2014 Annual Report

for the

Agricultural Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Nitrogen Fertilizer Management Options for Winter Wheat

(Project #20130306)

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Project Identification

1. **Project Title:** Nitrogen Fertilizer Management Options for Winter Wheat
2. **Project Number:** 20130313
3. **Producer Group Sponsoring the Project:** Indian Head Agricultural Research Foundation
4. **Project Location(s):** Indian Head (R.M. #156) and Scott (R.M. #380), Saskatchewan
5. **Project start and end dates (month & year):** September 2012-January 2014
6. **Project contact person & contact details:**

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Objectives and Rationale

7. **Project objectives:**

The specific objectives were to demonstrate 1) the feasibility of side-banding the entire N requirements of winter wheat at seeding relative to top-dressing N fertilizer in the early spring, 2) the potential merits of using slow release N products (i.e. Super-Urea®, ESN®) for both fall side-band and spring broadcast applications and 3) the potential merits of split N applications where some N is applied at seeding and the remainder is top-dressed in the early spring.

8. **Project Rationale:**

To minimize N fertilizer losses due to leaching and denitrification in the fall and early spring, the traditional recommendation for winter wheat in southeast Saskatchewan has been to broadcast N fertilizer early in the spring. However, the preferred product, ammonium nitrate (AN; 34-0-0), has not been readily available for many years and winter wheat growers have been forced to explore other options. The traditional alternatives include applying urea or anhydrous ammonia at seeding (side- or mid-row band) or surface applications of liquid urea ammonium nitrate or urea early in the spring. Due to the long growing season of winter wheat and high potential for environmental losses with fall or surface applications of N, slow release products such as Super Urea or ESN may have merit for use with this crop. Urea ammonium nitrate (UAN) has been a popular alternative to ammonium nitrate for spring broadcasting because it can be applied with a sprayer and has reduced the potential for NH_3 loss relative to urea; however, fall applications of UAN are not recommended because the NO_3-N, which comprises 25% of the total N in UAN, is susceptible to leaching and denitrification. This demonstration was a continuation from 2012-13 and is intended to provide updated information on the various options available to producers for managing N fertility in winter wheat. Access to this information will help growers choose appropriate methods of N fertilization that simultaneously fit their operations and minimize risks of economic loss and environmental harm.

Methodology and Results

9. **Methodology:**

Winter wheat field demonstrations / trials were established in both 2012 and 2013 at Indian Head (50°32’25” N, 103°38’50”) and 2013 at Scott (52°21’35” N, 108°50’05” W), Saskatchewan. A total of 24 N fertilizer treatments were arranged in a four replicate RCBD where the rates, placement methods, timings and forms of N fertilizer were varied. The applied N rates were 0, 75 or 115 kg N ha^{-1} and the forms were untreated urea (46-0-0), ESN (44-0-0), SUPERU (SU; 46-0-0), UAN (28-0-0) or AN (34-0-0). ESN and SUPERU are both slow release forms of N but they work in different manners. ESN is a polymer coated urea that dissolves within the coating and slowly diffuses into the soil solution to become plant available. SUPERU utilizes chemical urease and nitrification inhibitors which slow the conversion of urea to the highly available, but vulnerable NO_3 form. In 2012-13, NutriSphere-N was used in place of SUPERU. Nutrisphere-N is also purported to reduce or inhibit volatilization and nitrification; however, the active ingredients and modes of action of SUPERU and Nutrisphere-N differ and performance of the two products is not necessarily expected to be equal. An additional BMP treatment was included in 2013-14 where AN was spring broadcast at rates based on commercial soil test recommendations (ALS Laboratories). For fall applications, granular fertilizers were placed in a side-band (SB) or mid-row band at Scott while, for spring applications, granular fertilizer was broadcast on the soil surface (BC). Liquid UAN was always applied in surface dribble-band (DB). The specific treatments that were evaluated are described in Table 1.

Table 1. Treatments evaluated in ADOPT winter wheat N management demonstrations at Indian Head and Scott, Saskatchewan.

#	Rate (kg N ha^{-1})	Formulation	Timing / Placement
1	0	N/A	N/A
2	75	Urea	Fall / Side-band
3	75	ESN	Fall / Side-band
4	75	NSN/SU	Fall / Side-band
5	75	UAN	Fall / Surface-band
6	115	Urea	Fall / Side-band
7	115	ESN	Fall / Side-band
8	115	NSN/SU	Fall / Side-band
9	115	UAN	Fall / Surface-band
10	75	AN	Spring / Broadcast
11	75	Urea	Spring / Broadcast
12	75	ESN	Spring / Broadcast
13	75	NSN/SU	Spring / Broadcast
14	75	UAN	Spring / Surface-band
15	115	AN	Spring / Broadcast
16	115	Urea	Spring / Broadcast
17	115	ESN	Spring / Broadcast
18	115	NSN/SU	Spring / Broadcast
19	115	UAN	Spring / Surface-band
20	115	Urea	Split Application (40/60)
21	115	ESN	Split Application (40/60)
22	115	NSN/SU	Split Application (40/60)
23	115	UAN	Split Application (40/60)
24	Soil Test Recommended	AN	Spring / Broadcast

Urea – untreated urea; ESN – Environmentally Smart Nitrogen®; NSN – NutriSphere-N® (2012-13)
SU – SUPERU™ (2013-14); UAN – urea ammonium nitrate

Selected agronomic information for each of the individual sites is provided in Table 2. Weeds were controlled using registered herbicide options and foliar fungicide applications varied from site to site. At physiological maturity, the plots were terminated with pre-harvest glyphosate at all sites and were subsequently straight-combined when fit and dry.

Table 2. Selected agronomic information for winter wheat fungicide and seed treatment demonstrations and Indian Head and Scott, Saskatchewan.

Factor / operation	Indian Head 2012-13	Indian Head 2013-14	Scott 2013-14
Previous Crop	Canola (LL)	Canola (LL)	—
Soil Test	22-Oct-12	4-Nov-13	30-Aug-13
Pre-emergent herbicide	n/a	PrePass XC (28-Sep-13)	glyphosate (9-Sep-13)
Cultivar	CDC Buteo	Moats	AC Radiant
Seed Treatment	none	Raxil Pro	Raxil T
Seeding Date	14-Sep-12	23-Sep-13	11-Sep-13
Row spacing	30 cm	30 cm	25 cm
kg P_2O_5-K_2O-S ha^{-1}	35-48-16	35-48-16	22-17-5
Fall Fertilizer Apps.	17-Oct-13	13-Oct-13	11-Sep-14
Spring Fertilizer Apps.	17-May-13	2-May-14	1-May-14
In-crop herbicide 1	0.34 l/ac MCPA ester 500 + 5g florasulam/ac^{-1} (May-26-13)	0.4 l/ac Buctril M	0.5 l/ac Mextrol 450 (30-May-14)
In-crop herbicide 2	0.2 l/ac Simplicity (Jun-11-13)	0.2 l/ac Simplicity (8-Jun-14)	—
Flag-leaf fungicide	none	0.2 l/ac Twinline (24-Jun-14)	none
Anthesis fungicide	none	0.324 l/ac Prosaro (11-Jul-14)	none
Plant Density	29-May-13	n/a	12-May-14
NDVI	13-Jun-13	18-Jun-14	n/a
Harvest Aid	0.75 l/ac Matrix (18-Aug-13)	0.7 l/ac Roundup Ultra2 (Aug-20-14)	1.5 l/ac R/T 540 (Aug-12-14)
Harvest date	27-Aug-13	Aug-29-14	Aug-28-14

Data collection activities varied slightly from site-to-site but included spring plant density measurements, NDVI, grain yield, grain protein concentration, test weight and thousand kernel weight (TKW). Grain yields were determined by weighing the entire harvest sample, determining moisture content and percent dockage for each plot using CGC methods and converting the weights to kg ha^{-1} of clean seed corrected to a uniform moisture content of 14.5%. Cleaned grain samples were analyzed for percent protein using an

NIR instrument and values were recorded to the nearest 0.1%. Where applicable, test weights were determined using standard CGC methodology and TKW was determined by mechanically counting and weighing 500 seeds. Growing season weather data were estimated using data from the nearest Environment Canada weather station for each location.

Data were analyzed using the mixed procedure of SAS with Tukey's studentized range test to separate individual treatment means. Due to the large number of treatments and lack of a true factorial design, contrasts were used to make specific comparisons including: 75 kg N ha^{-1} versus 115 kg N ha^{-1}, fall application versus spring application (on average and for individual fertilizer forms), spring ammonium nitrate versus alternative forms and placements, and untreated urea versus individual slow release N forms for both spring and fall application.

10. Results:

Soil and Weather Information

Soil samples were collected late in the fall and analysed for residual nutrients. Subsequent fertilizer recommendations at Indian Head were made based on target wheat yields of 4032 kg ha^{-1} (Table 2). The recommended N rates were 99, 124 and 100 kg N ha^{-1} at Indian Head in 2013, 2014 Scott in 2014.

Table 3. Selected agronomic information for winter wheat fungicide and seed treatment demonstrations and Indian Head and Scott, Saskatchewan.

Soil Property / Recommendation	Indian Head 2012-13	Indian Head 2013-14	Scott 2013-14
	--	kg/ha	--
Residual NO_3-N (60 cm)	33	21	47
Residual P (15 cm)	12	8	52
Residual K (15 cm)	—	>605	>672
Residual S (60 cm)	—	20	>199
pH (15 cm)	7.5	7.8	6.2
Target Yield (kg/ha)	3360	3360	4707
Recommended N	99	124	100

Weather conditions in the fall of 2012 at Indian Head were such that it was extremely dry at seeding and there were no significant precipitation events until late in October (data not shown); therefore, no plants emerged in the fall at this site. The winter wheat emerged in mid-May with good initial soil moisture levels but dry conditions persisted until June when precipitation levels were 134% of the long-term average (Table 4). Precipitation in July was 79% of the long-term average and August was extremely dry. Temperatures for the 2013 growing season at Indian Head were above normal in May and below normal in July but were otherwise close to the long-term (1981-2010) average. In 2014 at Indian Head, May was again drier and warmer than average. June was extremely wet and slightly cooler than average, July was dry and hot, and August was also wet with close to normal temperatures. At Scott, temperatures and precipitation amounts were close to normal for much of the growing season, although June was slightly cooler than normal and July received 178% of the long-term normal precipitation.

Table 4. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2013 and 2014 growing seasons at Indian Head, SK.

Year	May	June	July	August	Avg. / Total
	---------------------------- Mean Temperature (°C) ----------------------------				
2014	14.4	14.4	17.3	17.4	15.9
2013	11.9	15.3	16.3	17.1	15.2
Long-term	10.8	15.8	18.2	17.4	15.6
	------------------------------- Precipitation (mm) -------------------------------				
2014	36.0	199.2	7.8	142.2	385
2013	17.1	103.8	50.4	6.1	177
Long-term	51.8	77.4	63.8	51.2	244

Table 5. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2014 growing season at Scott, SK.

Year	May	June	July	August	Avg. / Total
	---------------------------- Mean Temperature (°C) ----------------------------				
2014	9.3	13.9	17.4	16.8	14.4
Long-term	10.8	15.3	17.1	16.5	14.9
	------------------------------- Precipitation (mm) -------------------------------				
2014	23.1	60.4	128	30.1	194.5
Long-term	36.3	61.8	72.1	45.7	215.9

Indian Head 2013: Field Trial Results

Individual treatment means for plant density, NDVI, grain yield and protein concentrations at Indian Head in 2012-13 are presented along with the overall *F*-test results in Table 12. At this site, the winter wheat did not emerge in the fall due to dry conditions and mortality was high with an overall mean density of only 53 plants m^{-2} despite a seeding rate of 300 seeds m^{-2}. Interestingly and somewhat unexpectedly, N fertilizer treatment had a significant impact on crop establishment with increases in the range of 45-51% when some or all of the N requirements were applied in the fall, particularly when side-banded at seeding (Table 13). Timing appeared to less important than placement, as there was no difference in plant populations when UAN was dribble-banded on the soil surface in either the spring or fall. The improved establishment with fall-banded N was also evident in the NDVI (measured at the start of stem elongation) whereby the results mirrored those observed for plant densities (Table 14).

The observed benefits of fall-applied N at Indian Head carried through to grain yield with significantly higher yields achieved with either the fall or split applications versus spring applications (Table 6). While the overall response to N was significant ($P < 0.001$) with the treatments that received N out yielding the check by 42% on average, the greatest responses were with fall applications, particularly when N fertilizer was side-banded. For example, averaged across rates and products, fall applied N resulted in a 48% yield increase over check while spring applications only increased yields by only 20% and produced significantly lower yields than the treatments where either some, or all of the N was applied in the fall (*P* < 0.001). There was no yield difference between the 75 and 115 kg N ha^{-1} rates (*P* = 0.467) and no significant benefit to either ESN or Nutrisphere-N over urea, regardless of application time.

Table 6. Contrast results for comparisons of specific groups of winter wheat N fertilizer treatments and their effect on grain yield at Indian Head, 2013.

		Grain Yield			
#	Contrast	Group A	Group B	B – A	Pr > *F*
	(Group A vs. Group B)	------ kg ha^{-1} ------			-- *p-value* --
1	Check vs. Rest	2834	3843	1009	<0.001
2	75 N vs. 115 N	3718	3803	85	0.467
3	Fall vs. Spring	4196	3389	(-807)	<0.001
4	Fall vs. Split	4296	4213	(-83)	0.636
5	Spring vs. Split	3413	4213	800	<0.001
6	Fall SB urea vs. Spring BC Urea	4175	3510	(-665)	0.009
7	Fall SB ESN vs. Spring BC ESN	4239	3356	(-883)	<0.001
8	Fall SB NSN vs. Spring BC NSN	4306	3163	(-1143)	<0.001
9	Fall DB UAN vs. Spring DB UAN	4062	3528	(-534)	0.034
10	Spring BC AN vs. Fall SB Urea	3507	4175	668	0.009
11	Spring BC AN vs. Fall SB ESN	3507	4239	732	0.004
12	Spring BC AN vs. Fall SB NSN	3507	4306	799	0.002
13	Spring BC AN vs. Fall DB UAN	3507	4062	555	0.027
14	Spring BC AN vs. Spring BC Urea	3507	3510	3	0.991
15	Spring BC AN vs. Spring BC ESN	3507	3356	(-151)	0.542
16	Spring BC AN vs. Spring BC NSN	3507	3163	(-344)	0.167
17	Spring BC AN vs. Spring DB UAN	3507	3528	21	0.932
18	Fall SB Urea vs. Fall SB ESN	4175	4239	64	0.797
19	Fall SB Urea vs. Fall SB NSN	4175	4306	131	0.596
20	Fall SB Urea vs. Fall DB UAN	4175	4062	(-113)	0.649
21	Spring BC Urea vs. Spring BC ESN	3510	3356	(-154)	0.535
22	Spring BC Urea vs. Spring BC NSN	3510	3163	(-347)	0.164
23	Spring BC Urea vs. Spring DB UAN	3510	3528	18	0.941

The overall mean winter wheat protein concentration was 12.4%; however significant treatment differences were detected with a range of 11.7-12.9% amongst individual treatments (Table 12). Protein concentrations in the control did not significantly differ from those of the combined fertilized treatments (Table 7); however, there was a slight tendency for higher protein with N fertilizer (12.2 versus 12.5%; *P* = 0.107) and protein concentrations were higher at the 115 kg N ha^{-1}rate versus the 75 kg N ha^{-1} rate (*P* = 0.001). Despite the higher grain yields associated with fall applications, there were no significant differences between the fall, spring or split application times (*P* = 0.10-0.53) for protein concentration.

Table 7. Contrast results for comparisons of specific groups of winter wheat N fertilizer treatments and their effect on percent grain protein at Indian Head, 2013.

		Protein Concentration			
#	Contrast	Group A	Group B	B – A	Pr > *F*
	(Group A vs. Group B)	----------------------	%	----------------------	-- *p-value* --
1	Check vs. Rest	12.2	12.5	0.3	0.107
2	75 N vs. 115 N	12.3	12.6	0.3	0.001
3	Fall vs. Spring	12.4	12.5	0.1	0.260
4	Fall vs. Split	12.4	12.5	0.1	0.529
5	Spring vs. Split	12.7	12.5	(-0.2)	0.102
6	Fall SB urea vs. Spring BC Urea	12.5	12.5	0.0	0.891
7	Fall SB ESN vs. Spring BC ESN	12.3	12.6	0.3	0.067
8	Fall SB NSN vs. Spring BC NSN	12.3	12.7	0.4	0.019
9	Fall DB UAN vs. Spring DB UAN	12.5	12.1	(-0.4)	0.067
10	Spring BC AN vs. Fall SB Urea	12.4	12.5	0.1	0.376
11	Spring BC AN vs. Fall SB ESN	12.4	12.3	(-0.1)	0.732
12	Spring BC AN vs. Fall SB NSN	12.4	12.3	(-0.1)	0.631
13	Spring BC AN vs. Fall DB UAN	12.4	12.5	-0.1	0.338
14	Spring BC AN vs. Spring BC Urea	12.4	12.5	-0.1	0.451
15	Spring BC AN vs. Spring BC ESN	12.4	12.6	0.2	0.134
16	Spring BC AN vs. Spring BC NSN	12.4	12.7	0.3	0.058
17	Spring BC AN vs. Spring DB UAN	12.4	12.1	(-0.3)	0.374
18	Fall SB Urea vs. Fall SB ESN	12.5	12.3	(-0.2)	0.219
19	Fall SB Urea vs. Fall SB NSN	12.5	12.3	(-0.2)	0.172
20	Fall SB Urea vs. Fall DB UAN	12.5	12.5	0.0	0.945
21	Spring BC Urea vs. Spring BC ESN	12.5	12.6	0.1	0.451
22	Spring BC Urea vs. Spring BC NSN	12.5	12.7	0.2	0.246
23	Spring BC Urea vs. Spring DB UAN	12.5	12.1	(-0.4)	0.103

Indian Head 2014: Field Trial Results

Conditions at seeding were more typical at Indian Head in the fall of 2013 and, although seeding was somewhat late (September 23), the winter wheat got off to a relatively good start with 3-4 full leaves established before going into dormancy. Individual treatment means and *F*-test results for Indian Head 2013-14 are provided in the Appendices (Table 15).

Spring plant density measurements were not completed at this site; however, NDVI was measured and able to detect significant treatment effects on early season growth ($P < 0.001$). The overall mean NDVI was 0.407 while individual treatment means ranged from 0.313 in the check to as high as 0.474 amongst the fertilized treatments. While the NDVI of the check was lower than for the combined fertilized treatments ($P < 0.001$), there was no difference between the 75 and 115 kg N ha^{-1} rates ($P = 0.780$) or fall versus spring applications ($P = 0.743$) at this site (Table 16). There was however, an apparent benefit to split applications with higher NDVI values compared to both the strictly fall ($P = 0.034$) and spring ($P = 0.06$) application times. For urea and SuperU, NDVI was similar for both fall and spring applications but for ESN, fall-side banding appeared to be preferable to spring broadcast ($P = 0.013$) and, for DB UAN, spring application was preferable to a fall application ($P = 0.008$). NDVI values with spring applied AN were similar to fall applied ESN ($P = 0.624$) and fall applied SUPERU ($P = 0.129$) but higher than the fall applied urea or UAN and all of the other products when the entire N requirements were applied in the spring ($P < 0.001$-0.017). For either spring or fall N application timing, mean NDVI with urea did not significantly differ from that achieved with ESN or SUPERU when applied at the same time ($P = 0.089$-0.751) with the exception of fall-applied UAN where NDVI was lower than for spring application ($P = 0.004$). This result was expected as UAN is not a recommended product for fall application since 25% of N in UAN is already in the NO_3 form which is susceptible to leaching and denitrification.

Winter wheat yields at Indian Head in 2014 averaged 4910 kg ha^{-1} and ranged from 2933 kg ha^{-1} in the check to 3726-5759 kg ha^{-1} amongst the fertilized treatments and there was a consistent yield response to N fertilizer whereby all individual fertilized treatments yielded significantly higher than the check ($P \leq 0.05$; Table 15). Contrasts comparing yields of specific groups of treatments are presented in Table 8. As expected, the check yield was significantly lower than the combined fertilized treatments ($P < 0.001$) and yields at the 115 kg N ha^{-1} rate exceeded those at the 75 kg N ha^{-1} rate ($P < 0.001$) indicating a strong overall response to N fertilizer. In contrast to the previous season, spring N applications yielded slightly higher (4%) than fall applications when averaged across products and rates ($P = 0.047$). Split applications of N also produced higher grain yield than when all N was applied in the fall (6.7%; $P = 0.022$) while yields with spring application and split application were similar ($P = 0.337$). Despite the overall lower yields associated with fall application, closer inspection of the data reveals that most of this difference was due to the UAN where yields were 21% higher when applied in the spring. For urea, ESN and SUPERU, there was no significant difference between yields with fall side-band versus spring broadcast applications when averaged across the two rates ($P = 0.646$-0.941). Spring broadcast AN, the traditionally recommended practice for southeast Saskatchewan, performed well at this site and resulted in significantly higher yields than fall SB urea ($P = 0.015$), fall DB UAN ($P < 0.001$), spring BC urea ($P = 0.010$), spring BC ESN ($P = 0.047$) and spring DB UAN ($P < 0.001$. Side-banded ESN, SB SUPERU and BC SUPERU all produced statistically similar yields as spring BC AN ($P = 0.066$-0.222); however, numerically, the highest yields tended to be with spring BC AN (5441 kg ha^{-1} on average). When all of the N was applied in either the spring or fall, mean yields with urea did not significantly differ from those achieved with ESN or SUPERU ($P = 0.157$-0.592); however, yields with fall side-banded urea were significantly higher than fall DB UAN ($P < 0.001$) and spring BC urea tended to produce higher yields than spring dribble-banded UAN. Urea ammonium nitrate is normally considered a good choice for spring applications due to a lower risk of volatile losses compared to untreated urea; however, under specific conditions (i.e. prolonged wet conditions following application) losses could potentially be higher for UAN.

Table 8. Contrast results for comparisons of specific groups of winter wheat N fertilizer treatments and their effect on grain yield at Indian Head, 2014.

#	Contrast	Grain Yield			
		Group A	Group B	B – A	Pr > *F*
	(Group A vs. Group B)	------------------- *kg ha⁻¹*		-------------------	-- *p-value* --
1	Check vs. Rest	2933 b	4995 a	2062	<0.001
2	75 N vs. 115 N	4534 b	5084 a	550	<0.001
3	Fall vs. Spring	4712 b	4916 a	204	0.047
4	Fall vs. Split	4986 b	5319 b	333	0.022
5	Spring vs. Split	5182 a	5319 a	137	0.337
6	Fall SB urea vs. Spring BC Urea	4939 a	4908 a	(-31)	0.875
7	Fall SB ESN vs. Spring BC ESN	5052 a	5036 a	(-16)	0.941
8	Fall SB SU vs. Spring BC SU	5102 a	5194 a	92	0.646
9	Fall DB UAN vs. Spring DB UAN	3753 b	4528 a	775	<0.001
10	Spring BC AN vs. Fall SB Urea	5441 a	4939 b	(-502)	0.015
11	Spring BC AN vs. Fall SB ESN	5441 a	5051 a	(-390)	0.066
12	Spring BC AN vs. Fall SB SU	5441 a	5102 a	(-339)	0.095
13	Spring BC AN vs. Fall DB UAN	5441 a	3753 b	(-1688)	<0.001
14	Spring BC AN vs. Spring BC Urea	5441 a	4907 b	(-534)	0.010
15	Spring BC AN vs. Spring BC ESN	5441 a	5036 b	(-405)	0.047
16	Spring BC AN vs. Spring BC SU	5441 a	5194 a	(-247)	0.222
17	Spring BC AN vs. Spring DB UAN	5441 a	4453 b	(-988)	<0.001
18	Fall SB Urea vs. Fall SB ESN	4939 a	5051 a	112	0.592
19	Fall SB Urea vs. Fall SB SU	4939 a	5102 a	163	0.419
20	Fall SB Urea vs. Fall DB UAN	4939 a	3753 b	(-1186)	<0.001
21	Spring BC Urea vs. Spring BC ESN	4908 a	5036 a	128	0.523
22	Spring BC Urea vs. Spring BC SU	4908 a	5194 a	286	0.157
23	Spring BC Urea vs. Spring DB UAN	4908	4453 a	(-455)	0.062

At 10.5%, mean protein concentrations were lower in 2014 at Indian Head than for the previous year but again, were significantly affected by N treatment ($P < 0.001$) with a range from 9.5-11.3% amongst individual treatments (Table 15). Again, protein concentrations were significantly higher than the check when all fertilized treatments were combined ($P = 0.017$) and also when the rate of N was increased from 75 to 115 kg N ha^{-1} ($P < 0.001$; Table 9). Averaged across products and rates, grain protein concentrations were not affected by application time / application method with similar protein concentrations regardless of whether N was applied in fall, spring, or in a split application ($P = 0.232$-0.579). Compared to spring BC AN, urea, ESN and SUPERU resulted in similar protein concentrations ($P = 0.070$-0.845) but protein was significantly lower with both fall and spring applications of UAN ($P < 0.001$-0.003).

Table 9. Contrast results for comparisons of specific groups of winter wheat N fertilizer treatments and their effect on grain protein at Indian Head, 2014.

#	Contrast	Grain Protein Concentration			
		Group A	Group B	B – A	Pr > *F*
	(Group A vs. Group B)	----------- *g protein 100 g seed*$^{-1}$ -----------			-- *p-value* -
1	Check vs. Rest	10.0 b	10.5 a	0.5	0.017
2	75 N vs. 115 N	10.1 b	10.7 a	0.6	<0.001
3	Fall vs. Spring	10.4 a	10.4 a	0.0	0.535
4	Fall vs. Split	10.7 a	10.6 a	(-0.1)	0.232
5	Spring vs. Split	10.7 a	10.6 a	(-0.1)	0.579
6	Fall SB urea vs. Spring BC Urea	10.8 a	10.5 a	(-0.3)	0.194
7	Fall SB ESN vs. Spring BC ESN	10.4 a	10.5 a	0.1	0.557
8	Fall SB SU vs. Spring BC SU	10.6 a	10.8 a	0.2	0.328
9	Fall DB UAN vs. Spring DB UAN	10.0 a	9.7 a	(-0.3)	0.136
10	Spring BC AN vs. Fall SB Urea	10.4 a	10.8 a	0.4	0.070
11	Spring BC AN vs. Fall SB ESN	10.4 a	10.4 a	0.0	0.845
12	Spring BC AN vs. Fall SB SU	10.4 a	10.6 a	0.2	0.437
13	Spring BC AN vs. Fall DB UAN	10.4 a	10.0 b	(-0.4)	0.013
14	Spring BC AN vs. Spring BC Urea	10.4 a	10.5 a	0.1	0.601
15	Spring BC AN vs. Spring BC ESN	10.4 a	10.5 a	0.1	0.695
16	Spring BC AN vs. Spring BC SU	10.4 a	10.8 a	0.4	0.081
17	Spring BC AN vs. Spring DB UAN	10.4 a	9.7 b	(-0.7)	<0.001
18	Fall SB Urea vs. Fall SB ESN	10.8	10.4	(-0.4)	0.046
19	Fall SB Urea vs. Fall SB SU	10.8	10.6	(-0.2)	0.297
20	Fall SB Urea vs. Fall DB UAN	10.8	10.0	(-0.8)	<0.001
21	Spring BC Urea vs. Spring BC ESN	10.8	10.5	(-0.3)	0.896
22	Spring BC Urea vs. Spring BC SU	10.8	10.8	0.0	0.217
23	Spring BC Urea vs. Spring DB UAN	10.8	9.7	(-0.9)	<0.001

Scott 2014: Field Trial Results

At Scott in 2013-14, conditions at seeding were dry and remained dry for most of the fall and early spring. Data collection at this site included spring plant density, grain yield, grain protein, test weight and thousand seed weight – treatment means and overall *F*-tests for these variables are provided in Table 17. With the initially dry conditions that were encountered, spring plant densities were relatively low averaging 57 plants m^{-2}; however the overall *F*-test was not significant ($P = 0.319$) and no significant differences were detected amongst individual treatments with Tukey's multiple comparisons test ($P \leq 0.05$). The contrasts for plant density were generally not significant; however, averaged across products and rates, higher plant populations were achieved with fall N application than with either spring ($P = 0.006$) and split applications ($P = 0.040$).

Winter wheat grain yields at this site averaged 2436 kg ha^{-1} and ranged from 1661-3077 kg ha^{-1}; however, the overall *F*-test was not significant and no significant differences amongst the individual treatments were detected (Table 17). Focussing on the contrasts comparing specific groups of treatments, the check did yield significantly lower than the combined fertilized treatments (P = 0.020) but there was no yield difference between the two rates (P = 0.230) and yields were similar regardless of whether N was applied in the fall, spring or a split application (P = 0.076-0.398). Contrasts comparing time of application for individual N forms and comparing the various treatments to either spring BC AN or untreated urea applied in the same manner were generally not significant (Table 10).

Table 10. Contrast results for comparisons of specific groups of winter wheat N fertilizer treatments and their effect on grain yield at Scott, 2014.

#	Contrast	Grain Yield			
		Group A	Group B	B – A	Pr > *F*
	(Group A vs. Group B)	--------------------- *kg ha^{-1}*		---------------------	--- *p-value* ---
1	Check vs. Rest	1661 a	2471 a	810	0.020
2	75 N vs. 115 N	2614 a	2429 a	(-185)	0.230
3	Fall vs. Spring	2614 a	2398 a	(-216)	0.076
4	Fall vs. Split	2537 a	2357	(-180)	0.398
5	Spring vs. Split	2119 a	2428	309	0.362
6	Fall urea vs. Spring urea	2804 a	2254	(-550)	0.072
7	Fall ESN vs. Spring ESN	2944 a	2492	(-452)	0.154
8	Fall SU vs. Spring SU	2204 a	2297	93	0.757
9	Fall UAN vs. Spring UAN	2392 a	2128	(-264)	0.576
10	Spring AN vs. Fall Urea	2685 a	2804	119	0.703
11	Spring AN vs. Fall ESN	2685 a	2944	259	0.424
12	Spring AN vs. Fall SU	2685 a	2204	(-481)	0.114
13	Spring AN vs. Fall UAN	2685 a	2490	(-195)	0.532
14	Spring AN vs. Spring Urea	2685 a	2254	(-431)	0.156
15	Spring AN vs. Spring ESN	2685 a	2492	(-193)	0.521
16	Spring AN vs. Spring SU	2685 a	2297	(-388)	0.216
17	Spring AN vs. Spring UAN	2447 a	2128	(-319)	0.499
18	Fall Urea vs. Fall ESN	2804 a	2944	140	0.664
19	Fall Urea vs. Fall SU	2804 a	2204 b	(-600)	0.050
20	Fall Urea vs. Fall UAN	2804 a	2490 a	(-314)	0.316
21	Spring Urea vs. Spring ESN	2254 a	2492 a	238	0.412
22	Spring Urea vs. Spring SU	2254 a	2297 a	43	0.888
23	Spring Urea vs. Spring UAN	2150 a	2128 a	(-22)	0.960

While the yield response to N at Scott was relatively weak, a significant overall effect of N treatment on grain protein was detected (P < 0.001) with values ranging from 10.8% in the control to as high as 13.0% amongst the fertilized treatments (Table 17). As expected, protein concentrations of the combined fertilized treatments were higher than those of the check (P = 0.010) and increasing the rate from 75 to

115 kg N ha^{-1} increased average protein concentrations from 11.3% to 12.2% (*P* < 0.001). While fall and spring N applications resulted in similar overall protein concentrations (*P* = 0.235), split applications resulted in slightly higher protein than spring applications (*P* = 0.025) but similar concentrations to the fall applications (*P* = 0.688). Protein concentrations were higher with fall SB application of SUPERU compared to spring BC applications of the same product (*P* = 0.032) while, in contrast, DB UAN applied in the spring resulted in higher protein levels than DB UAN applied in the fall.

Table 11. Contrast results for comparisons of specific groups of winter wheat N fertilizer treatments and their effect on grain protein at Scott, 2014.

		Grain Protein Concentration			
#	Contrast	Group A	Group B	B – A	Pr > *F*
	(Group A vs. Group B)	--------------- *g protein 100 g seed^{-1}* ---------------			--- *p-value* ---
1	Check vs. Rest	10.8 b	11.9 a	1.1	0.010
2	75 N vs. 115 N	11.3 b	12.2 a	0.9	<0.001
3	Fall vs. Spring	11.9 a	11.7 a	(-0.2)	0.235
4	Fall vs. Split	12.5 a	12.6 a	0.1	0.688
5	Spring vs. Split	12.1 b	12.5 a	0.4	0.025
6	Fall urea vs. Spring urea	11.8 a	11.5 a	(-0.3)	0.404
7	Fall ESN vs. Spring ESN	12.0 a	11.7 a	(-0.3)	0.292
8	Fall SU vs. Spring SU	12.2 a	11.5 b	(-0.7)	0.032
9	Fall UAN vs. Spring UAN	11.5 b	12.6 a	1.1	0.022
10	Spring AN vs. Fall Urea	11.6 a	11.8 a	0.2	0.575
11	Spring AN vs. Fall ESN	11.6 a	12.0 a	0.4	0.230
12	Spring AN vs. Fall SU	11.6 a	12.2 a	0.6	0.057
13	Spring AN vs. Fall UAN	11.6 a	11.8 a	0.2	0.420
14	Spring AN vs. Spring Urea	11.6 a	11.5 a	(-0.1)	0.798
15	Spring AN vs. Spring ESN	11.6 a	11.7 a	(0.1)	0.850
16	Spring AN vs. Spring SU	11.6 a	11.5 a	(-0.1)	0.804
17	Spring AN vs. Spring UAN	11.6 a	11.1 b	(-0.5)	0.042
18	Fall Urea vs. Fall ESN	11.8 a	12.0 a	0.2	0.506
19	Fall Urea vs. Fall SU	11.8 a	12.2 a	0.4	0.180
20	Fall Urea vs. Fall UAN	11.8 a	11.8 a	0.0	0.804
21	Spring Urea vs. Spring ESN	11.5 a	11.7 a	0.2	0.642
22	Spring Urea vs. Spring SU	11.5 a	11.5 a	0.0	1.000
23	Spring Urea vs. Spring UAN	11.2 b	12.6 a	1.4	0.002

Test weights and TKW were also measured at Scott and these results are provided in the Appendices. The overall *F*-tests were not significant for either variable (Table 17); however, the contrast comparisons did detect some significant treatment effects on test weight (Table 19). Averaged across rates and forms, test weights were slightly higher with fall versus the spring application (*P* = 0.025); however, this was mostly due to the observed results with UAN (*P* < 0.001) as there was no difference in test weights between the two timing/placement options for urea, ESN or SUPERU (P = 0.307-0.940). For TKW, a measure of average seed size, none of the predetermined contrast comparisons were significant.

Extension and Acknowledgement

At Indian Head, the winter wheat site and these trials were a formal stop at the Indian Head Crop Management Field Day on July 22, 2014. Agronomists from IHARF and Ducks Unlimited led a discussion of the opportunities and challenges associated with winter wheat production and discussed best management practices for this crop, particularly with regard to N fertility and disease management, which were the subject of 2013-14 ADOPT projects. The tour was attended by over 200 producers and industry representatives and signs were in place to identify treatments and acknowledge the support of the Agricultural Demonstrations of Technologies and Practices (ADOPT) program. At Scott, these trials were shown at WARC's annual summer field day on July 17 which was attended by approximately 175 producers and agronomists / industry representatives. Brian Beres and Lyze Boivert were invited to discuss the practices being demonstrated at Scott. Results from this project will be made available in the 2014 IHARF Annual Report (available online) and also made available through a variety of other media (i.e. oral presentations, popular agriculture press, fact sheets, etc.).

11. Conclusions and Recommendations:

With three sites where the conditions at planting and through early spring varied from extremely dry to relatively wet, this demonstration has provided insights into some of the risks and benefits of contrasting N management practices. Under the dry conditions encountered at Indian Head in 2012-13 and, to a lesser extent, Scott (2013-14), fall applications performed well and tended to be less risky than the deferring the entire N application until early spring. Under such conditions, with relatively low potential for N loss and lower overall response to N fertilizer, the benefits to slow release N products were negligible. Furthermore, when the fall and early spring were dry, fall side-band applications of fertilizer performed as well or better than the traditional recommended practice of broadcasting ammonium-nitrate (34-0-0) in the early spring. In contrast, at Indian Head in 2013-14, where conditions were wetter and planting and quite wet through the early spring and following the spring fertilizer applications, applying N in the spring performed well and resulted in yields that were similar to or higher than when all N was applied in the fall. Under these wetter conditions, broadcast AN was extremely effective and produced some of the highest yields in the demonstration; however, fall SB ESN and SUPERU and spring BC SUPERU performed similarly to spring broadcast AN. Yields with untreated urea were lower than those with spring broadcast AN, regardless of whether the urea was SB at seeding or BC in the early spring. As expected, fall DB UAN did not perform consistently and that practice should be avoided, particularly under wetter conditions. Split applications performed well under all conditions and may be the lowest risk option for winter wheat producers under a broad range of conditions, especially if using untreated urea where the potential for losses may be high. Another potential benefit to split applications is that total N rates can be adjusted in the spring, after the stand and environmental conditions can be more accurately assessed. That being said, there is a cost associated with spring application of N fertilizer which must be considered when weighing the risks and benefits of the different options. While slow release products such as ESN and SUPERU are sold at a premium and are therefore more expensive than untreated urea, this cost could be offset by avoiding the additional time and cost of a spring application and, as such, may be an attractive alternative for many growers. Focussing on the slow release products, ESN must take on and maintain sufficient moisture for the N to diffuse through the granule's polymer coating into the soil solution and, consequently, is better suited to in-soil placement (i.e. side-banding) than surface broadcast applications. In contrast, SUPERU is urea impregnated with urease and nitrification inhibitors with delay the conversion from urea to NH_4 and from NH_4 to NO_3-N, and therefore slow down the conversion to forms that are susceptible to environmental losses such as volatilization (especially when broadcast) and denitrification (under wet conditions). SUPERU is generally considered to be well suited to both side-band and broadcast applications.

Supporting Information

12. Acknowledgements

The project was supported by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement. Acknowledgement of the Saskatchewan Ministry of Agriculture's support for this demonstration will be included as part of all written reports and oral presentations that arise from this work.

13. Appendices:

Table 12. Least squares means for N fertilizer treatment effects on winter wheat plant density, NDVI, seed yield and protein at Indian Head in 2013. Means within a column followed by the same letter do not significantly differ according to Tukey's studentized range test ($P \leq 0.05$).

#	Treatment Description	Spring Plant Density	NDVI	Seed Yield	Protein
		-- *plants m^{-2}* --	------ *n/a* ------	---- *kg ha^{-1}* ---	------- *%* ------
1	Check (0 N)	44 ab	0.187 a	2834 c	12.2 ab
2	Fall SB – Urea – 75 N	80 a	0.200 a	3962 abc	12.6 ab
3	Fall SB– ESN – 75 N	70 ab	0.215 a	4259 a	12.2 ab
4	Fall SB – NSN – 75 N	72 ab	0.202 a	4257 a	12.1 ab
5	Fall DB – UAN – 75 N	46 ab	0.200 a	3903 abc	12.5 ab
6	Fall SB – Urea –115 N	66 ab	0.202 a	4389 a	12.5 ab
7	Fall SB – ESN – 115 N	58 ab	0.207 a	4218 ab	12.4 ab
8	Fall SB – NSN – 115 N	68 ab	0.202 a	4355 a	12.4 ab
9	Fall DB – UAN – 115 N	59 ab	0.191 a	4222 ab	12.6 ab
10	Spring BC – AN – 75 N	36 ab	0.195 a	3623 abc	12.2 ab
11	Spring BC – Urea – 75 N	47 ab	0.203 a	3717 abc	12.4 ab
12	Spring BC – ESN – 75 N	32 b	0.191 a	3311 abc	12.5 ab
13	Spring BC – NSN – 75 N	29 b	0.182 a	2923 bc	12.6 ab
14	Spring DB – UAN – 75 N	47 ab	0.190 a	3508 abc	11.7 b
15	Spring BC – AN –115 N	30 b	0.186 a	3391 abc	12.5 ab
16	Spring BC – Urea – 115 N	48 ab	0.184 a	3302 abc	12.6 ab
17	Spring BC – ESN – 115 N	48 ab	0.187 a	3401 abc	12.8 a
18	Spring BC – NSN – 115 N	58 ab	0.184 a	3402 abc	12.9 a
19	Spring – UAN – 115 N	39 ab	0.180 a	3548 abc	12.7 a
20	Split – Urea – 115 N	72 ab	0.196 a	4312 a	12.6 ab
21	Split – ESN – 115 N	79 a	0.204 a	4089 abc	12.5 ab
22	Split – NSN – 115 N	54 ab	0.208 a	4406 a	12.4 ab
23	Split – UAN – 115 N	57 ab	0.208 a	4046 abc	12.6 ab
	SE	8. 7	0.009	283.3	0.19
	Pr > *F*	<0.001	0.133	<0.001	0.028

Table 13. Contrast results for comparisons of specific groups of winter wheat N fertilizer treatments and their effect on spring plant densities at Indian Head, 2013.

		Spring Plant Density			
#	Contrast	Group A	Group B	B – A	Pr > *F*
	(Group A vs. Group B)	--------------------- *plants m*$^{-2}$	---------------------		-- *p-value* --
1	Check vs. Rest	43.5	54.3	10.8	0.212
2	75 N vs. 115 N	50.9	52.9	2.0	0.632
3	Fall vs. Spring	65.0	43	(-22.0)	<0.001
4	Fall vs. Split	63.0	65.3	2.3	0.690
5	Spring vs. Split	48.5	65.3	16.8	0.006
6	Fall urea vs. Spring urea	73.3	47.8	(-25.5)	0.004
7	Fall ESN vs. Spring ESN	64.1	39.8	(-24.3)	0.005
8	Fall NSN vs. Spring NSN	70.0	43.7	(-26.3)	0.003
9	Fall UAN vs. Spring UAN	52.5	43.0	(-9.5)	0.268
10	Spring AN vs. Fall Urea	32.8	73.3	40.5	<0.001
11	Spring AN vs. Fall ESN	32.8	64.1	31.3	<0.001
12	Spring AN vs. Fall NSN	32.8	70.0	37.2	<0.001
13	Spring AN vs. Fall UAN	32.8	52.5	19.7	0.023
14	Spring AN vs. Spring Urea	32.8	47.8	15.0	0.079
15	Spring AN vs. Spring ESN	32.8	39.8	7.0	0.412
16	Spring AN vs. Spring NSN	32.8	43.7	10.9	0.200
17	Spring AN vs. Spring UAN	32.8	43.1	10.3	0.229
18	Fall Urea vs. Fall ESN	73.3	64.1	(-9.2)	0.282
19	Fall Urea vs. Fall NSN	73.3	70.0	(-3.3)	0.699
20	Fall Urea vs. Fall UAN	73.3	52	(-21.3)	0.016
21	Spring Urea vs. Spring ESN	47.8	39.8	(-8.0)	0.343
22	Spring Urea vs. Spring NSN	47.8	43.7	(-4.1)	0.629
23	Spring Urea vs. Spring UAN	47.8	43.1	(-4.7)	0.573

Table 14. Contrast results for comparisons of specific groups of winter wheat N fertilizer treatments and their effect on NDVI at Indian Head, 2013.

		Normalized Difference Vegetation Index			
#	Contrast	Group A	Group B	B – A	Pr > *F*
	(Group A vs. Group B)	---------------------- *NDVI* ----------------------			-- *p-value* --
1	Check vs. Rest	0.187 a	0.196 a	0.009	0.264
2	75 N vs. 115 N	0.198 a	0.193 a	(-0.005)	0.110
3	Fall vs. Spring	0.202 a	0.188 b	(-0.014)	0.001
4	Fall vs. Split	0.201 a	0.204 a	0.003	0.543
5	Spring vs. Split	0.184 b	0.204 a	0.020	0.001
6	Fall urea vs. Spring urea	0.201 a	0.194 a	(-0.007)	0.369
7	Fall ESN vs. Spring ESN	0.211 a	0.189 b	(-0.022)	0.009
8	Fall NSN vs. Spring NSN	0.202 a	0.183 b	(-0.019)	0.023
9	Fall UAN vs. Spring UAN	0.196 a	0.185 a	(-0.011)	0.205
10	Spring AN vs. Fall Urea	0.191 a	0.201 a	0.010	0.221
11	Spring AN vs. Fall ESN	0.191 b	0.211 a	0.020	0.015
12	Spring AN vs. Fall NSN	0.191 a	0.202 a	0.011	0.187
13	Spring AN vs. Fall UAN	0.191 a	0.196 a	0.005	0.557
14	Spring AN vs. Spring Urea	0.191 a	0.194 a	0.003	0.742
15	Spring AN vs. Spring ESN	0.191 a	0.189 a	(-0.002)	0.825
16	Spring AN vs. Spring NSN	0.191 a	0.183 a	(-0.008)	0.327
17	Spring AN vs. Spring UAN	0.191 a	0.185 a	(-0.006)	0.492
18	Fall Urea vs. Fall ESN	0.201 a	0.211 a	0.010	0.215
19	Fall Urea vs. Fall NSN	0.201 a	0.202 a	0.001	0.922
20	Fall Urea vs. Fall UAN	0.201 a	0.196 a	(-0.005)	0.521
21	Spring Urea vs. Spring ESN	0.194 a	0.189 a	(-0.005)	0.582
22	Spring Urea vs. Spring NSN	0.194 a	0.183 a	(-0.011)	0.192
23	Spring Urea vs. Spring UAN	0.194 a	0.185 a	(-0.009)	0.310

Table 15. Least squares means for N fertilizer treatment effects on winter wheat NDVI, seed yield and protein at Indian Head in 2014. Means within a column followed by the same letter do not significantly differ according to Tukey's studentized range test ($P \leq 0.05$).

#	Treatment Description	NDVI	Seed Yield	Protein
		--------- *n/a* ---------	-------- *kg ha^{-1}* -------	---------- *%* ---------
1	Check (0 N)	0.313 d	2933 h	10.0 defg
2	Fall SB – Urea – 75 N	0.398 abcd	4526 defg	10.4 abcdefg
3	Fall SB– ESN – 75 N	0.425 abc	4523 cdefg	10.2 bcdefg
4	Fall SB – SU – 75 N	0.426 abc	4971 abcde	10.1 cdefg
5	Fall DB – UAN – 75 N	0.340 cd	3726 gh	9.9 fg
6	Fall SB – Urea –115 N	0.408 abcd	5353 abcd	11.2 a
7	Fall SB – ESN – 115 N	0.449 ab	5580 abcd	10.7 abcdef
8	Fall SB – SU – 115 N	0.407 abcd	5232 abcd	11.1 abc
9	Fall DB – UAN – 115 N	0.350 bcd	3780 fgh	10.0 defg
10	Spring BC – AN – 75 N	0.460 a	5218 abcde	10.0 efg
11	Spring BC – Urea – 75 N	0.419 abc	4761 abcdefg	10.1 cdefg
12	Spring BC – ESN – 75 N	0.372 abcd	4683 bcdefg	10.4 abcdefg
13	Spring BC – SU – 75 N	0.405 abcd	4925 abcde	10.4 abcdefg
14	Spring DB – UAN – 75 N	0.402 abcd	4235 efg	9.5 g
15	Spring BC – AN –115 N	0.433 abc	5663 abc	10.9 abcde
16	Spring BC – Urea – 115 N	0.390 abcd	5055 abcde	11.0 abcd
17	Spring BC – ESN – 115 N	0.401 abcd	5389 abcd	10.6 abcdef
18	Spring BC – SU – 115 N	0.390 abcd	5463 abcd	11.1 ab
19	Spring – UAN – 115 N	0.395 abcd	4821 abcdef	9.9 fg
20	Split – Urea – 115 N	0.474 a	5588 abcd	10.4 abcdefg
21	Split – ESN – 115 N	0.421 abc	5256 abcde	11.3 a
22	Split – SU – 115 N	0.445 ab	5759 a	10.9 abcde
23	Split – UAN – 115 N	0.393 abcd	4671 bcdefg	9.8 fg
24	Spring BC– AN – 134 N z	0.450 ab	5716 ab	11.3 a
	SE	0.043	240.6	0.42
	Pr > *F*	<0.001	<0.001	<0.001

Table 16. Contrast results for comparisons of specific groups of winter wheat N fertilizer treatments and their effect on NDVI at Indian Head, 2014.

		Normalized Difference Vegetation Index			
#	Contrast	Group A	Group B	B – A	Pr > *F*
	(Group A vs. Group B)	---------------------- *NDVI* ----------------------			-- *p-value* --
1	Check vs. Rest	0.313 b	0.411 a	0.098	<0.001
2	75 N vs. 115 N	0.405 a	0.403 a	(-0.002)	0.780
3	Fall vs. Spring	0.400 a	0.397 a	(-0.003)	0.743
4	Fall vs. Split	0.403 b	0.433 a	0.030	0.034
5	Spring vs. Split	0.394 b	0.433 a	0.039	0.006
6	Fall urea vs. Spring urea	0.403 a	0.405 a	0.002	0.931
7	Fall ESN vs. Spring ESN	0.437 a	0.387 b	(-0.050)	0.013
8	Fall SU vs. Spring SU	0.416 a	0.398 a	(-0.018)	0.351
9	Fall UAN vs. Spring UAN	0.345 b	0.398 a	0.053	0.008
10	Spring AN vs. Fall Urea	0.445 a	0.403 b	(-0.042)	0.030
11	Spring AN vs. Fall ESN	0.445 a	0.437 a	(-0.008)	0.624
12	Spring AN vs. Fall SU	0.445 a	0.416 a	(-0.029)	0.129
13	Spring AN vs. Fall UAN	0.445 a	0.345 b	(-0.100)	<0.001
14	Spring AN vs. Spring Urea	0.445 a	0.405 b	(-0.040)	0.034
15	Spring AN vs. Spring ESN	0.445 a	0.387 b	(-0.058)	0.003
16	Spring AN vs. Spring SU	0.445 a	0.398 b	(-0.047)	0.016
17	Spring AN vs. Spring UAN	0.445 a	0.398 b	(-0.047)	0.017
18	Fall Urea vs. Fall ESN	0.403 a	0.437 a	0.034	0.089
19	Fall Urea vs. Fall SU	0.403 a	0.416 a	0.013	0.498
20	Fall Urea vs. Fall UAN	0.403 a	0.345 b	(-0.058)	0.004
21	Spring Urea vs. Spring ESN	0.405 a	0.387 a	(-0.018)	0.365
22	Spring Urea vs. Spring SU	0.405 a	0.398 a	(-0.007)	0.732
23	Spring Urea vs. Spring UAN	0.405 a	0.398 a	(-0.007)	0.751

Table 17. Least squares means for N fertilizer treatment effects on winter wheat NDVI, seed yield and protein at Scott, 2014. Means within a column followed by the same letter do not significantly differ according to Tukey's studentized range test (*P* ≤ 0.05).

#	Treatment Description	Spring Density	Seed Yield	Grain Protein	Test Weight	TKW
		plants m^{-2}	*-- kg ha^{-1} --*	*--- % ----*	*- g 0.5 l^{-1} -*	*g 1000 seeds^{-1}*
1	Check (0 N)	45.8 a	1661 a	10.8 bc	379.7 ab	34.3 a
2	Fall SB – Urea – 75 N	77.3 a	3077 a	11.0 bc	378.6 ab	34.3 a
3	Fall SB– ESN – 75 N	70.4 a	2917 a	11.5 abc	383.8 ab	33.6 a
4	Fall SB – SU – 75 N	73.3 a	2351 a	11.5 abc	381.3 ab	34.5 a
5	Fall DB – UAN – 75 N	64.5 a	2392 a	11.5 abc	384.1 ab	33.3 a
6	Fall SB – Urea –115 N	63.5 a	2531 a	12.5 ab	383.8 ab	33.2 a
7	Fall SB – ESN – 115 N	68.4 a	2972 a	12.5 abc	383.1 ab	33.2 a
8	Fall SB – SU – 115 N	65.0 a	2056 a	12.9 a	380.1 ab	33.6 a
9	Fall DB – UAN – 115 N	67.0 a	2589 a	12.2 abc	381.2 ab	33.2 a
10	Spring BC – AN – 75 N	52.2 a	2447 a	11.6 abc	378.1 ab	33.3 a
11	Spring BC – Urea – 75 N	64.0 a	2150 a	11.2 bc	376.9 ab	32.1 a
12	Spring BC – ESN – 75 N	74.3 a	2945 a	10.8 c	378.5 ab	34.0 a
13	Spring BC – SU – 75 N	53.2 a	2633 a	11.1 bc	380.4 ab	33.8 a
14	Spring DB – UAN – 75 N	39.9 a	2128 a	12.6 ab	364.7 b	33.0 a
15	Spring BC – AN –115 N	64.5 a	2923 a	11.6 abc	380.9 ab	34.1 a
16	Spring BC – Urea – 115 N	46.2 a	2359 a	11.9 abc	381.4 ab	33.1 a
17	Spring BC – ESN – 115 N	50.7 a	2039 a	12.5 abc	380.9 ab	33.2 a
18	Spring BC – SU – 115 N	41.8 a	1961 a	12.0 abc	381.5 ab	33.2 a
19	Spring – UAN – 115 N	54.2 a	—	—	—	—
20	Split – Urea – 115 N	50.2 a	2389 a	12.4 abc	382.0 ab	32.5 a
21	Split – ESN – 115 N	65.0 a	2801 a	12.2 abc	387.2 a	33.0 a
22	Split – SU – 115 N	41.4 a	2093 a	13.0 a	378.4 ab	33.7 a
23	Split – UAN – 115 N	41.8 a	2145 a	12.9 a	376.6 ab	32.6 a
24	Spring BC– AN – 134 N	43.3 a	2464 a	11.6 abc	380.0 ab	34.3 a
	SE	11.5	503.8 [Z]	0.40 [Y]	3.57 [X]	0.80 [W]
	Pr > *F*	0.319	0.126	<0.001	0.238	0.286

[Z] S.E. ranged from 493-521 due to missing data points
[Y] S.E. ranged from 0.39-0.49 due to missing data points
[x] S.E. ranged from 3.37-3.88 due to missing data points
[x] S.E. ranged from 0.77-0.84 due to missing data points

Table 18. Contrast results for comparisons of specific groups of winter wheat N fertilizer treatments and their effect on spring plant density at Scott, 2014.

		Spring Plant Density			
#	Contrast	Group A	Group B	B – A	Pr > *F*
	(Group A vs. Group B)	---------------------- *plants* m^{-2}	----------------------		-- *p-value* --
1	Check vs. Rest	46 a	58 a	12	0.288
2	75 N vs. 115 N	63 a	58 a	(-5)	0.314
3	Fall vs. Spring	69 a	53 b	(-16)	0.006
4	Fall vs. Split	66 a	50 b	(-16)	0.040
5	Spring vs. Split	48 a	48 a	0	0.863
6	Fall urea vs. Spring urea	70 a	55 a	(-15)	0.172
7	Fall ESN vs. Spring ESN	69 a	63 a	(-6)	0.536
8	Fall SU vs. Spring SU	69 a	47 a	(-22)	0.055
9	Fall UAN vs. Spring UAN	66 a	47 a	(-19)	0.096
10	Spring AN vs. Fall Urea	58 a	70 a	12	0.280
11	Spring AN vs. Fall ESN	58 a	69 a	11	0.321
12	Spring AN vs. Fall SU	58 a	69 a	11	0.332
13	Spring AN vs. Fall UAN	58 a	66 a	8	0.507
14	Spring AN vs. Spring Urea	58 a	55 a	(-3)	0.772
15	Spring AN vs. Spring ESN	58 a	63 a	5	0.707
16	Spring AN vs. Spring SU	58 a	47 a	(-11)	0.331
17	Spring AN vs. Spring UAN	58 a	47 a	(-11)	0.310
18	Fall Urea vs. Fall ESN	70 a	69 a	(-1)	0.928
19	Fall Urea vs. Fall SU	70 a	69 a	(-1)	0.911
20	Fall Urea vs. Fall UAN	70 a	66 a	(-4)	0.674
21	Spring Urea vs. Spring ESN	55 a	63 a	8	0.506
22	Spring Urea vs. Spring SU	55 a	47 a	(-8)	0.494
23	Spring Urea vs. Spring UAN	55 a	47 a	(-8)	0.467

Table 19. Contrast results for comparisons of specific groups of winter wheat N fertilizer treatments and their effect on test weight at Scott, 2014.

		Test Weight			
#	Contrast	Group A	Group B	B – A	Pr > *F*
	(Group A vs. Group B)	---------------------- *g 0.5 l*$^{-1}$	----------------------		-- *p-value* --
1	Check vs. Rest	379.7 a	390.1 a	10.4	0.900
2	75 N vs. 115 N	380.2 a	381.6 a	1.4	0.427
3	Fall vs. Spring	382.1 a	377.8 b	(-4.3)	0.025
4	Fall vs. Split	382.0 a	381.0 a	(-1.0)	0.678
5	Spring vs. Split	381.3 a	382.5 a	1.2	0.842
6	Fall urea vs. Spring urea	381.2 a	379.2 a	(-2.0)	0.557
7	Fall ESN vs. Spring ESN	383.4 a	379.7 a	(-3.7)	0.307
8	Fall SU vs. Spring SU	380.7 a	380.9 a	0.2	0.940
9	Fall UAN vs. Spring UAN	384.1 a	364.7 b	(-19.4)	<0.001
10	Spring AN vs. Fall Urea	379.5 a	381.2 a	1.7	0.634
11	Spring AN vs. Fall ESN	379.5 a	383.4 a	3.9	0.293
12	Spring AN vs. Fall SU	379.5 a	380.7 a	1.2	0.730
13	Spring AN vs. Fall UAN	379.5 a	384.1 a	4.6	0.383
14	Spring AN vs. Spring Urea	379.5 a	379.2 a	(-0.3)	0.552
15	Spring AN vs. Spring ESN	379.5 a	379.7 a	0.2	0.881
16	Spring AN vs. Spring SU	379.5 a	380.9 a	1.4	0.690
17	Spring AN vs. Spring UAN	378.1 a	364.7 a	(-13.4)	0.925
18	Fall Urea vs. Fall ESN	381.2 a	383.4 a	2.2	0.948
19	Fall Urea vs. Fall SU	381.2 a	380.7 a	(-0.5)	0.685
20	Fall Urea vs. Fall UAN	381.2 b	384.1 a	2.9	0.016
21	Spring Urea vs. Spring ESN	379.2 a	379.7 a	0.5	0.868
22	Spring Urea vs. Spring SU	379.2 a	380.9 a	1.7	0.608
23	Spring Urea vs. Spring UAN	376.9 a	364.7 b	(-12.2)	0.018

Table 20. Contrast results for comparisons of specific groups of winter wheat N fertilizer treatments and their effect on thousand seed weight at Scott, 2014.

		Thousand Kernel Weight			
#	Contrast	Group A	Group B	B – A	Pr > *F*
	(Group A vs. Group B)	*g 1000 seeds^{-1}*			*-- p-value --*
1	Check vs. Rest	34.3 a	33.4 a	(-0.9)	0.172
2	75 N vs. 115 N	33.7 a	33.2 a	(-0.5)	0.387
3	Fall vs. Spring	33.7 a	33.2 a	(-0.5)	0.143
4	Fall vs. Split	33.3 a	33.0 a	(-0.3)	0.409
5	Spring vs. Split	33.2 a	33.1 a	(-0.1)	0.889
6	Fall urea vs. Spring urea	33.8 a	32.6 b	(-1.2)	0.045
7	Fall ESN vs. Spring ESN	33.4 a	33.6 a	0.2	0.711
8	Fall SU vs. Spring SU	34.0 a	33.5 a	(-0.5)	0.348
9	Fall UAN vs. Spring UAN	33.4 a	33.0 a	(-0.4)	0.749
10	Spring AN vs. Fall Urea	33.7 a	33.8 a	0.1	0.911
11	Spring AN vs. Fall ESN	33.7 a	33.4 a	(-0.3)	0.615
12	Spring AN vs. Fall SU	33.7 a	34.0 a	0.3	0.566
13	Spring AN vs. Fall UAN	33.7 a	33.4 a	(-0.3)	0.443
14	Spring AN vs. Spring Urea	33.7 a	32.6 a	(-1.1)	0.541
15	Spring AN vs. Spring ESN	33.7 a	33.6 a	(-0.1)	0.647
16	Spring AN vs. Spring SU	33.7 a	33.5 a	(-0.2)	0.379
17	Spring AN vs. Spring UAN	33.3 a	33.0 a	(-0.3)	0.059
18	Fall Urea vs. Fall ESN	33.8 a	33.4 a	(-0.4)	0.878
19	Fall Urea vs. Fall SU	33.8 a	34.0 a	0.2	0.724
20	Fall Urea vs. Fall UAN	33.8 a	33.4 a	(-0.4)	0.721
21	Spring Urea vs. Spring ESN	32.6 a	33.6 a	1.0	0.069
22	Spring Urea vs. Spring SU	32.6 a	33.5 a	0.9	0.124
23	Spring Urea vs. Spring UAN	34.3 a	33.0 a	(-1.3)	0.320

Abstract

14. Abstract/Summary:

Field trials to demonstrate N fertilizer management options for winter wheat in Saskatchewan were conducted near Indian Head in 2012-13 and 2013-14 and Scott in 2013-14. Conditions in the fall/early spring at the three sites ranged from extremely dry to relatively wet and the response to N fertilizer treatments varied depending on the specific conditions that were encountered. When the fall/early spring were dry, fall applications performed well and tended to be less risky than deferring the entire N application until early spring and the benefits to slow release N products were negligible under such conditions. In contrast, where conditions were wetter at planting and through the early spring, applying N in the spring was quite effective and resulted in yields that were similar to or higher than when all N was applied in the fall. Under these wetter conditions, broadcast AN was extremely effective and produced some of the highest yields in the demonstration; however, fall SB ESN and SUPERU and spring BC SUPERU performed similarly to spring broadcast AN. Fall dribble-banded UAN did not perform consistently and that practice should be avoided, particularly under wetter conditions. Split applications performed well under all conditions and may be the lowest risk option for winter wheat producers under a broad range of conditions; however, there is a cost associated with spring applications of N fertilizer which must be considered when weighing the different options. While slow release products such as ESN and SUPERU are more expensive than untreated urea, this cost could be offset by avoiding the additional time and cost of a spring application and, as such, this may be an attractive alternative for many growers. These demonstrations were shown at both the IHARF and WARC summer field tours with a total of approximately 375 producers and industry representatives toured the plots. Results from the project will be made available in the 2014 IHARF Annual Report (available online) and also made available through a variety of other media (i.e. oral presentations, popular agriculture press, fact sheets, etc.).
