

2025 Interim Report

for the

Saskatchewan Canola Development Commission (SCDC)

Canola Response to Enhanced Efficiency Nitrogen Fertilizer Products and Blends
(Project #CARP-ADOPT 2024.999)



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Project Identification

1. **Project Title:** Canola Response to Enhanced Efficiency Nitrogen Fertilizer Products and Blends
2. **Project Number:** CARP ADOPT 2024.999
3. **Producer Group Sponsoring the Project:** Indian Head Agricultural Research Foundation (IHARF), Northeast Agriculture Research Foundation (NARF), Conservation Learning Centre (CLC), Western Applied Research Corporation (WARC), Wheatland Conservation Area (WCA), and East Central Research Foundation (ECRF)
4. **Project Locations:** Indian Head (R.M. 156), Melfort (R.M. 428), Prince Albert (R.M. 461), Scott (R.M. 380), Swift Current (R.M. #137), and Yorkton (R.M. #244)
5. **Project Start & End Dates:** April 2024 – March 2027
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Objectives and Rationale**7. Project Objectives:**

The overall project objective was to investigate and demonstrate Argentine canola (*Brassica napus*) response to side-banded enhanced efficiency fertilizer (EEF) nitrogen (N) products and blends, relative to untreated urea. The focus was primarily on canola establishment, yield, and seed quality; however, with this information, we also aimed to determine whether the agronomic N use-efficiency (ANUE) of side-banded urea could be improved with EEF formulations and provide information on which products performed best for a range of Saskatchewan environments.

8. Project Rationale:

All the enhanced efficiency fertilizer (EEF) products we demonstrate in this project are widely available and have been proven effective for their intended purposes in both the scientific literature and various technical reports. Their potential agronomic advantages over untreated urea, however, often vary depending on how the fertilizer is applied, and the specific environmental conditions encountered. While EEF products are more likely to be advantageous when the timing and/or placement leaves the N prone to environmental loss, they can also potentially be beneficial with spring in-soil banding, a practice which is recognized as amongst the most effective and efficient options for supplying N to spring-seeded crops.

Environmentally Smart Nitrogen (ESN[®]) is a polymer coated urea product where the release of N is controlled by soil moisture and temperature. With sites throughout Alberta and Saskatchewan and side-band placement, Blackshaw et al. (2011) showed that ESN[®] improved hybrid canola yields over untreated urea at 25% of the site-years. In Minnesota, Farmah and Sims (2013) varied the ratios of ESN[®] blended with urea with spring broadcast-incorporation as the timing/placement and spring wheat as the test crop. Under cool, dry conditions they reported that, as the proportion of ESN[®] in the blend increased, yields decreased slightly; however, the opposite occurred under warm, wet conditions where yields were highest with 100% ESN[®]. Grain protein increased as the proportion of ESN[®] increased, regardless of environment. This suggested that N release could be too slow with 100% ESN[®] for short-season crops under dry conditions and provides the rationale for applying this product in a blend with spring, in-soil band placement in western

Canada. The use of ESN[®] also reduces the potential for seedling injury associated with side-banding high rates of N in sensitive crops and, while not specifically applicable to this demonstration, greatly increases the amount of N fertilizer that can safely be placed in the seedrow (Malhi and Lemke, 2013). Additionally, ESN[®] has been shown to be effective in reducing cumulative N₂O emissions relative to untreated urea with side-band placement (Gao et al. 2015).

The most widely recognized chemical urease inhibitor is N-(n-Butyl) thiophosphoric triamide (NBPT). ANVOL[®] is a relatively new product that utilizes this active ingredient in a mixture with Duromide, the combination of which is claimed to improve the robustness and duration of protection over NBPT alone. While volatilization losses can occur with side-banded urea under certain conditions, particularly shallow banding in coarse soils at high rates (i.e., Rochette et al. 2013), actual yield results in field trials have been variable. Malhi and Lemke (2013) showed a slight yield advantage to high rates of side-banded NBPT treated urea over untreated urea in one year, but the opposite occurred the second year. With high rates of side-banded N in Manitoba, NBPT increased canola yields at 3/6 sites but decreased yields at 1/6 sites (Grant et al. 2010). With side-band application in winter wheat, Beres et al. (2018) mostly saw similar yields with both urea and NBPT treated urea.

Nitrification inhibitors slow the conversion of ammonium (NH₄⁺) to nitrate (NO₃⁻) and, in general, have greater potential to reduce N losses under wet conditions where the risk of denitrification and/or leaching is high. Nitrification inhibitors can also be beneficial with fall applications, especially in depressional areas or poorly drained fields where soils often become saturated during the early spring snowmelt period. Utilizing both anhydrous ammonia and urea as the N sources, Degenhardt et al. (2016), found that fall applications of nitrapyrin treated urea resulted in 21-63% more NH₄-N and 10-19% more total mineral N in the spring when compared to non-stabilized fertilizer. Spring applications of nitrapyrin resulted in larger pools of NH₄-N for at least 8 weeks after treatment and increased total mineral N by up to 25% over non-stabilized treatments. Karamanos et al. (2013) occasionally improved nitrogen use efficiency of urea and anhydrous ammonia with a nitrification inhibitor, with the greatest benefit when combined with early fall application. Over the full duration of a growing season and with spring application, Thilakarathna et al. (2020) reduced cumulative nitrous oxide (N₂O) emissions by 15% with eNtrench[®] (nitrapyrin) over untreated urea.

Dual inhibitors offer protection against volatilization losses and slow the conversion from ammonium to nitrate. The most widely recognized of such products, is SUPERU[®] which utilizes both NBPT and dicyandiamide (DCD). In winter wheat, Beres et al. (2018) found that, while side-banding generally performed poorer than split applications, SUPERU[®] applied in this manner performed well and was consistently one of the highest yielding treatments. Fast et al. (2024) found that, with side-band placement, the dual inhibitor SUPERU[®] increased wheat yields by over 3% relative to untreated urea within the Dark Brown soil zone, but there was no benefit in the Black soil zone locations. Thilakarathna et al. (2020) reported a 10% reduction in cumulative nitrous oxide emissions with spring application of SUPERU[®] relative to untreated urea and a 20% reduction with fall application. In another example with mid-row band placement, utilizing SUPERU[®] as the source did not increase yields over untreated urea, but reduced cumulative nitrous oxide emissions 75% of the time and by an overall average of 34% at two locations over a two-year period (Gao et al. 2015). There has been some concern that side-banded SUPERU[®] may not convert to nitrate quickly enough to meet the demands of rapidly growing crops under some conditions. For that reason, and to reduce costs, blending SUPERU[®] may be an attractive option to Saskatchewan farmers and agronomists.

This work was justified on the basis that N fertilizer management has long been amongst the most important considerations for Saskatchewan grain farmers and canola is one of the largest users of this nutrient. Optimizing N fertilizer use-efficiency is of utmost importance with high fertilizer prices, tight profit margins, and pressure to minimize greenhouse gas emissions associated with N fertilization. Adoption of EEF

products will likely continue to increase and farmers will benefit from understanding both the mechanisms of environmental N loss they are most susceptible to, and how EEFs differ in their ability to reduce said losses. To varying degrees, the products we are utilizing have been evaluated in numerous field trials conducted over the years, often in combination with contrasting application timings or placement methods. In such trials, fertilizer timing and placement has typically been more important than N form with respect to yield/protein and EEF products have shown the greatest potential to be beneficial when combined with sub-optimal timing or placement. The current project was initiated to build upon past and ongoing projects focused on 4R nitrogen management, but with a greater focus on these fundamentally different N formulations as opposed to timing/placement options. It aimed to provide opportunities for discussion of how common EEF products differ, and the types of N losses farmers will generally be most vulnerable to when banding N during the seeding operation. While our focus is canola, essentially all the major commodity groups and numerous agronomists have identified evaluations of different N forms and blends as research priorities and these results will be applicable to a wide variety of crops.

Literature Cited

Beres, B. L., Graf, R. J., Irvine, R. B., O'Donovan, J. T., Harker, K. N., Johnson, E.N., Brandt, S., Hao, X., Thomas, B. W., Turkington, T. K., and Stevenson, F. C. 2018. Enhanced nitrogen management strategies for wheat production in the Canadian prairies. **98**: 683-702.

Blackshaw, R. E., Hao, X., Brandt, R. N., Clayton, G. W., Harker, H. N., O'Donovan, J. T., Johnson, E. N., and Vera, C. L. 2011. Canola response to ESN and urea in a four-year no-till cropping system. *Agron. J.* **103**: 92-99.

Degenhardt, R. F., Juras, L. T., Smith, L. R. A., MacRae, A. W., Ashigh, J., and McGregor, W. R. 2016. Application of nitrapyrin with banded urea, urea ammonium nitrate, and ammonia delays nitrification and reduces nitrogen loss in Canadian Soils. *Crop Forage Turfgrass Manage.* **2**: 1-11.
Doi:10.2134/cftm2016.03.0027

Farmaha, B. S., and Sims. A. L. 2013. The influence of polymer coated urea and urea fertilizer mixtures on spring wheat protein concentrations and economic returns. *Agron. J.* **105**: 1328-1334.

Fast, A., Strydhorst, S., Wang, Z., Hernandez-Ramirez, G., Hao, X., Semach, G., Thompson, L., Holzapfel, C., Enns, J., Spaner, D., and Beres, B. 2024. Integrating enhanced efficiency fertilizers and nitrogen rates to improve Canada Western Red Spring wheat. *Can. J. Plant Sci.* **104**: 144-160.

Gao, X., Asgedom, H., Tenuta, M., and Flaten, D. 2015. *Agron. J.* Enhanced efficiency urea sources and placement options on nitrous oxide emissions. **107**: 265-277.

Grant, C. A., Derksen, D. A., McLaren, D. L., and Irvine, R. B. 2010. Nitrogen fertilizer and urease inhibitor effects on canola emergence and yield in a one-pass seeding and fertilizing system. *Agron. J.* **102**: 875-884.

Karamanos, R. E., Hanson, K., and Stevenson, F. C. 2014. Nitrogen form, time and rate of application, and nitrification inhibitor effects on crop production. *Can. J. Plant Sci.* **94**: 425-432.

Malhi, S. S., and Lemke, R. L. 2013. Effectiveness of seedrow-placed N with polymer-coated and NBPT-treated urea for canola and wheat. *J. Plant Nutr.* **36**: 2205-2224.

Rochette, P., Angers, D. A., Chantigny, M. H., Gasser, M., MacDonald, J. D., Pester, D. E. and Bertrand. 2013. Ammonia volatilization and nitrogen retention: How deep to incorporate urea? *J. Environ. Qual.* **42**: 1635-1642.

Thilakarathna, S. K., Hernandez-Ramirez, G., Puurween, D., Kryzanowski, L., Lohstraeter, G., Powers, L., Quan, N., and Tenuta, M. 2020. Nitrous oxide emissions and nitrogen use efficiency in wheat: Nitrogen fertilization timing and formulation, soil nitrogen, and weather effects. **84**: 1910-1927.

Methodology and Results

9. Methodology:

In both 2024 and 2025, field trials were conducted at Indian Head (IH), Melfort (ME), Prince Albert (PA), and Yorkton (YK) in the Black soil zone, Scott (SC) in the Dark Brown soil zone, and Swift Current (SW) in the Brown soil zone. For each location, fourteen nitrogen (N) fertilizer treatments were arranged in a four replicate Randomized Complete Block Design (RCBD). The N fertilizer was always side-banded, and the targeted application rates included both residual soil N and N provided by other fertilizer products (i.e., 11-52-0 or 21-0-0-24). In addition to a control and three rates of untreated urea to establish N response curves for each site, 10 separate EEF N forms or blends were evaluated. The intent was to compare EEF N products at rates that were slightly limiting so that any differences in N use-efficiency could be revealed in the yield and/or quality data. The treatments are listed and described in detail in Table 1.

Table 1. Nitrogen treatments evaluated in canola side-banded nitrogen (N) fertilizer formulation demonstration trials. All N fertilizer was side-banded, and rates include soil NO₃-N (0-60 cm) and any N provided by phosphorus or sulfur products.

#	Formulation	N Rate ^z (soil + fertilizer)	Description
1	n/a	0 N	- only soil N and N from N & P products
2	Urea	75 kg N/ha	- low rate, untreated
3	Urea	125 kg N/ha	- medium rate, untreated
4	Urea	175 kg N/ha	- high rate, untreated
5	25% ESN [®]	125 kg N/ha	- medium rate, low percentage polymer coated
6	50% ESN [®]	125 kg N/ha	- medium rate, medium percentage polymer coated
7	75% ESN [®]	125 kg N/ha	- medium rate, high percentage polymer coated
8	100% ESN [®]	125 kg N/ha	- medium rate, pure polymer coated
9	25% SUPERU [®]	125 kg N/ha	- medium rate, low percentage dual inhibitor
10	50% SUPERU [®]	125 kg N/ha	- medium rate, medium percentage dual inhibitor
11	75% SUPERU [®]	125 kg N/ha	- medium rate, high percentage dual inhibitor
12	100% SUPERU [®]	125 kg N/ha	- medium rate, pure dual inhibitor
13	ANVOL [®]	125 kg N/ha	- medium rate, volatilization inhibitor
14	eNtrench [™]	125 kg N/ha	- medium rate, nitrification inhibitor

Aside from N, all controllable factors were intended to be non-limiting. Canola was always direct-seeded into cereal stubble and all sites used modern, high-yielding hybrids with target seeding rates of approximately 115 seeds/m². Phosphorus fertility was provided by side-banded monoammonium phosphate (11-52-0) while sulfur was provided by either side-banded ammonium sulfate (21-0-0-24) or potassium sulfate (0-0-53-18; either broadcast or side-banded). Weeds were managed using registered pre-emergent and in-crop herbicides and preventative fungicide applications were recommended but at the discretion of individual site managers. In any instances where foliar fungicide was not applied, the sclerotinia risk was low. All seed was treated with an insecticide/fungicide, and foliar insecticides were utilized as required. Pre-harvest glyphosate or diquat was used at the discretion of site managers and the centre rows of each plot were straight-combined when it was fit to do so, excluding outside crop rows wherever possible. Plot sizes and harvest areas varied by location depending on the seeding, spraying, and combining equipment. Pertinent agronomic information and dates of operations/data collection activities are provided in Table 11 of the Appendices.

The response data that were collected included plant density, grain yield, seed oil concentrations, and seed protein concentrations. The seed protein and oil concentrations were determined using NIR instruments; however, the specific makes and models of the equipment used for these measurements varied by location. Wherever sufficient information to do so was provided, seed oil and protein data were adjusted to 10% seed moisture content. Agronomic N use-efficiency was calculated for all treatments except the unfertilized control using the following equation where all units are kg N/ha, N_{fert} was the N removed in the seed of the fertilized plot, N_{check} was the N removed in the seed of the corresponding control plot, and N_{rate} was the rate of N applied as fertilizer (not including that from PKS products). $(N_{fert} - N_{check})/N_{rate}$. Percent seed N was estimated by dividing protein by a coefficient of 6.3. For the purposes of adjusting N rates and site characterization, each site provided a soil test report for the trial area. Mean monthly temperatures and precipitation amounts (May through August) were recorded from the nearest Environment and Climate Change Canada or private weather stations.

At this time, data have not been combined across locations for statistical analyses; however, the final report will incorporate a combined analyses for selected sites. Individual site data were analyzed using the Generalized Linear Mixed Model (GLIMMIX) procedure of SAS Studio. Orthogonal contrasts were utilized to test whether responses to the rate of untreated urea were linear, quadratic (curvilinear), or non-significant. Another contrast compared the unfertilized control to all fertilized treatments. Individual treatment means were separated using Tukey's multiple comparison test. All treatment effects and differences between means were considered significant at $P \leq 0.05$; however, P -values of ≤ 0.1 may also be acknowledged when they make agronomic sense and had potential to provide meaningful insights.

10. Results:

Soil Test Results and Growing Season Weather

Soil test results for each location are summarized in Table 2 and the reported residual N levels were those which were utilized to calculate the N fertilizer rates. For Prince Albert in both 2024 and 2025, we adjusted the target N levels upwards by 25 kg N/ha for all treatments to accommodate the high residual N levels. For Swift Current and Yorkton in both 2024 and 2025, there was essentially no supplemental urea applied in Treatment 2 because, once the N from PKS fertilizer products was accounted for, the total N rates were already near, or above, the target rate of 75 kg N/ha. Residual soil N levels at Indian Head, Melfort, and Scott, were generally considered low to medium. In addition to not being able to achieve meaningful separation between treatments 1 and 2, an important drawback to high residual N was that a relatively low proportion of the total N supply is provided by the EEF products, thus reducing the potential influence they might have on yield or quality responses. Additionally, initially high residual N creates challenges for calculating agronomic N use-efficiency (ANUE) because the applied N rates are lessened and the actual responses tend to become more variable.

Table 2. Selected soil test results for canola side-banded nitrogen (N) formulation demonstration trials conducted at Indian Head (IH), Melfort (ME), Prince Albert (PA), Scott (SC), Swift Current (SW), and Yorkton (YK) in 2024 (24) and 2025 (25). Unless otherwise indicated, all measurements are representative of the 0-15 cm soil profile.

Site	pH	SOM (%)	CEC (meq)	NO ₃ -N (kg/ha) ^z	Olsen-P (ppm)	K (ppm)	kg S/ha (kg/ha) ^z
IH-24	7.9	4.5	46	29	6	524	29
IH-25	8.0	4.7	50.1	20	11	606	34
ME-24	5.9	7.9	30.8	48	28	402	105
ME-25	5.9	8.3	35.0	39	17	395	60
PA-24	5.8	4.7	20.4	74 ^y	7	199	44 ^y
PA-25	5.7	5.4	21.6	67 ^y	6	215	>175 ^y
SC-24	5.4	4	14.6	32	16	219	139
SC-25	5.0	3.6	16.0	36	13	176	99
SW-24	7.5	2.7	23.2	71	14	248	36
SW-25	5.9	2.9	13.1	84	22	326	81
YK-24	7.4	5.6	24.9	54 ^y	14	376	37 ^x
YK-25	7.1	5.4	23.9	72 ^y	14	267	81

^z Values for residual NO₃-N and S are for the 0-60 cm soil profile

^y Values estimated from a 30 cm soil sample by multiplying values by 1.5

Mean monthly temperatures and precipitation amounts for the 2024 and 2025 growing seasons at each location are presented relative to the long-term (1981-2010) averages in Tables 3 and 4, respectively. For all locations in 2024, temperatures were slightly below average or approximately average in May, well-below average in June, well-above average in July, and slightly or (in the case of Swift Current) well-above in August. Looking at precipitation, all locations started the season with relatively low soil moisture reserves; however, rainfall in May and June was above average and, combined with the cooler conditions, the canola got off to a strong start. In July however, the high temperatures were accompanied by well-below average precipitation at all sites. With the hot, dry weather coinciding with flowering and early pod fill, the canola lost substantial yield potential. On average, temperatures and precipitation amounts were reasonably close to average for all locations; however, this does not adequately describe the shift from cool and wet to heat/drought stress as the 2024 season progressed.

In 2025, May was generally quite warm, but the weather became cooler for most sites in June and July. The cooler than average summer temperatures tended to more prominent at the northern sites and at least partly attributable to smoky, hazy conditions. In August, temperatures returned to warmer than average for all sites which, while not ideal for pod fill and yield potential, helped the canola mature at many sites where the crop was delayed by the prior cool and dry conditions. Precipitation patterns and amounts varied widely by location in 2025. Precipitation in May was slightly below-average at Indian Head and Swift Current and more intermediate at Yorkton, but extremely dry at the more northern sites (Melfort, Prince Albert, and Scott). In June through July, moisture conditions improved dramatically at these initially dry northern sites and were more intermediate at Swift Current and Yorkton but became progressively drier at Indian Head. August precipitation in 2025 was variable; however, Indian Head remained dry and, for many sites (i.e., Swift Current in particular), much of the August rain was considered too late to be of much benefit to the crop. Over the four-month period, total precipitation amounts in 2025 ranged from only 56% of average at Indian Head (136 mm), to 110% of average at Swift Current (236 mm).

Table 3. Mean monthly temperatures and long-term (LT; 1981-2010) averages for the 2024 (24) and 2025 (25) growing seasons at Indian Head (IH), Melfort (ME), Prince Albert (PA), Scott (SC), Swift Current (SW), and Yorkton (YK), Saskatchewan.

Year	May	June	July	August	May-Aug
----- Mean Temperature (°C) -----					
IH-24	10.6	13.6	19.5	17.9	15.4 (-0.2)
IH-25	12.7	15.3	17.0	17.8	15.7 (+0.1)
IH-LT	10.8	15.8	18.2	17.4	15.6
ME-24	10.1	13.2	19.4	17.4	15.0 (-0.2)
ME-25	13.8	15.0	17.0	18.0	16.0 (+0.8)
ME-LT	10.7	15.9	17.5	16.8	15.2
PA-24	10.1	12.9	20.0	17.0	15.0 (-0.1)
PA-25	11.2	12.7	14.9	17.1	14.0 (-0.9)
PA-LT	10.4	15.3	18.0	16.7	15.1
SC-24	9.8	13.3	18.9	17.4	14.9 (+0.1)
SC-25	12.9	14.6	15.8	17.4	15.2 (+0.3)
SC-LT	10.8	14.8	17.3	16.3	14.8
SW-24	10.6	14.3	21.3	19.4	16.4 (+0.6)
SW-25	13.1	15.9	18.0	19.0	16.5 (+0.7)
SW-LT	10.9	15.4	18.5	18.2	15.8
YK-24	10.5	14.2	20.3	17.7	15.7 (+0.5)
YK-25	12.4	15.7	17.5	18.3	16.0 (+0.8)
YK-LT	10.4	15.5	17.9	17.1	15.2

Table 4. Monthly precipitation totals and long-term (LT; 1981-2010) averages for the 2024 (24) and 2025 (25) growing seasons at Indian Head (IH), Melfort (ME), Prince Albert (PA), Scott (SC), Swift Current (SW), and Yorkton (YK), Saskatchewan.

Year	May	June	July	August	May-Aug
----- Total Precipitation (mm) -----					
IH-24	63.7	74.9	37.4	71.2	248 (102%)
IH-25	42.6	39.4	27.1	26.9	136 (56%)
IH-LT	51.7	77.4	63.8	51.2	244
ME-24	73.0	84.0	36.1	16.9	210 (93%)
ME-25	4.8	93.2	25.9	113.5	237 (105%)
ME-LT	42.9	54.3	76.7	52.4	226
PA-24	66.9	123.1	27.0	37.6	255 (101%)
PA-25	2.2	137.6	8.6	51.2	200 (79%)
PA-LT	44.7	68.6	76.6	61.6	252
SC-24	74.2	112.0	26.7	42.8	256 (113%)
SC-25	11.8	103.7	28.7	64.5	209 (98%)
SC-LT	36.3	61.8	72.1	45.7	216
SW-24	73.6	52.1	18.6	18.2	163 (76%)
SW-25	34.2	31.3	78.2	92.6	236 (110%)
SW-LT	48.5	72.8	52.6	41.5	215
YK-24	56.0	120.4	22.9	42.3	242 (89%)
YK-25	23.6	63.4	36.8	71.2	195 (72%)
YK-LT	51.3	80.1	78.2	62.2	272

Canola Establishment

Treatment means and results from the test of fixed effects, check versus rest comparisons, and orthogonal contrasts for canola establishment are in Table 5. Overall establishment was generally considered sufficient to not negatively affect canola yield, uniformity, or maturity; however, populations were marginal at PA-25 where the overall average was 38 plants/m². With all fertilizer side-banded, treatment effects on plant density were not necessarily expected. However, depending on equipment, soil, and environmental

conditions, separation between seed and fertilizer with side-banding is not always sufficient to eliminate potential fertilizer toxicity with sensitive crops like canola. The overall F-test was only significant in 4/12 sites: IH-24, SC-24, SC-25, and SW-24. At IH-25, the final plant density numbers were higher than expected (overall average of 155 plants/m²) but, with no linear or quadratic responses to increasing rates of untreated urea ($P = 0.123-0.639$), any discrepancies between treatments appeared to be largely random and unimportant. At SC-24, plant densities declined linearly ($P < 0.001$) from 99 to 69 plants/m² as the rate of untreated urea was increased from 38 to 175 kg total N/ha, or 7 to 137 kg fertilizer N/ha. Furthermore, we saw interesting differences in emergence amongst N forms with plant densities increasing incrementally from 79 to 104 plants/m² as the proportion of ESN in the blend was increased from 0 to 100%. Aside from 100% ESN, plant populations did not significantly differ from untreated urea for any other EEF formulations or blends. At SC-25, we saw a slight linear decline in plant densities as the side-banded urea rate was increased ($P = 0.042$), but no meaningful advantage to ESN. Significant differences between forms at SC-25 were infrequent and seemingly random. At SW-24, establishment was good overall; however, individual treatment means were variable ranging from 79-111 plants/m² ($P = 0.002$). Aside from the highest plant density being achieved with 100% ESN[®] (a potentially expected result), without the 'Check versus Rest' comparison ($P = 0.917$) or orthogonal contrasts ($P = 0.082-0.142$) being significant, the observed variation appeared largely random. Despite the lack of significant overall F-tests ($P = 0.055-0.375$), significant linear or quadratic responses ($P = 0.011-0.017$) for side-banded urea rate provided evidence of minor ammonia toxicity with higher side-banded urea rates at IH-25, ME-24, and SW-25.

Canola Seed Yield

Treatment means and results from the overall test of fixed effects, 'Check vs. Rest' comparisons, and orthogonal contrasts for seed yield are presented in Table 6. Due to the importance of this variable and implications for future analyses, we look closely at each site separately.

At IH-24, canola yields were increased by up to 36% (from 1914 kg/ha to 2599 kg/ha) with N fertilizer; however, no significant differences between N forms were detected and yields with untreated urea were amongst the highest in the trial. The quadratic response ($P < 0.001$) was due to the lack of further yield increases going from 125 to 175 kg N/ha, despite a strong response at lower rates.

At IH-25, canola yields increased by up to 90% with N fertilizer, from 1574 kg/ha to 2985 kg/ha. Like the previous season, a quadratic response ($P < 0.001$) indicated diminishing yield gains going from 125 kg N/ha to 175 kg N/ha. No differences between forms were significant, despite a range of 2771-2947 kg/ha amongst them. Numerically, yields with untreated urea were intermediate amongst the various forms that were evaluated.

Due to the higher residual N, the difference between the control and 75 kg N/ha treatment at ME-24 was only 15 kg N/ha. Despite higher residual N levels, yields increased by up to 37% (from 2100 kg/ha to 2868 kg/ha) with N. Like both years at Indian Head, the response was quadratic ($P < 0.001$) with diminishing yield increases with additional N at the higher rates. No significant differences between N forms were detected and, numerically, yields with untreated urea were amongst the highest of the forms evaluated.

At ME-25, the N response was more linear ($P < 0.001$) than quadratic ($P = 0.082$) with canola yields increasing by up to 104% at the 175 kg N/ha rate. The 125 kg N/ha rate was well within the responsive range but did not reveal any significant differences between forms and yields with untreated urea (2466 kg/ha) were intermediate within the observed range of 2333-2559 kg/ha observed at this site. The 75-100% ESN treatments trended lower, suggesting that the higher percentages of controlled release N may not have become available quickly enough under the initially dry conditions.

At PA-24, the N rates were adjusted upwards due to the initially high soil N; however, yields were still increased by up to 21% with N fertilizer. The response was quadratic ($P = 0.003$) with yields increasing with

N rates up to 150 kg total N/ha but tending to decline with further increases to 200 kg N/ha. This may have limited our ability to detect benefits associated with the EEF N formulations.

Like the previous season at this location, target N rates at PA-25 were increased to accommodate high residual N. Yields were more variable with no significant F-test ($P = 0.415$); however, the 'Check vs. Rest' comparison ($P = 0.016$) indicated higher overall yields with N. Yields increased linearly ($P = 0.013$), but the response was modest in that yields only increased by 16%. With the relatively high variability, no differences between forms were detected. Due to the higher target N rates in both years, data from Prince Albert will be analyzed separate from the other locations for the final report.

At SC-24, yields were increased by up to 62% at the 175 kg total N/ha rate of untreated urea. While the quadratic response was significant ($P < 0.001$) due to diminishing yield increases at the highest rate, it appeared that we were still within the responsive range at 125 kg total N/ha, where the EEF N forms were evaluated. Yield amongst the N forms ranged from 2176-2363 kg/ha, with no significant differences amongst them.

Despite the relatively low residual soil N and marginally significant overall F-test ($P = 0.052$) at SC-25, neither the 'Check vs. Rest' comparison nor orthogonal contrasts were significant ($P = 0.082-0.399$). This lack of response and high overall variability may have been attributable to the drought stressed conditions early on; however, this was our highest yielding site with an overall average of 3433 kg/ha. Due to these unusual results and our inability to explain them, data from this site will be excluded from any future, combined analyses.

At SW-24, residual N was high and, with no adjustments to the target N rates, there was no meaningful separation between the control (Trt. 1) and 75 kg N/ha treatment (Trt. 2). This, combined with heat and drought stress resulted in low yields and essentially no N response. While the overall F-test and 'Check vs. Rest' comparisons were significant ($P = 0.006-0.037$), neither the linear nor quadratic orthogonal contrasts were ($P = 0.350-0.441$). There were no significant differences between N forms and the only significant difference amongst individual treatments was between the lowest yielding 175 kg N/ha treatment and the numerically highest yielding treatment (50% ESN). The low yields at 175 kg N/ha were attributed to the reduced emergence and apparent NH_4 toxicity at this high rate of urea under the dry conditions. Due to the lack of N response and unusually poor conditions, data from this site will not be included in any future, combined analyses.

At SW-25, yields were much higher than the previous season at this location; however, high residual N and extreme variability limited the response to N along with our ability to evaluate the different forms. The overall F-test was marginally significant ($P = 0.076$); however, there were no meaningful trends and neither the 'Check vs. Rest' nor linear/quadratic orthogonal contrasts were significant ($P = 0.206-0.825$). Due to the high residual N levels and lack of response, data from this site will not be included in any future, combined analyses.

At YK-24, residual soil N was high, resulting in no meaningful difference between the control (Trt. 1) and 75 kg N/ha (Trt. 2) treatments. Overall, the data at this site were somewhat variable; however, there was a modest response to N with yields increased by up to 31% with side-banded urea. The 'Check vs. Rest' comparison and linear orthogonal contrast were both significant ($P < 0.001$) while the quadratic response was marginally significant ($P = 0.058$) and due to diminishing yield gains with additional N at higher rates. At 125 kg N/ha, the range was 2504-2780 kg/ha, but no differences between individual N forms were significant.

At YK-25, residual soil N was extremely high, resulting in no difference between the control and 75 kg N/ha treatment while also diminishing the amount of N applied to reach the 125 kg N/ha target. While the linear orthogonal contrast was significant ($P = 0.004$) due to slightly higher yields with 125-175 kg N/ha, neither

the overall F-test nor 'Check vs. Rest' comparisons were ($P = 0.170-0.248$). Contributing to the lack of N response is that yields were quite low overall, indicating that other factors were more limiting than N. Due to the high residual N, lack of response, and low overall yields, data from YK-25 will not be included in any combined analyses.

Canola Seed Oil Concentration

Treatment means and other statistics for seed oil concentrations are presented in Table 7. While the data were adjusted to 10% seed moisture content wherever possible, we cannot rule out NIR equipment differences as major sources of variability, limiting our ability to compare values across sites and, potentially, detect treatment effects at some sites.

At IH-24, soil content declined linearly from 46.6% to 42.8% as total N rates increased from 37 kg N/ha to 175 kg N/ha. Amongst N forms at the 125 kg N/ha rate, values ranged from 43.9-44.3% with no significant differences amongst them.

At IH-25, seed oil content fell from 47.8% to 41.9% with increasing N. The response was quadratic ($P = 0.044$) with the rate of decline in oil concentrations accelerating at the higher N rates. This is essentially the opposite of what often occurs with yield (i.e., diminishing yield increases at higher N rates) and consistent with what we might expect with grain protein, but in the opposite direction. At 125 kg N/ha, seed oil concentrations ranged from 44.0-44.8% with no significant differences amongst N formulations.

At ME-24, seed oil declined more subtly, from 46.7% to 45.1% going from 60 kg total N/ha to 175 kg N/ha. Values were similar for Treatments 1 and 2, which was not unexpected given the high residual N. Across N forms, values ranged from 45.5-46.4% with no significant differences amongst them.

At ME-25, the seed oil response to N was quadratic ($P = 0.002$), increasing from 45.5% to 46.1% with the first 26 kg fertilizer N/ha, but declining to 45.0% at the highest rate and dropping most rapidly going from 125 kg N/ha to 175 kg N/ha. Comparing formulations, the observed range was 44.8-46.0% with the sole significant difference being between the lowest (100% ESN) and highest (25% SUPERU) individual means. It is possible that 100% ESN deferred N availability until later in the season than many other forms, resulting in slightly lower seed oil concentrations (and higher protein). In any case, the response was subtle and may lose its significance in future, combined analyses.

Canola seed oil concentrations at PA-24 were not affected by N treatment. The observed range was 45.8-46.3% and neither the overall F-test, 'Check vs. Rest' comparison, nor orthogonal contrasts were significant ($P = 0.119-0.767$). There was, however, a subtle trend for seed oil to decline linearly from 46.3% to 45.7% as the total N rate was increased from 83 kg N/ha to 200 kg N/ha.

At PA-25, high variability limited our confidence in the seed yield responses; however, the trends were strong and the overall F-test for seed oil concentrations was significant ($P = 0.015$). As the total N rate was increased from 88 kg N/ha to 200 kg N/ha, seed oil concentrations declined linearly from 47.8% to 46.4%. At 125 kg N/ha, seed oil ranged from 45.8-47.2% with no significant differences amongst forms.

At SC-24, there were no effects on seed oil with no significant overall F-test, 'Check vs. Rest' comparison, nor orthogonal contrasts ($P = 0.413-0.945$). This lack of response was quite unexpected given the low residual N levels and strong yield response to N fertilization.

At SC-25, the overall F-test for seed oil content was only marginally significant ($P = 0.097$); however, the 'Check vs. Rest' comparison provided evidence of an overall reduction with N ($P = 0.008$) and the orthogonal contrasts showed a linear decline from 45.0% to 43% as total N was increased from 40 kg N/ha to 175 kg N/ha. The observed range amongst forms at 125 kg N/ha was 42.7-44.2%; however, variability was too high for any differences be treated as significant. Again, data from this site will be excluded from future combined analyses.

At SW-24, with high residual N and severe drought stress, the N treatments did not affect seed oil with no significant F test, 'Check vs. Rest' comparison, nor orthogonal contrasts ($P = 0.155-0.753$). In general, seed oil concentrations were low under these stressed conditions and background variability was high. Again, data from this site will be excluded from future combined analyses.

At SW-25, growing conditions were better and seed oil concentrations higher relative to the previous season; however, the data were still variable with no significant overall F-test nor 'Check vs. Rest' comparison ($P = 0.123-126$). The quadratic response to N rate was significant ($P = 0.016$), but unusual in the oil content declined with N rates up to 125 kg N/ha but then increased with further increases to 175 kg N/ha. Again, residual N was very high, yields were variable, there was essentially no response to N; therefore, data from this site will be excluded from future combined analyses.

At YK-24, the overall F-test for seed oil concentrations was highly significant along with the 'Check vs. Rest' comparison ($P < 0.001$). The linear orthogonal contrast ($P < 0.001$) showed seed oil concentrations falling from 47.5% at 75 kg total N/ha to 45.3% at 175 kg N/ha. Oil concentrations ranged from 46.1-46.5% across the various N forms at 125 kg N/ha, with no significant differences amongst them.

At YK-25, neither the overall F-test, 'Check vs. Rest' comparison, nor orthogonal contrasts were significant at the desired probability ($P = 0.060-0.524$). With high residual N and other factors seemingly being more limiting to yield, this lack of response was not unexpected and, again, this site will be excluded from future combined analyses.

Canola Seed Protein Concentration

Treatment means and other statistics for canola seed protein concentrations are in Table 8. As with seed oil, the values were adjusted to 10% seed moisture wherever possible. Protein was of interest because it is an accepted indicator of N status in crops and was also used to estimate seed N concentrations.

At IH-24, protein increased linearly ($P < 0.001$) from 17.5% to 22.3% as total N was increased from 37 kg N/ha to 175 kg N/ha. At 125 kg N/ha, no significant differences amongst the various N forms were detected and the observed range was 20.5-21.2%.

At IH-25, protein increased linearly ($P < 0.001$) from 16.1% to 21.6% as total N was increased from 28 kg N/ha to 175 kg N/ha. When N was applied at 125 kg total N/ha, protein concentrations ranged from 19.0-20.0%, with no significant differences amongst forms. At 20.0%, however, values with 100% ESN were the highest with the next closest being 75% ESN at 19.7% and these trends could become important with sufficient consistency across sites or increased statistical power. Previous research has reported high grain protein concentrations with ESN.

At ME-24, protein increased linearly from 18.6% to 20.5% as total N was increased from 60 kg N/ha to 175 kg N/ha. The observed range at 125 kg total N/ha was 18.9-19.9% with no significant differences between forms detected.

At ME-25, neither the overall F-test nor 'Check versus Rest' comparison was significant ($P = 0.103-0.358$); however, the linear and quadratic orthogonal contrasts ($P = 0.020-0.022$) revealed elevated protein at 175 kg total N/ha (19.9%) compared to the lower rates (18.5-19.2%). At 125 kg total N/ha, we observed a range of 18.7-19.7% but no significant differences amongst them.

At PA-24, neither the overall F-test, 'Check vs. Rest' comparison, nor orthogonal contrasts were significant ($P = 0.204-0.937$), despite the reasonably strong seed yield response at this site. There was a trend for protein to increase with additional N whereby, numerically, protein increased from 19.0% at 83 kg total N/ha to 19.5% at 200 kg total N/ha.

At PA-25, protein increased linearly ($P = 0.001$) from 17.6% to 19.2% as total N was increased from 88 kg N/ha to 200 kg N/ha. At 150 kg total N/ha, values ranged from 18.3-19.2% with no significant differences amongst them detected; however, the values with untreated urea were amongst the lowest. Again, data from PA-24 and PA-25 will not be combined with other locations; however, they will tentatively be analyzed together.

Despite a strong yield response to N, for seed protein at SC-24 neither the overall F-test, 'Check vs. Rest' comparison, nor orthogonal contrasts were significant ($P = 0.131-0.823$). The observed range was narrow at 20.6-21.3%. As with seed oil concentrations, this lack of response was unexpected and difficult to explain given the low residual N levels and strong response to fertilization.

At SC-25, seed protein was not affected by N treatment with no significant overall F-test, 'Check vs. Rest' comparison, nor orthogonal contrasts ($P = 0.109-0.511$). No meaningful trends were observed; however, this site was not responsive to N for seed yield, and this data will be excluded from future combined analyses.

Under the stressful, drought conditions at SW-25, seed protein concentrations were extremely high, ranging from 30.5-32.6%; however, neither the overall F-test nor 'Check vs. Rest' comparison were significant ($P = 0.256-0.518$). The only evidence of any treatment effects was a linear increase from 31.0% to 32.6% as the total N rate was increased from 78 kg N/ha to 175 kg N/ha. Again, data from this location will be excluded from future combined analyses.

Neither the overall F-test nor 'Check vs. Rest' comparisons at SW-25 were significant ($P = 0.093-0.110$). The quadratic orthogonal contrast was due to protein increasing slightly from 27.1% to 28.3% going from 80 kg N/ha to 125 kg N/ha but then declining to 27.5% when the rate was increased further to 175 kg N/ha. While consistent with the unusual results for oil content, this response may have been largely random based on the high overall variability. It is not clear whether the extremely high protein concentrations observed at Swift Current were due the environment, the specific NIR equipment/calibration, or a combination of these factors.

At YK-24, canola seed protein concentrations increased linearly from 16.7% to 20.3% as total N was increased from 75 kg N/ha to 175 kg N/ha. Amongst the various N forms at 125 kg N/ha, the observed range was 18.2-19.0% with no significant differences amongst them.

At YK-25, with high residual N and no yield response to N fertilizer, neither the overall F-test nor 'Check vs. Rest' comparison was significant ($P = 0.128-0.453$). Despite the broader lack of response, the linear orthogonal contrast did show seed protein increasing from 19.0-20.5% as total N was increased from 92 kg N/ha to 175 kg N/ha.

Fertilizer Agronomic Nitrogen Use-Efficiency

Results for agronomic N use-efficiency (ANUE) of the applied N fertilizer are in Table 9. These values should be interpreted cautiously as they were often quite variable, especially in cases where residual N was high and/or the yield response to N was weak. Furthermore, these values do not represent the absolute N use-efficiency as they only reflect the estimated proportion of N applied as urea or EEF formulations (i.e., excluding that provided by any monoammonium phosphate or ammonium sulfate) that was removed from the seed in the harvested grain. The reason they do not account for the small amounts of N provided by P or S fertilizer products is that this N also applied in the control plots. Furthermore, these values do not account for any N retained in the straw, chaff, or roots of the harvested crop or any applied N that was immobilized or retained in the soil, potentially to be utilized by future crops. There is also some uncertainty as to how much variation across sites was due to differences in the equipment used to estimate seed protein. As such, only the relative differences between treatments within each site have potential to provide meaningful insights.

At IH-24, ANUE declined quadratically with increasing N rate ($P = 0.020$), holding at 38% until the N rate exceeded what was required to achieve maximum yield (>125 kg total N/ha), at which point ANUE fell to 26%. Amongst the various N forms, ANUE ranged from 28-38%, with the lowest value (75% SUPERU) being significantly less than the highest (eNtrench), but no other differences amongst them. This result appeared to be largely due to random yield variation since, although seed yield and protein were high with eNtrench, both 100% urea and 100% SUPERU performed similarly to this form.

With strong responses to N, the ANUE values were relatively high at IH-25, but values declined linearly, from 54% to 42%, as the total N rate was increased from 75 kg N/ha to 125 kg N/ha ($P < 0.001$). For the individual N forms at 125 kg N/ha, ANUE values ranged from 45-51% with no significant differences amongst them.

At ME-24, ANUE values ranged from 28-44% but, due to high variability, neither the overall F-test ($P = 0.127$) nor any differences amongst individual treatments were significant. There was a trend for lower ANUE at 175 kg N/ha (28%) versus 125 kg N/ha as untreated urea (38%); however, orthogonal contrasts were not possible since we excluded the 75 kg N/ha treatment because of the low rates of urea/EEF N forms applied in this treatment. Amongst the various forms at 125 kg total N/ha, ANUE ranged from 31-44% with highest values observed with 100% SUPERU which had both high yields and protein; however, variability was too high to dwell on these numerical differences.

At ME-25, neither the overall F-test nor orthogonal contrasts were significant for ANUE ($P = 0.703-0.980$). The observed range amongst treatments was 37-48%; however, the overall variability was too high to draw inferences from any differences between individual treatments.

At PA-24, where we increased the target N rates to account for higher residual N, ANUE declined linearly ($P < 0.001$) from 51% to 12% with increasing N rates. The quadratic response was also marginally significant ($P = 0.061$) due to values being quite high at the 100 kg total N/ha target, where only 17 kg N/ha was provided as urea, but dropping rapidly from there as the corresponding yield increases diminished. For individual N forms at 150 kg total N/ha, ANUE values ranged from 20-27% with no significant differences amongst them.

At PA-25, the N response was weak and variability was high. As such, the overall F-test was not significant ($P = 0.729$) despite a range of 16-31% observed across treatments. Treatment 2 was removed from this analysis due to the low rates of urea and EEF N forms applied in this treatment and extreme variability in the calculated values. As such, orthogonal contrasts were not possible at this site.

At SC-24, the overall F-test for ANUE was not significant ($P = 0.687$); however, the orthogonal contrasts revealed a linear ($P = 0.040$) decline with increasing N rates. The ANUE values fell from 34% to 21% as the total amount of N was increased from 75 kg N/ha to 175 kg N/ha. This was attributed to diminishing yield increases going from 125 kg N/ha to 175 kg N/ha versus from 75 kg N/ha to 125 kg N/ha. Amongst the various N forms, values ranged from 23-33% but with no significant differences or meaningful trends identified.

Despite the general lack of N response at SC-25, both the overall F-test and linear orthogonal contrast were significant ($P = 0.002-0.023$). The linear response was such that ANUE rapidly declined from a maximum of 31% as the total N rate was increased past 75 kg N/ha. Past this point, due to the lack of further yield increases and, in some cases, negative responses, ANUE ranged from -9% to 9%, with no significant differences amongst N forms.

At SW-24, the overall F-test was significant ($P = 0.033$); however, no significant differences amongst individual treatments were significant according to multiple comparisons test. At the highest N rate, we reduced yields slightly under the stressful conditions encountered at this site, resulting in a negative ANUE value. The data were variable overall with values ranging from 4-23% amongst the N forms; however, no

meaningful trends were identified. With background N rates exceeding the 75 kg N/ha target, orthogonal contrasts were not possible.

At SW-25, the yield data were highly variable with no response to N detected; therefore, ANUE values were also highly variable and did not provide any meaningful information. The overall F-test was not significant at the desired probability ($P = 0.093$) despite a wide range of -11% to 34%. The high protein concentrations for both years at Swift Current exacerbated the variability in ANUE estimates. Like the previous season, orthogonal contrasts were not possible at SW-25 since the background N levels exceed the 75 kg N/ha target.

At YK-24, ANUE values were reasonably high and consistent, but not affected by N treatment ($P = 0.898$). There was a trend for ANUE to decline as total N was increased from 125 kg N/ha to 175 kg N/ha; however, orthogonal contrasts were not possible due to the high residual N. For the various N forms at 125 kg total N/ha, ANUE ranged from 33-45%; however, no specific trends were identified and values with untreated urea were amongst the highest observed at this site.

At YK-25, yields were too variable to produce meaningful ANUE values; however, the overall F-test was significant ($P = 0.024$). Values ranged from -6% to 22% with no meaningful trends identified. As alluded to earlier, data from this site will be excluded from any future combined statistical analysis.

Extension Activities

In 2024, this project could not be shown during the Indian Head Crop Management Field Day; however, Chris Holzapfel presented preliminary findings at the IHARF Soil and Crop Management Seminar held in Melville, Saskatchewan (Feb. 5, 2025; 100 attendees). In 2024 at Swift Current, Kaeley Kindrachuk (SaskOilseeds) discussed the project during the WCA/AAFC Annual Field Day on July 19 (75 participants) and it was also featured in 'Walk the Plots' with Glenda Lee Allan Vossler (August 13), broadcast throughout southwest Saskatchewan. At Yorkton in 2024, the plots were shown during the ECRF annual field with Kaeley Kindrachuk as a presenter (July 23, 2024; ~100 attendees). At Scott, Koralie Mack presented highlights from 2024 during the WARC Crop Opportunity meeting on February 28, 2025 (75 attendees). In 2025, Chris Holzapfel showed the plots during the Indian Head Crop Management Field Day (July 15, 2025; 157 attendees) and presented highlights during both the IHARF Soil and Crop Management Seminar at Balgonie (Feb. 4, 2026; 185 attendees), and Agvise Soil Fertility Seminars at Portage la Prairie (March 3, 2026; ~150 attendees) and Saskatoon (March 5, 2026; ~75 attendees). The project was featured during the 2025 CLC annual field day (July 29, 2025; 85 attendees) and at Yorkton in 2025, the plots were shown during the ECRF annual field with Warren Ward as a presenter (July 24, 2025; ~100 attendees). While the topic was not formally presented, the plots were signed and shown during the NARF/AAFC Annual Field Day (July 23, 2025; 126 attendees) and the NARF/AAFC Niche Crop Field Day (July 24, 2025; 36 attendees). All interim reports pertaining to the project have been and will continue to be available for download and viewing on the IHARF website (<https://iharf.ca/library/>).

Table 5. Treatment means, overall F-tests, and orthogonal contrast results for canola emergence in side-banded enhanced efficiency fertilizer (EEF) nitrogen (N) form trial at Indian Head (IH), Melfort (ME), Prince Albert (PA), Scott (SC), Swift Current (SW), Yorkton (YK) in 2024 (24) and 2025 (25). Means within a column followed by the same letter do not significantly differ (Tukey's, $P \leq 0.05$); however, letter groupings are only provided when justified by the overall F-test.

Nitrogen Rate	IH-24 ^Z	IH-25 ^Y	ME-24 ^X	ME-25 ^W	PA-24 ^V	PA-25 ^U	SC-24 ^T	SC-25 ^S	SW-24 ^T	SW-25 ^R	YK-24 ^Q	YK-25 ^P
----- Emergence (plants/m ²) -----												
¹ Control	144 ab	75	107	82	86	43	98 ab	73 a	98 abc	77	97	59
² 75N – urea	142 ab	81	114	100	67	35	91 abc	55 bcd	88 abc	77	99	59
³ 125N – urea	142 ab	81	118	89	80	36	79 bc	63 a-d	79 c	60	109	64
⁴ 175N – urea	149 ab	63	91	68	85	33	69 c	59 a-d	86 bc	63	100	69
⁵ 125N – 25% ESN	160 ab	71	108	74	75	39	79 bc	60 a-d	103 abc	72	101	67
⁶ 125N – 50% ESN	171 a	73	92	93	86	45	85 abc	54 cd	103 abc	78	102	54
⁷ 125N – 75% ESN	153 ab	74	108	84	80	35	98 ab	71 ab	101 abc	78	104	62
⁸ 125N – 100% ESN	146 ab	73	112	92	86	37	104 a	66 bcd	111 a	71	103	61
⁹ 125N – 25% SU	161 ab	69	104	80	84	40	85 abc	71 abc	106 ab	71	92	58
¹⁰ 125N – 50% SU	168 ab	68	117	75	81	40	79 bc	56 bcd	94 abc	70	103	68
¹¹ 125N – 75% SU	167 ab	73	95	84	77	38	88 abc	70 abc	98 abc	66	101	66
¹² 125N – 100% SU	172 a	65	97	80	77	38	81 bc	55 bcd	104 ab	65	91	51
¹³ 125N – ANVOL	151 ab	74	109	89	73	36	91 abc	51 d	100 abc	61	98	62
¹⁴ 125N - eNtrench	137 b	74	110	82	76	42	76 c	57 a-d	103	71	102	55
S.E.M.	6.7	4.9	6.6	8.5	7.3	5.1	4.8	3.3	5.0	5.1	5.9	7.0
----- Pr > F (p-values) -----												
Overall F-test	0.003	0.375	0.055	0.409	0.841	0.927	<0.001	<0.001	0.002	0.118	0.799	0.732
Check vs Rest	0.123	0.598	0.898	0.906	0.351	0.319	0.005	<0.001	0.917	0.145	0.548	0.729
N Rate – lin	0.639	0.101	0.065	0.091	0.495	0.295	<0.001	0.042	0.142	0.011	0.552	0.194
N Rate - quad	0.507	0.017	0.013	0.062	0.347	0.694	0.862	0.055	0.082	0.082	0.151	0.867

^Z 37 kg total N/ha background N at IH-24; ^Y 28 kg total N/ha background N at IH-25; ^X 60 kg total N/ha background N at ME-24; ^W 49 kg total N/ha background N at ME-25; ^V 83 kg total N/ha background N at PA-24 (all target N rates increased by 25 kg N/ha to maintain treatment separation); ^U 88 kg total N/ha background N at PA-25 (all target N rates increased by 25 kg N/ha to maintain treatment separation); ^T 38 kg total N/ha background N at SC-24; ^S 40 kg total N/ha background N at SC-25; ^T 78 kg total N/ha background N at SW-24; ^R 80 kg total N/ha background N at SW-25; ^Q 73 kg total N/ha background N at YK-24; ^P 92 kg total N/ha background N at YK-25

Table 6. Treatment means, overall F-tests, and orthogonal contrast results for canola seed yield in side-banded enhanced efficiency fertilizer (EEF) nitrogen (N) form trial at Indian Head (IH), Melfort (ME), Prince Albert (PA), Scott (SC), Swift Current (SW), Yorkton (YK) in 2024 (24) and 2025 (25). Means within a column followed by the same letter do not significantly differ (Tukey's, $P \leq 0.05$); however, letter groupings are only provided when justified by the overall F-test.

Nitrogen Rate	IH-24^Z	IH-25^Y	ME-24^X	ME-25^W	PA-24^V	PA-25^U	SC-24^T	SC-25^S	SW-24^T	SW-25^R	YK-24^Q	YK-25^P
----- Seed Yield (kg/ha) -----												
¹ Control	1914 c	1574 c	2100 c	1426 d	2283 b	2665	1499 c	3306 a	835 ab	2229	2154 b	1935
² 75N – urea	2234 b	2380 b	2282 bc	1816 c	2543 ab	2792	1945 b	3585 a	836 ab	2236	2144 b	1899
³ 125N – urea	2599 a	2854 a	2825 a	2466 b	2769 a	2990	2348 ab	3556 a	862 ab	2184	2714 a	2015
⁴ 175N – urea	2513 a	2985 a	2868 a	2904 a	2669 a	3079	2431 a	3468 a	783 b	2471	2820 a	2200
⁵ 125N – 25% ESN	2496 a	2927 a	2785 a	2484 b	2791 a	2898	2350 a	3473 a	1020 ab	2240	2654 a	2018
⁶ 125N – 50% ESN	2422 ab	2937 a	2710 a	2423 b	2715 a	2866	2256 ab	3522 a	1031 a	2058	2753 ab	2011
⁷ 125N – 75% ESN	2470 ab	2782 a	2812 a	2333 b	2863 a	3105	2215 ab	3188 a	1015 ab	2077	2557 ab	1960
⁸ 125N – 100% ESN	2550 a	2857 a	2750 a	2337 b	2709 a	2926	2225 ab	3523 a	996 ab	2028	2780 a	1843
⁹ 125N – 25% SU	2497 a	2897 a	2750 a	2475 b	2743 a	2964	2348 a	3113 a	928 ab	2273	2678 a	2105
¹⁰ 125N – 50% SU	2476 a	2947 a	2627 ab	2521 b	2755 a	2999	2285 ab	3350 a	980 ab	2394	2504 ab	2037
¹¹ 125N – 75% SU	2366 ab	2833 a	2716 a	2428 b	2806 a	3037	2227 ab	3505 a	995 ab	2593	2622 ab	2044
¹² 125N – 100% SU	2561 a	2906 a	2838 a	2494 b	2827 a	3089	2291 ab	3537 a	891 ab	2588	2557 ab	2120
¹³ 125N – ANVOL	2517 a	2771 a	2659 a	2505 b	2660 a	2915	2363 a	3489 a	949 ab	2135	2594 ab	2078
¹⁴ 125N - eNtrench	2575 a	2785 a	2728 a	2559 ab	2782 a	3057	2176 ab	3458 a	953 ab	2115	2612 ab	2030
S.E.M.	61.1	87.5 a	91.8	89.8	78.0	150.4	84.1	101.4	47.2	163.8	102.6	83.5
----- Pr > F (p-values) -----												
Overall F-test	<0.001	<0.001	<0.001	<0.001	<0.001	0.415	<0.001	0.052	0.006	0.076	<0.001	0.170
Check vs Rest	<0.001	<0.001	<0.001	<0.001	<0.001	0.016	<0.001	0.199	0.037	0.825	<0.001	0.248
N Rate – lin	<0.001	<0.001	<0.001	<0.001	<0.001	0.013	<0.001	0.399	0.441	0.206	<0.001	0.004
N Rate - quad	<0.001	<0.001	0.002	0.082	0.003	0.504	0.002	0.082	0.350	0.336	0.058	0.858

^Z 37 kg total N/ha background N at IH-24; ^Y 28 kg total N/ha background N at IH-25; ^X 60 kg total N/ha background N at ME-24; ^W 49 kg total N/ha background N at ME-25; ^V 83 kg total N/ha background N at PA-24 (all target N rates increased by 25 kg N/ha to maintain treatment separation); ^U 88 kg total N/ha background N at PA-25 (all target N rates increased by 25 kg N/ha to maintain treatment separation); ^T 38 kg total N/ha background N at SC-24; ^S 40 kg total N/ha background N at SC-25; ^T 78 kg total N/ha background N at SW-24; ^R 80 kg total N/ha background N at SW-25; ^Q 73 kg total N/ha background N at YK-24; ^P 92 kg total N/ha background N at YK-25

Table 7. Treatment means, overall F-tests, and orthogonal contrast results for canola seed oil concentrations in side-banded enhanced efficiency fertilizer (EEF) nitrogen (N) form trial at Indian Head (IH), Melfort (ME), Prince Albert (PA), Scott (SC), Swift Current (SW), Yorkton (YK) in 2024 (24) and 2025 (25). Means within a column followed by the same letter do not significantly differ (Tukey's, $P \leq 0.05$); however, letter groupings are only provided when justified by the overall F-test.

Nitrogen Rate	IH-24	IH-25	ME-24	ME-25	PA-24	PA-25	SC-24	SC-25	SW-24	SW-25	YK-24	YK-25
	----- Seed Oil (%) -----											
¹ Control	46.6 a	47.8 a	46.7 ab	45.5 abc	46.3	47.8 a	48.2	45.0	37.6	43.4	47.2 a	46.5
² 75N – urea	45.5 ab	46.5 b	46.7 a	46.1 a	46.0	47.5 a	47.5	44.4	37.5	43.3	47.5 a	46.0
³ 125N – urea	44.1 cd	44.5 c	46.1 abc	45.8 ab	45.9	47.2 ab	48.3	44.0	36.7	41.4	46.1 b	46.4
⁴ 175N – urea	42.8 d	41.9 d	45.1 d	45.0 bc	45.7	46.4 ab	47.9	43.0	36.4	42.5	45.3 c	45.4
⁵ 125N – 25% ESN	43.9 cd	44.8 c	45.9 a-d	45.5 abc	45.6	46.6 ab	48.4	42.9	37.6	42.6	46.2 b	45.4
⁶ 125N – 50% ESN	44.2 c	44.9 c	46.0 abc	45.6 abc	45.5	45.8 b	47.6	44.2	39.1	41.7	46.5 b	46.0
⁷ 125N – 75% ESN	44.0 cd	44.3 c	45.9 a-d	45.4 abc	46.0	46.5 ab	48.1	43.3	37.5	42.6	46.2 b	45.4
⁸ 125N – 100% ESN	44.2 c	44.0 c	45.8 bcd	44.8 c	45.8	46.8 ab	48.0	43.3	37.4	41.8	46.3 b	46.0
⁹ 125N – 25% SU	44.1 c	44.7 c	46.0 abc	45.7 abc	46.3	47.0 ab	48.0	43.6	37.1	43.1	46.1 b	45.9
¹⁰ 125N – 50% SU	44.4 bc	44.7 c	45.9 a-d	45.5 abc	45.9	47.0 ab	47.9	44.1	37.8	42.7	46.3 b	46.0
¹¹ 125N – 75% SU	44.2 c	44.8 c	46.4 abc	46.0 ab	45.9	47.0 ab	48.1	42.9	37.1	43.4	46.2 b	45.9
¹² 125N – 100% SU	44.0 cd	44.3 c	45.5 cd	45.2 abc	45.9	46.5 ab	47.8	43.3	37.4	43.4	46.2 b	45.9
¹³ 125N – ANVOL	44.3 bc	44.7 c	45.9 a-d	45.5 abc	45.9	47.2 ab	48.2	42.7	37.0	42.9	46.2 b	45.9
¹⁴ 125N - eNtrench	43.9 cd	44.7 c	45.9 a-d	45.2 abc	46.0	47.0 ab	47.9	43.9	37.5	42.7	46.2 b	46.1
S.E.M.	0.28	0.57	0.26	0.20	0.32	0.50	0.32	0.52	0.75	0.52	0.26	0.35
	----- Pr > F (p-values) -----											
Overall F-test	<0.001	<0.001	<0.001	0.001	0.702	0.015	0.640	0.097	0.693	0.123	<0.001	0.524
Check vs Rest	<0.001	<0.001	<0.001	0.842	0.119	0.004	0.413	0.008	0.733	0.136	<0.001	0.092
N Rate – lin	<0.001	<0.001	<0.001	0.017	0.138	0.002	0.945	0.008	0.155	0.088	<0.001	0.060
N Rate - quad	0.777	0.044	0.111	0.002	0.767	0.806	0.787	0.844	0.753	0.016	0.289	0.238

^z 37 kg total N/ha background N at IH-24; ^y 28 kg total N/ha background N at IH-25; ^x 60 kg total N/ha background N at ME-24; ^w 49 kg total N/ha background N at ME-25; ^v 83 kg total N/ha background N at PA-24 (all target N rates increased by 25 kg N/ha to maintain treatment separation); ^u 88 kg total N/ha background N at PA-25 (all target N rates increased by 25 kg N/ha to maintain treatment separation); ^t 38 kg total N/ha background N at SC-24; ^s 40 kg total N/ha background N at SC-25; ^r 78 kg total N/ha background N at SW-24; ^q 80 kg total N/ha background N at SW-25; ^p 73 kg total N/ha background N at YK-24; ^o 92 kg total N/ha background N at YK-25

Table 8. Treatment means, overall F-tests, and orthogonal contrast results for canola seed protein concentrations in side-banded enhanced efficiency fertilizer (EEF)nitrogen (N) form trial at Indian Head (IH), Melfort (ME), Prince Albert (PA), Scott (SC), Swift Current (SW), Yorkton (YK) in 2024 (24) and 2025 (25). Means within a column followed by the same letter do not significantly differ (Tukey's, $P \leq 0.05$); however, letter groupings are only provided when justified by the overall F-test.

Nitrogen Rate	IH-24	IH-25	ME-24	ME-25	PA-24	PA-25	SC-24	SC-25	SW-24	SW-25	YK-24	YK-25
----- Seed Protein (%) -----												
¹ Control	17.5 d	16.1 d	18.6 cd	19.0	19.0	17.6 b	21.3	19.5	31.0 a	27.1	17.4 cd	19.0
² 75N – urea	18.9 c	17.3 c	18.5 d	18.7	19.2	17.8 b	20.6	19.9	31.2 a	27.5	16.7 d	19.0
³ 125N – urea	20.9 b	19.6 b	19.2 bcd	18.7	19.3	18.2 ab	20.6	19.4	31.8 a	28.3	18.8 b	19.3
⁴ 175N – urea	22.3 a	21.6 a	20.5 a	19.9	19.5	19.2 ab	20.7	19.2	32.6 a	27.5	20.3 a	20.5
⁵ 125N – 25% ESN	21.2 ab	19.3 b	19.5 abc	19.2	19.8	19.1 ab	21.0	19.1	31.2 a	27.6	18.8 b	20.3
⁶ 125N – 50% ESN	20.7 b	19.1 b	19.2 bcd	19.1	19.7	19.8 a	20.9	19.3	30.5 a	28.4	18.2 bc	19.7
⁷ 125N – 75% ESN	21.2 ab	19.7 b	19.5 a-d	19.3	19.4	19.2 ab	21.0	19.4	31.6 a	27.9	18.9 b	20.4
⁸ 125N – 100% ESN	20.7 b	20.0 b	19.7 ab	19.7	19.4	18.6 ab	21.0	19.3	31.5 a	28.3	18.7 b	19.4
⁹ 125N – 25% SU	20.9 b	19.2 b	19.2 bcd	19.0	19.0	18.5 ab	21.0	19.3	32.0 a	27.3	18.8 b	19.4
¹⁰ 125N – 50% SU	20.3 bc	19.3 b	19.5 a-d	19.2	19.4	18.3 ab	20.7	19.3	31.4 a	27.5	18.6 bc	19.6
¹¹ 125N – 75% SU	20.5 b	19.0 b	18.9 bcd	19.0	19.4	18.4 ab	20.8	19.0	32.1 a	27.2	19.0 b	19.8
¹² 125N – 100% SU	20.9 b	19.6 b	19.9 ab	19.7	19.4	19.1 ab	21.0	19.4	31.6 a	26.9	18.8 b	19.7
¹³ 125N – ANVOL	20.8 b	19.2 b	19.4 bcd	19.4	19.3	18.3 ab	21.2	19.1	31.7 a	27.4	18.8 b	19.6
¹⁴ 125N - eNtrench	21.2 ab	19.3 b	19.6 abc	19.5	19.3	18.4 ab	20.6	20.1	31.4 a	27.6	18.8 b	19.8
S.E.M.	0.30	0.53	0.30	0.29	0.34	0.57	0.30	0.35	0.551	0.36	0.50	0.47
----- Pr > F (p-values) -----												
Overall F-test	<0.001	<0.001	<0.001	0.103	0.792	0.004	0.823	0.123	0.518	0.093	<0.001	0.453
Check vs Rest	<0.001	<0.001	<0.001	0.358	0.216	0.004	0.131	0.511	0.256	0.110	<0.001	0.128
N Rate – lin	<0.001	<0.001	<0.001	0.020	0.204	0.001	0.207	0.109	0.021	0.376	<0.001	0.014
N Rate - quad	0.305	0.184	0.074	0.022	0.937	0.560	0.161	0.336	0.965	0.022	0.845	0.588

^z 37 kg total N/ha background N at IH-24; ^y 28 kg total N/ha background N at IH-25; ^x 60 kg total N/ha background N at ME-24; ^w 49 kg total N/ha background N at ME-25; ^v 83 kg total N/ha background N at PA-24 (all target N rates increased by 25 kg N/ha to maintain treatment separation); ^u 88 kg total N/ha background N at PA-25 (all target N rates increased by 25 kg N/ha to maintain treatment separation); ^t 38 kg total N/ha background N at SC-24; ^s 40 kg total N/ha background N at SC-25; ^r 78 kg total N/ha background N at SW-24; ^q 80 kg total N/ha background N at SW-25; ^p 73 kg total N/ha background N at YK-24; ^o 92 kg total N/ha background N at YK-25

Table 9. Treatment means, overall F-tests, and orthogonal contrast results for canola agronomic nitrogen use-efficiency (ANUE) in canola side-banded enhanced efficiency fertilizer (EEF) nitrogen (N) form trial at Indian Head (IH), Melfort (ME), Prince Albert (PA), Scott (SC), Swift Current (SW), Yorkton (YK) in 2024 (24) and 2025 (25). Means within a column followed by the same letter do not significantly differ (Tukey's, $P \leq 0.05$); however, letter groupings are only provided when justified by the overall F-test.

Nitrogen Rate	IH-24	IH-25	ME-24	ME-25	PA-24	PA-25	SC-24	SC-25	SW-24	SW-25	YK-24	YK-25
----- Agronomic N Use-Efficiency (%) -----												
¹ Control	–	–	–	–	–	–	–	–	–	–	–	–
² 75N – urea	38 a	54 a	–	41	51 a	–	34	31 a	–	–	–	–
³ 125N – urea	38 a	50 abc	38	40	24 bc	19	30	8 ab	5 a	5	42	10 ab
⁴ 175N – urea	26 c	42 d	28	39	12 c	17	21	2 ab	-1 a	13	31	15 ab
⁵ 125N – 25% ESN	35 abc	51 abc	39	43	28 bc	22	31	4 ab	21 a	5	38	19 a
⁶ 125N – 50% ESN	30 abc	50 abc	33	40	24 bc	25	27	6 ab	19 a	-7	39	13 ab
⁷ 125N – 75% ESN	34 abc	48 a-d	39	37	29 b	31	26	-5 b	21 a	-9	34	15 ab
⁸ 125N – 100% ESN	35 abc	52 ab	39	39	21 bc	19	27	7 ab	23 a	-11	45	-6 b
⁹ 125N – 25% SU	34 abc	50 abc	35	42	20 bc	20	31	-9 b	13 a	6	40	19 a
¹⁰ 125N – 50% SU	31 abc	52 abc	31	44	21 bc	20	27	0 b	17 a	19	28	15 ab
¹¹ 125N – 75% SU	28 bc	47 bcd	31	40	26 bc	23	26	4 ab	21 a	34	38	18 a
¹² 125N – 100% SU	36 ab	52 abc	44	46	27 bc	30	29	7 ab	8 a	32	33	22 a
¹³ 125N – ANVOL	35 abc	45 cd	32	44	19 bc	16	33	4 ab	15 a	-6	35	18 a
¹⁴ 125N - eNtrench	38 a	46 bcd	36	48	24 bc	24	23	9 ab	4 a	-7	36	16 ab
S.E.M.	2.5	2.3	4.7	5.8	4.5	8.0	6.7	7.2	6.4	12.8	7.0	7.9
----- Pr > F (p-values) -----												
Overall F-test	<0.001	<0.001	0.127	0.961	<0.001	0.729	0.687	0.023	0.033	0.093	0.898	0.024
Check vs Rest	–	–	–	–	–	–	–	–	–	–	–	–
N Rate – lin	<0.001	<0.001	–	0.703	<0.001	–	0.040	0.002	–	–	–	–
N Rate - quad	0.020	0.305	–	0.980	0.061	–	0.726	0.274	–	–	–	–

^z 37 kg total N/ha background N at IH-24; ^y 28 kg total N/ha background N at IH-25; ^x 60 kg total N/ha background N at ME-24; ^w 49 kg total N/ha background N at ME-25; ^v 83 kg total N/ha background N at PA-24 (all target N rates increased by 25 kg N/ha to maintain treatment separation); ^u 88 kg total N/ha background N at PA-25 (all target N rates increased by 25 kg N/ha to maintain treatment separation); ^t 38 kg total N/ha background N at SC-24; ^s 40 kg total N/ha background N at SC-25; ^r 78 kg total N/ha background N at SW-24; ^q 80 kg total N/ha background N at SW-25; ^p 73 kg total N/ha background N at YK-24; ^o 92 kg total N/ha background N at YK-25

Recommendations, Acknowledgements, and Appendices:

11. Conclusions and Recommendations:

With high residual soil nitrogen (N) or other environmental issues diminishing our responses to N fertilizer at multiple sites (i.e. SC-25, SW-24, SW-25, YK-24, and YK-25), this project has proven more challenging than expected. While PA-24 and PA-25 had to increase the target N rates to accommodate high background N and data from PA-25 was quite variable, these sites were still responsive to N fertilization. However, this revision creates challenges for combined data analyses and presentation of results.

In a few cases, we saw evidence of seedling toxicity with high rates of side-banded N. While the losses were not generally large enough to negatively impact yields, polymer coated urea (ESN[®]) reduced these negative impacts at SC-24 and, to a lesser extent, SW-24. Polymer coated ESN[®] is known to improve seed safety and commonly recommended to allow higher N rates to be applied with single shoot drills; therefore, this result was not unexpected. Side-banding is generally considered safe for high rates of urea; however, minor NH₄ toxicity in sensitive crops often still occurs under dry conditions or if separation between the seed and fertilizer is compromised. Injury associated with side-banded urea is typically minor and outweighed by the benefits of enhanced fertility, but such risks are still important to acknowledge and manage to the best of our ability.

Under the conditions encountered to date, there have been no cases where enhanced efficiency fertilizer (EEF) N products improved yields over untreated urea. Significant effects on seed quality were exceedingly rare and, as such, difficult to predict. The lack of response was attributed to the risk of environmental N losses being low with side-band placement and under the conditions encountered. Although denitrification losses can be sizeable in saturated soils, this process only affects N that has already converted to nitrate. Concentrating N in bands beneath the soil surface slows and delays nitrification, even without the use of inhibitors (i.e., eNtrench[®] or SUPERU[®]) or polymer coatings (i.e. ESN[®]). Despite high precipitation in May and June at many sites in 2024, initial soil moisture was extremely low. As such, the plots were unlikely to be saturated for long if they were situated on reasonably well drained land. Aside from lower slope or depressional areas on coarse textured soils, leaching losses during the growing season, which polymer coatings or nitrification inhibitors can reduce, are rather unlikely. Furthermore, the risk of N loss due to NH₃ volatilization also low with the early season precipitation in 2024. Simply placing the N beneath the soil surface is enough to greatly reduce or eliminate volatilization, regardless of whether a urease inhibitor is used. While volatilization losses are possible with shallow banding at high rates in coarse soils, or if the furrow/fertilizer band is not properly sealed, timely rain can largely eliminate this risk. In 2025, several sites were extremely dry in May, but conditions improved in June and the soils were never likely saturated long enough to pose a serious risk of denitrification or leaching losses. While these initially dry conditions might increase risk of volatilization with shallow banding, the worst affected sites also had more acidic soils (pH < 6, which increases the NH₄:NH₃ ratio) and either had relatively fine-textured soils (i.e., ME-25) or were generally not responsive to N. With these environmental conditions in mind, the lack of advantages of EEF N formulations over urea, was not unexpected. Again, EEF N formulations will only be advantageous when the crop is responsive to N fertilization, and the risk of environmental N loss is sufficient.

The agronomic N use-efficiency (ANUE) measurements were good indicators of the overall economic response to N fertilizer and diminishing returns with increasingly high N rates but have generally been too variable to be useful for detecting differences between forms. It is also important not to misinterpret these values. As indicated earlier, ANUE is not an absolute measure of NUE. For example, an ANUE value of 30% does not mean that 70% of the N was lost to the environment. A substantial portion of this applied N could remain in the crop material (straw, chaff, roots), be immobilized, and/or remain in the soil as mineral N forms. The ANUE values in the current project only account for the estimated proportion of the applied N, as

urea or EEF N (i.e., not the N from monoammonium or ammonium sulfate), that was physically removed in the harvested grain.

While we expect EEF N products to be more beneficial with less desirable timing and placement options (i.e., fall applications, surface broadcast applications), such products can still be beneficial and economically advantageous with side or mid-row banding under certain conditions. However, our results reinforce that such benefits are never guaranteed and, when timing, placement, and environmental conditions are all favorable, can be unlikely. The risk of environmental losses with in-soil banded N will vary with year, regionally, and with landscape position (i.e., greater potential for denitrification in depressional areas). Importantly, small plot trials are not typically placed in the depressional areas of fields where some of these losses will be most severe on a more localized basis. Furthermore, nitrification inhibitors consistently reduce N₂O emissions, which can occur both with rapid nitrification and denitrification processes. Nitrous oxide emissions are generally too small to impact yields or economic returns but are important environmental. Depending on commodity and fertilizer prices, relatively small yield benefits can often cover the cost of EEF N products. Government programming is sometimes available to reduce the cost of these technologies which, if utilized, can greatly improve the economics of qualifying EEF N formulations.

This project will be repeated at four locations in 2026 and a final, combined statistical analyses will be completed at this time. Data from Prince Albert will need to be analyzed separately due to the adjusted target N rates. Data from SC-25, SW-24, SW-25, and YK-25 will be excluded because of high residual N and/or adverse environmental conditions resulting in high variability and/or a general lack of N response. For those four sites, this report will serve as a final record of the work completed and results obtained. In future combined analyses, the control treatment (where no supplemental urea or EEF N was applied) will be excluded from most statistical analyses to minimize the effects of background N, to the best of our ability, when comparing EEF N forms. Effects of background N variability across sites cannot be fully eliminated since the proportion of N provided by the EEF N forms diminishes as background N increases. Consequently, and because of environment effects on N losses, site effects will be treated as fixed in our final, combined analyses. We will plant to utilize a second model, incorporating the unfertilized control (Trt. 1) to retain the 'Check vs. Rest' comparison and orthogonal contrasts for individual sites. This information provides useful additional context when interpreting differences (or lack thereof) between formulations. Furthermore, in future reports, it is possible that ANUE will only be used as an indicator of the overall N response at each site. Due to high variability, potential inconsistencies across sites, and possibility of misleading results, we will use discretion before committing to use ANUE to compare the relative performance of the EEF N forms.

12. Acknowledgements:

Financial support for this demonstration at all sites over both years has been provided by SaskOilseeds. Signs were in place for any plot tours to acknowledge the funding sources and appropriate acknowledgements will be made in all written communications, oral presentations, or other printed materials pertaining to the project. We would like to acknowledge the Boards of Directors for the participating organizations in addition to the many technical and support staff who worked on the project. Several of the enhanced efficiency fertilizer and crop protection products that were utilized were also donated. IHARF, iSask, NARF, WARC, and WCA have strong working relationships and memorandum of understanding with Agriculture and Agri-Food Canada, and all participating organizations have received funding for infrastructure and basic operating expenses from the Saskatchewan Ministry of Agriculture and several other producer/commodity groups, all of which has helped to make work like this possible.

13. Appendices:

Table 10. Selected agronomic information and dates of operations for ADOPT-CARP (20230443) canola side-banded nitrogen (N) formulation demonstration trials conducted at Indian Head (IH), Melfort (ME), Prince Albert (PA), Scott (SC), Swift Current (SW), and Yorkton (YK) in 2024.

Activity	IH-24	ME-24	PA-24	SC-24	SW-24	YK-24
Previous Crop	Canaryseed	Wheat	Barley	Wheat	Wheat	Wheat
Pre-Emergent Herbicide	May-22-2024 (glyphosate)	–	May-28-2024 (glyphosate)	May 22-2024 (glyphosate + AIM)	Apr-23-2024 (glyphosate)	–
Seeding Date	May-23-2024	May-28-2024	May-24-2024	May-26-2024	May-10-2024	May-29-2024
Row Spacing	31 cm	31 cm	25 cm	25 cm	21 cm	31 cm
kg N-P ₂ O ₅ -K ₂ O-S/ha ²	8-40-43-15	12-56-50-17	9-42-0-0	7-33-0-0	8-40-41-14	19-23-0-16
Emergence Counts	Jun-18-2024	Jun-18-2024	Jun-28-2024	Jun-20-2024	May-28-2024	Jun-21-2024
In-crop Herbicide 1	Jun-20-2024 (Liberty 150 SN)	Jun-9-2024 (Liberty 150 SN)	Jun-26-2024 (Assure II)	Jun-26-2024 (Liberty 150 SN)	Jun-11-2024 (Liberty 150 SN)	Jun-15-2024 (glyphosate)
In-crop Herbicide 2	Jun-20-2024 (Centurion)	Jun-9-2024 (Centurion)	–	Jun-26-2024 (Centurion)	Jun-11-2024 (Centurion)	–
In-crop Herbicide 3	–	Jun-21-2024 (Facet L)	–	–	–	–
In-crop Herbicide 3	–	–	–	–	–	–
Foliar Fungicide	Jul-14-2024 (Cotegra)	–	Jul-30-2024 (Priaxor)	Jul-11-2024 (Cotegra)	–	Jul-13-2024 (Dyax)
Foliar Insecticide 1	–	–	Jun-17-2024 (Matador)	None	Jul-23-2024 (Voliam Xpress)	–
Foliar Insecticide 2	–	–	–	–	–	–
Pre-harvest Herbicide or Desiccant	Aug-31-2024 (glyphosate)	–	Aug-30-2024 (diquat)	Aug-30-2024 (diquat)	–	–
Harvest Date	Sep-9-2024	Sep-9-2024	Sep-7-2024	Sep-6-2024	Aug-15-2024	Sep-16-2024

Table 11. Selected agronomic information and dates of operations for ADOPT-CARP (20230443) canola side-banded nitrogen (N) formulation demonstration trials conducted at Indian Head (IH), Melfort (ME), Prince Albert (PA), Scott (SC), Swift Current (SW), and Yorkton (YK) in 2025.

Activity	IH-25	ME-25	PA-25	SC-25	SW-25	YK-25
Previous Crop	Canaryseed	Wheat	Wheat	Wheat	Wheat	Wheat
Pre-Emergent Herbicide	May-24-2025 (glyphosate)	May-21-2025 (glyphosate + trifluralin)	–	May 13-2025 (glyphosate + AIM)	Apr-18-2025 (glyphosate + AIM)	May-24-2025 (glyphosate)
Seeding Date	May-27-2025	May-23-2025	May-21-2025	May-15-2025	May-8-2025	May-20-2025
Row Spacing	31 cm	31 cm	25 cm	25 cm	21 cm	31 cm
kg N-P ₂ O ₅ -K ₂ O-S/ha ^z	8-40-43-15	10-46-50-17	21-54-0-11	7-33-0-0	8-40-49-17	19-23-0-16
Emergence Counts	Jun-17-2025	Jun-11-2025	Jul-4-2025	Jun-9-2025	May-29-2025	Jun-5-2025
In-crop Herbicide 1	Jun-15-2025 (Liberty 150 SN)	Jun-20-2025 (Liberty 150 SN)	Jun-11-2025 (glyphosate)	Jun-17-2025 (Liberty 150 SN)	Jun-20-2025 (Liberty 150 SN)	Jun-11-2025 (glyphosate)
In-crop Herbicide 2	Jun-15-2025 (Centurion ADV)	Jun-20-2025 (Facet L)	Jun-25-2025 (Centurion)	Jun-17-2025 (Centurion)	–	–
In-crop Herbicide 3	Jun-27-2025 (Liberty 150 SN)	–	Jul-11-2025 (glyphosate – off label)	–	–	–
In-crop Herbicide 4	Jun-27-2025 (Centurion ADV)	–	–	–	–	–
Foliar Fungicide	Jul-16-2025 (Cotegra)	Jul-10-2025 (Cotegra)	Jul-8-2025 (Priaxor)	Jul-7-2025 (Cotegra)	–	Jul-7-2025 (Acapella)
Foliar Insecticide 1	Jul-12-2025 (Decis 5 EC)	–	Jun-12-2025 (Matador)	–	Jun-27-2025 (Voliam Xpress)	–
Foliar Insecticide 2	–	–	Jun-17-2025 (Malathion)	–	–	–
Pre-harvest Herbicide or Desiccant	Aug-31-2024 (glyphosate)	Sep-5-2025 (glyphosate)	Sep-10-2025 (diquat)	Aug-30-2025 (diquat)	Aug-20-2025 (diquat)	Aug-20-2025 (diquat)
Harvest Date	Sep-9-2024	Sep-25-2025	Sep-24-2025	Sep-14-2025	Sep-16-2025	Sep-3-2025

14. Abstract:

Exploring potential benefits of enhanced efficiency fertilizer (EEF) nitrogen (N) products and blends with side-banding was identified as a priority by SaskOilseeds. In the spring of 2025, field trials to address this topic were initiated at Indian Head, Melfort, Prince Albert, Scott, Swift Current, and Yorkton, Saskatchewan. These locations encompass a wide range of soil/climatic conditions. In addition to a control and several rates of side-banded urea, the treatments included polymer coated urea (ESN[®]), a urease inhibitor (ANVOL[®]), a nitrification inhibitor (eNtrench[®]), and a dual urease/nitrification inhibitor (SUPERU[®]). In addition to being applied alone, ESN[®] and SUPER[®] were tested in 25%, 50%, and 75% blends with untreated urea. Evidence of stand reduction with high rates of untreated urea was occasionally detected. At Scott in 2024, polymer coated ESN[®] reduced this risk with clear improvements in establishment as the proportion of ESN[®] in the blend was increased; however, no other EEF products showed such benefits. At 5/12 sites, high residual N or other limiting factors resulted in essentially no benefit to N fertilization; however, the remaining sites were responsive. For all sites, the risks of environmental N losses (denitrification, leaching, and volatilization) were generally considered low, and we did not observe any yield benefits to any of the EEF N products evaluated. The seed oil and protein measurements did not provide any evidence of improved NUE relative to untreated urea with EEF N products. The agronomic N use-efficiency (ANUE) estimates were effective for describing the overall economic response to N fertilizer applications and the diminishing yield responses at increasingly high rates but were generally too variable to detect or describe differences amongst N formulations. While yield benefits to EEF products are more likely with less optimal application timing/placement, they could occur with side-banding in years, locations, or landscape positions where environmental N losses are higher. To date, the project has been featured at six field days and five oral presentations with a combined attendance of more than 1200 participants. The project is being repeated at four locations in 2026, at which point final, combined statistical analyses will be completed and our recommendations will be updated.

15. Finances:

Detailed expenditure statements are provided in a separate document and are available upon request.