SFP #20200439 Final Report

1. **Project Title:** Top Dressing Nitrogen Fertilizer on Frozen or Snow-Covered Soils in Saskatchewan

Should Management Differ Between Barley Varieties?

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2. **Project Number:** #20200439

3. **Contractor undertaking the project:**
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4. **Project locations:**
   This project was conducted at seven AgriARM locations:
   Conservation Learning Centre (CLC) – Prince Albert, SK
   East Central Research Foundation (ECRF) – Yorkton, SK
   Indian Head Agricultural Research Foundation (IHARF) – Indian Head, SK
   Irrigation Crop Diversification Corporation (ICDC) – Outlook, SK
   Northeast Agriculture Research Foundation (NARF) – Melfort, SK
   South East Research Farm (SERF) – Redvers, SK
   Wheatland Conservation Area (WCA) – Swift Current, SK

5. **Project start and end dates (month & year):**
   Start: November/2020
   Completion: December/2022

6. **Project contact person & contact details:**
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7. Project objectives:

The objectives of the project are to develop Saskatchewan specific data showing the loss of production and economic risks associated with broadcast applications of nitrogen fertilizers on frozen and snow-covered soils.

8. Project Rationale:

The use of nitrogen fertilizers has a large impact on crop production in western Canada. It is often the largest single bulk nutrient that is applied annually to crops such as wheat, barley, canola, etc. High rates of nitrogen being applied at seeding can significantly slow down operations due to the extra time required to haul and fill seeder tanks. As well, there are added labour requirements and increased capital investment for trucks to haul the product and seeders capable of banding. In response to these logistical issues, producers have looked at ways to apply nitrogen fertilizer at different times of the year. One of these practices involves the broadcasting granular nitrogen fertilizer onto cold or frozen soils often covered with snow. This practice has started to be utilized more in many regions across the province. Some producers have opted to use products that can help to reduce losses associated with broadcasting nitrogen fertilizers such as urease inhibiters (UI) and urease + nitrification inhibitors (U + NI) while other do not.

To date there is very little Saskatchewan specific independent information or research available to agronomist or producers that directly measures the potential losses (crop yield and economic cost) for nitrogen broadcast onto frozen or snow-covered ground with or without the use of a nitrification and/or urease inhibitors. Furthermore, there is potential to have regional differences in nutrient losses within the province of Saskatchewan, due to significant differences in soil type and growing season moisture. To account for some of the regional variability this project will be conducted on multiple sites across the province to determine if nitrogen losses and crop responses are different due to environmental factors as well as soil types.

9. Methodology:

The test was set up as a Randomized Complete Block Design (RCBD) with 4 replicates. Plots were at least 3 m by 9 m in size. All plots received nitrogen applications based on soil test recommendations. The method of application and timing for nitrogen was based on treatments.

All plots received a seed placed phosphorus application at a rate of 34 kg P_2O_5/ha. The plots were seeded to hard red spring wheat.

All applications of pesticides were done on an as required basis.

9.1. Treatments:

1. 1x Urea broadcast mid-November

2. 1x Super U® (urease + nitrification inhibitor) broadcast mid-November
3. 1X Anvol® (urease inhibitor) treated Urea broadcast mid-November
4. 1x Urea broadcast early February
5. 1x Super U® broadcast early February
6. 1X Anvol® treated Urea broadcast early February
7. 1x Urea broadcast early April
8. 1x Super U® broadcast early April
9. 1X Anvol® treated Urea broadcast early April
10. Spring side band 1x urea at seeding

9.2. Data collection:

Fall soil test/recommendations
Fertility rate
Application dates
Soil temperature at application
Depth of frozen soil at application
Snow depth at application
Meteorological data Nov – April
Seeding rate and date
Crop Variety
Seed and nitrogen costs
Grain yield
Grain protein

10. Results:

10.1. Operations and Environmental Conditions:

Six sites (CLC, ECRF, IHARF, NARF, SERF and WCA) were established in November, 2020 under dryland conditions and one site (ICDC) conducted the project under irrigated conditions. Locations of these sites were: Prince Albert (CLC), Yorkton (ECRF), Indian Head (IHARF), Melfort (NARF), Redvers (SERF), Swift Current (WCA) and Outlook (ICDC), Saskatchewan. Research was commenced and completed over two years (2021 and 2022) for all seven sites resulting in 14 site years of data.

Target application timing dates for the broadcast nitrogen fertilizers was the middle of November (1st), early February (2nd), and early April (3rd), with a comparison side band treatment that was applied during seeding. All applications, with the exception of the second broadcast application timing in 2022 at IHARF, were completed within the month specified in the protocol but there were some deviations from the targeted date (Tables 1a and 1b).

Table 1a. 2020-21 Broadcast application dates.

Timing	CLC	ECRF	ICDC	IHARF	NARF	SERF	WCA
1st	16-Nov-20	10-Nov-20	17-Nov-20	16-Nov-20	16-Nov-20	14-Nov-20	19-Nov-20
2nd	2-Feb-21	9-Feb-21	16-Feb-21	19-Feb-21	16-Feb-21	15-Feb-21	1-Feb-21
3rd	1-Apr-21	22-Apr-21	15-Apr-21	9-Apr-21	8-Apr-21	6-Apr-21	7-Apr-21
Seeding	13-May-21	14-May-21	5-May-21	6-May-21	10-May-21	6-May-21	5-May-21

Table 1b. 2021-22 Broadcast application dates.

Timing	CLC	ECRF	ICDC	IHARF	NARF	SERF	WCA
1st	23-Nov-21	19-Nov-21	17-Nov-21	19-Nov-21	15-Nov-22	18-Nov-21	22-Nov-21
2nd	7-Feb-22	7-Feb-22	15-Feb-22	1-Mar-22	23-Feb-22	24-Feb-22	7-Feb-22
3rd	7-Apr-22	22-Apr-22	13-Apr-22	8-Apr-22	Missed	12-Apr-22	7-Apr-22
Seeding	31-May-22	6-May-22	3-May-22	12-May-22	24-May-22	6-Jun-22	2-May-22

Environmental conditions such as soil temperature and snow depth were recorded for each of the broadcast application timings and precipitation was recorded for the May to August growing season. Tables 2a, 3a & 4a show the recorded soil temperatures, snow depth and precipitation for the 2020-21 season and the 2021-22 season data is presented in tables 2b, 3b, & 4b.

These recordings indicate that at ICDC, NARF and WCA in 2020-21 the soils were not frozen at the time of the first application and as expected all were frozen by the second application timing (Table 2a). In the 2021-22 season four sites (ECRF, NARF, SERF, and WCA) had soils that were not frozen during the first application timing, and all were again frozen by the second application timing (Table 2b).

Table 2a. 2020-21 Soil temperature at broadcast application date (°C).

Timing	CLC	ECRF	ICDC	IHARF	NARF	SERF	WCA
1st	-7	-4	1.8	-2	1	-1	2.4
2nd	-5.5	-12	-10.5	-18	-10	-25.6	-5.2
3rd	2.5	0	4	5	1	11.5	3.8

Table 2b. 2021-22 Soil temperature at broadcast application date (°C).

Timing	CLC	ECRF	ICDC	IHARF	NARF	SERF	WCA
1st	-5.5	0.6	-0.1	-4	3	2	0.1
2nd	-6.5	-7.2	-4.7	-6	-5	-21	-5
3rd	-1	0	0.3	3	-	-2	6.5

All sites in both seasons had snow cover to a varying degree for the first and second application timings but only the CLC had any significant snow cover during the third (Tables 3a & 3b).

While some of the soils were frozen and others remained unfrozen and snow depth varied during the first application timing, it could not be determined within this test if applications made in mid-November would benefit from frozen/unfrozen soils with more or less snow cover.

Table 3a. 2020-21 Snow cover depth at broadcast application date (cm).

Timing	CLC	ECRF	ICDC	IHARF	NARF	SERF	WCA
1st	28	1.5	26	9	19	2	30
2nd	39	20	24	9.5	26	20.5	11
3rd	6	0	0	0	0	0	0

Table 3b. 2021-22 Snow cover depth at broadcast application date (cm).

Timing	CLC	ECRF	ICDC	IHARF	NARF	SERF	WCA
1st	14	11.5	16.5	5	16	11	2
2nd	40	19	21.5	19	49	31	10
3rd	36	0	0.5	0	-	0	0

In 2021 growing season, four of the six dryland sites (CLC, ECRF, NARF & WCA) received significantly less than the long-term average precipitation over the May to August growing season (Table 4a). This condition had the potential to mask differences in nitrogen availability/loss due to moisture being a limiting factor to overall production.

For the 2022 growing season, only two dryland sites (CLC & WCA) had below the long-term average precipitation, three (ECRF, IHARF & NARF) were near the average and one site (SERF) received significantly greater than the long-term average precipitation (Table 4b).

Table 4a. 2020-21 May - August precipitation (mm).

	CLC	ECRF	ICDC	IHARF	NARF	SERF	WCA
2021	151.8	147.6	Irrigated	295.1	146	247	159.3
Long-term avg	251.5	272	-	244.1	265	272	213.7
% of avg	60	54	N/A	121	55	91	75

Table 4b. 2021-22 May - August precipitation (mm).

	CLC	ECRF	ICDC	IHARF	NARF	SERF	WCA
2022	195.1	325	Irrigated	285.6	269.9	480.2	186.8
Long-term avg	233.9	272	-	244.1	265	272	213.7
% of avg	83	119	N/A	117	102	177	87

Soil tests were conducted for all sites and residual nitrogen was recorded as well as the nitrogen application rate for all timings (Tables 5a & 5b). All sights had relatively low residual nitrogen levels in both years except ECRF and SERF.

Table 5a. 2020-21 Soil residual nitrogen and nitrogen application rates (kg N/ha).

	CLC	ECRF	ICDC	IHARF	NARF	SERF	WCA
Residual (0-15)	9	76	3	5.6	15	76*	25
Residual (15-30)	7	13	3	10.1	12	-	6
Applied	144	78	155	112	172	78	112

* Soil test for 0-30 cm

Table 5b. 2021-22 Soil residual nitrogen and nitrogen application rates (kg N/ha).

	CLC	ECRF	ICDC	IHARF	NARF	SERF	WCA
Residual (0-15)	13	74*	6	7	20	76*	8
Residual (15-30)	8	-	2	3	12	-	11
Applied	136	122	155	112	164	67	112

* Soil test for 0-30 cm

10.2. Grain Yield:

Grain yield was measured for each plot and adjusted to 14.5% moisture content. Mean yields for the 2021 growing season are reported in Table 6a and 6b for 2022. The results were statistically compared through analysis of variance with multiple comparisons of means. The Coefficient of Variance (CV), Least Significant Difference (LSD) for the 95% confidence intervals and indication of significance are also reported for both years.

The treatments with the highest mean grain yields for each site are indicated in blue for each year (Tables 6a & 6b) and a missed application for the early April broadcast timing at NARF in 2022 is displayed in red (Table 6b). The values reported for the missed application have been removed from all statistical analysis and discussion.

Table 6a. 2021 Mean grain yields adjusted to 14.5% moisture content (kg/ha).

Treatment	CLC	ECRF	ICDC		IHARF	NARF	SERF		WCA	
Urea mid-Nov	3427	2678	4939	b	3653	3273	2924	bc	949	bc
U + NI mid-Nov	3685	2748	5561	ab	3717	3312	2889	bd	1030	ab
UI mid-Nov	3718	2731	5488	ab	3630	3086	3021	bc	898	b
Urea early Feb	3560	2831	5182	bc	3654	2985	3027	bc	1044	ab
U + NI early Feb	3487	2765	5466	ab	3660	2906	3183	ac	982	ab
UI early Feb	3153	2816	5031	b	3666	2972	2834	b	1006	ab
Urea early April	3679	2589	5795	ac	3721	2798	3064	bc	1023	ab
U + NI early April	3604	2858	5895	a	3775	3019	3097	bc	989	ab
UI early April	3571	2835	5811	ac	3819	2892	3136	cd	1132	a
Side band	3723	2758	6020	a	3825	2996	3445	a	1088	ac
CV (%)	11.7	8.6	8.3		3	10.9	6		11.2	
LSD (0.05)	900.0	399.7	659.1		258.9	577.8	264.9		171.4	
Significance	NS	NS	**		NS	NS	**		**	

Table 6b. 2022 Mean grain yields adjusted to 14.5% moisture content (kg/ha).

Treatment	CLC	ECRF	ICDC		IHARF		NARF	SERF	WCA	
Urea mid-Nov	4646	4349	4498	bc	4918	b	5488	1674	2452	ab
U + NI mid-Nov	4481	4624	5286	ac	4965	b	5462	2413	2466	ab
UI mid-Nov	4509	4825	4963	ab	5004	b	5470	2408	2475	ab
Urea early Feb	4623	4632	4895	ab	4383	b	5025	1524	2373	b
U + NI early Feb	4525	4639	4001	b	4490	b	4946	1638	2518	ab
UI early Feb	4723	4705	4067	b	4628	b	5001	1786	2332	b
Urea early April	4526	4671	5107	ab	4927	b	4251	1950	2592	ab
U + NI early April	4421	4593	5289	ac	5025	b	3870	2147	2465	ab
UI early April	4303	4781	5337	ac	5023	b	3936	2202	2382	b
Side band	4485	4685	5884	a	5806	a	5561	2252	2675	a
CV (%)	9.9	7.9	14.5		7.6		5.9	23.2	5.7	
LSD (0.05)	614.2	751.3	1188.9		757.6		696.6	1142.9	263.6	
Significance	NS	NS	**		**		NS	NS	*	

Four sites (CLC, ECRF, IHARF and NARF) showed no significant differences in mean grain yields between treatments in 2021 (Table 6a) and four sites (CLC, ECRF, NARF and SERF) indicated no significant differences in mean grain yields between treatments in 2022 (Table 6b).

There are a number of reasons that may have contributed to the lack of significant yield differences at these sites. Firstly, three of the sites (CLC, ECRF and NARF) received 60 per cent or less than the long-term average precipitation during the 2021 growing season (Table 4a). In the case of the CLC and NARF, the high target yields that were chosen led to increased nitrogen application rates in both years (Tables 5a & 5b). These high nitrogen application rates in both years coupled with below average precipitation in 2021 were likely able to supply the crop with the highest yield potential for all treatments regardless of losses. In the case of ECRF, the target yields were also high but, the maximum yield potential was potentially met with the high soil residual nitrogen in both years rather than the amount that was applied (Tables 5a & 5b).

In 2021, the SERF site indicated there were significant differences in mean grain yields between some treatments despite the high residual nitrogen due to adequate precipitation (Table 6a). However, excessive precipitation in 2022 (Table 4b) delayed seeding and reduced the number of replications that could be seeded to three due to the wet field conditions. These conditions reduced confidence in the data recorded as indicated by the excessive coefficient of variation at 23.2 % (Table 6b).

Where significant yield differences were observed in 2021 (ICDC, SERF and WCA) and in 2022 (ICDC, IHARF and WCA), five of these six site years indicated that the side banding nitrogen treatment had the highest overall yield (Tables 6a & 6b) and was significantly better than all broadcast treatments at IHARF in 2022 (Table 6b).

In the same five site years indicating significant differences in yield, side banding had a significantly greater yield than the early February application of nitrogen treated with the urease inhibitor (U + NI) (Tables 6a & 6b). As well, the side banding treatment indicated it had a significantly higher yield than the mid-November and early February applications of bare urea in four of these site years.

When soil moisture was not limiting such as at ICDC under irrigation and IHARF in both years (Tables 4a & 4b), side band applications of nitrogen consistently produced the highest treatment yields that were significantly greater than many of the other application timings (Tables 6a & 6b).

Overall, regardless of the significance of yield differences, side banding nitrogen at seeding produced the highest mean yield in eight of the 14 site years (Tables 6a & 6b).

The average yields for all sites in both years are presented in Table 7 and represented graphically in Figure 1. Table 7 indicates that the side banding nitrogen treatment had the highest overall average yield (4073 kg/ha) when compared to all broadcast treatments and timings.

When all yields were averaged over both site years broadcast applications of bare urea was found to be almost identical regardless of the application timing (Table 7). Urea applied in mid-November, early February and early April produced an average yields of 3707, 3709 and 3708 kg/ha respectively (Table 7).

Table 7. Average grain yields (kg/ha)

Treatment	Average Yield
Urea mid-Nov	3707
U + NI mid-Nov	3864
UI mid-Nov	3832
Urea early Feb	3709
U + NI early Feb	3659
UI early Feb	3610
Urea early April	3708
U + NI early April	3753
UI early April	3752
Side band	4073

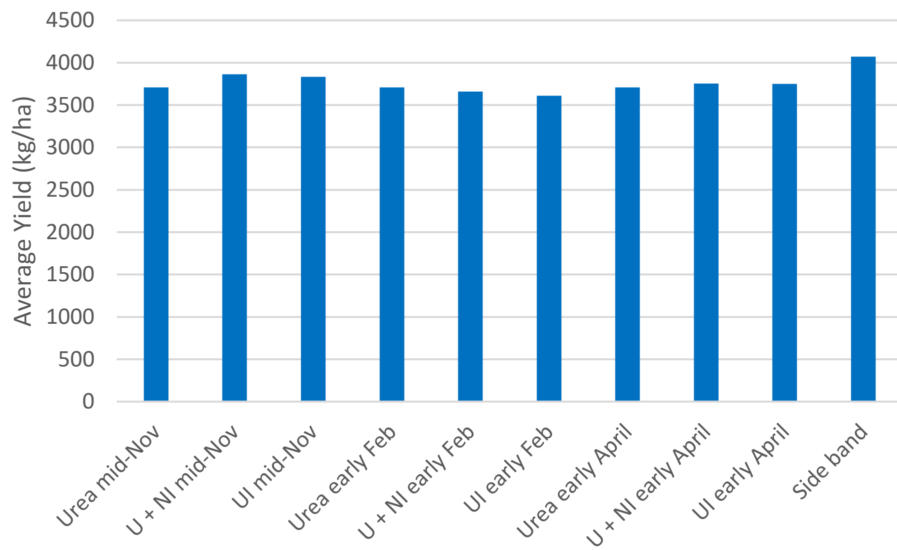

Figure 1. Overall Average Yield by Treatment.

Since all treatments at each site received the same rate of nitrogen, the reductions in yield for all broadcast treatments on frozen or snow-covered ground represent a loss of available nitrogen for grain production.

Addition of enhanced efficiency fertilizer products such as urease inhibiters or urease + nitrification inhibitors, indicated that there was a trend to improving the overall average yields for both broadcast nitrogen applied in mid-November and early April (Figure 1) when compared to untreated urea at the same timing. However, these differences were not significant for any sight year and were not equal to yields achieved when the nitrogen was side banded.

10.3. Grain Protein:

The percent protein was assessed for each grain sample that was harvested from each plot. The mean protein percentages are reported for each site in Table 8a for 2021 and Table 8b for 2022. The results were statistically compared through analysis of variance with multiple comparisons of means. The Coefficient of Variance (CV), Least Significant Difference (LSD) for the 95% and 99% confidence intervals and indication of significance are also reported for both years.

The treatments with the highest mean protein values for each site are indicated in blue for each year (Tables 8a & 8b) and a missed application for the early April broadcast timing at NARF in 2022 is displayed in red (Table 8b). The values reported for the missed application have been removed from all statistical analysis and discussion.

Table 8a. 2021 Mean grain protein (%).

Treatment	CLC		ECRF	ICDC		IHARF		NARF		SERF		WCA	
Urea mid-Nov	12.5	b	15.3	10.6	b	13.2	b	14.6	ac	12.7	b	19.2	ac
U + NI mid-Nov	13.4	ab	15.4	12.6	ac	13.5	bcd	14.6	ac	12.8	bf	19.3	ac
UI mid-Nov	13.4	ab	15.1	11.3	bcd	13.3	bd	14.8	a	13.2	bef	19.7	a
Urea early Feb	12.8	b	15.2	11.1	bd	13.7	ad	13.1	b	13.2	bd	17.9	b
U + NI early Feb	12.5	b	15.5	11.0	b	13.7	ad	13.7	bc	13.6	cde	18.3	b
UI early Feb	13.1	ab	15.2	10.9	b	13.5	bcd	13.2	b	13.1	bef	17.9	b
Urea early April	12.1	b	15.5	12.0	bcd	13.8	ad	13.5	b	13.4	cdf	19.3	ac
U + NI early April	13.3	ab	15.2	12.4	ad	13.8	ac	13.7	bc	13.8	ad	19.1	ac
UI early April	13.1	ab	15.3	12.5	ac	13.9	ac	13.6	bc	13.9	ac	19.0	bc
Side band	14.3	a	15.2	13.6	a	14.1	a	15.4	a	14.4	a	19.2	ac
CV (%)	5.5		1.8	8.3		2		4.5		2.6		2.4	
LSD (0.05)	1.57		0.47	1.39		0.49		1		0.61		0.64	
Significance	**		NS	**		**		**		**		**	

Table 8b. 2022 Mean grain protein (%).

Treatment	CLC		ECRF	ICDC		IHARF		NARF		SERF		WCA	
Urea mid-Nov	14.1	ac	14.2	11.4	b	12.9	ab	14.6	a	12.9	ab	16.0	b
U + NI mid-Nov	14.2	ac	14.2	12.2	b	12.8	ab	14.6	a	12.7	ab	16.1	ab
UI mid-Nov	14.6	a	14.3	11.6	b	12.9	ab	14.6	a	12.9	ab	16.3	ab
Urea early Feb	14.5	a	14.3	11.5	b	12.4	b	13.8	b	12.6	ab	16.0	b
U + NI early Feb	14.7	a	14.3	11.1	b	12.9	ab	14.4	ab	12.5	ab	16.2	ab
UI early Feb	14.6	a	14.3	11.0	b	12.6	ab	13.8	b	12.7	ab	16.1	b
Urea early April	13.3	bc	14.2	11.6	b	13.0	ab	13.4	-	12.6	ab	16.3	ab
U + NI early April	12.9	b	14.2	11.9	b	13.0	ab	12.7	-	12.9	ab	16.6	a
UI early April	13.0	b	14.5	12.1	b	12.9	ab	12.7	-	13.1	a	16.4	ab
Side band	15.0	a	14.3	14.1	a	14.0	a	14.7	a	12.2	b	16.3	ab
CV (%)	4.8		2.2	6.0		4.7		2.8		2.2		1.0	
LSD (0.05)	0.96		0.51	1.29		1.55		0.67		0.8		0.49	
Significance	**		NS	**		*		*		*		*	

Twelve of the 15 site years showed significant differences in protein levels and eight of these were highly significant (Tables 8a & 8b). As well, there was a significant range in protein levels from site to site (10.6 to 19.7 %). This wide range is most prevalent in 2021 and is likely reflective of the range of available moisture during that growing season.

Nine of the twelve sites showing significant differences indicated that the highest grain protein was achieved where the nitrogen fertilizer was side banded at seeding (Tables 8a & 8b).

There were only three sites that indicated significant protein differences (WCA in both years and SERF in 2022) that did not record the highest level for the side banded treatment (Tables 8a & 8b). Two (SERF & WCA in 2022) of these achieved the highest protein level in the early April application treatments with the addition of enhanced efficiency fertilizer products. One was recorded for the mid-November application with the addition of a urease inhibitor (WCA in 2021).

The only site that did not indicate any significant differences in protein levels was ECRF in both years (Tables 8a & 8b).

Broadcast applications in early February had significantly lower protein levels than the side banding treatment in eight site years when untreated urea was used, seven site years when urea with a urease inhibitor was used and six site years when a dual inhibitor was used (Tables 8a & 8b).

Untreated urea also frequently had significantly lower protein contents when broadcast in mid-November and early April as compared to the nitrogen side banded at time of seeding treatments (Tables 8a & 8b). These protein levels were significantly less than side banding in five site years when applied in mid-November and six site years when applied in early April.

While adequate moisture at the ICDC site due to irrigation produced the highest overall yields in both years (Tables 7a &7b), it also produced the lowest grain protein (Tables 8a & 8b). This is likely due to a limitation of available nitrogen during the growing period where the plants were building grain protein. Data from the ICDC site indicates that the grain protein level of the side band treatment was greater than all of the broadcast treatments in both years and significantly greater than all of the broadcast treatments in 2022.

Overall, the WCA site recorded the highest grain protein of all the sites reporting in both years (Tables 8a & 8b). This is not surprising since, the WCA also recorded the lowest yields due to limited precipitation and low wheat yields are generally characterized by reduced starch content. Thus, the relative amount of protein to starch is higher.

Figure 2 shows the protein content averaged over all site years. The graph indicates that, on average, side banding nitrogen at seeding produced the highest average protein content. All nitrogen applications in early February had the lowest average protein levels. Broadcast applications in mid-November and early April improved the average protein contents but did not achieve the same level as when the nitrogen was side banded at the time of seeding.

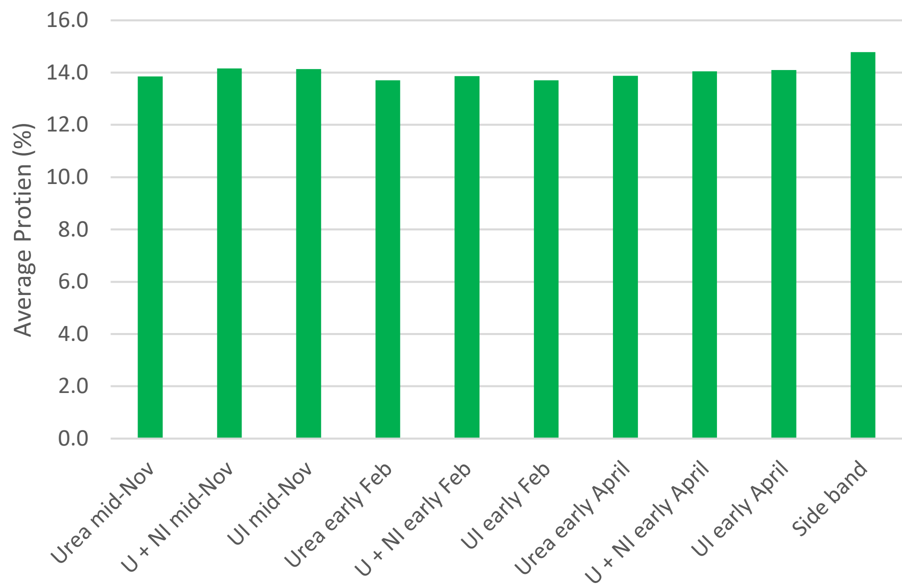

Figure 2. Overall Average Protein Content by Treatment.

Treating the broadcast urea with a urease inhibitor or urease + nitrification inhibitors appear to improve the potential to build protein in wheat (Figure 2). However, no significant differences were measured between bare urea and urea treated with an inhibitor for any of the three application timings (Tables 8a & 8b).

10.4. Economics:

To determine the economic gains or losses for each treatment, the difference in the mean yield of each broadcast application relative to the mean yield achieved for side banding nitrogen at seeding, was multiplied by the current sale value of Canadian Western Red Spring wheat (CWRS). This value was found to be $397.48 per tonne as indicated by the Government of Saskatchewan website (Government of Saskatchewan, 2023. Grain and Specialty Crop Prices. https://dashboard.saskatchewan.ca/agriculture).

In addition, broadcast applications incorporating enhanced efficiency fertilizer products such as urease or urease and nitrification inhibitors had an added cost for this product. The premium paid (amount paid above the cost of bare urea) for these products was subtracted from the relative gain or loss for each treatment that incorporated an inhibitor. The amount that was subtracted was based on the value of the inhibitor relative to the amount of nitrogen applied for each treatment (Tables 5a & 5b). Values of the premiums for the enhanced efficiency fertilizer products were determined through personal contact with industry providers and are subject to change. The values used for calculation purposes were $128 per tonne for Anvol® and $150 per tonne for Super U®.

Each broadcast application could be considered have an added cost for the operation. However, this cost would be quite variable due to service providers charges, or the ownership of broadcasting equipment and the type used. Therefore, this cost has been omitted.

The gains or losses relative to side banding the nitrogen fertilizer at seeding for 2021 are indicated in Tables 9a and for 2022 in Table 9b. Positive values indicate an economic gain to using the practice described in the treatment column and negative values denote losses.

Table 9a. 2021 Economic Differences Relative to Side Banding ($/ha)

Treatment	CLC	ECRF	ICDC	IHARF	NARF	SERF	WCA
Urea mid-Nov	-118	-32	-430	-68	110	-207	-55
U + NI mid-Nov	-62	-29	-233	-79	70	-246	-59
UI mid-Nov	-42	-32	-255	-109	-12	-190	-107
Urea early Feb	-65	29	-333	-68	-4	-166	-17
U + NI early Feb	-140	-23	-271	-102	-92	-129	-78
UI early Feb	-266	1	-436	-94	-57	-264	-63
Urea early April	-17	-67	-89	-41	-78	-151	-26
U + NI early April	-94	14	-100	-56	-47	-164	-76
UI early April	-100	9	-126	-33	-89	-144	-14
Side band	-	-	-	-	-	-	-

Table 9b. 2022 Economic Differences Relative to Side Banding ($/ha)

Treatment	CLC	ECRF	ICDC	IHARF	NARF	SERF	WCA
Urea mid-Nov	64	-133	-551	-353	-29	-	-88
U + NI mid-Nov	-46	-64	-288	-371	-93	-	-119
UI mid-Nov	-28	22	-409	-350	-82	-	-111
Urea early Feb	55	-21	-393	-566	-213	-	-120
U + NI early Feb	-28	-58	-799	-560	-298	-	-99
UI early Feb	57	-26	-765	-499	-268	-	-167
Urea early April	16	-6	-309	-349	-	-	-33
U + NI early April	-70	-76	-287	-347	-	-	-120
UI early April	-110	4	-260	-342	-	-	-147
Side band	-	-	-	-	-	-	-

Where fertilizer applications were missed (NARF, 2022) and where the coefficient of variance indicated there was low confidence in mean yields (SERF, 2022) the relative gain or loss data has been omitted (Table 9b).

Very few economic gains are recorded for any broadcast applications and these are restricted to site years with no significant yield differences such as ECRF and NARF in 2021 and CLC and ECRF in 2022 (Tables 9a & 9b).

Data from the ICDC site in both years and IHARF in 2022 indicates that when growing season moisture is less limiting, economic losses can be quite high. These losses ranged from $89/ha to $799/ha (Tables 9a & 9b).

When the economic differences relative to side banding nitrogen at seeding are averaged over all locations and years, broadcasting nitrogen onto frozen or snow-covered ground with or without the use of a urease or urease and nitrification inhibitor resulted in a net economic loss (Table 10).

Table 10. Average Economic Differences Relative to Side Banding ($/ha)

Treatment	Average Economic Difference
Urea mid-Nov	-145
U + NI mid-Nov	-123
UI mid-Nov	-130
Urea early Feb	-145
U + NI early Feb	-205
UI early Feb	-218
Urea early April	-145
U + NI early April	-167
UI early April	-162
Side band	-

10.5 Extension Activities

Preliminary results (first year) of this project were presented online to 20 specialists within the Saskatchewan Ministry of Agriculture, Regional Services Branch and invited guests on January 24, 2022. These preliminary results were also presented at the 2022 Northeast Agricultural Research Foundation's annual field day on July 20, 2022. Approximately 60 attendees were present.

As well, a Crop Walk video detailing information about this project was filmed and will be posted on the Government of Saskatchewan YouTube page.

Future extension activity will include presentations of the projects final results to the Saskatchewan Ministry of Agriculture, Regional Services Branch and at various extension events throughout the province.

11. Conclusions and Recommendations:

Below average precipitation, high residual soil nitrogen and high target yield fertilizer application rates allowed the crops at many sites to achieve a maximum yield potential regardless of nitrogen losses. As a result, eight of the fourteen site years showed no significant differences in mean grain yields between treatments.

At the sites that were less limited in growing season moisture, five of the six site years indicated that the side banding nitrogen treatment had the highest overall mean yield and there were some significant differences between treatments. These significant differences between side banding and the broadcast treatments varied but, one site year did indicate that side banding nitrogen was significantly better than all broadcast treatments.

Averaging all the treatment yields over both years indicated there is a strong trend for side banding nitrogen at seeding to produce greater yields than any of the broadcasting nitrogen treatments onto frozen or snow-covered ground.

Addition of enhanced efficiency fertilizer products such as urease or urease + nitrification inhibitors, indicated that there was a trend to improving the overall average yields for broadcast nitrogen applied in mid-November and early April. Although, these differences were not significant for any sight year and were not equal to yields achieved when the nitrogen was side banded.

Mean grain protein levels measured for each treatment indicated there was a strong advantage to side banding nitrogen at seeding when compared the broadcasting nitrogen onto frozen or snow-covered ground. Maximum grain protein was achieved in nine of the 14 site years when nitrogen was side banding at seeding.

As with yield, the addition of enhanced efficiency fertilizer products indicated that there was a trend to improving the overall average protein content for broadcast nitrogen applied in mid-November and early April. These differences were again not significant and did not restore protein content to what could be achieved through side banding.

Economic comparisons indicated that broadcasting nitrogen onto frozen or snow-covered ground with or without the use of a urease or urease + nitrification inhibitor resulted in a net economic loss when compared to side banding nitrogen at seeding.

Economic differences will vary depending on the cost of inputs and the price of the crop. It is possible that these differences may be smaller or larger than what is reported here.

Since, grain buyers rarely pay a premium for high protein wheat anymore, the economic advantages to wheat with improved protein was not considered. It is possible that some of the very low proteins seen in this research may be less desirable to grain buyers. Therefore, agronomic practices that promote improved protein levels such as side banding nitrogen at seeding rather than broadcasting it onto frozen or snow-covered ground should be encouraged.

12. Acknowledgements:

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13. Abstract/Summary:

Nitrogen fertilizers are often the largest single bulk nutrient that is applied annually to crops such as wheat, barley, canola, etc. High rates of nitrogen being applied at seeding can significantly slow down operations due to the extra time required to haul and fill seeder tanks as well as increase labour requirements and increased capital investment. In an attempt to alleviate these logistical issues, some have opted to broadcast granular nitrogen fertilizer in the winter months onto cold or frozen soils often covered with snow. This practice leaves nitrogen fertilizer vulnerable to losses from volatilization and displacement due to runoff. To counteract some of the potential losses, urease inhibiters or urease plus nitrification inhibitors have sometimes been incorporated. To examine the potential losses from broadcasting nitrogen fertilizers onto frozen or snow-covered soils in Saskatchewan, a project was designed to evaluate three nitrogen sources applied at three winter timings at seven sites across the province. The average of all the treatment data over both years indicated there is a strong trend for side banding nitrogen at seeding to produce greater yields and protein than any of the broadcasting nitrogen treatments onto frozen or snow-covered ground. Addition of urease inhibiters or urease + nitrification inhibitors, indicated that there was a trend to improving the overall average yields and protein for broadcast nitrogen for some application timings. However, these differences were not significant and did not equal to yields and protein levels achieved when the nitrogen was side banded. Broadcasting nitrogen onto frozen or snow-covered ground with or without the use of a urease or urease + nitrification inhibitor resulted in a net economic loss when compared to side banding nitrogen at seeding.

14. Budget Report:

The budget report is provided in the accompanying spread sheets.