2019 Annual Report for the Agriculture Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Developing 4R Nitrogen Management Principles in Spring Wheat

Project Number: 20180396

Producer Group Sponsoring the Project: Western Applied Research Corporation

Project Location(s):

- Scott Saskatchewan, R.M. #380 Legal land description: NE 17-39-20 W3

Project start and end dates (month & year): May 2018 and completed January 2019

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Objectives and Rationale

Project objectives:

Developing Best Management Practices (BMPs) for nutrient applications has long been focused 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:

Nitrogen (N) 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 labor 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 crop's 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.

Methodology and Results

Methodology:

A field demonstration with CWRS AAC Brandon spring wheat was established in the spring of 2019 at Scott, Saskatchewan with fertilizer treatments applied in the fall of 2018. The demonstration was managed as two separate studies for ease of management. For the first component of the demonstration, all nitrogen will be side-banded urea at seven varying 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 nitrogen (residual NO_3-N + fertilizer N). The second component focusses on nitrogen management options and consisted of a factorial combination of three timing/placement options (fall broadcast, side-band, and spring surface broadcast) and four nitrogen sources (untreated urea, ESN®, Agrotain® treated urea, and SuperU®). The fall broadcast treatments were applied October 19th while the spring broadcast treatments were applied prior to seeding (Table A1). The total nitrogen rates used will be equivalent to the 1x rate in the first component (adjusted for residual NO_3-N and N provided by MAP (11-52-0). The plots were direct seeded into canola stubble using a Fabro knife-opener drill with 10-inch row spacing and all other factors (i.e. weeds, disease and insects) were kept non-limiting throughout the season. Soil samples were utilized to ensure the site was low in residual nitrogen and thus suitable for demonstrating an overall response to nitrogen and potential treatment differences. The treatments were replicated four times and arranged as two integrated, but separate, RCBD trials. To assist in understanding the trials, treatment lists are provided in Table 1.

Table 1. Proposed 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) **	1) Fall Broadcast – untreated urea
2) 0.5x (68 kg total N/ha)	2) Fall Broadcast – ESN®
3) 0.75x (94 kg total N/ha)	3) Fall Broadcast – Agrotain® treated urea
4) 1.0x (125 kg total N/ha)	4) Fall Broadcast – SuperU®
5) 1.25x (156 kg total N/ha)	5) Side-band – untreated urea
6) 1.50x (188 kg total N/ha)	6) Side-band – ESN®
7) 1.75x (219 kg total N/ha)	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

Data Collection:

Soil samples in the fall of 2018 were collected at three depth increments (0-15 cm, 15-30 cm and 30-60 cm) in order to determine fertilizer rate recommendations. Plant densities were determined by counting numbers of emerged plants on 2 x 1 meter row lengths per plot approximately four weeks after crop emergence. Normalized Difference Vegetation Index (NDVI) captures how much near infrared light is reflected compared to visible red. NDVI differentiates bare soil from the crop, comparing canopy thickness between treatments. Ratings for NDVI were conducted for each plot using a handheld Greenseeker. Yields were determined from cleaned harvested grain samples and corrected to the required moisture content. Protein for each plot was conducted as an additional seed quality parameter. Weather data was from Environment Canada.

Growing Conditions:

The 2019 growing season started out extremely dry in April with only 6.1mm of precipitation and continued into May with 12.7mm. The average temperatures of April and May fell well within the long-term average of 4.2°C and 9.1°C. The month of June also had normal temperatures (14.9°C) but precipitation increased by 28.6% (97.7mm) compared to the long-term average. July was a slightly colder month with a decline of 1.2^{o}C lower than the long-term average with higher than normal precipitation of 107.8 mm compared to 69.4mm. August was far below the long-term rainfall average with 18mm and cooler temperatures throughout the majority of the month with a few exceptionally warm days. September temperatures on average were normal, however, temperatures were higher at the beginning of the month and were substantially lower in the last 2 weeks normal. Precipitation in September was 37% higher compared to the long-term average. There was also a snow fall event that occurred on September 29th. On average, there was 120.5 less growing degree days compared to the long-term average (Table 2). The majority of these days fell between July and August, resulting in a delayed crop maturity.

Table 2. Mean monthly temperature, precipitation and growing degree day accumulated from April to September 2019 at Scott, SK

Year	April	May	June	July	August	Sept.	Average
--*Temperature (°C)* --							
2019	4.2	9.1	14.9	16.1	14.4	11.3	11.7
Long-term^{z}	3.8	10.8	14.8	17.3	16.3	11.2	12.4
--*Precipitation (mm)*--							
2019	6.1	12.7	97.7	107.8	18	41.8	284.1
Long-term^{z}	24.4	38.9	69.7	69.4	48.7	26.5	277.6
--*Growing Degree Days*--							
2019	35.2	185.3	295.4	333.3	291.1	202.6	1342.9
Long-term^{z}	44	170.6	294.5	380.7	350.3	192.3	1432.4

^{z}Long-term average (1985 - 2014)

Analysis

The data was statistically analysed using the PROC MIXED in SAS 9.4. The residuals were tested for normality and equal variance to meet the assumptions of ANOVA. The means were separated using a Tukey's Honestly Significant Difference (HSD) test with level of significance at 0.05. Replications were treated as random effect factor whiles treatments were fixed effect factors.

Results & Discussion

Plant densities

The effect of nitrogen application rates on plant densities was relatively limited (P= 0.0514), however, several trends were noted. The unfertilized check resulted in the highest plant density of 227 plants/m^2. Plant densities decreased as nitrogen rates increased with the exception of 1.25x (156 kg total N/ha) and the 1.50x (188 kg total N/ha) application rates. Overall, plant densities were the highest from 0x > 0.5x > 0.75x > 1.25x > 1.0x > 1.75x > 1.5x with plant densities of 227, 220, 216, 211, 203, 189, and 187 plants/m^2, respectively (data not shown).

The application timing (fall vs. spring) of ESN, SuperU, Agrotain and urea did not influence overall plant densities (Figure 5). Fall applications resulted in 190 plants/m^2 and spring applications resulted in 186 plants/m^2. Similar plant densities were seen between side banding versus broadcasting (fall and spring). Side banding resulted in two additional plants/m^2 (189 plants/m^2) compared to broadcasting (187 plants/m^2). The greatest plant density differences between treatments were seen when comparing products. The application of Agrotain resulted in the highest plant densities followed by urea, SuperU and ESN. Respectively, the plant densities were 193, 188, 187, and 184 plants/m^2.

NDVI

Nitrogen application rates significantly affected NDVI ratings (P=0.004). NDVI ratings were greatest at N applications based on the current recommended rate (1x; 125 kg total N/ha) and slightly below the recommendation (0.75x; 94 kg total N/ha). NDVI tended to decrease with N rates exceeding the recommended rates of 1.25 x (156 kg total N/ha) > 1.5x (188 kg total N/ha) > 1.75x (219 kg total N/ha). Additionally, NDVI ratings declined when N was applied lower than the recommended rate with the lowest rating occurring at unfertilized (0x) and 0.5x (68 kg total N/ha) application rates (Figure 1).

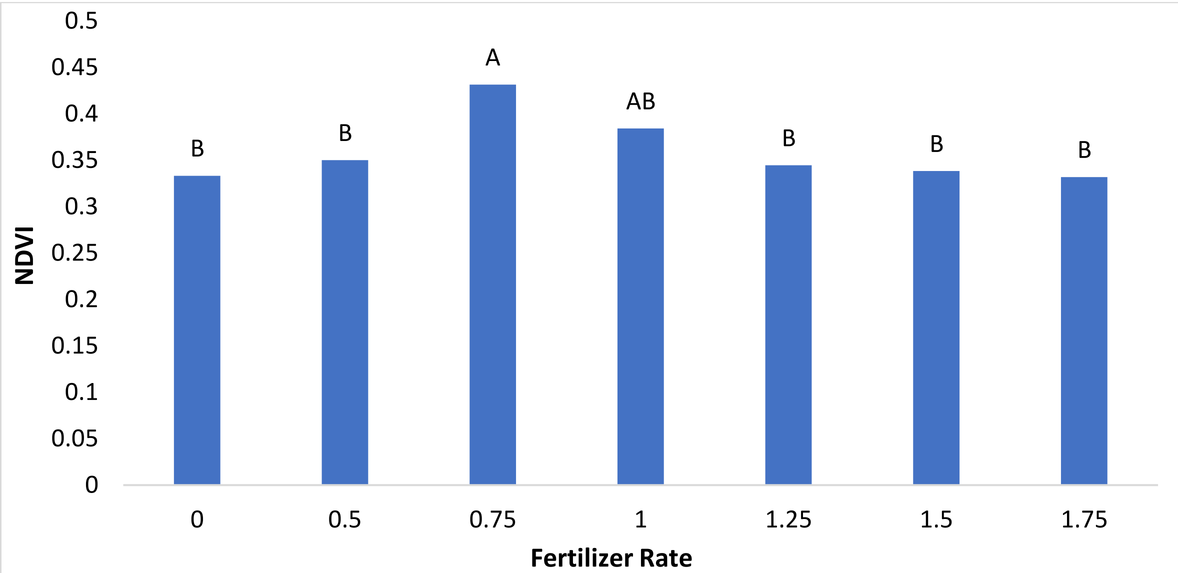

Figure 1. Comparison of NDVI approximately four weeks after crop emergence between fertilizer rates (0x, 0.5x, 0.75x, 1x, 1.25x, 1.5x and 1.75x of the soil test adjusted rate of 125 kg/ha total nitrogen (residual NO_3-N + fertilizer N)) in 4R Nitrogen Rate Management Principles in Spring Wheat in Scott, SK in 2019.

There was a significant interaction between application timing and fertilizer product (P=0.0479) on NDVI. This interaction indicates that the performance of each fertilizer was dependent on its application timing and placement. The two highest NDVI ratings were recorded when SuperU was fall and spring broadcasted while sidebanding SuperU resulted in the third lowest NDVI. The third highest NDVI rating was recorded with urea side-banded and in contrast had the lowest NDVI when it was fall broadcasted. Agrotain performed slightly better when it was applied as a fall broadcast > side-band> spring broadcast. In contrast, ESN worked best when spring broadcasted > side-banded > fall-broadcasted (Figure 2).

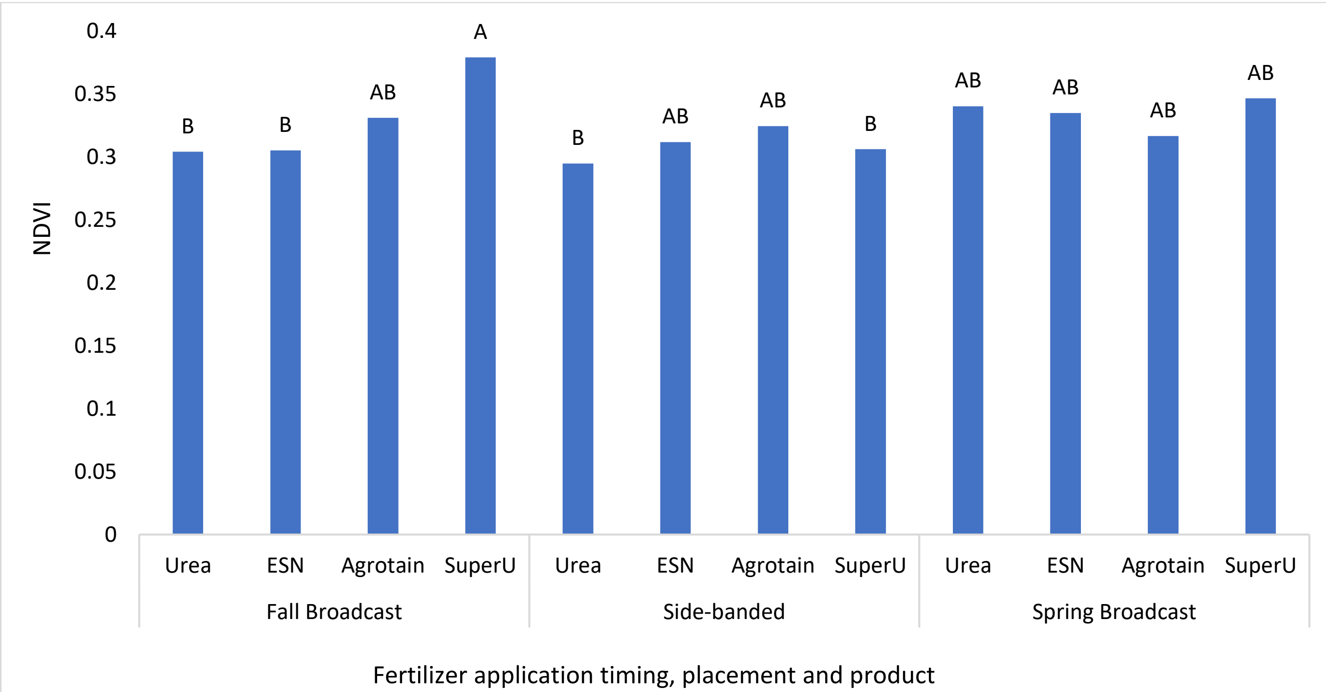

Figure 2. Comparison of NDVI approximately four weeks after crop emergence between fertilizer products (ESN, Urea, SuperU and Agrotain) and application timing (fall vs. spring) on spring wheat production at Scott, SK in 2019.

Yield & Protein

The rate of nitrogen applied had a significantly linear effect on yield indicating that the higher rates of nitrogen resulted in the greatest yields (P=0.0011) and that yield may have continued to increase if N rates exceeded 219 kg N/ac (1.75x) (Figure 3). The highest yield of 4396 kg/ha occurred with the highest N rates applied at 219 kg N/ac (1.75x) but it did not significantly vary from the recommended N rate (1x) (Figure 3). The difference between the highest yield and highest N rate to the recommended rate was 7% (4 bu/ac). Protein remained relatively stable among the higher N rates applied (1.75x to 1x) with an average protein of 14.9%. Yield remained relatively stable with a slight decline (1 bu/ac) when N rates were reduced by 25%, however, protein dropped dramatically from 14.8% to 14.0%. Yield was strongly reduced when N rates were reduced by 10 /ac and 16 bu/ac at the 0.5x and 0x rates. Protein followed a similar trend with a 7% and 11% reduction at 0.5x and 0x rate compared to the recommended rate (1x) (Figure 3).

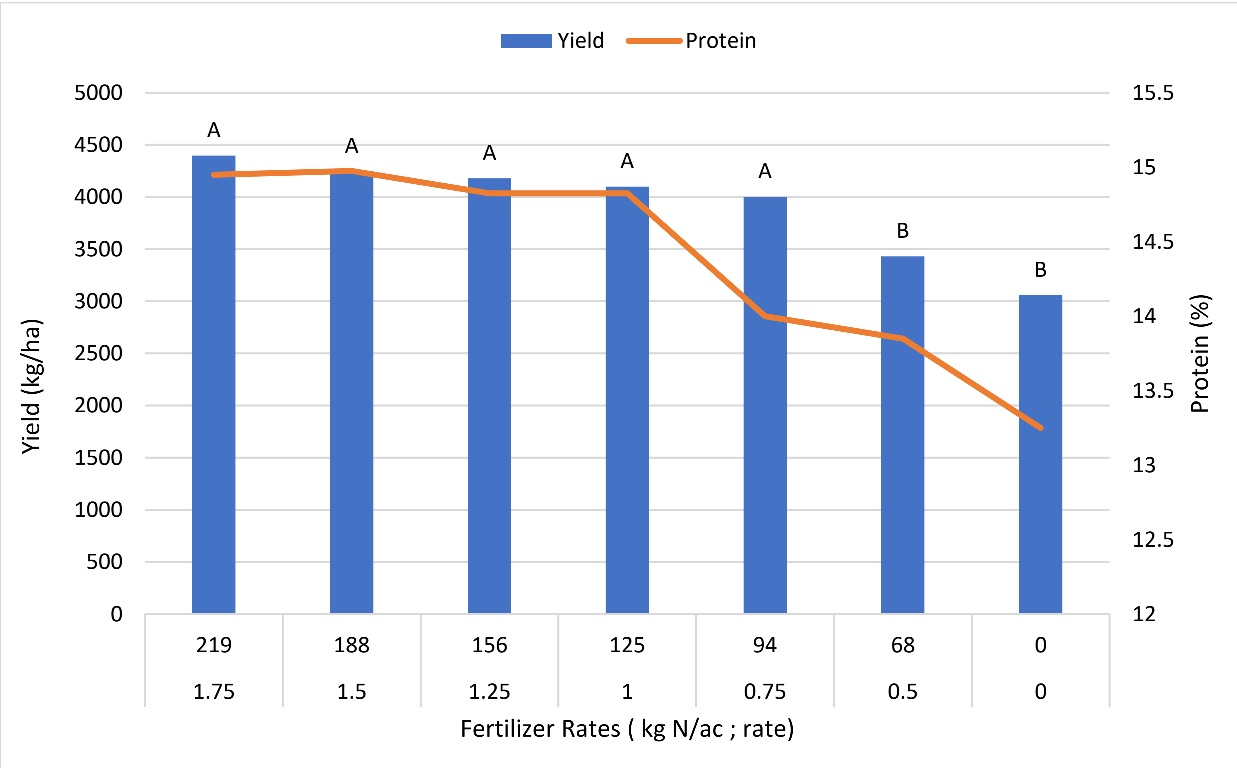

Figure 3. Comparison of yield (kg/ha) and protein between fertilizer rates (0x, 0.5x, 0.75x, 1x, 1.25x, 1.5x and 1.75x) of the soil test adjusted rate of 125 kg/ha total nitrogen (residual NO_3-N + fertilizer N) in 4R Nitrogen Rate Management Principles in spring wheat in Scott, SK in 2019.

Placement, time and product played a significantly role in spring wheat yield (P=0.0345), indicating the importance of using the right timing and placement (fall vs. spring broadcast vs. side banding) for the right product. The two highest yields were achieved with a fall and spring broadcast application of SuperU while side-banding SuperU was the least effective placement (Figure 4). Agrotain productivity was also influenced by placement as fall broadcasting and side-banding were relatively similar (2 bu/ac yield difference). In contrast, spring applications of Agrotain resulted in a 10% yield loss compared to fall applications. Fertilizer placement of ESN was less influenced by placement compared to the other two specialty products. The best application of ESN occurred with fall and spring broadcasting followed by side-banding, however, the total yield difference between the worst and best placement was a 4% yield difference. Urea was influenced by placement with the largest yield losses occurring with fall broadcast applications (7% yield loss) compared to spring broadcast applications. Side-banding and spring broadcasting resulted in similar yields. Protein was not significantly influenced by product or placement but a general trend can be noted. The protein levels amongst the four different fertilizers were slightly elevated for ESN> Agrotain> urea > SuperU. The lower protein recorded for SuperU is likely a function of the inverse relationship between yield and protein (high yield results in lower protein).

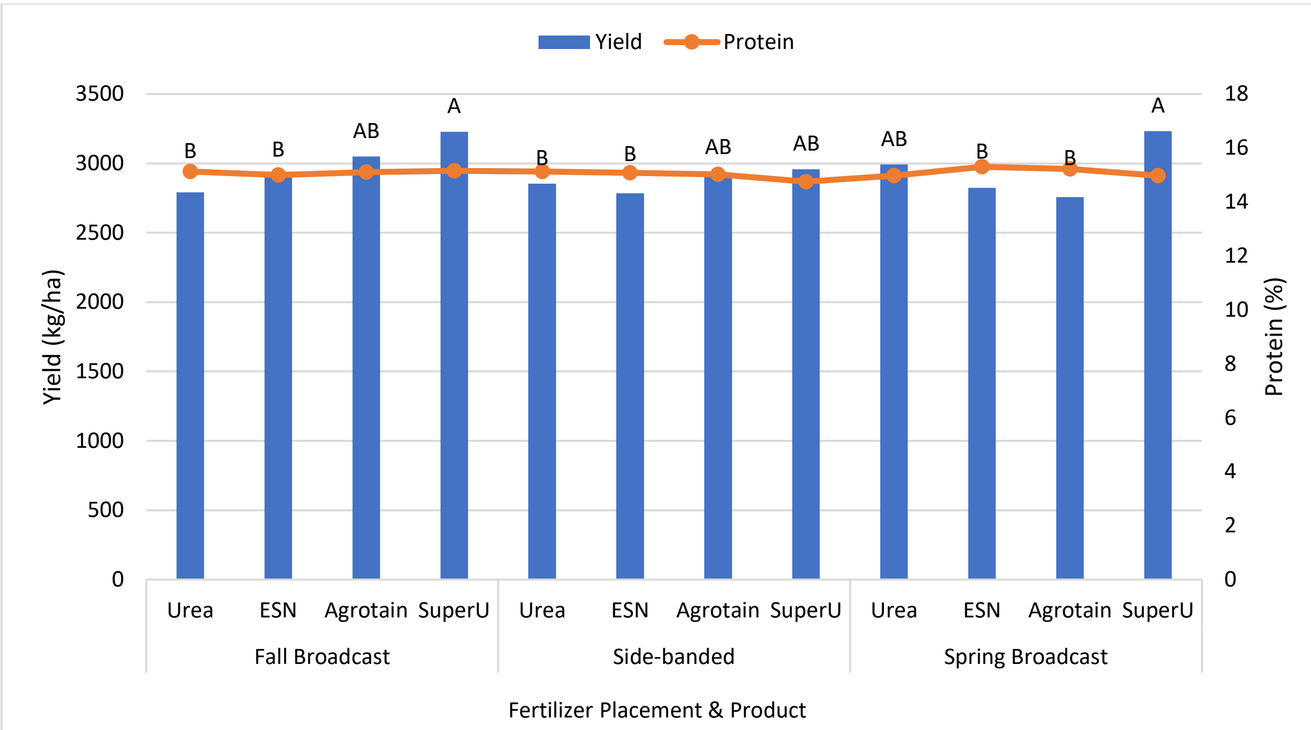

Figure 4. Comparison of yield (kg/ha) and protein (%) between fertilizer products (ESN, Urea, SuperU and Agrotain) and application timing (fall vs. spring) on spring wheat production at Scott, SK in 2019.

Discussion

The importance of utilizing the 4R principles of right rate, right source, right time and right placement and the interaction between these principles for improved crop production were apparent throughout the growing season. Crop establishment best occurred under proper fertilization rates but declined with each increase in nitrogen rate. The two highest N rates resulted in plant densities below the current spring wheat establishment recommendations of 23 to 28 plants/ft^2 (Government of Manitoba, 2019). Stand reductions can occur through ammonia toxicity and salt injury. In most instances, utilizing different N rates and products can influence overall plant density by reducing seed damage. When soil moisture conditions are very good to excellent during germination and emergence, higher N rates can be tolerated. With moist soil conditions, water dilutes the concentration of nitrogen molecules around the seed. In dry conditions, nitrogen fertilizer tends to produce higher concentrations of ammonia that can damage young seedlings. Utilizing products with a polymer coating (ESN) can allow for higher safe-rates by lowering the concentration of ammonia that is in contact with the seedling. Nitrogen in the form of urea should be placed further from the seed at the recommended rates when conditions are drier. Overall, nitrogen rates, placement and product can play a large role in plant density under certain environmental conditions and consequentially can influence overall plant growth, yield and seed quality.

Early season vigor captured through NDVI also highlighted the importance of the 4R practices. The greatest vegetation produced (highest NDVI value) occurred when N rates were applied based on the recommended rate or slightly lower. Applying excessive amounts of N was equivalent to no N applied, as both methods resulted in the lowest NDVI. A low NDVI indicates poor canopy closure and reduced vegetative growth. This can occur in two ways: (1) reduced plant densities due to seedling damage and (2) starving the plants of essential nutrients required for growth and development. This highlights the importance of utilizing the right rate as over applying N can cause more damage than if no fertilizer was applied at all.

The use of enhanced efficiency fertilizers used at the right time and placement also played a role in early season vigor. Enhanced efficiency fertilizers such as volatilization inhibitors (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). These benefits were quickly realized as the two highest NDVI ratings were recorded when SuperU was fall and spring broadcasted while urea fall broadcasted resulted in the one of the lowest NDVI. These results highlight the importance of the right rate, source, time and placement as each product performed best when it was properly applied to provide the greatest early season benefits.

Utilizing the 4R principles to improve early season vigor can often translate into increased development and productivity to ultimately enhance yields. The two highest yields which corresponded with the highest NDVI were achieved with a fall and spring broadcast application of SuperU while side-banding SuperU was the least productive placement.
Urea efficacy was also influenced by timing and placement with the largest yield losses occurring with fall broadcast applications (7% yield loss) compared to spring broadcast and side-banded applications. Achieving the highest yields can be achieved simply by following the basic 4R principles to ensure each product is placed at the right time and at the right rate.

Yield was also largely influenced by N application rate. The highest N rates applied at 219 kg N/ac (1.75x) resulted in the highest yields, however the difference between the highest yield and highest N rate to the recommended rate was only 4 bu/ac. This minor yield gain would not offset the costs incurred from the additional 94 kg/ha of fertilizer applied. In contrast, reducing the fertilizer rates by half had a 10 bu/ac yield loss that would not be economically profitable. Additionally, applying too low of a nitrogen rate can deplete soil nutrient reserves to ultimately result in future yield losses. Ensuring that all four principles are utilized together is essential to maximize productivity and profitability.

Conclusions and Recommendations

The importance of utilizing the 4R principles of right rate, right source, right time and right placement and the interaction between these principles for improved crop production were apparent throughout the growing season. Crop establishment best occurred under proper fertilization rates but declined with each increase in nitrogen rate. Stand reductions occurred through ammonia toxicity and salt injury occurred at the highest application rates. Early season vigor was reduced at both the highest N rates due to a reduced plant stand while the unfertilized spring wheat plants were starved of the essential nutrients required for growth and development. The importance of utilizing the right rate were clear as over applying N caused greater early season damage than if no fertilizer was applied at all. The spring wheat crop was able to compensate for the reduced plant densities and lower crop vigor at the highest N application rate (219 kg N/ac). Fertilizing the spring wheat in excess of the recommended rate (125 kg N/ac) resulted in the highest yields. However, the difference between the highest yield and highest N rate to the recommended N rate was only 4 bu/ac. This minor yield gain would not offset the costs incurred from the additional 94 kg/ha of fertilizer applied. In contrast, reducing the fertilizer rates by half had a 10 bu/ac yield loss that would not be economically profitable. Additionally, applying too low of a nitrogen rate can deplete soil nutrient reserves to ultimately result in future yield losses. Ensuring that all four principles are utilized together is essential to maximize productivity and profitability.

Supporting Information

Acknowledgements

Financial support was provided by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Canadian Agricultural Partnership (CAP) bi-lateral agreement. The Saskatchewan Ministry of Agriculture will be acknowledged in any written or oral presentations which may arise regarding this study. We would like to acknowledge Herb Schell and our summer staff, Keanna Svendsen-Striga, Jocelyn Leidl and Haile Wangler, for their technical assistance with project development and implementation for the 2019 growing season. This report will be distributed through WARC's website and included in WARC's and Agri-ARM annual reports.

Appendices

Appendix A

Table A1. Agronomic information for the study of nitrogen rates on spring wheat production (Trial 1) and the effects of placement, timing and source of nitrogen fertilizers (Trial 2) at Scott, 2019

	Product	Rate	Date
Fertilizer:			
Trial 1	*Based on protocol*		May 14th
Trial 2	*Based on protocol*		May 21st
	Fall Broadcast		October 19th
Seed:			
Trial 1	AAC Brandon	300 seeds/m^2	May 14th
Trial 2	AAC Brandon	300 seeds/m^2	May 21st
Herbicide:			
Pre-plant	Glyphosate 540 & AIM EC	1L/ac & 35mL/ac	May 19th
In-Crop	Axial & Buctril M	0.5L/ac & 0.4L/ac	June 26th
Desiccation	Heat LQ, Roundup 540 & Merge	42.8mL/ac, 0.67L/ac & 0.2L/ac	September 6th

Abstract

Abstract/Summary

The 4R nutrient principles of right rate, right source, right time and right placement and the interaction between these principles was demonstrated on spring wheat at Scott, SK 2019. For the first component of the demonstration, all nitrogen was side-banded urea and there was seven nitrogen 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 focused on nitrogen management options and consisted of a factorial combination of three timing/placement options (fall broadcast, side-band, and spring surface broadcast) and four nitrogen sources (untreated urea, ESN®, Agrotain® treated urea, and SuperU®). Crop establishment best occurred under proper fertilization rates but declined with each increase in nitrogen rate. Stand reductions occurred through ammonia toxicity and salt injury occurred at the highest application rates. Early season vigor was reduced at both the highest N rates due to a reduced plant stand while the unfertilized spring wheat plants were starved of the essential nutrients required for growth and development. The importance of utilizing the right rate were clear as over applying N caused greater early season damage than if no fertilizer was applied at all. The spring wheat crop was able to compensate for the reduced plant densities and lower crop vigor at the highest N application rate (219 kg N/ac). Fertilizing the spring wheat in excess of the recommended rate (125 kg N/ac) resulted in the highest yields. However, the difference between the highest yield and highest N rate to the recommended N rate was only 4 bu/ac. This minor yield gain would not offset the costs incurred from the additional 94 kg/ha of fertilizer applied. In contrast, reducing the fertilizer rates by half had a 10 bu/ac yield loss that would not be economically profitable. Additionally, applying too low of a nitrogen rate can deplete soil nutrient reserves to ultimately result in future yield losses. Ensuring that all four principles are utilized together is essential to maximize productivity and profitability.

Extension Activities:

This trial was mentioned but not viewed during the WARC/AAFC Annual Field Day on July 10 and attended by approximately 150 producers, agrologists and company or governmental representatives. The trial was clearly posted with ADOPT signage. A fact sheet will be generated and distributed on the WARC website as well as all Agri-ARM and WARC events to ensure the information will be transferred to producers.

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