day (July 13, 2023)	200	n/a
G. Singh (ICDC) Presentation	Irrigation Saskatchewan Conference, Saskatoon (December 5-7, 2023)	300	https://www.irrigationsaskatchewan .com /SIPA/event/irrigation-saskatchewan-2023-conference/
C. Holzapfel (IHARF) Presentation	2024 IHARF Soil and Crop Management Seminar & AGM, Balgonie (February 7, 2024)	150	https://iharf.ca/iharf-soil-and-crop-management-seminar-agm/
C. Holzapfel (IHARF) Presentation	2024 ICAN Conference, Moose Jaw (February 8, 2024)	40	https://www.icanhelpyourfarm.com/
R. Lokken (CLC) Presentation	Crop Talk 2024, Prince Albert (March 13, 2024)	TBD	https://conservationlearningcentre .com/events/

J. Enns (WARC) Presentation	Agri-ARM Research Update, March 19, 2024 (virtual)	TBD	https://attendee.gotowebinar.com /register/468816801821751389
J. Enns (WARC) Presentation	Crop Opportunity, North Battleford/Virtual (March 7, 2024)	TBD	https://www.westernappliedresearch .com/events/
Full Report – Available Online	IHARF Website (also on other Agri-ARM websites)	TBD	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, as federal-provincial-territorial initiative. The Saskatchewan Wheat Development Commission administered the project in-kind. Envita® was provided in-kind by Syngenta Canada and Utrisha™-N was provided by Corteva. We would also like to acknowledge the Board of Directors from each of the participating organizations in addition to the many technical and professional staff, without whom this project could not have been completed. IHARF, NARF, WARC, and WCA have strong working relationships and memorandums of understanding with Agriculture and Agri-Food Canada which should also be acknowledged.

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 the 2023 biological N fixation product trials with wheat at Indian Head (IH), Melfort (ME), Outlook (OL), Prince Albert (PA), Redvers (RV), Scott (SC), Swift Current (SW), and Yorkton, Saskatchewan.

Activity	IH-23	ME-23	OL-23	PA-23	RV-23	SC-23	SW-23	YK-23
Previous Crop	Canola	Canola	Canola	Canola	Barley	Canola	Wheat	Wheat
Pre-Emergent Herbicide	May-16 (glyphosate)	May-19 (glyphosate)	nil	May-26 (PrePass XC)	May-22 (glyphosate)	May-14 (glyphosate)	May-2 (glyphosate)	nil
Seeding Date	May-11	May-18	May-9	Jun-5	May-22	May-15	May-17	May-17
Row Spacing	31 cm	31 cm	25 cm	25 cm	25 cm	25 cm	21 cm	31 cm
Soil NO_3-N (0-60 cm)	16 kg/ha	41 kg/ha	24 kg/ha	72 kg/ha	29 kg/ha	21 kg/ha	19 kg/ha	55
kg N-P_2O_5-K_2O-S/ha [z]	28-40-20-20	18-56-17-11	7-35-0-0	4-17-0-0	5-22-16-0	24-22-11-22	37-57-0-28	7-34-0-0
Emergence Counts	May-31	Jun-6	Jun-5	Jun-19	May-31	Jun-13	May-29	Jun-2
In-crop Herbicide 1	Jun-8 (Octain XL)	Jun-7 (Prestige XL)	Jun-7 (Buctril M)	nil	Jun-21 (Buctril M)	Jun-2 (Infinity)	Jun-8 (Buctril M)	Jun-7 (Simplicity)
In-crop Herbicide 2	Jun-8 (Simplicity)	Jun-20 (Axial)	nil	nil	June-21 (clodinafop)	Jun-2 (Axial)	Jun-8 (Achieve)	Jun-12 (Axial)
In-crop Herbicide 3	nil	nil	nil	nil	n/a	Jun-13 (Buctril M)	nil	nil
Foliar Treatment Date	Jun-14	Jun-21	Jun-8	Jun-27	Jun-13	Jun-13	Jun-12	Jun-12
Fungicide Date	Jun-30 (ProsaroPRO)	Jul-7 (Caramba)	nil	nil	nil	Jul-13 (Caramba)	nil	Jul-5 (ProsaroXTR)
Pre-harvest Herbicide	Aug-12 (glyphosate)	nil	nil	nil	nil	Aug-17 (glyphosate + saflufenacil)	nil	nil
Harvest Date	Aug-18	Aug-29	Aug-26	Sep-13	Sep-8	Aug-28	Aug-18	Aug-28

[z] Fertility information only includes nutrients provided by phosphorus, potassium, and/or sulfur products applied (i.e., do not include soil residual nutrients or N provided by supplemental urea applied to achieve the target N levels)

Table 6. Tests of fixed effects for site, nitrogen level (N), foliar treatment (F), and all possible interactions for selected spring wheat response variables at five Saskatchewan locations in 2023. Data were analysed using the Generalized Linear Mixed Model procedure of SAS. P-values (Pr > F) less than 0.05 are considered significant while values below 0.1 may also be acknowledged.

Effect	Plant Density	Grain Yield	Grain Protein
	---------- Pr > F (p-value) ----------		
Site (S)	<0.001	<0.001	<0.001
Nitrogen (N)	0.006	<0.001	<0.001
S x N	0.556	<0.001	<0.001
Foliar (F)	–	0.793	0.256
S x F	–	0.995	0.901
N x F	–	0.637	0.740
S X N X F	–	0.966	0.456

Table 7. Tests of fixed effects for nitrogen level (N), foliar treatment (F), and the N x F for selected spring wheat response variables at Prince Albert (PA), Swift Current (SW), and Yorkton (YK), in 2023. Data were analysed for each site individually using the Generalized Linear Mixed Model procedure of SAS. P-values (Pr > F) less than 0.05 are considered significant while values below 0.1 may also be acknowledged.

Effect	**PA-23**	**SW-23**	**YK-23**
	---------- Plant Density ----------		
Nitrogen (N)	0.695	0.796	0.771
	---------- Seed Yield ----------		
Nitrogen (N)	0.555	0.012	0.004
Foliar (F)	0.320	0.831	0.990
N x F	0.672	0.649	0.126
	---------- Seed Protein Concentration ----------		
Nitrogen (N)	0.264	<0.001	<0.001
Foliar (F)	0.753	0.941	0.088
N x F	0.419	0.888	0.590

Table 8. Main effect means for plant density and multiple comparison test results for nitrogen (N) level in spring wheat at Indian Head (IH), Melfort (ME), Outlook (OL), Prince Albert (PA), Redvers (PA), Scott (SC), Swift Current (SW), Yorkton (YK), and averaged across sites in 2023. For each location, values within a column followed by the same letter do not significantly differ (Tukey-Kramer, $P \leq 0.05$).

Main Effect	IH-23 [Z]	ME-23 [Z]	OL-23 [Z]	PA-23 [Y]	RV-23 [Z]	SC-23 [Z]	SW-23 [Y]	YK-23 [Y]	AVG [Z]
Nitrogen [X]	Plant Density (plants/m^2)								
Low	311.4 a	241.8 a	211 a	183.7 a	274.0 b	305.7 a	184.9 a	272.7 a	268.7 B
Medium	331.9 a	243.1 a	232 a	195.7 a	284.4 ab	313.4 a	182.9 a	282.3 a	281.0 A
High	337.3 a	244.0 a	231 a	189.3 a	300.5 a	306.4 a	178.6 a	272.8 a	283.9 A
S.E.M.	10.80	10.80	10.80	9.85	10.80	10.80	7.67	12.2	4.83
	Pr > F (p-value)								
Pr > F	0.049	0.980	0.090	0.695	0.055	0.743	0.649	0.796	0.006
N Rate – lin	0.020	0.843	0.063	0.692	0.017	0.946	0.512	0.993	0.002
N Rate – quad	0.427	0.989	0.244	0.453	0.770	0.443	0.887	0.475	0.274

[Z] Data combined for analyses across sites with SITE (S), Nitrogen (N), and the S x N interaction as fixed effects

[Y] Data excluded from the combined analyses and analyzed individually with Nitrogen (N) as the sole fixed effect

[X] Nitrogen rates included fall soil residual (0-60 cm) and targeted 50, 100, and 150 kg total N/ha

Table 9. Main effect means and multiple comparison test results for nitrogen (N) level and foliar-applied biological for spring wheat grain yield at Indian Head (IH), Melfort (ME), Outlook (OL), Prince Albert (PA), Redvers (PA), Scott (SC), Swift Current (SW), Yorkton (YK), and averaged across sites in 2023. For each location, values within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Main Effect	IH-23 [Z]	ME-23 [Z]	OL-23 [Z]	PA-23 [Y]	RV-23 [Z]	SC-23 [Z]	SW-23 [Y]	YK-23 [Y]	AVG [Z]
Nitrogen [X]	Grain Yield (kg/ha)								
Low	3310 c	2947 b	4114 c	3698 a	3437 c	3835 b	1213 b	3880 b	3529 C
Medium	4691 b	3252 b	5316 b	3699 a	4450 b	4720 a	1413 a	4530 a	4486 B
High	5483 a	4055 a	6300 a	3841 a	5221 a	4886 a	1372 ab	4533 a	5189 A
S.E.M.	104.2	114.2	107.9	149.6	237.6	298.4	63.0	182.6	85.1
	Pr > F (p-value)								
Pr > F	<0.001	<0.001	<0.001	0.555	<0.001	<0.001	0.012	0.004	<0.001
N Rate – lin	<0.001	<0.001	<0.001	0.351	<0.001	<0.001	0.022	0.003	<0.001
N Rate – quad	0.023	0.053	0.392	0.589	0.353	0.006	0.043	0.072	0.028
Foliar [Y]	Seed Yield (kg/ha)								
UTC	4494 a	3447 a	5283 a	3803 a	4333 a	4508 a	1337 a	4302 a	4413 A
Envita	4503 a	3342 a	5174 a	3823 a	4388 a	4469 a	1311 a	4330 a	4375 A
Utrisha-N	4487 a	3466 a	5273 a	3613 a	4387 a	4464 a	1350 a	4311 a	4415 A
S.E.M.	70.5	87.5	176.9	149.6	239.5	290.2	63.0	182.6	85.1
	Pr > F (p-value)								
Pr > F	0.994	0.662	0.716	0.320	0.916	0.947	0.831	0.990	0.793

[Z] Data combined for analyses across sites with SITE (S), Nitrogen (N), and the S x N interaction as fixed effects

[Y] Data excluded from the combined analyses and analyzed individually with Nitrogen (N) as the sole fixed effect

[X] Nitrogen rates included fall soil residual (0-60 cm) and targeted 50, 100, and 150 kg total N/ha

Table 10. Individual nitrogen (N) level x foliar-applied biological treatment means for spring wheat grain yield and multiple comparison test results at Indian Head (IH), Melfort (ME), Outlook (OL), Prince Albert (PA), Redvers (PA), Scott (SC), Swift Current (SW), Yorkton (YK), and averaged across sites in 2023. For each location, values within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Main Effect	IH-23 [Z]	ME-23 [Z]	OL-23 [Z]	PA-23 [Y]	RV-23 [Z]	SC-23 [Z]	SW-23 [Y]	YK-23 [Y]	AVG [Z]
N x Foliar	Grain Yield (kg/ha)								
Low – UTC	3288 d	2906 c	4069 d	3896 a	3448 e	3860 b	1196 a	4319 a	3514 C
Low – Envita	3367 d	2912 c	4161 d	3764 a	3386 e	3828 b	1211 a	3625 a	3531 C
Low – Utrisha	3277 d	3023 c	4111 d	3435 a	3479 de	3817 b	1231 a	3696 a	3542 C
Med – UTC	4640 c	3252 bc	5439 bc	3749 a	4258 cd	4751 a	1406 a	4341 a	4468 B
Med – Envita	4687 bc	3252 bc	4988 c	3694 a	4488 bc	4685 a	1335 a	4644 a	4420 B
Med – Utrisha	4748 bc	3252 bc	5523 bc	3654 a	4603 abc	4725 a	1499 a	4603 a	4570 B
High – UTC	5554 a	4182 a	6342 a	3763 a	5294 a	4914 a	1410 a	4246 a	5257 A
High – Envita	5457 ab	3861 ab	6373 a	4010 a	5292 ab	4895 a	1386 a	4720 a	5175 A
High - Utrisha	5437 abc	4123 a	6184 ab	3750 a	5078 abc	4850 a	1320 a	4633 a	5134 A
S.E.M.	180.5	186.4	182.7	211.7	278.8	332.8	90.6	269.3	107.5
	Pr > F (p-value)								
Pr > F	<0.001	<0.001	<0.001	0.672	<0.001	<0.001	0.649	0.126	0.637

[Z] Data combined for analyses across sites with SITE (S), Nitrogen (N), and the S x N interaction as fixed effects

[Y] Data excluded from the combined analyses and analyzed individually with Nitrogen (N) as the sole fixed effect

[X] Nitrogen rates included fall soil residual (0-60 cm) and targeted 50, 100, and 150 kg total N/ha

Table 11. Table 12. Main effect means and multiple comparison test results for nitrogen (N) level and foliar-applied biological for spring wheat protein concentrations at Indian Head (IH), Melfort (ME), Outlook (OL), Prince Albert (PA), Redvers (PA), Scott (SC), Swift Current (SW), Yorkton (YK), and averaged across sites in 2023. For each location, values within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Main Effect	IH-23 [Z]	ME-23 [Z]	OL-23 [Z]	PA-23 [Y]	RV-23 [Z]	SC-23 [Z]	SW-23 [Y]	YK-23 [Y]	AVG [Z]
Nitrogen [X]	Grain Protein (%)								
Low	8.5 c	9.2 b	10.4 b	14.4 a	10.1 c	11.8 c	15.9 b	11.2 c	10.0 C
Medium	9.3 b	9.5 b	10.3 b	14.8 a	10.7 b	12.3 b	18.1 a	12.5 b	10.4 B
High	10.9 a	11.0 a	11.5 a	14.9 a	11.6 a	13.6 a	19.0 a	13.4 a	11.7 A
S.E.M.	0.21	0.21	0.21	0.36	0.21	0.21	0.26	0.20	0.09
	Pr > F (p-value)								
Pr > F	<0.001	<0.001	<0.001	0.264	<0.001	<0.001	<0.001	<0.001	<0.001
N Rate – lin	<0.001	<0.001	<0.001	0.121	<0.001	<0.001	<0.001	<0.001	<0.001
N Rate – quad	0.005	<0.001	<0.001	0.633	0.379	0.004	0.046	0.307	<0.001
Foliar [Y]	Grain Protein (%)								
UTC	9.6 a	10.1 a	10.8 a	14.8 a	10.9 a	12.6 a	17.7 a	12.3 a	10.8 A
Envita	9.6 a	9.9 a	10.7 a	14.8 a	10.9 a	12.6 a	17.7 a	12.6 a	10.7 A
Utrisha-N	9.6 a	9.8 a	10.7 a	14.5 a	10.6 a	12.6 a	17.6 a	12.2 a	10.7 A
S.E.M.	0.21	0.21	0.21	0.36	0.21	0.21	0.26	0.20	0.09
	Pr > F (p-value)								
Pr > F	0.934	0.433	0.900	0.753	0.147	0.936	0.941	0.088	0.256

[Z] Data combined for analyses across sites with SITE (S), Nitrogen (N), and the S x N interaction as fixed effects

[Y] Data excluded from the combined analyses and analyzed individually with Nitrogen (N) as the sole fixed effect

[X] Nitrogen rates included fall soil residual (0-60 cm) and targeted 50, 100, and 150 kg total N/ha

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Table 13. Individual nitrogen (N) level x foliar-applied biological treatment means for spring wheat grain protein concentrations and multiple comparison test results at Indian Head (IH), Melfort (ME), Outlook (OL), Prince Albert (PA), Redvers (PA), Scott (SC), Swift Current (SW), Yorkton (YK), and averaged across sites in 2023. For each location, values within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Main Effect	IH-23 [Z]	ME-23 [Z]	OL-23 [Z]	PA-23 [Y]	RV-23 [Z]	SC-23 [Z]	SW-23 [Y]	YK-23 [Y]	AVG [Z]
N x Foliar	---------- Grain Protein (%) ----------								
Low – UTC	8.5 b	9.3 b	10.5 bcd	14.3 a	10.3 cd	11.8 c	16.1 bcd	11.0 cd	10.1 CD
Low – Envita	8.6 b	9.2 b	10.4 cd	14.1 a	10.0 e	12.0 c	15.6 d	11.6 bcd	10.0 CD
Low – Utrisha	8.5 b	9.3 b	10.5 bcd	14.7 a	9.9 e	11.8 c	15.9 cd	10.9 d	10.0 D
Med – UTC	9.3 b	9.8 b	10.6 bcd	14.8 a	10.9 bcd	12.2 c	18.1 ab	12.6 ab	10.5 B
Med – Envita	9.3 b	9.4 b	10.0 d	14.9 a	10.8 b-e	12.4 bc	18.4 a	12.7 ab	10.4 BC
Med – Utrisha	9.3 b	9.4 b	10.3 d	14.8 a	10.4 cde	12.3 c	17.9 abc	12.1 bc	10.3 BCD
High – UTC	10.9 a	11.1 a	11.2 abc	15.3 a	11.5 ab	13.8 a	19.0 a	13.3 a	11.7 A
High – Envita	11.0 a	11.1 a	11.8 a	15.3 a	11.9 a	13.3 ab	19.1 a	13.5 a	11.8 A
High - Utrisha	10.9 a	10.9 a	11.3 ab	14.2 a	11.4 abc	13.8 a	19.0 a	13.4 a	11.6 A
S.E.M.	0.14	0.21	0.24	0.51	0.34	0.35	0.45	0.28	0.12
	---------- Pr > F (p-value) ----------								
Pr > F	<0.001	<0.001	<0.001	0.419	<0.001	<0.001	0.888	0.590	0.740

[Z] Data combined for analyses across sites with SITE (S), Nitrogen (N), and the S x N interaction as fixed effects

[Y] Data excluded from the combined analyses and analyzed individually with Nitrogen (N) as the sole fixed effect

[X] Nitrogen rates included fall soil residual (0-60 cm) and targeted 50, 100, and 150 kg total N/ha

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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.