2015 Annual Report
for the
Agriculture Demonstration of Practices and Technologies
(ADOPT) Program

Project Title: Demonstrating nitrogen fertilizer options to maximize spring wheat grain yield and protein

Project Number: 20140343

Producer Group Sponsoring the Project: Western Applied Research Corporation

Project Location: AAFC Scott Research Farm, R.M. #380, NE 17-39-21 W3

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Objectives and Rationale

Project Objectives

The objective of this project was to demonstrate the effects of several enhanced efficiency nitrogen (N) fertilizer treatments on lodging and grain yield and protein content of three spring wheat cultivars with contrasting lodging resistance and grain yield and protein potential.

Project Rationale

Wheat continues to be a very popular crop in northwest Saskatchewan. In recent years the region has experienced very high yields; however, protein content of wheat has dropped dramatically to levels as low as 10 %. When protein drops this low, the value of the crop may drop to a level close to $ 1.5/bu. Attempts to increase protein by applying more fertilizer N often leads to increased lodging and associated yield loss and/or difficulty with harvest. Several enhanced efficiency N fertilizer products can delay conversion or release of plant available N. This in turn leaves more N for later in the growing season to support protein formation. Another option may be to grow more lodging resistant cultivars that would allow for greater amounts of untreated fertilizer N to be applied at seeding. A third option would be to grow cultivars with genetic traits that result in higher protein content. The dilemma that growers face is in knowing which option or combination of options would be most effective. The intent of this demonstration is to identify the most effective strategy.

Methodology and Results

Methodology

This demonstration was conducted at the AAFC Scott Research Farm in 2015. The demonstration was set up as a 3 x 7 factorial in a randomized complete block design with four replicates. The first factor was wheat variety (Shaw VB, Goodeve VB and Lillian) and the second factor was the type of nitrogen source (N blends). On May 15, all the wheat varieties were seeded at a rate of 250 seeds m^{-2} with an R-Tech drill seeder in 10 inch row spacing and at a depth of 3-4cm. Fertilizer was applied at seeding according to the treatments except UAN that was applied at early heading (see Table 1 for complete treatment list). Weeds were controlled using a pre-seed burndown and registered in-crop herbicides (See Appendix, Table A.1 for complete details of field maintenance activities).

Table 1. Detailed treatment list for the "*Demonstrating nitrogen fertilizer options to maximize spring wheat grain yield and protein*" at Scott, Saskatchewan, 2015.

Treatment #	Wheat variety	N fertilizer options
1	Shaw VB	90 kg/ha of N urea
2	Shaw VB	90 kg/ha of N (50/50 blend ESN/urea)
3	Shaw VB	90 kg/ha of N (50/50 blend Super U/urea)
4	Shaw VB	90 kg/ha of N (75/25 blend ESN/urea)
5	Shaw VB	90 kg /ha of N (75/25 blend Super U/urea)
6	Shaw VB	80 kg/ha of N urea + 20 kg/ha of N UAN dribble banded @ early heading
7	Shaw VB	No N fertilizer (check)
8	Goodeve VB	90 kg/ha of N urea
9	Goodeve VB	90 kg/ha of N (50/50 blend ESN/urea)
10	Goodeve VB	90 kg/ha of N (50/50 blend Super U/urea)
11	Goodeve VB	90 kg/ha of N (75/25 blend ESN/urea)
12	Goodeve VB	90 kg /ha of N (75/25 blend Super U/urea)
13	Goodeve VB	80 kg/ha of N urea + 20 kg/ha of N UAN dribble banded @ early heading
14	Goodeve VB	No N fertilizer (check)
15	Lillian	90 kg/ha of N urea
16	Lillian	90 kg/ha of N (50/50 blend ESN/urea)
17	Lillian	90 kg/ha of N (50/50 blend Super U/urea)
18	Lillian	90 kg/ha of N (75/25 blend ESN/urea)
19	Lillian	90 kg /ha of N (75/25 blend Super U/urea)
20	Lillian	80 kg/ha of N urea + 20 kg/ha of N UAN dribble banded@ early heading
21	Lillian	No N fertilizer (check)

Plant densities were assessed when there were visible rows to determine plant emergence among treatments. These were assessed by counting two 1 m rows in the front and back of the plot for a total of four rows per plot. The average of the four rows was converted to plants per m^{-2} based on 10 inch row spacing. At early heading, UAN was applied in treatments 6, 13 and 20 at a rate of 20 kg/ha. Grain yields were determined after plots were mechanically harvested, cleaned and corrected to 14.5 % seed moisture. Test weights were determined using the Canadian Grain Commission protocols (Canadian Grain Commission, 2014) and percent protein was determined at the Scott Research Farm laboratory.

Statistical Analysis

An analysis of variance (ANOVA) was conducted on all response variables using the PROC MIXED in SAS 9.3. Wheat varieties and nitrogen blends were considered as fixed effect factors and replicates were considered a random effect factor. The assumptions of ANOVA (equal variance and normally distributed) were tested using Levene's test, and Shapiro-Wilks. The data fitted to the ANOVA assumptions. The data was normally distributed; therefore no data transformation was necessary. Treatment means were separated according to Tukey's Honestly Significant Difference (HSD) and considered significant at $P \leq 0.05$. Weather data was collected from the Scott Environment Canada weather station (Table 2).

Weather Conditions

In 2015, the early growing season was very dry with only 4.1 mm and 19.4 mm accumulated precipitation during the month of May and June, respectively. July received 36 % less rainfall compared to the long term average. However, August received 39 % more moisture compared to the long-term average. The mean monthly temperatures were comparable to previous years (Table 2).

Table 2. Mean monthly temperature, precipitation and growing degree day accumulated from May to September 2015 at Scott, SK

Year	May	June	July	August	September	Average /Total
			Temperature (°C)			
2015	9.3	16.1	18.1	16.8	10.9	14.24
Long-term^z	10.8	15.3	17.1	16.5	10.4	14.0
			Precipitation (mm)			
2015	4.1	19.4	46.4	74.5	49.6	194.0
Long-term^z	36.3	61.8	72.1	45.7	36.0	215.9
			Growing Degree Days			
2015	140.3	332	405.1	365.8	179.8	1423.0
Long-term^z	178.3	307.5	375.1	356.5	162.0	1379.4

^{z}Long-term average (1981-2010)

Results

Days to Maturity, Bushel weight and TKW

Days to maturity (DTM) was significantly affected by wheat variety (P <.0001). Both nitrogen blends (P = 0.5766) and variety x nitrogen blends interaction (P = 0.4360) did not have significant effects on DTM (Table 3). The trend in DTM somehow followed the data from the SaskSeed guide 2016 where Goodeve VB matured faster relative to Carberry (Check), followed by Lillian and Shaw VB (SaskSeed Guide, 2016). In this study, however, both Lillian and Shaw VB matured at the same time. Since all varieties were seeded at the same seeding rate, the difference in DTM might be a physiological attribute of the varieties rather than plant stand effects.

Bushel weight was significantly affected by wheat variety (P <.0001). However, both nitrogen blend (P = 0.0763) and variety x nitrogen blend interaction (P = 0.6013) did not have significant effects on bushel weight (Table 3). The trend in bushel weight followed the data from the SaskSeed guide 2016 where Shaw VB had the highest volume weight relative to Carberry (Check), followed by Lillian and Goodeve VB (SaskSeed Guide, 2016). In this study, however, Lillian had a significantly lowest bushel weight.

Thousand kernel weight (TKW) was also significantly affected by wheat variety (P <.0001). Again, neither nitrogen blend (P = 0.5232) nor variety x nitrogen blend interaction (P = 0.5784) had significant effects on TKW (Table 3). Variations of kernels per pound can be fairly large when comparing between varieties within a crop. These large variations can result in over-seeding or under-seeding of a crop, which could result reduction in yield (Geiszler and Hoag, 1967; Riveland et al., 1979). In this study, since the varieties had differences in kernel weights at the onset of seeding, the variations in TKW could be attributed to that.

No data on lodging was recorded. This is because, due to the dry growing season, there was no lodging in any of the plots, irrespective of the wheat varieties and N blend.

Table 3. Effects of variety, nitrogen blend and their interactions on measured response variable in wheat at Scott, SK in the 2015 growing season.

Effects	***Days to Maturity*** *(Days)*	***Yield*** *(kg/ha)*	***Bushel W.*** *(kg/hL)*	***TKW*** *(g/1000seeds)*	***Protein*** *(%)*
	--	----------	*P values*	----------	----------------------------------
Variety (VAR)	*<.0001*	0.0793	*<.0001*	*<.0001*	*0.0070*
Nitrogen blend (NTYPE)	0.5766	*0.0270*	0.0763	0.5232	*0.0537*
VAR x NTYPE	0.4360	0.9280	0.6013	0.5784	0.8112

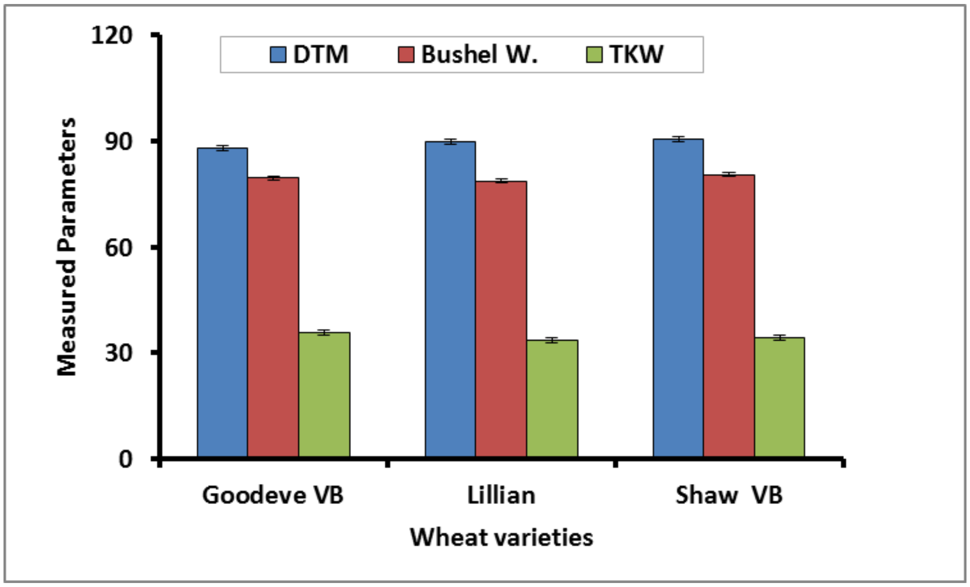

Figure 1. Effects of wheat variety on days to maturity, bushel weight (kg/hL) and thousand kernel weight (g/1000s) at Scott, SK during the 2015 growing season.

Grain yield and percent protein

Grain yield was significantly affected by nitrogen blends (P = 0.0270) but neither wheat variety (P = 0.0793) nor variety x nitrogen blend interaction (P = 0.9280) had significant effects on yield (Table 3, Figure 2). However, both wheat variety (P = 0.0070) and nitrogen blend (P = 0.0537) had significant effects on protein % but not variety x nitrogen blend interaction (P = 0.8112) (Table 3, Figure 3). Grain yield was highest for Lillian with Goodeve VB and Shaw VB yielding 0. 4 % and 4 % less, respectively. This trend was not expected as Shaw VB had consistently yielded higher relative to other varieties (such as Lillian and Goodeve VB) as well as to the check variety (SaskSeed Guide, 2016). Goodeve VB and Lillian had 4 % and 2 % higher protein, respectively relative to Shaw VB (Figure 2). This trend is consistent with the data from the SaskSeed guide 2016 where Goodeve VB and Lillian had higher protein content relative to Shaw VB (SaskSeed Guide, 2016). Fertilizer N blend, regardless of how it was applied increased grain yield relative to the check (Figure 3), suggesting that N fertilizer is essential to achieve acceptable yield. However, yield differences among the different N blends were relatively small and not statistically significant (Figure 3).

Since protein percentage has an inverse relationship to grain yield, the expectation was that, the higher yielding variety should have lower protein % due to dilution effects. However, this did not happen in this trial, suggesting yield dilution did not fully account for differences in protein content. This is because % protein was highest for the highest yielding varieties, Goodeve VB and Lillian yielding 14.5 % and 14.2 %, respectively. Shaw VB which was the low-yielding variety had the lowest % protein of 13.9 % (Figure 2). Fertilizer N blends increased protein % with all N fertilized treatments having higher protein % compared to the check, except where Super U and urea were applied at 50/50 blend (Figure 3).

Despite the non-significant effects of the different N blends on grain yield, urea treatment (100

%) had the highest yield relative to all the blends (Figure 3). This can be explained by the fact that, since the start of the growing season was dry and the treated urea needed moisture to dissolve, it gave the untreated urea the ability to dissolve faster with the little moisture for uptake than the treated. The general trend of higher protein % in all the treated N treatments relative to the untreated urea can be explained by the fact that, since later in the season there was a bit of moisture, the treated treatments had reserve of N which contributed to % protein but not yield because by that period the crop had all the kernels formed. The subtle differences in % protein within the N blends may either be due to the chemistry of the N blends or timing. In figure 3, UAN blend had the highest % protein relative to the ESN and Super U blends, possibly because 20% of the N was applied as liquid UAN at the flag leaf stage rather than at seeding.

Environmentally Smart Nitrogen (ESN) – a urea with a polymer coating releases its N under temperature controlled diffusion (Grant and Dowbenko, 2008). This mechanism regulates how quickly the dissolved fertilizer move into the soil solution and gets converted to plant available ammonium (NH_4^+) and nitrate (NO_3^-)-N. Over time, water moves into the polymer coated granule, dissolving the N within. Once the N is dissolved, it moves out through the polymer and into the soil solution. The rate of release of N depends on soil temperature and moisture and generally requires around 12 weeks for completion (Ruark, 2010). Super Urea (Super U) – on the other hand is a urea impregnated with the urease inhibitor N-(n-butyl) thiophosphoric triamide (NBPT) and the nitrification inhibitor dicyandiamide (DCD). These components block the conversion of urea to ammonia and the conversion of NH_4^+ to NO_3^- (Grant, 2005).

These chemistries make both ESN and Super U recalcitrant to dissolve to make their N available to plant. However, whiles ESN controls only the release process, Super U controls both nitrification and volatilization processes (Olson-Rutz et al., 2009). There was slightly higher protein % for the ESN treatments compared to the Super U treatments (Figure 3), a 2 % and 0.7 % for the 50/50 and 75/25 blends, respectively. This may be because in drought years, due to the chemical composition, Super U could provide a quicker source of nitrogen to the plant compared to ESN (McDonald, 2010). This leaves more N for the ESN treatments for later use, leading to relatively higher protein %.

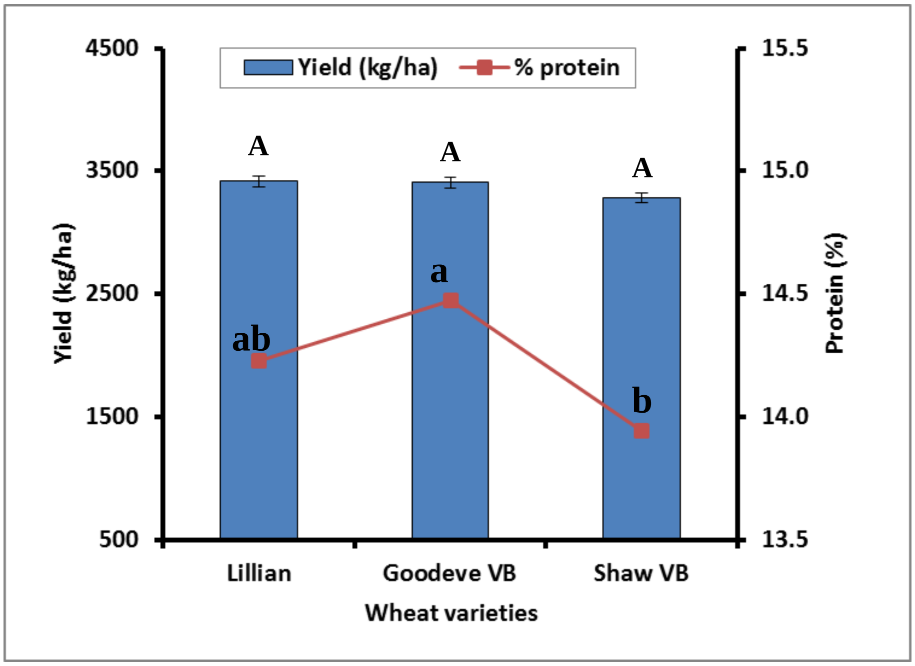

Figure 2. Effects of wheat variety on grain yield (*columns*) and grain protein % (*line*) at Scott, SK during the 2015 growing season. Means followed by the same letters (according to respective upper/lower case) means they are not significantly different at P > 0.05 according to Tukey's Honestly Significant Difference (HSD).

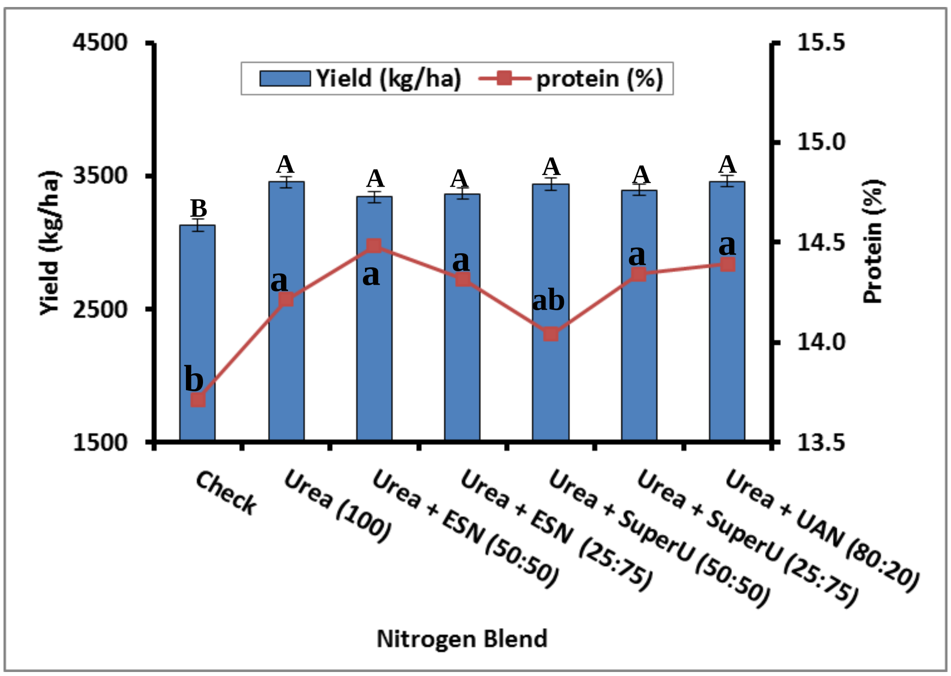

Figure 3. Effects of nitrogen blend on grain yield (*columns*) and grain protein % (*line*) at Scott, SK during the 2015 growing season. Means followed by the same letters (according to respective upper/lower case) means they are not significantly different at P > 0.05 according to Tukey's Honestly Significant Difference (HSD).

Conclusions and Recommendations

From the study, it can be concluded that, the most effective strategy for increasing protein in spring wheat was to choose a low yielding but high protein varieties and fertilize them adequately with N fertilizer. Therefore, either Lillian or Goodeve VB will be the right candidate for this objective. They both had protein levels above 14 % and did not differ significantly in yield compared to Shaw VB. When considering only yield, we found no advantage for the slow release N fertilizers or for the products ESN and Super U because using untreated granular urea at seeding was as effective as any of the combinations of ESN, Super U or UAN used in this study. However, the treated N fertilizer products could potentially delay N availability until later in the season and cause an increase in protein content. These results clearly suggest that shifting away from high pre-plant applications of untreated urea and applying treated N later in the season, especially UAN, has the capacity to provide more N later in the season and may offer a significant protein improvement without jeopardizing yield. This information could prove highly valuable for growers in choosing wheat varieties that provide the optimum tradeoff between protein and yield to meet their production standards. To the grower wondering whether ESN, Super U or UAN pay? Although not statistically different, UAN overall resulted in the greatest protein %. The grower must base their decision factoring in yield and/or price vs added costs and crop damage from application at early heading. Therefore, there is the need to conduct further trials over several years to determine whether applying different blends of untreated and treated N compared to untreated urea alone is profitable or not. This is because it involves extra cost and therefor farmers and producers must make sure they have a net gain.

Supporting Information

Acknowledgements

We would like to thank the Ministry of Agriculture for the funding support on this project. We would also like to acknowledge the support of Herb Schell and our summer staff for their technical assistance with project development and implementation. This report will be distributed through WARC's website and included in WARC's annual report. A combined result from WARC (Scott) and NARF (Melfort) was presented at the Agri-ARM Research Update on January 14, 2016 during the Crop Production Week.

Appendices

Appendix A – Agronomic information for the demonstration

Abstract

Abstract/Summary

Wheat continues to be a very popular crop in northwest Saskatchewan. In recent years the region has experienced very high yields; however, protein content has dropped dramatically to levels as low as 10 %. When protein drops this low, the value of the crop can drop by close to $1.5/bu. The use of several enhanced efficiency products as fertilizer N source such as ESN and Super U can delay conversion of fertilizer N into plant available forms, leaving more N available for uptake later in the growing season to increase protein %. This practice may delay N availability until later in the season leading to an added benefit of reducing early season vegetative growth and, potentially, lodging whiles increasing protein %. The dilemma that growers face is in knowing which option or combination of options would be most effective. Therefore, a 3 x 7 factorial experiment in a randomized complete block design was set up to determine the effects of wheat varieties and N fertilizer blends on yield and protein in wheat. Comparisons were made with the check and with untreated urea N fertilizer alone. Days to maturity, bushel weight and TKW were all affected by only wheat variety. Grain yield was also affected by only fertilizer N blend ($P = 0.0270$). However, both wheat variety ($P = 0.0070$) and fertilizer N blend ($P = 0.0537$) had significant effects on % protein. From the study, it can be concluded that, the most effective strategy for increasing protein in wheat was to choose a low yielding but high protein varieties and fertilize them adequately with N fertilizer. Therefore, either Lillian or Goodeve VB will be the right candidate for this objective for NW SK. They both had protein levels above 14 % and did not differ significantly in yield compared to Shaw VB. When considering only yield, we found no advantage for the slow release N fertilizers or for the products ESN and Super U because using untreated granular urea at seeding was as effective as any of the combinations of ESN, Super U or UAN. However, the treated fertilizer N products could potentially delay N availability until later in the season and may cause an increase in protein content. Results from this demonstration will be distributed through WARC’s website and included in WARC’s annual report.

Appendix A
Agronomic information for 2015 demonstration

Table A.1. Selected agronomic information for the "*Demonstrating nitrogen fertilizer options to maximize spring wheat grain yield and protein*" at Scott, Saskatchewan, 2015.

Seeding Information	**2015**
Seeder	R-Tech Drill, 10 inch row spacing, knife openers
Seeding Date	May 15, 2015
Cultivar	Hard Red Spring Wheat – Shaw VB, Goodeve VB and Lillian
Seeding Rate	250 seeds m^{-2}
Stubble Type	Canola
Fertilizer applied	Applied based on treatment list
Plot Maintenance Information	
Pre-plant herbicide	Roundup ¾ L/ac + Pardner 0.4 L/ac (May 8, 2015)
In-crop herbicide	Buctril M 0.4 L/ac + Axial 0.48 L/ac (June 6, 2015)
Desiccation	Glyphosate @ 1L/ac (August 20, 2015)
Emergence Counts	June 02, 2015
Harvest Date	September 01, 2015

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