2017 Annual Report
for the

Agricultural Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Demonstrating 4R Nitrogen Principles in Canola

(Project #20160392)

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Project Identification

1. **Project Title:** Demonstrating 4R Nitrogen Principles in Canola
2. **Project Number:** 20160392
3. **Producer Group Sponsoring the Project:** Indian Head Agricultural Research Foundation
4. **Project Location(s):** Indian Head, Saskatchewan, R.M. #156
5. **Project start and end dates (month & year):** April-2017 to February-2018
6. **Project contact person & contact details:**

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Objectives and Rationale

7. **Project objectives:**

Developing Best Management Practices (BMPs) for nutrient applications has long been focussed on the 4R principles which emphasize using the: 1) right source, 2) right rate, 3) right time and 4) right place. These factors are not necessarily independent of each other. For example, depending on the N source, application timings or placement options that would normally be considered high risk can be viable. The objective of this project was to demonstrate canola response to varying rates of nitrogen (N) fertilizer along with different combinations of formulations, timing and placement methods relative to side-banded, untreated urea as a control. The treatments in this demonstration encompassed all four considerations (source, rate, time and place) for 4R nutrient management.

8. **Project Rationale:**

Nitrogen is the most commonly limiting nutrient in annual crop production and often accounts for one of the most expensive crop nutrients, particularly for crops with high N requirements like wheat and canola. Most inorganic N fertilizers contain NH_4-N but some (i.e. UAN) also contain NO3-N. Since the advent of no-till and innovations in direct seeding equipment, side-band or mid-row band applications and single pass seeding / fertilization quickly became the standard and most commonly recommended BMP for N. Side- or mid-row banding is effective with the major forms of N including anhydrous ammonia (82-0-0), urea (46-0-0) and urea ammonium-nitrate (28-0-0) and the combination of concentrating fertilizer (safely away from the seed row) and placing it beneath the soil surface dramatically reduces the potential for environmental losses while maintaining seed safety. Fall applications have always been popular for many producers (with regional exceptions), largely because fertilizer prices tend to be lower and applying N in a separate pass can reduce logistic pressure during seeding when labour and time are limited. It is primarily for such logistic reasons that there is increased uptake of two pass seeding / fertilization strategies amongst growers. While the timing and/or placement associated with two-pass systems are usually not ideal, enhanced efficiency formulations (EEF) such as polymer coats (ESN), volatilization inhibitors (i.e. Agrotain) and volatilization / nitrification inhibitors (Super Urea) can reduce some of the risks associated with applying N well ahead of peak crop uptake (i.e. fall applications) or sub-optimal placement methods (i.e. surface broadcast). Enhanced efficiency N products are more expensive than their traditional counterparts; however, this higher cost may be offset by potential improvements in efficacy and logistic advantages of alternative fertilization practices.

This project is relevant to producers because, for many, there has been movement back to two pass seeding / fertilization system due to logistics while others have struggled with excess moisture and simply want to improve the efficiency of their N fertilizer through either in-soil applications of EFF products or split-applications. Agronomists throughout western Canada frequently receive questions regarding the potential merits of EEF products for pre-seed, side or mid-row band, and post-seeding / post-emergent applications and the overall risks associated with surface-applications under less favourable environmental conditions. While most do not specifically want to encourage growers to revert to two pass seeding / fertilization systems, it is important for producers to have flexibility with respect to how they manage N on their farms. By demonstrating different N fertilization strategies according to the 4R principles and providing regional data on their relative efficacy, this project was intended to help producers make better informed N management decisions with consideration to the potential advantages and disadvantages of the various options. Canola is a good candidate for this project as it is a widely adapted, economically important crop and is highly responsive to N fertilizer and fertilizer rates for canola are amongst the highest for crops commonly grown is Saskatchewan.

Methodology and Results

9. Methodology:

A field trial was initiated in the spring of 2017 near Indian Head, Saskatchewan (50.551 N, 103.568 W) to evaluate the response of canola to various N strategies relative to the conventional practice of banding all N during the seeding operation. Indian Head is situated in the thin-Black soil zone of southeast Saskatchewan and the soil is classified as an Indian Head clay with typical organic matter concentrations of 4.5-5.5%. The treatments were a combination of varying rates of side-banded urea relative to alternative sources of N and placement/timing options. The application rates were based on a 1x target set at 145 kg/ha of total mineral N (residual NO_3-N plus fertilizer). The forms evaluated were untreated granular urea, liquid urea ammonium-nitrate, granular Agrotain® (volatilization inhibitor) and granular SuperUrea® (volatilization and nitrification inhibitors). In addition to side-banding, the placement/timing options evaluated were pre-seed, surface dribble-band / broadcast applications and split-application where 50% of the fertilizer N was side-banded urea and the remainder was applied at the early bolting stage as a post-emergent surface dribble-band or broadcast application. The twelve N fertilizer treatments were arranged in Randomized Complete Block Design (RBCD) with four replicates and are described in Table 1.

Table 1. Nitrogen management treatments in 4R Nitrogen demonstration with canola (Indian Head, 2017).			
#	**Formulation**	**Timing / Placement**	**Fertilizer Rate [Z]**
1	N/A	N/A	N/A
2	Urea	Side-band (during seeding)	0.5x (55 kg N/ha)
3	Urea	Side-band (during seeding)	1.0x (110 kg N/ha)
4	Urea	Side-band (during seeding)	1.5x (165 kg N/ha)
5	Urea	Pre-seed surface broadcast	1.0x (110 kg N/ha)
6	Urea Ammonium-Nitrate (UAN)	Pre-seed surface dribble-band	1.0x (110 kg N/ha)
7	Agrotain® (AT)	Pre-seed surface broadcast	1.0x (110 kg N/ha)
8	SuperUrea® (SU)	Pre-seed surface broadcast	1.0x (110 kg N/ha)
9	Urea / Urea	50:50 Split Application [Y]	1.0x (110 kg N/ha)
10	Urea / UAN	50:50 Split Application	1.0x (110 kg N/ha)
11	Urea / Agrotain®	50:50 Split Application	1.0x (110 kg N/ha)
12	Urea / SuperUrea®	50:50 Split Application	1.0x (110 kg N/ha)

[Z] 35 kg/ha residual NO_3-N as determined by fall composite soil sample for the site. Target total (soil plus fertilizer) N rates were: 0x = 35 kg N/ha, 0.5x = 90 kg N/ha, 1.0x = 145 kg N/ha, 1.5x = 200 kg N/ha

[Y] 55 kg N/ha side as side-banded 11-52-0, 21-0-0-24 and 46-0-0 plus a post-emergent surface application of 55 kg N/ha (forms varied as per protocol) at the early bolting stage

Selected agronomic information is provided in Table 2. While fertilizer rates were adjusted based on fall soil sampling results, the site was resampled intensively in the spring (0-15 cm, 15-60 cm) and analysed for select quality parameters and residual nutrients. InVigor® 233P, a high yielding shatter resistant canola variety, was direct-seeded into wheat stubble on May 14 at a target rate of 115 seeds/m^2. A blend of monoammonium phosphate (11-52), potash (0-0-60) and ammonium-sulphate (21-0-0-24) was side-banded in all treatments except the unfertilized control where it was assumed that N would be the most important yield limiting nutrient. Weeds were controlled using registered pre-emergent and in-crop herbicide applications while fungicides were applied at mid-bloom to ensure that disease did not become a yield limiting factor. Pre-harvest glyphosate was applied at approximately 70-80% seed colour change and the centre five rows of each plot were straight-combined.

Various data were collected over the growing season and from the harvest samples. To assess N response during the season, the NDVI of each plot was measured at early bolting using a handheld Trimble GreenSeeker sensor. A chlorophyll meter (SPAD-502) was also used at this time (10 leaves per plot) – the measurements were always completed on the 2nd newest leaf. Grain yields were determined from the harvested grain samples and are corrected for dockage and to a uniform moisture content of 10%. Daily temperatures and precipitation were recorded at the Environment Canada weather station located approximately 6 km from the field site.

Table 2. Selected agronomic information for the 4R Nitrogen demonstration with canola at Indian Head (2017).

Factor / Field Operation	Indian Head 2017
Previous Crop	CWRS Wheat
Pre-emergent herbicide	894 g glyphosate/ha (May-10-2017)
Soil Nutrient Sampling	May-4-2017
Pre-seed N applications	May-5-2017 (as per protocol)
Variety / Seeding Rate	InVigor® L233P 115 seeds/m^2
Seed Treatment	Prosper plus Lumiderm
Seeding Date	May 14-2017
Row spacing	30 cm
kg P_2O_5-K_2O-S ha^{-1}	30-15-15
In-crop herbicide	202 g clopyralid/ha (Jun-6-2017) 600 g glufonsinate/ha + 30 g clethodim/ha (Jun-18-2017)
In-crop N applications	Jun-20-2017 (as per protocol)
NDVI measurements	Jul-1-2017 (early bolting)
SPAD measurements	Jul-2-2017 (early bolting)
Foliar fungicide	245 g boscalid/ha + 81 g pyraclostrobin/ha (July-5-2017)
Pre-harvest herbicide	894 g glyphosate/ha (Aug-20-2017)
Harvest date	Sep-3-2017

Response data were analysed using the GLM procedure of SAS with the treatment effects considered fixed and replicate effects treated as random. Treatment means were separated using Fisher's protected LSD test and orthogonal contrasts were used to determine whether the observed responses to side-banded N rate were linear or quadratic (curvilinear). An additional contrast compared the pre-seed surface applications to the split applications across all forms. All treatment effects and differences between means were considered significant at $P \leq 0.05$.

10. Results:

Growing season weather

Weather data for 2017 growing season at Indian Head is presented with the long-term (1981-2010) averages in Table 3. Despite less than normal precipitation through the winter months (60% of average from November 2016 through April 2017), with the wet fall, initial soil moisture conditions in 2017 were considered excellent. However, less than half of the long-term average precipitation was received during the growing season (May through August 2017). Nonetheless, crop establishment was good and stored soil moisture along with timely and substantial rainfall in mid-June (10 mm on June 9 and 50 mm on June 14) prevented drought from becoming a major limiting factor leading to high overall yields. Averaged across the four month period, temperatures were normal; however, May was warmer than the long-term average while August was cooler. Temperatures were approximately normal in June and July and conditions were such that disease pressure was negligible throughout the season.

Table 3. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2017 growing season at Indian Head, SK.

Year	May	June	July	August	Avg. / Total
			Mean Temperature (°C)		
IH-2017	11.6	15.5	18.4	16.7	15.6
IH-LT	10.8	15.8	18.2	17.4	15.6
			Precipitation (mm)		
IH-2017	10.4	65.6	15.4	25.2	117
IH-LT	51.8	77.4	63.8	51.2	244

Field Trial Results

Residual soil test nutrient levels are presented for the site in Table 4. Soil pH and percent organic matter were considered typical for the region at 7.9 and 4.5%, respectively. Residual NO_3-N was low, estimated at 22 kg/ha (0-60 cm) which was less than the fall estimate of 35 kg N/ha which was used to calculated the rates used in the N treatments. Residual phosphorus was considered very low, while potassium and sulphur were sufficient; however, all nutrients other than N were intended to be non-limiting in the trial.

Table 4. Selected soil test results for 4R Nitrogen Trial with canola at Indian Head, Saskatchewan (2017).

Attribute / Nutrient	0-15 cm	15-60 cm	0-60 cm
pH	7.9	–	–
S.O.M. (%)	4.5	–	–
C.E.C. (meq)	51.3	–	–
NO_3-N (kg/ha)[Z]	9	13	22
Olsen-P (ppm)	5	–	–
K (ppm)	615	–	–
S (kg/ha)	11	34	45

[Z] Nitrogen rates based on fall-composite sample showing 35 kg/ha residual NO_3-N

Individual treatment means and other statistics are presented in Table 5 of the Appendices while the results are also summarized graphically in Figures 1-6 below.

Normalized difference vegetation index (NDVI) is an indirect measure of above-ground biomass / plant health that takes in to account both overall vegetative cover and chlorophyll status (i.e. greenness) of the canopy being measured. Nitrogen rate effects on NDVI are presented in Fig. 1and showed a quadratic response where NDVI increased substantially when N was increased from the 0-0.5x rates (35-90 kg/ha total N) but more subtlety with further increase in N rate with no significant differences amongst the 0.5-1.5x (90-200 kg /ha total N) N rates. Focussing on N sources and timing/placement methods, which all received a 1x rate, a few differences amongst treatments were detected (Fig. 2). While no treatments had a significantly lower NDVI than the benchmark practice of side-banding urea, the observed NDVI was higher when N was applied as surface dribble-banded UAN prior to seeding. NDVI for this treatment was significantly higher than all treatments except the pre-seed surface broadcast of urea. These results are somewhat difficult to explain but may have been partly due to treatment effects or variability in emergence (not measured). Under dry-conditions, lower plant populations can sometimes be observed with side-banded N with sensitive crops such as canola. With lower overall populations and the ability of canola to compensate for lower populations with increased branching, mid-season NDVI measurements can be variable with this crop and not as well correlated with yield as they are a little bit later in the season (i.e. late bolting / start of flowering). Despite the fact that differences in emergence/crop stage cause NDVI to vary and many factors can continue to influence yield between sensing and harvest, previous research has shown that in-season NDVI measurements are generally well correlated with canola yield potential and N status.

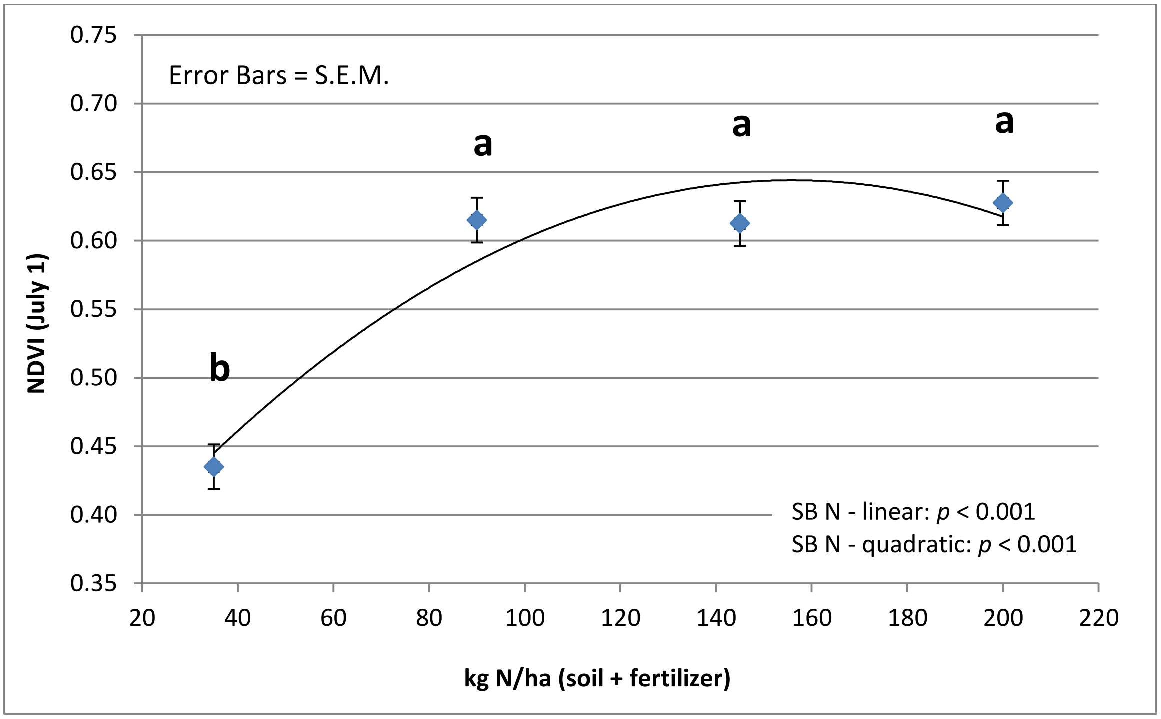

Figure 1. Side-banded urea rate effects on NDVI values in canola (July 1, early bolting) at Indian Head (2017).

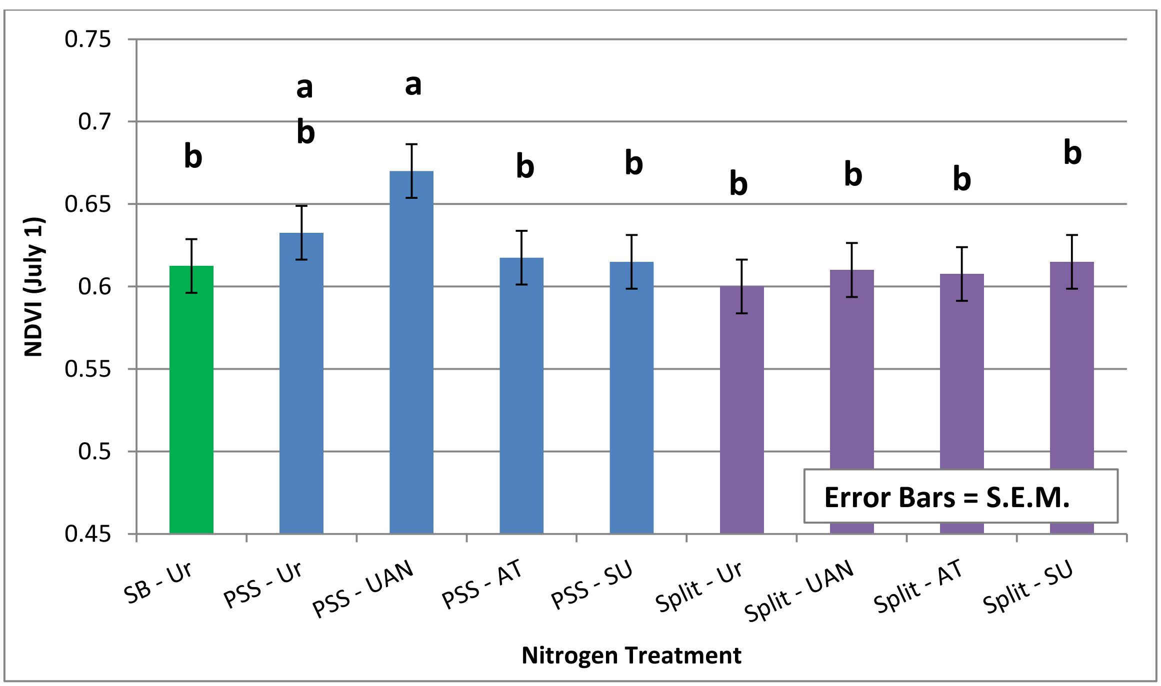

Figure 2. Nitrogen form/placement/timing effects on NDVI values in canola (July 1, early bolting) at Indian Head (2017). SB – side-band, PSS – pre-seed surface, Split – 50% side-banded urea 50% post-emergent surface, Ur - u–treated urea, UAN – urea ammonium-nitrate, AT – Agrotain, SU – SuperUrea.

Chlorophyll meter readings of individual leaves (10 per plot, 2nd newest leaf) were completed at a similar time as the NDVI measurements (July 2, Figs. 3 and 4). Compared to NDVI, there was more separation between N rates with significant increases from 0-0.5x (35-90 kg/ha total N) and from 0.5-1.0x (90-145 kg/ha total N) but no differences between the 1.0x and 1.5x treatments (145-200 kg/ha total N; Fig. 3). Focussing on form/timing/placement options, the highest SPAD values occurred with side-banded N (Fig. 4) where the mean SPAD value was significantly higher than that of all other treatments (where the same N rate was applied) except for the split-UAN treatment where the observed SPAD values were intermediate and did not differ from any other treatments. Tthe mean value with side-banded urea was 60.7, compared to56.4-58.9 for the remaining treatments where the same N rate was applied. The treatment effects on SPAD values were inconsistent with NDVI where values were amongst the lowest with side-banded urea; however, NDVI takes into account the entire canopy and is more sensitive to crop stage, plant density and variability in emergence while SPAD measurements are specific to the chlorophyll content of individual leaves.

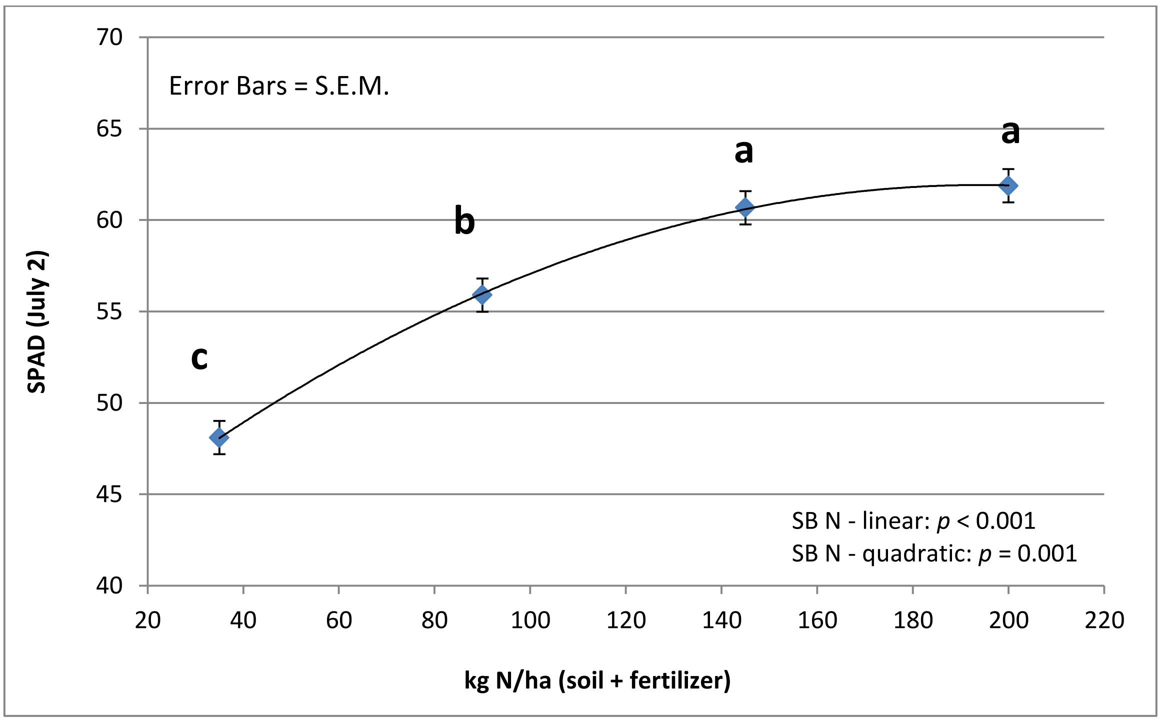

Figure 3. Side-banded urea rate effects on SPAD values in canola (July 2, early bolting) at Indian Head (2017).

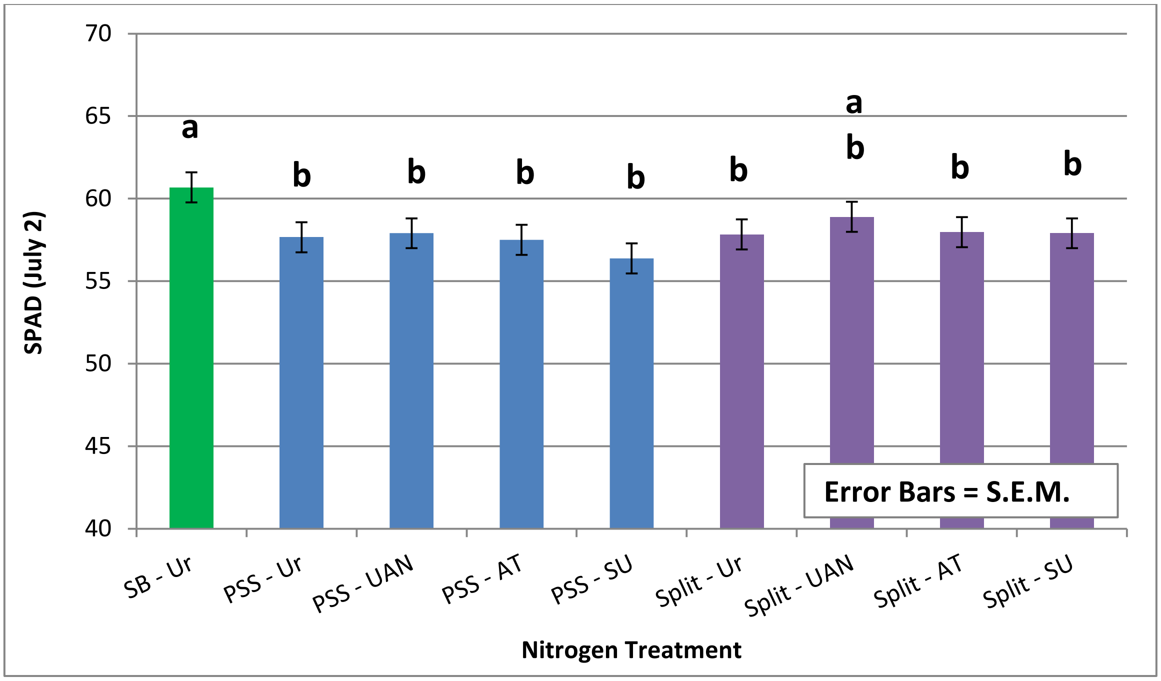

Figure 4. Nitrogen form/placement/timing effects on SPAD meter values in canola (July 2, early bolting) at Indian Head (2017). SB – side-band, PSS – pre-seed surface, Split – 50% side-banded urea 50% post-emergent surface, Ur - u–treated urea, UAN – urea ammonium-nitrate, AT – Agrotain, SU – SuperUrea.

Overall, the rate response to N was strong with yields increasing sharply from the 0-1.0x rates and then tapering off between the 1.0-1.5x rates (145-200 kg/ha soil plus fertilizer N; Fig. 5). The 1x rate was intended to be within the responsive range so that differences in N use-efficiency amongst the different management strategies could be detected in yield. Yields were remarkably high overall considering the dry conditions, reaching over 3000 kg/ha at the highest N rate and averaging 2637 kg/ha across all treatments where the 1x rate was applied. Comparing individual management strategies (Fig. 6), side-banded urea resulted in higher yields than any other individual treatments except for the split application with Agrotain®. Few differences amongst the alternative N management treatments were detected, the exception being that the split-application with Agrotain® yielded significantly higher than the treatment where Agrotain® was broadcast prior to seeding. Averaged across forms, yields were similar for the pre-seed broadcast / dribble band versus split-application treatments; therefore the difference between the spring and in-crop applications of Agrotain may have largely been due to naturally occurring variability as opposed to a true treatment effect. At the 1x rate, the mean canola yield with side-banded urea was 2894 kg/ha compared to 2466-2703 kg/ha for the less conventional N management strategies.

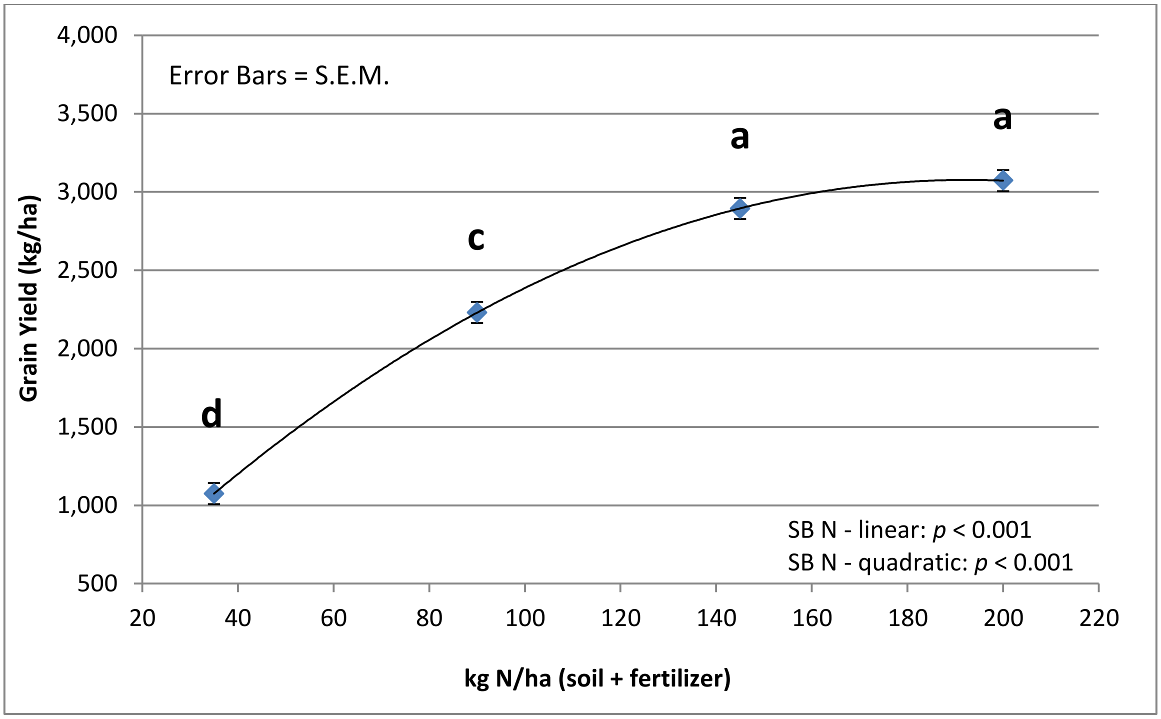

Figure 5. Side-banded urea rate effects on canola grain yield at Indian Head (2017).

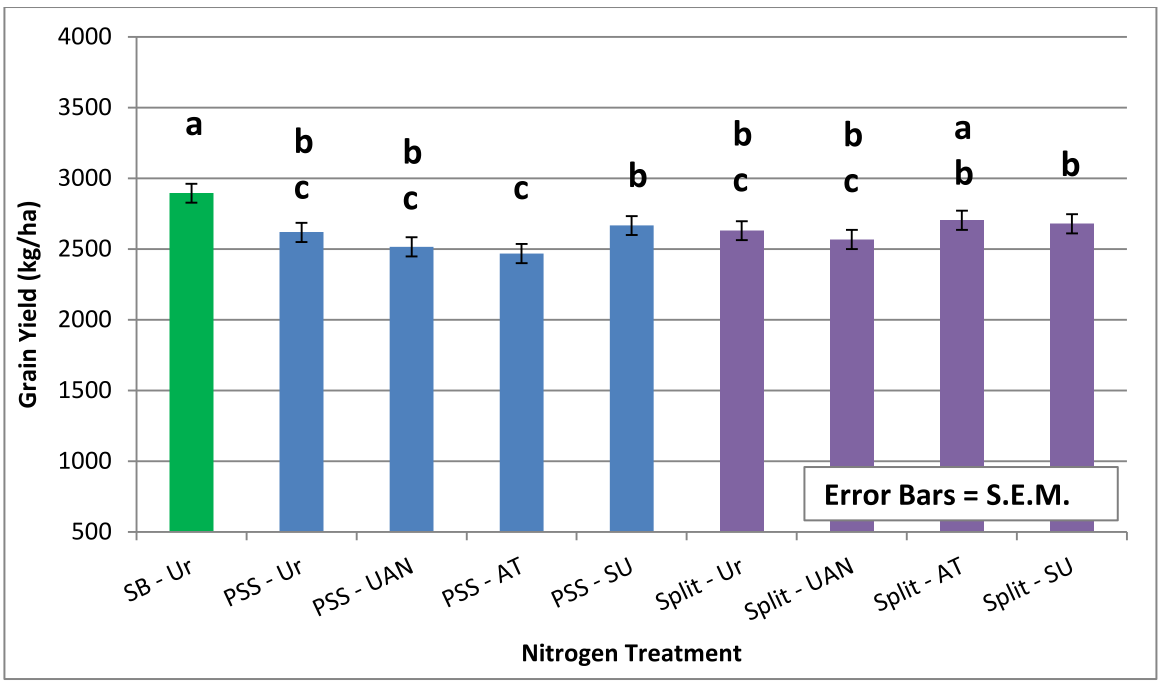

Figure 6. Nitrogen form/placement/timing effects on canola grain yield at Indian Head (2017). SB – side-band, PSS – pre-seed surface, Split – 50% side-banded urea 50% post-emergent surface, Ur - u–treated urea, UAN – urea ammonium-nitrate, AT – Agrotain, SU – SuperUrea.

Extension Activities and Dissemination of Results

This project was discussed and the plots were toured by approximately 200 guests at the Indian Head Crop Management Field Day on July 18, 2017 with a detailed discussion on 4R N management principles and contributions from Chris Holzapfel (IHARF), Stewart Brandt (NARF) and Rigas Karamanos (Koch Agronomic Services). Additionally, the site was shown on two smaller guided tours for Federated Co-Op (July 13) and Richardson-Pioneer (July 21) agronomists. The full project report will be made available online (www.iharf.ca) and potentially elsewhere in the winter of 2017-18. Results will also be made available through a variety of other media (i.e. oral presentations, popular agriculture press, fact sheets, etc.) as opportunities arise. Data may be combined with that from other sites in the future for extension purposes.

11. Conclusions and Recommendations

This project has demonstrated the overall response of canola to varying rates of N fertilizer along with different strategies for managing N involving various formulations (urea, UAN, Agrotain® and SuperUrea®) and timing/placement options (side-band, pre-seed surface broadcast/dribble-band, split application with both side-banded and post-emergent surface applications of N). The growing season at Indian Head was dry with less than half the long-term average growing season precipitation; however, initial soil moisture along with the overall yield potential of the canola was high). Under these conditions, the traditionally recommended practice of banding fertilizer in the soil during seeding performed the best with regard to effects on seed yield. Previous research has shown that early in-soil applications are most advantageous in dry years while, under more optimal conditions, N fertilizer placement and timing of application tend to be less critical. In very wet years, environmental losses can be high regardless of application method depending on the formulation. It is in these years that denitrification inhibitors or split-applications are likely to be most beneficial.

It is well accepted that surface-applications of N need either incorporation or substantial precipitation to move the fertilizer into the rooting zone and minimize losses. This would, to a large extent, explain why the surface applications did not generally perform as well as side-banded N. The risk of volatilization and stranding for both application dates was substantial since rainfall following application was always negligible and, with less than 10% seed-bed utilization, the seeding operation did not constitute incorporation for the pre-seed applications. This was evident in the results with the better performance of the soil-applied N; however, consistent benefits to Agrotain® and/or SuperUrea® were not detected. There were no broader differences between the pre-seed surface and split applications for yield when averaged across N formulations. While split-applications (particularly where some N is placed beneath the soil surface) may generally be considered less risky than broadcasting the entire N amounts prior to seeding (fall or early spring), results can vary from year-to-year depending on precipitation amounts and timing. That being said, a significant advantage to split-applications is the ability to adjust N rates during the season for crop and moisture conditions. In extremely dry springs, which may be the case for many Saskatchewan growers in 2018, there can be a reluctance to apply high rates of N based on average or above-average yields when the actual yield potential could vary dramatically with growing season precipitation. With split applications, there is the option to apply a portion of the fertilizer at seeding, largely protecting against early season deficiency and subsequent yield loss, but only applying the remainder if justifiable by the actual growing conditions and the anticipated yield potential part way through the season. Split applications can also be beneficial in very wet fields or years where the potential for losses is high if N is applied too far ahead of uptake and, furthermore, precipitation is usually adequate to move top-dressed N into the rooting zone where it can be utilized by the crop.

Supporting Information

12. Acknowledgements:

This project was supported by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement and Fertilizer Canada as part of their 4R nutrient stewardship program. Specialty fertilizer products were provided in-kind by Koch Agronomic Services while seed and crop protection products were provided in-kind by Bayer CropScience and BASF. The many contributions of IHARF staff Danny Petty, Christiane Catellier, Dan Walker, Karter Kattler, and Shaelyn Stadnyk are greatly appreciated.

13. Appendices

Table 5. Individual treatment means for selected response variables in the ADOPT 4R Nitrogen Principles in Canola demonstration at Indian Head, 2017. Means within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

Entry	NDVI (July 1)	SPAD (July 2)	Grain Yield (kg/ha)
1) Control (0x)	0.435 c	48.1 e	1074 f
2) Ur – SB – 0.5x	0.615 b	55.9 d	2230 e
3) Ur – SB – 1x	0.613 b	60.7 ab	2894 ab
4) Ur – SB – 1.5x	0.628 ab	61.9 a	3072 a
5) Ur – PSS – 1x	0.633 ab	57.7 cd	2616 cd
6) UAN – PSS – 1x	0.670 a	57.9 cd	2515 cd
7) AT – PSS – 1x	0.618 b	57.5 cd	2467 d
8) SU – PSS – 1x	0.615 b	56.4 cd	2665 c
9) Ur – Split – 1x	0.600 b	57.8 cd	2629 cd
10) UAN – Split – 1x	0.610 b	58.9 bc	2567 cd
11) AT – Split – 1x	0.608 b	58.0 cd	2703 bc
12) SU – Split – 1x	0.615 b	57.9 cd	2678 c
S.E.M.	0.0163	0.91	67.2
PSS vs Split (*p*-value)	0.033	0.226	0.109
Pr > *F* (*p*-value)	< 0.001	< 0.001	< 0.001
C.V. (%)	5.4	3.2	5.4

N Rates (kg N/ha - residual NO_3-N + fertilizer N): 0x – 35, 0.5x – 90, 1x = 145, 1.5x = 200

Formulations: Ur = untreated urea, UAN = urea ammonium-nitrate, AT = Agrotain®, SU = SuperUrea®

Timing/placement: SB = side-band at seeding, PSS – pre-seed surface application, Split – 50:50 side-band/post-emergent surface application

Figure 7. Site overview at Indian Head, Saskatchewan (August 12, 2017).

Figure 8. Spring wheat with no supplemental N fertilizer (~35 kg/ha residual NO_3-N) at Indian Head, Saskatchewan (August 12, 2017).

Figure 9. Canola with 165 kg N/ha supplemental N fertilizer plus ~35 kg/ha residual NO_3-N (1.5x rate) at Indian Head, Saskatchewan (August 12, 2017).

Abstract

14. Abstract/Summary:

A field trial with canola was conducted near Indian Head, Saskatchewan in 2017 to demonstrate the response to varying rates, forms, and application method/timing options of N fertilizer. The shatter tolerant variety InVigor® L233P was seeded in early May and, as side-banded urea, the total N rates were 35, 90, 145 and 200 kg/ha (included 35 kg/ha residual). At the 145 kg total N/ha rate, various N alternative management strategies incorporating untreated urea, urea ammonium-nitrate, Agrotain® and SuperUrea® and pre-seed surface broadcast or post-emergent (split) applications. Overall it was a dry season with less than half the long-term average precipitation but initial soil moisture and yield potential were high. In-season assessments using a handheld GreenSeeker (NDVI) or SPAD (chlorophyll) meter both distinguished between rates to some extent; however, the SPAD meter was better able to detect subtle differences amongst rates and management strategies. The yield response to N was high with strong increases through the 1x rate then levelling off between 145-200 kg/ha total N. Focusing on N management strategies, side-banded urea was the most effective overall and differences amongst the strategies where surface applications were incorporated were mostly not significant. This is consistent with previous research which has shown that early in-soil applications are most advantageous under dry conditions. Under optimal moisture conditions, timing and placement methods tend to be less important while, under extremely wet conditions, enhanced efficiency products and split-applications generally have the greatest potential to be advantageous. Both application dates of (surface-applied) N were subject to stranding at the soil surface and volatilization as the most significant rainfall events of the season occurred over five weeks after the pre-seed applications and prior to the split applications. Overall, these results support the recommendation of banding N during seeding and suggest that this is

the least risky and most efficient application method for N regardless of form; however, results can vary widely from season to season with weather conditions.