FINAL PROJECT REPORT
Canola Agronomic Research Program (CARP)

The Annual Final Report should fully describe the work completed for the year and note the personnel involved. It should also note any deviations from the original plan and next and/or corrective steps as may be required if deviations are noted. The report should also provide an update on the status of the Project including forecasted date of completion. A complete statement of expenses should be included. In the event major changes are anticipated within the budget supporting notes along with a proposed budget should also be included. The report should also capture a complete summary of activity for the year.

Project Title: Canola Response and Minimizing Nitrogen Losses in Two-Pass Seeding-Fertilization Systems with Varying Placement Methods in Manitoba

Research Team Information

Lead Researchers:		
Name	***Institution***	***Expertise Added***
Mario Tenuta	University of Manitoba	PI, Greenhouse Gas Emissions
Research Team Members		
Name	***Institution***	***Expertise Added***
Kevin Baron	University of Manitoba	Agronomy, project management
Brad Sparling	University of Manitoba	Gas analyses
Mervin Bilous	University of Manitoba	Soil and plant analyses
Don Flaten	University of Manitoba	Agronomy

Project Start Date: April 1, 2016 **Project Completion Date: August 31, 2017**

Reporting Period: April 1, 2014 to March 31, 2017

CARP Project Number: 2016.25

Instructions: This Final Project Report shall be completed and submitted on or about March 31st of the fiscal year that the agreement is in effect (upon completion of the project). The Lead Researcher of the project in question shall complete and submit the report on behalf of his/her complete research team.

This Report is a means by which to provide a detailed account upon completion of the project.. Final project financial reporting should be provided at this time.

The following template is provided to assist you in completing this task. Please forward the completed document electronically to your appropriate CCC contact.

1. Date of Completion:

August 31, 2017

2. Status of Activity: (please check one)

_____ Ahead of Schedule _____ On Schedule _____ Behind Schedule __X___ Completed

Comment:

We have outstanding analysis for total N of grain and residue to determine total N uptake. These will be done once our new CNS analyzer is operational in the laboratory.

3. Completed actions, deliverables and results; any major issues or variance between planned and actual activities.

Introduction:

Starting in 2014 the Soil Ecology Lab at the University of Manitoba initiated a two-year project evaluating combinations of right placement and N source practices in canola, with specific emphasis on changes in source and placement that increase nitrogen use efficiency and reduce N_2O emissions. The project was funded jointly by KOCH and the Manitoba Canola Growers. KOCH has asked us to continue the project for another year and thus we propose to again partner with canola growers but this time under CARP for the 2016 growing season. The grower contribution allowed determination of treatments emitting least amounts of nitrous oxide (N_2O) gas, as well as qualitative assessment of ammonia (NH_3) emissions, an indirect source of N_2O to the atmosphere.

For this third year of the study, upon the request of KOCH and CARP, fall broadcast treatments were also included.

The overall project aimed to establish research sites in Manitoba to evaluate the agronomic and environmental performance of surface broadcast, shallow banding and deep banding methods of applying nitrogen fertilizer to canola. With support from Koch Agronomic Services and CARP, we will compare canola yield and nitrogen uptake for urea, agrotain treated urea and SuperU at the different placements. In addition, nitrous oxide (N_2O) emissions from urea and SuperU® as well as ammonia volatilization using dosimeters will be done.

The main objectives of the project across the three study years are:

1) Demonstrate and quantify changes in canola yield and agronomic nitrogen use efficiency that occur with surface broadcast, shallow banding and deep banding methods of applying nitrogen fertilizer in one-pass seeding operations of canola.

2) Quantify changes in canola yield and loss of fertilizer N associated with surface applications of urea in the fall, and whether Agrotain® or SuperU® can mitigate nitrogen losses associated with fall broadcasting of granular urea products.

3) Monitor nitrous oxide (N_2O) emissions from urea and SuperU® products applied in the spring using surface broadcast, shallow band and deep banding placement methods.

4) Determine cumulative seasonal N_2O emissions and N_2O intensity (N_2O produced per unit of canola produced) associated with alternative methods of applying urea and SuperU®.

Background:

The project provides quantitative information regarding the agronomic and environmental performance of enhanced efficiency fertilizer formulations when combined with recommended nitrogen application practices (e.g. deep banding vs. surface broadcast). Nitrous oxide (N_2O) emissions data collected from these soil fertility studies can also support the Nitrous Oxide Emissions Reduction Protocol (NERP) which seeks to compensate growers for adopting nitrogen management practices which mitigate N_2O emissions. The outcomes of the research project will yield critical information for growers to apply towards managing fertilizer nitrogen inputs and selecting appropriate strategies to increase the management intensity of canola production while simultaneously reducing the overall environmental footprint per unit of canola produced.

With increasing pressure to complete field operations in a timely manner and trend to using fertilizer custom applicators, a segment of growers in Western Canada are transitioning towards surface applications of granular urea; this represents a departure from the recommended practice of deep banding.

Surface applications of fertilizer or manure increase the risk that nitrogen will be lost through NH_3 volatilization, which occurs when urea hydrolysis elevates pH levels and increases the concentration of gaseous NH_3 around granules. When fertilizer granules are deep banded (3" plus) or buried in the soil, gaseous NH_3 formed around urea granules can be interconverted to ammonium (NH_4^+), a non-volatile ion which subsequently absorbs to negatively charged soil particles. While deep banding is a superior technique with respect to protecting nitrogen fertilizer from gaseous losses via NH_3 volatilization or N_2O emissions, the placement technique does require additional horsepower, can slow field operations at seeding time, and may also have undesirable effects on seedbed quality and moisture content.

As a compromise, we hypothesized shallow banding of urea or commercially available enhanced efficiency fertilizers (e.g. SuperU or Agrotain) may represent a means for growers to accelerate field operations yet still provide adequate protection against NH_3 volatilization and N_2O loss. Several commercially available enhanced efficiency fertilizers (e.g. Agrotain®, SuperU®) contain active ingredients that inhibit enzymatic or microbial processes that contribute to NH_3 (urease activity) or N_2O (nitrification) loss from soils.

Activities:
Sites were initially characterized for low baseline levels of residual soil nitrate to increase likelihood of a response to fertility treatments. Plots were layed out at each site to also have treatment combinations of source (urea, Agrotain, SuperU), placement (surface, shallow and deep mid-row banded) and rate (100 and 70% of soil test recommendation) for spring applications. Inclusion of the 70% rates was purposely to short nitrogen for the canola crop to determine treatments providing better nitrogen use efficiency evident as yield improvements. A 0N Control was also included for each site. The experimental design was treatment plots randomized within each of four blocks. A total of six trial sites were conducted with two sites being done in each of three years of the study (Fig. 1). In late 2015, with additional funding provided by Koch Fertilizer Canada and CARP, a series of fall fertilizer treatments (all broadcast) were initiated at field sites in Brunkild, and Domain, MB. The list of all treatments for each site is given in Table 1.

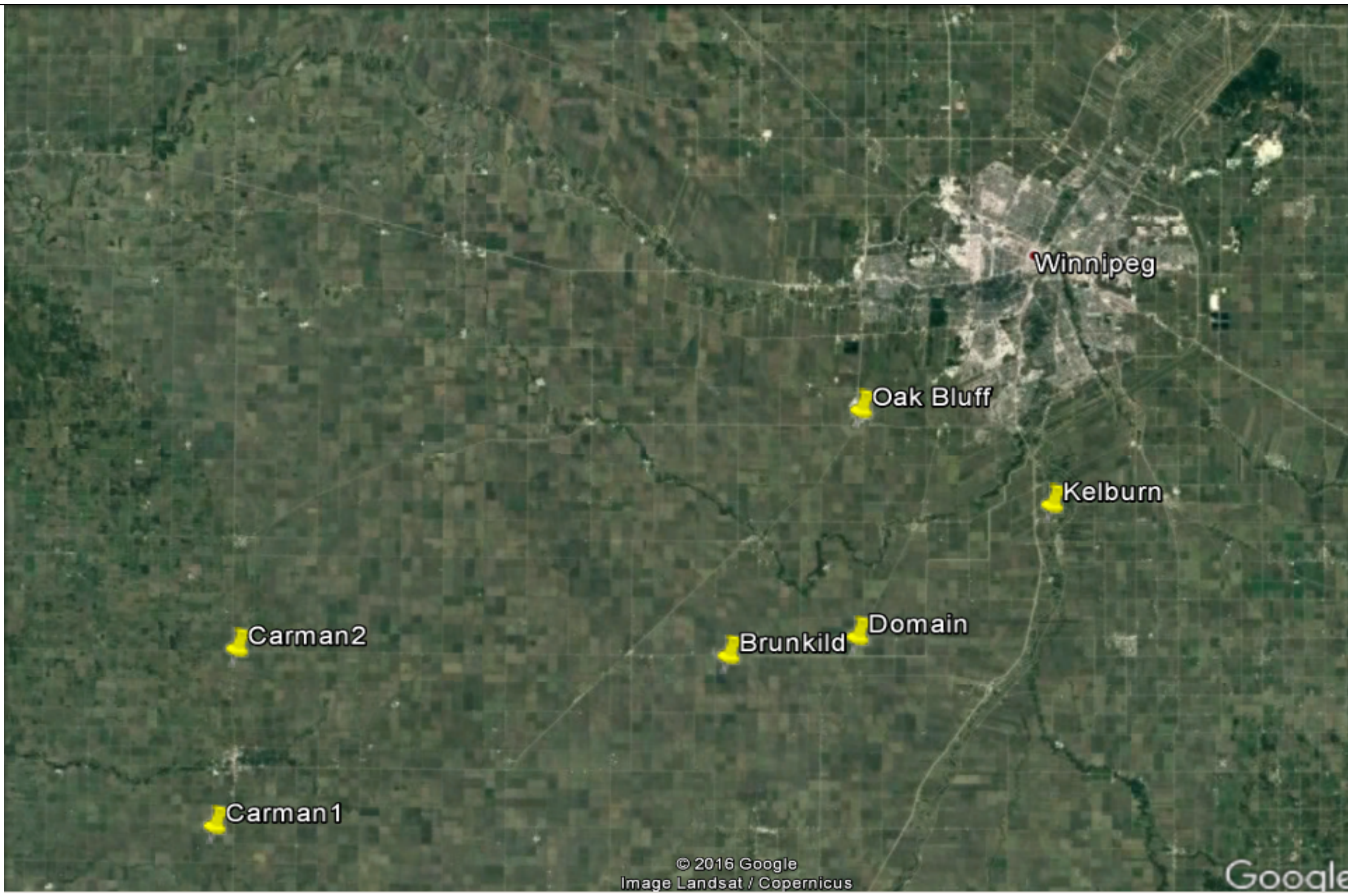

Figure 1. Location of trial sites for this study relative to the City of Winnipeg in Manitoba.

Table 1. Nitrogen fertility treatments established within field sites located at Brunkild and Domain, Manitoba for the 2016 study year. For 2014 and 2015, only the spring treatments were included. Treatments with check marks were monitored for N_2O and NH_3 emissions.

TREATMENT	TIMING	PRODUCT	RATE	PLACEME
A	FALL	0 N Control		
B	FALL	Urea	70%	Surface Bro
C	FALL	Urea	100%	Surface Bro
D	FALL	Agrotain®	70%	Surface Bro
E	FALL	Agrotain®	100%	Surface Bro
F	FALL	SuperU®	70%	Surface Bro
G	FALL	SuperU®	100%	Surface Bro

TREATMENT	TIMING	PRODUCT	RATE	PLACEME
1	SPRING	0 N Control		
2	SPRING	Urea	70%	Surface Bro
3	SPRING	Urea	100%	Surface Bro
4	SPRING	Agrotain®	70%	Surface Bro
5	SPRING	Agrotain®	100%	Surface Bro
6	SPRING	SuperU®	70%	Surface Bro
7	SPRING	SuperU®	100%	Surface Bro
8	SPRING	0 N Control		
9	SPRING	Urea	70%	Shallow Ban
10	SPRING	Urea	100%	Shallow Ban
11	SPRING	Agrotain®	70%	Shallow Ban
12	SPRING	Agrotain®	100%	Shallow Ban

In spring, plots of combinations of spring applied fertilizer (urea, SuperU, Agrotain) and placement methods (surface broadcast, shallow banded, deep banded) were carried out with seeding operations.

A summary of agronomic conditions for each of the trial sites in this study is given in Table 2.

Table 2. Summary of agronomic conditions (spring soil test residual nitrate, N rates, depth of placement, seeding dates and canola hybrid used) of the study. Carman1 and Kelburn is year 1, Oak Bluff and Carman2 is year 2, and Brunkild and Domain is year 3 (2016 cropping year) of the study.

	Carman1	Kelburn	Oak Bluff	Carman2	Brunkild	Domain
Residual N	56	97	100	91	68	28
100% N	98	85	80	80	95	129
70% N	69	60	56	56	67	91
Shallow	3/4"	3/4"	3/4"	1/2"	1"	3/4"
Deep	1.5"	2"	4.0"	2.5"	3.0"	3.5"
Seeding Date	26-May-14	04-Jun-14	27-May-15	27-May-15	17-May-16	09-May-16
Hybrid	Invigor L156H	DeKalb 73-45RR	Dekalb 73-45RR	Pioneer RR 45H29 w/LD	Invigor L140	Pioneer 46H75 w/LD

Note: Residual N is lbs nitrate-N/ac in spring. 100% and 70% N are rates in lbs N/ac applied.

Immediately following seeding, a subset of treatments were intensively sampled for greenhouse gas emissions (N_2O) using the static-vented chamber method and ammonia (NH_3) volatilization losses using dosimeter tubes. For emission of nitrous oxide (N_2O) in particular, sampling crews of 2-3 people travelled to each of the field sites ~ 30 sampling days between seeding and harvest. The intensive sampling of greenhouse gases and subsequent analysis of samples by gas chromatography in the Soil Ecology Laboratory was necessary to capture the spatial and temporal variability in N_2O emissions driven by environmental variables such as soil moisture and temperature. Images of field activities are given in Figure 2.

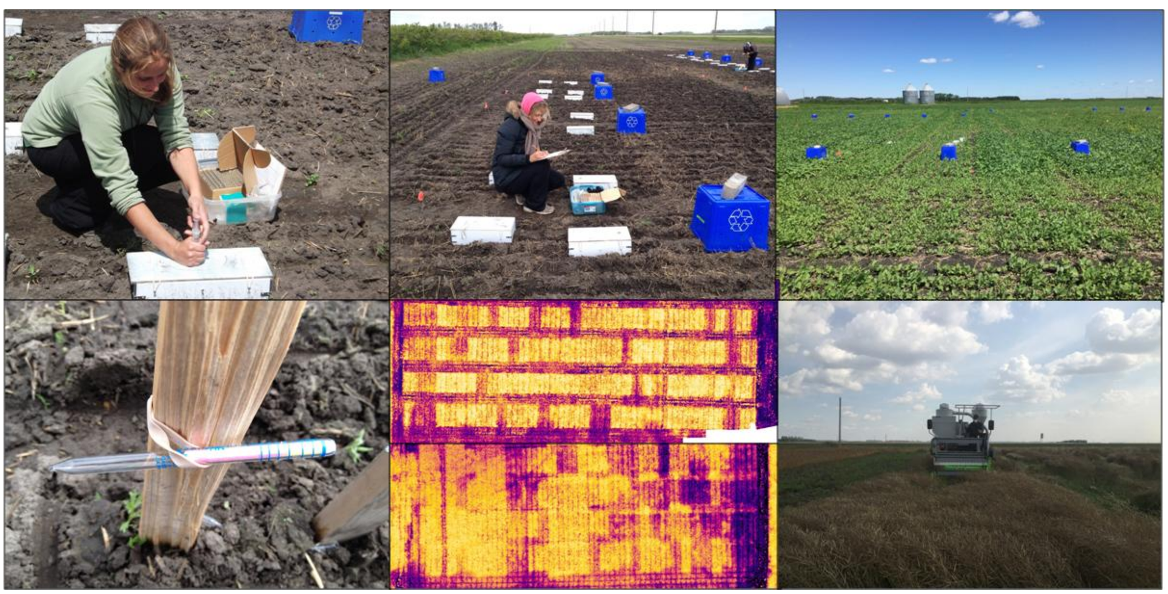

Figure 2. Images of field activities in the study. Clockwise from upper right; sampling N_2O from chamber following planting, sampling for ammonia loses with dosimeter boxes (blue boxes) visible, after emergence with dosimeter boxes and some chamber evident, up close of dosimeter under a blue box suspended above soil by attachment to a wooden stake, NDVI images of both sites, and harvest using a plot combine.

Aerial images of the two sites for the 2016 cropping year is given in Figure 3.

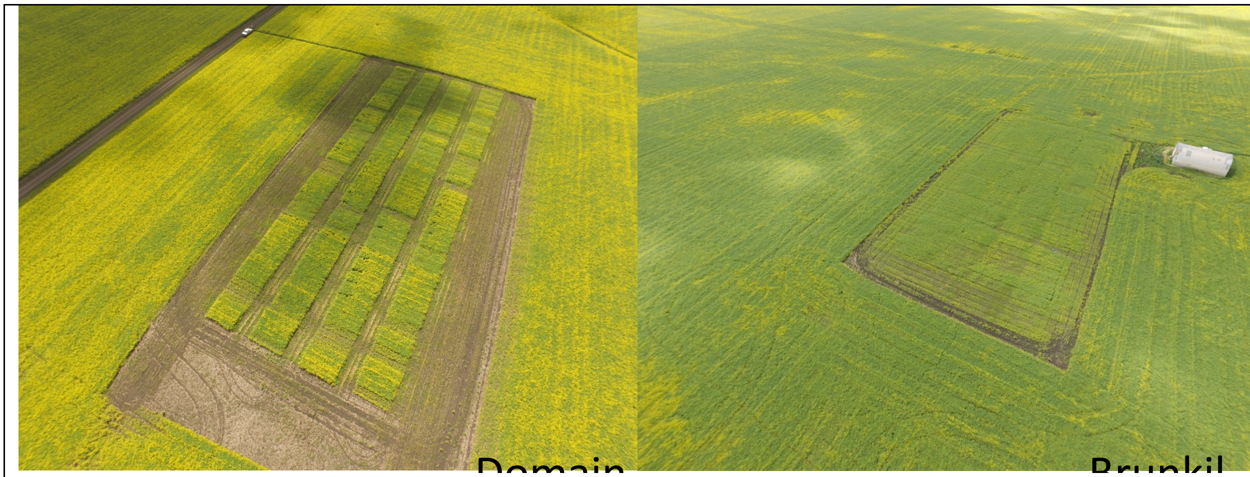

Figure 3. Aerial images of the Domain and Brunkild study sites in the 2016 cropping year of this study. The Domain site was mowed around plots to allow for tours.

Beyond sampling and collection of greenhouse gases, these same soil fertility trials given above were also evaluated for soil nitrogen dynamics and agronomic nitrogen use efficiency which included determinations of the following;

- Nitrogen Availability Characteristics: At 2, 4 and 6 weeks following spring fertilizer application, a subset of plots (Control, as well as urea and SuperU placements) were sampled to monitor ammonium and nitrate levels,
- Nitrogen Uptake: At harvest, subsamples of grain and straw were be obtained from all plots to estimate total above ground nitrogen uptake and apparent nitrogen recovery of fertilizer nitrogen,
- Residual inorganic N: Following harvest, soils were sampled to 0-24” to determine residual nitrate and ammonium in the soil.

Each year of the study we also conducted tours at the sites specifically for staff of KOCH Agronomic Services and a general public tour as part of the annual University of Manitoba and Manitoba Agriculture 4R Field Tour headed by Dr. Tenuta. Dr. Tenuta also has shown results of the study at several grower invited talks. MCGA and the CARP program were acknowledged in our outreach activities. Unfortunately, I did not know or realize SaskCanola was a sponsor of the project through the CARP program in 2016 and did not acknowledge the organization. Dr. Tenuta apologies for the omission of acknowledgement of SaskCanola. Moving forward it will be insured SaskCanola and MCGA and the CARP program are all acknowlwedged in outreach activities and publications.

Following harvest and field operations in late Aug/Sept of each year, members of the soil ecology lab focused activities towards laboratory analysis of greenhouse gas, plant and soil samples collected and stored throughout the growing season. Processing samples, compiling flux and statistical analysis of data sets was done. We still need to analyze the 2016 grain and residue samples for total N. Our new CNS analyzer is presently being commissioned. This data will be required to report total N uptake by treatments for the peer-review publication we are presently working on.

Results:

N_2O Emissions

Not surprisingly, N_2O emissions were consistently higher for treatments with fertilizer N added than the

Control. Over the three growing seasons of the study, N_2O emissions from urea varied with placement and site year. At both sites in 2014, Deep Banding of urea emitted less N_2O than other placements with shallow placement emitting noticeably more at the Kelburn location (Figure 4 and 5, Table 2). In 2015, N_2O emissions were noticeably higher for shallow placement of urea at the Carman location (Figure 6 and 7, Table 3). In 2016, there was a clear trend for surface placement to have least N_2O emissions and shallow placement the highest at the two locations (Figure 8 and 9, Table 4).

Consistently for all site years, placement treatments of SuperU emitted less N_2O than Urea of the same placement (Figures 4 to 9, Tables 2 to 4). As a result, the range in site year cumulative emissions between SuperU placement treatments was less than within Urea placements.

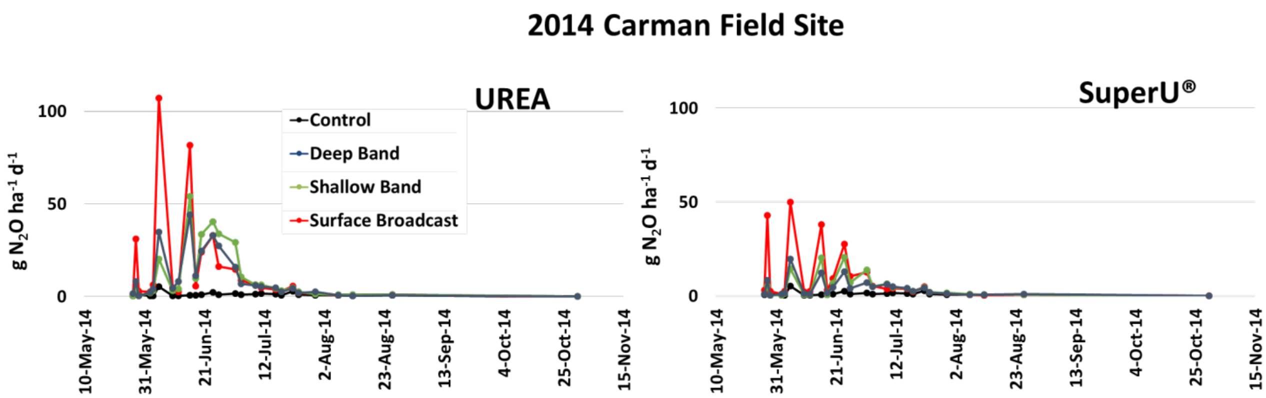

Figure 4. Daily emission of nitrous oxide (N_2O) from Carman field site in 2014. For each nitrogen sources (Urea vs SuperU) emissions are reported for surface broadcast, shallow banding and deep banding placement methods. The same 0N control is utilized for both Urea and SuperU graphs.

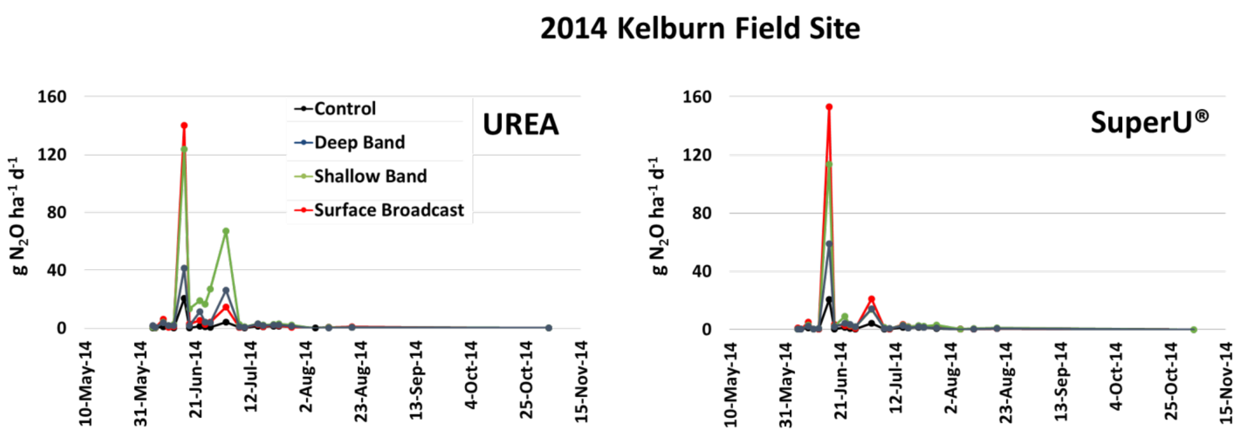

Figure 5. Daily emission of nitrous oxide (N_2O) from Kelburn field site in 2014. For each nitrogen source (Urea vs SuperU) emissions are reported for surface broadcast, shallow banding and deep banding placement methods. The same 0N control is utilized for both Urea and SuperU graphs.

Table 2. Canola yield and cumulative N_2O emissions for intensively monitored nitrogen fertility treatments at Kelburn and Carman over the 2014 growing season.

		Kelburn				
Treatment	Placement	Yield bu/ac	SD	Letter	Cumulative N_2O Emissions kg N_2O-N ha^{-1}	Yield bu/ac
Check		28.1	3.1	C	0.141	26.4
Urea	Surface Broadcast	50.6	3.6	AB	0.576	57.0
Urea	Shallow Banding	44.6	6.7	B	1.093	43.1
Urea	Deep Banding	55.4	6.5	A	0.422	46.3
SuperU®	Surface Broadcast	49.2	5.1	AB	0.684	56.7

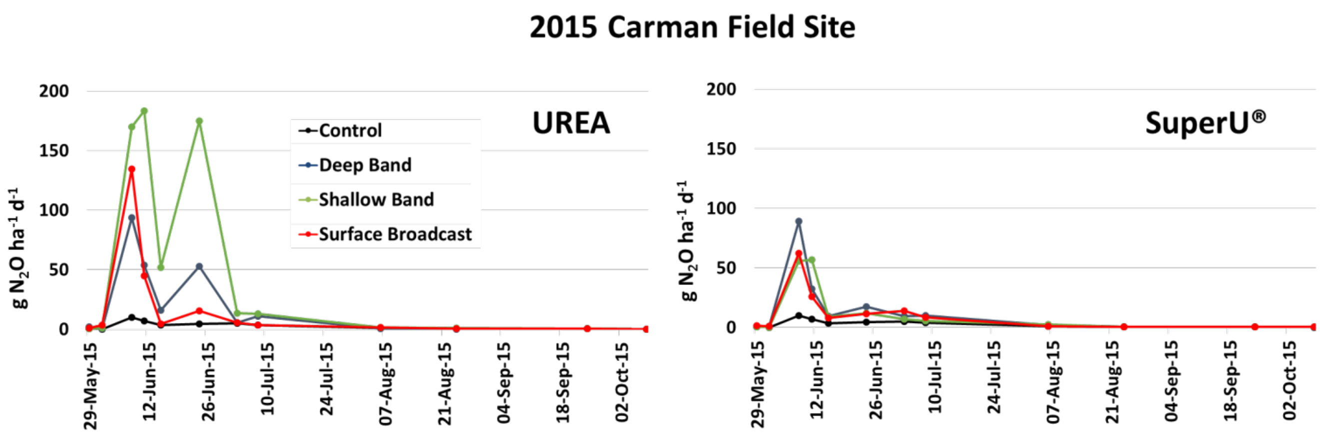

Figure 6. Daily emission of nitrous oxide (N_2O) from Carman field site in 2015. For each nitrogen source (Urea vs SuperU) emissions are reported for surface broadcast, shallow banding and deep banding placement methods. The same 0N control is utilized for both Urea and SuperU graphs.

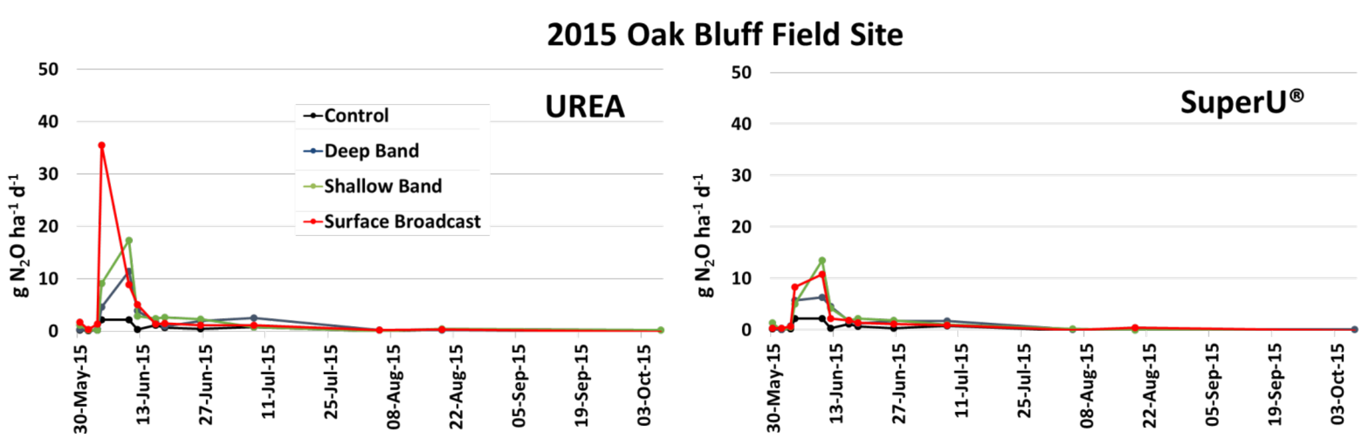

Figure 7. Daily emission of nitrous oxide (N_2O) from Oak Bluff field site in 2015. For each nitrogen source (Urea vs SuperU) emissions are reported for surface broadcast, shallow banding and deep banding placement methods. The same 0N control is utilized for both Urea and SuperU graphs.

Table 3. Canola yield and cumulative N_2O emissions for intensively monitored nitrogen fertility treatments at Oak Bluff and Carman over the 2015 growing season.

		Oak Bluff					
		Yield bu/ac	SD	Letter	Cumulative N_2O Emissions kg N_2O-N ha^{-1}	Yield bu/ac	!
Treatment	Placement						
Check		44.7	4.1	B	0.045	20.9	5
Urea	Surface Broadcast	54.9	5.7	A	0.231	23.7	8
Urea	Shallow Banding	50.7	2.9	A	0.187	27.9	9
Urea	Deep Banding	54.1	3.5	A	0.161	24.6	5
SuperU®	Surface Broadcast	53.4	2.9	A	0.129	24.0	(

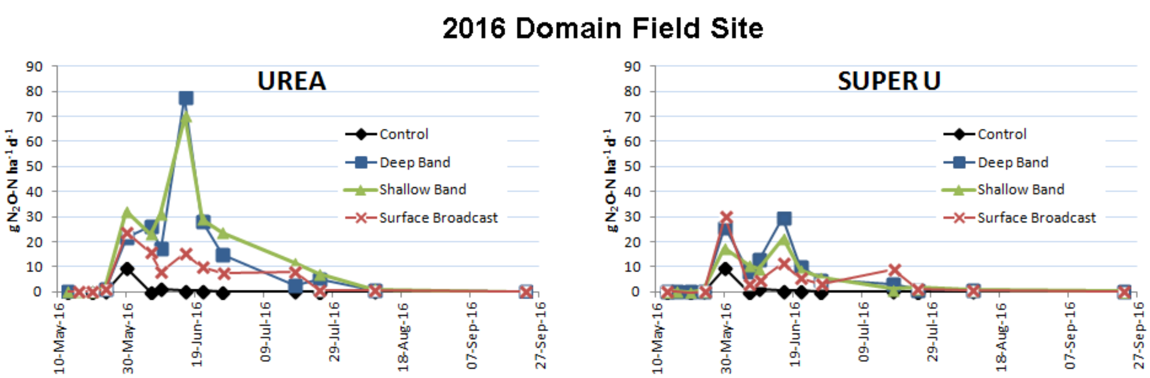

Figure 8. Daily emission of nitrous oxide (N_2O) from the Domain field site in 2016. For each nitrogen source (Urea vs SuperU) emissions are reported for surface broadcast, shallow banding and deep banding placement methods. The same 0N control is utilized for both Urea and SuperU graphs.

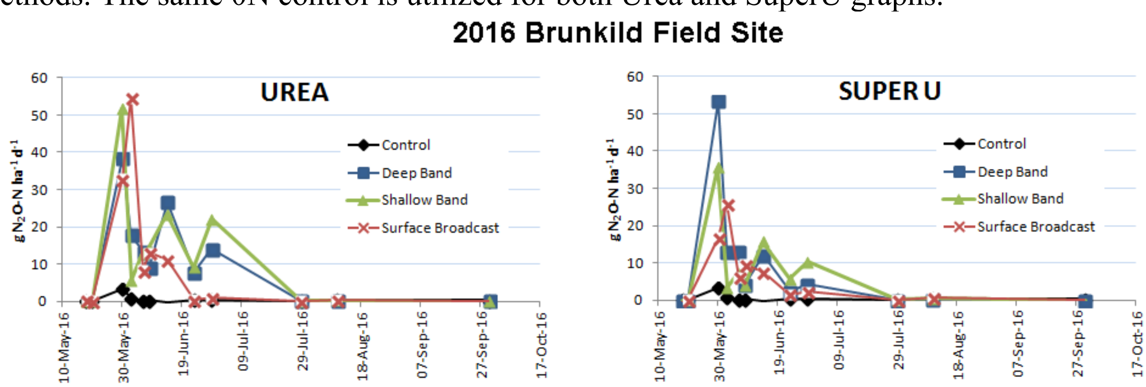

Figure 9. Daily emission of nitrous oxide (N_2O) from the Brunkild field site in 2016. For each nitrogen source (Urea vs SuperU) emissions are reported for surface broadcast, shallow banding and deep banding placement methods. The same 0N control is utilized for both Urea and SuperU graphs.

Table 4. Canola yield and cumulative N_2O emissions for intensively monitored nitrogen fertility treatments at Domain and Brunkild over the 2016 growing season.

		Domain				Brunkild			
Treatment	Placement	Yield bu/ac	SD	letter	Cumulative N_2O Emissions kg N_2O-N ha^{-1}	Yield bu/ac	SD	letter	Cumulative N_2O Emissions Kg N_2O-N ha^{-1}
Check		15.3	2.4	C	0.086	21.2	2.4	B	0.061
Urea	Surface Broadcast	43.7	1.5	B	0.662	56.0	2.8	A	0.596
Urea	Shallow Banding	47.5	0.5	AB	1.660	56.5	2.0	A	1.107
Urea	Deep Banding	48.6	1.9	AB	1.295	63.7	2.6	A	0.914
SuperU®	Surface Broadcast	45.8	1.8	B	0.523	58.8	4.2	A	0.386
SuperU®	Shallow Banding	50.8	1.5	A	0.537	60.0	3.5	A	0.647
SuperU®	Deep Banding	47.8	1.8	AB	0.649	56.9	5.8	A	0.654
		LSD	**5.0**						**10.5**

NH_3 Emissions

In 2015 and 2016 we used passive NH_3 absorbers (dosimeter tubes) to qualify emissions of the gas from Urea and SuperU placement treatments for the 100% recommended N rate. The tubes indicated volatilization was greater for the Carman site year in 2015 than the other site years (Figure 10 to 14). For the Carman 2015 site year, there was a clear pattern of decreasing NH_3 loss in order of, surface > shallow > deep = control (Figure 10). For the other three site years, there was a clear pattern for surface placement increasing NH_3 loss compared to Shallow and Deep placements. Deep placement consistently emitted the same amount of NH_3 as the Control. The benefit of SuperU in reducing NH_3 was evident for the Carman site year in 2015 that had the most vigorous loses of the gas, loss was reduced with SuperU the Urea for surface placement (Figure 10). Where NH_3 loss ceased after 1 month with Urea surface placement, SuperU at the same placement continued to evolve the gas.

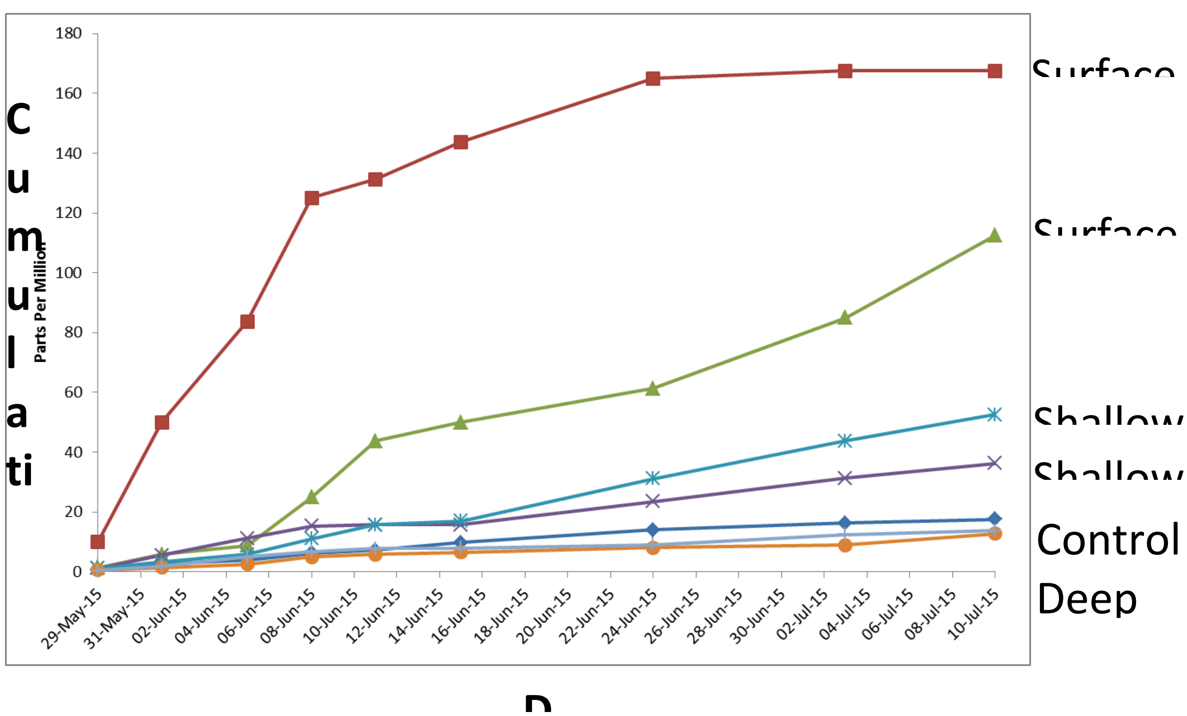

Figure 10. Ammonia recovery from dosimeter tubes for the Carman site in 2015.

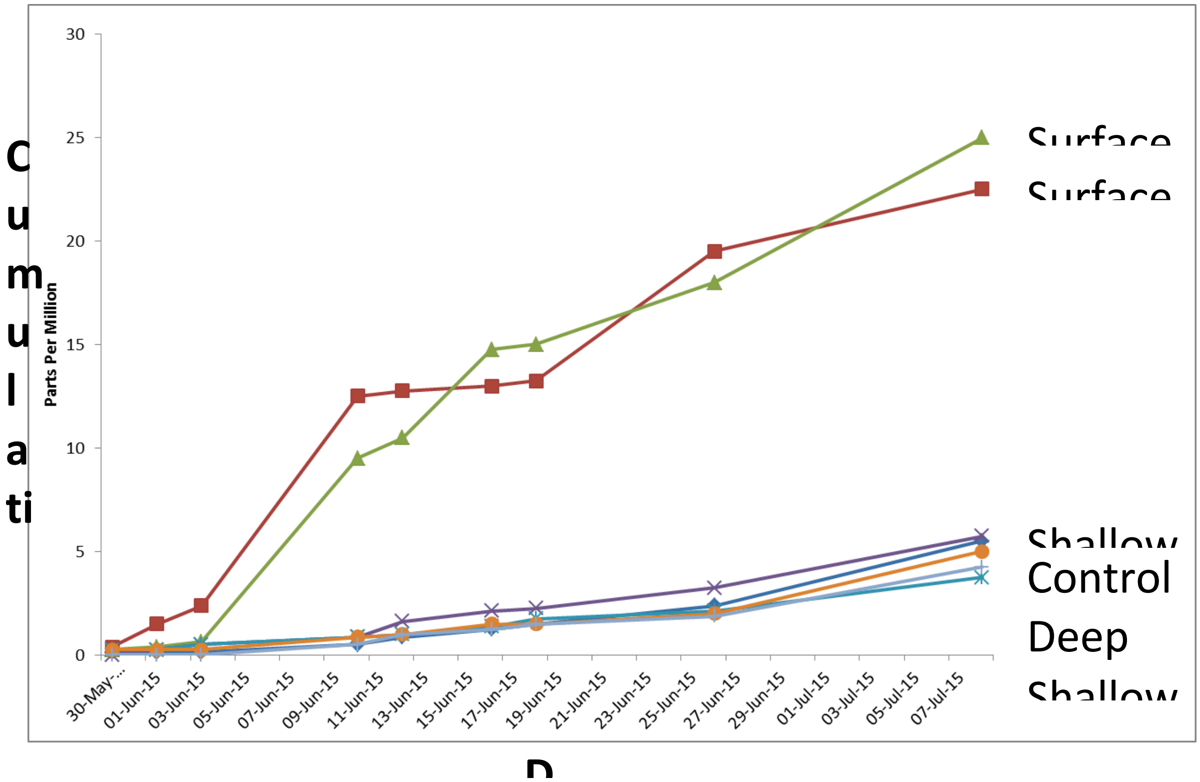

Figure 11. Ammonia recovery from dosimeter tubes for the Oak Bluff site in 2015.

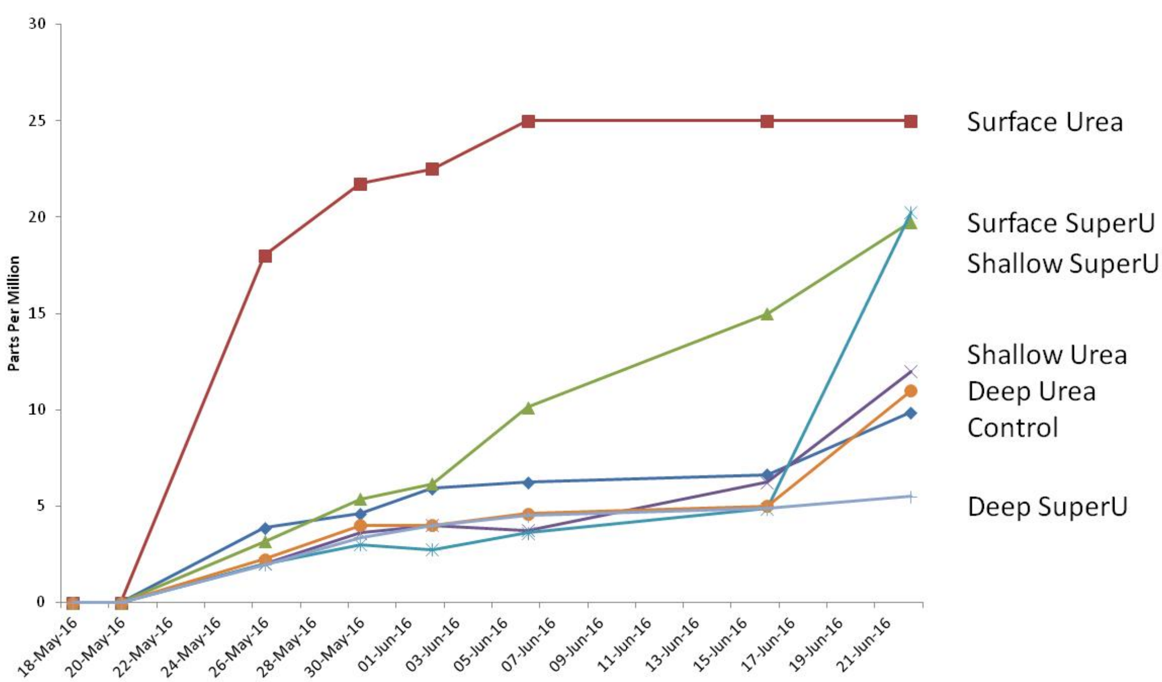

Figure 12. Ammonia recovery from dosimeter tubes for the Brunkild site in 2016. Treatments were applied at planting (spring).

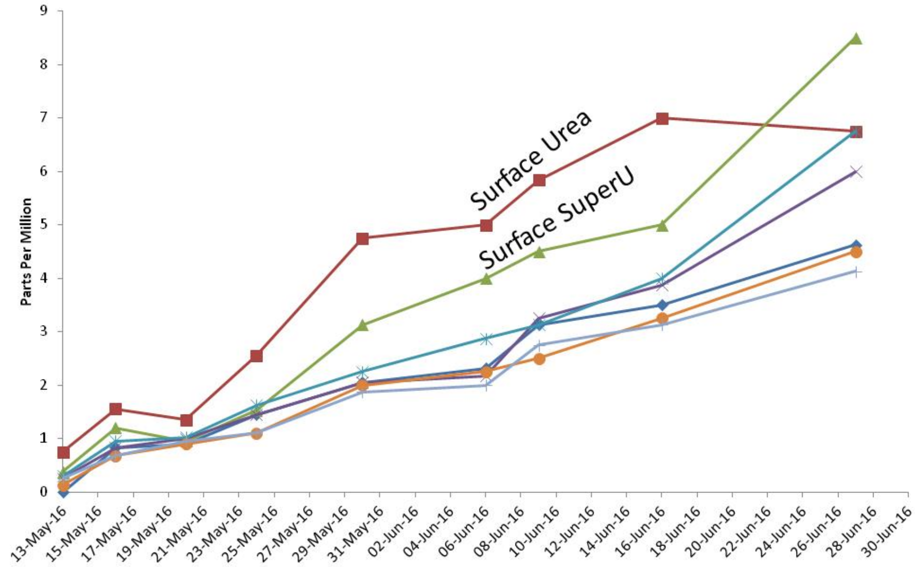

Figure 13. Ammonia recovery from dosimeter tubes for the Domain site in 2016. Treatments were applied at planting (spring).

Yield

Yield at the 100% recommended N rate was not greatly affected by the placement or SuperU treatments that gas emissions were monitored above. For 2014 at both sites, there was a pattern for Shallow placement to have lower yields than other placement (Table 2). For the Domain iste year in 2016, Surface placement had the lowest yield (Table 4). It is not surprising that yield was not affected by the treatments as N rates were at provincial guideline recommendation based on soil test. N rates would be above or at the top end of the N response curve for yield with loses of N as N_2O and NH_3 not greatly affecting crop N availability.

Yields for each of the trials across all treatments (N addition levels, sources and placements) were comparable to that a grower would expect except for the Carman site in 2015 (Carman2; Figure 14). The Carman 2015 site had poor crop emergence and therefore was removed from subsequent statistical analyses. There was a good response to N addition rate for yield across the sites in order 100% > 70% > Conrol (0N, Figure 15). This indicates the 70% N rate did short the crop of N as we had hoped. That the 70% rate was short in N, it provides a good basis to then examine the impact of treatments on yield and nitrogen use efficiency.

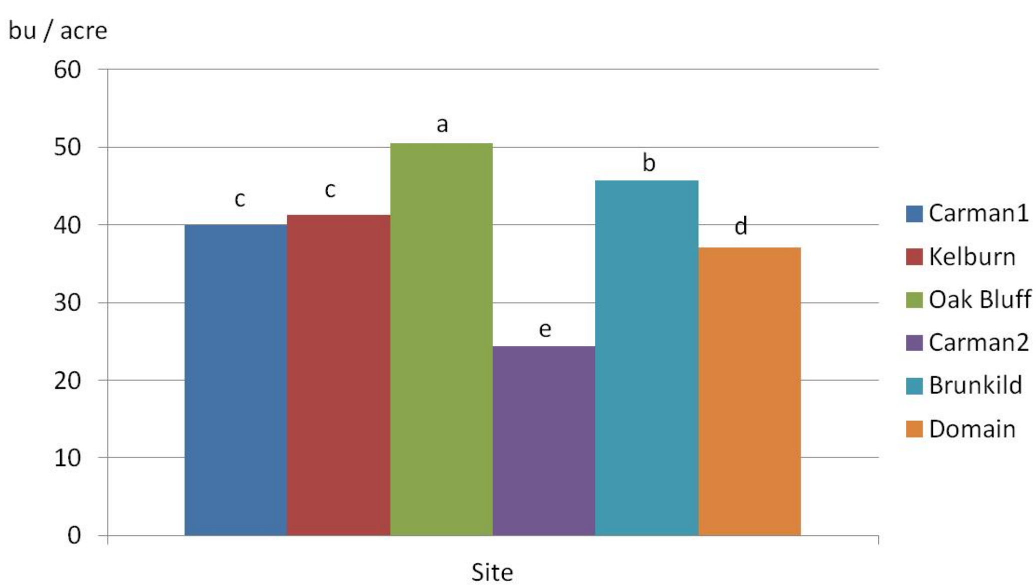

Figure 14. Yield of canola for each of the six trial sites. Mean grain yield as columns topped by different letters

are significantly different $P < 0.05$.

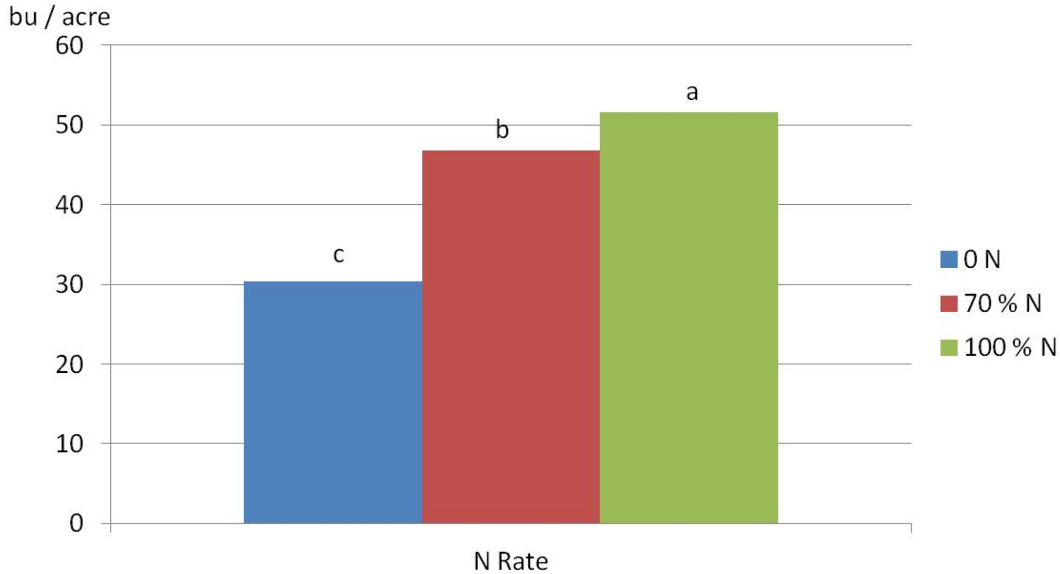

Figure 15. Yield of canola across five of the six trial sites in response to N addition as a percentage of recommended rate. Results for the Carman 2015 site (Carman2) were not included as that site had poor emergence. Mean grain yield as columns topped by different letters are significantly different $P < 0.05$.

For the 70% N rate, banding increased yield compared to surface application (Figure 16). There were no statistical difference between banding depths, though deep banding had numerically one bu/ac more yield than shallow banding. There was no effect of N source on yield at the 70% rate. For the 100% rate, the effect of banding on yield for N treatments was not evident (Figure 17). As mentioned above, this makes sense because at 100% N rate, N was supplied to insure minor changes in N availability would not affect yield (ie., N rate in non-responsive range of the N rate response curve). In addition, not surprising, there was no effect of N source on yield at the 100% rate.

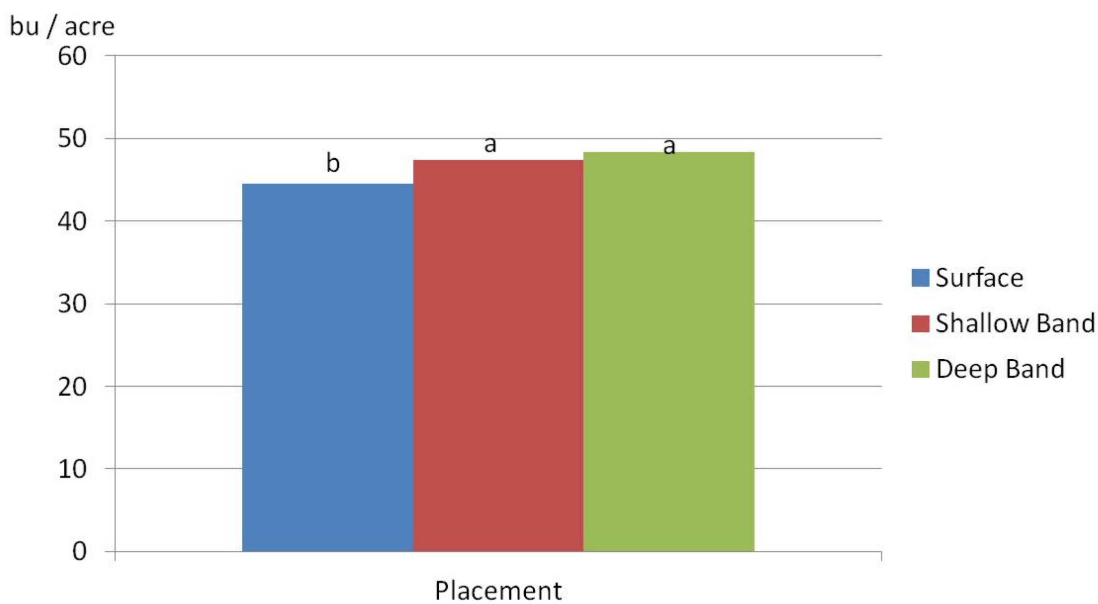

Figure 16. Yield of canola across five of the six trial sites in response to N addition placement at the 70% recommended N rate. Date for one site (Carman2) is not included as that site had poor emergence. Mean grain yield as columns topped by different letters are significantly different $P < 0.05$.

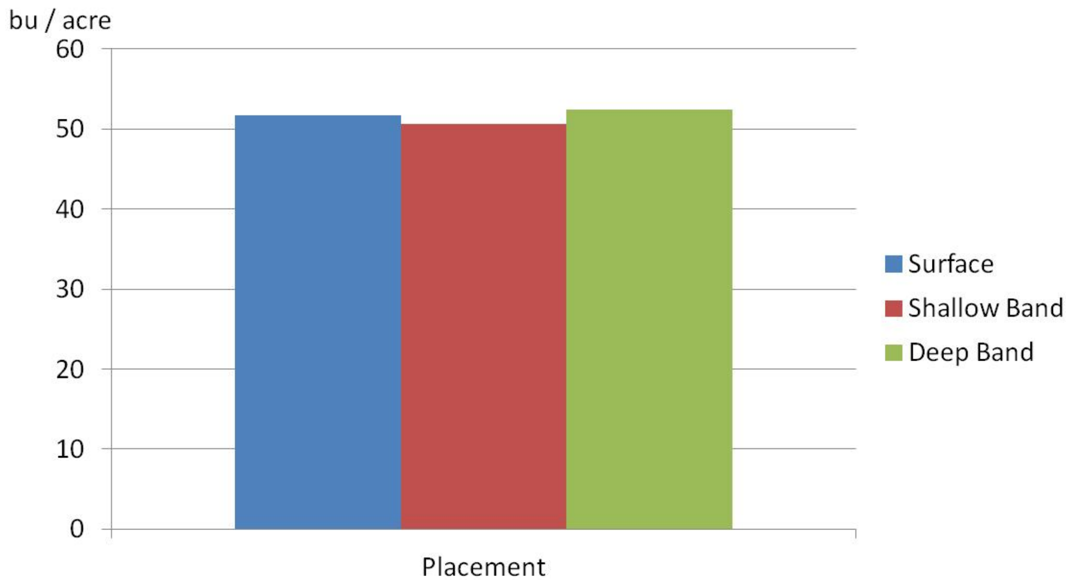

Figure 17. Yield of canola across five of the six trial sites in response to N addition placement at the 100% recommended N rate. Date for one site (Carman2) is not included as that site had poor emergence. Mean grain yield as columns topped by different letters are significantly different $P < 0.05$.

For the 2016 cropping year, the study had additional treatments in fall 2015 of surface application of N sources (urea, Agrotain and SuperU) to compare yields to surface application of the same N sources in spring 2016. The response in yield to N sources was not significant. However, there was a big effect on yield across N sources by time of application, yields were depressed by 13 bu/ac with fall surface than spring surface application to the two sites in 2016 (Figure 18).

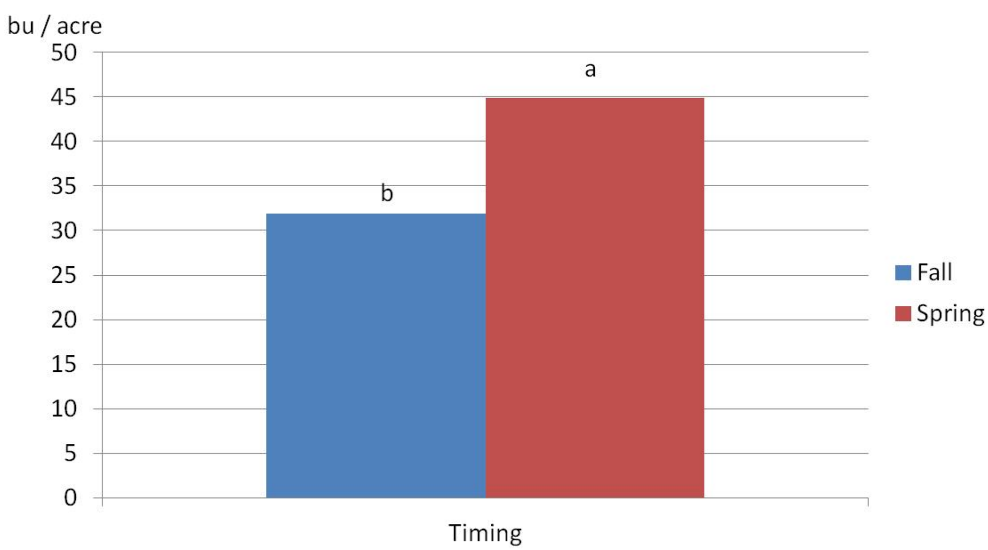

Figure 18. Yield of canola across two trial sites for the 2016 cropping year in response to fall and spring surface application of N sources (urea, Agrotain and SuperU) at the 100% recommended N rate. Mean grain yield as columns topped by different letters are significantly different $P < 0.05$.

4. Significant Accomplishments

- we completed a 3 year study with 6 site years in the Red River Valley area of Manitoba. The results here are applicable the types of soils in that valley, clay and imperfectly drained,

- application of N at 70% of Manitoba Provincial recommendation based on soil test allowed treatment effects for spring placement treatments to be evident,

- the N source products examined did not affect canola yield,

- for the spring application timing, surface placement had lower yields (3 to 5 bu/ac) than shallow or deep banding,

- fall surface application of granular urea and enhanced efficiency fertilizer products with urease and nitrification inhibitor at 100% of Provincial recommendation rates had lower yield (13 bu/ac) than spring surface applications of the products,

- across the whole study, there was no clear pattern of a placement effect on N_2O emissions. At some sites subsurface placement decreased emissions while for some others, increased emissions,

- granular urea with urease and nitrification inhibitor (SuperU) did consistently reduce N_2O emissions from ¼ to ¾ of that for regular granular urea,

- surface application of granular urea consistently had greater NH_3 emissions than subsurface placement,

- for surface application, granular urea with urease and nitrification inhibitor (SuperU) consistently reduced or delayed NH_3 loses compared to regular urea, and

- the results verify past research that subsurface banding of granular urea improves yields compared to surface application. As well, surface application in fall is way less efficient than spring application. There was no benefit to yield in using granular urea with urease alone or urease plus nitrification inhibitors to yield. However, urease plus nitrification inhibitor did reduce N_2O and NH_3 loses for surface applied granular urea.

5. Research and Action Plans

Many growers opt for surface application of granular N fertilizer for a number of reasons: use of custom application services, ease of application when soil is wet, and lack of ability of some seeders to side or mid-row band large N rates. Further, growers often shallow band granular urea to limit seed row disturbance with canola that is shallow seeded and that deep placement slows seeding. Growers also use fall application of N fertilizers for many of the reasons above, to spread workload and to capture lower N prices. Further, greenhouse gas loses of fertilizer N is being scrutinized and expected to be reduced in time. Thus research involving placement and timing of N application in canola is extremely relevant to growers.

The following recommendations for further research and action plans is recommended:

- that similar studies concentrating on N_2O and NH_3 loses be conducted on soil in the Prairies of lighter texture and lower precipitation. KOCH Agronomic Services has completed a cross Prairie study using similar treatments but did not conduct N loss measurements,

- that future studies include at least an N rate that shorts availability of the nutrient to pickup treatment effects on N availability. In this study, 70% or Manitoba Provincial recommendation was useful,

- that studies be done including fall subsurface application of enhanced efficiency N fertilizers,

- that methods to determine actual NH_3 loses rather than qualitative assessment be done. This is however costly but useful because N_2O and NH_3 loses can tradeoff where a treatment reduces one but increases the other,

- that research be conducted examining in-season application of N to canola. Some growers are using in-season application. For soils prone to N loses such as with good drainage or prone to fall and spring water-logging, in-season N application may reduce loses and improve yields, and

- examine methods assessing the N status of the canola crops using spectral reflectance methods such as NDVI (normalized difference vegetation index) and NDRE (red edge) need to be examined to provide tools to determine in-season N rates. Inclusion of commercially available sensors such as GreenSeeker and Crop Circle that some growers and crop consultants are using is also advised.

6. Final Project Budget and Financial Reporting

Please refer to University of Manitoba financial report for the CARP funding for this project 2016/17 provided directly from the Office of Research. The University account for the CARP funding was 319084-312800-2000. The industry matching funding by KOCH Agronomic Services according to the original proposal was provided to this project in 2016/17 under the University account 316591-312800-2000. A financial report for the industry contribution is available upon request.

Please forward an electronic copy of this completed document to:

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