2022 Annual Report

for the

Saskatchewan Ministry of Agriculture's

Agricultural Demonstration of Practices & Technologies (ADOPT) Program

Project Title: Flax Response to Non-Traditional Nitrogen Fertilizer Management Strategies

Project #20211052

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Project Identification

1. **Project Title:** Flax response to non-traditional nitrogen fertilizer management strategies
2. **Project Number:** 20211052
3. **Producer Group Sponsoring the Project:** Saskatchewan Flax Development Commission (SaskFlax)
4. **Project Location(s):** Indian Head (#156), Melfort (#428), Redvers (#61), Swift Current (#136), and Yorkton (#244), Saskatchewan
5. **Project start and end dates(s):** April-2021 to February-2023
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Objectives and Rationale

7. Project Objectives:

The objectives of this project were to:

1. Demonstrate flax yield response to a range of nitrogen fertilizer rates for a variety of Saskatchewan locations.
2. Demonstrate the seed-safety and potential yield benefits of polymer coated urea (ESN) relative to urea when side-banded at high rates.
3. Demonstrate the potential merits of utilizing split-applications of nitrogen in flax to reduce the likelihood of seedling injury and lodging while potentially enhancing yield.

8. Project Rationale:

Flax has potential to be quite a profitable crop provided that sufficiently high yields can be achieved with reasonable consistency. For most crops, increasing N fertilizer rates is one of the more effective and common means by which farmers strive for higher yields and flax is no exception. This crop has been proven to be quite responsive to N fertilization but also extremely sensitive and, even with side-banding, high rates can lead to stand reduction. This project aimed to benefit producers by demonstrating the overall response of flax to N fertilizer and different means by which growers might further enhance yields by supplying sufficient rates of N without compromising stands.

A 40 bu/ac (2.5 Mt/ha) flax crop requires a total of 120-140 kg N/ha, 30-40 kg P_2O_5/ha, 70-90 kg K_2O/ha and 20-30 kg S/ha (Canadian Fertilizer Institute, 2001). A recent, Prairie-wide project evaluated flax response to varying rates of both N and phosphorus (P) at eight locations over a three-year period (Holzapfel et al. 2019). Generally consistent with previous research (i.e., May et al. 2010), flax responded reasonably well to N fertilizer with an overall average increase of 39% at 100 kg N/ha and occasional responses to even higher N rates. Importantly, flax was sensitive to side-banded urea with linear reductions in plant density with increasing N rate at 75% of the 19 site-years considered and, amongst these, an average plant loss of 28% as the rate was increased from 13 kg N/ha to 150 kg N/ha. Other studies have shown similar effects (i.e., Malhi et al. 2008; Grant et al. 2016). We hypothesized that utilizing an ESN® (Environmentally Smart Nitrogen, Agrium) blend in place of urea would greatly reduce the risk of stand reductions with high rates of side-banded N. ESN® is a polymer coated urea product, where the release of N is controlled by diffusion (i.e., moisture and temperature), and this N form is known for its improved seed safety over untreated urea. Qin et al. (2014) found that substitution of urea with ESN® allowed 3x rates of seed-placed N in wheat and canola before seedling injury occurred.

Regarding split-applications, the Flax Council of Canada suggested that flax may be a good candidate for this practice, recognizing that it is both extremely sensitive to N fertilizer damage and can be susceptible to mid-season N deficiencies (i.e. https://flaxcouncil.ca/tips_article/fertility-requirements-for-flax/). The rate of N accumulation in the leaves and capsule pericarps peaks at anthesis and early seed development for flax, at which point it declines due to translocation to the seed followed by senescence (Xie et al. 2015). Previous Prairie research with canola showed that at least 50% of the total N requirements should be applied during (or before) seeding and in-crop N should be applied by the bolting stage. Yield losses could occur if less than this was applied up front and/or the remainder was delayed until flowering (Lafond et al. 2008). There is anecdotal evidence of flax producers having success with in-crop applications at the budding stage; however, specific results will likely vary depending on whether there is any deficiency earlier in the season and/or sufficient precipitation is received after the application to move the N into the rooting zone before permanent yield losses can occur.

Literature cited:

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Methodology and Results

9. Methodology:

In the spring of 2021, flax field trials were initiated with locations at Indian Head, Melfort, Redvers, Swift Current, Yorkton, and Scott. The project was repeated at all locations except for Scott in 2022. The treatments were selected to explore flax response to a range of N fertilizer rates (17-130 kg N/ha), contrasting fertilizer forms (untreated urea versus polymer coated urea – ESN®) at the higher rates, and split-applications of N with the post-emergent treatments applied during either the vegetative (4-10 cm tall) or early reproductive (bud formation/early flower) stages, with and without a volatilization inhibitor (NBPT; Agrotain®). Nutrients other than N were intended to be non-limiting and, aside from the in-crop broadcast N, all fertilizer products (including any P, K, and S sources) were side-banded. For the treatments calling for polymer coated urea, we utilized a 75% blend (25% untreated urea) to ensure that enough N would be available early in the season and because this is a commonly recommended industry practice with ESN®. Although we did not adjust the N rates for residual soil test levels, the intention was for all collaborators to secure sites with initially low residual NO_3-N, if possible. The 11 N fertility treatments were arranged in a four replicate RCBD and are described in greater detail in Table 1.

Table 1. Treatments evaluated in ADOPT nitrogen management demonstration in flax (2021 and 2022).

#	Name	kg N-P_2O_5-K_2O-S/ha	Comments
1	Check	17-40-0-11	- N from 77 kg/ha MAP and 42 kg/ha AS
2	Low N – urea	55-40-0-11	- all N side-banded as either untreated urea or a blend of 75% ESN:25% untreated urea
3	Medium N – urea	80-40-0-11	
4	High N – urea	105-40-0-11	
5	High N – 75% ESN	105-40-0-11	
6	Ultra N – urea	130-40-0-11	
7	Ultra N – 75% ESN	130-40-0-11	
8	Split – early in-crop urea	105-40-0-11	- 55 kg N/ha side-banded and 50 kg N/ha broadcast as untreated urea or Agrotain when the flax is 4-10 cm tall
9	Split – early in-crop Agrotain	105-40-0-11	
10	Split – late in-crop urea	105-40-0-11	- 55 kg N/ha side-banded and 50 kg N/ha broadcast as untreated urea or Agrotain when the flax is budding to starting to flower
11	Split – late in-crop Agrotain	105-40-0-11	

Selected agronomic information and dates of operations are provided in Table 15 of the Appendices. In all cases but Redvers in 2022, where the previous crop was flax, the plots were established on cereal stubble (wheat, canary seed, or oat). Seeding dates ranged from May 5-28. Seeding equipment varied across locations with row spacing ranging from 21-30 cm; however, all sites used narrow opener hoe drills with side-band capabilities. Seeding rates ranged from 47-55 kg/ha and the variety was CDC Glas at all locations except for Swift Current in both years (CDC Sorrel) and Redvers 2022 (CDC Rowland). Weeds were controlled using registered pre-emergent and post-emergent herbicide applications. Foliar fungicides were applied at the discretion of individual site managers to reduce the potential for pasmo to develop into a yield limiting or confounding factor. Insecticides were only applied if necessary. Pre-harvest glyphosate or diquat was applied after all treatments had reached maturity to kill weeds and/or assist with crop dry-down. The flax was straight combined using small plot harvesters when it was fit to do so with outside rows excluded from the harvest area wherever possible.

Various data were collected during the growing season and from the harvested grain samples. Overall soil fertility and residual NO_3-N was estimated from composite soil samples submitted to AGVISE Laboratories (Northwood, ND). Weather data were compiled from either Environment and Climate Change Canada, or privately owned weather stations located within a few kilometers of each field trial site. Plant densities were assessed by counting plants in 4 x 1 m sections of crop row per plot, after emergence was complete, and converting the values to plants/m^2. The plots were monitored for lodging throughout the latter part of the growing season and rated on a scale of 1-9 (where 1 is perfectly upright); however, lodging was only observed at 1/8 possible sites. Seed yields, reported in kg/ha were determined from the harvested plot areas and are adjusted for dockage and to a uniform seed moisture content of 10%.

Response data were analyzed separately for each location using the generalized linear mixed model (GLIMMIX) in SAS® Studio. Orthogonal contrasts were utilized to determine if responses to side-banded urea (Treatments 1, 2, 3, 4, and 6) were linear, quadratic (curvilinear), or not significant. For both plant density and seed yield, additional contrasts were used to compare the control (1) to all of the plots that received additional N (2-11), side-banded untreated urea (4, 6) to side-banded polymer coated urea (5, 7), side-banded untreated urea (4) to split-applications of untreated urea (8, 10). For yield only, two additional contrasts compared early in-crop N applications (8, 9) to late in-crop N applications (10, 11), and in-crop untreated urea (8, 10) to in-crop NBPT treated urea (9,11). 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 and discussed. To aid in interpreting the collective results from all eight sites, a second analyses was completed using the combined data with site, N treatment, and the site by N treatment interaction considered fixed. Heterogeneous variance component estimates for individual sites were permitted when heterogeneity was detected and doing so improved the model fit. The combined analyses were only used to test whether responses differed across sites and for means separations/contrasts across sites.

10. Results:

Due to issues with drought, high residual N levels, salinity, and/or errors during treatment applications, data from Scott, Swift Current, and Yorkton in 2021 were removed for this report. This left a total of eight-site years including Indian Head (IH), Melfort (ME), and Redvers (RV) in both 2021 and 2022 and Swift Current (SW) and Yorkton (YK) in 2022 only.

Mean monthly temperatures and total precipitation amounts for May through August (2021) at each location are presented alongside the long-term averages (1981-2010) in Tables 2 and 3, respectively. Overall mean temperatures for the 4-month growing season were above normal at all locations in 2021 and at Yorkton and Swift Current in 2022, ranging from 103-106% (0.4-1.0 °C above-average) of the long-term average. Temperatures were more typical at Indian Head, Melfort, and Redvers in 2022 (101-102%, or 0.2-0.3 °C above average). The combination of low initial soil moisture reserves and high summer temperatures resulted in all 2021 sites and Swift Current in 2022 being considered somewhat dry; however, the extent of the drought varied widely. At Indian Head 2021, for example, growing season precipitation amounts were above average; however, soil moisture reserves at the start of the season were extremely low and much of the August precipitation came too late to benefit the crop. At the remaining dry sites, warmer than normal temperatures were coupled with growing season precipitation amounts of only 61-93% of the long-term average. In contrast, Indian Head, Melfort, Redvers, and Yorkton in 2022 were wetter than normal with much higher initial soil moisture reserves than the previous season and May-August precipitation amounts that were 106-180% of the long-term average. Overall, the soil and weather conditions across the eight sites provided a wide range of environments and yield potentials to evaluate flax response to the various N treatments. Precipitation amounts for the 14-day periods following each in-crop N application are also provided in Table 15 of the Appendices so that they may be referred to when interpreting flax responses to the top-dressed N.

Table 2. Mean monthly temperatures and long-term (1981-2010) averages for the 2021 and 2022 growing seasons at Indian Head (IH), Melfort (MF), Redvers (RV), Yorkton (YK), and Swift Current (SW), SK.

Location-Year	May	June	July	August	May-Aug
	------------------------------------- Mean Temperature (°C) -------------------------------------				
IH – 2021	9.0	17.7	20.3	17.1	16.0 (103%)
IH – 2022	10.9	16.1	18.1	18.3	15.8 (101%)
IH – Long Term	10.8	15.8	18.2	17.4	15.6
ME – 2021	9.6	18.2	20.1	16.9	16.2 (106%)
ME – 2022	9.8	15.2	18.2	18.7	15.5 (102%)
ME – Long Term	10.7	15.9	17.5	16.8	15.2
RV – 2021	10.0	18.7	20.8	17.5	16.8 (105%)
RV – 2022	10.2	16.3	19.2	18.9	16.2 (101%)
RV – Long Term	11.1	16.2	18.7	18.0	16.0
YK – 2022	10.6	15.7	18.6	18.9	16.0 (105%)
YK – Long Term	10.4	15.5	17.9	17.1	15.2
SW – 2022	10.8	15.7	19.7	20.9	16.8 (106%)
SW – Long Term	11.0	15.7	18.4	17.9	15.8

Table 3. Monthly precipitation amounts along with long-term (1981-2010) averages for the 2021 and 2022 growing seasons at Indian Head (IH), Melfort (MF), Redvers (RV), Yorkton (YK), Swift Current (SW), SK.

Location-Year	May	June	July	August	May-Aug
	------------------------------------- Total Precipitation (mm) -------------------------------------				
IH – 2021	81.6	62.9	51.2	99.4	295 (121%)
IH – 2022	97.7	27.5	114.5	45.9	286 (117%)
IH – Long Term	51.8	77.4	63.8	51.2	244
ME – 2021	31.4	37.6	0.2	69.3	139 (61%)
ME – 2022	90.8	78.1	34.9	36.5	240 (106%)
ME – Long Term	42.9	54.3	76.7	52.4	226
RV – 2021	41.4	95.2	38.4	72.1	247 (93%)
RV – 2022	121	75	259	25.2	480 (180%)
RV – Long Term	60.0	95.2	65.5	46.6	267
YK – 2022	137.9	57.9	38.4	90.8	325 (119%)
YK – Long Term	51.3	80.1	78.2	62.2	272
SW – 2022	43.2	31.2	83.5	6.7	165 (88%)
SW – Long Term	42.1	66.1	44.0	35.4	188

Selected results from the composite soil sample test analyses are presented in Table 4 below. Soil pH for the upper 15 cm was generally as expected ranging from 6.0-6.6 at Melfort, Swift Current, and Yorkton and 7.6-8.1 at Indian Head and Redvers. Soil organic matter was lowest at Swift Current (2.4%), followed by Redvers (3.4-3.6%), Indian Head (4.6-4.9%), Yorkton (7%), and Melfort (8.7-11.2%). Cation exchange capacity (CEC) is a good indicator of soil texture with higher values being correlated with increased clay content; however, CEC is also positively correlated with organic matter and soil pH. Residual NO_3-N was lowest at Indian Head (9-19 kg N/ha), more intermediate at Melfort, Redvers 2021, and Swift Current 2022 (32-50 kg N/ha), and relatively high at Redvers 2022, and Yorkton 2022 (62-67 kg N/ha). Phosphorus, potassium, and sulphur fertility information is also provided; however, responses to applications of these nutrients were not evaluated and they were intended to be non-limiting in all treatments.

Table 4. Selected soil test results for flax nitrogen management demonstrations at Indian Head, Melfort, Redvers, Swift Current, Yorkton, and Scott, Saskatchewan in 2021 and 2022.

Depth	pH	SOM (%)	CEC (meq/100g)	NO_3-N (kg/ha)	Olsen-P (ppm)	K (ppm)	S (kg/ha)
Indian Head 2021							
0-15	8.0	4.6	43.9	9	9	532	7
15-60	8.3	–	–	10	–	–	34
Indian Head 2022							
0-15	8.1	4.9	52.6	2	3	542	18
15-60	8.1	–	–	7	–	–	34
Melfort 2021^Z							
0-15	6.4	11.2	–	24	9	476	16
15-30	6.1	–	–	26	–	–	13
Melfort 2022^Z							
0-15	6.0	8.7	–	19	8	396	18
15-30	6.5	–	–	15	–	–	29
Redvers 2021							
0-15	8.0	3.6	34.6	21	6	227	134+
15-60	–	–	–	24	–	–	403+
Redvers 2022							
0-15	7.6	3.4	26.5	13	13	243	16
15-60	8.0	–	–	54	–	–	67
Swift Current 2022^Z							
0-15	6.6	2.4	17.8	13	12	273	13
15-60	7.4	–	–	19	–	–	13
Yorkton 2022^Z							
0-15	6.6	7.0	26.8	31	22	473	31
15-60	7.7			31			40

^{Z}Soil samples were only collected to a depth of 30 cm at Melfort and Swift Current; therefore, residual NO_3-N and S levels are likely underestimated relative to the other locations

Overall tests of fixed effects from the combined statistical analyses are presented in Tables 5 and 6 below. For emergence, the effect of site (S) was significant (P < 0.001) while the N treatment (N) effect was not (P = 0.265); however, a significant S x N interaction (P = 0.014) indicated that N effects differed for individual sites. For seed yield, the effects of S, N, and the S x N interaction were all highly significant (P < 0.001) indicating that yields varied by site and were affected by N treatment when averaged across sites; however, the specific N responses at individual sites varied.

Table 5. Type 3 tests of fixed effects for flax plant density. This combined analysis includes 8 site-years of data from various Saskatchewan locations in 2021 and 2022. Data were analysed using a generalized linear mixed model (GLIMMIX) in SAS Studio with homogenous (by site) variance component estimates.

Effect	Num. DF.	Den DF	F Value	Pr > F
Site (S)	7	24	99.49	<0.001
N Treatment (N)	10	240	1.24	0.265
S x N	70	240	1.49	0.014

Table 6. Type 3 tests of fixed effects for flax seed yield. This combined analysis includes 8 site-years of data from various Saskatchewan locations in 2021 and 2022. Data were analysed using a generalized linear mixed model (GLIMMIX) in SAS Studio with heterogeneous (by site) variance component estimates.

Effect	Num. DF.	Den DF	F Value	Pr > F
Site (S)	7	24	555.21	<0.001
N Treatment (N)	10	240	53.45	<0.001
S x N	70	240	5.24	<0.001

Overall mean plant densities and seed yields for individual sites are presented in Table 7 below. Plant populations were lowest at Swift Current and Redvers in 2022 (220-268 plants/m^2), highest at Indian Head in both years (652-673 plants/m^2), and intermediate at the remaining sites (311-561 plants/m^2). Minimum plant populations of approximately 300 plants/m^2 are commonly recommended to ensure uniform stands where yields are not limited by establishment; however, flax has some ability to compensate for poor stands with extra branching and prolonged flowering. Seed yields also ranged widely across sites and, in general, were lowest at Indian Head 2021, Redvers 2021, and Swift Current 2022 (1171-1474 kg/ha) and highest at Indian Head, Melfort, and Yorkton in 2022 (2974-3072 kg/ha). Yields at the remaining two sites were more intermediate with an average of 1706 kg/ha at Melfort 2021 and 2615 kg/ha at Redvers 2022. Broadly, the overall flax yield potential was considerably higher in 2022 than in 2021.

Table 7. Least squares means for site effects on flax plant density and seed yield. Standard errors of the treatment means are provided in parentheses. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, $P \leq 0.05$).

Site	Plant Density	Seed Yield
	---------------- plants/m^2 ----------------	------------------ kg/ha ------------------
Indian Head - 2021	673 A (17.6)	1171 D (92.9)
Indian Head – 2022	652 A (17.6)	2985 A (74.6)
Melfort – 2021	311 C (17.6)	1706 C (20.6)
Melfort – 2022	508 B (17.6)	2974 A (11.7)
Redvers – 2021	561 B (17.6)	1252 D (130.0)
Redvers – 2022	268 CD (17.6)	2615 B (79.1)
Swift Current – 2022	220 D (17.6)	1474 D (46.4)
Yorkton – 2022	528 B (17.6)	3072 A (112.2)

With significant S x N interactions for both response variables, it is necessary to look at the results from individual sites. Individual treatment means along with the overall F-test from each site are provided for plant density and yield in Tables 16 and 17 of the Appendices; however, the discussion will mostly focus on the orthogonal contrasts and pre-determined contrast comparisons.

Past research has shown that flax is sensitive to high rates of untreated urea with respect to seedling mortality, even with side-banding which is considered to be an effective and safe placement option. In the current project, the overall F-test for N treatment effects on emergence were at least marginally significant at 4/8 sites (P < 0.001-0.073) and, for all of these, either the linear or quadratic responses to increasing rates of side-banded, untreated urea were significant (Table 8). At Melfort (both years) and Swift Current (2022), the response was linear (P < 0.001-0.052) with the highest plant densities coinciding with the 17-55 kg N/ha rates and an overall decline in emergence as the rates were increased. At Redvers in 2022, the response was quadratic with somewhat variable stands at 17-105 kg N/ha of side-banded urea but a marked reduction at the highest N rate of 130 kg N/ha. In general, the effects were always most apparent at N rates of 105-130 kg N/ha as plant populations with 17-80 kg N/ha never significantly differed from each other according to the multiple comparisons tests for individual sites. Again, there was no effect of side-banded urea rate on emergence at Indian Head (both years), Redvers 2022, and Yorkton 2022, according to both the orthogonal contrasts (P = 0.270-0.899) and site-specific F-tests (P = 0.357-0.764). The inconsistencies of this response are largely attributed to seeding conditions and, perhaps, seeding equipment in addition to the weather following seeding. In general, seeding into wet soils can result in poorer overall seed placement and, importantly, separation between the seed and side-banded fertilizer. This is especially true in clay soils. Sufficient rainfall after seeding, however, can reduce the potential impact poor seeding conditions on establishment, as was the case for essentially all the non-responsive sites. While drier soil during seeding is often preferable with respect to seed and fertilizer placement, the overall potential for ammonium toxicity is higher if such conditions persist, especially in soils with coarser texture or lower organic matter.

Table 8. Orthogonal contrast results for side-banded urea rate effects on flax plant densities at eight Saskatchewan sites (Indian Head - IH, Melfort - ME, Redvers - RV, Swift Current - SW, and Yorkton - YK). P-values of ≤ 0.05 are considered significant, but values of ≤ 0.1 may also be worth acknowledging.

Nitrogen Rate	IH-21	IH-22	ME-21	ME-22	RV-21	RV-22	SW-22	YK-22
	Plant Density (plants/m^2)							
17 kg N/ha	653	645	347	507	528	278	257	486
55 kg N/ha	711	628	317	531	637	277	219	508
80 kg N/ha	696	685	298	462	555	254	213	525
105 kg N/ha	639	649	263	450	605	285	176	533
130 kg N/ha	716	642	240	451	446	315	202	495
Orth. Contrast	Pr > F (p-value)							
N Rate – lin	0.703	0.848	<0.001	0.029	0.144	0.381	0.052	0.619
N rate – quad	0.899	0.545	0.613	0.750	0.002	0.270	0.402	0.336

While the negative effects of high rates of side-banded urea on establishment are often offset by positive yield responses, sufficient stands are still required for optimum yields and can be especially important with respect to field uniformity, competition with weeds, and maturity. With this in mind, we explored utilizing polymer coated urea and split-applications of N where the rate of side-banded during seeding was low enough that it was unlikely to reduce emergence. The contrast comparisons that evaluated these practices for individual sites are presented in Table 9 below. Switching from untreated urea to the 75% polymer coated urea had at least a marginally significant (P <0.001-0.069) positive effect at three of the four sites where side-banding high rates of urea negatively affected establishment. The polymer coated urea was only evaluated at the 105-130 kg N/ha rates and resulted in 11-27% (48-68 plants/m^2) higher plant populations at Melfort (both years) and Swift Current 2022. At Redvers 2021, this comparison was not significant (P = 0.250); however, inspection of individual treatment means showed an advantage to the polymer coated urea at 130 kg N/ha but not at 105 kg N/ha where the opposite trend was observed. Unexpectedly and inexplicably, Redvers 2022 reported significantly higher plant populations with untreated versus polymer coated urea when averaged across rates (P = 0.051). With no other significant treatment effects or differences between means, we can only assume that this unexpected result was due to experimental error/random variability. Again, utilizing split-applications of N resulted in a low rate (55 kg N/ha) of side-banded urea with the rest top-dressed as per protocol; thus, we expected this practice to reduce the severity of stand reductions at the sites where they occurred. This was observed at Melfort in both years, but no other locations. It should be noted that, unlike the 75% polymer coated urea, the split-N applications were not evaluated at the highest N rate of 130 kg/ha.

Table 9. Pre-determined contrast comparisons exploring N management effects on plant densities for flax at eight Saskatchewan sites (Indian Head - IH, Melfort - ME, Redvers - RV, Swift Current - SW, and Yorkton - YK). P-values of ≤ 0.05 are considered significant, but values of ≤ 0.1 may also be worth acknowledging.

Contrast Comparisons	IH-21	IH-22	ME-21	ME-22	RV-21	RV-22	SW-22	YK-22
	-------------------- Plant Density (plants/m^2) --------------------							
Check (1) vs.	653 A	645 A	347 A	507 A	528 A	278 A	257 A	486 A
N Applied (2-11)	675 A	653 A	308 B	508 A	564 A	267 A	216 A	533 A
Pr > F (p-value)	0.695	0.779	0.022	0.953	0.325	0.711	0.125	0.174
SB Urea (4,6) vs.	678 A	645 A	252 B	451 A	525 A	300 A	189 B	514 A
SB polymer (5,7)	698 A	676 A	320 A	499 A	566 A	245 B	239 A	546 A
Pr > F (p-value)	0.695	0.231	<0.001	0.069	0.250	0.053	0.051	0.326
Urea SB (4) vs.	639 A	649 A	263 B	450 B	605 A	285 A	176 A	533 A
Urea Split (8,10)	623 A	653 A	340 A	552 A	559 A	261 A	203 A	535 A
Pr > F (p-value)	0.801	0.903	<0.001	0.003	0.282	0.476	0.383	0.951

Lodging, rated on a scale of 1-9 (9 is flat) was only observed at Yorkton in 2022 and, as such, was excluded from the detailed results Tables and combined analyses. At this site, the overall treatment effect was significant (P = 0.015) with the lowest values observed in the control (2.6) and values of 3.1-5.0 reported for the fertilized treatments. The orthogonal contrasts showed that lodging increased linearly (P < 0.001) from 2.6 to 4.6 with side-banded N rates ranging from 17 kg N/ha to

130 kg N/ha. The pre-determined contrast comparisons did not show any significant benefit to either the 75% polymer coated urea (P = 0.877) or split applications (P= 0.801) as possible options for reducing lodging. Anecdotally, early seeding and foliar fungicide applications may help to reduce lodging; however, these practices may not always be practical or profitable.

Seed yields for individual treatments at each site are presented in Table 17 of the Appendices. In all cases, the overall F-test for N treatment effects on flax yield were highly significant (P < 0.001-0.019), but the S x N interaction in the combined analyses confirmed that the specific nature of the responses varied across sites. In all cases, the 'Check vs. N Applied' comparison was highly significant (P < 0.001-0.007), confirming that there was an overall response to N at all sites (Table 11). The orthogonal contrasts (Table 10) focussed specifically on side-banded, untreated urea and indicated quadratic responses at 6/8 sites (P < 0.001-0.043), a linear response at one site (YK-2022; P < 0.001), and no response at one site (SW-22; P = 0.136-0.307). The quadratic responses were largely expected and due to the greatest yield increases with additional N occurring at the lower end of the range (i.e., from 17 kg N/ha to 55-80 kg N/ha) and either diminishing or no further yield increases with subsequent additions of N. At these sites, maximum yields of 27-75% over the control were achieved with side-banded urea rates of 55-130 kg N/ha. Most sites showed signs of yields levelling off at 105 kg N/ha or less. At Yorkton 2022, with relatively high residual N (62 kg NO_3-N/ha), the yield response to N was modest but linear in that yields tended to keep climbing right to the highest application rates. It may be that the higher N fertility helped the crop recover from the hail damage that occurred on June 23; however, again, the observed responses were relatively small, peaking at only 16% higher than the control with 130 kg N/ha as side-banded urea. At Swift Current, while the previously mentioned contrast indicated a small N response when the control was compared to all fertilized treatments, the lack of any significant orthogonal contrasts for this site indicates that this response was weak, at best. Again, SW-22 had amongst the lowest yields and modest residual N levels (32 kg NO_3-N/ha); thus, it is likely that other factors were simply more limiting to yield than N.

Yield benefits specifically attributed to either the polymer coated urea applied in a side-band or to split-applications were essentially non-existent, regardless of site. At one site, Melfort 2022, a sizeable yield penalty of 466 kg/ha or 14% (P < 0.001) was attributed to the split applications when compared to side-banded, untreated urea. The timing (P = 0.207) or formulation (P = 0.094) of the in-crop N alone could not explain the poor results observed with the split applications at this site. It almost appeared as if in-crop N had a negative effect on yield at ME-22 where yields were numerically lower with each of the split application treatments (2648-2892 kg/ha) than when 55 kg N/ha was side-banded during seeding and no additional N was applied (3033 kg/ha). While none of the split N treatments improved yields over side-banding the equivalent total rates, there was a tendency for slightly higher yields with early (2790 kg/ha) as opposed to late (2590 kg/ha) top-dressing at Redvers in 2022 (P = 0.059). The yield advantage to top-dressing with NBPT treated urea over untreated urea was never significant at the desired probability; however, at ME-22, NBPT treated urea (2857 kg/ha) did tend to produce slightly higher yields than untreated urea (2757 kg/ha; P = 0.094), particularly at the early application date (Table 17).

Table 10. Orthogonal contrast results for side-banded urea rate effects on flax seed yield at eight Saskatchewan sites (Indian Head - IH, Melfort - ME, Redvers - RV, Swift Current - SW, and Yorkton - YK). P-values of ≤ 0.05 are considered significant, but values of ≤ 0.1 may also be worth acknowledging.

Nitrogen Rate	IH-21	IH-22	ME-21	ME-22	RV-21	RV-22	SW-22	YK-22
	Seed Yield (kg/ha)							
17 kg N/ha	793	1964	1438	2188	903	1689	1374	2714
55 kg N/ha	1075	2662	1654	3033	1300	2548	1501	3022
80 kg N/ha	1130	2999	1780	3186	1208	2948	1415	3081
105 kg N/ha	1328	3231	1715	3223	1276	2770	1477	3103
130 kg N/ha	1239	3194	1831	3297	1148	2810	1435	3152
Orth. Contrast	Pr > *F* (p-value)							
N Rate – linear	<0.001	<0.001	<0.001	<0.001	0.018	<0.001	0.307	<0.001
N rate – quadratic	0.030	<0.001	0.043	<0.001	0.001	<0.001	0.136	0.107

Table 11. Pre-determined contrast comparisons exploring N management effects on flax seed yield at eight Saskatchewan sites (Indian Head - IH, Melfort - ME, Redvers - RV, Swift Current - SW, and Yorkton - YK). P-values of ≤ 0.05 are considered significant, but values of ≤ 0.1 may also be worth acknowledging.

Contrast Comparisons	IH-21	IH-22	ME-21	ME-22	RV-21	RV-22	SW-22	YK-22
	Seed Yield (kg/ha)							
Check (1) vs.	793 B	1964 B	1438 B	2188 B	903 B	1689 B	1374 B	2714 B
N Applied (2-11)	1209 A	3088 A	1733 A	3052 A	1287 A	2708 A	1484 A	3108 A
Pr > *F* (p-value)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.007	<0.001
SB Urea (4,6) vs.	1284 A	3213 A	1773 A	3260 A	1212 A	2790 A	1456 A	3128 A
SB polymer (5,7)	1238 A	3105 B	1763 A	3278 A	1317 A	2673 A	1448 A	3119 A
Pr > *F* (p-value)	0.425	0.007	0.805	0.756	0.139	0.371	0.824	0.914
Urea SB (4) vs.	1328 A	3231 A	1715 A	3223 A	1276 A	2770 A	1477 A	3103 A
Urea Split (8,10)	1234 A	3157 A	1730 A	2757 B	1367 A	2647 A	1508 A	3093 A
Pr > *F* (p-value)	0.122	0.116	0.775	<0.001	0.292	0.443	0.483	0.924
Early Split (8,9) vs.	1201 A	3134 A	1727 A	2770 A	1285 A	2790 A	1529 A	3103 A
Late Split (10,11)	1219 A	3155 A	1686 A	2844 A	1368 A	2537 A	1528 A	3137 A
Pr > *F* (p-value)	0.757	0.579	0.324	0.207	0.235	0.059	0.966	0.679
Urea Split (8,10) vs.	1217 A	3157 A	1730 A	2757 A	1367 A	2647 A	1508 A	3093 A
NBPT Split (9,11)	1203 A	3132 A	1681 A	2857 A	1286 A	2680 A	1549 A	3147 A
Pr > *F* (p-value)	0.810	0.497	0.251	0.094	0.248	0.802	0.265	0.508

Extension Activities

In 2021, this project was highlighted during the Indian Head Crop Management Field Day on July 20. The event was attended by approximately 70 producers, agronomists, and industry representatives and the discussion focussed on the current project objectives, past results with flax fertility research, and general flax agronomy considerations. Additionally, the trial was also shown to an assortment of industry representatives and producers during smaller, informal tours throughout the season. At Swift Current, the plots were shown during multiple tours throughout the season and highlighted during a CKSW radio program entitled 'Walk the Plots' which was broadcast weekly throughout the growing season. This project was also discussed by Michelle Beaith (SFDC) during WCA's annual summer tour on July 15, 2021, which was attended by approximately 80 participants. At Redvers in 2021, the project was shown and discussed during a two-day field tour attended by approximately 35 participants. Results from all locations in 2021 were presented by Chris Holzapfel to over 200 participants (live and post webinar) during the IHARF Winter Seminar and AGM on February 2, 2022. In 2022, the project could not be shown during the main Indian Head Crop Management Field Day; however, it was toured by numerous producers, agronomists, and industry representatives through the season and was briefly shown and acknowledged during a Canola Crop Walk hosted in collaboration with SaskCanola on August 4. The project was also shown by Lana Shaw during the SERF Field Day on July 28, 2022. All technical reports and extension materials will be available online through IHARF and/or Agri-ARM websites and results from this project will continue to be incorporated into oral presentations as appropriate opportunities arise.

11. Conclusions and Recommendations

Although environmental conditions were not always ideal, we were still successful in achieving many of the stated objectives and demonstrating flax responses to N fertilizer rates and non-traditional management practices with respect to establishment and yield. Focussing on establishment, the results were consistent with past Prairie research whereby emergence declined as the rate of side-banded urea was increased at 50% of the locations. The magnitude of the declines in plant densities ranged from 57-107 plants/m^2, or 11-57%. Averaged across the eight sites, all treatments had similar plant populations according to the multiple comparisons test (Table 12); however, the orthogonal contrasts showed a slight, albeit weak linear decline in plant populations with increasing rates of side-banded N (Table 13). While the risk of such losses may be theoretically higher in dry, coarse textured soils, the results of this project and past research suggest that they can occur on any soil, depending on the specific conditions at seeding and weather during the emergence period. The S x N interaction for plant density confirmed that environment is important in this regard and actual responses will vary. As hypothesized, when they did occur, the observed reductions in plant density were frequently reduced or eliminated by substituting untreated urea with a 75% blend of polymer coated urea or with split-applications where a portion of the N was side-banded and the remainder was top-dressed during the growing season. When averaged across sites, the benefit of polymer coated urea blends with respect to emergence was significant (*P* = 0.008) with 7% more plants observed with the 75% ESN® blend (Table 14). The averaged (across sites) response was not significant when side-banded urea was compared to split-applications; however, this practice was not evaluated at the highest N rates and the trend favoured the split-applications. The downside to these approaches is that using polymer coated urea (ESN®) results in higher input costs due to the premium price associated with this product relative to untreated urea and split-applications result in added costs due to the extra labour, fuel, and equipment wear-and-tear associated with in-crop applications. That said, neither of these practices improved yield, regardless of the effects on establishment. Crop responses to in-crop N are less consistent than to in-soil bands applied before or during seeding, primarily due to the higher risk of volatilization and need for subsequent precipitation to move the N into the rooting zone. When weighing the potential negative effects of side-banded N on flax establishment, producers should, first and foremost, aim to do a good job of seeding (i.e., optimal depth, avoid seeding into very wet conditions where placement may be compromised) and utilize seeding rates that allow for a realistic level of seedling mortality. From a practical perspective, paying close attention to seeding depth and the actual environmental conditions during seeding are likely much more important than the rate of side-banded urea in terms of the absolute flax plant populations achieved. For producers who have the option, placing the urea in a mid-row band will provide more than enough separation between the seedrow and the fertilizer band, regardless of the application rate.

Table 12. Least squares means for nitrogen (N) fertilizer treatment effects on flax plant density and seed yield. The results are for the average of eight Saskatchewan sites and responses at individual sites varied. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Treatment	Plant Density	Seed Yield
	---------------- plants/m^2 ----------------	------------------ kg/ha ------------------
Check	462 A	1633 C
Low N – urea	478 A	2099 B
Med N – urea	461 A	2219 A
High N – urea	450 A	2265 A
High N – polymer	476 A	2225 A
Ultra N – urea	438 A	2263 A
Ultra N – polymer	472 A	2260 A
Split – early urea	463 A	2191 AB
Split – early NBPT	468 A	2194 AB
Split – late urea	468 A	2178 AB
11. Split – late NBPT	470 A	2190 AB
S.E.M.	12.2	37.1

Focussing on seed yield, all sites were responsive to N fertilization, but to varying degrees. Maximum yields were achieved with anywhere from 55-130 kg N/ha but, in most cases, showed signs of levelling off at more modest rates of 55-105 kg N/ha. The magnitude of the maximum yield response was as low as 9% at Swift Current in 2022 to greater than 65% at Indian Head (both years) and Redvers in 2022. Soil test N levels along with actual yield potential were not always able to predict the optimal rate of N or the magnitude of the N response. For example, residual N was consistently low at Indian Head while the yield potential in 2022 was approximately 2.5x that of 2021; however, the optimum rate was the same both years at approximately 105 kg N/ha. Redvers in 2022 had the greatest magnitude of response (75% over the control at 80 kg N/ha), despite having the highest residual N levels of all the locations. Yorkton 2022 was the sole site where yields increased linearly with N rate, despite having relatively high residual N and the magnitude of the response being relatively low a 16%; however, this unusual response may have been partly due to the hail damage that occurred in late June. When averaged across the eight sites, the highest yields were achieved with an N rate of 105 kg N/ha (Table 12); however, the multiple comparisons test and significant quadratic response (Table 13; $P < 0.001$) indicated that yields were levelling off at closer to 80 kg N/ha. Again, there was no yield benefit to side-banding polymer coated urea versus untreated urea for any individual sites or when averaged across the eight sites (Table 14; $P = 0.375$). There were never any yield advantages to split-applications of N over side-banding the full requirements while, at one site (ME-2022) and when averaged across sites, there was a slight yield penalty associated with the split applications. Again, responses varied by site and this result was mostly due to Melfort in 2022. Across sites, the efficacy of the split-applications was not affected by either application timing ($P = 0.732$) or N formulation (untreated urea versus NBPT; $P = 0.771$). The sole site where there were any trends in this regard suggested that the earlier timing of the split applications was favourable over the later applications. We know that NBPT has potential to reduce volatilization losses, especially with surface broadcast applications; however, yield benefits will not always occur depending on the actual environmental collections and there could even be drawbacks to anything that delays the availability of N applied to a deficient crop during the growing season.

Table 13. Orthogonal contrast results for flax plant density and yield response to increasing side-banded urea rates. The results are for the average of eight Saskatchewan sites and responses at individual sites varied. P-values of ≤ 0.05 are considered significant, but values of ≤ 0.1 may also be worth acknowledging.

Nitrogen Rate	**Plant Density**	**Seed Yield**
	-------------- plants/m^2 --------------	----------------- kg/ha -----------------
17 kg N/ha	462	1630
55 kg N/ha	478	2099
80 kg N/ha	461	2219
105 kg N/ha	450	2265
130 kg N/ha	438	2263
Orthogonal Contrast	---------------------- Pr > *F* (p-value) ----------------------	
N Rate – linear	0.043	<0.001
N rate – quadratic	0.133	<0.001

In conclusion, this work has shown reasonably strong and consistent responses to N fertilizer. While the optimum rate varied across sites, rates ranging from 80-105 kg N/ha are likely to suffice under most circumstances. Although higher rates of side-banded urea can have a negative effect on establishment, the magnitude of any such effects is likely to be small at typical N rates and not nearly as important as other factors (i.e., seeding rate, depth, soil moisture during and after seeding) in determining the absolute plant populations that are achieved. Striving to do a good job of seeding and utilizing adequate seeding rates is likely far more beneficial than utilizing polymer coated urea or split applications when it comes to achieving optimal plant stands. There were no yield benefits to utilizing controlled release N forms or split applications but, on one occasion, a substantial yield penalty was associated with the split applications. It should be appreciated that the relative performance of different N forms will vary with environmental conditions and in-crop N may occasionally be useful to correct deficiencies during the season; however, side-banded, untreated urea performed consistently well overall in the current project and continues to be the recommended practice under most circumstances.

Table 14. Pre-determined contrast comparisons exploring N management effects on flax plant density and seed yield. The results are for the average of eight Saskatchewan site-years and responses at individual sites varied. P-values of ≤ 0.05 are considered significant, but values of ≤ 0.1 may also be worth acknowledging.

Nitrogen Rate	Plant Density	Seed Yield
	--------------- plants/m^2 ---------------	------------------ kg/ha ------------------
Check (1) vs.	462 A	1633 B
N Applied (2-11)	465 A	2208 A
Pr > *F* (p-value)	0.800	<0.001
SB Urea (4,6) vs.	444 B	2264 A
SB polymer (5,7)	474 A	2242 A
Pr > *F* (p-value)	0.008	0.375
Urea SB (4) vs.	450 A	2265 A
Urea Split (8,10)	466 A	2185 B
Pr > *F* (p-value)	0.247	0.008
Early Split (8,9) vs.	–	2193 A
Late Split (10,11)	–	2184 A
Pr > *F* (p-value)	–	0.732
Urea Split (8,10) vs.	–	2185 A
NBPT Split (9,11)	–	2192 A
Pr > *F* (p-value)	–	0.771

Supporting Information

12. Acknowledgements:

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13. Appendices:

Table 15. Selected agronomic information and dates of operations for flax nitrogen management demonstrations completed at eight Saskatchewan sites in 2021 and 2022. The locations were Indian Head (IH), Melfort (ME), Redvers (RV), Swift Current (SW), and Yorkton (YK).

Factor / Operation	IH-2021	IH-2022	ME-2021	ME-2022	RV-2021	RV-2022	SW-2022	YK-2022
Previous Crop	Canary seed	Oat	Wheat	Wheat	Wheat	Flax	Wheat	Wheat
Pre-Emergent Weed Control	894 g glyphosate/ha (Sep-28-2020)	894 g glyphosate /ha (May-22) 292 ml Authority 480/ha (May-27)	none	1334 g glyphosate/ha (May-27)	none	894 g glyphosate/ha (May-27)	894 g glysphosate/ha + carfentrazone (May-2)	none
Seeding Date	May-10	May-26	May-18	May-26	May-10	May-28	May-5	May-25
Variety	CDC Glas	CDC Glas	CDC Glas	CDC Glas	CDC Glas	CDC Rowland	CDC Sorrell	CDC Glas
Seed Rate / Row Spacing	50 kg/ha / 30 cm	50 kg/ha / 30 cm	47 kg/ha / 30 cm	55 kg/ha / 30 cm	49 kg/ha / 25 cm	50 kg/ha / 25 cm	50 kg/ha / 21 cm	46 kg/ha / 30 cm
kg P_2O_5-K_2O-S/ha	40-0-10	40-0-10	40-0-11	40-0-11	39-0-0	40-0-0	40-0-10	40-0-10
Emergence Counts	Jun-16	Jun-10	Jun-14	Jun-20	Jun-8	Jun-16	Jun-21	Jun-7
In-Crop Herbicides	370 ml Centurion/ha (Jun-13) 2 l Curtail M/ha (Jun-19)	370 ml Centurion/ha (Jun-20) 2 l Curtail M/ha (Jun-24)	0.74 l Assure II/ha (Jun-14) 2.25 l Basagran Forte/ha (Jun-18)	2.3 l Basagran Forte/ha (Jun-24)	1 l Buctril M/ha (Jun-7) 185 ml Centurion/ha (Jun-14)	1 l Buctril M/ha + 185 ml Centurion/ha (Jun-22)	247 ml Centurion/ha (Jun-7) 1 l Buctril M/ha (Jun-9)	2 l Curtail M/ha (Jun-16) 247 ml Centurion/ha (Jun-20)
In-Crop N Dates (precip. within 14 days of app.)	Jun-12 (1 mm) Jun-28 (13 mm)	Jun-20 (32 mm) Jul-4 (54 mm)	Jun-15 (13 mm) Jul-5 (0 mm)	Jun-13 (64 mm) Jul-12 (21 mm)	Jun-7 (56 mm) Jun-30 (22 mm)	Jun-20 (204 mm) Jul-13 (91 mm)	Jun-16 (28 mm) Jun-27 (43 mm)	Jun-16 (32 mm) Jul-15 (27 mm)
Foliar Fungicide	395 ml Dyax/ha (Jul-5)	395 ml Dyax/ha (Jul-23)	none	445 ml Priaxor /ha (Jul-22)	none	none	none	395 ml Dyax/ha (Jul-15)
Foliar Insecticide	855 ml Malathion 85E/ha (Jul-27)	none	none	381 ml Cygon 480 (Aug-8)	none	none	none	none
Lodging Ratings	Aug-6	Sep-14	Sep-8	Sep-12	Aug-8	Sep-14	Aug-12	Aug-24
Pre-harvest Application	894 g glyphosate/ha (Aug-27)	894 g glyphosate/ha (Sep-12)	894 g glyphosate/ha (Aug-19)	894 g glyphosate/ha (Aug-31)	287 g diquat/ha (Sep-2)	410 g diquat/ha (Sep-11)	410 g diquat/ha (Aug-12)	410 g diquat/ha (Sep-16)
Harvest Date	Sep-17	Oct-1	Sep-8	Sep-12	Sep-18	Sep-29	Aug-16	Sep-25

Table 16. Overall tests of fixed effects and mean flax plant densities as affected by nitrogen (N) treatment at Indian Head (IH), Melfort (ME), Redvers (RV), Swift Current (SW), and Yorkton (YK), in 2021 and 2022. Data were analyzed separately for each site using a generalized linear mixed model (GLIMMIX) in SAS Studio and means within a column followed by the same letter do not significantly differ (Tukey-Kramer, P ≤ 0.05).

Source / Treatment		IH-2021	IH-2022	ME-2021	ME-2022	RV-2021	RV-2022	SW-2022	YK-2022
		Pr > *F* (p-values)							
#	Entry	0.512	0.357	<0.001	0.012	0.052	0.691	0.073	0.764
		Plant Density (plants/m²)							
1	Check	653 a	645 a	347 a	507 ab	528 ab	278 a	257 a	486 a
2	Low N – urea	711 a	628 a	317 ab	531 ab	637 a	277 a	219 a	508 a
3	Med N – urea	696 a	685 a	298 abc	462 ab	555 ab	254 a	213 a	525 a
4	High N – urea	639 a	649 a	263 bc	450 b	605 ab	285 a	176 a	533 a
5	High N – polymer	780 a	704 a	306 abc	502 ab	531 ab	228 a	209 a	545 a
6	Ultra N – urea	716 a	642 a	240 c	451 b	446 b	315 a	202 a	495 a
7	Ultra N – polymer	616 a	648 a	335 ab	496 ab	601 ab	263 a	270 a	547 a
8	Split – early urea	619 a	640 a	344 a	557 ab	541 ab	262 a	229 a	514 a
9	Split – early NBPT	680 a	604 a	296 abc	583 a	578 ab	282 a	191 a	533 a
10	Split – late urea	627 a	665 a	337 ab	547 ab	576 ab	261 a	176 a	557 a
11	11. Split – late NBPT	665 a	660 a	344 a	503 ab	570 ab	244 a	275 a	569 a
	S.E.M.	50.9	36.6	25.5	30.4	38.0	29.9	28.3	33.9

Table 17. Overall tests of fixed effects and mean flax seed yields as affected by nitrogen (N) treatment at Indian Head (IH), Melfort (ME), Redvers (RV), Swift Current (SW), and Yorkton (YK), in 2021 and 2022. Data were analyzed separately for each site using a generalized linear mixed model (GLIMMIX) in SAS Studio and means within a column followed by the same letter do not significantly differ (Tukey-Kramer, P ≤ 0.05).

Source / Treatment		IH-2021	IH-2022	ME-2021	ME-2022	RV-2021	RV-2022	SW-2022	YK-2022
		---------- Pr > *F* (p-values) ----------							
#	Entry	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.019	0.019
		---------- Seed Yield (kg/ha) ----------							
1	Check	793 b	1964 d	1438 b	2188 d	903 b	1689 b	1374 b	2714 b
2	Low N – urea	1075 a	2662 c	1654 a	3033 ab	1300 a	2548 a	1501 ab	3022 ab
3	Med N – urea	1130 a	2999 b	1780 a	3186 a	1208 ab	2948 a	1415 ab	3081 ab
4	High N – urea	1328 a	3231 a	1715 a	3223 a	1276 ab	2770 a	1477 ab	3103 ab
5	High N – polymer	1243 a	3061 ab	1731 a	3245 a	1278 a	2620 a	1447 ab	3174 a
6	Ultra N – urea	1239 a	3194 a	1831 a	3297 a	1148 ab	2810 a	1435 ab	3152 a
7	Ultra N – polymer	1233 a	3150 ab	1794 a	3310 a	1355 a	2726 a	1448 ab	3064 ab
8	Split – early urea	1209 a	3150 ab	1749 a	2648 c	1336 a	2775 a	1541 ab	3122 a
9	Split – early NBPT	1194 a	3119 ab	1705 a	2892 bc	1234 ab	2806 a	1518 ab	3084 ab
10	Split – late urea	1226 a	3165 ab	1712 a	2867 bc	1397 a	2520 a	1476 ab	3064 ab
11	11. Split – late NBPT	1213 a	3146 ab	1658 a	2822 bc	1338 a	2554 a	1580 a	3209 a
	S.E.M.	107.6	82.5	44.9	57.4	145.5	146.0	57.9	135.6

Abstract

14. Abstract/Summary

In the spring of 2021 at multiple Saskatchewan locations, field trials with flax were initiated to demonstrate crop response to a range of side-banded urea rates and non-traditional nitrogen (N) management practices. The trials were repeated in 2022 and, after removing some sites due to severe weather or errors during treatment applications, eight sites remained and are discussed in the current report. The locations were Indian Head, Melfort, Yorkton, Redvers, and Swift Current. The treatments included a range (17-130 kg N/ha) of side-banded urea rates, high rates of a side-banded ESN® blend, and split-applications where the timing and sources of in-crop N were varied. In addition to residual soil nutrient levels, data collection included plant density, lodging, and yield. The 2021 growing season was considered dry at all locations while most locations, Swift Current being the exception, were wet in 2022. High rates of side-banded urea negatively impacted emergence at 50% of the sites, the exceptions being Indian Head (both years), Redvers 2022, and Yorkton 2022. Where they occurred, the magnitude of these reductions ranged from 11-32%. As hypothesized, substituting side-banded urea with the ESN® blend frequently reduced the stand reductions associated with side-banded urea and utilizing split-applications also helped in this regard. Lodging only occurred at 1 site and increased with N rate but was not alleviated by either the ESN® blend or split applications. When averaged across treatments, yields ranged from 1171-3072 kg/ha and responses to N fertilization occurred, to varying degrees, at all locations. Where responses occurred, maximum yields were achieved with 55-130 kg N/ha, but yields were generally levelling off at 55-105 kg N/ha. Despite the occasional improvements in establishment, yield benefits were never realized by substituting side-banded urea with the ESN® blend or with split applications of N. There was occasional, weak evidence that flax responded better to in-crop N applied during the vegetative versus the reproductive growth stages and to NBPT treated urea versus untreated urea. However, in most cases, the form or timing of in-crop N did not matter and, in one case and on average, the split applications did not yield as well as when all the N was side-banded.