2020 Annual Report

for the

Saskatchewan Ministry of Agriculture's

Agricultural Demonstration of Practices & Technologies (ADOPT) Program

and Fertilizer Canada

Project Title: Winter Wheat Response to Nitrogen Fertilizer Placement and Timing Options

(Project #20190371)

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Project Identification

1. **Project Title:** Winter wheat response to contrasting nitrogen fertilizer placement and timing options
2. **Project Number:** 20190371
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 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. This can create unique challenges for winter cereals since the growing season is much longer than for spring seeded crops and crop requirements for N are relatively small for the 8- to 9-month period after seeding. Consequently, and especially considering that establishment of winter cereals can be unpredictable, it is often recommended that N fertilizer applications be split between fall side- or mid-row band applications and an early spring surface broadcast application. This results in extra cost/labour for producers but reduces many of the risks associated with applying all the N either during seeding or in the early spring. Consequently, split applications of N tend to perform consistently well when averaged over multiple seasons and variable environmental conditions.

The objective of this project was to demonstrate winter wheat responses to N rate when all the N was applied as urea either in a sideband, early-spring broadcast, or a split-application with 50% of the N side-banded and the remainder as an early season broadcast application. While the N form was not varied in this demonstration and enhanced efficiency N products can be a good fit with winter cereals, urea is the most used N source in western Canada and an appropriate choice to demonstrate fundamental differences amongst the timing/placement options.

8. **Project Rationale:**

In order to minimize potential N fertilizer losses due to leaching and denitrification, the historical recommendation for winter wheat in southeast Saskatchewan has been to broadcast most of the crop's N fertilizer requirements early in the spring. However, the preferred product, ammonium nitrate (34-0-0), has not been available to purchase in bulk quantities for many years and producers have been forced to use other options. These include urea, which is less suitable for surface applications, or enhanced efficiency fertilizer (EEF) products (i.e., NBPT) which can reduce potential losses but also increase input costs and may provide inconsistent benefits depending on the specific conditions encountered. Liquid UAN is a popular choice for spring applications because it can be applied with a field sprayer and contains 25% NO_3-N which is not prone to volatilization; however, the NO_3-N is susceptible to leaching and denitrification which makes UAN a relatively poor option for fall applications.

Especially considering that urea is not ideal for broadcast applications and there is extra cost associated with spring applications, there is incentive to simply band the crop's entire N fertilizer requirements during seeding. This practice is operationally easiest for most farmers and, in many cases, the reduced potential for volatilization with in-soil banding can offset the higher potential for leaching or denitrification losses associated with fall applications. On the other hand, depending on when seeding is completed and the actual fall weather, applying high rates of N at seeding can cause excessive vegetative growth which can reduce winter hardiness along with N supply the following spring when it is needed most. Furthermore, establishment of winter wheat is not always successful, especially when it is dry; therefore, many growers are hesitant to commit their entire N budget prior to assessing crop condition in the early spring.

Deferring a large percentage of the N requirements until spring also has inherent risks, particularly if the following spring is extremely dry or application is delayed. Regardless of the form, N fertilizer needs precipitation to move it into the rooting zone before it can be utilized by crops. If this does not occur soon enough in the spring after the fertilizer is applied, early N deficiencies can lead to irreversible yield loss. Furthermore, dry conditions after application of untreated urea increases the potential for NH_3 volatilization, a permanent loss which results in lower use-efficiency of the applied N. Although spring, surface applied N tends to be more effective in wetter environments, when it is too wet, growers can have difficulty accessing fields to apply the fertilizer in a timely manner. This also potentially leads to early season deficiencies, particularly if not enough N was applied during seeding the previous fall.

Generally, side-banding a large proportion of the N works well under cool, dry conditions but can be risky in warmer, wetter regions where it is advisable to reserve much of the N until early spring. This is especially true in fields (or parts of the field) that are prone to flooding. Due to all these factors, split applications are often considered the least risky option over the long-term and for a broad range of conditions. The premise is to apply enough N up front to carry the crop through the fall and early spring and top up the remainder closer to when the crop will require it. This occurs after the crop has been successfully established and when the high-risk spring thaw period in the late winter/ early spring has passed.

Methodology and Results

9. Methodology:

A field trial with winter wheat was initiated in 2018-19 and repeated the following season (2019-20). The treatments were a factorial combination of three N fertilizer placement/timing strategies (100% sideband, 100% early spring broadcast, 50:50 split-application) and five N fertilizer rates (60, 90, 120, 150, 180 kg N/h). A control treatment where the only N fertilizer applied was 7 kg N/ha from seed-placed monoammonium phosphate (11-52-0) was also included. The N fertilizer rates were adjusted for residual soil NO_3-N and treatments (Table 1) were arranged in a four replicate RCBD.

Table 1. Winter wheat nitrogen fertilizer management by rate treatments

#	Timing / Placement	Total N Rate [Z]
1	N/A	7 kg N/ha [Y] + residual
2	Side-Band	60 kg N/ha
3	Side-Band	90 kg N/ha
4	Side-Band	120 kg N/ha
5	Side-Band	150 kg N/ha
6	Side-Band	180 kg N/ha
7	Spring Broadcast	60 kg N/ha
8	Spring Broadcast	90 kg N/ha
9	Spring Broadcast	120 kg N/ha
10	Spring Broadcast	150 kg N/ha
11	Spring Broadcast	180 kg N/ha
12	Split Application (50/50)	60 kg N/ha
13	Split Application	90 kg N/ha
14	Split Application	120 kg N/ha
15	Split Application	150 kg N/ha
16	Split Application	180 kg N/ha

[Z] Includes Residual NO_3-N (0-60 cm) based on fall composite soil samples

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

The plots were seeded into canola stubble using an eight-opener SeedMaster plot drill where the side-banded fertilizer is placed 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) this resulted in a side-banded fertilizer depth of approximately 1.5” (3.8 cm). Seeding was completed September 21-24, depending on the year (Table 2). The spring broadcast treatments were applied in the early spring (April 16 in 2019 and April 30 in 2020) with no incorporation and only natural precipitation events to move the fertilizer into the rooting zone. The variety used in both years was CDC Goldrush and the seeding rate was 400 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 when the crop was mature and fit for harvest with harvest dates ranging from August 16-17.

Various data were collected during the growing season and from the harvested grain. A Trimble® GreenSeeker® was used to measure the normalized difference vegetation index (NDVI) of each plot 2-3 times between early flag-leaf emergence and the initiation of heading. NDVI is a measure of above-ground vegetation and canopy closure – the values for each plot were averaged over this measurement period. At the milk stage, a Minolta Chlorophyll SPAD Meter SPAD-502 was used to measure the chlorophyll content of 8-10 flag-leaves per plot. Chlorophyll content is an indicator of plant condition and N sufficiency. Grain yields were determined from the harvested plot areas and 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 winter wheat nitrogen demonstrations at Indian Head in 2019 and 2020.

Factor / Field Operation	2018-19	2019-20
Previous Crop	Canola	Canola
Pre-emergent herbicide	894 g glyphosate/ha + 5 g florasulam/ha Sep-27-2018	894 g glyphosate/ha + 5 g florasulam/ha Sep-26-2019
Seeding Date	Sep-21-2018	Sep-24-2019
Seed Rate	400 seeds/m^2 (137 kg/ha)	400 seeds/m^2 (145 kg/ha)
kg P_2O_5-K_2O-S ha^{-1}	35-0-0	35-0-0
N Broadcast Applications	Apr-16-2019	Apr-30-2020
NDVI	Jun-11, Jun-19, and Jun-24 (2019)	Jun-17 and Jun-23 (2020)
SPAD	Jul-3 (2019)	Jul-7 (2020)
In-crop Herbicide	560 g MCPA/ha + 100 g clopyralid/ha + 15 g pyroxsulam/ha Jun-10-2019	560 g MCPA/ha + 100 g clopyralid/ha + 15 g pyroxsulam/ha Jun-5-2020
Foliar Fungicide	100 g prothioconazole/ha + 100 g tebuconazole/ha Jul-1-2019	100 g prothioconazole/ha + 100 g tebuconazole/ha Jul-3-2020
Pre-harvest herbicide	894 g glyphosate/ha Aug-8-2019	894 g glyphosate/ha Aug-6-2020
Harvest date	Aug-16-2019	Aug-17-2020

Response data from both seasons were combined prior to analyses. All data were analyzed using the Mixed procedure of SAS with Year (Yr), N timing/placement (TP), N rate (NR), and all possible interaction effects considered fixed. Replicate effects were treated as random. Heterogeneity in variance components between years was permitted; however, the more complex analyses were only use if doing so improved model fit. The control plots were incorporated into the orthogonal contrasts but removed for the factorial analyses. The orthogonal contrasts indicate whether responses to NR were linear, quadratic (curvilinear), or not significant. Treatment effects and differences between means were considered significant at $P \leq 0.05$ and Tukey's range test was used to separate treatment means.

10. Results:

Growing season weather and residual soil nutrients

In many respects, conditions for the two growing seasons were similar. The sites were well-drained, and the winter wheat was seeded into good moisture for germination, but dry weather followed. Both years, seeding was completed late enough that the weather between seeding and freeze-up was relatively cool; therefore, the potential for leaching or denitrification of the side-banded N was low. The early springs and subsequent growing seasons were drier than normal both years; however, there was always at least some rain shortly after the spring broadcast applications to start moving N into the rooting zone where it would be available to the crop and more protected against volatilization. Mean temperatures were 0.8-1 °C cooler than average over the entire April-August period; however, in 2019 this was mostly due to slightly lower temperatures in May and July while in

2020 it was cold temperatures in April that pulled the average down. Precipitation over the spring-summer period was 66% and 51% of the long-term (216 mm) in 2019 and 2020, respectively, but the previous fall was much wetter for the 2019-20 season and overall yield potentials and N responses were higher. Notably, spring broadcast N was applied 14 days later in 2020 than in 2019

Table 3. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2019 and 2020 growing seasons at Indian Head, SK. The growing season was April through July and data for the fall period (September through October) was also reported.

Year	Prev. Sep	Prev. Oct	April	May	June	July	Apr-July
	-- Mean Temperature (°C) --						
2019	7.6	1.3	3.9	8.9	15.7	17.4	11.5 (94%)
2020	11.9	1.0	0.3	10.7	15.6	18.4	11.3 (92%)
LT	11.5	4.0	4.2	10.8	15.8	18.2	12.3
	-- Total Precipitation (mm) --						
2019	39.6	25.5	25.3	13.3	50.4	53.1	142 (66%)
2020	120.8	10.9	22.0	27.3	23.5	37.7	111 (51%)
LT	35.3	24.9	22.6	51.8	77.4	63.8	216

Soil test results were based on composite samples that were collected each fall and used to adjust N rates and provide general background information for each site. The sites were within approximately 2 km of each other and the overall soil characteristics were similar. The soil was classified as an Indian Head heavy clay, pH ranged from 7.8-7.9 (0-15 cm), organic matter was 4.6-5.4%, and residual NO_3-N was considered very low ranging from 9-12 kg NO_3-N/ha (0-60 cm). Residual phosphorus was low while soil test potassium and sulphur levels were high.

Table 4. Soil test results for winter wheat demonstrations over two seasons at Indian Head, Saskatchewan.

Attribute / Nutrient	0-15 cm	15-60 cm	0-60 cm	0-15 cm	15-60 cm	0-60 cm
Crop Year	------------------- 2018-19 --------------------			------------------- 2019-20 --------------------		
pH	7.8	8.1	–	7.9	8.2	–
S.O.M. (%)	5.4	–	–	4.6		–
NO_3-N (kg/ha)^Z	5	7	12	6	3	9
Olsen-P (ppm)	3	–	–	2	–	–
K (ppm)	436	–	–	516	–	–
S (kg/ha)	22	34	56	11	27	38

Crop Responses to Nitrogen Management Strategies and Rates

Many of the detailed results tables are reserved for the Appendices but will be referred to, as necessary. The main effect of Year (Yr) was significant for all response variables (Table A-1); however, interactions between Yr and other factors indicate that the effects varied between seasons. The three-way Yr x TP x NR interactions were never significant.

Overall NDVI values were slightly lower in 2019 compared to 2020 but the general trends for NR responses were similar, despite the Yr x NR interaction. In both years, NDVI increased with NR and, when averaged over the two seasons, the response was curvilinear with NDVI levelling off at approximately 150 kg N/ha (Table 5). Focussing on TP and Yr x TP effects, there were no differences between strategies in 2019 while, in 2020, NDVI indicated increased vegetative growth with both side-banding and split applications relative to broadcasting all the N in the spring (Table 6). The two-year averaged responses mirrored those from 2020 in terms of letter groupings but the differences between treatments were smaller.

Table 5. Main effect means and orthogonal contrast results for average N rate (NR) effects on winter wheat normalized difference vegetation index (NDVI). The values are the average of 2-3 Trimble® GreenSeeker® measurements completed from the beginning of (Zadoks 37) to full flag leaf emergence (Zadoks 49). Means within a group (Yr x NR; NR) followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Treatment	2019	2020	Average
	-- *NDVI (flag leaf)* --		
Control	0.327	0.354	0.341
60 kg N/ha	0.383 e	0.475 c	0.429 C
90 kg N/ha	0.395 e	0.525 b	0.460 B
120 kg N/ha	0.414 de	0.541 b	0.477 B
150 kg N/ha	0.411 de	0.584 a	0.497 A
180 kg N/ha	0.427 d	0.590 a	0.509 A
S.E.M.	0.0104		0.0073
	-- *p-value* --		
NR – linear	<0.001	<0.001	<0.001
NR – quad	0.004	<0.001	<0.001

Table 6. Main effect means for average N timing/placement (TP) effects on winter wheat normalized difference vegetation index (NDVI). The N source was untreated urea (46-0-0) for all management strategies. The values are the average of 2-3 Trimble® GreenSeeker® measurements completed from the beginning of (Zadoks 37) to full flag leaf emergence (Zadoks 49). Means within a group (Yr x TP; TP) followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Treatment	2019	2020	Average
	-- *NDVI (flag leaf)* --		
Control	0.327	0.354	0.341
Side-Banded	0.406 c	0.568 a	0.487 A
Spr. Broadcast	0.406 c	0.508 b	0.457 B
50:50 Split App.	0.405 c	0.553 a	0.479 A
S.E.M.	0.0094		0.0067

The TP x NR interaction for NDVI was significant but the responses to NR were reasonably consistent regardless of how or when the N was applied (Table A-2; Fig. 1). The interaction appeared to be due to greater separation between management strategies at more modest N rates (where N was most limiting) and a tendency for NDVI to drop off slightly at the highest N rate. The latter may have been due to stand reductions at the highest rates of side-banded N but we do not have emergence counts to verify whether this was the case.

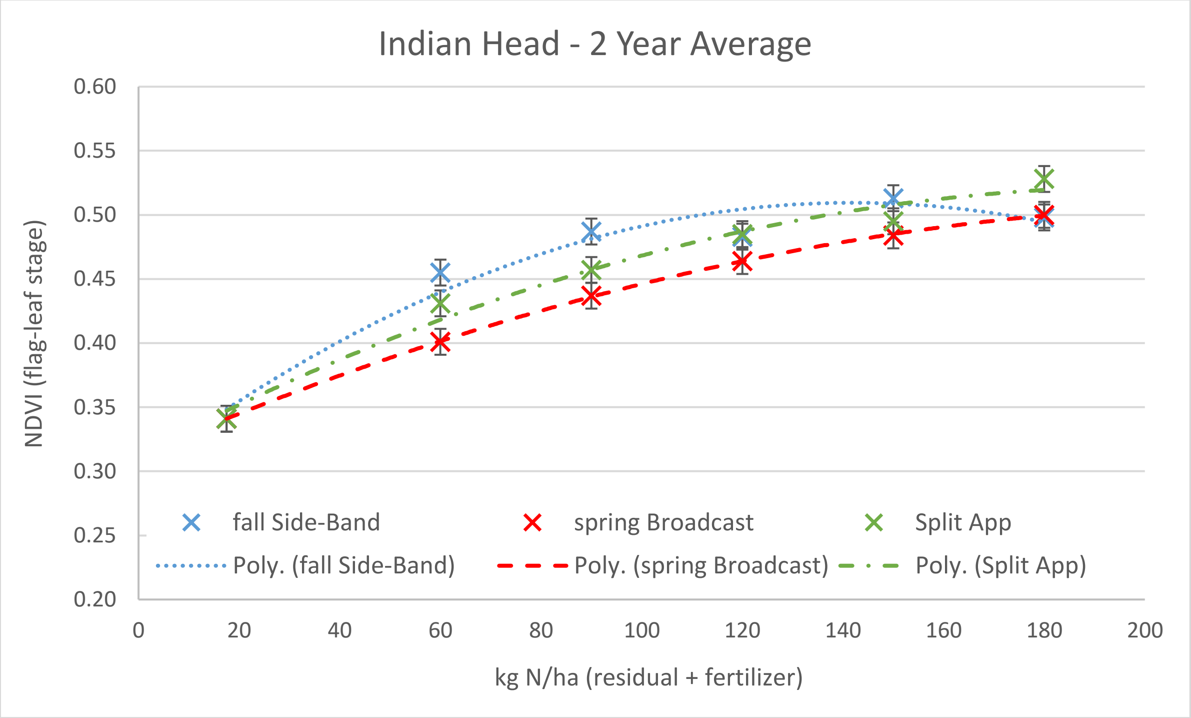

Figure 1. Winter wheat NDVI (early through late flag-leaf stage) response to nitrogen rate and placement/timing options when averaged over a two-year period at Indian Head (2019-2020).

The chlorophyll (SPAD) measurements were affected by NR with an Yr x NR interaction but not by TP (Table A-1). Although SPAD values where fertilizer was applied were always much higher than the control, there were no significant differences among the fertilized treatments in 2019, thus the response was quadratic (Table 7). There was greater separation amongst N rates in 2020 and a more linear response. When averaged over the two seasons, the chlorophyll response to NR was quadratic, peaking at 150 kg N/ha but with no significant differences between rates of 90-180 kg N/ha. Differences between timing/placement options were not significant when averaged across N rates (Table 8) and there was no TP x NR interaction (Table A-3; Fig. 2).

Table 7. Main effect means and orthogonal contrast results for average N rate (NR) effects on winter wheat chlorophyll meter (Minolta SPAD-502) measurements at the milk stage. The values are the average of 8-10 individual flag-leaf measurements per plot. Means within a group (Yr x NR; NR) followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Treatment	2019	2020	Average
		SPAD (milk stage)	
Control	39.7	34.8	37.2
60 kg N/ha	45.5 a	38.6 b	42.1 B
90 kg N/ha	48.0 a	43.8 ab	45.9 A
120 kg N/ha	47.6 a	45.9 a	46.8 A
150 kg N/ha	48.6 a	47.3 a	48.0 A
180 kg N/ha	47.4 a	47.5 a	47.4 A
S.E.M.	0.91	1.52	0.89
		p-value	
NR – linear	<0.001	<0.001	<0.001
NR – quad	<0.001	0.116	<0.001

Table 8. Main effect means for average N timing/placement (TP) effects on winter wheat chlorophyll meter (Minolta SPAD-502) measurements at the milk stage. The N source was untreated urea (46-0-0) for all management strategies. The values are the average of 8-10 individual flag-leaf measurements per plot. Means within a group (Yr x TP; TP) followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Treatment	2019	2020	Average
		SPAD (milk stage)	
Control	39.7	34.8	37.2
Side-Banded	47.8 a	44.8 a	46.3 A
Spr. Broadcast	47.5 a	44.1 a	45.8 A
50:50 Split App.	47.0 a	45.0 a	46.0 A
S.E.M.	0.75	1.20	0.89

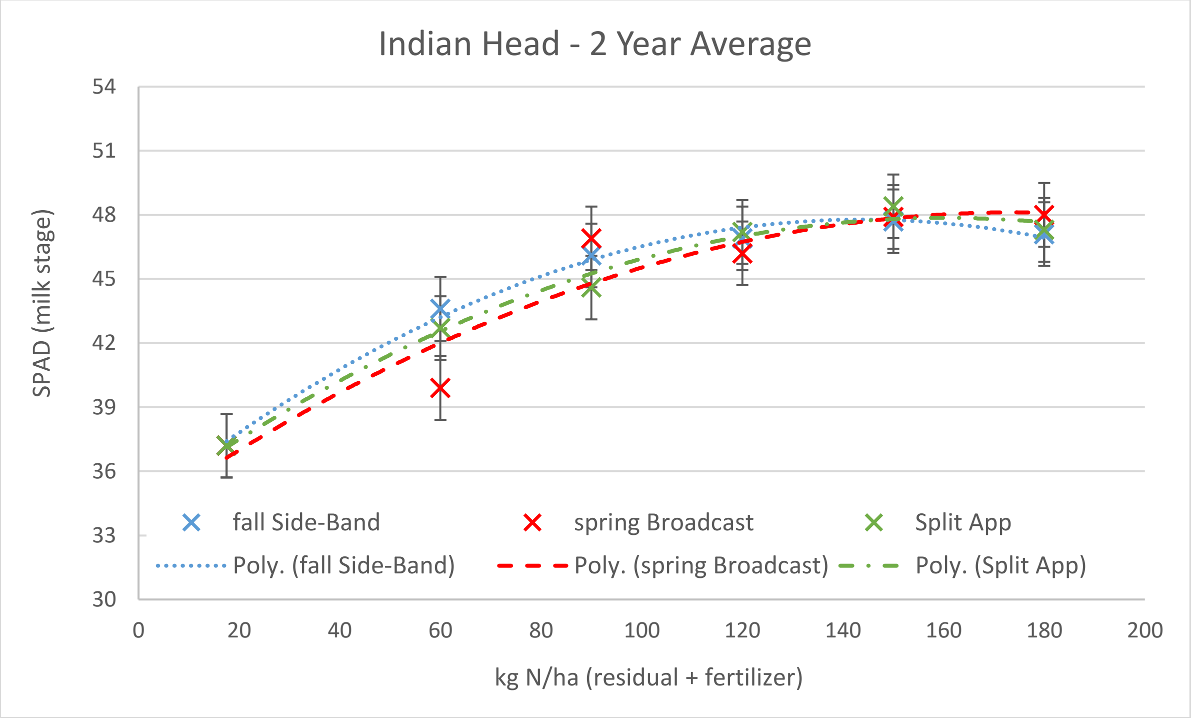

Figure 2. Winter wheat chlorophyll meter (Minolta SPAD-502) measurement response to nitrogen rate and placement/timing options when averaged over a two-year period at Indian Head (2019-2020). The measurements were of flag-leaves when the crop was at the milk stage.

Winter wheat grain yield was affected by both TP and NR with a significant Yr x NR and Yr x TP interactions (Table A-1). As expected, N fertilization always increased grain yield; however, the Yr x NR interaction occurred because the crop responded to higher rates and the increase was larger in 2020 compared to the previous season (Table 9). In 2019, yields levelled off at 90-120 kg N/ha and the highest yields achieved were 57% higher than the control. By contrast, yields in 2020 levelled off at 150-180 kg N/ha with a maximum increase of 118% over the control. Similar yields were achieved regardless of the timing/placement strategy in 2019. In 2020, the results favoured fall sideband over spring broadcast placement. Yields with the split N applications were intermediate, not significantly different from the fall side-banding but higher than with 100% spring broadcasting. In 2020, yields relative to side-banding and averaged across rates were 92% with spring broadcasting and 97% with the split applications. When averaged over the two-year period and across rates, yields trended highest with side-banding and lowest with spring broadcasting but all were within 179 kg/ha of each other and no differences between timing/placement strategies were significant when averaged across rates. With no TP x NR or Yr x TP x NR interaction, the N timing/placement effects on yield were reasonably consistent across application rates within each season (Figs. 3-4) and when averaged across seasons (Fig. 5).

Table 9. Main effect means and orthogonal contrast results for average N rate (NR) effects on winter wheat grain yield. Means within a group (Yr x NR; NR) followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Treatment	2019	2020	Average
	Grain Yield (kg/ha)		
Control	2570	2171	2370
60 kg N/ha	3467 e	3240 e	3353 D
90 kg N/ha	3708 d	3894 cd	3801 C
120 kg N/ha	3869 bcd	4219 b	4044 B
150 kg N/ha	3978 bc	4599 a	4288 A
180 kg N/ha	4038 bc	4731 a	4385 A
S.E.M.	88.0		62.2
	p-value		
NR – linear	<0.001	<0.001	<0.001
NR – quad	<0.001	<0.001	<0.001

Table 10. Main effect means for average N timing/placement (TP) effects on winter wheat yield. Means within a group (Yr x TP; TP) followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Treatment	2019	2020	Average
	Grain Yield (kg/ha)		
Control	2570	2171	2370
Side-Banded	3817 b	4287 a	4052 A
Spr. Broadcast	3793 b	3952 b	3873 A
50:50 Split App.	3825 b	4171 a	3998 A
S.E.M.	82.2		58.1

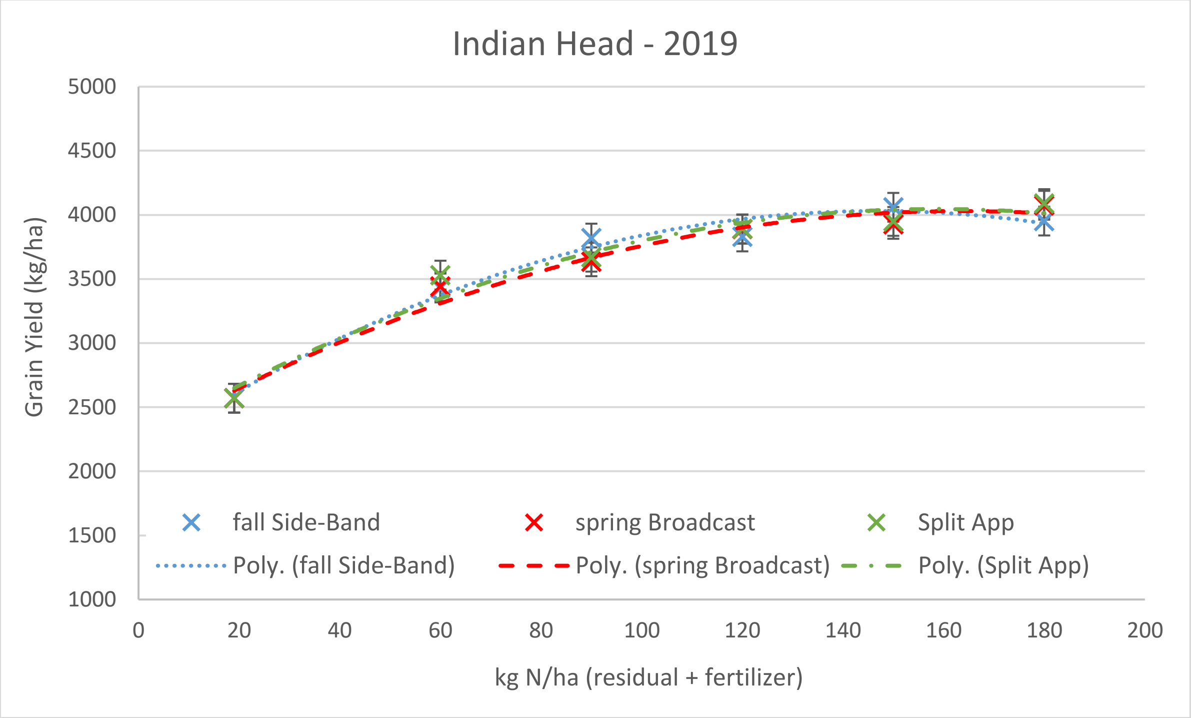

Figure 3. Winter wheat yield response to nitrogen rate and placement/timing options at Indian Head 2019.

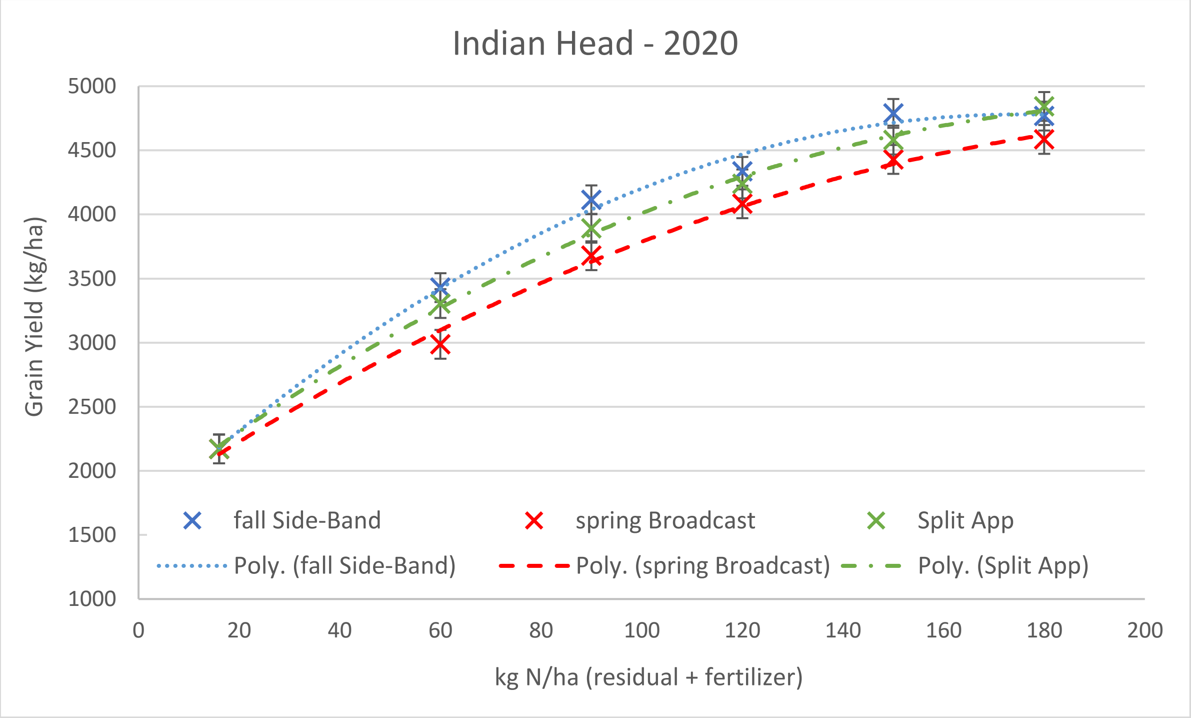

Figure 4. Winter wheat yield response to nitrogen rate and placement/timing options at Indian Head 2020.

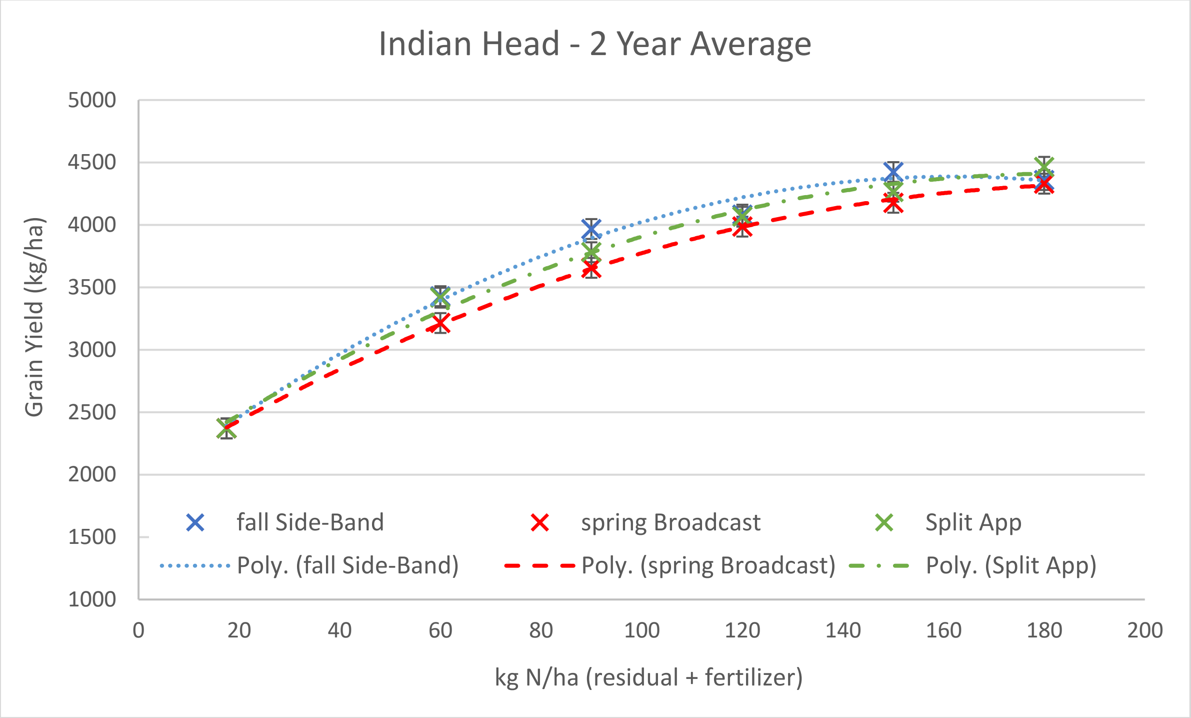

Figure 5. Winter wheat yield response to nitrogen rate and placement/timing options when averaged over a two-year period at Indian Head (2019-2020).

Grain protein was affected by TP and NR with a Yr x NR interaction but no TP x NR or Yr x TP interactions. This indicated that N fertilizer timing/placement effects on winter wheat protein were consistent across rates and growing seasons (Table A-1). The grain protein responses to NR were consistent over the two seasons in that they always increased quadratically with NR and were generally more responsive than yield; however, there were subtle differences due to the stronger N response in 2020. In 2020, there was less separation amongst the lower rates compared to 2019 but greater separation at the highest rates (Table 11). Consequently, when averaged over the two seasons, the protein response to N rate was more linear and protein increased significantly with each incremental increase in N rate. The timing/placement effects on protein varied. In 2019, protein concentrations were within 0.3% of each other with no significant differences between TP strategies. In 2020, the range between TP treatments was less than 0.5% but the values were slightly lower than the previous season and higher for the 100% spring broadcast treatments (11.7%) than for either the sideband or split applications which did not significantly differ from one another (11.2-11.4%). When averaged across seasons, the results from the multiple comparisons test indicated slightly but significantly higher protein with spring broadcasting (12.3% versus 11.9-12.1%). The slightly lower yields and higher protein concentrations with spring broadcast N suggests that the spring applied N may not have been available early enough to mitigate yield losses but was not necessarily lost altogether and still contributed to higher protein later in the season. While the effect was more pronounced in 2020, the trends were similar in both years. Figures 6-8 depict the results for individual treatments in 2019, 2020, and on average; however, there were no significant TP x NR interactions detected for this variable for individual seasons.

Table 11. Main effect means and orthogonal contrast results for average N rate (NR) effects on winter wheat grain protein concentrations. Means within a group (Yr x NR; NR) followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Treatment	2019	2020	Average
	Grain Protein (%)		
Control	10.40	9.86	10.13
60 kg N/ha	11.02 d	9.84 e	10.43 E
90 kg N/ha	12.29 c	10.28 e	11.29 D
120 kg N/ha	13.18 b	11.82 c	12.50 C
150 kg N/ha	13.54 ab	12.25 c	12.90 B
180 kg N/ha	13.81 a	13.02 b	13.41 A
S.E.M.	0.127		0.090
	p-value		
NR – linear	<0.001	<0.001	<0.001
NR – quad	0.006	<0.001	0.106

Table 12. Main effect means for average N timing/placement (TP) effects on winter wheat grain protein concentrations. The N source was untreated urea (46-0-0) for all management strategies. Means within a group (Yr x TP; TP) followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Treatment	2019	2020	Average
	Grain Protein (%)		
Control	10.40	9.86	10.13
Side-Banded	12.63 a	11.24 c	11.93 B
Spr. Broadcast	12.93 a	11.72 b	12.33 A
50:50 Split App.	12.75 a	11.36 c	12.06 B
S.E.M.	0.110		0.078

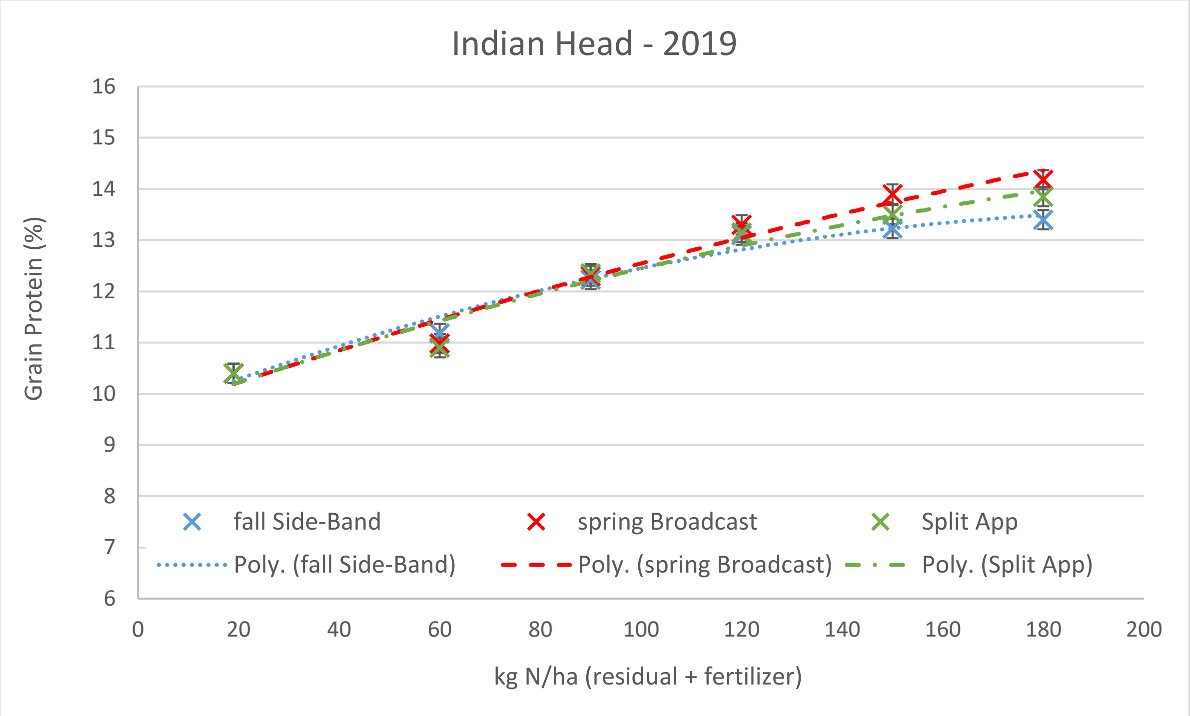

Figure 6. Winter wheat grain protein response to nitrogen rate and placement/timing options at Indian Head in 2019.

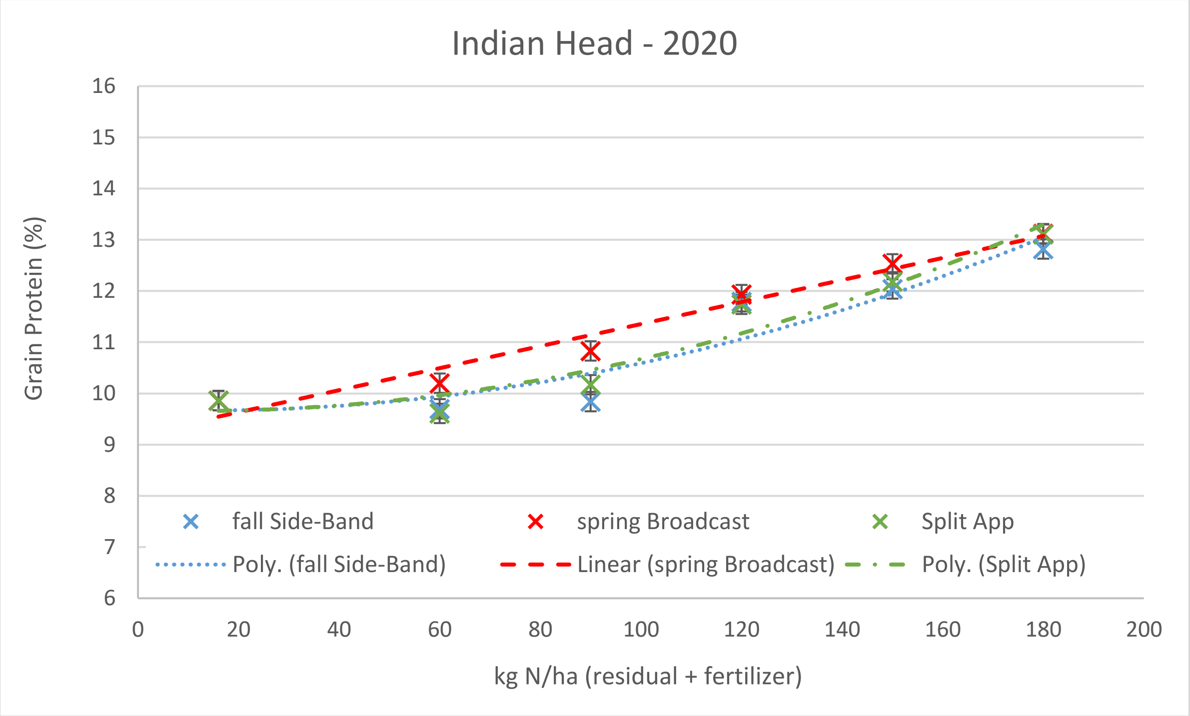

Figure 7. Winter wheat grain protein response to nitrogen rate and placement/timing options at Indian Head in 2020.

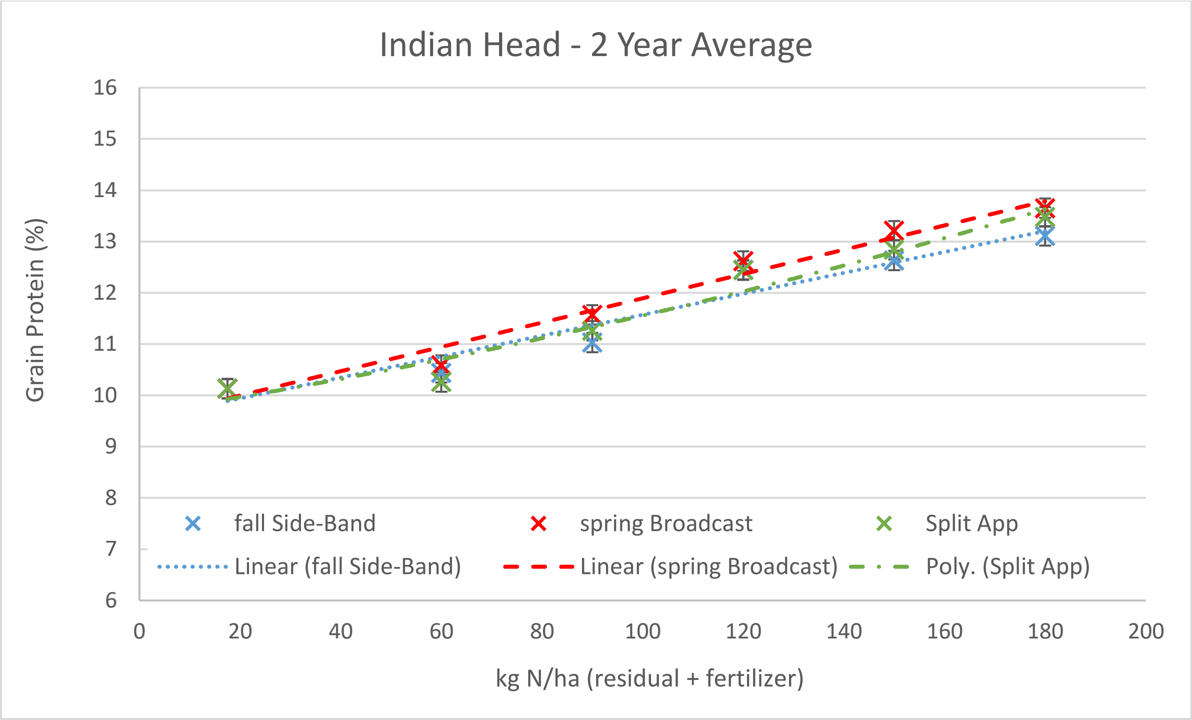

Figure 8. Winter wheat grain protein response to nitrogen rate and placement/timing options when averaged over a two-year period at Indian Head (2019-2020).

Extension Activities

This project was discussed, and the plots were toured by approximately 125 guests at the Indian Head Crop Management Field Day on July 16, 2019. In addition to Chris Holzapfel introducing the project and discussing the specific objectives, Dan Heaney with Fertilizer Canada led a broader discussion on 4R nitrogen management principles as they pertain to western Canadian crop production. The plots were also visited on July 12 during a tour for approximately 60 Federated Co-operatives Limited (FCL) agronomists from throughout the province. Chris Holzapfel presented highlights from the project at an Independent Consulting Agronomists Network (ICAN) meeting in Regina (Feb. 4) and the IHARF Winter Meeting and AGM in Balgonie (Feb. 5) with an estimated combined attendance of 175-200 people. Due to COVID-19 restrictions we were not able to show the field trials during any summer field tours or workshops in 2020; however, highlights of this work were shared 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 winter wheat response to fundamentally different N management strategies and a wide range of rates. Under the conditions encountered, the optimal N rate for maximizing yield was 120-150 kg N/ha (fertilizer plus soil residual). As expected, protein generally peaked at slightly higher rates than yield but the economic merits of fertilizing for maximum protein will vary depending on where the grain is marketed whether any premiums/discounts are in effect. In general, the potential for N losses due to denitrification or leaching with fall-applied N was reasonably low with relatively late seeding, dry weather, and well-drained sites. As for the spring broadcast treatments, the growing seasons were dry overall but well-timed precipitation events occurred both years which helped to mitigate losses due to NH_3 volatilization and start moving the N into the rooting zone where it could be available to the crop. All factors considered, each of the N timing/placement strategies performed reasonably well; however, the results support our initial hypotheses that split applications will provide the most flexibility in terms of allowing crop establishment to be assessed before committing the full N requirements while also buffering against potential losses of fall applied N and early season N deficiencies. That said, the added cost of two-pass seeding/fertilization systems must also be considered. Side-banded N is safest when later seeding is combined with relatively dry/cool climates and well drained fields. Deferring at least some of the crop's N requirements is increasingly recommended if seeding occurs early or in regions that are warmer and wetter on average. Deferring all of a winter cereal crop's N fertilizer requirement until spring is not recommended unless, perhaps, residual soil N levels are particularly high or relatively large quantities of N are provided with the phosphorus and/or sulphur fertilizer products.

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 while the seed was provided by McDougal Acres Ltd.

13. Appendices:

Table A-1. Overall tests of fixed effects for selected winter wheat response variables. The unfertilized control treatment was excluded so that the data could be analysed as a factorial. Heterogeneous estimates of variance components (between years) were permitted but the more complex model was only utilized if doing so improved the model fit.

	NDVI (avg)	SPAD (milk)	Yield (kg/ha)	Protein (%)
Variance Components (Year)	------------------------------- AICc ^{Z} (smaller is better) -------------------------------			
Homogeneous	**-358.8**	559.2	**1241.8**	**117.9**
Heterogeneous	-357.6	**547.9**	1243.7	119.6
Source	-- p-values --			
Year (Yr)	<0.001	0.023	0.023	<0.001
Time/Place (TP)	<0.001	0.868	<0.001	<0.001
N Rate (NR)	<0.001	<0.001	<0.001	<0.001
TP x NR	0.010	0.761	0.230	0.342
Yr x TP	<0.001	0.740	0.001	0.408
Yr x NR	<0.001	0.035	<0.001	<0.001
Yr x TP x NR	0.212	0.463	0.995	0.134

^{Z} Akaike information criterion – used to determine the most appropriate model for each variable

Table A-2. Individual treatment means and orthogonal contrast results for winter wheat NDVI. The values are the average of 2-3 Trimble® GreenSeeker® measurements completed from the beginning of (Zadoks 37) to full flag leaf emergence (Zadoks 49). Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Treatment	2019	2020	Average
	---------- *NDVI* ----------		
Control (7 kg N/ha + residual)	0.327	0.354	0.341
	---------- *100% Side-Banded Urea* ----------		
60 kg N/ha	0.381 a	0.530 cde	0.455 EF
90 kg N/ha	0.405 a	0.569 a-d	0.487 A-E
120 kg N/ha	0.409 a	0.557 bcd	0.483 B-E
150 kg N/ha	0.420 a	0.607 ab	0.513 AB
180 kg N/ha	0.418 a	0.579 a-d	0.498 A-D
fSB – linear	<0.001	<0.001	<0.001
fSB – quad	0.006	<0.001	<0.001
	---------- *100% Spring Broadcast Urea* ----------		
60 kg N/ha	0.379 a	0.423 f	0.401 G
90 kg N/ha	0.389 a	0.484 ef	0.437 FG
120 kg N/ha	0.414 a	0.514 de	0.464 C-F
150 kg N/ha	0.417 a	0.551 bcd	0.484 B-E
180 kg N/ha	0.432 a	0.567 a-d	0.500 ABC
sBC – linear	<0.001	<0.001	<0.001
sBC – quad	0.098	0.015	0.004
	---------- *50:50 Split Application of Urea* ----------		
60 kg N/ha	0.389 a	0.473 ef	0.431 FG
90 kg N/ha	0.392 a	0.522 de	0.457 DEF
120 kg N/ha	0.418 a	0.552 bcd	0.485 B-E
150 kg N/ha	0.397 a	0.593 abc	0.495 A-E
180 kg N/ha	0.432 a	0.624 a	0.528 A
Split – linear	<0.001	<0.001	<0.001
Split – quad	0.048	<0.001	<0.001
S.E.M.	0.0143		0.0101

Table A-3. Individual treatment means and orthogonal contrast results for winter wheat chlorophyll (Minolta SPAD-502) measurements at the milk stage. The values are the average of 8-10 flag leaves per plot. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Treatment	2019	2020	Average
	SPAD (milk stage)		
Control (7 kg N/ha + residual)	39.7	34.8	37.2
	100% Side-Banded Urea		
60 kg N/ha	45.8 a	41.3 ab	43.6 AB
90 kg N/ha	49.3 a	43.0 ab	46.1 AB
120 kg N/ha	48.5 a	45.2 ab	46.9 AB
150 kg N/ha	48.1 a	47.3 ab	47.7 A
180 kg N/ha	47.2 a	47.0 ab	47.1 AB
fSB – linear	<0.001	<0.001	<0.001
fSB – quad	<0.001	0.208	0.004
	100% Spring Broadcast Urea		
60 kg N/ha	46.4 a	33.4 b	39.9 B
90 kg N/ha	48.1 a	45.7 ab	46.9 AB
120 kg N/ha	46.1 a	46.3 ab	46.2 AB
150 kg N/ha	48.6 a	47.2 ab	47.9 A
180 kg N/ha	48.2 a	47.8 ab	48.0 A
sBC – linear	<0.001	<0.001	<0001
sBC – quad	0.023	0.303	0.039
	50:50 Split Application of Urea		
60 kg N/ha	44.4 a	41.0 ab	42.7 AB
90 kg N/ha	46.6 a	42.7 ab	44.6 AB
120 kg N/ha	48.2 a	46.2 ab	47.2 A
150 kg N/ha	49.2 a	47.5 a	48.4 A
180 kg N/ha	46.9 a	47.7 a	47.3 A
Split – linear	<0.001	<0.001	<0.001
Split – quad	0.012	0.235	0.020
S.E.M.	1.49	2.58	1.49

Table A-4. Individual treatment means and orthogonal contrast results for winter wheat grain yield. The values are corrected for dockage and to 14.5% seed moisture content. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, $P \leq 0.05$).

Treatment	2019	2020	Average
	Grain Yield (kg/ha)		
Control (7 kg N/ha + residual)	2570	2171	2370
	100% Side-Banded Urea		
60 kg N/ha	3430 c	3429 hij	3429 FG
90 kg N/ha	3819 abc	4114 d-g	3967 CD
120 kg N/ha	3828 abc	4336 b-f	4082 BC
150 kg N/ha	4059 a	4788 ab	4423 A
180 kg N/ha	3952 ab	4767 ab	4359 AB
fSB – linear	<0.001	<0.001	<0.001
fSB – quad	<0.001	<0.001	<0.001
	100% Spring Broadcast Urea		
60 kg N/ha	3441 c	2987 j	3214 G
90 kg N/ha	3634 abc	3678 ghi	3656 EF
120 kg N/ha	3888 abc	4083 efg	3986 CD
150 kg N/ha	3926 ab	4429 a-e	4177 ABC
180 kg N/ha	4075 a	4585 abc	4330 AB
sBC – linear	<0.001	<0.001	<0.001
sBC – quad	<0.001	<0.001	<0.001
	50:50 Split Application of Urea		
60 kg N/ha	3530 bc	3305 ij	3417 FG
90 kg N/ha	3670 abc	3892 fgh	3781 DE
120 kg N/ha	3891 abc	4238 c-f	4065 BCD
150 kg N/ha	3949 ab	4580 a-d	4265 ABC
180 kg N/ha	4088 a	4842 a	4465 A
Split – linear	<0.001	<0.001	<0.001
Split – linear	<0.001	<0.001	<0.001
S.E.M.	112.39		79.5

Table A-5. Individual treatment means and orthogonal contrast results for winter wheat grain protein. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, $P \leq 0.05$).

Treatment	**2019**	**2020**	**Average**
	--------- *Grain Protein (%)* ---------		
Control (7 kg N/ha + residual)	10.40	9.86	10.13
	--------- *100% Side-Banded Urea* ---------		
60 kg N/ha	11.18 e	9.70 f	10.44 EF
90 kg N/ha	12.23 d	9.84 f	11.03 DE
120 kg N/ha	13.10 bcd	11.79 c	12.45 C
150 kg N/ha	13.23 bc	12.04 bc	12.63 BC
180 kg N/ha	13.40 ab	12.82 ab	13.11 AB
fSB – linear	<0.001	<0.001	<0.001
fSB – quad	0.002	<0.001	0.297
	--------- *100% Spring Broadcast Urea* ---------		
60 kg N/ha	10.98 e	10.20 ef	10.59 EF
90 kg N/ha	12.30 cd	10.83 cd	11.57 D
120 kg N/ha	13.30 ab	11.93 bc	12.62 BC
150 kg N/ha	13.90 ab	12.53 abc	13.21 AB
180 kg N/ha	14.18 a	13.12 a	13.65 A
sBC – linear	<0.001	<0.001	<0.001
sBC – quad	0.207	0.062	0.662
	--------- *50:50 Split Application of Urea* ---------		
60 kg N/ha	10.90 e	9.61 f	10.26 F
90 kg N/ha	12.35 cd	10.17 ef	11.26 D
120 kg N/ha	13.15 bcd	11.74 cd	12.44 C
150 kg N/ha	13.50 ab	12.18 abc	12.84 BC
180 kg N/ha	13.85 ab	13.11 a	13.48 A
Split – linear	<0.001	<0.001	<0.001
Split – quad	0.066	<0.001	0.037
S.E.M.	0.189		0.134

Abstract

14. Abstract/Summary

With funding from the Saskatchewan Ministry of Agriculture's ADOPT program and Fertilizer Canada, a nitrogen (N) management demonstration with winter wheat was initiated in 2018-19 and repeated in 2019-20. Field trials were located near Indian Head in the thin-Black soil zone of southeast Saskatchewan. The treatments were a factorial combination of three N timing/placement strategies (100% sideband; 100% spring surface broadcast; 50:50 split application) and five N rate (60, 90, 120, 150, and 180 kg N/ha) plus a control where no supplemental N was applied. Rates included residual soil NO_3-N and the N source in all treatments was untreated urea. The response variables measured were 1) NDVI, 2) flag-leaf chlorophyll (SPAD) measurements at the milk stage, 3) grain yield, and 4) grain protein. Both NDVI and SPAD measurements increased with N fertilization and were reasonably good in-season indicators of the overall N status of the crops. Compared to the SPAD values, NDVI appeared to be more sensitive and consistent with yield when it came to timing/placement effects. Winter wheat yields were optimized with 120-150 kg N/ha (soil plus fertilizer) while protein responded similarly but continued increasing with slightly higher N rates compared to yield. Regarding timing/placement effects, environmental conditions were not especially conducive to leaching or denitrification losses of fall-applied N and timely spring precipitation events reduced volatile losses and increased availability of the spring applied N. Yields tended to be highest with side-banded N while protein was higher with spring broadcast applications. Results with the split applications were intermediate but generally more like the fall side-band applications. This suggests that losses were not necessarily higher with the spring applied N; however, the availability shifted later into the growing season at the expense of yield but in favour of protein synthesis. While all three strategies performed reasonably well under the conditions encountered, split-applications provide the most flexibility and can buffer against both fall/early spring N losses and early-spring N deficiencies. This demonstration is being conducted for a third and final season in 2020-21.
