2022 Final Report

from the

East Central Research Foundation

Project Title: Managing Drought Risk with Split Applications of Nitrogen in Spring Wheat
ADOPT #20211079, #20211130, #20211129, #20211127, #20211128, #20211131

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Project Identification

1. **Project Number:** ECRF #20211079, NARF #20211130, WARC #20211129, IHARF #20211127, WCA #20211128, ICDC #20211131
2. **Producer Group Sponsoring the Project:** None
3. **Project Location(s):** Yorkton, Indian Head, Melfort, Outlook, Scott, and Swift Current, SK
4. **Project start and end dates (month & year):** April 2022 to February 2023
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Objectives and Rationale

6. **Project objectives:**

In the spring of 2022, the perceived risk of drought was relatively high across much of Saskatchewan due to depleted reserves of soil moisture. In response, producers may have considered "holding back" on rates of N applied at seeding to save cost. Should adequate and timely precipitation be received, producers would then have the option to apply more N post-emergent to support higher yield potentials. However, initial application rates and timing of the post-emergent top-up will affect the efficacy of this approach.

Across a range of environmental conditions, the objective of this study was to demonstrate the efficacy of various rates and timings of split applied N relative to applying all of the N at seeding. Split applications of N are anticipated to be more efficacious when applied early and to a higher base rate of soil + fertilizer N available at seeding.

Note: An irrigation site was included in this study to guarantee one scenario where timely "precipitation" was received to move fertilizer into the soil.

7. **Project Rationale:**

The effect of added nitrogen (N) on wheat yield and grain protein is well understood. Side-banding N at seeding is most efficient, but producers will also dribble band UAN post-emergence to speed up seeding operations or to deal with other logistical issues. Post-emergent applications may provide results similar to side-banded urea, provided UAN is dribble banded at 3 to 5 leaf stage and N is moved into the soil by adequate and timely rainfall [1]. Work by Holzapfel et al from 2001-2003 at Indian Head and Scott, found dribble banding the total N requirement as UAN (1 to 30 days post seeding) did not consistently maintain yield relative to mid-row banding N at seeding for either canola or wheat, particularly under dry conditions[2]. Coulter applications of UAN were somewhat more efficacious but required specialized equipment and could result in mechanical plant damage.

Researchers now realize that side-banding a portion of the N requirement upfront at seeding will carry the crop and allow for a somewhat later post-emergent application of N with less risk of yield loss [1]. For spring wheat, Lafond et al evaluated mid-row band applications of urea at 100, 67, 50, 33 or 0 % of the targeted N rate with the remaining balance dribble banded as UAN at 1.5, 3.5, or 5.5 leaf stages [3]. The authors concluded that at least 50% of N should be applied upfront at seeding to reduce the risk of yield loss from split applications for wheat. Other research by Holzapfel has indicated split applications of N as late as early flag may also be viable provided that 50 to 67% of the required N was applied at seeding (personal communication).

With high background reserves of N and droughty conditions in spring, it may be prudent to reduce rates of N applied at seeding to reduce fertilizer costs. However, the producer needs to stay flexible in this situation. If environmental conditions improve, additional N may need to be applied to achieve the maximum yield and grain protein potential of the wheat crop. This study was initiated to evaluate this approach under a range of environmental conditions experienced between locations in 2022.

Literature Cited

[1] Grant, C. and J.H. Heard. Spring Options for Nitrogen Fertilization. http://www.umanitoba.ca/faculties/afs/MAC_proceedings/proceedings/2004/grant_spring_options.pdf

[2]Holzapfel, C.B., Lafond, G. P., Brandt, S. A., May, W. E. and Johnston, A. M. 2007. In-soil banded versus post-seeding liquid
nitrogen applications on no-till spring wheat and canola. Can. J. Plant Sci. 87: 223–232.

[3]Lafond, G. P., Brandt, S. A., Irvine, B., May, W. E. and Holzapfel, C. B. 2008. Reducing the risks of in-crop nitrogen fertilizer applications in spring wheat and canola. Can. J. Plant Sci. 88: 907_919.

8. Methodology:

Trials at each site were setup as a Randomized Complete Block Design (RCBD) with 4 replicates. Sites included were Indian Head (thin Black), Swift Current (dry Brown), Outlook (Brown), Scott (Dark Brown), Yorkton (Black), and Melfort (moist Black). Plot size varied between sites to accommodate seeding and spraying equipment.

Table 1a below lists the treatments that were followed at Indian Head, Outlook, Scott and Swift Current. Targeted rates of N at seeding include background soil N (0-24”) plus applied fertilizer. Rates were not based on N fertilizer alone because background soil N was anticipated to vary greatly, which was the case.

Treatments 1 to 5 determined the yield and grain protein response to increasing N when applied as banded urea at seeding. This is typically considered the most efficient means of applying N. Post-emergent applications of N were dribble banded UAN mixed with Agrotain where possible to reduce the risk of volatilization loss. Application timing was either the 3-5 leaf stage or early flag and the UAN was applied to base rates of soil + fertilizer N of either 80 or 110 lb/ac. Assuming a good yield potential of 60 bu/ac, a wheat crop requires 162 lb N/ac. Thus, 80 and 110 lb/ac of soil + fertilizer N would represent approximately 50 and 67% of the total N requirement.

Yield comparisons for treatments 6,7,10, and 11 relative to the treatment 4 check were used to determine the N use efficiency of split applications compared to side-banding all of the N at seeding for the 140 lb/ac level of N fertility. Similarly, yield comparisons between treatments 8,9,12, and 13 relative to the treatment 5 check were used to determine N use efficiencies at the 170 lb N/ac level. Post-emergent UAN was anticipated to be more efficient at maintaining wheat yield potential when applied early at the 3-5 leaf stage and if more N had been applied upfront at seeding. Grain protein was anticipated to be greater with higher rates of N and later applications.

Table 1a. Treatment list for Indian Head, Swift Current, Scott, and Outlook

Trt#	**Lb N/ac at seeding (soil+fert N)[a]**	**Post-emergent UAN[b] (30 lb N/ac)**	**Post-emergent UAN[b] (60 lb N/ac)**	**Post-emergent UAN[b] (90 lb N/ac)**
1	Soil N	--	--	--
2	80	--	--	--
3	110	--	--	--
4	140	--	--	--
5	170	--	--	--
6	80	--	3-5 lf (ideal)	--
7	80	--	Early Flag leaf	--
8	80	--	--	3-5 lf (ideal)
9	80	--	--	Early Flag leaf
10	110	3-5 lf (ideal)	--	--
11	110	Early Flag leaf	--	--
12	110	--	3-5 lf (ideal)	--
13	110	--	Early Flag leaf	--

[a]Side banded urea + background soil N (0-24”).
[b]Agrotain added to reduce volatilization loss of N.

At Yorkton and Melfort the treatment list needed to be modified to accommodate the very high residual levels of soil N which was 104 lb N/ac in the top 24 inches at both locations.

At Yorkton base rates for comparisons where increased to 140 and 170 lb N/ac resulting in the following treatments listed in Table 1b. At Melfort, the treatment list (Table 1c) was not adjusted appropriately to provide meaningful checks. However, a few useful comparisons were still possible.

Table 1b. Treatment list for Yorkton

Trt#	**Lb N/ac at seeding (soil+fert N)[a]**	**Post-emergent UAN[b] (30 lb N/ac)**	**Post-emergent UAN[b] (60 lb N/ac)**	**Post-emergent UAN[b] (90 lb N/ac)**
1	Soil N	--	--	--
2	110	--	--	--
3	140	--	--	--
4	170	--	--	--
5	200	--	--	--
6	110	--	3-5 lf (ideal)	--
7	110	--	Early Flag leaf	--
8	110	--	--	3-5 lf (ideal)
9	110	--	--	Early Flag leaf
10	140	3-5 lf (ideal)	--	--
11	140	Early Flag leaf	--	--
12	140	--	3-5 lf (ideal)	--
13	140	--	Early Flag leaf	--

[a]Side banded urea + background soil N (0-24”).
[b]Agrotain added to reduce volatilization loss of N.

Table 1c. Treatment list for Melfort				
Trt#	**Lb N/ac at seeding (soil+fert N)[a]**	**Post-emergent UAN[b] (30 lb N/ac)**	**Post-emergent UAN[b] (60 lb N/ac)**	**Post-emergent UAN[b] (90 lb N/ac)**
1	Soil N	--	--	--
2	Soil N	--	--	--
3	110	--	--	--
4	119	--	--	--
5	149	--	--	--
6	104	--	3-5 lf (ideal)	--
7	104	--	Early Flag leaf	--
8	104	--	--	3-5 lf (ideal)
9	104	--	--	Early Flag leaf
10	109	3-5 lf (ideal)	--	--
11	109	Early Flag leaf	--	--
12	109	--	3-5 lf (ideal)	--
13	109	--	Early Flag leaf	--
[a]Side banded urea + background soil N (0-24”). [b]Agrotain added to reduce volatilization loss of N.				

Dates of various field operations and products used for each trial location in 2022 are found in table 2.

Table 2. Dates of field operations and products used in 2022.						
Operations in 2020	**Indian Head**	**Melfort**	**Outlook**	**Scott**	**Swift Current**	**Yorkton**
Pre-seed/ pr-emergent herbicide application	Roundup Weathermax (0.67 L/ac) – May 22	Avadex - May 12 Roundup – May 21	None	Glyphosate 540 (1 L/ac) + Aim (35 mL/ac) – May 9	RT540 (0.67 L/ac) – May 2	None
Seeding Date	May 12	May 25	May 5	May 12	May 9	May 12
Emergence Counts	May 30	June 13	June 2	June 7	June 3	May 27
3-5 Leaf UAN Application	June 9	June 20	June 8	June 7	June 9	June 6
In-crop Herbicide Application	Prestige XC (0.85 L/ac) + Simplicity GoDRI (28 g/ac) – June 12	Axial – June 22 Presitge XC – June 28	Buctril M (0.4 L/ac) Simplicity (0.2 L/ac)	Axial Ipak- Axial (0.5 L/ac) + Infinity (0.33 L/ac) -June 16 Buctril M (0.4 L/ac) – June 22	Buctril M (0.4 L/ac)	Akito June 8 Axial June 22
Early Flag Leaf UAN Application	June 24	July 8	June 23	June 30	June 27	June 30
Fungicide and/or Insecticide Application	Decis 5 EC (60 mL/ac) – July 9 (Grasshoppers) Prosaro XTR – July 11	? July 18	None	Caramba (400 mL/ac) - July 14	None	Caramba July 18
Lodging Rating	September 2	?	August 2	August 31	August 16	August 22
Desiccation	Roundup Transorb HC – August 31	None	None	Glyphosate 540 – August 23	None	
Harvest	September 11	?	August 16	September 5	October 11	September 7

9. Results:

Growing Season Weather

Mean monthly temperatures and precipitation amounts with long-term (1981-2010) averages for the 6 sites are listed in Table 3 and 4. In 2022, the season at all sites was warmer than the long-term historical average. Precipitation varied greatly from historical norms between sites. Yorkton, Indian Head, and Melfort received above average seasonal precipitation. In contrast, Swift Current, Scott and Outlook received less than average rainfall. The low rainfall at Outlook was inconsequential to yield as the deficit was compensated for by irrigation.

Table 3. Mean monthly temperatures and long-term (1981-2010) normals for the 2022 growing seasons at 6 sites in Saskatchewan.

Location	**Year**	**May**	**June**	**July**	**August**	**Avg. / Total**
		-------------------*Mean Temperature (°C)* ----------------				
Indian Head	2022	10.9	16.1	18.1	18.3	15.8
	Long-term	**10.8**	**15.8**	**18.2**	**17.4**	**15.6**
Melfort	2022	9.9	15.2	18.2	18.7	15.5
	Long-term	***10.7***	***15.9***	***17.5***	***16.8***	***15.2***
Outlook	2022	11.8	16.3	19.8	20.6	17.1
	Long-term	***11.5***	***16.1***	***18.9***	***18***	***16.1***
Scott	2022	10	15	18.3	18.9	15.6
	Long-term	***10.8***	***14.8***	***17.3***	***16.3***	***14.8***
Swift Current	2022	10.9	15.9	19.8	20.9	16.9
	Long-term	***10.9***	***15.3***	***18.2***	***17.6***	***15.5***
Yorkton	2022	10.6	15.7	18.6	18.9	16
	Long-term	***10.4***	***15.5***	***17.9***	***17.1***	***15.2***

Table 4. Precipitation amounts along with long-term (1981-2010) normals for the 2022 growing seasons at 6 sites in Saskatchewan.

		---------------------- *Precipitation (mm)* -------------------				
Indian Head	2022	97.7	27.5	114.5	45.9	285.6
	Long-term	***51.7***	***77.4***	***63.8***	***51.2***	***244.1***
Melfort	2022	90.8	78.1	34.9	36.5	240.3
	Long-term	***42.9***	***54.3***	***76.7***	***52.4***	***226.3***
Outlook	2022	30.4	69.4	51.4	8	159.2
	Long-term	**43.2**	**69.3**	**57.6**	**44.2**	**214.3**
Scott	2022	11	57.1	86.5	32.1	186.7
	Long-term	***38.9***	***69.7***	***69.4***	***48.7***	***226.7***
Swift Current	2022	51.2	37.7	90.4	7.5	187
	Long-term	***44.1***	***74.5***	***51.9***	***43.2***	***213.7***
Yorkton	2022	137.9	57.9	38.4	90.8	325
	Long-term	***51***	***80***	***78***	***62***	***272***

As expected, the residual levels of soil N varied substantially between locations (Table 5). Background levels were particularly high at Melfort and Yorkton with both locations testing 104 lb N/ac. Residual soil N was also a little high at Scott (79 lb N/ac). At these 3 sites, treatments 1 and 2 were the same, as no N was added to either treatment. At Yorkton and Melfort the difference between treatments 2 and 3 was not great (ie 104 vs 110 lb/ac).

Table 5. Soil test results from 2022 for the "Managing Drought Risk with Split Applications of N in Spring Wheat" trial.

Soil N	**Indian Head**	**Melfort**	**Outlook**	**Scott**	**Swift Current**	**Yorkton**
Lb N/ac (0-24)	16	104	37	79	59	104

The results will be discussed by site, due to a strong site by treatment interaction with the yield and grain protein data (data not shown). As each site had different levels of soil N and experienced different levels of precipitation, the efficacy of split applied N differed greatly between locations. At high yielding sites such as Indian Head and Outlook (irrigation), split applications of N were economical due to excellent precipitation. Split applying N was not economical at Yorkton despite adequate precipitation, as soil N reserves were very high and the site received heavy hail damage that likely reduced yield potential by 20 to 30 percent. Drought caused low yields at Swift Current and Scott and split applying N proved costly at these locations. All sites established well with average plant stands ranging from a low of 189 plants/m^2 at Yorkton to a high of 275 plants/m^2 at Melfort (Tables 6 and 7). Plant emergence was not significantly affected by increasing rates of side-banded N at all sites except Outlook. At Outlook plant populations were significantly decreased with increasing N which will be discussed further below.

IHARF-Indian Head

At Indian Head, residual levels of N in the top 2 feet of soil were low (16 lb N/ac) and both wheat yield and grain protein were very responsive to added N. In response to increasing soil + fertilizer N to 140 lb/ac, yield was increased from 3013 kg/ha (trt 1) to a maximum of 6134 kg/ha (trt 4) (Table 8). In addition, grain protein increased from 12.2% (trt 1) to a high of 15.5% (trt 5) at 170 lb/ac of soil + fertilizer N (Table 10).

At the 140 lb N/ac level, side-banding the total N requirement at seeding (trt 4) resulted in significantly more yield but significantly lower grain protein compared to split applying 60 lb N/ac of UAN at the 3-5 leaf stage on a base rate of 80 lb N/ac of side-banded urea (trt 6) (Tables 8 and 10). Split applying 30 lb N/ac of UAN at the 3-5 leaf stage to a higher base rate of 110 lb N/ac (trt 10) resulted in a more similar yield and protein level to side-banding all the N at seeding (trt 4). For both split application scenarios (ie: 60N on 80N base and 30N on 110N base), dribble banding the UAN later in the year at early flag produced lower yields as anticipated, but did not increase grain protein as expected (trts 6 vs 7 and 10 vs 11). This same pattern of decreasing yield with late application of UAN was also apparent at the 170 lb/ac level of N fertility (trts 8 vs 9 and 12 vs 13).

The revenues generated or lost for each treatment relative to trt 2 are presented in Table 12. These calculations assume \$10.56/bu of wheat at 12.5% protein, a generous protein premium of \$0.66/%/bu, a \$1.33/lb N price and an additional application cost of \$10/ac for the UAN. At the 140 lb N/ac level, the strategy of holding back on N and then applying more N at the 3-5 leaf stage came with an economic cost of \$15/ac for the 60 N on 80 N base scenario (trt 6 vs 4). Although not anticipated, the economic loss was even greater at \$41/ac for the 30 N on 110 N base scenario (trt 10 vs 4). In contrast, the split applications proved to be somewhat economical at the 170 lb N/ac level of fertility. Compared to side-banding all N at seeding, applying 90 N to an 80 N base or 60 N to a 110N base resulted in economic gains of \$14/ac and \$6/ac, respectively. It is not understood why split applications proved more economical at the 170 lb/ac level of N fertility. However, the approach of split applying N as a means to reduce risk showed some potential when applications were made at the 3-5 leaf stage. However, split applications at early flag leaf generated considerably less revenue than just side-banding all the N at seeding.

ICDC-Outlook

At Outlook, the residual level of soil N was also relatively low (37 lb N/ac) and yield and grain protein were very responsive to added N. Yield increased from 3302 kg/ha to a high of 5093 kg/ha as soil + side-banded N was increased to 140 lb/ac. In addition, grain protein increased from 10.1% to a high of 13.6% at 170 lb/ac of soil + side-banded N (Tables 8 and 10). Yield started to decline at the highest rate of N fertility and may be the result of lower plant populations possibly caused by ammonia and salt effects from the fertilizer. Crop emergence was significantly reduced from a high 320 plants/m^2 to a 158.5 plants/m^2 at the 170 lb/ac level of soil + fertilizer N (Table 6).

At the 140 and 170 lb N/ac levels, split applications of N at the 3-5 leaf stage significantly and substantially increased yield compared to side-banding all the N at seeding. While percent grain protein was largely unaffected, the large increases in yield greatly increased economic returns anywhere from $44/ac to $137/ac depending on the comparison (Table 12). Delaying split applications until the early flag leaf stage tended to reduce yield but increase grain protein for both 140 and 170 lb/ac levels of N fertility (Tables 8 and 10). However, the economic gains from increased protein were much less than the economic loss associated with the reduced yield. Delaying split applications to early flag consistently reduced economic returns at the 140 lb/ac level of N fertility (Table 12). At the 170 lb N/ac level, delaying the split application reduced the economic returns for 90 N on a base rate of 80N but increased returns for 60 N on a base rate of 110 N. The increased returns were unexpected and were the result of a very minor yield loss but substantial protein boost when the split application was delayed.

Split applying N at the 3-5 leaf stage proved to be highly economical at the Outlook irrigation site. Split application of N on wheat is commonly practiced to increase nitrogen use efficiency in high precipitation regions (ie England). Perhaps split applications similarly increased N use efficiency at Outlook because it was under irrigation. Alternatively, split applications at the 170 lb N/ac level may have yielded more relative to the check because the toxic effects of the fertilizer. When 170 lb/ac of soil + fertilizer N was sided banded, emergence was substantially reduced and this in turn may have reduced yield. However, emergence wasn’t reduced substantially at 140 lb/ac of soil + fertilizer N and yet this check still performed poorer than the split applications.

ECRF-Yorkton

Residual levels of soil N in the top 2 feet were very high at the Yorkton site (104 lb N/ac). To maintain treatment 4 and 5 as side-banded checks, the rates for all side-banded treatments had to be increased by 30 lb N/ac, as well as the base applications for the split applications. Because of the high level of residual soil N, wheat yield and grain protein were not very responsive to added N, despite high yields. The site also received severe hail damage which may have reduced yield potential by 20 to 30 percent. While increases were not statistically significant, yield was increased from a low of 4923 kg/ha to a high of 5225 kg/ha at 170 lb/ac of soil + side-banded N (Table 9). Protein was increased from a low of 14.4% to a high of 15% at 110 lb/ac of soil + side-banded N (Table 11). Because wheat yield and grain protein were largely unresponsive to added N, all split applications and increases in N fertility beyond 110 lb/ac resulted in an economic loss (Table 13). Split applying N late, at the early flag leaf stage, consistently resulted in greater economic losses.

WCA-Swift Current

At Swift Current soil reserves of N were 59 lb/ac. While grain protein significantly increased in response to added N, yield increases were modest due to drought. While statistically insignificant, yield increased from a low of 2231 kg/ha to a high of 2464 kg/ha at the 140 lb/ac level of N fertility (Table 8). Grain protein significantly increased from a low of 14.6% to a high of 16.2% at the 170 lb N/ac level (Table 10). As yield was unresponsive to added N, increases beyond 80 lb N/ac resulted in an economic loss (Table 12). All split applications of N were uneconomical, with late applications at early flag incurring the greatest losses. The approach of "holding back" on side-banded N at seeding and then not applying any further N because of continued drought was the most economical approach for this site.

WARC-Scott

Soil reserves of N were moderately high at Scott (79 lb N/ac). Like Swift Current, grain protein significantly increased in response to added N but yield increases were modest and statistically insignificant. Scott also experienced drought. Yield increased from a low of 2940 kg/ha to a high of 3227 kg/ha at the 140 lb N/ac level (Table 8). Protein significantly increased from a low of 14.6% to a high of 16.2% at the 170 lb N/ac level (Table 10). Similar to Swift Current, increases in N fertility beyond 110 lb/ac resulted in economic losses (Table 12). Split applications resulted in the greatest economic losses, but unlike the other sites, late application at early flag did not consistently increase the loss. However, the best approach at this site would have been to provide 110 lb/ac of soil + fertilizer N with no further dribble band applications of UAN due to the continuing drought.

NARF-Melfort

At Melfort, soil reserves of N were very high (104 lb N/ac), but unlike the Yorkton site, wheat yield still responded to added N. Increasing soil + fertilizer N from 104 lb/ac to 149 lb/ac significantly increased yield from 3314 kg/ha to 4297 kg/ha (Table 9) but did not significantly affect grain protein (Table 11). Unfortunately, treatment rates were not adjusted appropriately at this site to a maintain treatments 4 and 5 as side-banded checks for comparison against split applications. Nonetheless, some useful comparisons were still possible. Dribble banding UAN late, at early flag, consistently reduced yields for all split applications (Table 9). Late applications of UAN also increased grain protein but differences were only significant for two of the comparisons (ie trt 6 vs 7; trt 12 vs 13

Table 11). No economic analysis was performed as fair comparisons could not be made against the checks.

10. Conclusions and Recommendations

In the majority of comparisons, this study successfully demonstrated that early season applications of UAN at the 3-5 leaf stage produced more yield and provided greater economic returns compared to late season applications at early flag. While late season applications usually produced more grain protein, this did not provide enough value to compensate for the economic loss of yield that often occurred. Late season applications of UAN were anticipated to be more efficacious when applied to a higher base rate of N but this was not consistently observed. The efficacy of split N differed greatly between sites. Under drought conditions, the most economic approach was to maintain a relatively low level of soil fertility of 80 lb N/ac at Swift Current and 110 lb N/ac at Scott. Increasing N fertility at Swift Current to 140 lb/ac and 170 lb/ac reduced economic returns by $8/ac and $57/ac, respectively. At Scott, supplying the same levels of N fertility reduced economic returns by $11/ac and $58/ac, respectively. These economic losses represent the risk of over applying N at seeding during drought. Of course, the economic cost of split applying N under these conditions was even greater, but producers would not likely apply additional N during drought to incur these costs. In contrast, under applying N at seeding for Indian Head and Outlook, where soil moisture was adequate, came with substantial economic losses if split N could not be applied in season. At Indian Head, the most economic rate was 170 lb N/ac but 140 lb N/ac provided essentially the same return. If N was held back to base rate of 80 lb/ac, and additional N was not dribble banded, the economic loss was $191/ac. Likewise, an economic loss of $113/ac by holding back N to 80 lb/ac would have occurred at Outlook. When split applications at Outlook were applied successfully at the 3-5 leaf stage, economic returns were greatly improved compared to putting all the N down at seeding (between $43/ac and $137/ac depending on comparison). At Indian Head, split applications provided modest economic returns at the 170 lb N/ac level ($14/ac for 90 N on 80 N base; $6/ac for 60 N on 110 N base). However, modest economic losses were observed at the 140 lb N/ac level (-$15/ac for 90 N on 80 N base; -$41/ac for 60 N on 110 N base). If split applications were delayed to early flag, economic losses were greatly increased at Indian Head (-$39/ac to -$95/ac depending on comparison) and economic returns even turned negative for the 140 lb N/ac level at Outlook. To conclude, split applying N may have potential to increase N use efficiency where dribble banded applications of UAN will be moved into the soil with irrigation. However, there is still a risk UAN would not be applied in a timely manner if excessive precipitation prevents equipment from accessing the field. The benefit of split applications on irrigated land requires further study to determine if the results can be replicated. For dry land farming, holding back on N at seeding will reduce economic loss from over fertilizing during drought. However, no more than 30 lb N/ac should be held back at seeding. The economic risk of holding back too much N and missing the opportunity to dribble band N in a timely manner, should conditions improve, is much greater than losses incurred from over fertilizing the crop by 30 lb N/ac at seeding. Perhaps the best approach with split applications on dry land farming is to “not do it on purpose”. Fertilize for a regular crop yield and if conditions look exceptional consider dribble-banding additional UAN in-crop.

Further study

In this study, Indian Head was the only dry land site where split application of N had any promise, as residual N was too high at Yorkton and drought was an issue at Swift Current and Scott. It would be worth repeating this study to obtain more data from dry land sites receiving adequate precipitation and to determine if substantially greater economic returns from split applications under irrigation can be repeated.

Extension

- A video covering the results from this study are available on youtube.
- https://www.youtube.com/watch?v=y8NLcr6UVkQ
- Project may have been discussed at various Agri-Arm field days.

Supporting Information

11. Acknowledgements:

This project was funded through Agricultural Demonstration of Practices and Technologies (ADOPT)

12. Appendices

Table 6. Individual treatment means of nitrogen application effects on wheat emergence (plants/m^2) at multiple locations in 2022.

Nitrogen Application Method		Indian Head	Outlook	Scott	Swift Current
1	Check: Soil N	272.3	300.0 ab	218.0	167.0
2	80 lb N/ac (SB + Soil N)	259.2	320.0 a	211.4	184.3
3	110 lb N/ac (SB + Soil N)	249.3	275.5 bc	206.0	189.1
4	140 lb N/ac (SB + Soil N)	265.8	270.8 bc	188.0	188.5
5	170 lb N/ac (SB + Soil N)	246.9	158.5 c	179.4	189.1
6	80 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5 lf	250.2	293.8 abc	194.9	187.9
7	80 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	255.5	295.8 abc	217.8	203.4
8	80 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ 3-5lf	256.3	280.3 bc	201.5	201.6
9	80 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ early flag lf	255.5	288.8 abc	210.4	191.5
10	110 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ 3-5lf	235.0	286.5 abc	204.7	178.4
11	110 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ early flag lf	244.0	265.0 bc	215.5	187.9
12	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5lf	258.8	261.8 c	207.2	219.6
13	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	235.0	285.5 abc	210.6	202.2
LSD		NS	37.7	NS	NS
P-values		NS	<0.0001	NS	NS

[Z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability

Table 7. Individual treatment means of nitrogen application effects on wheat emergence (plants/m²) at Yorkton and Melfort in 2022.

#	Nitrogen Application Method	Yorkton	#	Nitrogen Application Method	Melfort
1	Check: Soil N	186.2	1	Check: Soil N (104 lb N/ac)	257.1
2	110 lb N/ac (SB + Soil N)	174.3	2	Check: Soil N (104 lb N/ac)	284.2
3	140 lb N/ac (SB + Soil N)	212.5	3	110 lb N/ac (SB + Soil N)	288.3
4	170 lb N/ac (SB + Soil N)	196.4	4	119 lb N/ac (SB + Soil N)	303.1
5	200 lb N/ac (SB + Soil N)	183.8	5	149 lb N/ac (SB + Soil N)	235.0
6	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5 lf	166.9	6	104 lb N/ac Soil N + 60 lb N/ac of UAN @ 3-5 lf	264.1
7	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	196.9	7	104 lb N/ac Soil N + 60 lb N/ac of UAN @ early flag lf	272.3
8	110 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ 3-5lf	191.1	8	104 lb N/ac Soil N + 90 lb N/ac of UAN @ 3-5lf	277.3
9	110 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ early flag lf	205.5	9	104 lb N/ac Soil N + 90 lb N/ac of UAN @ early flag lf	273.2
10	140 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ 3-5lf	206.3	10	109 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ 3-5lf	294.9
11	140 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ early flag lf	202.2	11	109 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ early flag lf	266.6
12	140 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5lf	175.2	12	109 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5lf	301.0
13	140 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	162.4	13	109 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	264.9
	LSD	NS		LSD	NS
	P-values	NS		P-values	NS

[z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability

Table 8. Individual treatment means of nitrogen application effects on wheat grain yield (kg/ha @ 14.5% moisture) at multiple locations in 2022.

Nitrogen Application Method		Indian Head	Outlook	Scott	Swift Current
1	Check: Soil N	3013 g	3302 d	2961	2231
2	80 lb N/ac (SB + Soil N)	5119 f	4320 c	2940	2264
3	110 lb N/ac (SB + Soil N)	5556 e	5028 b	3134	2273
4	140 lb N/ac (SB + Soil N)	6134 a	5093 b	3227	2464
5	170 lb N/ac (SB + Soil N)	6060 ab	4887 b	3145	2406
6	80 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5 lf	5908 bcd	5765 a	3204	2140
7	80 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	5701 de	4879 b	3116	2095
8	80 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ 3-5lf	6060 ab	5667 a	3295	2227
9	80 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ early flag lf	5631 e	5325 ab	3275	2125
10	110 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ 3-5lf	5959 abc	5609 a	3191	2369
11	110 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ early flag lf	5751 cde	4943 b	3167	2182
12	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5lf	6148 a	5722 a	3262	2318
13	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	5873 bcd	5613 a	3167	2121
LSD		221	506	NS	NS
P-values		<0.0001	<0.0001	NS	NS

[z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability

Table 9. Individual treatment means of nitrogen application effects on wheat grain yield (kg/ha @ 14.5% moisture) at Yorkton and Melfort in 2022.

#	Nitrogen Application Method	Yorkton	#	Nitrogen Application Method	Melfort
1	Check: Soil N	4923 de	1	Check: Soil N (104 lb N/ac)	3314 d
2	110 lb N/ac (SB + Soil N)	5096 abcde	2	Check: Soil N (104 lb N/ac)	3232 d
3	140 lb N/ac (SB + Soil N)	4933 bcde	3	110 lb N/ac (SB + Soil N)	3167 d
4	170 lb N/ac (SB + Soil N)	5225 abcd	4	119 lb N/ac (SB + Soil N)	3669 cd
5	200 lb N/ac (SB + Soil N)	5220 abcd	5	149 lb N/ac (SB + Soil N)	4297 ab
6	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5 lf	5168 abcde	6	104 lb N/ac Soil N + 60 lb N/ac of UAN @ 3-5 lf	4289 b
7	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	4928 cde	7	104 lb N/ac Soil N + 60 lb N/ac of UAN @ early flag lf	3957 bc
8	110 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ 3-5lf	5334 abc	8	104 lb N/ac Soil N + 90 lb N/ac of UAN @ 3-5lf	4700 a
9	110 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ early flag lf	4834 de	9	104 lb N/ac Soil N + 90 lb N/ac of UAN @ early flag lf	3971 bc
10	140 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ 3-5lf	5480 a	10	109 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ 3-5lf	4027 bc
11	140 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ early flag lf	5020 bcde	11	109 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ early flag lf	3637 cd
12	140 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5lf	5341 ab	12	109 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5lf	4266 b
13	140 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	4759 e	13	109 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	3827 c
LSD		410		LSD	408
P-values		0.026		P-values	<0.0001

[z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability

Table 10. Individual treatment means of nitrogen application effects on wheat grain protein (%) at multiple locations in 2022.

	Nitrogen Application Method	Indian Head	Outlook	Scott	Swift Current
1	Check: Soil N	12.2 h	10.1 h	16.2 ef	14.6 d
2	80 lb N/ac (SB + Soil N)	12.8 g	10.8 gh	16.3 def	14.6 d
3	110 lb N/ac (SB + Soil N)	13.6 f	11.3 fg	16.6 bcde	15.8 cd
4	140 lb N/ac (SB + Soil N)	14.6 e	12.5 de	16.7 abc	16.1 ab
5	170 lb N/ac (SB + Soil N)	15.5 bcd	13.6 bc	17.0 a	16.2 ab
6	80 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5 lf	15.2 d	12.4 de	16.0 f	16.2 ab
7	80 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	15.2 cd	12.8 d	16.7 abcd	15.9 bc
8	80 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ 3-5lf	15.9 a	13.9 b	16.6 bcde	16.3 a
9	80 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ early flag lf	15.6 ab	14.7 a	17.0 a	16.1 ab
10	110 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ 3-5lf	14.6 e	12.0 ef	16.6 bcde	16.1 abc
11	110 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ early flag lf	14.3 e	12.8 d	16.6 abcd	16.0 bc
12	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5lf	15.5 bc	13.1 cd	16.4 cde	16.4 a
13	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	15.6 ab	13.8 bc	16.9 ab	16.3 a
LSD		0.34	0.74	0.39	0.35
P-values		<0.0001	<0.0001	<0.0001	<0.0001

[z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability

Table 11. Individual treatment means of nitrogen application effects on wheat grain grain protein (%) at Yorkton and Melfort in 2022.

#	Nitrogen Application Method	Yorkton	#	Nitrogen Application Method	Melfort
1	Check: Soil N	14.4	1	Check: Soil N (104 lb N/ac)	12.7 de
2	110 lb N/ac (SB + Soil N)	15.0	2	Check: Soil N (104 lb N/ac)	12.4 e
3	140 lb N/ac (SB + Soil N)	14.9	3	110 lb N/ac (SB + Soil N)	12.7 de
4	170 lb N/ac (SB + Soil N)	15.0	4	119 lb N/ac (SB + Soil N)	12.8 de
5	200 lb N/ac (SB + Soil N)	15.0	5	149 lb N/ac (SB + Soil N)	12.8 de
6	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5 lf	14.9	6	104 lb N/ac Soil N + 60 lb N/ac of UAN @ 3-5 lf	12.8 de
7	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	14.8	7	104 lb N/ac Soil N + 60 lb N/ac of UAN @ early flag lf	13.5 abc
8	110 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ 3-5lf	14.8	8	104 lb N/ac Soil N + 90 lb N/ac of UAN @ 3-5lf	13.6 a
9	110 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ early flag lf	15.0	9	104 lb N/ac Soil N + 90 lb N/ac of UAN @ early flag lf	13.6 a
10	140 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ 3-5lf	14.9	10	109 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ 3-5lf	13.0 cd
11	140 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ early flag lf	14.7	11	109 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ early flag lf	13.1 bcd
12	140 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5lf	14.9	12	109 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5lf	12.7 de
13	140 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	15.2	13	109 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	13.6 ab
LSD		Ns		LSD	0.506
P-values		Ns		P-values	<0.0001

[z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability

Table 12. Economic returns ($/ac)[1] relative to treatment #2 at multiple locations in 2022.

Nitrogen Application Method		Indian Head	Outlook	Scott	Swift Current
1	Check: Soil N	NA	NA	NA	NA
2	80 lb N/ac (SB + Soil N)	0.0	0	0	0
3	110 lb N/ac (SB + Soil N)	73	84	7	-12
4	140 lb N/ac (SB + Soil N)	190	113	-11	-8
5	170 lb N/ac (SB + Soil N)	191	94	-58	-57
6	80 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5 lf	175	203	-48	-78
7	80 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	137	84	-43	-93
8	80 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ 3-5lf	205	231	-51	-99
9	80 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ early flag lf	107	215	-42	-123
10	110 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ 3-5lf	149	157	-32	-36
11	110 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ early flag lf	96	94	-36	-74
12	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5lf	197	196	-64	-79
13	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	152	216	-67	-120

[1] Economic returns assume $10.56/bu @ 12.5% protein; $0.66/%/bu (protein premium); $1.33/lb N; $10/ac UAN application cost.

Table 13. Economic returns ($/ac)[1] relative to treatment #2 at Yorkton and Melfort in 2022.

#	Nitrogen Application Method	Yorkton	#	Nitrogen Application Method	Melfort
1	Check: Soil N	NA	1	Check: Soil N (104 lb N/ac)	NA
2	110 lb N/ac (SB + Soil N)	0	2	Check: Soil N (104 lb N/ac)	NA
3	140 lb N/ac (SB + Soil N)	-74	3	110 lb N/ac (SB + Soil N)	NA
4	170 lb N/ac (SB + Soil N)	-56	4	119 lb N/ac (SB + Soil N)	NA
5	200 lb N/ac (SB + Soil N)	-97	5	149 lb N/ac (SB + Soil N)	NA
6	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5 lf	-82	6	104 lb N/ac Soil N + 60 lb N/ac of UAN @ 3-5 lf	NA
7	110 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	-130	7	104 lb N/ac Soil N + 60 lb N/ac of UAN @ early flag lf	NA
8	110 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ 3-5lf	-97	8	104 lb N/ac Soil N + 90 lb N/ac of UAN @ 3-5lf	NA
9	110 lb N/ac (SB + Soil N) + 90 lb N/ac of UAN @ early flag lf	-177	9	104 lb N/ac Soil N + 90 lb N/ac of UAN @ early flag lf	NA
10	140 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ 3-5lf	-26	10	109 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ 3-5lf	NA
11	140 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ early flag lf	-118	11	109 lb N/ac (SB + Soil N) + 30 lb N/ac of UAN @ early flag lf	NA
12	140 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5lf	-91	12	109 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ 3-5lf	NA
13	140 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	-181	13	109 lb N/ac (SB + Soil N) + 60 lb N/ac of UAN @ early flag lf	NA

[1] Economic returns assume $10.56/bu @ 12.5% protein; $0.66/%/bu (protein premium); $1.33/lb N; $10/ac UAN application cost.

Abstract

13. Abstract/Summary:

In 2022, trials were conducted across a range of environmental conditions to demonstrate the efficacy of various rates and timings of split applied N relative to applying all the N at seeding. While the efficacy of split applications varied greatly between locations based on environmental conditions, economic returns were usually increased when UAN was dribble banded early at the 3-5 leaf stage compared to a late application at early flag. Early applications usually yielded more and late applications usually resulted in higher grain protein. However, the value of increased grain protein from late applications was not enough to compensate economically for the yield loss. Applying split N to a higher base rate of N was anticipated to better maintain yield and improve the economics, but this did not consistently happen within this study. During drought at Swift Current and Scott, the most economic approach was to maintain a relatively low level of soil fertility of 80 lb N/ac at Swift Current and 110 lb N/ac at Scott. In other words, "holding back" on N was an effective strategy to maximize returns at these locations because no further additions of N were required. Applying split applications of N at these locations did not significantly increase yield and only served to greatly reduce economic returns. In contrast, economic returns were greatly increased with split applications of N at the irrigation site near Outlook when applied at the 3-5 leaf stage. Split applications resulted in much higher crop yields by potentially increasing N use efficiency under higher moisture conditions. Alternatively, the split applications yielded more relative to the checks because of fertilizer toxicity issues on seedlings. However, further study is required to see if these results can be reproduced. Split applying N also increased economic returns at the Indian Head dry land site when applied at the 3-5 leaf stage. However, this only occurred for the 170 lb N/ac level of fertility. While split applying N has shown some potential, it is probably best not to hold back more than 30 lb N/ac at seeding. The economic risk of holding back too much N at seeding and missing the opportunity to dribble band N in a timely manner is much greater than the economic losses incurred from over fertilizing the crop by 30 lb N/ac at seeding.