2019 Research Report

from the

East Central Research Foundation

Project Title: Increasing Wheat Protein with a Post Emergent Applications of UAN vs Dissolved Urea

(SDWC # 132-190325)

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Project Identification

1. **Project Number:** 132-190325
2. **Producer Group Sponsoring the Project:** SaskWheat
3. **Project Location(s):** Yorkton, Prince Albert, Indian Head, Melfort, Redvers, Outlook, Scott and Swift Current, SK
4. **Project start and end dates (month & year):** April 2019 to March 2020
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Objectives and Rationale

6. **Project objectives:**

The overall objective of this project was to demonstrate the potential of an additional 30 lb N/ac applied late season to increase either wheat yield or grain protein compared to applying all nitrogen (N) at seeding. The impact of nitrogen source, crop staging and application method were compared.

Specifically, the intent was to demonstrate the following concepts:

a. Dribble banded applications of UAN cause less flag leaf burn than broadcast foliar sprays post-anthesis.
b. Dribble banding UAN at the earlier boot stage causes less flag leaf burn than when applied post-anthesis.
c. Diluting dribble band applications of UAN is not necessary and may actually increase leaf burn.
d. When broadcast foliar sprays are applied post-anthesis, dissolved urea will result in less leaf burn than UAN applied as a solution of 14% nitrogen.
e. Strategies resulting in less leaf burn will produce a better yield/protein response (ie: more protein/ac).

7. **Project Rationale:**

Recently, producers have been disappointed by low levels of grain protein. When regional protein levels are low, the premiums offered for high protein wheat tend to increase. This has left producers wondering what can be done to increase protein levels in the future. Many studies, dating back the 1990s, have shown post-emergent applications of nitrogen can increase grain protein when made at late vegetative stages. Guy Lafond assessed the feasibility of applying foliar N at both the boot stage and post-anthesis for spring and winter wheat [1]. He determined that this practice had merit but the results could be variable depending on initial N supply and weather conditions. However, dribble banding at the earlier boot stage increased grain protein more consistently and reduced the potential for leaf burn. UAN (28-0-0) produces large drops that do not disperse on the leaf surface because they have a high surface tension and tend to roll off. Dilution may reduce surface tension and actually increase leaf burn [2] or increased leaf burn may just be a function of a higher volume applied.

Western Canadian research has found little reason to support the use of broadcast foliar sprays over dribble banding. Broadcast foliar sprays cause more leaf burn and since little nitrogen is actually absorbed through the leaves there is little benefit to the practice. The University of Manitoba found recovery of foliar applied 15N labelled urea (in solution) was only 4-27% compared to 32-70% with soil application. Under field conditions with foliar UAN, most of the uptake occurs after rainfall events wash the N to the soil where it is taken up through roots [3].

Despite these results, broadcast foliar sprays post-anthesis are popular in the northern United States and are practiced in Manitoba. The general recommendation is to dilute UAN 50:50 with water and spray when conditions are cool to reduce leaf burning. While foliar applications of UAN post-anthesis frequently increase protein, this practice does not always prove to be economical. Research lead by John Heard with Manitoba Agriculture evaluated the benefit of post-anthesis UAN on 15 farm sites from 2015 to 2016 [4]. The impact on protein was largely positive and statistically significant 60% of the time. On average, protein of CNHR varieties was increased 0.6% when an additional 30 lb N/ac was applied post-anthesis. However, post-anthesis UAN only proved to be economical at 2 of 15 sites and premiums for higher protein concentrations are not guaranteed.

Broadcast foliar sprays with dissolved urea, instead of UAN may prove to be more beneficial. Amy Mangin with the University of Manitoba recently found broadcast foliar sprays of dissolved urea sprayed post-anthesis not only resulted in less leaf burn but also produced greater yields and higher grain protein compared to UAN [5]. Dissolved urea is a standard product used for foliar applications in the UK and is considered to be safer on the crop than UAN. While both UAN and dissolved urea were applied at 30 lb N/ac in Mangin's study, the % N concentration of the solutions differed between the products. The UAN solution was 14%, whereas the urea solution was only 9%. This may have also contributed to the greater crop safety observed with dissolved urea. In our demonstration, dissolved urea and UAN will be compared at a 14% solution of N. Producers can create their own solution of urea on farm, however, care must be taken as dissolving urea is extremely endothermic and can freeze lines. Urea should be dissolved slowly into warm water and not into cold water pulled from a well for example. In addition, producers should only dissolve urea with less than 1% biuret. Biuret is a by-product that can cause severe leaf burning, but it is normally not a concern with urea manufactured in North American.

[1] Lafond, G and J. McKell. 1998. The Effects of Foliar Applied Nitrogen on Grain Protein Concentration in Spring and Winter Wheat. Proceedings of the Wheat Protein Symposium 298-304

[2] Stu Brandt personal communication

[3] Rawluk, C. D. L., Racz, G. J. and Grant, C. A. 2000. Uptake of foliar or soil application of 15N-labelled urea solution at anthesis and its affect on wheat grain yield and protein. Can. J. Plant Sci. 80: 331–334.

[4] Heard, J., Sabourin, B., Faroq, A. and L. Kaminski. On-farm-tests evaluate nitrogen rate, source and timing for spring wheat yield and protein. Poster.

[5] http://umanitoba.ca/faculties/afs/agronomists_conf/media/7__1_30_PM_DEC_14_MANGIN_MAC_2017_NOV23.pdf

[6] personal communication with Chris Holzapfel

Methodology and Results

8. Methodology:

The treatments were arranged in a Randomized Complete Block Design (RCBD) with 4 replicates. Plot size, row spacing, and fertilizer application techniques at seeding varied between locations depending on equipment. Treatments are listed in Table 1 below. UAN (28-0-0) treatments were applied either undiluted or cut in half with water to create 14-0-0. Likewise, 14-0-0 of melted urea was created by diluting 1.66 kg of 46-0-0 per US gallon of water. Urea with less than 1% biuret was used to ensure optimum crop safety. The rate used for all post-emergent applications of nitrogen provided an extra 30 lb N/ac to a base rate of 70 lb N/ac that was side-banded at seeding. These treatments were compared to base rates of 70 and 100 lb N/ac (treatments 1 and 2, no post-emergent N applied) to determine if there were responses to the post-emergent N and/or any benefits from split applying N versus simply side-banding the extra 30 lb N/ac during seeding. Comparisons between treatments 3-9 determined if N source, application method or timing influences crop safety, yield or protein responses.

Table 1. Treatment List for the Increasing Wheat Protein with a Post Emergent Applications of UAN vs Dissolved Urea Trial

Treatment #	**Seeding**	**Post emergence application**				
	Lb N/ac of Side- banded Urea	N (lb/ac)	Product	%N	method	Stage
1	70	na	na	na	na	na
2	100	na	na	na	na	na
3	70	30	UAN	14	dribble[1]	boot
4	70	30	UAN	28	dribble[2]	boot
5	70	30	UAN	14	dribble[1]	Post-anthesis
6	70	30	UAN	28	dribble[2]	Post-anthesis
7	70	30	Urea Sol'n	14	Dribble [3]	Post-anthesis
8	70	30	UAN	14	foliar[4]	Post-anthesis
9	70	30	Urea Sol'n	14	foliar[5]	Post-anthesis

[1] Sprayed with dribble band nozzle at 20 gal/ac (10 gal/ac UAN + 10 gal/ac water = 14% N solution)
[2] Sprayed with dribble band nozzle at 10 gal/ac (undiluted UAN =28% N solution)
[3] Sprayed with dribble band nozzle at 20 gal/ac (1.66 Kg of urea dissolved in 1 US gallon of water = 14% N solution)
[4] Sprayed with 02 flat fan nozzles at 20 gal/ac (10 gal/ac UAN + 10 gal/ac water = 14% N solution)
[5] Spray with 02 flat fan nozzles at 20 gal/ac (1.66 Kg of urea dissolved in 1 US gallon of water = 14% N solution)

Dates of operation are listed in Table 2 below.

Table 2. Dates of operations in 2019 for the Increasing Wheat Protein with a Post Emergent Applications of UAN vs Dissolved Urea trial								
	---------------------------Date----------------------------							
Activity	**Indian Head**	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
Pre-seed Herbicide Application	May 12 Roundup Weatherma x 540 (0.67L/ac)	May 24 Glyphosate + Heat	N/A	N/A	N/A	May Glyphosate 540 (1L/ac) + AIM (35 ml/ac)	May 7 Glyphosate	N/A
Seeding	May 14	May 24	May 15	May 23	May 7	May 14	May 8	May 13
Emergence Counts	June 3	June 26	N/a	June 13	June 5	June 11	June 17	June 12
In-crop Herbicide Application	June 17 OcTTain XL (0.45L/ac) + Simplicity GoDRI (28g/ac)	June 27 Axial July 4 Prestige XC	June 10 Badge II (500 mL/ac) + Simplicity (21 gm/ac)	June 19 Axel Extreme, MCPA, Kinetic Copron	June 10 Clodinafop (283 mL/ac) + Buctril M (0.4mL/ac)	June 26 Axial (0.5 L/ac) + Buctril M (0.4 L/ac)	June 14 Varro (200ml/ac) + Octtain XL (450ml/ac) + Agral90 (25l/100L)	June 12 Simplicity + Prestige June 25 MCPA (200ml/ac) July 3 MCPA (200ml/ac)
Boot N application	July 3	July 16	July 6	July 9	July 3	July 4	July 3	July 3
Post-anthesis N application	July 20	Aug 8	July 19	July 26	July 20	July 23	July 29	July 19
Leaf Burn Rating	July 25	Aug 16	July 22	July 19 and July 29	N/A	July 11, 18, 30 & Aug 5	N/A	July 25

In-crop Fungicide Application	July 11 Prosaro (0.325 mL/ac)	N/A	July 18 Caramba (400 mL/ac)	June 19 Pivot 418EC	July 12 Caramba (400mL/ac)	N/A	July 10 Acapella (250ml/ac)	July 11 Caramba July 14 Caramba
Lodging Rating	Aug 9	N/A	N/A	Sept 23	Sept 7	N/A	Aug 19	Sept 3
Desiccant	Aug 28 Roundup Weatherma x 540 (0.67L/ac)	N/A	N/A	Sept 5 Glyphosate	N/A	Sept 6 Heat LQ (42.8 mL/ac) + Roundup 540 (0.67 L/ac) + Merge (0.2 L/ac)	N/A	Sept 3 Roundup Transorb (0.66l/ac)
Harvest	Sept 6	Oct 6	Sept 24	Sept 23	Sept 7	Sept 22	Aug 21	Sept 16

9. Results:

Growing Season Weather

Mean monthly temperatures and precipitation amounts with long term (1981-2010) averages for 8 sites are listed in Table 3 and 4. The 2019 season was cooler than the long-term average at all sites. Rainfall was below average for all sites except Scott and Swift Current. Irrigation applied to the Outlook site included 8 mm in May, 62.5 mm in June, 45.5 mm in July and 12.5 mm in August.

Table 3. Mean monthly temperatures amounts along with long-term (1981-2010) normals for the 2019 growing seasons at 8 sites in Saskatchewan.

Location	**Year**	**May**	**June**	**July**	**August**	**Avg. / Total**
		-----------------------------Mean Temperature (°C) --------------------				
Indian Head	2019	8.9	15.7	17.4	15.8	14.4
	Long-term	***10.8***	***15.8***	***18.2***	***17.4***	***15.6***
Melfort	2019	8.8	15.3	16.9	14.9	14.0
	Long-term	***10.7***	***15.9***	***17.5***	***16.8***	***15.2***
Outlook	2019	9.9	16.0	18.0	16.2	15.0
	Long-term	***11.5***	***16.1***	***18.9***	***18.0***	***16.1***
Prince Albert	2019	9.5	15.8	17.4	15.1	14.5
	Long-term	***10.4***	***15.3***	***18.0***	***16.7***	***15.1***
Redvers	2019	9.5	16.3	18.5	16.6	15.2
	Long-term	***12***	***16***	***19***	***18***	***16.3***
Scott	2019	*9.1*	*14.9*	*16.1*	*14.4*	*13.6*
	Long-term	***10.8***	***14.8***	***17.3***	***16.3***	***14.8***
Swift Current	2019	*9.5*	*15.8*	*17.7*	*16.8*	*15.0*
	Long-term	***11***	***15.7***	***18.4***	***17.9***	***15.8***
Yorkton	2019	8.6	16	18.3	16.1	14.8
	Long-term	***10.4***	***15.5***	***17.9***	***17.1***	***15.2***

Table 4. Precipitation amounts along with long-term (1981-2010) normals for the 2019 growing seasons at 8 sites in Saskatchewan.

Location	Year	May	June	July	August	Avg. / Total
		--------------------------------- Precipitation (mm) ---------------------				
Indian Head	2019	13.3	50.4	53.1	96.0	212.8
	Long-term	***51.7***	***77.4***	***63.8***	***51.2***	***241.4***
Melfort	2019	18.8	87.4	72.7	30.7	209.6
	Long-term	***42.9***	***54.3***	***76.7***	***52.4***	***226.3***
Outlook	2019	13.2	90.2	43.8	39.6	186.8
	Long-term	***42.6***	***63.9***	***56.1***	***42.8***	***205.4***
Prince Albert	2019	30.0	54.4	57.4	16.8	158.6
	Long-term	***44.7***	***68.6***	***76.6***	***61.6***	***251.5***
Redvers	2019	18.0	79.0	54.0	88	239
	Long-term	***60***	***91***	***78***	***64***	***293***
Scott	2019	12.7	97.7	107.8	18	236.2
	Long -term	***38.9***	***69.7***	***69.4***	***48.7***	***226.7***
Swift Current	2019	13.3	156	11.1	42.6	223
	Long-term	***42.1***	***66.1***	***44***	***35.4***	***187.6***
Yorkton	2019	11.1	81.6	49.1	32.2	174
	Long-term	***51***	***80***	***78***	***62***	***272***

Soil test Nitrate levels for each location are presented in Table 5. Swift Current had very high background levels and levels were relatively high at Redvers. Soil N was low at Outlook. The remaining sites had more typical levels of soil N in the 30 to 50 lb/ac range.

Table 5. Soil Test Nitrate Levels for each location (lb N/ac).								
Nitrate Levels (lbs NO_3-N/ac)	**Indian Head**	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
0-15cm (0-6in)	16	18	6	15	29	14	42	14
15-30cm (6-12in)				10				
15-60cm (6-24in)	33	17	9		42	18	186	18
Total 0-60cm (0-24in)	49	35	15	37.5[1]	71	32	228	32
Total 0-30cm (0-12in)				25				

[1]Estimation (25 lb N/ac*1.5)

Dates of application for post-emergent applications of N are given in Table 6 along with temperature at the time of application and rainfall pattern after application. It is recommended that post-emergent applications of N occur at temperatures below 20ºC to reduce leaf burning. For the most part, applications did not occur when temperatures were excessively hot. Sufficient rainfall to move N applied applied at the boot stage was received within a week at Melfort, Outlook, Redvers, Scott and Yorkton. Sufficient rainfall was received within two weeks at Indian Head and Redvers. At Swift Current, sufficient rainfall was not received for over a month. After the post-anthesis application, sufficient rainfall was not received within 2 weeks and in many cases was considerably later.

Table 6. Date of Post-Emergent Nitrogen Application, Temperature and Amount of Rain after Post-Emergent Nitrogen Application.						
	Date of Application		**Temperature During Application**		**Next Significant Rainfall after Post-emergent N Application**	
	Boot	Post-Anthesis	Boot	Post-Anthesis	Boot	Post-Anthesis
Indian Head	July 3	July 20	18-20ºC	17-18ºC	July 13 – 17 (30mm)	Aug 9- 12 (61mm)
Melfort	July 16	Aug 8	20.9ºC	19-20ºC	July 17-18 (29.3mm)	Aug 22-23 (15mm)
Outlook	July 6	July 19	16.3ºC	15.5ºC	July 14-16 (22.4mm) + Irrigation July 9 and 11 (20.5mm)	Aug 22 (22.8mm) + Irrigation Aug 1 (12.5mm)
Prince Albert	July 9	July 26	19ºC	22ºC	July 17-19 (24.3 mm)	Sept 2 (16.2 mm)

Redvers	July 3	July 20	18-20 ºC	19-21ºC	July 9 (21.3mm)	Aug 12 (20.3mm)
Scott	July 4	July 23	17.9º C	15.7ºC	July 11-12 (12mm) & July 19-20 (28.7mm)	Aug 7-8 (31.6mm)
Swift Current	July 3	July 29	18ºC	18-22ºC	Aug 11-12 (35.4mm)	Aug 11-12 (35.4mm)
Yorkton	July 3	July 19	20ºC	14ºC	July 6 (20.7mm)	Aug 25-27 (20.2)

<u>General Emergence, Yield and Protein Comparisons between locations</u>

Wheat emergence was reported from all locations except Outlook. Average stands of 402 plants/m^2 were on the high side at Swift Current and plant populations of 180 and 172/m^2 were on the low side at Melfort and Redvers, respectively. Average plant populations of 214, 205, 229 and 252/m^2 were at satisfactory levels at Prince Albert, Indian Head, Scott and Yorkton, respectively. Increasing the rate of side-banded urea from 70 to 100 lb N/ac (trt 1 vs 2) tended to decrease emergence modestly at most locations which is fairly typical (data not shown).

Average wheat yields and grain proteins varied between locations (Tables 7 and 8). Sites with higher yields tended to have lower proteins. Wheat yields were highest at Outlook under irrigation, averaging 7507 kg/ha (111 bu/ac) with a grain protein of 12.5%. At Yorkton, Redvers and Melfort yields were relatively high averaging 5780, 5041 and 5179 kg/ha with grain proteins of 12.4, 14.9, and 11.5%, respectively. Swift Current, Scott, Prince Albert and Indian Head had lower yields averaging 3185, 3938, 3753 and 3316 kg/ha and relatively higher proteins averaging 16.9, 14.6, 14.4, 16.0 %, respectively.

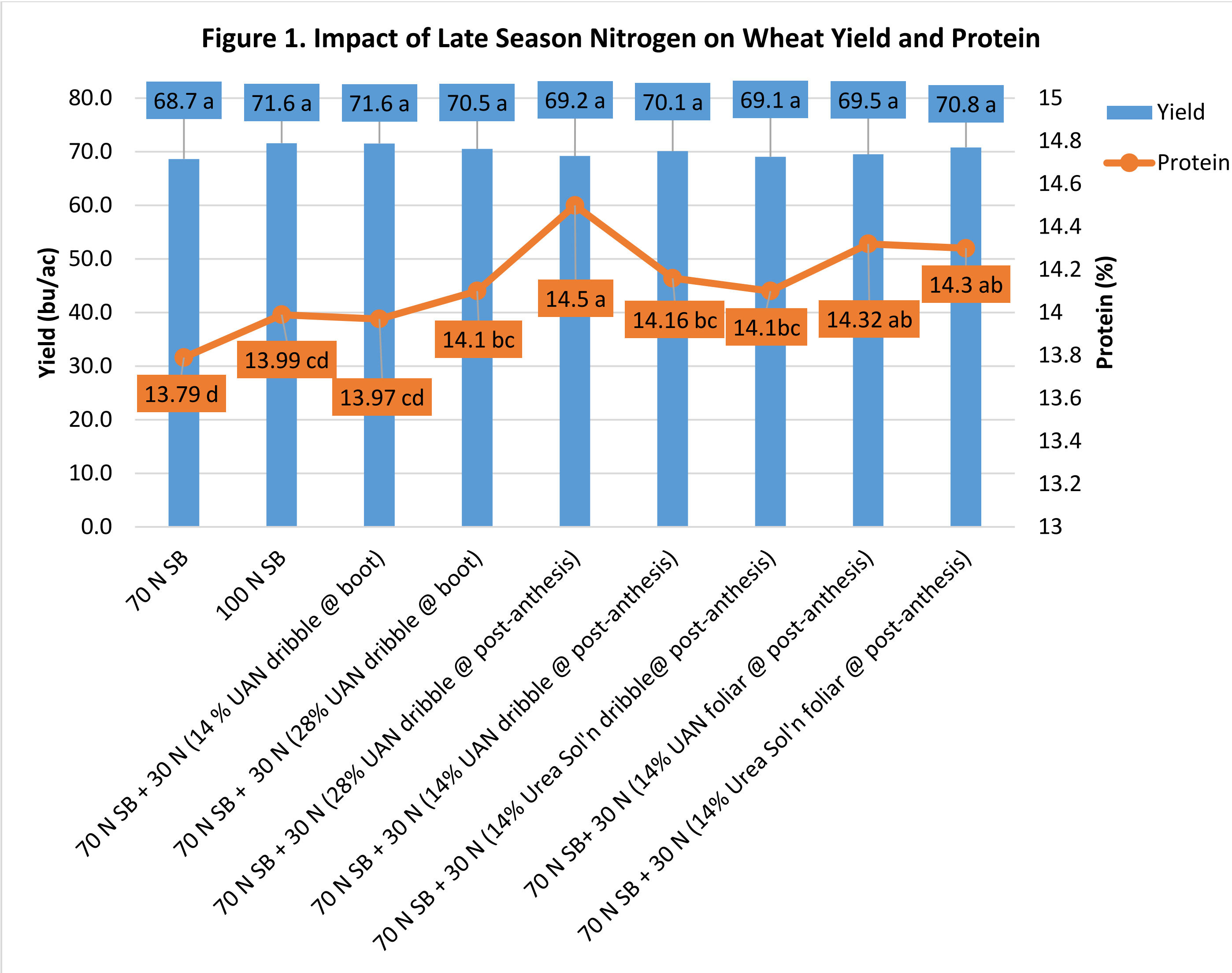
<u>Effect of N management on Leaf Burn, Yield and Protein</u>

Increasing side-banded N from 70 to 100 lb/ac increased yield and grain protein at all locations except Redvers, where yield decreased by 8.3% and Swift Current, where protein dropped by 0.9%. Both the loss in yield and protein were unexpected and can only be attributed to experimental variation. However, when averaged across locations, increasing the rate of side-banded urea from 70 to 100 lb N/ac increased yield and protein by 199 kg/ha (2.96 bu/ac) and 0.2%, respectively (Tables 7, 8 and Figure 1). On average, split applications of N at the boot stage did not tend to effect grain yield or protein relative to placing all the N down at seeding (treatment 2 -100 lb N/ac side-banded urea). However, a latter application post-anthesis produced 0.29% more protein and resulted in 2.7% less yield compared to treatment 2. This is not usual as latter season applications of N are more likely to cause increases in protein over increases in yield. For either of the boot or post-anthesis timings, dribble banding diluted UAN (14%N) resulted in smaller yield reductions and protein increases compared straight UAN (28% N). The reason for this is unclear as 30 lb N/ac was applied in both cases. If straight UAN (28 %N) was resulting in more protein due to greater crop injury and subsequent reductions in yield it was not apparent based on visual observations of leaf burn which did not significantly or consistently differ between concentrations of UAN (Table 9).

While split applications post-anthesis tended to result in higher grain protein but lower yield, the relative impact between the different split applications on leaf burn, yield and grain protein differed between locations. Dribble band applications of N at the boot stage did not cause leaf burn of the flag because it was not fully emerged at the time of spraying. For post-anthesis applications, UAN tended to cause more leaf burn than dissolved urea and broadcast foliar spray applications of N tended to cause more leaf burn than dribble band applications.

UAN (14% N) caused more leaf burn than dissolved urea (14% N) when dribble banded post-anthesis at Indian Head, Melfort, Prince Albert and Yorkton (Table 9). UAN also caused significantly more flag leaf burn than dissolved urea when applied as a broadcast foliar spray application at Indian Head, Outlook, Prince Albert, Scott and Yorkton. However, these differences did not significantly affect yield or protein at most locations except for Outlook, where grain protein was significantly higher when dribble banding UAN instead of dissolved urea.

The tendency for broadcast applications to cause more leaf burn that dribble band applications was more apparent with UAN compared to dissolved urea. For UAN, broadcast foliar spray applications caused significantly more leaf burn than dribble banding at Indian Head, Outlook and Prince Albert. In contrast, broadcast foliar spray application of dissolved urea only significantly caused more leaf burn than dribble banding at Prince Albert. Broadcast foliar spray applications of UAN or urea did not tend to affect yield compare to dribble band applications but did tend to increase grain protein. This difference was large and statistically significant at Indian Head.



Economic Analysis

As discussed earlier, many of the split applications of N post-anthesis resulted in higher grain protein compared to applying all the N at seeding (trt 2), but they also tended to produce lower yields. As a result of lower yields and additional costs associated with a split application, there were very few cases where a split application of N proved to be more economical than just putting all the N down at seeding, even when assuming a large protein premium spread of 66 cent/%/bu. The following discussion lays the case for this conclusion.

Table 10 shows an economic analysis based on grain yields and protein averaged over all locations. Gross ($/ac) for each treatment are based on the yield (bu/ac) for the treatment multiplied by a base price of $6.75/bu. A protein premium ($/ac) relative to treatment 1 was calculated using a protein spread of 66 cents/%/bu. The cost of N ($/ac) for each treatment assumed $0.50/ lb N. Where applicable the extra cost of making a split application was assumed to be $5/ac. The last column of table 10 shows the summation of Gross ($/ac) plus any protein premium ($/ac) minus the cost of N ($/ac) minus the cost of making an extra pass for the split application. These values can now be used to make fair economic comparisons between treatments.

Based on these assumptions, increasing the rate of side-banded N from 70 to 100 lb/ac increased gross returns by $14.02/ac ($442.75/ac - $428.73/ac –difference between treatments 1 and 2) when averaged across locations (Table 10). Only 2 of the 7 treatments where 30 lb N/ac was split applied to a base rate of 70 lb N/ac of side-banded urea gave greater economic returns compared to simply side-banding all the N (100 lb/ac) at seeding (treatment 2). Where greater economic returns existed, the difference was less than $4/ac which would hardly justify the extra effort of a split application. However, the relative economics between treatments varied among sites.

Table 11 compares the economics between treatments for each location. None of the split applications of N proved more economical then just side-banding all the N (100 lb/ac) at seeding for Yorkton, Scott, Melfort and Indian Head. Even though foliar applications resulted in substantially higher protein at Indian Head, the lower associated yield with those treatments resulted in lower economic returns. At the remaining sites, there were some split applications of N that were more economic. At Outlook, dribble banding UAN (28% N) post-anthesis resulted in substantial economic gains because protein was significantly higher with this treatment. The reason for the protein bump is unclear; however, this trend was also apparent at Prince Albert, Redvers and Swift Current. At Prince Albert, the split application treatments which were more profitable generally benefited from higher yields, not increased protein. At Swift Current, the economic returns for the 100 lb N/ac side-band check (treatment 2) were unexpectedly low due to a very low protein level, so comparisons against this check are questionable. However, a broadcast foliar spray of dissolved urea post-anthesis produced relatively high yield, protein and returns. At Redvers, yield was unexpectedly low with the 100 lb N/ac side-band check. Again, this makes comparisons against this check questionable. However, economic returns of split applications did not look much better than the 70 lb N/ac side-band check which had the benefit of lower input costs and less intensive management (i.e. one less pass with the sprayer). Overall, split applications of N were largely uneconomical even though a large protein spread (66 cents/%/bu) was assumed at each location regardless of protein level.

Extension Activities

The trial was toured at Swift Current on July 9 during their WCA director and staff tour (20 attendees) and on July 30 during their Swift Current Crop Club tour (12 attendees). The trial was also promoted on Swift Current's Facebook page and CKSW's weekly program "Walk the

Plots" reaching thousands of listeners in southwest Saskatchewan. Yorkton toured this trial during their Annual Field Tour on July 23 and an Agratactics private tour on Aug 8 where 100 and 37 people attended, respectively. Mike Hall presented data from this trial during his speech "Getting the Most Out of Nitrogen" at an Agronomy Update in Saskatoon on December 10 (190 attendees). Outlook toured the trial during their July 11 CSIDC Field Day where 200 producers and agronomists attended. The trial was toured at the Indian Head Crop Management Field Day on July 16 (125 attendees) and also during a Federated Co-operatives (FCL) tour on July 12 (40 attendees). Chris Holzapfel promoted and presented highlights for the project during a presentation entitled 'Agronomy of High Yielding Wheat' on January 15 during CropSphere (150 attendees?) A video covering the results of this trial is currently being developed.

10. Conclusions and Recommendations

Split applications of N at the boot stage did not tend to affect yield or protein but a latter application post-anthesis tended to increase protein and decrease yield relative to applying all the N at seeding. Dribble banding UAN at the earlier boot stage did not cause damage to the flag leaf because it was not fully emerged at the time of application. Flag leaf burn from split applications of N post-anthesis were worse with UAN compared to dissolved urea, particularly when applied as a broadcast foliar spray compared to dribble banding. However, differences in yield or protein were not usually detected between applications UAN compared dissolved urea. In contrast, grain protein tended to be higher with broadcast applications compared to dribble band applications and this difference was large and statistically significant at Indian Head. While there were many cases were split N resulted in greater grain protein, the lower yield and extra cost of application meant few cases proved economical compared to applying all the N at seeding, even assuming a wide protein spread of 66 cents/%/bu.

Supporting Information

1. **Acknowledgements:**

This project was funded through the Saskatchewan Wheat Development Commission.

2. **Appendices**

Table 7. Main Effect of Nitrogen Rate, Post Emergent Nitrogen Rate, Post Emergent Nitrogen Product, Post Emergent Application Method, Post Emergent Application Timing on wheat yield at Indian Head, Melfort, Outlook, Prince Albert, Redvers, Scott, Swift Current and Yorkton in 2019.

	Yield								
	I.H.	**Melfort**	**Outlook**	**P.A.**	**Redvers**	**Scott**	**S.C.**	**Yorkton**	**All Sites**
	-------kg/ha-------								
1) 70 lb N/ac side banded	3330bc	5179 bc	7213 a	3538 a	5179 a	3830 a	3038 a	5611 a	4615 a
2) 100 lb N/ac side banded	3598 a	5566 a	7909 a	3544 a	4754 a	4018 a	3263 a	5856 a	4814 a
3) 70 lb N/ac side banded + 30 lb N/ac of 14 % UAN dribble banded @ boot	3422 ab	5331 ab	7489 a	3936 a	5144 a	3857 a	3242 a	6056 a	4810 a
4) 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ boot	3388 b	5111 bc	7795 a	3600 a	5202 a	3858 a	3239 a	5729 a	4740 a
5) 70 lb N/ac side banded + 30 lb N/ac of 14% UAN dribble banded @ post-anthesis	3226 bcd	5071 cd	7623 a	3623 a	5206 a	4002 a	3251 a	5688 a	4711 a
6) 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ post-anthesis	3378 bc	4837 d	7722 a	3720 a	5020 a	3759 a	3055 a	5715 a	4651 a
7) 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea dribble banded @ post-anthesis	3188 cd	5123 bc	7199 a	3846 a	4942 a	3950 a	3177 a	5716 a	4643 a
8) 70 lb N/ac side banded + 30 lb N/ac of 14% UAN broadcast foliar sprayed @ post-anthesis	3266 bc	5161 bc	7182 a	4026 a	4918 a	4110 a	3075 a	5636 a	4672 a
9) 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea broadcast foliar sprayed @ post-anthesis	3045 d	5232 bc	7437 a	3952 a	5012 a	4059 a	3325a	6017 a	4760 a
P-values	0.000593	0.000462	NS	NS	NS	NS	NS	NS	NS
L.S.D.	197.8129	243.635	NS	NS	NS	NS	NS	NS	NS

Table 8. Main Effect of Nitrogen Rate, Post Emergent Nitrogen Rate, Post Emergent Nitrogen Product, Post Emergent Application Method, Post Emergent Application Timing on wheat protein at Indian Head, Melfort, Outlook, Prince Albert, Redvers, Scott, Swift Current and Yorkton in 2019.

	Protein								
	I.H.	**Melfort**	**Outlook**	**P.A.**	**Redvers**	**Scott**	**S.C.**	**Yorkton**	**All Sites**
	------------------------------------%----------------------------------								
1. 70 lb N/ac side banded	15.55 c	11.28 a	12.03 c	13.68 a	14.38 e	14.48 cde	16.90 a	12.08 a	13.80 d
2. 100 lb N/ac side banded	15.85 bc	11.48 a	12.18 bc	14.55 a	14.45 de	14.73 ab	16.05a	12.65 a	13.99 cd
3. 70 lb N/ac side banded + 30 lb N/ac of 14 % UAN dribble banded @ boot	15.63 c	11.45 a	12.30 bc	14.15 a	14.65 cde	14.65bc	16.50 a	12.40 a	13.97 cd
4. 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ boot	15.65 c	11.30 a	12.70 bc	13.98 a	14.83 bcd	14.90 a	16.70 a	12.65 a	14.09 bc
5. 70 lb N/ac side banded + 30 lb N/ac of 14% UAN dribble banded @ post-anthesis	16.00 b	11.45 a	12.85 b	14.30 a	14.95 abc	14.53 cd	16.78 a	12.45 a	14.16 bc
6. 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ post-anthesis	15.75 c	11.43 a	13.83 a	14.98 a	15.28 a	14.63 bcd	17.50 a	12.63 a	14.50 a
7. 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea dribble banded @ post-anthesis	16.03 b	11.60 a	12.00 c	14.50 a	15.10 ab	14.63bcd	16.55 a	12.43 a	14.11 bc
8. 70 lb N/ac side banded + 30 lb N/ac of 14% UAN broadcast foliar sprayed @ post-anthesis	16.60 a	11.40 a	12.53 bc	14.60 a	15.20 ab	14.33 e	17.53 a	12.38 a	14.32 ab
9. 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea broadcast foliar sprayed @ post-anthesis	16.78 a	11.70 a	12.13 bc	14.50 a	14.98 abc	14.50 cde	17.50 a	12.33 a	14.30 ab
P-values	<0.00001	NS	0.000523	NS	0.001682	0.000092	NS	NS	
L.S.D.	0.34	NS	0.72	NS	0.43	0.18	NS	NS	

Table 9. Main Effect of Nitrogen Rate, Post Emergent Nitrogen Rate, Post Emergent Nitrogen Product, Post Emergent Application Method, Post Emergent Application Timing on wheat flag leaf burn at Indian Head, Melfort, Outlook, Prince Albert, Redvers, Scott, Swift Current and Yorkton in 2019.

	Flag Leaf Burn							
	I.H.	**Melfort**	**Outlook**	**P.A.**	**Redvers**	**Scott**	**S.C.**	**Yorkton**
	------------------------------------%----------------------------------							
1. 70 lb side banded	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2. 100 lb side banded	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3. 70 lb side banded + 30 lb N/ac of 14 % UAN dribble banded @ boot	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4. 70 lb side banded + 30 lb N/ac of 28% UAN dribble banded @ boot	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5. 70 lb side banded + 30 lb N/ac of 14% UAN dribble banded @ post-anthesis	22.9 b	9.0 ab	1.8 c	11.3 b	N/A	59.4 ab	N/A	35.1 a
6. 70 lb side banded + 30 lb N/ac of 28% UAN dribble banded @ post-anthesis	19.9 b	11.5 a	10.5 b	11.7 b	N/A	50 b	N/A	36.4 a
7. 70 lb side banded + 30 lb N/ac of 14% Dissolved Urea dribble banded @ post-anthesis	12.8 c	3.4 bc	8.6 b	4.6 c	N/A	53 ab	N/A	23 b
8. 70 lb side banded + 30 lb N/ac of 14% UAN broadcast foliar sprayed @ post-anthesis	31.9 a	3.5 bc	26.8 a	17.5 a	N/A	62.5 a	N/A	36.4 a
9. 70 lb side banded + 30 lb N/ac of 14% Dissolved Urea broadcast foliar sprayed @ post-anthesis	11.4 c	5.7 abc	12.1 b	10.4 b	N/A	50 b	N/A	18.2 b
P-values	<0.00001	0.0060	<0.00001	<0.0001	N/A	<0.00001	N/A	<0.00001
L.S.D.	5.5	6.3	3.3	5.7	N/A	11.2	N/A	8.9

N/A: flag leaf burn ratings were collected but not applicable

Table 10. Economics based on yield and protein averaged over all locations.

	Yield (bu/ac)	Gross $/ac[1]	% grain protein	$ protein premium/ac[2]	Cost of N ($/ac)[3]	Split Application Cost ($/ac)	Gross ($/ac) + protein premium – Cost of N and split application
1) 70 lb N/ac side banded	68.7	463.46	13.80	0.00	35	0	428
2) 100 lb N/ac side banded	71.6	483.42	13.99	9.25	50	0	443
3) 70 lb N/ac side banded + 30 lb N/ac of 14 % UAN dribble banded @ boot	71.6	483.03	13.97	8.00	50	5	436
4) 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ boot	70.5	476.06	14.09	13.56	50	5	435
5) 70 lb N/ac side banded + 30 lb N/ac of 14% UAN dribble banded @ post-anthesis	70.1	473.15	14.16	16.97	50	5	435
6) 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ post-anthesis	69.2	467.08	14.50	32.25	50	5	444
7) 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea dribble banded @ post-anthesis	69.1	466.26	14.11	14.05	50	5	425
8) 70 lb N/ac side banded + 30 lb N/ac of 14% UAN broadcast foliar sprayed @ post-anthesis	69.5	469.18	14.32	24.06	50	5	438
9) 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea broadcast foliar sprayed @ post-anthesis	70.8	478.04	14.30	23.63	50	5	447

[1]bu/ac*$6.75/bu

[2]$ protein premium/ac relative to treatment 1 and based on 66 cents/%/bu

[3]Cost of N - application rate lb N/ac by $0.5/lb N

Table 11. Gross Returns ($/ac) + Protein Premium ($/ac) – Cost of N and split application for all locations ($/ac)									
	$/ac								
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**	**All sites**
1) 70 lb N/ac side banded	299	485	689	320	485	350	270	529	428
2) 100 lb N/ac side banded	**322**	**520**	**756**	**336**	**431**	**363**	**250**	**571**	**443**
3) 70 lb N/ac side banded + 30 lb N/ac of 14 % UAN dribble banded @ boot	291	489	717	359	475	339	258	572	436
4) 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ boot	289	459	779	317	490	348	264	552	435
5) 70 lb N/ac side banded + 30 lb N/ac of 14% UAN dribble banded @ post-anthesis	283	463	772	331	497	349	268	537	435
6) 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ post-anthesis	291	438	857	366	494	328	270	550	444
7) 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea dribble banded @ post-anthesis	280	476	666	362	476	348	253	539	425
8) 70 lb N/ac side banded + 30 lb N/ac of 14% UAN broadcast foliar sprayed @ post-anthesis	307	469	702	386	479	352	273	528	438
9) 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea broadcast foliar sprayed @ post-anthesis	288	492	699	374	478	353	299	564	447

Abstract

3. Abstract/Summary:

Trials were conducted at Yorkton, Redvers, Indian Head, Swift Current, Scott, Outlook, Prince Albert and Melfort to demonstrate the potential of split applications of nitrogen to either increase yield or grain protein of spring wheat. Split applications of N at the boot stage did not tend to affect yield or protein but a latter application post-anthesis tended to increase protein and decrease yield relative to applying all the N at seeding. Dribble banding UAN at the earlier boot stage did not cause damage to the flag leaf because it was not fully emerged at the time of application. Flag leaf burn from split applications of N post-anthesis were worse with UAN compared to dissolved urea, particularly when applied as a broadcast foliar spray compared to dribble banding. However, differences in yield or protein were not usually detected between applications UAN compared dissolved urea. In contrast, grain protein tended to be higher with broadcast applications compared to dribble band applications and this difference was large and statistically significant at Indian Head. While there were many cases were split N resulted in greater grain protein, the lower yield and extra cost of application meant few cases proved economical compared to applying all the N at seeding, even assuming a wide protein spread of 66 cents/%/bu.