2020 Annual Report

for the

Saskatchewan Ministry of Agriculture's

Agricultural Demonstration of Practices & Technologies (ADOPT) Program

and Fertilizer Canada

Project Title: Crop Response to Shallow versus Deep Banded Nitrogen Relative to Benchmark Practices

(Project #20190372)

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Project Identification

1. **Project Title:** Crop response to shallow- versus deep-banded nitrogen fertilizer formulations relative to other benchmark practices
2. **Project Number:** 20190372
3. **Producer Group Sponsoring the Project:** Indian Head Agricultural Research Foundation
4. **Project Location(s):** Indian Head, Saskatchewan, R.M. #156
5. **Project start and end dates(s):** September-2019 to February-2021
6. **Project contact person & contact details:**

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Objectives and Rationale

7. **Project Objectives:**

Developing Best Management Practices (BMPs) for applications of nutrients such as nitrogen (N) has long been focussed on the 4R principles which refer to using the: 1) right source, 2) right rate, 3) right time and 4) right placement. In addition to agronomic performance and fertilizer use efficiency, farmers must also consider logistic and economic factors when to deciding how to best manage N. The objectives of this project were:

1) To demonstrate the potential benefits, under field conditions, of banding urea at depths of at least 5 cm relative to the shallower banding depths commonly achieved when side-banding is combined with shallow seeding depths and other benchmark practices.

2) To demonstrate the potential benefits, under field conditions, of utilizing a commercially available volatilization/nitrification inhibitor to mitigate the risk of N losses for contrasting placement/timing options.

8. **Project Rationale:**

Nearly forty years ago, John Harapiak and his colleagues initiated a major shift in how N fertilizer was managed in western Canada. They achieved this by proving and communicating the benefits of applying fertilizer beneath the soil surface in concentrated bands prior to seeding. Work from this era also found that banding depths of 7.5-10 cm (3-4”) were ideal when both machinery capabilities and agronomic performance were considered. At this time, fertilization and seeding were primarily completed in two separate operations; however, seeding equipment rapidly evolved and single pass seeding/fertilization systems became the preferred and most recommended system. Two of the most important considerations of 4R N management are ‘right time’ and ‘right place’ – banding the N fertilizer beneath the soil surface at precisely same time as the crop is seeded was and still is seen by many as an ideal perfect fit with our short, frequently dry Western Canadian growing seasons.

Since this early work was completed, however, crop rotations have changed, farm sizes and fertilizer rates have increased, equipment capabilities/configurations are diverse, and there is growing concern that our side- or mid-row banded urea may not always be as safe or efficient as previously assumed. Furthermore, with large farms and narrow seeding windows, there has been some shift back to two-pass seeding-fertilization systems, including surface broadcast applications, as a means of reducing logistic pressure during seeding. Enhanced efficiency fertilizer products (such as Agrotain® or SUPERU®) are viable options for offsetting the increased potential for N losses due to sub-optimal placement (i.e., shallow-banding, surface broadcast) or timing (fall) options. This project was initiated to demonstrate the relative crop responses to N fertilizer under contrasting management along with the potential benefits of using N treated with volatilization and nitrification inhibitors. The comparison between shallow and deep banding will provide insights applicable to both two-pass and single-pass seeding-fertilizer systems. The intent of applying the fertilizer in the fall was to ensure sufficient time for losses to occur between fertilization and peak crop uptake.

Although the results from this project apply to all crops that require N fertilizer, CWRS wheat is an ideal test crop. Hard red spring wheat is responsive to high rates of N, widely adapted, and economically important in Saskatchewan and western Canada as a whole. Importantly, high protein is required for top grades and is also an excellent indicator of overall N availability, generally more responsive to N than yield.

Methodology and Results

9. Methodology:

A field trial with CWRS wheat was initiated with the first N treatments applied in the fall of 2019 followed by subsequent applications and seeding in the early spring of 2020. The treatments were a combination of six N fertilizer rate/placement/timing strategies and two formulations, plus a control where no supplemental N was applied. The timing/placement options were side banding, fall surface broadcast, spring surface broadcast, and fall deep versus shallow banding. A high N side-band treatment was also included. The two formulations were untreated urea and an enhanced efficiency option, SUPERU®. Specifically, SUPERU® is urea treated with 0.85% dicyandiamide (DCD; nitrification inhibitor) and 0.06% N-(n-butyl) thiophosphoric triamide (NBPT; urease inhibitor). For the control treatment, the only N fertilizer applied was 7 kg N/ha from seed-placed monoammonium phosphate (11-52-0). The N fertilizer rates in all but the control were adjusted for residual soil NO_3-N and the 1x rate was purposely somewhat lower than what was expected to be optimal. The purpose of the lower rate is to improve our ability to detect treatment differences. The treatments were arranged in a four replicate RCBD and are described in greater detail in Table 1.

Table 1. Nitrogen management treatments evaluated for CWRS wheat at Indian Head in 2020.

#	N Form	Treatment Name	Depth	Total N Rate [Z]
1	n/a	control	n/a	7 kg N/ha [Y] + residual
2	Untreated urea	high N side-band	≈3.5 cm (1.5”)	1.5x – 165 kg N/ha
3	Untreated urea	side-band	≈3.5 cm (1.5”)	1.0x – 110 kg N/ha
4	Untreated urea	fall surface broadcast	0 cm (0”)	1.0x – 110 kg N/ha
5	Untreated urea	spring surface broadcast	0 cm (0”)	1.0x – 110 kg N/ha
6	Untreated urea	fall deep band	≈5.6 cm (2.3”)	1.0x – 110 kg N/ha
7	Untreated urea	fall shallow band	≈2.5 cm (1”)	1.0x – 110 kg N/ha
8	SUPERU®	high N side-band	≈3.5 cm (1.5”)	1.5x – 165 kg N/ha
9	SUPERU®	side-band	≈3.5 cm (1.5”)	1.0x – 110 kg N/ha
10	SUPERU®	fall surface broadcast	0 cm (0”)	1.0x – 110 kg N/ha
11	SUPERU®	spring surface broadcast	0 cm (0”)	1.0x – 110 kg N/ha
12	SUPERU®	fall deep band	≈5.6 cm (2.3”)	1.0x – 110 kg N/ha
13	SUPERU®	fall shallow band	≈2.5 cm (1”)	1.0x – 110 kg N/ha

[Z] Includes residual NO_3-N (0-60 cm) estimated from fall composite soil samples

[Y] Provided by seed-placed 11-52-0 for all treatments

The fall fertilizer banding treatments and seeding/side-banding were completed using an eight-opener SeedMaster plot drill where the side-banded fertilizer placement is approximately 1. 5” (3.7 cm) beside and 0.75” (1.8 cm) below the seed-row. With a target seed depth of 0.75” (1.8 cm), the side-banded fertilizer depth is approximately 1.5” (3.8 cm). Depth of the fall banded treatments were varied as per protocol by either setting the drill to its shallowest marked setting (≈2.5 cm side-band depth) or the deepest possible (≈5.6 cm side-band depth). Broadcast N treatments were applied using handheld spreaders and pre-weighed quantities of fertilizer. The fall fertilizer treatments were applied on October 7 (2019), while the spring broadcast treatments were applied on May 10 and seeding/side-banding was completed May 11 (Table 2). Nutrients other than N were intended to be non-limiting. The variety was CDC Alida VB and the target seeding rate was 325 seeds/m^2. Weeds were controlled using registered pre-harvest and in-crop herbicides, fungicides were applied preventatively at approximately 50% anthesis, and no insecticides were required. The centre five rows of each plot were straight combined on August 26.

Various data were collected during the growing season and from the harvested grain. A Trimble® GreenSeeker® was used to determine the average normalized difference vegetation index (NDVI) of each plot at the flag-leaf stage. NDVI is a measure of above-ground vegetation and canopy density. A Minolta Chlorophyll SPAD Meter SPAD-502 was used at the milk stage to measure the chlorophyll content of 8-10 flag-leaves per plot. Chlorophyll content is an indicator of plant condition and overall N status. Grain yields were determined from the harvested plot areas, are adjusted for dockage, and to 14.5% seed moisture content. Grain protein was determined using a FOSS NIR instrument.

Table 2. Selected agronomic information and dates of operations for spring wheat 4R nitrogen demonstration at Indian Head in 2020.

Factor / Field Operation	2019-20
Previous Crop	Canola
Fall N applications	Oct-7-2019
Spring N applications	May-10-2020
Pre-emergent herbicide	894 g glyphosate/ha May-14-2020
Seeding Date	May-11-2020
Seed Rate	325 seeds/m^2 (138 kg/ha)
kg P_2O_5-K_2O-S ha^{-1}	35-0-0
NDVI	Jul-3-2020 (flag leaf)
SPAD	Jul-21-2020 (milk stage)
In-crop Herbicide	100 g fluroxypyr/ha + 400 g 2,4-D LV ester/ha + 15 g pyroxsulam/ha (Jun-15-2020)
Foliar Fungicide	100 g prothioconazole/ha + 100 g tebuconazole/ha Jul-10-2020
Pre-harvest herbicide	894 g glyphosate/ha Aug-19-2020
Harvest date	Aug-26-2020

Response data were analyzed using the Mixed procedure of SAS with treatment effects considered fixed and replicate effects treated as random. Predetermined contrasts were used to compare the two fertilizer forms, alternative timing/placement options to side-banding, and shallow banding to deep banding. Treatment effects and differences between means were considered significant at $P \leq 0.05$ and Fisher's protected LSD test was used to separate individual treatment means.

10. Results:

Growing season weather and residual soil nutrients

Mean temperatures and total precipitation amounts for May-August of 2020 at Indian Head are presented in Table 3 along with information from the previous October to coincide with the fall N applications. October of 2019 was cooler than average which would have slowed urea hydrolysis and nitrification; thus, reducing potential for fall/early spring N losses to some extent. However, the fall weather was also dry with less 6 mm of total precipitation over the two-week period following the fall N applications and just over 10 mm for the entire month of October (2019). Similarly, the period following the spring applications was also dry with less than 6 mm of precipitation over the two-weeks following the N applications and only 6 mm for the entire month of May (2020). The crop was seeded into enough soil moisture for reasonably uniform germination, but the weather stayed dry the entire season with only 46% of the long-term average precipitation from May through August. Temperatures over this period were approximately average. Overall, the weather was such that there was little risk of denitrification or leaching but modest potential for volatilization with surface applications. Timely precipitation in July and August resulted in reasonably high yield potential and a strong response to N fertilization.

Table 3. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2020 growing seasons at Indian Head, SK. The growing season was May through August and data for the previous October was also reported.

Year	Prev. Oct	May	June	July	August	May-Aug
	-- Mean Temperature (°C) --					
2020	1.0	10.7	15.6	18.4	17.9	15.7 (101%)
LT	4.0	10.8	15.8	18.2	17.4	15.6
	-- Total Precipitation (mm) --					
2020	10.9	27.3	23.5	37.7	24.9	113 (46%)
LT	24.9	51.8	77.4	63.8	51.2	244

Soil test results were based on a composite sample collected in the fall and used to adjust the target N rates and provide basic soil information for the site. The soil was classified as an Indian Head heavy clay, the surface (0-15 cm) pH was 7.9, organic matter was 4.6%, and residual NO_3-N was 9 kg N/ha (0-60 cm). Residual phosphorus was very low while residual sulfur was moderately high. This combination of low residual N and reasonably high yield potential was ideal for evaluating the relative efficacy of contrasting N management strategies.

Table 4. Soil test results for 4R nitrogen management demonstrations at Indian Head, 2020.

Attribute / Nutrient	0-15 cm	15-60 cm	0-60 cm
pH	7.9	8.2	–
S.O.M. (%)	4.6		–
NO_3-N (kg/ha)^Z	6	3	9
Olsen-P (ppm)	2	–	–
K (ppm)	516	–	–
S (kg/ha)	11	27	38

Crop Responses to Nitrogen Management Treatments

Overall F-test results and individual treatment means are presented in the Appendices (Table A-1) while these means are illustrated graphically along with results of the contrast comparisons in the main report.

The mean NDVI at the flag-leaf stage are shown in Fig. 1. With a mean of 0.53, NDVI of the control treatment was significantly lower than all other treatments (0.58-0.74); thus, indicating an overall increase in growth with N fertilizer application. The effects of timing/placement were consistent for both forms. While differences between individual treatments were not always significant, there were several trends. Differences in NDVI between the 1x and 1.5x rates (both side-banded) were not significant for individual treatments but values for the high N treatments tended to be amongst the highest. NDVI with spring broadcast N was substantially lower than for all other fertilization strategies, indicating that this N was less available early in the season relative to the fall and/or in-soil applications. Although the differences were not always significant, NDVI for the fall in-soil banded N tended to be higher than with the other options, including side-banding. These observations were verified with the contrast comparisons (Table 5) which showed higher NDVI at the 1.5x rate compared to the 1x rate with side-banding (averaged across forms) but no difference between forms (*P* = 0.188). When averaged across forms, the observed NDVI with side-banding was similar to fall broadcast N (*P* = 0.426), higher than spring broadcasting (*P* < 0.001), and slightly but significantly lower than with fall in-soil banding, regardless of the depth (*P* = 0.018-0.052). With fall banding, NDVI was similar regardless of depth when averaged across the two formulations (*P* = 0.645); however, particularly with urea, NDVI was higher. Whether this is a repeatable result is uncertain, but it could be that the deep banded, untreated urea was sufficiently protected against losses but also more mobile/available early in the season under the extremely dry conditions due to a greater proportion of the untreated urea N being in the nitrate form.

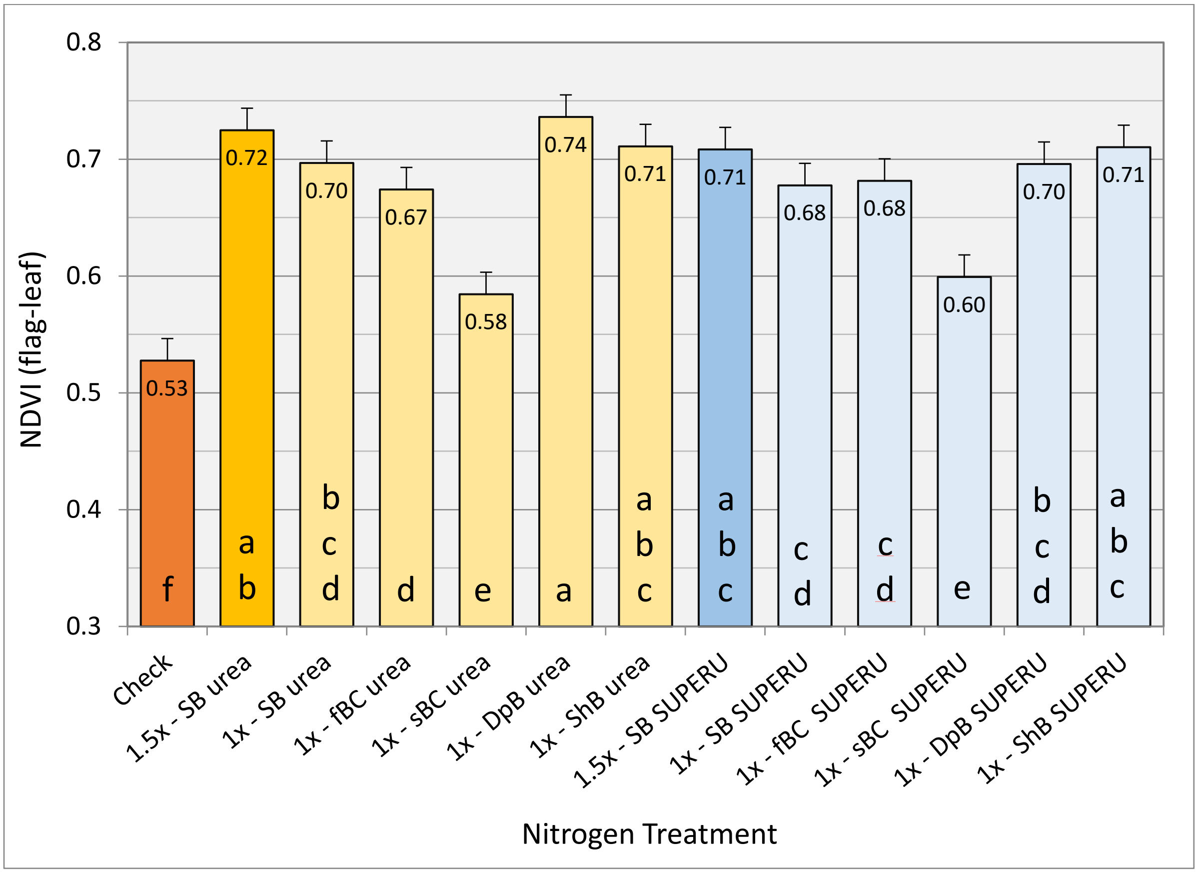

Figure 1. Individual nitrogen treatment means for spring wheat normalized difference vegetation index (NDVI) at Indian Head in 2020. Measurements were completed at the flag leaf stage using a handheld Trimble® GreenSeeker® sensor. Error bars are the standard error of the treatment means. The 1x rate is 110 kg N/ha (soil + fertilizer) and the 1.5x rate is 165 kg N/ha. SB is side-band, fBC is fall broadcast, sBC is spring broadcast, DpB is fall Deep Band, ShB is fall Shallow Band.

Table 5. Predetermined contrast comparisons for spring wheat normalized difference vegetation index (NDVI) at the flag leaf stage. P-values less than or equal to 0.05 indicate that the group means being compared did not significantly differ.

Contrast Comparison	Group A	Group B	Pr > F
	------------ NDVI (0-1)	------------	--- p-value ---
1.5x N rate (2,8) vs. 1x N rate (3,9)	0.717 A	0.687 B	0.016
Urea (2-7) vs. SUPERU (8-13)	0.688 A	0.679 A	0.188
Side-band (3,9) vs. fall Broadcast (4,10)	0.687 A	0.678 A	0.426
Side-band (3,9) vs. spring Broadcast (5-11)	0.687 A	0.592 B	<0.001
Side-band (3,9) vs. fall Deep Band (6,12)	0.687 B	0.716 A	0.018
Side-band (3,9) vs. fall Shallow Band (7,13)	0.687 B	0.711 A	0.052
Fall Deep Band (6,12) vs Fall Shallow Band (7,13)	0.716 A	0.711 A	0.645

Again, leaf chlorophyll content was measured at the milk stage, prior to senescence, by measuring 8-10 flag leaves per plot using a Minolta SPAD-502 SPAD meter. This occurred 18 days after the flag-leaf NDVI measurements. Like NDVI, SPAD values were significantly higher for all the fertilized treatments relative to the control (Fig. 2); thus, indicating an overall positive response to N. Additionally, the overall patterns were similar regardless of form and differences between N forms were never significant for any given timing/placement option. As expected, SPAD values were generally highest at the 1.5x N rate. Values for treatments that received the 1x rate tended to be highest with side-banding; however, significant differences were relatively rare. The contrast comparisons indicated no significant difference in SPAD values between the 1.5x and 1x rates (side-band placement) despite the former being numerically higher (*P* = 0.155) and nearly identical values between untreated urea and SUPERU® (*P* = 0.975; Table 6). Across forms, SPAD values with side-banding were higher than for both fall and spring broadcast N (*P* = 0.006-0.009) and fall-shallow banded N (*P* = 0.046). At 49.3 versus 47.8, SPAD values with side-banding were numerically but not significantly higher than fall-deep banding (*P* = 0.098) while values for deep versus shallow banded N did not significantly differ (*P* = 0.713).

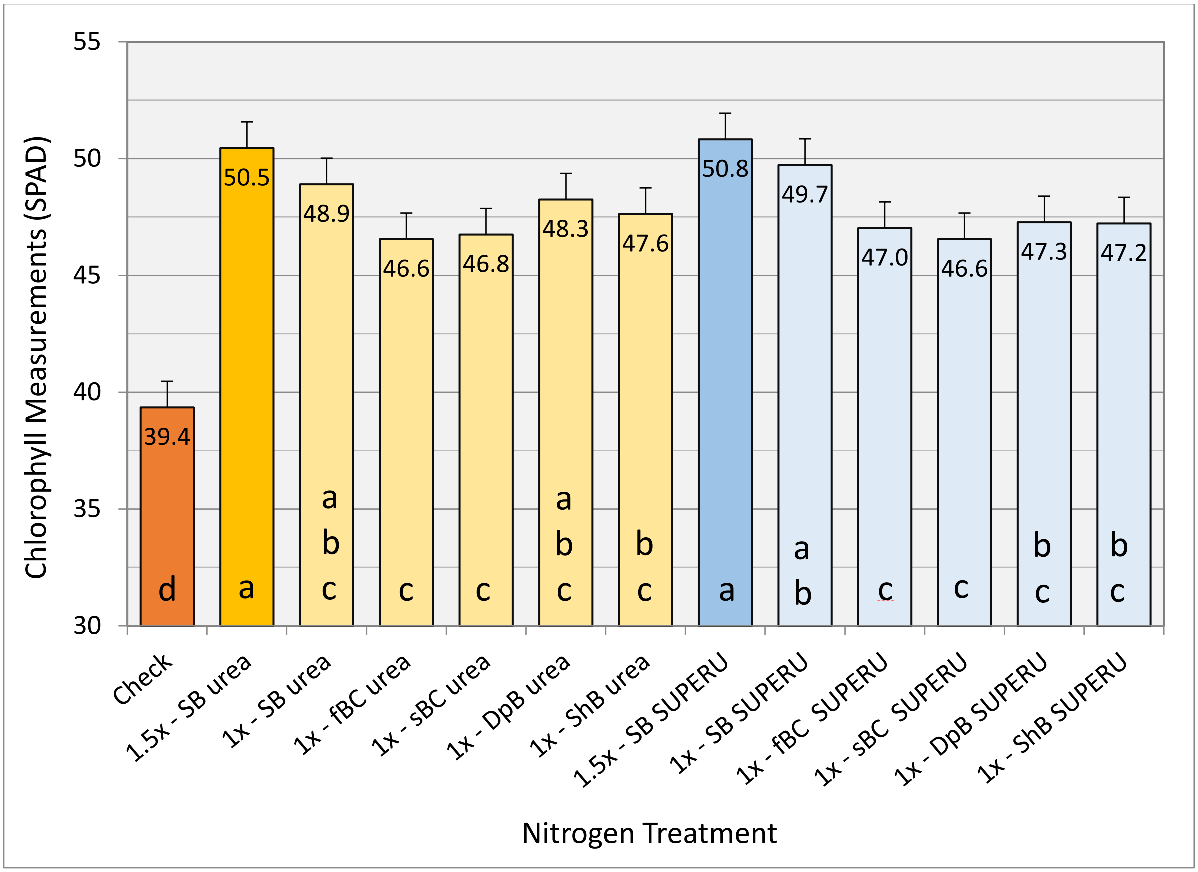

Figure 2. Individual nitrogen treatment means for spring wheat chlorophyll measurements (SPAD meter) at Indian Head in 2020. Measurements were completed at the milk stage and comprised of 8-10 flag leaves per plot. Error bars are the standard error of the treatment means. The 1x rate is 110 kg N/ha (soil + fertilizer) and the 1.5x rate is 165 kg N/ha. SB is side-band, fBC is fall broadcast, sBC is spring broadcast, DpB is fall Deep Band, ShB is fall Shallow Band.

Table 6. Predetermined contrast comparisons for spring wheat chlorophyll (SPAD) measurements (milk stage) at Indian Head in 2020. P-values less than or equal to 0.05 indicate that the group means being compared did not differ at the desired probability level.

Contrast Comparison	Group A	Group B	Pr > F
	------- SPAD (-9.9-199.9) -------		--- p-value ---
1.5x N rate (2,8) vs. 1x N rate (3,9)	50.6 A	49.3 A	0.155
Urea (2-7) vs. SUPERU (8-13)	48.1 A	48.1 A	0.975
Side-band (3,9) vs. fall Broadcast (4,10)	49.3 A	46.8 B	0.009
Side-band (3,9) vs. spring Broadcast (5-11)	49.3 A	46.7 B	0.006
Side-band (3,9) vs. fall Deep Band (6,12)	49.3 A	47.8 A	0.098
Side-band (3,9) vs. fall Shallow Band (7,13)	49.3 A	47.4 B	0.046
Fall Deep Band (6,12) vs Fall Shallow Band (7,13)	47.8 A	47.4 A	0.713

There was a strong grain yield response to N application with up to a 104% increase over the control (Fig. 3). Again, the general responses were similar between forms and, in most cases, individual treatment means for the two products did not significantly differ within any specific timing/placement options. Yields with side-banding were usually higher than for all other options but an exception was fall-banded urea which yielded similarly to side-banding. Yields were consistently lower with surface broadcast applications regardless of timing and, for SUPERU® specifically, yields were lower with spring versus fall broadcasting. With spring broadcasting for a short season crop under dry conditions, where the risk of volatilization is high but that for denitrification is low, Agrotain® would arguably be a more appropriate and less expensive controlled release N option than SUPERU®. In contrast, SUPERU® protects against volatilization but also against the denitrification and leaching losses that can potentially occur with fall N applications. In theory, spring broadcasting is preferable to fall broadcasting because it is closer to the period where the crop requires the N; however, actual results can vary depending on the specific weather events after application. Yields with fall in-soil banding were generally higher than with the surface applications but lower than with side-banding. Yields with shallow banding were similar to deep banding for SUPERU® but not for untreated urea where deep banding was advantageous.

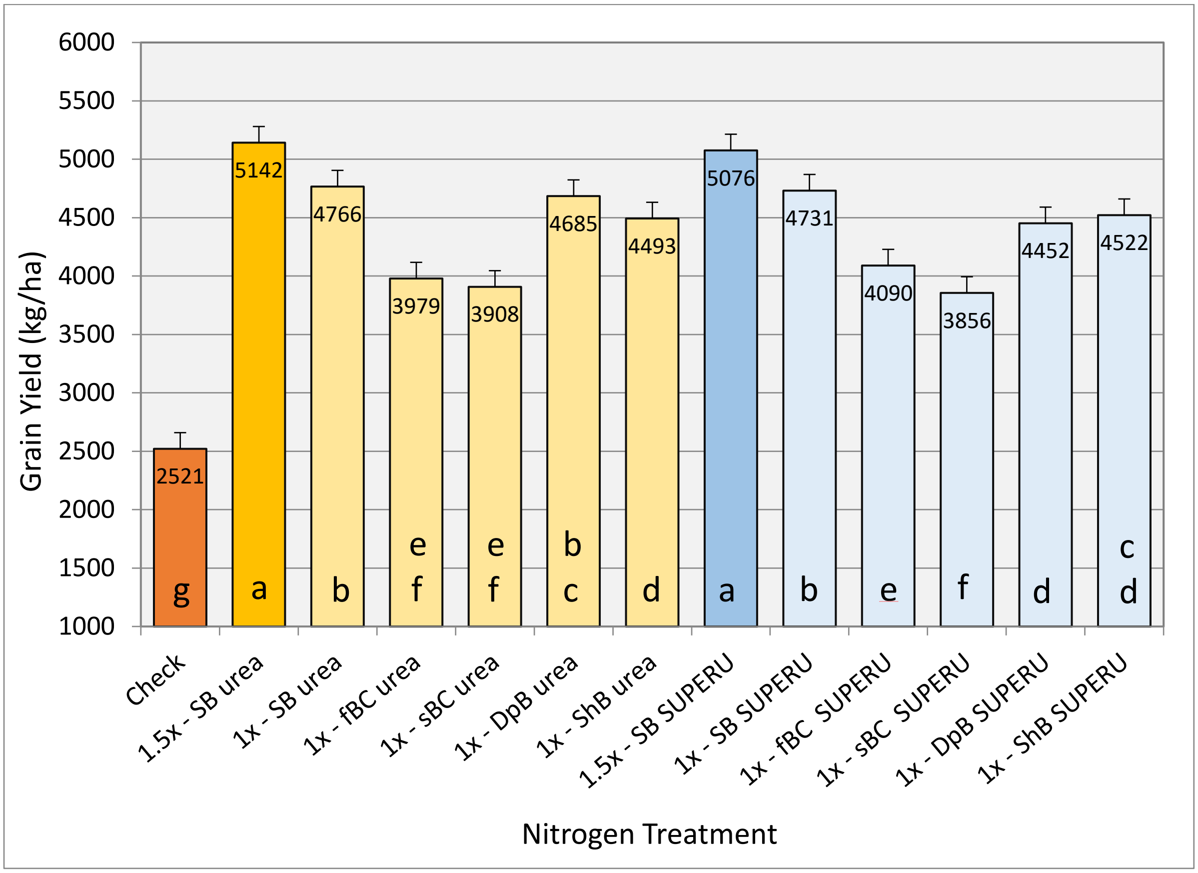

Figure 3. Individual nitrogen treatment means for spring wheat grain yield at Indian Head in 2020. Error bars are the standard error of the treatment means. The 1x rate is 110 kg N/ha (soil + fertilizer) and the 1.5x rate is 165 kg N/ha. SB is side-band, fBC is fall broadcast, sBC is spring broadcast, DpB is fall Deep Band, ShB is fall shallow band.

The contrast results for grain yield are presented in Table 7 below. These tests confirmed that yields with side-banding were higher at the 1.5x versus 1x rates (*P* < 0.001) but similar between forms when averaged across all the timing/placement options (*P* = 0.274). At the 1x rate and averaged across forms, yields with side-banding were higher than all other timing/placement options (*P* < 0.001-0.008) but did not differ between deep and shallow banding (*P* = 0.346).

Table 7. Predetermined contrast comparisons for spring wheat grain yield at Indian Head in 2020. P-values less than or equal to 0.05 indicate that the group means being compared did not differ at the desired probability level.

Contrast Comparison	Group A	Group B	Pr > F
	------- Grain Yield (kg/ha) -------		--- p-value ---
1.5x N rate (2,8) vs. 1x N rate (3,9)	5109 A	4749 B	<0.001
Urea (2-7) vs. SUPERU (8-13)	4495 A	4454 A	0.274
Side-band (3,9) vs. fall Broadcast (4,10)	4749 A	4035 B	<0.001
Side-band (3,9) vs. spring Broadcast (5-11)	4749 A	3882 B	<0.001
Side-band (3,9) vs. fall Deep Band (6,12)	4749 A	4568 B	0.008
Side-band (3,9) vs. fall Shallow Band (7,13)	4749 A	4507 B	<0.001
Fall Deep Band (6,12) vs Fall Shallow Band (7,13)	4568 A	4507 A	0.346

Individual treatment means for grain protein are illustrated in Fig. 4 and the overall patterns were like those observed for yield but with slightly greater separation between treatments. Grain protein in the control averaged 10.4% which was significantly lower than all other individual treatments and, as expected, the highest protein levels occurred at the 1.5x rate. For any of the individual application timing/placement options at the 1x rate, protein levels never significantly differed between the two N forms. While differences between individual treatments within a form did not always significantly differ, protein concentrations were generally highest with side-banding, followed by deep-banding, then shallow-banding. Spring broadcasting resulted in similar protein concentrations as fall shallow banding while the lowest protein levels (of the fertilized treatments) was observed with the fall broadcast applications. The contrast comparisons (Table 8) confirmed much higher protein concentrations at the 1.5x versus 1x rate (14.6% vs. 12.9%; *P* < 0.001). The protein concentrations achieved with the two forms did not differ when averaged across timing/placement options (*P* = 0.344). With these comparisons, side-banding resulted in higher protein levels than any of the other options (*P* < 0.001-0.007). Excluding side-banding, the lowest protein was observed with fall broadcasting (11.2%) while the highest was with the fall deep-band applications (12.5%). Furthermore, deep-banding was advantageous over shallow banding (*P* = 0.006) for this variable (12.5% vs. 12.1%). Interestingly, protein concentrations were higher with spring broadcast N than with fall broadcasting (11.8% vs. 11.2%) while the opposite occurred for grain yield (4035 kg/ha vs. 3882 kg/ha). It is possible that the total N losses for these two treatments were similar, but availability of the spring broadcast N had shifted later, to the extent that yields suffered but more N was available later in the season to contribute to protein accumulation.

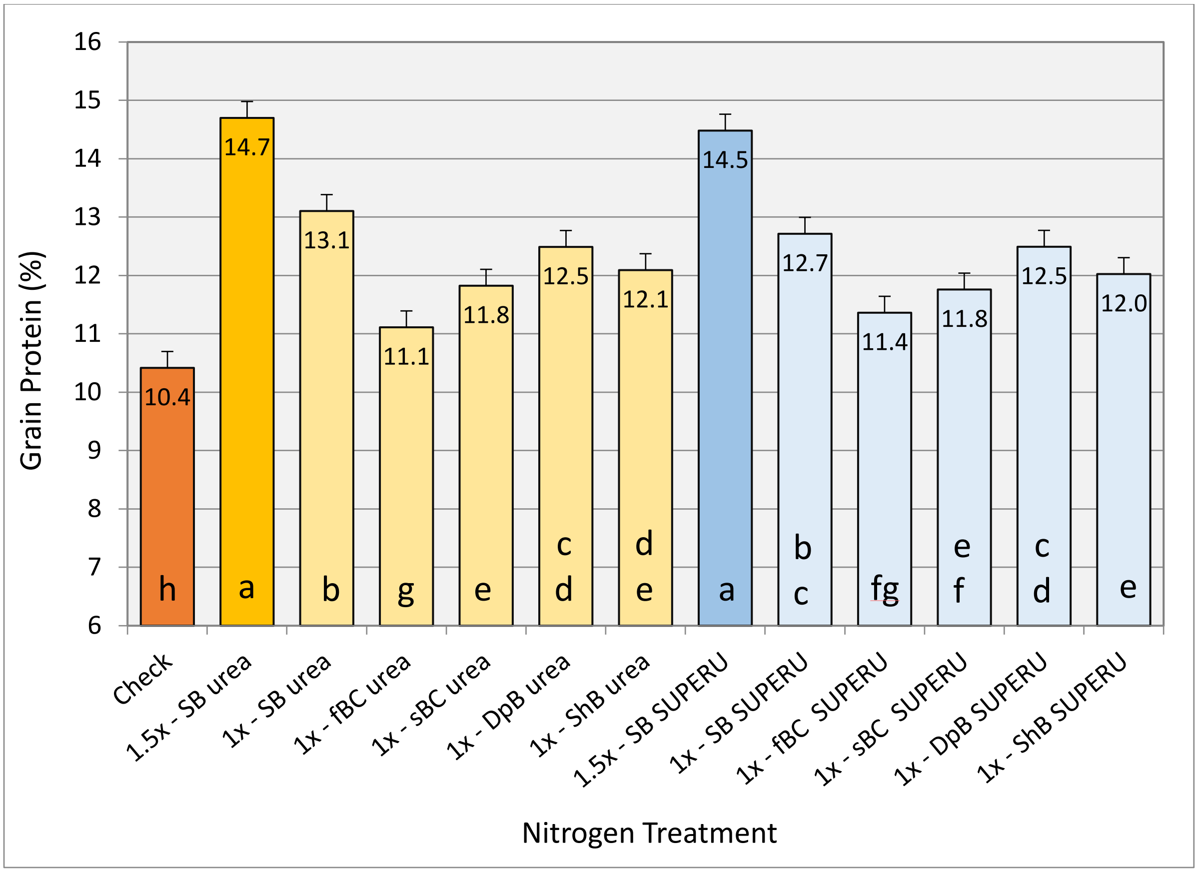

Figure 4. Individual nitrogen treatment means for spring wheat grain protein concentrations at Indian Head in 2020. Error bars are the standard error of the treatment means. The 1x rate is 110 kg N/ha (soil + fertilizer) and the 1.5x rate is 165 kg N/ha. SB is side-band, fBC is fall broadcast, sBC is spring broadcast, DpB is fall Deep Band, ShB is fall shallow band.

Table 8. Predetermined contrast comparisons for spring wheat grain protein concentrations at Indian Head in 2020. P-values less than or equal to 0.05 indicate that the group means being compared did not differ at the desired probability level.

Contrast Comparison	**Group A**	**Group B**	**Pr > F**
	-------- Grain Protein (%) --------		--- p-value ---
1.5x N rate (2,8) vs. 1x N rate (3,9)	14.6 A	12.9 B	<0.001
Urea (2-7) vs. SUPERU (8-13)	12.55 A	12.47 A	0.344
Side-band (3,9) vs. fall Broadcast (4,10)	12.91 A	11.24 B	<0.001
Side-band (3,9) vs. spring Broadcast (5-11)	12.91 A	11.79 B	<0.001
Side-band (3,9) vs. fall Deep Band (6,12)	12.91 A	12.49 B	0.007
Side-band (3,9) vs. fall Shallow Band (7,13)	12.91 A	12.06 B	<0.001
Fall Deep Band (6,12) vs Fall Shallow Band (7,13)	12.49 A	12.06 B	0.006

<u>Extension Activities</u>

Due to COVID-19 restrictions, we were not able to show the field trials during any summer field tours or workshops this past season; however, highlights of this work were presented at the 2020 Manitoba Agronomists Conference (virtual, December 16-17, 2020, approximately 350 attendees) and IHARF's Soil and Crop Management Seminar/AGM (virtual, February 3, 2021, approximately 170 attendees). Technical reports and extension materials will be available online through IHARF and/or Agri-ARM websites.

11. Conclusions and Recommendations

This project has demonstrated tremendous overall benefits to N fertilization and the relative efficacy of contrasting N management strategies that were selected to demonstrate certain 4R nutrient management principles. These principles promote providing nutrients in the Right form, at the Right time, in the Right place, and at the Right rate while recognizing the need to adapt to specific agronomic, economic, environmental, and logistic considerations. The premise is to provide nutrients as close to the time of crop uptake as possible, in a formulation and placement that will be relatively safe from losses but available to the crop, and at an adequate but not excessive rate. Achieving these goals will simultaneously maximize the efficiency of the applied N while minimizing the potential for environmental harm and will often also provide the greatest economic returns. This demonstration contrasted two N formulations (untreated urea and SUPERU®); however, these specific formulations were not intended to represent all available options and nor would they be considered appropriate for all the timing/placement options evaluated. With rare exceptions, both forms performed similarly under the conditions encountered. The management options were tested with N applied at a rate that was adjusted for residual soil nutrients and intended to be slightly less than optimal – this was confirmed with a combination of high N and unfertilized control plots.

In this single site-year, side-banding proved to be the most effective N management strategy of the options evaluated for both formulations, simultaneously resulting in the highest yields and grain protein concentrations. Coming back to the 4R nutrient management principles, side-banding places the N beneath the soil surface where it is relatively protected from NH_3 volatilization, and in concentrated bands which slows both urea hydrolyses and nitrification. Side-banding aims to place the N far enough away from the seed that it will not negatively impact emergence but close enough that it will still be readily accessible to the crop but less available to shallow rooted weeds growing between crop rows. Broadcasting N without incorporation is never ideal but can perform well if timely precipitation moves it into the rooting zone before environmental losses or yield reductions can occur. With the dry weather during 2019/20 study period, broadcasting without incorporation was the poorest performing option regardless of the formulation or specific timing. Of the broadcast treatments, fall application resulted in higher yields but lower protein concentrations compared to spring application; however, neither performed as well as the fall in-soil bands or side-banding. Fall-banding provides the benefits of concentrating the N in a location that is relatively protected from loss and available to crops; however, is less optimal than side- or mid-row banding with respect to timing. Fall applications are generally riskiest in wet regions or poorly drained fields where there is a high probability of standing water and/or saturated soils in the early spring. Enhanced efficiency fertilizer formulations (such as SUPERU®) can help protect again these losses in addition to reducing volatilization with surface applications. However, such products are more expensive and the actual agronomic and economic benefits that they provide depends on many factors that vary both spatially and from year to year. SUPERU® was only included as an example of a commercially available and proven enhanced efficiency product and, to be fair, would not necessarily be recommended for all of the timing/placement strategies that were evaluated in this demonstration. For example, Agrotain® treated urea (which protects against volatilization but does not inhibit nitrification) would be a less expensive and potentially more effective formulation for spring broadcast applications in dry environments where the window for preventing nutrient deficiency is closing and the risk of denitrification or leaching is low. With the many different formulations available and various timing/placement options for applying them (including split applications), there are countless N management strategies to choose from. When this is considered along with farm specific economic and logistic factors, no single option will be ideal for all farms in all years. The important thing is to recognize the needs of the farm along with the potential N losses that are most likely to occur and, taking these factors into consideration, choose the placement/timing options that make the most sense for the operation and the form that best protects against the losses that will be most likely to occur. Side- or mid-row banding N fertilizer in single-pass seeding/fertilization systems has repeatedly shown to be difficult to improve upon for annual crop production in the Canadian Prairies; however, it is also important for farmers to have some flexibility in how they choose to manage this critical input. It is also important to recognize that the relative efficacy of different 4R N management strategies can vary from year-to-year for the same field and/or farming operation. This project will be completed for a second growing season and was re-established in the fall of 2020.

Supporting Information

12. Acknowledgements:

This project was jointly funded by Fertilizer Canada and the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canadian Agricultural Partnership bi-lateral agreement between the federal government and the Saskatchewan Ministry of Agriculture. IHARF has a strong working relationship and a memorandum of understanding with Agriculture and Agri-Food Canada which should be acknowledged and IHARF provided the land, equipment, and infrastructure required to complete this project. Certain crop protection products were provided in-kind by Corteva and Bayer CropScience.

13. Appendices:

Table A-1. Overall tests of fixed effects and individual treatment means for selected response variables. Values within a column followed by the same letter do not significantly differ from one another (Fisher's protected LSD test; $P \leq 0.05$). The 1x rate is 110 kg N/ha (soil + fertilizer) and the 1.5x rate is 165 kg N/ha. SB is side-band, fBC is fall broadcast, sBC is spring broadcast, DpB is fall Deep Band, ShB is fall shallow band.

	NDVI (flag)	**SPAD (milk)**	**Yield (kg/ha)**	**Protein (%)**
Source	------------------------------------- Pr > *F* (p-values) --------------------------------------			
Entry	<0.001	<0.001	<0.001	<0.001
Control (0 N)	0.528 f	39.4 d	2521 g	10.42 h
Urea – 1.5x SB	0.725 ab	50.5 a	5142 a	14.7 a
Urea – 1x SB	0.697 bcd	48.9 abc	4766 b	13.11 b
Urea – 1x fBC	0.674 d	46.6 c	3979 ef	11.11 g
Urea – 1x sBC	0.584 e	46.8 c	3908 ef	11.83 e
Urea – 1x DpB	0.736 a	48.3 abc	4685 bc	12.49 cd
Urea – 1x ShB	0.711 abc	47.6 bc	4493 d	12.09 de
SUPERU – 1.5x SB	0.708 abc	50.8 a	5076 a	14.48 a
SUPERU – 1x SB	0.678 cd	49.7 ab	4731 b	12.72 bc
SUPERU – fBC	0.682 cd	47.0 c	4090 e	11.36 fg
SUPERU – sBC	0.599 e	46.6 c	3856 f	11.76 ef
SUPERU –DpB	0.696 bcd	47.3 bc	4452 d	12.49 cd
SUPERU –ShB	0.710 abc	47.2 bc	4522 cd	12.03 e
S.E.M.	0.0189	1.12	138.6	0.281

Abstract

14. Abstract/Summary

With funding from the Saskatchewan Ministry of Agriculture's ADOPT program and Fertilizer Canada, a 4R nitrogen (N) management demonstration was initiated in the fall of 2019 near Indian Head, Saskatchewan. The test crop was CWRS wheat and the treatments were a combination of two N formulations (untreated urea and SUPERU®) and six rate/timing/placement combinations (1.5x side-band, 1x side-band, 1x fall broadcast, 1x spring broadcast, 1x fall deep band, and 1x fall shallow band) plus an unfertilized control. Rates were adjusted for residual NO_3-N with 110 kg N/ha and 165 kg N/ha (soil plus fertilizer) as the 1x and 1.5x rates, respectively. The response variables measured were 1) NDVI at the flag-leaf stage, 2) flag-leaf chlorophyll (SPAD) measurements at the milk stage, 3) yield, and 4) grain protein. All the response variables indicated strong responses to N when the fertilized treatments were compared to the unfertilized control treatment while comparisons to the 1.5x rate confirmed that the 1x rate was below optimal and, therefore, should allow for differences between strategies to be readily detected. The two N formulations performed similarly to one another but there was considerable variation amongst the timing/placement strategies. Both NDVI and SPAD measurements were good indicators of the response to N but the relative rankings of the treatments were not always consistent with the yield/protein results, particularly for NDVI which favoured fall-banding. Consistent with previous work at this location, side-banding performed well and simultaneously resulted in both the highest yields and grain protein concentrations. Surface broadcast applications were the least efficient placement option with fall applications favouring yield and spring applications favouring protein accumulation. Fall banding, regardless of depth, performed better than the surface applications but not as well as side-banding. When both yield and protein were considered, deep banding performed better than shallow banding, particularly with untreated urea. Results should be expected to vary widely depending on the specific conditions encountered. Farmers/agronomists are advised to understand the mechanisms of N losses and options for mitigating those to which they are most vulnerable. This information, along with economic and logistic considerations, will allow farmers to adopt appropriate N management strategies that are tailored to their operation and specific environment in which it exists. This demonstration is continuing in 2020-21.