2017 Annual Report for the Agriculture Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Demonstrating 4R Nitrogen Principles in Canola

Project Number: 20160375

Producer Group Sponsoring the Project: Western Applied Research Corporation

Project Location(s):

- Scott Saskatchewan, R.M. #380 Legal land description: NE 17-39-20 W3

Project start and end dates (month & year): May 2017 and completed January 2018

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Objectives and Rationale

Project objectives:

Developing best management practices (BMPs) for nutrient applications has long been focussed on the 4R principles which refer to using the: 1) right formulation, 2) right rate, 3) right placement and 4) right timing. These factors are not necessarily independent of each other. For example, depending on the formulation, application timings or placement options that would normally be considered high risk can become viable.

The objective of this trial is to demonstrate canola response to varying rates of N along with different combinations of formulations, timing and placement methods relative to side-banded, untreated urea as a control. The proposed field trial design encompasses all four considerations (rate, form, placement and timing) for 4R nutrient management.

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 NH4-N but some (i.e. UAN) also contain NO3-N. Since the advent of no-till and innovations in direct seeding equipment, side- or mid-row band applications and single pass seeding / fertilization quickly became the standard and most commonly recommended BMP for nitrogen. 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 reduced the potential for environmental losses while maintaining seed safety. Fall applications have always been popular, at least on a regional basis, in that fertilizer prices are usually lower and applying N in a separate pass can take logistic pressure off during seeding when labour and time are limited. It is primarily for these logistic reasons that many growers are again considering two pass seeding / fertilization strategies as a means of spreading out their workload and managing logistic challenges associated with handling large product volumes during the narrow seeding window. While the timing and/or placement associated with two pass systems are usually not ideal, enhanced efficiency formulations such as polymer coats (ESN), volatilization inhibitors (i.e. Agrotain) and volatilization / nitrification inhibitors (Super Urea) can reduce the potential 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 more traditional counterparts; however, this higher cost may be justified by the potential improvements in efficacy and logistic advantages of alternative fertilization practices.

This project is relevant to producers because, for many, there has been a movement back to two pass seeding fertilization systems for logistic reasons. While we do not necessarily want to encourage growers to revert to two pass seeding / fertilization systems, it is important for them to have a certain amount of flexibility with respect to how they manage N on their farms. By demonstrating different N fertilization strategies according to the 4R principles and providing data on their efficacy relative to benchmark BMPs we can help them to make informed decisions while taking into consideration both the advantages and potential disadvantages of the various options. Canola is a good candidate for this project since it is highly responsive to N fertilizer applications.

Methodology and Results

Methodology:

The demonstration was arranged as a randomized complete block design with four replicates at Scott 2017. The treatments consisted of fertilizer N rate, fertilizer placement and product to result in a total of ten treatments (Table 1). Prior to seeding, soil samples were collected at two depth increments (0-15 cm and 15-60 cm) in order to determine fertilizer rates recommendations (Table A1). The trial was sown on wheat stubble using an R-tech drill with 10-inch row spacing. The canola variety was Liberty Link 140P and was seeded at 115 seeds/m^2. Weeds and disease were controlled using registered herbicide and foliar fungicide applications.

Table 1. Treatment list representing treatment numbers, variety and seeding date.

Trt #	Rate of Nitrogen	Fertilizer Placement	Products
1	0	-	-
2	0.5x[Z]	Side Band	Urea
3	1.0x	Side Band	Urea
4	1.5x	Side Band	Urea
5	1.0x	Pre-Seed Broadcast	Urea
6	1.0x	Pre-Seed Broadcast	Agrotain
7	1.0x	Pre-Seed Broadcast	Super U
8	1.0x[Y]	Split Broadcast	Urea
9	1.0x	Split Broadcast	Agrotain
10	1.0x	Split Broadcast	Super U

[Z]1x =Based on soil test recommendations.

[Y] Split application with 50% of total N side-banded during seeding and remainder applied as per protocol approximately 4 weeks after planting (4-6 leaf stage).

Data Collection:

Plant densities were determined by counting numbers of emerged plants on 2 spots x 2 rows x 1m row lengths per plot approximately two weeks after emergence. In-season normalized difference vegetative index (NDVI) was conducted on each plot at early- to mid-bolting using a GreenSeeker optical sensor. Yields were determined from cleaned harvested grain samples and corrected to 10% moisture content. Protein analysis was conducted to determine seed nitrogen. Weather data was recorded from the online database of Environment Canada weather station.

Growing Conditions:

The 2017 growing season started with great soil moisture in April and May with 30.9 mm and 69 mm of precipitation, respectively. Midseason growing conditions in June and July were very dry with 51% and 68% less precipitation compared to the long-term average. Growing degree days were higher than the long-term average for the months of May and July, and lower for the remaining months (Table 2).

Table 2. Mean monthly temperature, precipitation and growing degree day accumulated from April to September in 2016 and 2017 at Scott, SK.

Year	April	May	June	July	August	Sept.	Average /Total
Temperature (°C)							
2016	5.9	12.4	15.8	17.8	16.2	10.9	13.2
2017	3.0	11.5	15.1	18.3	16.6	11.5	12.7
Long-term^z	3.8	10.8	14.8	17.3	16.3	11.2	12.4
Precipitation (mm)							
2016	1.9	64.8	20.8	88.1	98.2	22.2	296
2017	30.9	69.0	34.3	22.4	53	18.9	228.5
Long-term^z	24.4	38.9	69.7	69.4	48.7	26.5	277.6
Growing Degree Days							
2016	58.9	224.9	303	398.7	343.8	176.2	1505.5
2017	16.6	202.7	283.3	399.1	348.4	194.8	1444.9
Long-term^z	44	170.6	294.5	380.7	350.3	192.3	1432.4

^{z}Long-term average (1985 - 2014)

Analysis:

The data was statistically analysed using the PROC MIXED in SAS 9.4. The residuals were tested for normality and equal variance to meet the assumptions of ANOVA. The means were separated using a Tukey's Honestly Significant Difference (HSD) test with level of significance at 0.05. Replications were treated as random effect factor whiles treatments were fixed effect factors. Treatments were grouped in order to determine if nitrogen rate, placement and product type had an effect on canola plant density, NDVI, yield and protein. Nitrogen rate was also analysed using PROC GLM to determine if a significant linear or quadratic response occurred.

Results & Discussion:

Plant density was not significantly influenced by either nitrogen rate (P=0.2425), placement (P=0.9837), product (P=0.707) or any combination of these factors. However, several trends can be concluded from the data set due to the change in plants per sq. meter. Plant density at each nitrogen rate tended to increase up to the full recommended rate with a slight decline when nitrogen exceeded the recommended rate (Table 3). Excessive nitrogen can reduce plant stand as a result of seed damage caused through salt injury and ammonia toxicity (Canola Council of Canada, 2015a).

Table 3. Urea rates, placement and product effects on plant density (plants per sq. meter), normalized difference vegetative index (NDVI), yield (bu per acre) and protein (%) at Scott, 2017. Treatment means were generated and separated using Tukey's HSD.

	Plant Density (plant per sq. meter)	NDVI	Yield (bu per acre)	Protein (%)
Urea Rate				
None	75 a	0.3984 a	41 a	17.8 a
Half Rate (0.5x)	81 a	0.5924 b	56 b	17.7 ab
Full Rate (1x)	92 a	0.7557 c	64 c	18.2 b
Full and Half Rate (1.5x)	85 a	0.7878 c	74 d	19.0 b
Placement				
Sideband	92 a	0.7557 a	64 ab	18.2 b
Broadcast	89 a	0.7167 a	66 a	19.2 a
Split Broadcast	88 a	0.6543 b	63 b	19.5 a
None	75 a	0.3984 c	41 c	17.8 b
Product				
Urea	91 a	0.7055 a	64 a	19.0 a
SuperU	89 a	0.6913 a	64 a	19.1 a
Agrotain	86 a	0.6849 a	65 a	19.5 a

Ammonia can damage crops through direct toxicity while nitrate will damage seedlings by desiccation through the salt effect. Canola is sensitive to both the salt effect and direct toxicity, which is why there is no distinction made between products containing straight ammonium and those containing a mixture of ammonium and nitrate N when it comes to safe seed-placed N rates for canola (Canola Council of Canada, 2015b). Products such as polymer coating (e.g. ESN), volatilization inhibitors (i.e. Agrotain) and volatilization / nitrification inhibitors (Super Urea) can allow for higher safe-rates of seed-placed urea by lowering the concentration of ammonia that is in contact with the seedling.

In most instances, utilizing different nitrogen products and placement can influence overall plant density by reducing seed damage. However, plant densities were not influenced by product in this demonstration. This could be attributed to high precipitation received in April and May. When soil moisture conditions are very good to excellent during germination and emergence, higher seed-placed urea N rates can be tolerated. With moist soil conditions, water dilutes the concentration of nitrogen molecules around the seed and seedling. Water also disperses nitrogen molecules throughout the soil, reducing concentrations around the seed. Thus, moist soil conditions observed at seeding diluted the nitrogen concentration to negate the effect of product type on plant density. In dry conditions, seed-placed nitrogen fertilizer tends to produce higher concentrations of ammonia and ammonium that can damage young seedlings. Seed-placed nitrogen rates should be lowered when conditions are drier than normal. Overall, nitrogen rates, placement and product type can play a large role in plant density under certain environmental conditions and consequentially can influence overall plant growth, yield and seed quality.

Nitrogen Rates

On deficient soils, a nitrogen response can be easily detected through several techniques including the comparison of normalized difference vegetative index (NDVI) response values. NDVI is calculated from the amount of absorbed visible light and the proportion of near-infrared light reflected by vegetation. NDVI therefore provides an indication of the relative biomass present based on the relative NDVI value. NDVI had a positive linear response to nitrogen applications ($P=<0.0001$). A denser canopy formed when nitrogen was more readily available compared to lower nitrogen rates, resulting in a thinner canopy and thus a lower NDVI value. NDVI strongly ($r = 0.97$) correlated to yield, in which both NDVI and seed production increased with the highest available nitrogen compared to the lower N rates (P= <0.0001). Similarly, several studies (Ghanbari-Malidarreh, 2010; Imran et al., 2014; Tunçtürk and Çiftçi, 2007; Khan et al., 2017) reported a linear relationship between seed yield and nitrogen rate. A positive yield response was attributed to higher number of branches, pods per plant, seeds per pods, and seed-carrying pods under high nitrogen conditions.

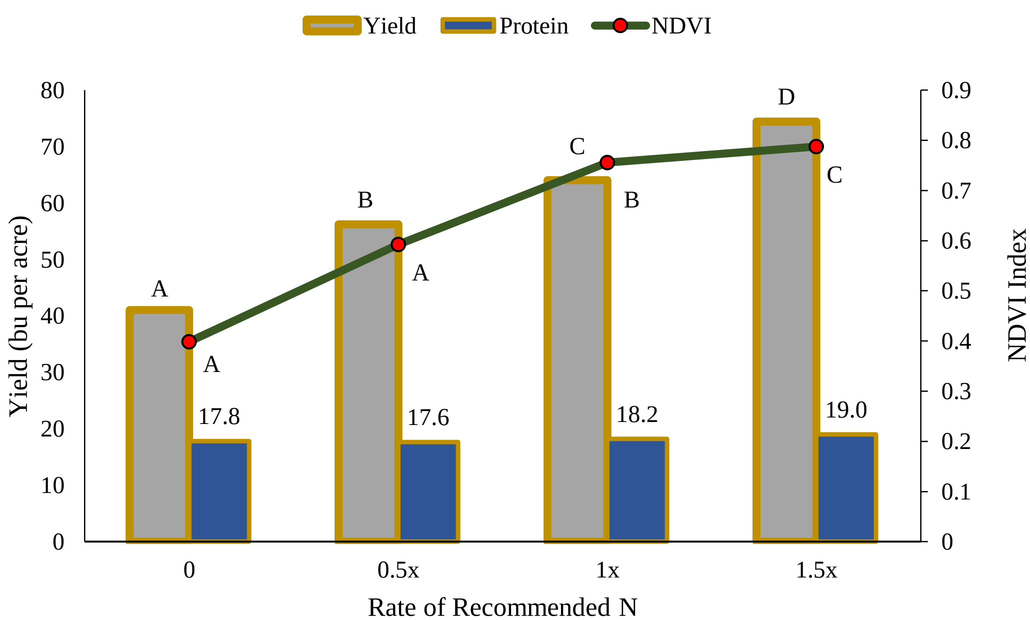
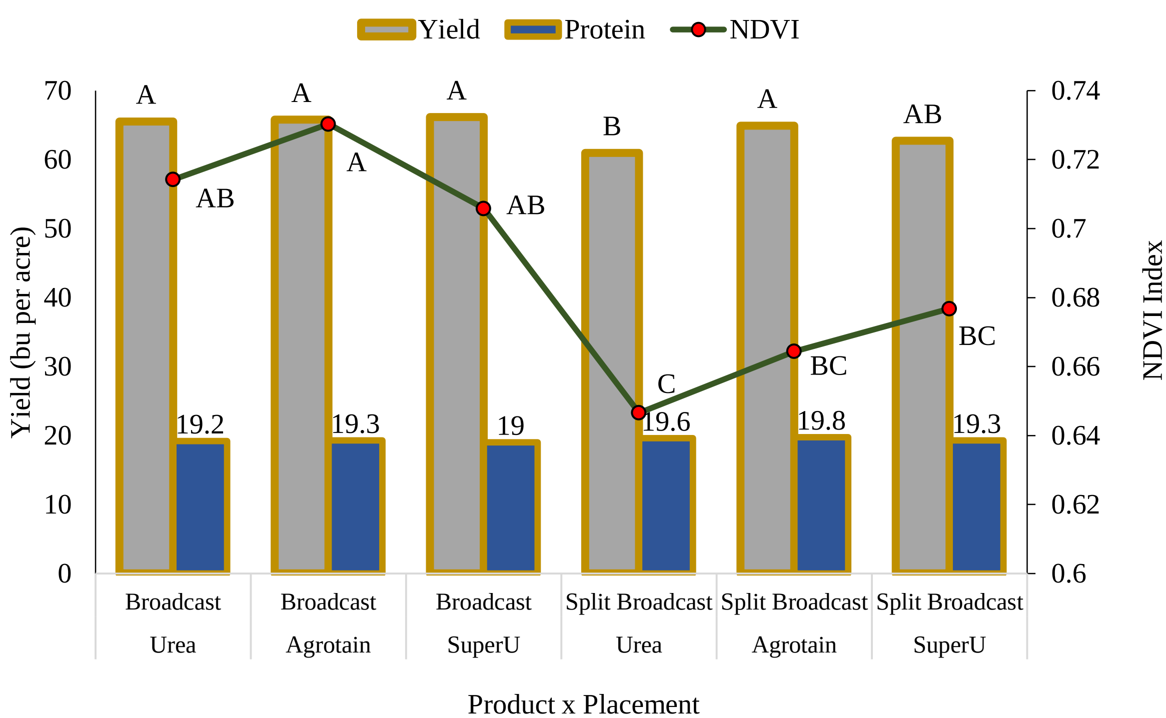


Figure 1. Nitrogen response rate applied at 0, 0.5x, 1x and 1.5x recommended rate to plant biomass measured via NDVI, yield (bu per acre), and seed protein content on canola, Scott, SK 2017.

In addition to improving yield, protein content may increase with higher rates of available nitrogen. In this study, the highest protein contents correlated to the highest yields (r = 0.82) when the greatest rate of nitrogen was applied (P= 0.0153) (Figure 1). Protein is an indicator of oil content as an inverse relation occurs between oil and protein. Thus, higher yield and protein associated with higher nitrogen rates typically results in lower oil content per seed. However, total oil per acre rises due to a higher overall seed production. Maintaining adequate nitrogen fertility and a balanced nutrient program are critical to balance yield and oil content.

Application of nitrogen may increase yield and protein by improving growth, but its excessive use can lead to higher production costs, increase risk of nitrate leaching and water contamination and reduce nitrogen use efficiency (Sieling and Kage, 2010; Zhang et al., 2013). Additionally, high nitrogen rates promote lodging by increasing plant height and decreasing lignin and cellulose content, stem diameter and cell wall thickness of basal internodes (Wang et al., 2012; Zhang et al., 2013). Excess vegetative growth can also deplete soil moisture leading to greater moisture stress during grain fill. Controlling the rate of nitrogen supply with enhanced-efficiency fertilizers (EEF) such as Agrotain, ESN and SuperU can help increase nitrogen-use efficiency by protecting most nitrogen from loss until the period of rapid crop uptake.

Nitrogen losses can occur through four main pathways via immobilization, volatilization, denitrification and leaching. The degree of loss can be largely influenced by environmental conditions, placement and product selection. In particular, nitrogen losses through surface broadcasted urea produce the greatest losses up to 88% after 7 days under zero tillage conditions (Grant et al. 1996). Enhanced- efficacy nitrogen fertilizers are an excellent substitute for urea, particularly for broadcast applications to reduce nitrogen losses. Tenuta et al. (2016) reported a 39% decrease in nitrogen fertilizer emissions from enhanced-efficiency fertilizers compared to urea applied alone. Retaining available nitrogen throughout the growing season can increase plant growth and yield production, as nitrogen is readily available during peak uptake. Plant growth measured via NDVI indicated a significant product x placement interaction (P= 0.0329) in the early growing season. Broadcasted nitrogen (Urea, Agrotain, SuperU) resulted in similar NDVI values, however, product type for split applications resulted in diverse NDVI values. Split broadcast application of urea resulted in the lowest NDVI and consequentially the least plant growth with a slight incline for applications of Agrotain and SuperU (Figure 2). Overall, EEF products will likely reduce nitrogen



losses compared to urea applied alone under distressed conditions.

Figure 2. Product placement and product type interaction effect on plant biomass measured via NDVI, yield (bu per acre), and seed protein content on canola, Scott, SK 2017.

A slight yield benefit also occurred from a placement x product interaction. On average, broadcast applications increased yield by 4 bu per ace compared to split broadcast urea applications (Figure 2). The urea split broadcast application resulted in the lowest yield and NDVI compared to all other treatments. This is likely attributed to the warm temperatures ($^{+}$18.5^{o}C) and a lack of rainfall (3.9mm) following application. The EEF were less affected because of the urease and nitrification inhibitors, resulting in less nitrogen losses. Drury et al. (2016) reported similar results in which corn yield positively responded to broadcast urease inhibitors ($^{+}$5.7 bu per acre) and urease inhibitors plus nitrification inhibitors ($^{+}$10.7 bu per acre) compared to urea based applications. Protein was not significantly affected by product x placement (P=0.4145). Protein is less affected by available nitrogen compared to yield, and thus a slight nitrogen loss is unlikely to affect protein.

In general, fertilizer placement (sideband ≥ broadcast > split broadcast) played a significant role in plant growth (NDVI, P=0.0003) and seed production (yield, P=<0.0001) compared to product selection (NDVI, P=0.8566; yield, P= 0.384). Sideband and broadcast nitrogen applications produced similar plant growth and seed production (Figure 3). This was unexpected as broadcast applications typically have greater nitrogen losses compared to nitrogen side banding (Malhi et al. 2001). Nitrogen losses were likely limited due to the ideal environmental conditions that occurred after application (cool temperatures, $^{+}$15^{o}C; rainfall, 13.9 mm). Furthermore, seeding occurred two days after applications, resulting in the incorporation of product via soil disturbances.

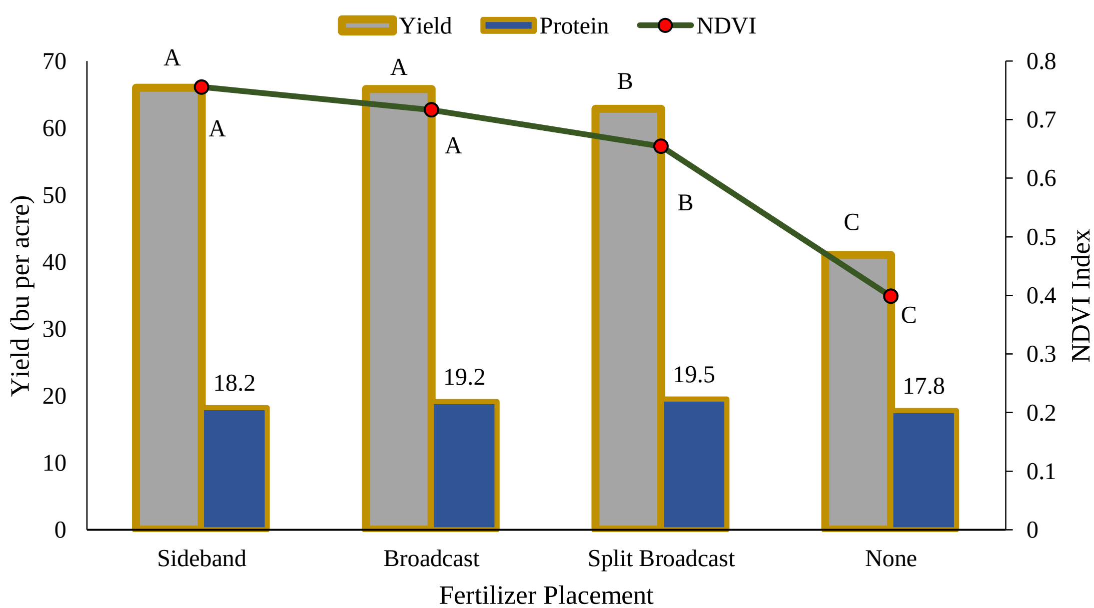


Figure 3. Fertilizer placement effect on plant biomass measured via NDVI, yield (bu per acre), and seed protein content on canola, Scott, SK 2017.

Sideband and broadcast applications produced greater plant growth (11%) and higher yields (4%) compared to split broadcast applications (Figure 3). Warm daily temperatures ($^{+}18.5^{o}C$) and drier conditions (3.9mm) prevailed for 7 DAA of split broadcast. Warm, dry conditions result in greater nitrogen losses and consequentially diminished plant growth and seed production. Although yield declined with split broadcast applications, yield in general greatly responded to nitrogen fertilizer applications ($^{+}$ 24 bu per acre) compared to the unfertilized canola check (Figure 3). Protein remained unchanged regardless of fertilizer placement, however, protein was significantly higher ($^{+}$6%) for fertilized canola compared to unfertilized check (Figure 3). Overall, these results indicate that placement is important for canola production, but ultimately, environmental conditions will dictate the effect nitrogen on plant growth and seed production. Therefore, to reduce the risk nitrogen losses caused by unfavourable conditions, producers should utilize the 4Rs (Right Rate, Right Time, Right Source, Right Place).

Conclusions and Recommendations:

The results of this trial have provided insights to improve nitrogen fertilization in canola production by demonstrating the effect of nitrogen rate, placement and the interaction of placement and product. NDVI had a positive linear response to nitrogen applications. NDVI strongly correlated to yield and protein, in which NDVI, yield and protein increased with the highest available nitrogen. A positive yield response may be attributed to higher number of branches, pods per plant, seeds per pods, and seed-carrying pods under high nitrogen conditions. High nitrogen rates are required to achieve maximum yield and proteins; however, excessive applications can cause substantial nitrogen losses, reduced nitrogen-use efficiency, and lodging. Controlling the rate of nitrogen supply with enhanced-efficiency fertilizers can improve nitrogen-use efficiency by reducing the amount of nitrogen losses that occur until the period of rapid crop uptake. A significant interaction for product type and placement occurred, indicating that greater losses were recorded for split broadcast applications of urea compared to the enhanced- efficiency fertilizer applications. Fertilizer placement (sideband ≥ broadcast > split broadcast) in general played a significant role in plant growth (NDVI, $P=0.0003$) and seed production (yield, $P=<0.0001$). In general, these results indicate that utilizing the proper rate, source and placement can influence overall plant growth and seed production. In order to reduce the risk nitrogen losses caused by unfavourable conditions, producers should utilize the 4Rs (Right Rate, Right Time, Right Source, Right Place).

Supporting Information

Acknowledgements

We would like to thank the Ministry of Agriculture for the funding support on this project. We would like to acknowledge Herb Schell and our summer staff for their technical assistance with project development and implementation for the 2017 growing season. This report will be distributed through WARC's website and included in WARC's and Agri-ARM annual reports.

Appendices

Appendix A

Table A1. Soil test nutrient level results (lb/ ac) from Scott, SK 2017.

	NO_3-N	P	K	SO_4 -S	Cu	Mg	Mn	Zn	B	Fe	Cl
0 - 15	16	62	816	12	4160	910	59	4	1.4	174	8
15 - 60	10			196							

Table 1. Treatment list representing treatment numbers, variety and seeding date.

Trt #	Rate of Nitrogen	Total Nitrogen Applied (lb/ac)	Fertilizer Placement	Products
1	0	0	-	-
2	$0.5x^Z$	30	Side Band	Urea
3	1.0x	113	Side Band	Urea
4	1.5x	198	Side Band	Urea
5	1.0x	113	Pre-Seed Broadcast	Urea
6	1.0x	113	Pre-Seed Broadcast	Agrotain
7	1.0x	113	Pre-Seed Broadcast	Super U
8	$1.0x^Y$	30; 85	Split Broadcast	Urea
9	1.0x	30; 85	Split Broadcast	Agrotain
10	1.0x	30; 85	Split Broadcast	Super U

Monoammonium phosphate and ammonium sulphate remained consistent with 29 lb/ac and 104 lb/, respectively.

Abstract

Nitrogen is commonly a limiting nutrient in annual crop production and often accounts for one of the most expensive crop nutrients, particularly for crops with high nitrogen requirements like canola. To minimize nitrogen losses and maximize crop yields, producers need to develop best management practices (BMPs) for nutrient applications such as the 4R principles. The objective of this trial is to demonstrate canola response to varying rates of nitrogen along with different combinations of formulations, timing and placement methods relative to side-banded, untreated urea as a control. The proposed field trial design encompasses all four considerations (rate, form, placement and timing) for 4R nutrient management. The demonstration was arranged as a randomized complete block design with four replicates at Scott 2017. The treatments consisted of fertilizer nitrogen rate (0, 0.5x, 1x and 1.5x recommended rate), fertilizer placement (sideband, broadcast, split broadcast) and product (Urea, Agrotain, SuperU) to result in a total of ten treatments. The results of this trial have provided insights to improve nitrogen fertilization in canola production by demonstrating the effect of nitrogen rate, placement and the interaction of placement and product. NDVI had a positive linear response to N applications. NDVI strongly correlated to yield and protein, in which NDVI, yield and protein increased with the highest available nitrogen. A positive yield response may be attributed to higher number of branches, pods per plant, seeds per pods, and seed-carrying pods under high N conditions. High nitrogen rates are required to achieve maximum yield and proteins; however, excessive applications can cause substantial nitrogen losses, reduced nitrogen -use efficiency, and lodging. Controlling the rate of nitrogen supply with enhanced-efficiency fertilizers can improve nitrogen -use efficiency by reducing the amount of nitrogen losses that occur until the period of rapid crop uptake. A significant interaction for product type and placement, indicating that greater losses were recorded for split broadcast applications of urea compared to the enhanced- efficiency fertilizer applications. Fertilizer placement (sideband ≥ broadcast > split broadcast) in general played a significant role in plant growth (NDVI, P=0.0003) and seed production (yield, P=<0.0001). In general, these results indicate that utilizing the proper rate, source and placement can influence overall plant growth and seed production. In order to reduce the risk nitrogen losses caused by unfavourable conditions, producers should utilize the 4Rs (Right Rate, Right Time, Right Source, Right Place).

Extension Activities

The project was highlighted by Dr. Rigas Karamonas at the Scott Field Day with approx. 140 people in attendance. The results will also be shared at the annual Crop Opportunity event hosted in March with approximately 150 people in attendance. A fact sheet will be generated and distributed on the WARC website, as well as all Agri-ARM and WARC events to ensure the information will be transferred to producers.

Finances

Expenditure Statement

Majority of expenses associated with this project went towards labor ($3,700) required for the establishment of this field trial, including field operations, data collection, extension, data analyses and reporting. An amount of $1,250 was requested for materials and supplies to cover costs of research supplies, fuel, crop inputs etc. There was a request for $350 each was requested for administration costs (see attached expenditure statement for details).

Expenditure information for *Demonstrating 4R Nitrogen Principles in Canola* at Scott, SK in 2017 (ADOPT 20160375).

	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total ($)
Salaries & Benefits				
Students	2,200			2,200
Postdoctoral / Research Associates				
Technical / Professional Assistants	1,500			1,500
Consultant Fees / Contractual Services				
Rental Costs				
Materials & Supplies	1,250			1,250
Project Travel				
Field Work				
Collaborations / consultations				
Other				
Field Day				
Administration	350			350
Miscellaneous	120			120
Total	**$5,420**			**$5,420**

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