Agriculture Demonstration of Practices and Technologies (ADOPT)

Project Final Report

The final project report should be made available electronically (MS Word). Additional data tables and or graphs may be submitted in spreadsheet format. Due to formatting, printing and distribution requirements, final reports will not be accepted as PDF documents. Completed reports must be returned by email to Evaluation.Coordinator@gov.sk.ca.

Project Title: N management in Oats to increase grain protein, reduce lodging and maintain test weight

Project Number: 20241050

Producer Group Sponsoring the Project: SaskOats

Project Location(s): *Provide the name or number of the rural municipality, nearest town or legal land location if possible. Provide the name of any cooperating landowner(s).* Yorkton, Saskatchewan; Indian Head, Saskatchewan; Swift Current, Saskatchewan; Scott, Saskatchewan; Melfort, Saskatchewan; Prince Albert, Saskatchewan; Redvers, Saskatchewan

Project start date *(month & year):* 4/1/2025

Project end date *(month & year):* 4/1/2026

Project Manager Contact

Full Name: Mike Hall

Organization: East Central Research Foundation

Mailing Address: Box 1939, Yorkton, SK, S3N 3X3

Phone Number: 306-621-6032

E-mail: m.hall@suncrestcollege.ca

Abstract *(maximum 200 words)*

Detail key elements from the project objectives, methodology, results and conclusions to provide a short concise summary of the project. List extension activities such as field days or workshops and include the number of people who visited the project.

Trials were established at Yorkton, Indian Head, Swift Current, Scott, Melfort, Prince Albert, and Redvers to determine if delaying the crop's access to nitrogen could decrease lodging, increase protein, and maintain test weight and yield of milling oat. Applying a portion of the total N as dribble banded UAN (4 leaf vs boot stages) or side banded ESN was compared to side banding all the N as urea. These comparisons were made at total N levels of 110 and 140 lb/ac (soil + fertilizer). Some benefits from managing N were detected, however, they were rare and inconsistent. While yield and protein did not typically differ between levels of N management at most sites, applying a portion of the total N as UAN at the boot stage decreased both yield and grain protein at Indian Head. This highlights the environmental risks associated with split applications. However, there were a couple instances where supplying a portion of the N as ESN or dribble banded UAN did increase grain protein by providing late season N to the crop. Levels of lodging were very low at

most locations, making it difficult to detect any differences between N management. However, even at sites where lodging was high, no significant effects were detected. Maintaining oat test weight with UAN at the boot with the use of ESN was detected in a couple of instances at Swift Current. However, these effects were not detected at any of the other locations despite test weight being responsive to added N at 4 of the locations. In conclusion, there was limited evidence that applying a portion of the N requirement as ESN or dribble banded UAN could maintain yield and test weight, increase grain protein, or reduce lodging. Effects were inconsistent between sites and even between levels of total N within a site.

Project Objectives

Provide a short statement outlining the project objectives. Identify the key concept this project was designed to demonstrate. For example, you might use a statement such as *"This project was intended to demonstrate and compare the benefits of……" or "The objective of this project was to demonstrate the impact of…."*

The overall objective was to determine if a split application of nitrogen (N) or side banding ESN at seeding can decrease lodging, increase protein, and maintain test weight and yield of milling oat relative to putting all the N down at seeding. Dribble banded UAN and side banded ESN were applied at 30 lb N/ac to based rates of 80 and 110 lb N/ac of soil + side-banded urea. The efficacy of the dribble banded UAN were determined for applications made at the 4 leaf versus boot stages.

Project Rationale

Briefly describe why this project is of interest to local producers. Why is it important to have this project? What are the potential beneficial outcomes? What is the perceived need?

Interest in plant-based protein is increasing. Millers are interested in exploring N management strategies, which might increase grain protein of oat without increasing lodging and reducing test weights below acceptance for milling. Late season applications of N, at either the boot stage or later, are well documented to increase grain protein in wheat [1]. Dribble banding UAN is an effective way to apply late season applications of N, provided adequate and timely rainfall is received after application. Dribble banding typically causes less leaf burn than foliar broadcast sprays, and is still an effective way to apply N, as most nitrogen is taken up by the roots, and little is absorbed by the foliage [2]. Late season applications of 30 lb N/ac typically increase grain protein by 0.5% on average in western Canada [3]. Split applying N has also been reported to reduce the risk of lodging in wheat [4,5]. Work by Wu et al. found delaying application of half the N until after jointing, increased lodging resistance, increased grain protein and maintained yield potential relative to applying all the N at seeding. Side banding Environmentally Smart Nitrogen (ESN) is another way to supply late season N, as it takes time for the polymer coating around each granule of fertilizer to break down and release the urea.

The impact of late season N on Oat grain protein, lodging and test weight stability is less well researched. This study will determine if split applying N or the use of ESN can increase grain protein, reduce lodging and still maintain yield and test weight of milling oat. Determining how to increase oat grain protein without increasing lodging or reducing test weight is of interest to oat millers and producers. If oat protein can be effectively managed, millers may be willing to incentivize oat producers by offering protein premiums in the future.

[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] 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.

[3]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.

[4]Mangin, A., Brule-Babel, A., Flaten, D., Wiersma, J., and Lawley, Y. 2022. Canopy manage: the balance between lodging risk and nitrogen use for spring wheat production in the Canadian Prairies. Can. J. Plant Sci. 102: 984-1000

[5]Wu, W., Ma, B.L., Fan, J.J., Sun, M., Yi, Y., and Guo, W.S., 2019. Management of nitrogen fertilization to balance reducing lodging risk and increasing yield and protein content in spring wheat. F. Crop. Res. 241: 107584.

Methodology

Fully describe how the project was set up and run. You should provide enough information so that any reader can understand what you did, and where and when you did it. From that they can determine if your report has any relevance to their own operation. For example, your description should include all relevant items such as 1) the number and size of any field plots, 2) what was seeded, 3) what treatments were applied to the plots, 4) the schedule or timing of any relevant activities such as seeding, treatment application or harvest, and 5) what was measured to evaluate the success of any treatment. If your project dealt with animals, you should be sure to include 1) the number of animals in each trial group, 2) the treatment or procedure applied to each group, and 3) what was measured to evaluate the success of each treatment.

Each trial was established as a Randomized Complete Block Design with 4 replications. Treatments were established at each location as described in Table 1. All trials were "small plot". However, plot size varied based on available equipment and standard practices for each location. CS Camden was used at all sites as it has the lowest test weight on the Grain Millers preferred list. Seed lots of CS Camden differed between locations. Treatments 1 to 4 established the crop response to increasing rates of side-banded nitrogen at seeding. Treatments 5-8 evaluated the impact of dribble banding 30 lb N/ac of UAN at the 4-leaf stage and boot stage to base rates of 80 and 110 lb/ac of soil + fertilizer N. For comparison, treatments 9 and 10 evaluated the impact of including an additional 30 lb N/ac of ESN to the base rates of 80 and 110 lb/ac of soil + fertilizer N. Trials were harvested using plot combines and data was statistically analyzed to determine if treatment means significantly differ. Factors which were measured included:

- Spring Soil Nutrients
- Emergence (plants/m^2)
- Lodging rating (0-9)
- Yield (kg/ha adjusted to 13.5% moisture)
- Grain Protein (%)
- Test weight (g/0.5 l)
- Weather Data

Dates of key operations for each location are listed in table 2.

Table 1. Treatment list for each location 2025.

Treatment #	**Seeding**	**Post-emergence application**				
	Lb /ac of soil + Side-banded N	N (lb/ac)	Product	%N	Method	Stage
1	Soil N	Na	Na	Na	Na	Na
2	80	Na	Na	Na	Na	Na
3	110	Na	Na	Na	Na	Na
4	140	Na	Na	Na	Na	Na
5	80	30	UAN	28	dribble[1]	4 lf
6	80	30	UAN	28	dribble[1]	boot

7	110	30	UAN	28	dribble[1]	4 lf
8	110	30	UAN	28	dribble[1]	boot
9	80 (urea) + 30 (ESN)	Na	Na	Na	Na	Na
10	110 (urea) + 30 (ESN)	Na	Na	Na	Na	Na

[1] Sprayed with dribble band nozzle at 10 ga/ac (undiluted UAN =28% N solution)

Table 2. Dates of key operations for all participating sites.

	Swift Current	Scott	Yorkton	Indian Head	Redvers	Melfort	Prince Albert
Spring Soil Test	April 16	April 30	April 25	May 12		May 8	May 7
Pre-seed Herbicide	April 18 *(RT540 @ 0.5L/ac)*	May 13 *(Glyphosate 540 @ 1L/ac & AIM @ 35 ml/ac)*	May 22 *(Transorb @ 1L/ac)*	May 13 *(Roundup Weathermax @ 0.67L/ac)*	May 13 *(RU 540 @ 0.67L/ac)*	May 15 *(Heat LQ 21 ml/ac StartUp 0.67L/ac)*	May 10 *(Glyphosate @ 0.88L/ac + Heat @ 29ml/ac)*
Seeded Trial	April 28	May 13	May 24	May 12	May 11	May 14	May 22
Rolled	N/A	May 14	N/A	N/A	N/A	N/A	N/A
Emergence (plant/m^2)	May 28	June 2	June 6	June 5	June 5 & 6	June 3	June 25
Dribble Band UAN on treatment 5 & 7 @ 4 leaf stage	June 2	June 10	June 12	June 6	June 18	June 11	June 11
Dribble Band UAN on treatment 6 & 8 @ boot stage	June 18	June 27	July 4	June 25	June 30	July 4	July 11
In-crop Herbicide	N/A	June 16 *(Buctril M @ 0.4L/ac)*	June 16 *(Prestige XL 900 ml/ac)*	June 11 *(Buctril M @ 0.405L/ac)*	June 11 *(Buctril M @ 0.4L/ac)*	June 20 *(Momentum 0.45L/ac MCPA 0.38L/ac)*	N/A
In-crop Fungicide	N/A	July 9 *(Caramba @ 400ml/ac)*	N/A	July 2 *(Trivapro A @ 0.4 L/ac & Trivapro B @ 0.12 L/ac)*	N/A	N/A	N/A
Lodging	September 12	August 18	September 22	August 14	Before Harvest	September 11	September 25
Harvest	September 15	September 4	September 24	August 27	August 20	September 11	September 25

Results *(you must provide the following information)*

Present and discuss any project results, including any data or measurements taken to evaluate the demonstration. Include things that didn't appear to work. These results are just as important to share. List extension activities such as field days or workshops. List the activity, the date it occurred, and the number of people who attended.

Environmental Conditions

In 2025, All locations were warmer than their long-term averages except Prince Albert and Swift Current (Table 3). Prince Albert was 1.57 °C cooler than normal and Swift Current was average. July was cooler than average at all locations and June and July were particularly cool for Prince Albert. Precipitation was substantially below average at Yorkton, Indian Head, and Redvers. Every month from May to August was dry at Indian Head. At Yorkton, only August received above average rainfall and June was particularly dry for Redvers. Average oat yield for Yorkton, Indian Head and Redvers was 98, 143 and 115 bu/ac, respectively. The lower yield potential at Yorkton is likely related to heavy lodging by harvest. Precipitation was above average at Scott and Swift Current with June being by far the wettest month for both locations. Oat yield at Scott was high at 133 bu/ac. Despite above average rainfall at Swift Current, oat yield was still relatively low because this was still a dry location. Near average precipitation fell at Prince Albert and Melfort. However, May and July were very dry for both locations. Melfort had the highest location yield at 157 bu/ac and the yield at Prince Albert was 107 bu/ac.

Table 3. Mean monthly temperatures and precipitation amounts for 2024 and 2025 along with long-term normals for Yorkton, Indian Head, Scott, Prince Albert, Melfort, Redvers, and Swift Current Saskatchewan.

Location	Year	May	June	July	August	Avg./Total
			Mean Temperature (°C)			
Yorkton	2025	12.4	15.7	17.5	18.3	15.98
	Long-term	***10.4***	***15.5***	***17.9***	***17.1***	***15.2***
Indian Head	2025	12.7	15.3	17.0	17.8	15.7
	Long-term	***10.8***	***15.8***	***18.2***	***17.4***	***15.6***
Scott	2025	12.9	14.6	15.8	17.4	15.2
	Long-term	***10.8***	***14.8***	***17.3***	***16.3***	***14.8***
Prince Albert	2025	11.2	12.7	14.9	17.1	13.98
	Long-term	***11.2***	***16.0***	***18.3***	***16.7***	***15.55***
Melfort	2025	13.8	15.0	17.0	18.0	15.95
	Long-term	***10.1***	***15.2***	***17.8***	***16.7***	***14.95***
Redvers	*2025*	13.2	16.2	17.5	17.9	16.2
	Long-term	***11.1***	***16.2***	***18.7***	***18***	***16.0***
Swift Current	*2025*	13.1	15.9	18.0	19.0	16.5
	Long-term	***11.9***	***16.4***	***19.1***	***18.7***	***16.5***
			Precipitation (mm)			

Yorkton	2025	23.6	63.4	36.8	71.2	195.0
	Long-term	***51***	***80***	***78***	***62***	***272***
Indian Head	2025	42.6	39.4	27.1	26.9	136.0
	Long-term	***51.7***	***77.4***	***63.8***	***51.2***	***244.1***
Scott	2025	11.8	103.7	28.7	64.5	273.2
	Long-term	***38.9***	***69.7***	***69.4***	***48.7***	***226.7***
Prince Albert	2025	2.2	137.6	8.6	51.2	199.6
	Long-term	***36.5***	***66.8***	***61.3***	***43.6***	***208.18***
Melfort	2025	4.8	93.2	25.9	113.5	237.4
	Long-term	***33.4***	***79.5***	***69.6***	***45.9***	***228.4***
Redvers	*2025*	65.0	27.0	80.0	40	212
	Long-term	***60.0***	***95.2***	***65.5***	***46.6***	***267.3***
Swift Current	*2025*	34.2	31.3	78.2	92.6	236.3
	Long-term	***47.5***	***56.0***	***56.3***	***38.0***	***197.8***

Combined analysis and Overview

Treatments were divided into two different analyses. The first 4 treatments were analyzed in isolation to determine if there was a significant response (linear or quadratic) to increasing rate of side banded N (urea). This analysis is needed as the efficacy of N management strategies (ie: UAN and ESN) can only be properly assessed on sites which were responsive to added N. When analyzing all sites combined, a significant effect of N rate was detected on yield, seed protein and test weight (Table 4). However, significant interactions between N rate and site were detected for yield and seed protein, indicating that these effects differed between sites (Table 5). The effect of site was significant for all parameters measured. Differences between sites will be referred to in later discussion.

The second analysis evaluated treatments 3 to 10 as a 2 x 4 factorial. The first factor compared total N levels (soil + fertilizer) of 110 versus 140 lb N/ac. The second factor compared different approaches to N management. The full amount of N was either all side banded, or partially side banded with 30 lb N/ac added as either dribble banded UAN (4 leaf vs boot stages) or ESN. Table 6 shows the significance of total N, N management, site, and all possible interactions for the parameters measured. Significant effects of site were detected for all parameters and several interactions with site were detected for seed protein. The significance of the main effects and their interactions on an individual site basis are listed in table 7. These differences will be discussed in turn by parameter measured.

Table 4. Test of fixed effects for N rate (R), site (S), and all possible interactions for all parameters measured. Effects significant at P<0.05 are bolded. Effects significant at P<0.1 are bolded and italicized.

Fixed effects	Emergence	Yield	Seed Protein	Test wt.	Lodging
N rate (R)	0.109	**<0.001**	**<0.001**	**0.019**	0.829
Site (S)	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Block	0.102	**0.011**	0.131	**0.006**	0.340
R x Site	0.612	***0.057***	**<0.001**	0.679	0.117

Table 5. Significance of N rate for measured parameters at each location. Effects significant at P<0.05 are bolded. Effects significant at P<0.1 are bolded and italicized.

Site	Emergence	Yield	Seed Protein	Test wt.	Lodging
Swift Current	0.476	**0.048**	0.359	0.329	NA
Scott	***0.065***	**<0.001**	**0.009**	**0.004**	NA
Yorkton	0.910	0.565	0.662	**0.006**	***0.087***
Indian Head	0.981	**<0.001**	**<0.001**	**0.015**	NA
Redvers	0.615	**<0.001**	**<0.001**	***0.091***	NA
Melfort	0.364	**<0.001**	**<0.001**	0.111	0.185
Prince Albert	0.300	0.139	0.789	0.809	0.517

Table 6. Test of fixed effects for total N (N), N management (M), site (S), and all possible interactions for all parameters measured. Effects significant at P<0.05 are bolded. Effects significant at P<0.1 are bolded and italicized.

Fixed effects	Emergence	Yield	Seed Protein	Test wt.	Lodging
Total N (N)	0.502	0.103	**<0.001**	0.374	0.788
N management (M)	**0.011**	0.749	0.478	0.404	0.307
Site (S)	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Block	**0.008**	0.265	0.455	0.169	0.255
N x M	0.806	0.989	**0.257**	0.446	0.334
N x Site	0.550	0.603	**0.002**	0.296	0.347
M x Site	0.665	0.855	**0.001**	0.953	0.988
N x M x Site	0.296	0.964	**<0.001**	0.440	0.995

Table 7. Significance of total N (N), N management (M) and their interaction for all measured parameters at each location. Effects significant at P<0.05 are bolded. Effects significant at P<0.1 are bolded and italicized.

Site	Factor	Emergence	Yield	Seed Protein	Test wt.	Lodging
Swift Current	N	0.536	0.446	0.814	0.479	NA
	M	0.218	0.388	***0.059***	**0.001**	NA
	N x M	0.975	0.610	0.868	**<0.001**	NA
Scott	N	0.167	0.634	0.294	0.877	NA
	M	0.187	0.194	0.882	0.434	NA
	N x M	0.174	0.181	0.116	0.185	NA
Yorkton	N	0.323	0.383	***0.089***	**0.025**	0.390
	M	0.132	0.286	***0.084***	0.843	0.636
	N x M	0.545	0.479	**0.033**	0.537	0.942
Indian Head	N	0.666	**0.012**	**<0.001**	0.341	0.502
	M	0.514	***0.064***	**0.007**	0.355	**0.017**
	N x M	0.372	0.388	0.276	0.683	0.708
Redvers	N	0.849	***0.063***	**<0.001**	0.563	NA
	M	0.388	0.228	**0.018**	0.921	NA
	N x M	0.155	0.100	0.911	0.333	NA
Melfort	N	0.459	**0.023**	**<0.001**	**<0.001**	0.305
	M	0.138	0.684	0.423	0.565	**0.003**

	N x M	0.348	0.803	0.343	0.647	**0.039**
Prince Albert	N	0.170	0.110	0.446	0.684	0.304
	M	0.783	0.899	0.376	0.627	0.950
	N x M	0.434	0.817	0.792	0.484	0.743

Emergence

While emergence did significantly differ between sites, increasing N rate did not significantly affect emergence when sites were analyzed together (Table 4). However, when analyzed on an individual site basis, there was a linear (p=0.007) decrease in emergence with increasing N at Scott (p=0.065) (Table 5). This is likely the result of "fertilizer burn", as increasing N rate reduced emergence from 226.4 plants/m^2 down to 183.6 plants/m^2 at the highest rate of N (Table 7). However, the effect of reduced plant stand on yield potential was likely minimal.

While not significant at any individual site (Tables 7 and 9), N management had a significant effect on emergence when all sites were analyzed together (p=0.011) (Table 6). Side banding all the N reduced average emergence by roughly 14 plants/m^2 compared to the treatments receiving 30 lb N/ac as dribble banded UAN (data not shown). The seed safety is higher for the UAN treatments, because less urea is being side banded with these treatments. The use of ESN in the side band also increased emergence, albeit insignificantly. ESN is a coated urea, which delays release and increases seed safety. Increasing total N rates from 110 to 140 lb/ac (soil + fertilizer) did not significantly affect emergence on an individual or combined site basis (Tables 6-9).

Overall, emergence was good as most sites but was on the low side at Melfort and Prince Albert.

Table 8. Effect of increasing N on **oat emergence** (plants/m^2) for all participating sites. Values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, P<0.05)

Trt #	Lb /ac of soil + Side-banded N	Swift Current	Scott	Yorkton	Indian Head	Redvers	Melfort	Prince Albert
1	Soil N[1]	177.1[a]	226.4[a]	214.5[a]	252.6[a]	209.5[a]	134.9[a]	125.5[a]
2	80	175.3[a]	226.4[a]	224.3[a]	253.0[a]	232.9[a]	145.2[a]	144.5[a]
3	110	169.9[a]	204.0[a]	217.8[a]	255.9[a]	223.9[a]	98.4[a]	143.5[a]
4	140	163.9[a]	183.6[a]	231.3[a]	250.6[a]	228.0[a]	112.0[a]	110.0[a]
S.E.M.		*6.56*	*11.11*	*17.74*	*9.17*	*12.69*	*19.44*	*13.79*
		Pr > F (p-value)						
N Rate – Linear		0.209	**0.007**	0.547	0.961	0.485	0.196	0.217
N Rate – Quadratic		0.948	0.132	0.889	0.782	0.587	0.806	0.197
[1]Background Soil N (lb/ac in top 24")		*67*	*29*	*60*	*20*	*30*	*33*	*80*

Table 9. Means and LSD separations for the main effects and interactions of total N and N management on **oat emergence** (%).

Total N (N)	Swift Current	Scott	Yorkton	Indian Head	Redvers	Melfort	Prince Albert
110 lb N/ac	173.3[a]	207.4[a]	232.9[a]	259.8[a]	234.6[a]	121.4[a]	136.8[a]
140 lb N/ac	170.2[a]	199.1[a]	243.3[a]	263.0[a]	236.4[a]	114.5[a]	124.3[a]

S.E.M.	*3.5*	*4.1*	*7.3*	*5.1*	*6.8*	*6.44*	*6.2*
N management (M)							
SB urea	166.9[a]	193.8[a]	224.6[a]	253.2[a]	226.0[a]	105.2[a]	126.8[a]
UAN at 4 lf	176.8[a]	206.4[a]	239.1[a]	267.6[a]	243.0[a]	126.9[a]	129.3[a]
UAN at Boot	177.7[a]	211.9[a]	230.1[a]	259.4[a]	245.0[a]	131.2[a]	138.3[a]
ESN	165.7[a]	200.9[a]	258.6[a]	265.3[a]	228.0[a]	108.5[a]	127.8[a]
S.E.M.	*5.0*	*5.8*	*10.3*	*7.3*	*9.6*	*9.11*	*8.9*
N x M							
110 lb N/ac; (SB urea)	169.9[a]	204.0[a]	217.8[a]	255.9[a]	223.9[a]	98.4[a]	143.5[a]
110 lb N/ac; (UAN at 4 lf)	177.1[a]	201.5[a]	232.2[a]	259.6[a]	259.6[a]	123.9[a]	128.5[a]
110 lb N/ac; (UAN at Boot)	180.1[a]	223.2[a]	237.1[a]	251.4[a]	242.8[a]	141.9[a]	137.5[a]
110 lb N/ac; (ESN)	166.3[a]	201.0[a]	244.5[a]	272.3[a]	212.0[a]	121.4[a]	137.5[a]
140 lb N/ac; (SB urea)	163.9[a]	183.6[a]	231.3[a]	250.6[a]	228.0[a]	112.0[a]	110.0[a]
140 lb N/ac; (UAN at 4 lf)	176.5[a]	211.4[a]	246.1[a]	275.6[a]	226.4[a]	130.0[a]	130.0[a]
140 lb N/ac; (UAN at Boot)	175.3[a]	200.5[a]	272.8[a]	267.4[a]	247.3[a]	120.6[a]	139.0[a]
140 lb N/ac; (ESN)	165.1[a]	200.8[a]	223.1[a]	258.4[a]	244.0[a]	95.6[a]	118.0[a]
S.E.M.	*7.1*	*8.3*	*14.6*	*10.3*	*13.6*	*12.9*	*12.4*

Yield and Protein

When combing all sites, increasing rate of side banded N significantly increased yield and protein (Table 4). However, significant interactions with site were detected for both parameters. When analyzed individually, yield and protein effects were not detected at Yorkton and Prince Albert (Table 5). Effects on seed protein were also insignificant at Swift Current. Background soil N was high, and yield potential was relatively low at all these locations, which may account for the lack of responses. In addition, lodging was high at Yorkton and Prince Albert which likely created variability. At Scott, Indian Head, Redvers, and Melfort, sites were responsive to added N with maximum yields and grain protein occurring at either 110 or 140 lb N/ac (soil + fertilizer) (Tables 10 and 12).

For the factorial analysis, significant effects of site were detected for both the yield and seed protein data (Table 6). Moreover, several interactions with "site" were detected with the protein data, indicating sites need to be analyzed separately (Table 7). Increasing total N from 110 to 140 lb/ac significantly increased yield and grain protein at Indian Head, Redvers (p=0.063 for yield), and Melfort (Tables 7, 11 and 13). Yields were lower (p=0.064) at Indian Head when a portion of the total N was supplied with side banded ESN or dribble banded UAN at the 4 leaf stage. Grain protein was also significantly reduced at this site by 0.28% when UAN was applied at the boot (Tables 7 and 13). These yield and protein losses may have been the result of an excessive delay in N release from the ESN, or environmental conditions which stranded UAN in dry soil or enhanced ammonia volatilization. This highlights the environmental risks associated with split applications of UAN.

At Yorkton, a significant N x M interaction (p=0.033) found the use of ESN significantly increased grain protein but only at the 140 lb N /ac level. While the reason for the inconsistency is unclear, ESN is known to increase grain protein by delaying the release of N. At Redvers, applying UAN at the boot stage significantly increased grain protein by 0.33% compared to side banding all the N (Tables 7 and 11). Again, late season application of N is known to favor the development of protein. At Scott and Melfort, management did not significantly affect grain protein even though these sites were responsive to increasing N. While the study found some examples where N management could maintain yield and increase grain protein, the effects were inconsistent between sites and even between total N levels within sites.

Table 10. Effect of increasing N on **oat yield** (kg/ha) for all participating sites. Values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, P<0.05)

Trt #	Lb /ac of soil + Side-banded N	Swift Current	Scott	Yorkton	Indian Head	Redvers	Melfort	Prince Albert
1	Soil N	2401.0[b]	4244.4[c]	3711.3[a]	4170.7[c]	3103.9[b]	4123.0[c]	3892.1[a]
2	80	3192.4[ab]	4767.7[b]	3742.6[a]	5542.5[b]	4266.4[a]	5263.3[b]	4306.0[a]
3	110	3534.7[a]	5267.8[a]	4299.5[a]	5693.6[ab]	4242.3[a]	6034.9[ab]	3976.6[a]
4	140	3312.2[a]	5259.3[a]	3766.1[a]	5917.8[a]	4664.1[a]	6450.0[a]	4371.5[a]
S.E.M.		*249.8*	*67.4*	*330.9*	*93.8*	*167.2*	*247.1*	*154.4*
		---------- Pr > F (p-value) ----------						
N Rate - linear		***0.092***	**4.22E-06**	0.678	**1.25E-06**	**0.034**	**2.51E-05**	0.329
N Rate - Quadratic		***0.087***	0.233	0.352	0.009	0.569	0.59088	0.247
[1]Background Soil N (lb/ac in top 24")		*67*	*29*	*60*	*20*	*30*	*33*	*80*

Table 11. Means and LSD separations for the main effects and interactions of total N and N management on **oat yield** (kg/ha).

Total N (N)	Swift Current	Scott	Yorkton	Indian Head	Redvers	Melfort	Prince Albert
110 lb N/ac	3471.6[a]	5225.6[a]	3830.4[a]	5474.4[b]	4485.6[a]	6132.4[b]	3960.5a
140 lb N/ac	3669.1[a]	5191.7[a]	3616.7[a]	5737.3[a]	4657.8[a]	6447.7[a]	4207.3a
S.E.M.	*179.7*	*49.5*	*169.7*	*67.7*	*62.2*	*91.3*	*104.7*
N management (M)							
SB urea	3423.5[a]	5263.5[a]	4032.8[a]	5805.7[a]	4453.2[a]	6242.4[a]	4174.1a
UAN at 4 lf	3664.8[a]	5072.6[a]	3481.5[a]	5465.7[b]	4554.4[a]	6286.8[a]	4043.8a
UAN at Boot	3890.6[a]	5263.5[a]	3494.9[a]	5665.1[ab]	4719.2[a]	6211.6[a]	4029.3a

ESN	3302.4[a]	5234.9[a]	3885.0[a]	5486.9[b]	4560.1[a]	6419.4[a]	4088.3a
S.E.M.	*254.2*	*70.0*	*240.0*	*95.8*	*87.9*	*129.1*	*148.0*
N x M							
110 lb N/ac; (SB urea)	3534.7[a]	5267.8[a]	4299.5[a]	5693.6[ab]	5693.6[a]	5693.6[a]	5693.6[ab]
110 lb N/ac; (UAN at 4 lf)	3690.9[a]	4982.1[a]	3418.3[a]	5460.0[bc]	4565.8[a]	6067.5[a]	3857.0[a]
110 lb N/ac; (UAN at Boot)	3577.3[a]	5280.0[a]	3823.0[a]	5495.8[bc]	4525.9[a]	6154.6[a]	4002.5[a]
110 lb N/ac; (ESN)	3083.5[a]	5372.4[a]	3780.8[a]	5248.3[c]	4608.6[a]	6272.5[a]	4005.7[a]
140 lb N/ac; (SB urea)	3312.2[a]	5259.3[a]	3766.1[a]	5917.8[a]	4664.1[a]	6450.0[a]	4371.5[a]
140 lb N/ac; (UAN at 4 lf)	3638.8[a]	5163.1[a]	3544.7[a]	5471.4[bc]	4543.0[a]	6506.0[a]	4230.6[a]
140 lb N/ac; (UAN at Boot)	4203.9[a]	5247.1[a]	3166.8[a]	5834.5[ab]	4912.5[a]	6268.6[a]	4056.1[a]
140 lb N/ac; (ESN)	3521.4[a]	5097.4[a]	3989.1[a]	5725.5[ab]	4511.7[a]	6566.3[a]	4170.8[a]
S.E.M.	*359.5*	*99.1*	*339.4*	*135.4*	*124.4*	*182.5*	*209.3*

Table 12. Effect of increasing N on **oat grain protein** (%) for all participating sites. Values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, P<0.05)

Trt #	Lb /ac of soil + Side-banded N	Swift Current	Scott	Yorkton	Indian Head	Redvers	Melfort	Prince Albert
1	Soil N	11.40[a]	15.58[b]	12.11[a]	9.63[d]	10.76[c]	7.91[c]	11.65[a]
2	80	11.73[a]	16.29[a]	12.26[a]	12.30[c]	11.65[b]	8.26[c]	11.59[a]
3	110	11.77[a]	16.44[a]	11.84[a]	13.62[b]	12.55[a]	8.95[b]	11.84[a]
4	140	11.87[a]	16.26[a]	12.82[a]	14.02[a]	12.80[a]	9.90[a]	11.55[a]
S.E.M.		*0.185*	*0.144*	*0.555*	*0.09*	*0.115*	*0.182*	*0.212*
		---------- Pr > F (p-value) ----------						
N Rate – Linear		***0.086***	0.010	0.444	2.76E-10	**8.55E-09**	3.52E-06	0.949
N Rate – Quadratic		0.461	**0.036**	0.394	**0.007**	0.523	**0.010**	0.491
[1]Background Soil N (lb/ac in top 24")		*67*	*29*	*60*	*20*	*30*	*33*	*80*

Table 13. Means and LSD separations for the main effects and interactions of total N and N management on **oat protein** (%).

Total N (N)	Swift Current	Scott	Yorkton	Indian Head	Redvers	Melfort	Prince Albert
110 lb N/ac	11.74a	16.34[a]	12.12[a]	13.51[b]	12.62[b]	9.01[b]	11.82[a]
140 lb N/ac	11.77a	16.44[a]	12.77[a]	14.03[a]	12.93[a]	9.74[a]	11.71[a]

S.E.M.	*0.09*	*0.07*	*0.26*	*0.05*	*0.05*	*0.09*	*0.10*
N management (M)							
SB urea	11.81a	16.35[a]	12.32[a]	13.82[a]	12.67[b]	9.43[a]	11.69[a]
UAN at 4 lf	12.01a	16.39[a]	12.23[a]	13.83[a]	12.77[b]	9.27[a]	11.91[a]
UAN at Boot	11.56a	16.36[a]	11.94[a]	13.54[b]	13.00[a]	9.54[a]	11.84[a]
ESN	11.62a	16.45[a]	13.29[a]	13.87[a]	12.66[b]	9.29[a]	11.58[a]
S.E.M.	*0.12*	*0.09*	*0.37*	*0.07*	*0.08*	*0.13*	*0.14*
N x M							
110 lb N/ac; (SB urea)	11.77[a]	16.44[a]	11.84[b]	13.62[c]	12.55[c]	8.95d[e]	11.84[a]
110 lb N/ac; (UAN at 4 lf)	12.05[a]	16.24[a]	12.53[b]	13.53[c]	12.53b[c]	8.93[e]	11.99[a]
110 lb N/ac; (UAN at Boot)	11.60[a]	16.19[a]	12.05[b]	13.20[d]	12.80[bc]	9.06[de]	11.92[a]
110 lb N/ac; (ESN)	11.54[a]	16.50[a]	12.06[b]	13.68[bc]	12.53[c]	9.10[cde]	11.53[a]
140 lb N/ac; (SB urea)	11.87[a]	16.26[a]	12.82[b]	14.02[a]	12.80[bc]	9.90[ab]	11.55[a]
140 lb N/ac; (UAN at 4 lf)	11.98[a]	16.55[a]	11.93[b]	14.14[a]	12.93[ab]	9.60[abc]	11.84[a]
140 lb N/ac; (UAN at Boot)	11.52[a]	16.55[a]	11.83[b]	13.90[ab]	13.20[a]	10.01[a]	11.78[a]
140 lb N/ac; (ESN)	11.7[a]	16.40[a]	14.52[a]	14.07[a]	12.81[bc]	9.47[bcd]	11.65[a]
S.E.M.	*0.17*	*0.13*	*0.52*	*0.09*	*0.11*	*0.18*	*0.20*

Lodging

For all sites combined, increasing rate of side banded N did not significantly affect lodging (Table 4). However, the lodging rating for the first 4 treatments were all zeros at Swift Current, Scott, Indian head, and Redvers. As a result, statistical analysis has not been performed for these sites (Table 5). The effect of increasing N on lodging was insignificant at Melfort and Prince Albert, despite the high level of lodging recorded at Prince Albert. Lodging was very high at Yorkton and a significant linear (p=0.037) increase in lodging with increasing N was observed (Table 14).

For the factorial analysis, lodging did not significantly differ between the 110 vs 140 lb N/ac levels for any location. A significant effect of management on lodging was detected at Indian Head and Melfort (Table 7). At Indian Head, lodging was significantly higher compared to other levels of management when UAN was applied at the boot stage. The effect, while very small, was unexpected as Mangin et al. (2022) found split application of N showed potential to reduce lodging in spring wheat. At Melfort, a significant N x M interaction found ESN significantly increased lodging relative to side banding all the N, but the effect was stronger at the 110 lb/ac level of total N. Again, this result is hard to explain as

late season release of N is purported to decrease lodging. However, the effects at Indian Head and Melfort were very small and unlikely to have had an agronomic impact. Overall, there was no evidence from this study to suggest N management could reduce the risk of lodging.

A. Mangin et al. (2022). Canopy management: the balance between lodging risk and nitrogen use for spring wheat production in the Canadian Prairies, Canadian Journal of Plant Science.

Table 14. Effect of increasing N on **oat lodging** (0-9) for all participating sites. Values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, P<0.05)

Trt #	Lb /ac of soil + Side-banded N	Swift Current	Scott	Yorkton	Indian Head	Redvers	Melfort	Prince Albert
1	Soil N	0	0	5.50[a]	0	0	1.50[a]	4.25[a]
2	80	0	0	6.25[a]	0	0	1.50[a]	4.50[a]
3	110	0	0	7.00[a]	0	0	0.00[a]	4.00[a]
4	140	0	0	6.75[a]	0	0	0.00[a]	5.00[a]
S.E.M.		*0*	*0*	*0.38*	0	*0*	*0.61*	*0.47*
		---------- Pr > F (p-value) ----------						
N Rate – Linear		NA	NA	**0.037**	NA	NA	***0.088***	0.467
N Rate – Quadratic		NA	NA	0.160	NA	NA	0.750	0.307
[1]Background Soil N (lb/ac in top 24")		*67*	*29*	*60*	*20*	*30*	*33*	*80*

Table 15. Means and LSD separations for the main effects and interactions of total N and N management on **oat lodging** (0-9).

Total N (N)	Swift Current	Scott	Yorkton	Indian Head	Redvers	Melfort	Prince Albert
110 lb N/ac	0	0	7.18[a]	0.03a	0	0.25[a]	4.31[a]
140 lb N/ac	0	0	6.93[a]	0.06a	0	0.13[a]	4.81[a]
S.E.M.	*NA*	*NA*	*0.20*	*0.03*	*NA*	*0.08*	*0.34*
N management (M)							
SB urea	0	0	6.87[a]	0.00b	0	0.00[b]	4.50[a]
UAN at 4 lf	0	0	6.87[a]	0.00b	0	0.00[b]	4.38[a]
UAN at Boot	0	0	7.25[a]	0.19a	0	0.13[b]	4.75[a]
ESN	0	0	7.25[a]	0.00b	0	0.63[a]	4.63[a]
S.E.M.	*NA*	*NA*	*0.28*	*0.05*	*NA*	*0.12*	*0.47*
N x M							
110 lb N/ac; (SB urea)	0	0	7.00[a]	0.00[b]	0	0.00[b]	4.00[a]
110 lb N/ac; (UAN at 4 lf)	0	0	7.00[a]	0.00[b]	0	0.00[b]	4.25[a]
110 lb N/ac; (UAN at Boot)	0	0	7.25[a]	0.125[ab]	0	0.00[b]	4.25[a]

110 lb N/ac; (ESN)	0	0	7.50[a]	0.00[b]	0	1.00[a]	4.75[a]
140 lb N/ac; (SB urea)	0	0	6.75[a]	0.00[b]	0	0.00[b]	5.00[a]
140 lb N/ac; (UAN at 4 lf)	0	0	6.75[a]	0.00[b]	0	0.00[b]	4.50[a]
140 lb N/ac; (UAN at Boot)	0	0	7.25[a]	0.25[a]	0	0.25[b]	5.25[a]
140 lb N/ac; (ESN)	0	0	7.00[a]	0.00[b]	0	0.25[b]	4.50[a]
S.E.M.	*NA*	*NA*	*0.40*	*0.06*	*NA*	*0.17*	*0.67*

Test Weight

An analysis of all sites combined, found increasing N rate significantly decreased test weight, with no interaction detected between sites (Table 4). When analyzed individually, increasing N rate linearly reduced test weight at Melfort, Yorkton, and Indian Head. At Scott, the decrease was quadratic (Table 16). However, no significant effects could be detected at Swift Current, Redvers, or Prince Albert.

The factorial analysis found increasing the "total N" from 110 to 140 lb/ac only significantly decreased test weight at Yorkton and Melfort (Table 7 and 17). N management only significantly affected oat test weight at Swift Current. A significant N x M interaction found applying UAN at the boot provided the highest test weight at the 110 lb N/ac level, whereas ESN provided the highest test weight at the 140 lb N/ac level. While this is a desired result, showing test weight was maintained by N management, the effects were inconsistent between the N levels at Swift Current. Moreover, none of the N management treatments at the other sites significantly increased test weight compared to side banding all the N at seeding.

Table 16. Effect of increasing N on **oat test weight** (g/0.5l) for all participating sites. Values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, P<0.05)

Trt #	Lb /ac of soil + Side-banded N	Swift Current	Scott	Yorkton	Indian Head	Redvers	Melfort	Prince Albert
1	Soil N	219.5[a]	242.8[a]	237.4[a]	263.0[a]	227.3[a]	259.5[a]	226.6[a]
2	80	225.4[a]	238.1[b]	237.0[a]	262.2[a]	220.3[a]	258.3[a]	229.3[a]
3	110	222.9[a]	237.8[b]	235.3[a]	259.3[b]	220.3[a]	257.8[a]	227.2[a]
4	140	221.4[a]	238.0[b]	232.4[b]	259.1[b]	220.2[a]	254.5[a]	226.1[a]
S.E.M.		*2.18*	*0.81*	*0.77*	*0.81*	*2.05*	*1.36*	*2.50*
		Pr > F (p-value)						
N Rate – Linear		0.989	**0.002**	**0.004**	**0.038**	0.233	**0.027**	0.564
N Rate – Quadratic		0.200	**0.021**	0.402	0.696	0.490	0.363	0.970
[1]Background Soil N (lb/ac in top 24")		*67*	*29*	*60*	*20*	*30*	*33*	*80*

Table 17. Means and LSD separations for the main effects and interactions of total N and N management on **oat test weight** (g/0.5l).

Total N (N)	Swift Current	Scott	Yorkton	Indian Head	Redvers	Melfort	Prince Albert
110 lb N/ac	222.5[a]	238.0[a]	234.5[a]	258.0[a]	221.3[a]	258.4[a]	224.0[a]
140 lb N/ac	223.1[a]	238.1[a]	232.0[b]	259.6[a]	220.3[a]	254.8[b]	224.8[a]
S.E.M.	*0.54*	*0.47*	*0.74*	*1.15*	*1.14*	*0.66*	*1.38*
N management (M)							
SB urea	222.1[bc]	237.9[a]	233.9[a]	259.2[a]	220.3[a]	256.1[a]	226.6[a]
UAN at 4 lf	220.1[c]	237.5[a]	233.2[a]	256.3[a]	221.5[a]	256.0[a]	223.6[a]
UAN at Boot	224.0[ab]	239.0[a]	232.6[a]	259.5[a]	221.2[a]	257.7[a]	224.1[a]
ESN	224.9[a]	237.8[a]	233.4[a]	260.2[a]	220.2[a]	256.8[a]	223.3[a]
S.E.M.	*0.76*	*0.66*	*1.04*	*1.62*	*1.62*	*0.93*	*1.96*
N x M							
110 lb N/ac; (SB urea)	222.9[bc]	237.8[a]	235.3[a]	259.3[a]	220.3[a]	257.8[ab]	227.2[a]
110 lb N/ac; (UAN at 4 lf)	221.2[cd]	238.5[a]	233.4[ab]	253.8[a]	219.7[a]	257.4[ab]	220.8[a]
110 lb N/ac; (UAN at Boot)	226.1[b]	237.8[a]	235.0[a]	258.9[a]	222.3[a]	260.5[a]	223.6[a]
110 lb N/ac; (ESN)	219.9[cd]	237.8[a]	234.3[ab]	260.0[a]	222.7[a]	258.1[ab]	224.5[a]
140 lb N/ac; (SB urea)	221.4[cd]	238.0[a]	232.4[ab]	259.1[a]	220.2[a]	254.5[b]	226.1[a]
140 lb N/ac; (UAN at 4 lf)	219.0[d]	236.5[a]	232.9[ab]	258.7[a]	223.2[a]	254.6[b]	226.6[a]
140 lb N/ac; (UAN at Boot)	222.0[cd]	240.1[a]	230.2[b]	260.1[a]	220.1[a]	254.9[b]	224.5[a]
140 lb N/ac; (ESN)	230.0[a]	237.7[a]	232.4[ab]	260.5[a]	217.7[a]	255.5[b]	222.1[a]
S.E.M.	*1.08*	*0.93*	*1.48*	*2.29*	*2.28*	*1.32*	*2.77*

Conclusions and Recommendations

Describe what was learned from the demonstration. Highlight any significant conclusions and provide recommendations for the application and adoption of the project results. Be sure that you have presented the relevant data to support your conclusions. Identify any further research, development and communication needs, if applicable.

Conclusion

The overall objective was to determine if split application of nitrogen using UAN (4 leaf vs boot stages) or side banding ESN could decrease lodging, increase protein, and maintain test weight and yield of milling oat, relative to side banding all the N at seeding. There was some evidence to support these benefits from managing N, however, they were rare and inconsistent. While yield at 5 out of the 7 sites were responsive to added N, yield did not significantly differ between levels of N management for all sites except Indian Head. For Indian Head, applying a portion of the total N as ESN or UAN significantly decreased yield. In addition, a significant decrease in grain protein (-0.28%) also occurred when UAN was applied at the boot. These yield and protein losses at Indian Head may have been the result of an excessive delay in N release from the ESN, or environmental conditions after UAN applications that were conducive to ammonia loss or stranding of N in dry soil. This highlights the environmental risks associated with split applications. However, in a few instances supplying a portion of the N as ESN or dribble banded UAN increased grain protein. At Yorkton, the use of ESN significantly increased grain protein but the effect was only detected at the total N level of 140 lb/ac. At Redvers, applying UAN at the boot stage significantly increased grain protein by 0.33%, relative to side banding all the N. Both situations make sense, as late season release of N is known to increase grain protein. At Scott and Melfort, grain protein did not differ between N management strategies, even though these sites were responsive to increasing N. Neither increasing N or N management increased grain protein at Prince Albert and Swift Current. Overall, there were only a couple of instances where grain protein was increased by applying a portion of the N as ESN or dribble banded UAN. Levels of lodging were very low at most locations, making it difficult to detect any differences between N management. However, even at sites where lodging was high, no significant effects were detected. Oat test weight was only significantly affected by N management at Swift Current. UAN at the boot stage provided the highest test weight at the 110 lb N/ac, whereas the use of ESN provided the highest test weight at the 140 lb N/ac level. While maintaining high test weight with N management was a desired result, the effects were inconsistent between the total N levels. Moreover, none of the N management treatments at the other sites significantly increased test weight in relation to side banding all the N at seeding. This was true for Scott, Yorkton, Indian head, and Redvers, where test weights were significantly reduced by increasing N in the side band. In conclusion, there was limited evidence that applying a portion of the N requirement as ESN or dribble banded UAN could maintain yield and test weight, increase grain protein, or reduce lodging. However, effects were inconsistent between sites and even between levels of total N within a site.

Sustainable Canadian Agricultural Partnership (Sustainable CAP) Performance Indicators

a) List of performance indicators

Sustainable CAP Indicator	Total Number
Scientific publications from this project (List the publications under section b)	
• Published	
• Accepted for publication	

Highly Qualified Personnel (HQPs) trained during this project	
• Master's students	
• PhD students	
• Post docs	
Knowledge transfer products developed based on this project (presentations, brochures, factsheets, flyers, guides, extension articles, podcasts, videos)[1]. List the knowledge transfer products under section (c)	

[1] Please only include the number of unique knowledge transfer products.

b) List of scientific journal articles published/accepted for publication from this project. Please ensure that each line includes the following: **Title, Author(s), Journal, Date Published or Accepted for Publication and Link to Article (if available).** *Add additional lines as needed*.

1.
2.
3.
4.

c) List of knowledge transfer products/activities developed from this project.

Knowledge Transfer Product or Activity	Event/Location Where Knowledge Transfer Was Conducted	Estimated Number of Producers Participated in Knowledge Transfer	Link (if available)
ECRF Annual Plot Tour	Yorkton SK	90	

Acknowledgements

Include actions taken to acknowledge support by the Ministry of Agriculture, the Canadian Agriculture Partnership (for projects approved between 2017 and 2023) and the Sustainable Canadian Agriculture Partnership (for projects approved between 2023 and 2028).

Appendices

Include any additional materials supporting the previous sections, e.g. detailed data tables, maps, graphs, specifications, literature cited (Use a consistent reference style throughout).

Expenditure Statement

You must provide an expenditure statement showing how ADOPT funds were used. Expenditures must be reported using the budget categories shown in Appendix B of your contract. We recommend that you report your expenditures using the Excel spreadsheet we have developed for this purpose (ADOPT Expenditure Statement.xls). That spreadsheet is available from the research branch project manager or the evaluation coordinator.

Note that the ADOPT contract requires you to retain all receipts and financial records relating to the project for at least six years after the project is completed.