Wheatland Conservation Area Inc.
Swift Current, SK.

Demonstrating 4R Nitrogen Management Principles in Spring Wheat

Project #20180393

Start Date: August 2, 2018
End Date: February 15, 2020

ADOPT 2019
Fertilizer Canada
Final Report

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Abstract

In 2019 a trial was established in Swift Current Saskatchewan titled "Demonstrating 4R Nitrogen Management Principles in Spring Wheat," consisting of both spring and fall applied fertilizer treatments. While the demonstration consisted of two separate components, it was managed as a single trial for both efficiency and to aid in the interpretation of results in the N source/timing/placement component. For the first component of the demonstration, all N was side-banded with untreated urea at 7 rates; 0x, 0.5x, 0.75x, 1x, 1.25x, 1.5x and 1.75x the soil test adjusted rate of 125 kg/ha total N (residual NO_3-N + fertilizer N). The second component focuses on N management options and consisted of a factorial combination of three timing/placement options (fall broadcast, spring side-band, and spring surface broadcast) and four N sources (untreated urea, ESN®, Agrotain® treated urea, and SuperU®). Fall broadcast treatments were targeted mid- to late-October (September 25, 2018) while the spring broadcast treatments target application was 1-7 days post-seeding (May 13, 2019). The total N rate used is equivalent to the 1x rate in the first component, adjusted for residual NO_3-N and N provided by MAP (11-52-0). The treatments were replicated four times and arranged as two integrated, but separate, RCBD trials. One treatment (1x side-banded untreated urea) will be shared between the two components. The growing season at Swift Current was extremely dry with May and July well below the long-term average growing season precipitation; however, overall soil moisture was adequate. The first component showed that yield, protein, and chlorophyll content all increased with increasing N rates. Under the second component of the study, the best yields were observed when applying fertilizer in the spring, whether broadcasted, or side-banded at seeding. More specifically, untreated urea performed most consistently when side-banded in the spring when yield, protein, and chlorophyll content were each considered. Previous research has shown that early in-soil applications are most advantageous in dry years while, under more optimal conditions, N fertilizer placement and timing of application tend to be less critical. In very wet years, environmental losses can be high regardless of application method depending on the formulation. It is in these years that denitrification inhibitors such as Agrotain, SuperU, or other considerations such as split-applications are likely to be most beneficial.
This trial was promoted on a CKSW radio program called "Walk the Plots" that is broadcasted on a weekly basis throughout the summer.

Project Objectives

Developing Best Management Practices (BMPs) for nutrient applications 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. These factors are not necessarily independent of each other. For example, depending on the source, application times or placement options that would normally be considered high risk can become viable. The objective of this trial is to demonstrate the feasibility of various N management strategies and overall N rate response using spring wheat as a test crop. Nitrogen rates included in the demonstration will be adjusted for residual nitrate and range from nil to nearly double a conservative soil test recommendation. The management strategies will vary with regard to timing (fall versus spring), placement (surface broadcast versus in-soil band), and formulation (untreated urea, ESN®, Agrotain® treated urea, and SuperU®). The proposed demonstration encompasses all four considerations (source, rate, time and placement) for 4R nutrient management.

Project Rationale

Crop response to N fertilizer and the 4R principles have been widely researched for various crops in western Canada and abroad. It is generally accepted that single pass seeding / fertilization is an efficient and effective method that, on average, minimizes the potential for losses. Alternative methods such as fall banding, fall or spring broadcasts and top dressing are often utilized and reasonably effective but do have potential to result in higher losses and reduced efficacy under certain environmental conditions. Additionally, all of the enhanced efficiency products to be included in this demonstration have been proven effective for their specific purposes and commercially available for many years; however, whether or not they are economically or agronomically beneficial depends on environmental conditions and overall crop response to N.

Nitrogen is commonly the most limiting nutrient in annual crop production and is often one of the most expensive crop nutrients, particularly for crops with large N requirements like high protein spring wheat. Most inorganic N fertilizers contain ammoniacal-N (i.e. anhydrous ammonia, urea) but some (i.e. urea ammonium-nitrate) also contain NO_3-N – both forms are readily available for crop uptake but are also subject to unique and important environmental losses. Urea-based fertilizers initially convert to NH_3 which, in addition to potentially being harmful to seedlings, can be readily lost via volatilization before converting to NH_4 if on or near the soil surface. In contrast, under saturated conditions, NO_3-N can be leached beneath the rooting zone or lost through denitrification as soil microbes seek alternate forms of oxygen and convert it back to N_2 or N_2O. Such losses can not only result in substantial economic losses to producers, but also lead to potential environmental harm such as ground/surface water contamination and climate change (i.e. N fertilizers are energy intensive to manufacture and N_2O is a powerful greenhouse gas).

Since the advent of no-till and innovations in direct seeding equipment, side or mid-row band applications and single pass seeding / fertilization quickly became the standard and most commonly recommended BMP for nitrogen. Side- or mid-row banding is effective with the major forms of N including anhydrous ammonia (82-0-0), urea (46-0-0) and urea ammonium-nitrate (28-0-0) and the combination of concentrating fertilizer safely away from the seed row and placing it beneath the soil surface dramatically reduced the potential for environmental losses while maintaining seed safety. Fall applications have always been popular, at least on a regional basis, in that fertilizer prices are usually lower and applying N in a separate pass can reduce logistic pressure during seeding when labour and time are limited. While fall applied anhydrous ammonia is always banded beneath the soil surface, granular products are more commonly surface broadcast as this tends to be much faster and less expensive than in-soil applications. With narrow seeding windows, large farm sizes, and higher fertilizer rates to consider, many growers are reverting to or considering two pass seeding/fertilization strategies. Despite certain inefficiencies, 2-pass seeding/fertilization systems are seen as a means of spreading out the workload and managing logistic challenges associated with handling large product volumes at seeding time. While the timing and/or placement associated with two-pass systems are usually not ideal, enhanced efficiency formulations (EEF) such as polymer coats (ESN), volatilization inhibitors (i.e. Agrotain) and volatilization / nitrification inhibitors (SuperU) can reduce the potential risks associated with applying N well ahead of peak crop uptake (i.e. fall applications) or sub-optimal placement methods (i.e. surface broadcast). Enhanced efficiency N products are more expensive than their traditional counterparts; however, this higher cost may be justified by the potential improvements in efficacy and logistics advantages of alternative fertilization practices. Even with banding there can be merits to EEF products as crops may benefit from the delayed N availability under certain conditions and, when placed shallow into dry soils, volatilization losses can still occur.

This project is relevant to producers because, for many, there has been a movement back to two-pass seeding fertilization systems to increase efficiency at seeding. While we do not necessarily want to specifically encourage growers to revert to a two-pass seeding / fertilization system, it is vital for growers to have a certain amount of flexibility with respect to how they manage N on their farms. By demonstrating different N fertilization strategies according to the 4R principles and providing data on their efficacy relative to benchmark practices, we can help farmers make better informed decisions while taking into consideration both the advantages and disadvantages of some of their options. Spring wheat is an ideal candidate for this project since it is a rotationally and economically important field crop throughout all of Saskatchewan and sensitive to N management with regard to both grain yield and protein.

Methods

The trial was set up similar to that submitted by Chris Holzapfel at IHARF who developed the protocol. A field demonstration with CWRS Adamant wheat was established in the spring of 2019 near Swift Current, consisting of both spring and fall applied fertilizer treatments (Table 1, Table 2). While the demonstration consisted of two separate components, it was managed as a single trial for both efficiency and to aid in the interpretation of results in the N source/timing/placement component. For the first component, all N was side-banded untreated urea at 7 rates; 0x, 0.5x, 0.75x, 1x, 1.25x, 1.5x and 1.75x of the soil test adjusted rate of 125 kg/ha total N (residual NO_3-N + fertilizer N). The second component focuses on N management options and is consistent of a factorial combination of three timing/placement options (fall broadcast, side-band, and spring surface broadcast) and four N sources (untreated urea, ESN®, Agrotain® treated urea, and SuperU®). The timing of the fall broadcast treatments was targeted to mid- to late-October, while the spring broadcast treatments were targeted to be applied within 1-7 days post-seeding. The total N rate used was equivalent to the 1x rate in the first component, as well as adjusted for residual NO_3-N and N provided by MAP (11-52-0). The plots were direct seeded into canola stubble and all other factors (i.e. weeds, disease and insects) were kept non-limiting throughout the season. The demonstration site was moderately low in residual N (51lbs/ac or 57.25kg/ha) as determined by soil testing and therefore suitable for demonstrating an overall response and potential treatment differences. The treatments were replicated four times and arranged as two integrated, but separate, RCBD trials. One treatment (1x side-banded untreated urea) is shared between the two components. All response data was statistically analysed as two separate trials to describe the overall responses to N and to determine whether observed differences were due to treatment effects as opposed to random and natural variability.

Table 1. Treatments in ADOPT-Fertilizer Canada 4R N Management Trials

Trial #1: Right Rate*	Trial #2: Right Time, Right Place, Right Form**
1) 0x (no added N fertilizer) 2) 0.5x (68 kg total N/ha) 3) 0.75x (94 kg total N/ha) 4) 1.0x (125 kg total N/ha) 5) 1.25x (156 kg total N/ha) 6) 1.50x (188 kg total N/ha) 7) 1.75x (219 kg total N/ha) *side-banded urea in all trts, rates adjusted for residual N and N from 11-52-0 Trts received 8 kg N/ha from 11-52-0	1) Fall Broadcast – untreated urea 2) Fall Broadcast – ESN® 3) Fall Broadcast – Agrotain® treated urea 4) Fall Broadcast – SuperU® 5) Side-band – untreated urea 6) Side-band – ESN® 7) Side-band – Agrotain® treated urea 8) Side-band – SuperU® 9) Spring Broadcast – untreated urea 10) Spring Broadcast – ESN® 11) Spring Broadcast – Agrotain® treated urea 12) Spring Broadcast – SuperU® **1.0x rate (soil + fert = 125 kg N/ha) in all trts

The following data was collected from each plot:

1) Soil nutrient/properties – fall composite sample used for background information and N fertilizer rate determination
2) Plant Emergence Counts – determined for each plot 3-4 weeks after seeding
3) Leaf chlorophyll – determined at full flag / early heading using a SPAD meter from 10 flag leaves per plot
4) Seed yield – corrected for dockage and to 14.5% seed moisture content
5) Grain Protein – determined from NIR for each plot

<u>Other field notes were as follows:</u>

Table 2. 2018-2019 List of Operations

18-Sep-18	Fall Soil Sampled (0-6") and (6-12") NPKS analysis (Canola Stubble)
25-Sep-18	Trial #2 Fall Applied Broadcast on Treatments 1 to 4 (1x rate soil + fert) Soil N (57.25 kg/ha) + Fert (67.75 kg/ha) = 125 kg N/ha Total N
10-May-19	Seeded both trials with fabro built plot drill, 8.25" row spacing Trial #1 Sidebanded urea in all trts, rates adjusted for residual N and N from 11-52-0 CDC Adament Spring Wheat @ 25 plants/ft2 269 plts/m2 TKW: 33.52 Germ 98% Mortality 10%
13-May-19	Trial #2 Spring Broadcast applied T9-T12
18-Jun-19	Varro @ 200ml/ac + OcttainXL @450ml/ac + Agsurf @.25l/ac
4-Jul-19	SPAD meter measurements (10 flag leaves/plot)
10-Jul-19	Acapella @ 250ml/ac
28-Aug-19	Harvested 7 rows with zurn

2019 General Site Conditions

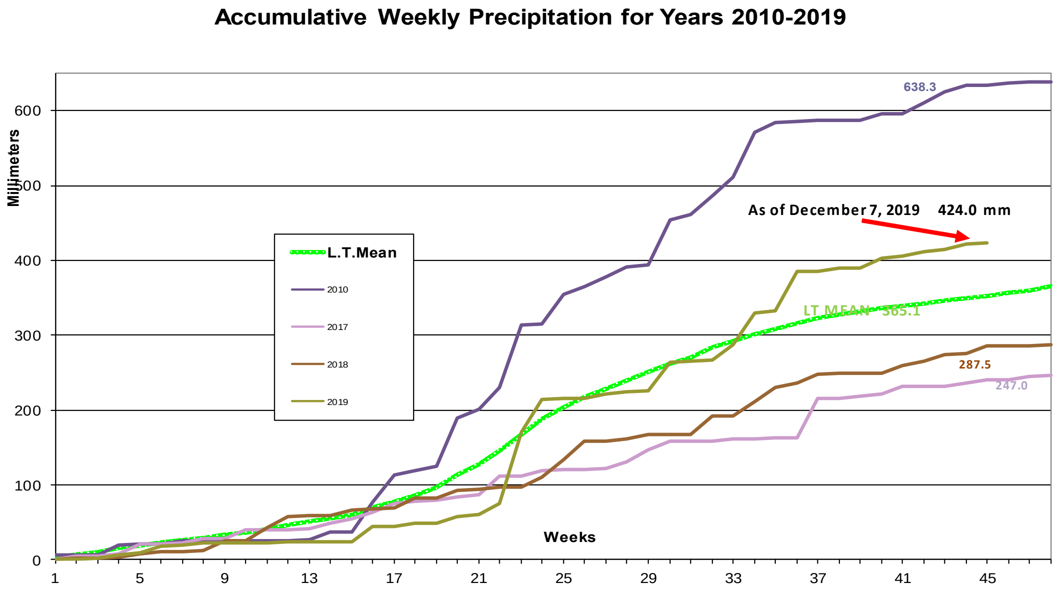

Figure 1. Accumulative weekly precipitation for years 2010 (record high), and 2017-2019 (AAFC Swift Current).

Table 3. Mean monthly temperatures and precipitation vs long-term (30 year) means for the 2019 growing season.

Year	May	June	July	August	Avg. / Total
		----------------------------*Mean Temperature (°C)* -------------------			
2019	9.52	15.78	17.72	16.75	14.9
Long-term	**10.9**	**15.3**	**18.2**	**17.6**	**15.5**
		-------------------------------- *Precipitation (mm)* ---------------------			
2019	13.3	156	11.1	42.6	223.0
Long-term	**51.2**	**77.1**	**60.1**	**47.4**	**235.8**

The trial was direct seeded into dry canola stubble, but received adequate moisture from seeding to harvest with majority of the rainfall accumulating from June 14, 2019 to harvest (Figure 1, Table 3). Spring was cool and frost occurred more than once from May 18th to May 20th. With strong winds and little rainfall, the already moisture deficient fields resulted in crop progression behind normal stages of development. Much needed rainfall in mid-June lead to highly variable crop conditions with a variety of growth stages. Topsoil moisture deteriorated into July with these conditions generally resulting in poor yield. Plots were harvested August 28, 2019 before significant rainfall events caused harvest delays through September and late into October.

Results and Discussion

Trial 1: Right Rate

Plant density was variable ranging from 58% to 69% emergence (155-185plants/m2), but generally decreased as nitrogen rate increased.

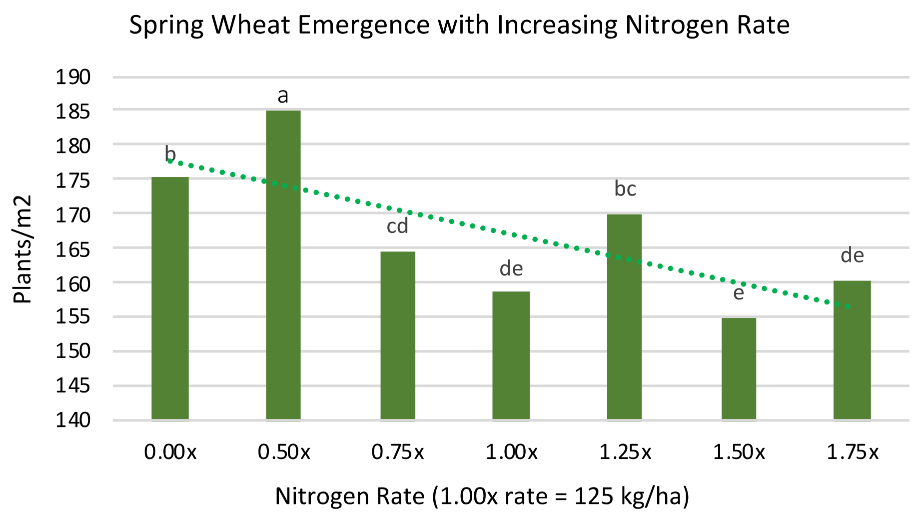

Figure 2. Spring wheat emergence counts in response to increasing fertilizer rate. The 1.00x rate is equal to 125 kg N /ha (soil + fertilizer) and was side-banded at seeding. (CV=10.9%, LSD=8.4 plants/m2)

Protein increased with nitrogen rate (CV=7.9%, LSD=0.4%) and ranged from 9.3% at the lowest rate to 15.3% at the highest rate. Treatments with nitrogen rates under the 1.00x rate were below the acceptable protein level of 10%. The highest N rate (219 kg/ha) resulted in the highest protein level of 15.3% (Table 4).

Chlorophyll also increased with nitrogen indicating increased nutritional content (CV=7.9%, LSD=0.6%). A chlorophyll content meter (CCM-200 Plus) was used at full flag/early head (average of 10 flag-leaves per plot) to measure chlorophyll content index (CCI) as a relative indicator of chlorophyll concentration of individual leaves[1] (Table 4).

Although stored soil moisture was at an extreme low until mid-June, plots received adequate moisture throughout the growing season and most treatments yielded above the Saskatchewan Crop Reports[2] provincial average of 46 bu/ac. However, optimal nitrogen will vary depending on the environment, as nitrogen fertilizer requires precipitation to move into the rooting zone. Yield increased as nitrogen rate increased and was closely related to chlorophyll content, an important factor for growth (Figure 3). The highest yielding treatment of 56.6 bu/ac (3817 kg/ha) resulted from the highest nitrogen rate (1.75x rate) of 219 kg N /ha. The next highest rate, (1.50x rate) 188 kg N/ha yielded 4 bu/ac less at 52.7 bu/ac (3553 kg/ha) and was significantly different.

[1] Parry, C., Blonquist, J.M., Jr. and Bugbee, B. (2014), The optical/absolute chlorophyll relationship. Plant Cell Environ, 37: 2508-2520. doi:10.1111/pce.12324

[2] https://www.saskatchewan.ca/crop-report.

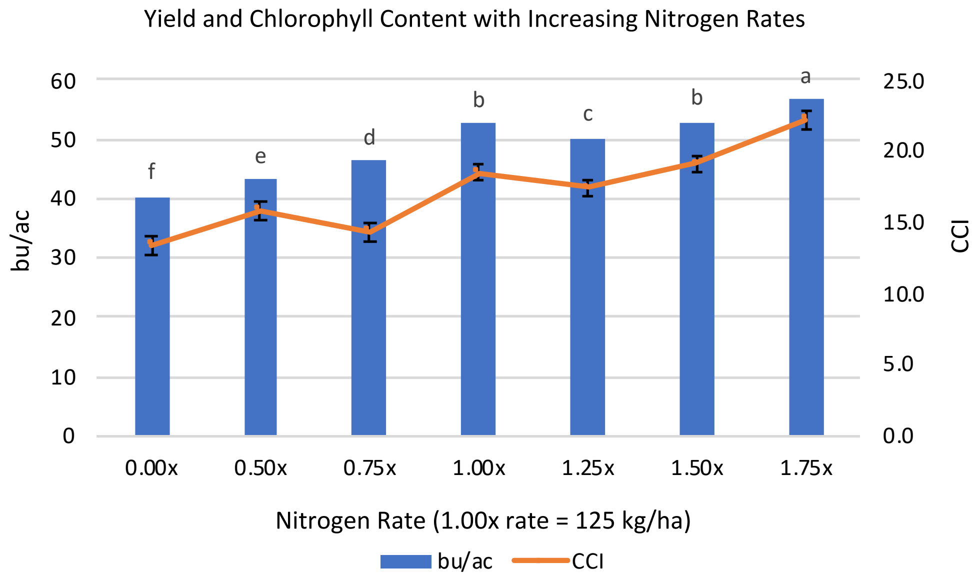

Figure 3. Spring wheat yield in response to increasing fertilizer rate. The 1.00x rate is equal to 125 kg N/ha (soil + fertilizer) and was side-banded at seeding. (CV=8.8%, LSD=1.98 bu/ac)

Trial 2: Right Time, Right Place, Right Form

Plant density ranged from 154-195 plants/m2. With the exception of SuperU, each form applied as a fall broadcast emerged relatively well. These fall treatments, as well as spring broadcasted ESN and SuperU also had greater emergence compared to other treatments. Spring side-banded treatments generally showed the lowest emergence.

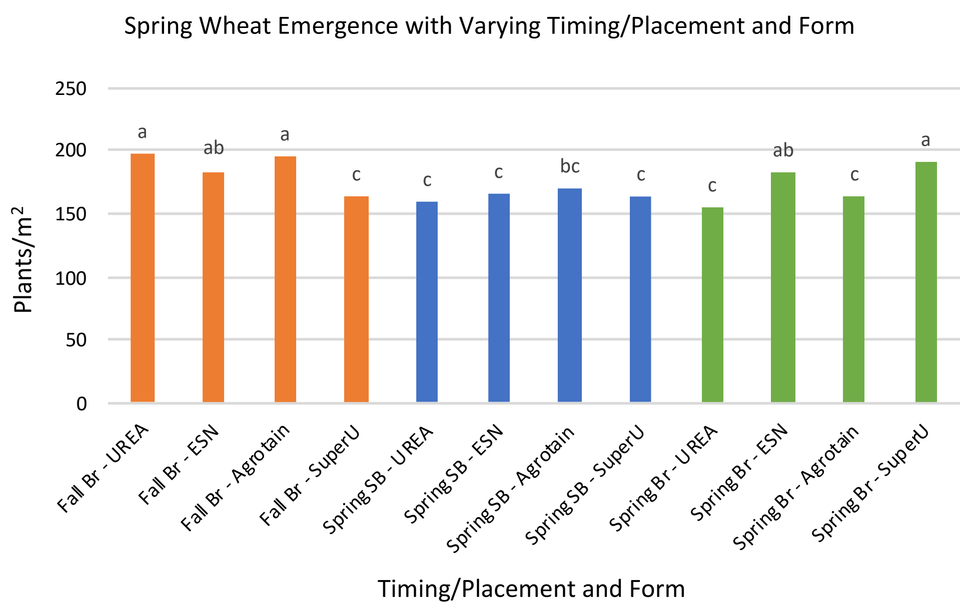

Figure 4. Spring wheat emergence counts in response to fertilizer timing/placement and form. Nitrogen rate is the 1.00x rate applied in Trial #1 (125 kg N /ha soil + fertilizer). (CV=15.0%, LSD=9.06 plants/m2)

Differences in N use-efficiency amongst the different management strategies could be detected in protein. Under the environmental conditions encountered, side-banding the nitrogen in spring produced higher protein wheat than any treatments where a surface broadcast was utilized. This is consistent with previous research which has shown that early in-soil applications are generally most advantageous under dry conditions. Protein ranged from 9.7% to 11.1%; only the fall broadcasted ESN fell below the 10% minimum accepted by the CGC.[3] The highest protein concentration resulted from spring side-banded Agrotain treated urea, although not significantly different from spring side-banded SuperU, untreated urea, or fall broadcasted SuperU.

A chlorophyll content meter (CCM-200 Plus) was also used at full flag/early head (average of 10 flag-leaves per plot) to measure chlorophyll content index, as a relative indicator of chlorophyll concentration of individual leaves[1] (Table 4, Figure 5). Chlorophyll content ranged from 16.2 to 18.7 CCI (CV=15.2%, LSD=0.9%).

In terms of yield, the timing of precipitation generally favoured treatments with spring applied nitrogen, with the exception of spring broadcasted ESN and spring side-banded SuperU. The highest yielding treatments resulted from side-banded or spring broadcasted untreated urea yielding 53 bu/ac (Figure 5). More specifically, untreated urea performed most consistently side-banded in the spring when yield, protein concentrations and chlorophyll content are all considered. Yield did not greatly vary across form when fall broadcasted, with the exception of SuperU performing higher in terms of yield and protein. If you are applying fertilizer as a fall broadcast, SuperU is likely the most effective, although did not perform significantly different than spring broadcasted SuperU. This is a result of the dry spring conditions as fall broadcasted N would have sat on the soil surface for a long time without any precipitation, therefore not have been able to move into the soil.

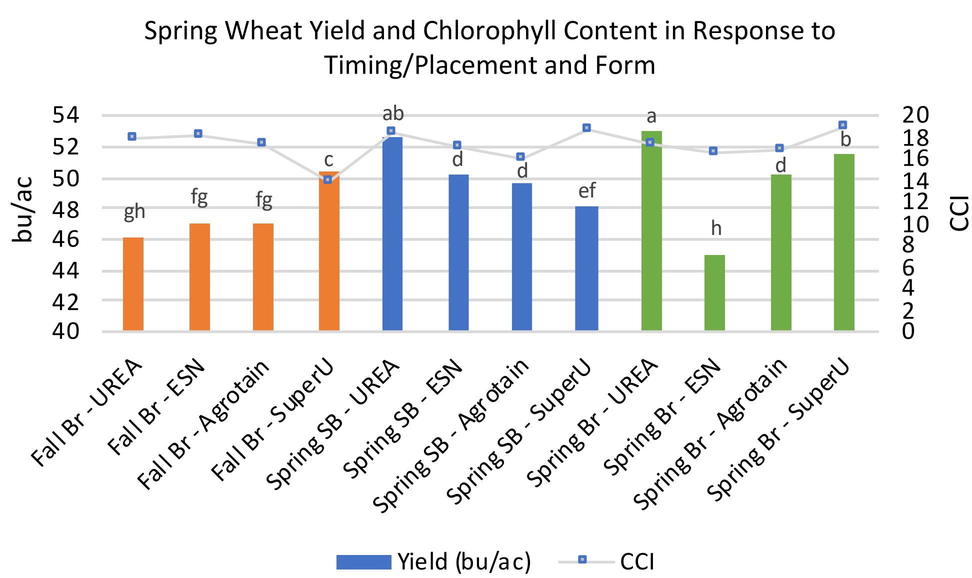

Figure 5. Spring wheat yield in response to fertilizer timing/placement and form. Nitrogen rate is the same across treatments (125 kg N/ha soil + fertilizer). (CV=7.4%, LSD=1.25 bu/ac)

3 https://www.grainscanada.gc.ca/en/grain-quality/official-grain-grading-guide/04-wheat/primary-grade-determinants/cwrs-en.html

This trial was promoted on a CKSW radio program called "Walk the Plots" that is broadcasted on a weekly basis throughout the summer. This project was highlighted on small crop tours with industry and ministry staff throughout the summer. Results will be shared locally and a summary can be found on our website at www.wheatlandconservation.ca.

Table 4. Individual treatment means for selected response variables at Swift Current, 2019.

Trt #	Rate*	Form	Time	Placement	N kg/ha	plants/m2	CCI	umol m-2	kg/ha	bu/ac	Protein %
Trial 1 Right Rate											
1	0.00x	Untreated UREA	Spring	Sideband	0	175.2	13.4	290.2	2712	40.2	9.3
2	0.50x	Untreated UREA	Spring	Sideband	68	184.9	15.8	329.0	2901	43.1	9.6
3	0.75x	Untreated UREA	Spring	Sideband	94	164.7	14.3	304.9	3125	46.4	9.3
4	1.00x	Untreated UREA	Spring	Sideband	125	158.8	18.5	370.1	3543	52.6	11.0
5	1.25x	Untreated UREA	Spring	Sideband	156	170.1	17.4	353.7	3378	50.1	12.4
6	1.50x	Untreated UREA	Spring	Sideband	188	155.1	19.1	378.5	3553	52.7	13.7
7	1.75x	Untreated UREA	Spring	Sideband	219	160.5	22.2	422.1	3817	56.6	15.3
Trial 2 Right Time, Right Place, Right Form											
1	1.00x	Untreated UREA	Fall	Broadcast	125	197.4	18.0	362.6	3109	46.1	10.5
2	1.00x	ESN	Fall	Broadcast	125	183.7	18.1	365.4	3171	47.1	9.7
3	1.00x	Agrotain treated UREA	Fall	Broadcast	125	195.7	17.3	351.7	3167	47.0	10.2
4	1.00x	SuperU	Fall	Broadcast	125	164.0	13.9	292.3	3402	50.5	10.9
5	1.00x	Untreated UREA	Spring	Sideband	125	158.8	18.5	370.1	3543	52.6	11.0
6	1.00x	ESN	Spring	Sideband	125	166.4	17.1	348.5	3383	50.2	10.6
7	1.00x	Agrotain treated UREA	Spring	Sideband	125	169.5	16.2	331.5	3346	49.6	11.1
8	1.00x	SuperU	Spring	Sideband	125	164.0	18.7	373.5	3252	48.2	11.0
9	1.00x	Untreated UREA	Spring	Broadcast	125	154.6	17.4	354.9	3579	53.1	10.4
10	1.00x	ESN	Spring	Broadcast	125	182.6	16.6	340.8	3032	45.0	10.8
11	1.00x	Agrotain treated UREA	Spring	Broadcast	125	163.6	16.9	346.6	3384	50.2	10.6
12	1.00x	SuperU	Spring	Broadcast	125	190.4	18.9	376.6	3476	51.6	10.7

*1.00x rate (soil + fert = 125 kg N/ha) in all trts)

Conclusions and Recommendations

This project has demonstrated the overall response of wheat to varying rates of N fertilizer along with different strategies for managing N involving various formulations (urea, ESN, Agrotain® and SuperUrea®) and timing/placement options (fall broadcast, spring side-band, and spring broadcast surface applications of N). The growing season at Swift Current was extremely dry with May and July well below the long-term average growing season precipitation; however, overall soil moisture was adequate. Under these conditions, the best yields were observed when applying fertilizer in the spring, whether broadcasted, or side-banded at seeding. More specifically, untreated urea performed most consistently when side-banded in the spring when yield, protein concentrations and chlorophyll content were each considered. Previous research has shown that early in-soil applications are most advantageous in dry years while, under more optimal conditions, N fertilizer placement and timing of application tend to be less critical. In very wet years, environmental losses can be high regardless of application method depending on the formulation. It is in these years that denitrification inhibitors such as Agrotain, SuperU, or other considerations such as split-applications are likely to be most beneficial.

It is well accepted that substantial precipitation, or some method of incorporation is needed for surface-applications of N to move the fertilizer into the rooting zone and minimize losses. This would, to a large extent, explain why the surface applications did not perform as well as side-banded N when considering yield and protein. The risk of volatilization for each treatment was high since rainfall following application was always negligible. This was indicated in the results with the better performance of the soil-applied N. Side-banding 100% of the applied nitrogen might not always be desirable for reasons such as potentially poor establishment, or environmental concerns, but when soil moisture is adequate at the time of seeding, side band application of all nitrogen fertilizer can certainly increase yield potential, particularly in the Brown and Dark Brown soil zones where potential N losses are low. If potential for N loss is a high, products such as SuperU may be more effective in these situations, but if conditions for N loss are minimal as in Swift Current, urea is the most economical product to use.

There is no single optimal solution for N management for producers, therefore understanding the available options and outcomes can allow for fertilizer application flexibility. In this particular year, spring applications of nitrogen showed the greatest yield response when compared to fall broadcasting. Broadcasting of urea in the dry and windy fall conditions resulted in substantial nitrogen losses due to volatilization. If using a broadcast system, it may be worth consulting your local agronomist to help you consider an N stabilizer and apply these products in a timely matter, possibly prior to a rainfall to help with breakdown into the soil.

Acknowledgements

We thank the Ministry of Agriculture for all ADOPT projects including plot signage and verbal acknowledgement at field days and on PowerPoint slides during presentations. This will continue at each venue where an extension activity occurs. We also thank Shannon Chant with the Saskatchewan Ministry of Agriculture, Chris Holzapfel at Indian Head Agricultural Research Foundation for protocol development, as well as Fertilizer Canada and the 4R Nutrient Stewardship.

Image 1. Spring wheat (Trial #1). T1: 0.00x rate (no added N fertilizer) August 7, 2019.

Image 4. Spring wheat (Trial #1). T4: 1.00x rate (125 kg N/ha soil + fertilizer) August 7, 2019.

Image 7. Spring wheat (Trial #1). T7: 1.75x rate (219 kg N/ha soil + fertilizer) August 7, 2019.