2018

Annual Report

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www.ecrf.ca

Table of Contents

Introduction

The East Central Research Foundation (ECRF) is a non-profit, producer directed research organization which works closely with various levels of government, commodity groups, private industry and producers. Founded in 1996, the mission of ECRF is to promote profitable and sustainable agricultural practices through applied research and technology transfer to the agricultural industry.

In 2013, ECRF signed a memorandum of understanding with Parkland College that allow the partners to jointly conduct applied field crop research in the Yorkton area. The City of Yorkton renewed the lease with ECRF/Parkland College providing a 3 year lease of land (108 acres) located just a half mile South of the city on York Lake road and another 60 acre parcel located just West of the city. We will be entering the 6^{th} year of leased land provided by the City of Yorkton.

Parkland College is the first regional college in Saskatchewan to undertake an applied research program. Parkland College is thrilled to be involved in applied research because it fits with one of their mandates to “serve regional economic development”. The partnership also provides the college with a location and equipment to use for training students. Both partners benefit from each other’s expertise and connections. ECRF and Parkland College also have access to different funding sources which is another strength of the partnership.

ECRF Board of Directors

ECRF is led by a 6 member Board of Directors consisting of producers and industry stakeholders who volunteer their time and provide guidance to the organization. Residing all across East-central Saskatchewan, ECRF Directors are dedicated to the betterment of the agricultural community as a whole.
Unfortunately, Wayne Barsby and Ken Waldherr passed away in 2018. Both were long time board member of ECRF. Wayne and Ken both dedicated their time to the ECRF board for 10 years. Glen Blakely resigned from the board in 2018 after serving for 22 years. Glen started the formation of ECRF in the fall of 1995 working with the 4 ADD boards. Glen was the chairperson on and off for the last 22 years.

The 2018 ECRF Directors are:

- Blair Cherneski (Chairperson) - Goodeve, SK
- Gwen Machnee (Vice Chairperson) - Yorkton, SK - Co-ordinator for University and Applied Research-Parkland College
- Fred Phillips - Yorkton, SK
- Dale Peterson - Norquay, SK

Ken Waldherr Wayne Barsby Glen Blakley

Ex-Officio

- Charlotte Ward - Regional Forage Specialist - Saskatchewan Agriculture
- Lyndon Hicks - Regional Crops Specialist - Saskatchewan Agriculture

Staff

Heather Sorestad transitioned from summer student to research assistant in the fall of 2018.

- Mike Hall - Research Coordinator
- Heather Sorestad - Research Assistant
- Kurtis Peterson - Administrator
- Clark Anderson - "On Call" Equipment Technician
- Brendan Dzuba - Summer Student

Agri-Arm

The Saskatchewan Agri-ARM (Agriculture Applied Research Management) program connects eight regional, applied research and demonstration sites into a province-wide network. Each site is organized as a non-profit organization, and is led by volunteer Boards of Directors, generally comprised of producers in their respective areas.

Each site receives base-funding from the Saskatchewan Ministry of Agriculture to assist with operating and infrastructure costs, with project-based funding sought after through various government funding programs, producer / commodity groups and industry stakeholders. Agri-ARM provides a forum where government, producers, researchers and industry can partner on provincial and regional projects.

The eight Agri-ARM sites found throughout Saskatchewan include:
- Conservation Learning Centre (**CLC**), Prince Albert
- East Central Research Foundation (**ECRF**), Yorkton
- Indian Head Agricultural Research Foundation (**IHARF**), Indian Head
- Irrigation Crop Diversification Corporation (**ICDC**), Outlook
- Northeast Agriculture Research Foundation (**NARF**), Melfort
- South East Research Farm (**SERF**), Redvers
- Western Applied Research Corporation (**WARC**), Scott
- Wheatland Conservation Area (**WCA**), Swift Current

For more information on Agri-ARM visit http://Agri-ARM.ca/

Research and Statistical analysis

Unless otherwise stated all trials are small plot research. Plot size is typically either 11 or 22 feet wide and 30 feet long. The trials are seeded with a 10 foot wide SeedMaster drill which has 12inch row spacing. The middle 4 rows of plots are harvested using a small plot Wintersteiger combine. In the case for forage trials, the middle 4 rows of each plot are harvested with a small plot forage harvester.

Treatments are replicated and randomized throughout the field so that data may be analyzed. If a treatment is seeded in multiple plots throughout the field, experience tells us we are unlikely to obtain the same yield for each of these plots. This is the result of experimental variation or variation within the trial location. This variation must be taken into consideration before the difference between two treatment means can be considered "significantly" different. This is accomplished through proper trial design and statistical analysis.

Trials are typically set up as Randomized Complete Blocks, Factorial or Split-Plot designs and replicated 4 times. This allows for an analysis of variance. If the analysis of variance finds treatments to differ statistically then means are separated by calculating the least squares difference (lsd). For example, if the lsd for a particular treatment comparison is 5 bu/ac then treatment means must differ more than 5 bu/ac from each other to be considered significantly (statically) different. In this example, treatment means that do not differ more than 5 bu/ac are not considered to be significantly different. All data in our trials must meet or exceed the 5% level of significance in order to be considered significantly different. In other words, the chance of concluding there is a significant difference between treatments when in reality there is not, must be less than 1 out of 20. For the sake of simplicity, treatment means which are not significantly different from each other will be followed by the same letter.

Extension Events

ECRF/Parkland College Farm Tour July 12, 2018 (attendance ~80)

Speaking engagements

- January 2018 - Crop Production Show - Soybeans: Expectations vs Results (70 in attendance)
- February 2018- Parish and Heimbecker - Wheat Protein (100-150 in attendance)
- July 2018 - WARC Field Day – Increasing Wheat Protein through Applications of Post Anthesis Nitrogen (200 in attendance)
- November 2018 - Canadian Association of Farm Advisors – ECRF Who Are We and What Do We Do? (15 in attendance)

2018 Videos- Website

- Farm Tour Promo 2018- (78)
- 4R Fall Applied Urea to Spring Wheat 2018 (571)
- Oat Vigour Improves with Larger Seed Size 2018 (107)
- Strategies for Managing Feed and Malt Barley 2017/2018 (133)
- Control of Glyphosate Resistant Canola in Glyphosate Resistant Soybeans 2018 (97)
- Increasing Wheat Protein with a Post Emergent Application of UAN 2018 (158)
- Inoculant Options for Faba Beans 2015-2017 (50)
- Oats Busting Bins and Making the Grade (83)
- Wheat Profitability Study 2017:18 (145)

- Are Farmers Applying Enough Nitrogen and Phosphorus to Flax 2016 to 2018?

2017 Videos- Website

- An Introduction to ECRF- (97)
- Demonstrating 4R Nitrogen Principles in Canola the benefit of Agrotain and SuperU - (140) (WARC linked to this video from their website)
- Wheat Profitability 2017-(53)
- Hastening Maturity of Oats without Pre-Harvest Glyphosate 2017- (125)
- Soybean Expectations versus Results 2013-2017- (50)
- Strategies for Management of Feed and Malt Barley 2017- (57)
- Effect of Seeding Date, Seeding Rate and Seed Treatment on Winter Wheat - (96)
- Importance of Dual Inoculation and Seeding Soybeans into Warm Soil - (66)

2016 Videos- Website

- Lentil Production in the Black Soil Zone - (177)
- Effect of Nozzle Selection and Boom Height on Fusarium Head Blight - (87)
- Effect of Preceding Legume Crop on Spring Wheat – (45)
- Effect of Fall Cultivation on Soybeans Seeded Early, Mid, and Late May - (58)
- Effect of Variety, Nitrogen Rate ad Seeding Rate on Forage Corn - (55)
- Effect of Variety, and Nitrogen Rate on Oat Yield and Test Weight - (180)
- Flax Response to Nitrogen and Phosphorus - (112)
- Evaluating Inoculant Options for Faba beans - (47)

2015 Videos -Website

1. Flax Studies with IHARF and NARF - (67)
2. Early Defoliation of Cereals for Swath Grazing - (207)
3. Soybean Stature by Row Spacing - (120)
4. Manipulator Effects on Lodging in Wheat 2015 - (764)
5. Forage Termination 2015 - (96)

2014 Videos - Website

- Canary Seed Fertility - (137)
- Wheat Fungicide Timing - (214)
- Soybean Variety by Seeding Date - (128)
- Cereal Forage by Seeding Date - (47)

Total website views (**3,282**) as of Jan 2, 2019 and (4,647) as of March 11, 2019

Environmental Data

Data for Yorkton was obtained from Environment Canada from the following internet site: [http://www.climate.weatheroffice.gc.ca/climateData/canada_e.html].

Mean monthly temperatures and precipitation amounts for 8 Agri-Arm sites during the 2018 season are presented relative to the long-term averages in Table 1 and 2. Temperatures were above average across all locations. Precipitation was below the long term average.

Table 1. Mean monthly temperatures and long-term (1981-2010) normals for the 2018 growing seasons at 8 sites in Saskatchewan.

Location	Year	May	June	July	August	Avg. / Total
		---------------------*Mean Temperature (°C)*	-------------------			
Indian Head	2018	13.9	16.5	15.4	17.6	15.8
	Long-term	***10.8***	***15.8***	***18.2***	***17.4***	***15.6***
Melfort	2018	13.9	16.8	17.5	15.8	16.0
	Long-term	***10.7***	***15.9***	***17.5***	***16.8***	***15.2***
Outlook	2018	14.8	17.4	18.5	17.5	17.1
	Long-term	***11.5***	***16.1***	***18.9***	***18.0***	***16.1***
Prince Albert	2018	13.2	16.6	17.4	15.1	15.6
	Long-term	***10.4***	***15.3***	***18.0***	***16.7***	***15.1***
Redvers	2018	15.2	18.3	18.6	17.8	17.5
	Long-term	-	-	-	-	-
Scott	2018	13.6	16.6	17.5	15.9	15.9
	Long-term	***10.8***	***14.8***	***17.3***	***16.3***	***14.8***
Swift Current	2018	14.6	17.1	18.8	18.7	17.3
	Long-term	***10.9***	***15.4***	***18.5***	***18.2***	***15.8***
Yorkton	2018	13.9	17.6	18.3	18.1	17.0
	Long-term	***10.4***	***15.5***	***17.9***	***17.1***	***15.2***

Table 2. Precipitation amounts along with long-term (1981-2010) normals for the 2018 growing seasons at 8 sites in Saskatchewan.

Location	Year	May	June	July	August	Avg. / Total
---------------------------- *Precipitation (mm)* ------------------------						
Indian Head	2018	23.7	90	30.4	3.9	148
	Long-term	***49***	***77.4***	***63.8***	***51.2***	***241.4***
Melfort	2018	38.5	46.6	69.5	43.2	196.8
	Long-term	***42.9***	***54.3***	***76.7***	***52.4***	***226.3***
Outlook	2018	24.9	12.9	35.2	12.6	85.6
	Long-term	***42.6***	***63.9***	***56.1***	***42.8***	***205.4***
Prince Albert	2018	20.6	41.0	112.4	42.2	216.2
	Long-term	***44.7***	***68.6***	***76.6***	***61.6***	***251.5***
Redvers	2018	21.1	137.2	48.3	9.9	216.5
	Long-term	-	-	-	-	-
Scott	2018	35.6	58	85.8	20.2	199.4
	Long -term	***38.9***	***69.7***	***69.4***	***48.7***	***226.7***
Swift Current	2018	25.6	16.9	51.2	31.0	124.7
	Long-term	***48.5***	***72.8***	***52.6***	***41.5***	***215.4***
Yorkton	2018	0.8	120.1	53.8	21.1	196.1
	Long-term	***51***	***80***	***78***	***62***	***272***

4R's Fall Applied Urea on Spring Wheat

Mike Hall[1] and Heather Sorestad[1]

[1]East Central Research Foundation

Abstract/Summary:
This study demonstrated the effect of nitrogen source, placement and time of application on yield and protein of wheat. Side banding urea at seeding is the most efficient timing and placement of urea. This treatment produced substantially higher yield, protein and economic returns compared to any treatment of fall applied N. Gross returns minus the cost of N were $414/ac for side banded urea at seeding and $331/ac for urea banded in late fall (October 27). This implies that denitrification or leaching loss of N were substantial in this experiment as banding the nitrogen should have minimized volatilization. Late fall (October 27) applications are ideal because the soil is nearing "freeze up" which reduces the degree to which urea is converted to nitrate. Once urea is converted to nitrate, N can be lost to leaching and denitrification. Broadcasting urea in early fall (October 2) produced the lowest yield, protein and economic return because substantial N was likely lost to some combination of volatilization, denitrification and leaching. Broadcasting SUPERU instead of urea in early fall substantially increased yield and protein of wheat by guarding against these avenues of N loss. The use of SUPERU over urea increased economic returns by $40/ac when applied early fall. Broadcasting SUPERU in late fall was also more economical than urea but the gain was more modest ($12/ac) as either volatilization and/or denitrification losses were less with that application timing. SUPERU provided no economic benefit to urea when applied early winter (November 5) on 10 cm of snow. Yield and protein were low regardless of what form of N was applied at this time. Frozen ground below the snow likely served as a barrier to N and increased volatilization or run-off losses during spring melt. In

conclusion, side banding urea at seeding was the most efficient use of N and provided by far the highest economic returns. If N needs to be broadcast in fall, producers should apply in late October. If producers wish to apply in early October, the use of SUPERU is strongly recommended. Broadcasting on snow should be avoided if at all possible as N losses were high whether the applied product was urea or SUPERU.

Project Objectives:

To save time with spring seeding operations, producers are interested in broadcasting urea in the fall and are wanting to push the window of application. This practice can potentially reduce nitrogen (N) efficiency and come with economic and environmental consequences.

The objectives of this proposal are:

- to demonstrate poorer N efficiency of fall broadcast versus fall banded applications of urea.
- to demonstrate poorer N efficiency of fall applied urea vs spring banded urea at seeding.
- to demonstrate the optimum timing of fall broadcasted urea in regards to N efficiency.
- to demonstrate how SUPERU can improve the N efficiency of fall broadcasted urea.

Project Rationale:

The earlier nitrogen fertilizer is applied before seeding the more susceptible it is to leaching, volatilizing, denitrification and runoff losses. The greatest N use efficiency occurs when urea is banded at the same time of seeding. However, because of time constraints at seeding many producers prefer to apply large amounts of N in the fall. Application of urea in the fall can be 20% less efficient particularly in the moist soil zones. Nitrogen losses can be reduced by banding applications which protects against volatilization of ammonia. Tight bands also delay microbial conversion of ammonium to nitrate, preventing nitrate losses from leaching and denitrification. Early fall applications should be avoided as soils are still warm and ammonium has more time to be converted to nitrate. Urea should be applied in late fall when soil temperatures are less than $7^{o}C$ and microbial activity is minimal. However, urea should not be applied to snow deeper than 10 cm particularly if an ice layer has formed because this can increase N losses via run-off or volatilization. Utilizing a nitrogen stabilizing product such as SUPERU can also reduce losses when nitrogen application occurs at less than ideal times. SUPERU protects against 3 pathways of nitrogen loss. SUPERU slows the conversion of urea to ammonia which reduces the risk of N loss to volatilization. It also slows the conversion of ammonium to nitrate which reduces the loss of N to leaching and denitrification. Producers need to be able to quantify the risks associated with various timings, placements and products when applying urea.

<u>Methodology and Results</u>

Methodology:

The trial was set up as a randomized complete block with 4 replicates. Plot size was 11 by 30 feet and seeded with a 10 foot SeedMaster drill on 12 inch row spacings. The following treatments were established:

1. Early Fall (October 2) broadcast urea

2. Early Fall (October 2) broadcast SUPERU
3. Late Fall (October 27) broadcast urea
4. Late Fall (October 27) broadcast SUPERU
5. Late Fall (October 25) band urea (fall check)
6. Early Winter on 10 cm of snow (November 5) broadcast urea
7. Early Winter on 10 cm of snow broadcast (November 5) SUPERU
8. Check: Spring side-banded urea at seeding (May 5)

A 10ft SeedMaster drill was used to band urea in the fall. Broadcast applications were applied by hand. The whole trial was seeded to Redberry wheat at 149 lb/ac with 69 lb/ac of monoammonium phosphate side banded. Plots were fertilized equally with 80lb/ac of actual N. The lower rate of nitrogen fertilizer makes it easier to detect differences in N efficiency in terms of wheat yield and grain protein. An excessively high N rate would have obscured differences in N efficiency. No pre-seed herbicide was required. The middle 4 rows of each plot were harvested with a Wintersteiger plot combine to minimize edge effects.

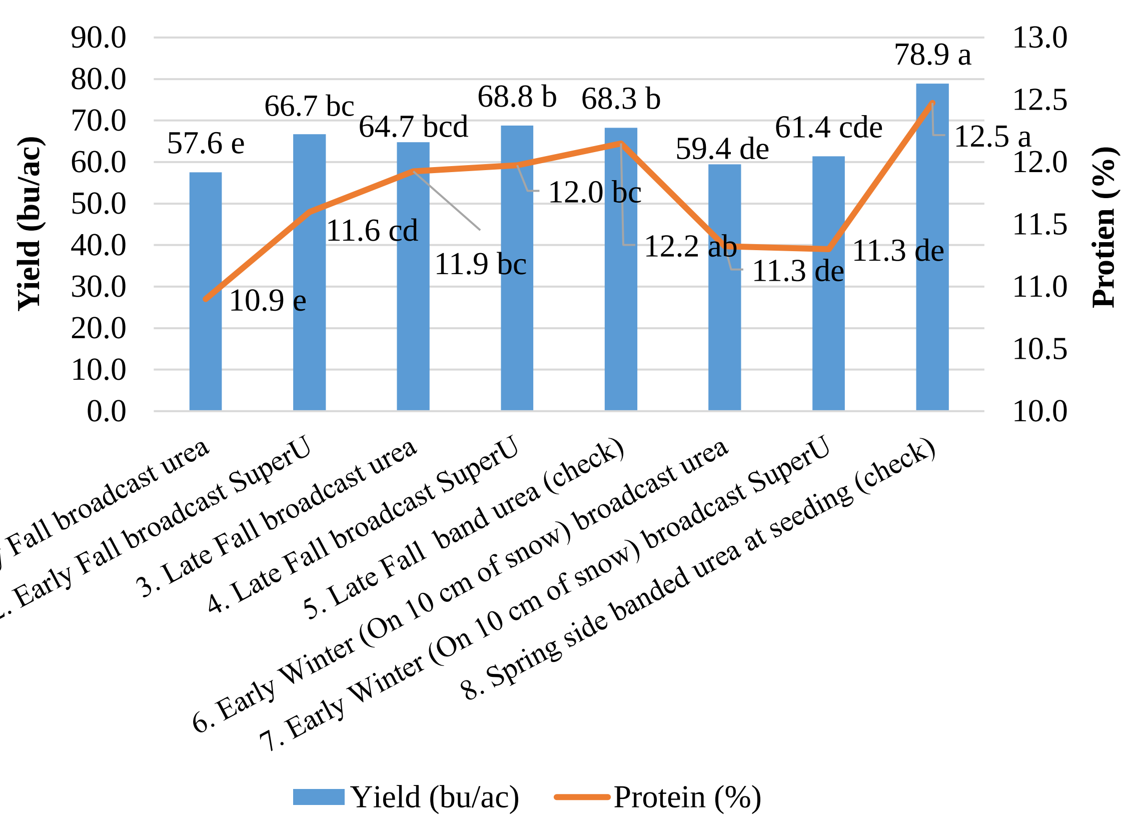
Table 1. Dates of operations in 2017 and 2018 for the 4Rs Fall Applied Urea in Spring Wheat Trial

Operations in 2017	
Early Fall Applications	October 2
Late Fall Applications	October 27
Early Winter Applications	November 5
Operations in 2018	
Trial seeded	May 5
Emergence counts	May 24
In-Crop Herbicide (Prestige)	June 20?
In-Crop Herbicide (Axial)	June 21?
Caramba fungicide	June 25
Harvest	August 21

Results:
Wheat emergence was uniform, averaging 339 plants/m^2 and did not significantly differ between treatments. This indicates emergence was not affected by nitrogen placement.

Side banding urea in spring when seeding wheat resulted in significantly higher grain yield and protein than any of the fall applied urea or SUPERU treatments (Figure 1). This was not surprising as side banding urea at seeding is considered to be the most efficient timing and placement of N. Broadcast application of urea early in fall (October 2) produced the lowest yield and protein response. In season nitrogen deficiency was visually apparent for this treatment compared to side-banded urea at seeding (Figure 2). Broadcasting in early fall on warm soils, provides time for urea to be converted to nitrate and subsequently to be lost to either leaching or denitrification. Broadcasting SUPERU instead of straight urea in early fall significantly increased grain protein and yield by delaying the conversion of urea to nitrate and reducing volatilization losses. Broadcasting urea in late fall (October 27) produced significantly higher yield and protein responses compared to the early fall timing because soils were cooler and there was less time for the urea to be converted to nitrate before freeze up. As with the early fall timing, the late fall application of SUPERU resulted in more yield and protein compared to straight urea. However, the increases were more modest as the potential for N loss is less with the late October timing. Late October is considered the ideal timing to broadcast urea to minimize losses. Yield and protein was somewhat higher when urea was banded instead of broadcast in late fall. This implies banding reduced N losses to volatilization. Broadcasting urea on 10 cm deep snow in early winter (November 5) produced relatively low yield and grain protein levels which were not improved by broadcasting SUPERU instead. Broadcasting urea on snow is not an ideal. The frozen soil beneath the snow creates a barrier to N, increasing losses to run-off and volatilization in spring.

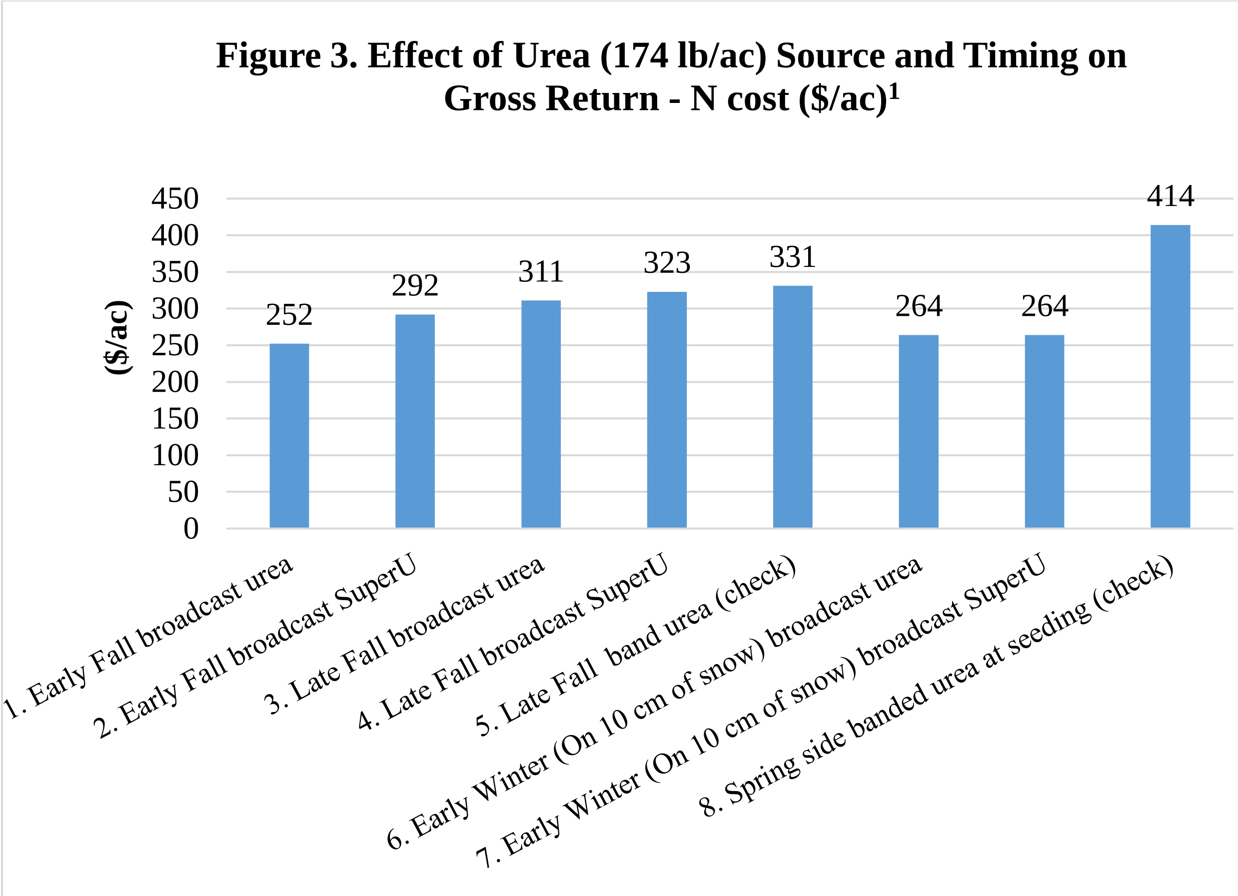
Figure 1. Effect of Urea (174 lb/ac) Source and Timing on Yield and Protein of Wheat[1]



[1]Yield and Protein values followed by the same letter are not statistically different at the 5% level of significance. Early fall, late fall and early winter applications occurred on October 2, 27 and November 5.

Figure 2

Figure 3 presents the Gross Returns per acre minus the cost of added N. Calculations are based on Yorkton elevator prices from February 9, 2018 (Table 2) and urea and SUPERU costs of $509 and $725 per tonne, respectively. By far, side banding urea at seeding produced the greatest economic returns. When comparing between fall applications, late fall produced the greater economic returns than either early fall or early winter applications. SUPERU increased economic returns over straight urea when broadcasted in early and late fall but did not when broadcasted in early winter. The greatest economic returns from using SUPERU occurred with the early fall applications.



[1]Gross Return- N cost calculations are based wheat prices and protein spreads available from Yorkton on Feb 9, 2018. Nitrogen costs were based on $590/tonne of urea and $725/tonne of SUPERU.

Table 2. Wheat prices available from Yorkton on Feb 9, 2018 for CWRS No 1

Grain Protein (%)	$/bushel
15.5	7.74
15	7.44
14.5	7.14
14	6.79
13.5	6.44
13	6.14
12.5	5.84
12	5.54
11.5	5.24
11	5.19
10.5	5.04
10	4.89

Conclusions and Recommendations:

Side banding urea at seeding provided substantially better yield, protein and economic returns than any fall applied N treatments. This is the best practice as nitrogen is being applied at the "right time and place". However, producers may need to apply N in the fall due to logistic and time management issues. For fall applications, economic returns were maximized by applying in late fall (Oct 27), banding or using SUPERU. SUPERU increased economic returns over straight urea when broadcast in early and late October. It was particularly beneficial for early October applications. SUPERU did not perform well for early winter applications (Nov 5) on 10 cm of snow. Broadcasting any N fertilizer at this time of year should be avoided.

<u>Supporting Information</u>

Acknowledgements:

This project was funded through the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement. ADOPT signs were posted during the annual tour.

Double Spray for Fusarium Head Blight

Mike Hall[1] and Heather Sorestad[1]

[1]East Central Research Foundation

Abstract/Summary:
Fusarium head blight is a costly disease that largely affects wheat acres in western Canada. Producers often struggle with uniform coverage on the front and back of wheat heads. This demonstration analyzed if two fungicide passes in opposite directions could increase Fusarium head blight control. Visually, Fusarium damaged heads were significantly reduced with more fungicide applications. Spraying twice in opposite directions reduced incidence of Fusarium damaged kernels the most compared to a single pass and the no fungicide control. Yield increased by 9% with the single pass and 12% with two passes in opposite directions, compared to the no fungicide control. Protein decreased slightly with fungicide application. However, no yield or quality results were significant with 5% level of confidence largely due to the small trial size.

Project Objectives:
The objective is to demonstrate the importance of uniform and complete coverage of the wheat head with fungicide to maximize the suppression of fusarium head blight (FHB).

Project Rationale:

Fusarium head blight is a serious and costly disease for wheat producers. There are only a couple fungicides registered for suppression and it is crucial to get uniform wheat head coverage to maximize efficacy. However, since wheat heads stand vertically it is difficult to achieve good front and back coverage. Uniform coverage can also be difficult with dual nozzles. A few producers have taken the extra time to spray for fusarium head blight in opposite directions to improve coverage. This is certainly not an approach most would be willing to adopt. This trial will investigate if a double pass with a conventional single stream nozzle has better control than one pass. Both strategies will be compared at equal water volumes and rate of fungicide.

Methodology and Results

Methodology:

The trial was setup as a RCBD with 4 replicates. Plots were 22 by 30 feet and wheat was seeded with a 10 foot SeedMaster drill on 12 inch row spacing. Redberry wheat was seeded at 128lb/ac with 69lb/ac of monoammonium phosphate and 217lb/ac of urea side banded. The middle 4 rows were harvested with a Wintersteiger plot combine.

The treatments were:
1. Unsprayed check
2. Caramba (400 ml/ac) sprayed one direction 12 ga/ac 02 nozzle 40 psi
3. Caramba (200 ml/ac) sprayed twice in opposite directions 6 ga/ac 01 nozzle

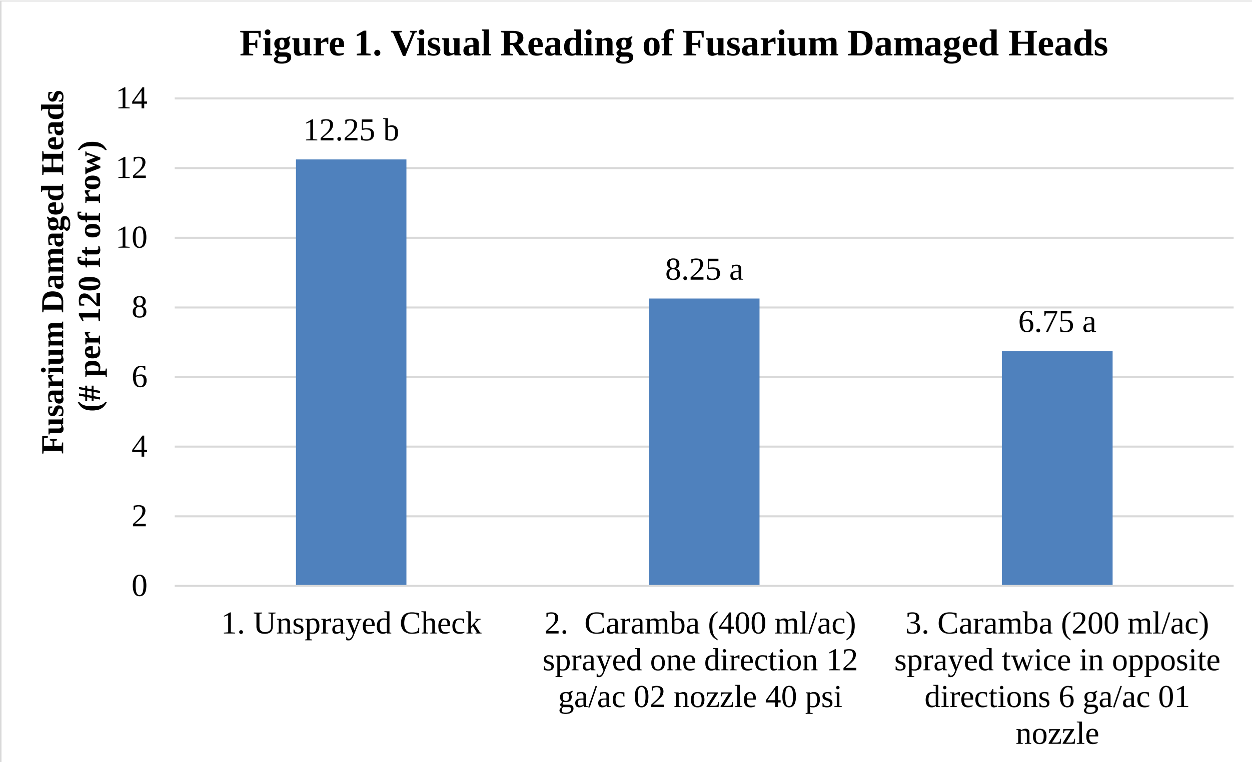
The total fungicide rate and water volume is equivalent for treatments 2 and 3. Dates of operations can be found in Table 1.

Table 1. Dates of operations in 2018 for the Double Spray for Fusarium Head Blight Trial

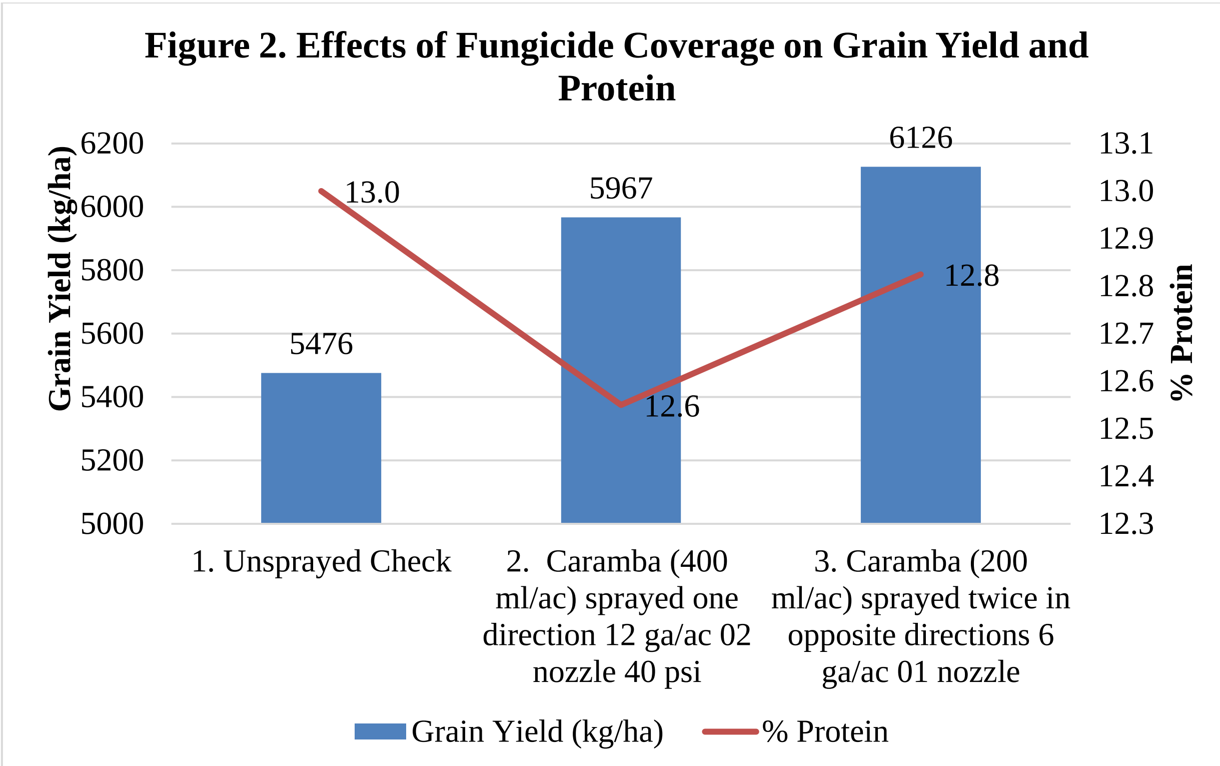
Operations in 2018	Yorkton
Seeded Wheat	May 4
Post Seeding Burnoff with Roundup Transorb	May 8
Emergence Counts	May 25?
Fungicide: Caramba	June 27
Visual Symptoms of FHB	
Harvest	Aug 30?

Results:

The incidence of Fusarium damaged heads significantly decreased with the application of fungicide (Figure 1). Spraying twice provided the greatest reduction. However, the level of Fusarium damaged kernels did not significantly differ between treatments. Fusarium damaged kernels are fairly light and many of them may have been blown out the back of the combine.



Grain yield increased with the frequency of spraying but were not quite significant at the 5% level of confidence (Figure 2). Spraying once increased yield by 9% and spray twice in opposite directions increased yield by 12%. Protein did not differ significantly between treatments but was somewhat lower for the fungicide treatments. This may have been the result of dilution as grain yields were increased.



Conclusions and Recommendations:

The use of fungicide reduced the incidence of fusarium head blight and increased yield. Yield was somewhat improved (2.6%) by double spraying which also tended to better control Fusarium. However, these affects were small and statistically insignificant. It is debatable whether the increase in yield would cover the added expense of double spraying. It was brought to our attention that spraying a half rate in two passes in opposite directions is considered to be an “off label” practice which could cause the buildup of fungicide resistance. Therefore, always read/follow label directions before preforming a new practices. If you are unsure if the practice will be “off label”, contact your local chemical representative.

Supporting Information

Acknowledgements:
This project was funded internally by East Central Research Foundation and Parkland College.

Oat Vigour Improves with Larger Seed Size

Mike Hall[1] and Chris Holzapfel[2]

[1]East Central Research Foundation, Yorkton, SK.
[2]Indian Head Research Foundation, Indian Head, SK.

Abstract/Summary:

The objective of this study was to demonstrate the benefit of screening out the small seed from an oat seed lot. Small seed tends to be less vigorous and its removal before planting can increase crop competition and yield. A seed lot of CS Camden was screened to remove the small seed constituting 8% of the original mass. This created 3 seed lots of large (42 mg/seed), small (26 mg/seed) and unscreened (41 mg/seed) seed sizes. These 3 different seed size lots were planted shallow at 100, 200 and 300 seed/m^2 near Yorkton and Indian Head. In addition, each lot was also seeded deep at 200 seed/m^2. While the vigor of the seed lots all tested over 98%, oats grown from small seed was found to be less vigorous than oats from large seed under field conditions. Plants grown from small seed had reduced emergence and less early-season above ground biomass at both locations. Oats grown from the large seed yielded 8% higher than with the small seed at Yorkton, but seed size did not significantly affect yields at Indian Head. In the field, large seed size oats did not statistically outperform the unscreened seed by any measure at either location. While oats from small seed was less vigorous, there was little evidence that their removal was enough to significantly improve the vigor over the original seed lot as they constituted 8% of the original mass. Increasing seeding rates from 100 to 300 seeds/m^2 did not improve yield at either location in this study. However, the high seeding rate should still be recommended as results may differ under more optimal conditions and it hastened maturity by 4 days and reduced wild oat pressure at Indian Head.

Project Objectives:

The objective of this project was to demonstrate how seedling vigor of oats can be improved by screening out smaller less vigorous seed. Increasing the average seed size of a seed lot should result in greater emergence, improved stand establishment, greater competitiveness against wild oats, earlier maturity and greater yield.

Project Rationale:

Planting vigorous seed is the first step towards producing a high yielding, milling quality oat crop. Vigorous seed provides better stands, particularly under stressful conditions such as cold soils, deeper than optimal seed placement, and heavy weed competition (ie: wild oats). Oats grown from vigorous seed are more competitive against wild oats. This is particularly important when wild oat populations are high as there are no herbicides available to control wild oats in tame oats. A simple means by which producers can improve the vigor of their own seed lots is to have it cleaned more aggressively to assure small less vigorous seeds are removed. This has potential to increase economic returns for oat growers.

Methodology and Results

Methodology:

Field trials using CS Camden oats were direct seeded near Yorkton and Indian Head to establish the treatments listed in Table A. Treatments were replicated 4 times and only the middle rows of each plot were harvested to minimize the influence of edge effects. Different parts of the treatment list were analyzed as two separate factorial experiments. The first factorial analysis used treatments 1-9 and evaluated 3 seed sizes of large (42 mg/seed), small (26 mg/seed) and unscreened (41 mg/seed) at 3 seeding rates of 100, 200 and 300 seeds/m^2. The 3 seed sizes were sieved from the same seed lot. At Yorkton, the second factorial analysis used treatments 2, 5, 9, 10, 11 and 12 to evaluate the 3 seed sizes at shallow and deep seeding. At Indian Head, only treatments 2, 5, 9 and 10 were used to evaluate 2 seed sizes (large and small) at shallow and deep seeding. Data from the unscreened seed was omitted as there was a seeding error for treatment 12. Both unscreened treatments 11 and 12 were omitted to balance the trial for a factorial analysis. All treatment comparisons for the second factorial analysis were seeded at 200 seeds/m^2. The dates of various operations can be found in Table B.

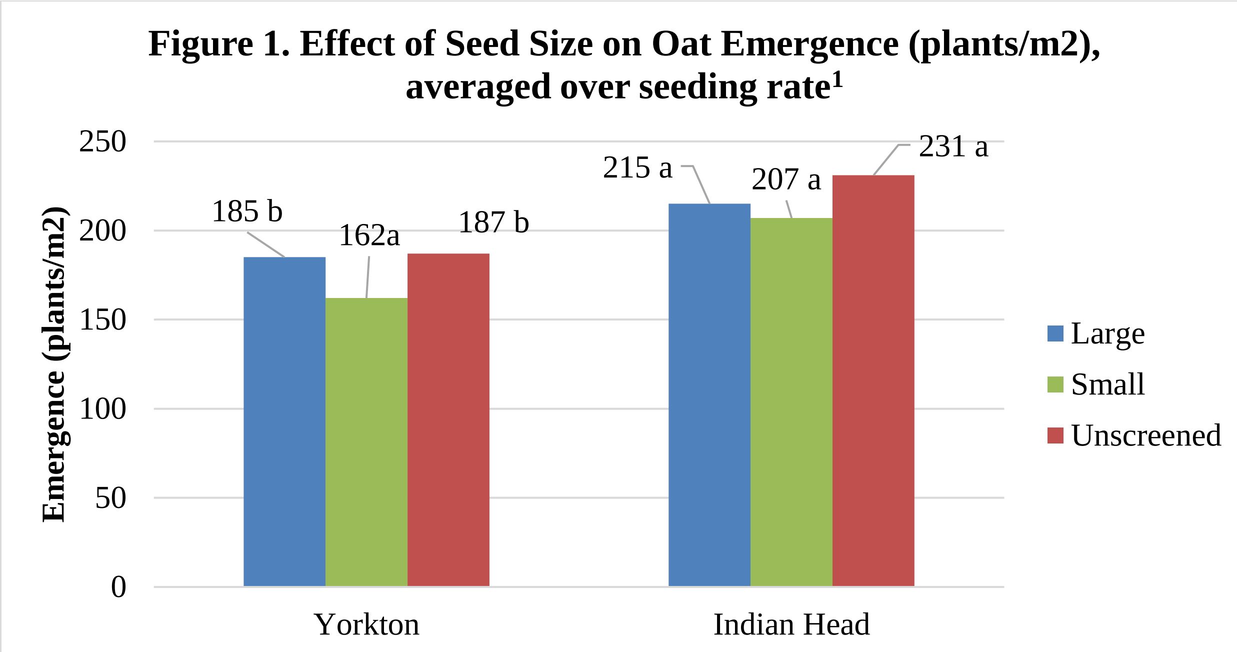
Table A. Treatment list for oat vigour improves with larger seed size.			
Trt.	**Seed Size**	**Seeding rate ($Seeds/m^2$)**	**Seeding depth (inches)**
1	Large	100	Shallow (1”)
2	Large	200	Shallow (1”)
3	Large	300	Shallow (1”)
4	Small	100	Shallow (1”)
5	Small	200	Shallow (1”)
6	Small	300	Shallow (1”)
7	Unscreened	100	Shallow (1”)
8	Unscreened	200	Shallow (1”)
9	Unscreened	300	Shallow (1”)
10	Large	200	Deep (2-3”)
11	Small	200	Deep (2-3”)
12	Unscreened	200	Deep (2-3”)

Table B. Dates of operations in 2018 for the Oat Vigour Improves with Larger Seed Size		
Operations in 2018	Indian Head	Yorkton
Seeded	May 7	May 10
Tame Oat Emergence (4 by 0.5 m)	May 28	May 28
In-crop Herbicide	June 6 (Buctril M)	June 8 (Prestige)
Tame Oat Biomass	June 5	June 7
Fungicide at Flag	June 25 (Quilt)	June 25 (Caramba)
Wild Oat Rating	July 18	July 20
Harvest	August 10	August 30

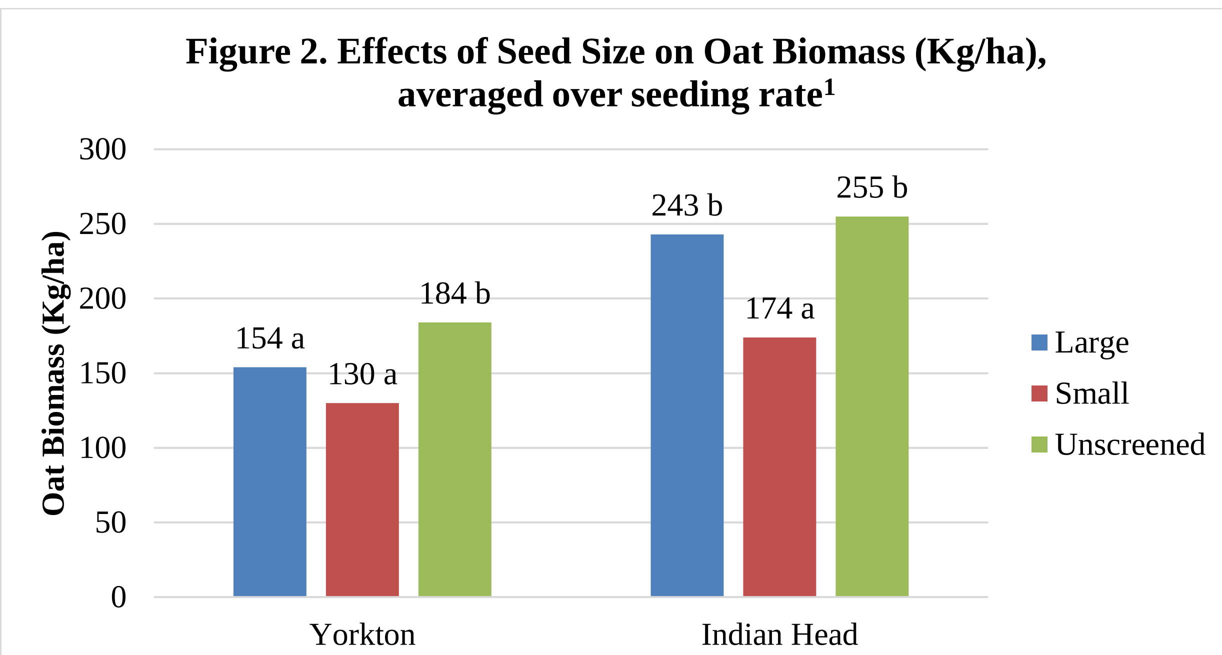
Results:

Tables 1-12 showing results from both factorial analyses for Yorkton and Indian Head are found in the appendices.

Target seeding rates of 100, 200 and 300 seeds/m^2 resulted in average plant populations of 109, 182 and 243 plants/m^2, respectively at Yorkton (Table 2) and 122, 214 and 316 plants/m^2, respectively at Indian Head (Table 5). At Yorkton and Indian Head, emergence of oats from small seed was the poorest and produced less early season biomass (Tables 2, 5 and Figures 1 and 2).



[1]Seed sizes are large (42 mg/seed), small (26 mg/seed) and unscreened (41 mg/seed)



[1]Seed sizes are large (42 mg/seed), small (26 mg/seed) and unscreened (41 mg/seed)

Compared to large seed, emergence for oats from small seed was 13% poorer at Yorkton and 4% poorer at Indian Head. Likewise, early season biomass for oats from small seed was 16% lower at Yorkton and 29% lower at Indian Head. Differences in emergence could, to a certain extent, potentially reflect improper calibration or random variability in sampling error. However, the reduction in above grown biomass is greater than the reduction in emergence suggesting the smaller seed oats were less vigorous. This was visually obvious at Yorkton as Figure 3 shows the difference in early vegetative growth between small and large size oat seed when planted deep. Seeding deeper tended to further reduce emergence and early season biomass at both locations (Tables 8 and 11). Emergence and early season biomass did not differ between large and unscreened oats, indicating the removal of smaller seed was insufficient to greatly improve the quality of the seed lot. This was likely due to the fact that the seed lot was of very high quality to begin with, as evident in the very similar TKW values for the large and unscreened seed.

For the most part, early season oat biomass increased significantly as seeding rate was increased at both Yorkton and Indian Head (Tables 2 and 5). This is intuitive as more plants emerging should mean more biomass when measurements are taken early in the season. However, there was an unexpected interaction with the biomass data at Yorkton which the author cannot explain. As expected, the biomass increased as seeding rate increased for oats from large seed and unscreened seed (Table 3). However, the opposite was true for oats grown from small seed. As seeding rates were increased from 200 to 300 seeds/m^2, oat biomass dropped from 169 to 118 kg/ha.

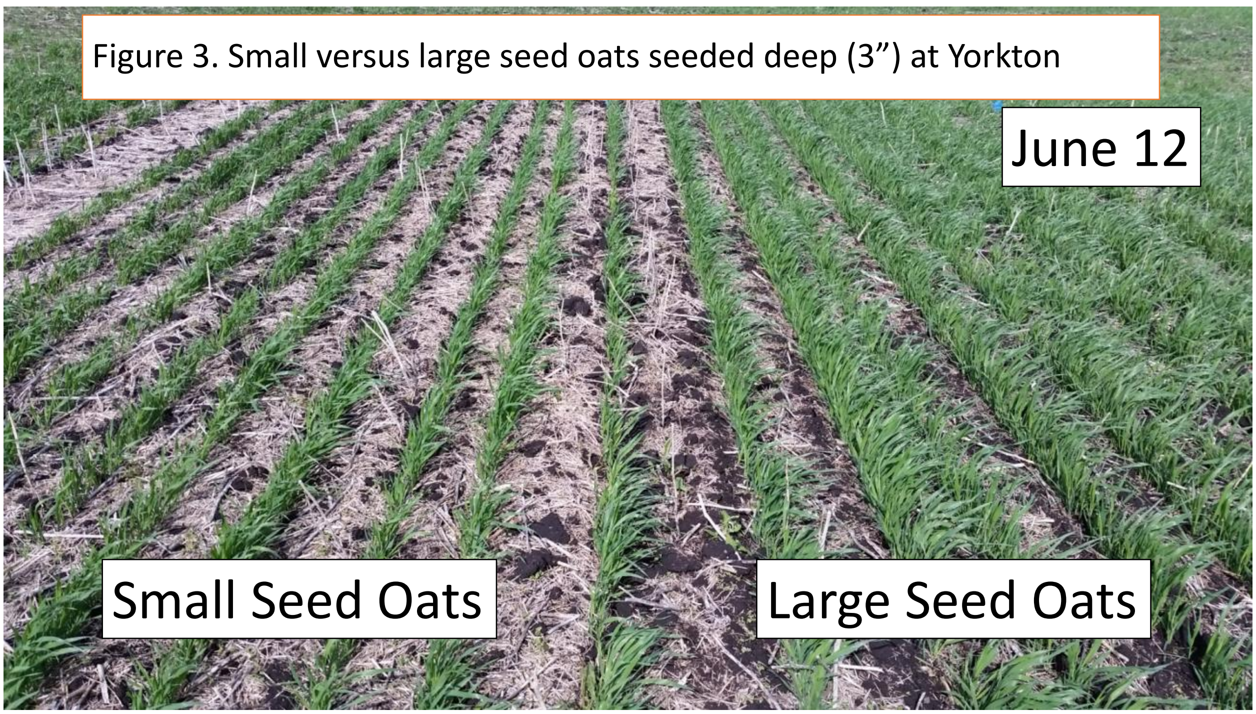
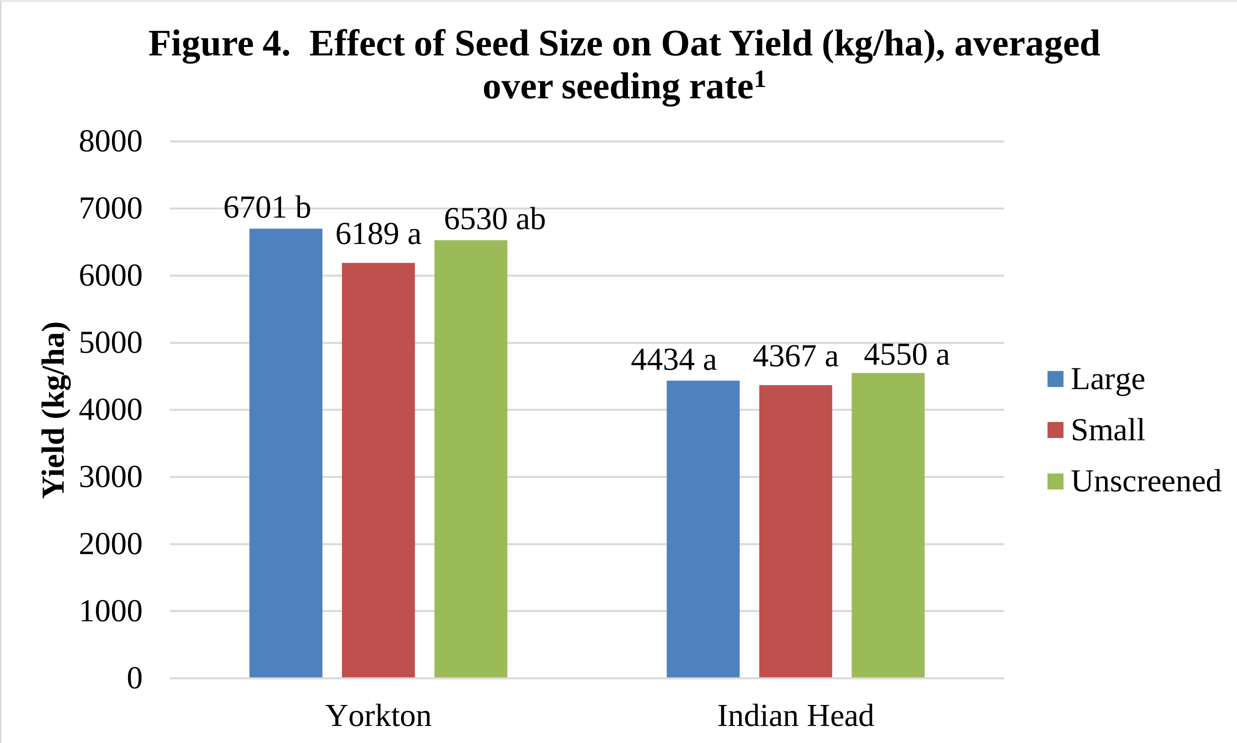


Figure 3. Small versus large seed oats seeded deep (3”) at Yorkton

Although oats from large seed emerged more vigorously at both locations, this only resulted in significantly higher yields at the Yorkton site (Tables 2 and 5 Figure 4). At Yorkton, oats from large seed significantly yielded 8% more than oats from small seed size, but only 2.6% more than unscreened oats which was not statistically significant. At Indian Head, small seed size oats did yield the least, but differences between the seed sizes were small and insignificant.



[1]Seed sizes are large (42 mg/seed), small (26 mg/seed) and unscreened (41 mg/seed)

While increasing seeding rates did not significantly affect yield, the highest yields were numerically associated with the lowest seeding rate at both Yorkton and Indian Head (Tables 2 and 5, Figure 5). The seeding rate of 100 seeds/m^2 is far below the recommended rate of 300 seeds/m^2. Perhaps lower plant populations benefitted from less inter-plant competition for water as conditions were dry, especially in Indian Head. Increasing seeding rates had little effect on yield in this study but should still be recommended as it improved competition with wild oats and hastened maturity. While wild oat pressures were low at both locations, increasing seeding rate from 100 to 300 seeds/m^2 did significantly reduce wild oat pressure from a visual rating of 1.5 to 0.5 out of 10 at Indian Head. No differences were detected at Yorkton as wild oat populations were quite low (data not shown). Maturity ratings were lost at Yorkton, but increasing seeding rate from 100 to 300 seeds/m^2 significantly hastened maturity by 4 days at Indian Head. Maturity was also significantly affected by seed size (Table 5) and seeding depth (Table 11). Seeding deep and seeding oats with a small seed size statistically delayed maturity, but the differences were within a day and not agronomically important. Test weights were not a required measure for this study but this data was collected from the Yorkton site. While not statistically significant, tests weights were numerically higher for oats grown from large seed and statistically higher for oats grown at the lowest seeding rate (Table 2 figure 6). The observed test weights were well above the minimum of 240 g/0.5 l required for milling oats.

Figure 5. Effect of Seeding Rate (seeds/m^2) on Yield (kg/ha), averaged over seed size

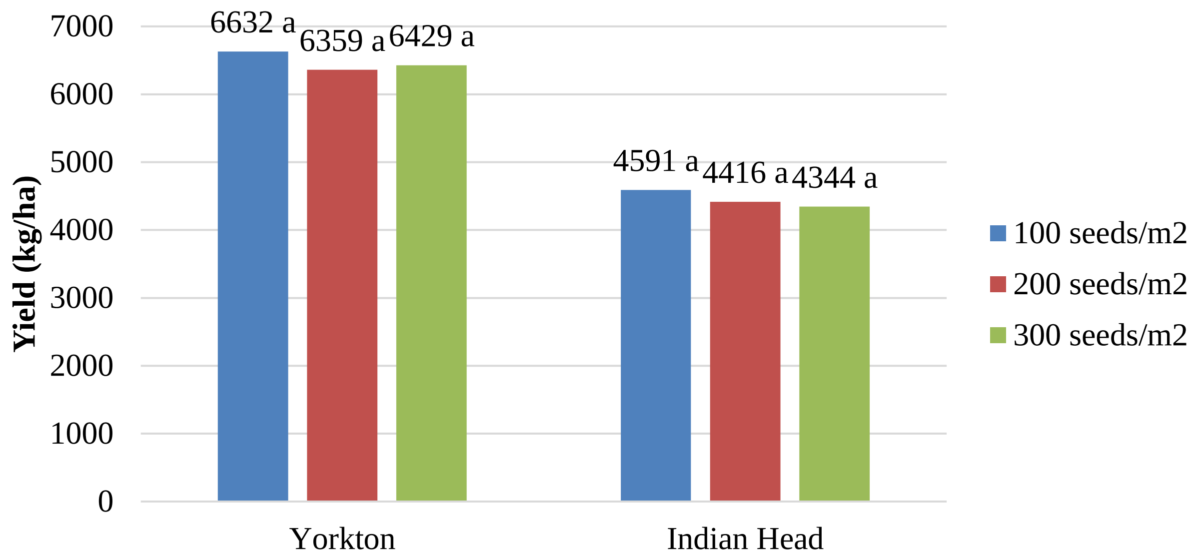
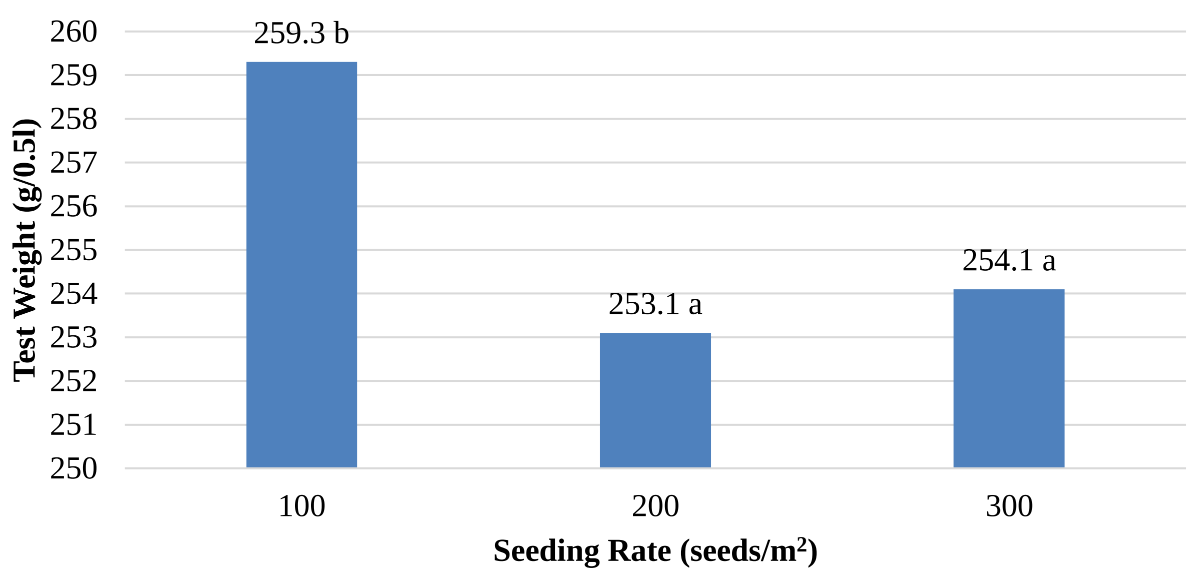


Figure 6. Effects of Seeding Rate on Oat Test Weight (g/0.5 l) in Yorkton, averaged over seed size



Conclusions and Recommendations:

The small seed size oats were found to be less vigorous and oats grown from this seed produced lower yield at Yorkton. However, removing these seeds from the original seed lot did little to improve overall seed vigor or increase crop yield as they only constituted 8% of the original unscreened seed lot. The quality of the small seed in this seed lot was still good and tested 98% vigor. However, this may not always be the case and it still may be a good practice for producers to remove thin seed from seed lots they intend to plant. Increasing seeding rates from 100 to 300 seeds/m^2 did not improve yield at either location in this study. However, the high seeding rate should still be recommended as it hastened maturity by 4 days and reduced wild oat pressure at Indian Head.

Supporting Information

Acknowledgements:

This project was supported through the Saskatchewan Oat Development Commission and funded by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement. Adopt signs were posted and the project was highlighted during the annual tours at both locations.

Appendices:

Table 1. Seed size and seeding rate effects on oat emergence, biomass, maturity, test weight and yield at Yorkton in 2018[1].

Main effect	Emergence (plants/m^2)	Oat Biomass (Kg/ha dry)	Maturity (days)	Test Weight (g/0.5 l)	Yield (kg/ha)
Effect	-------------------------------------p-values [z] ----------------------------------				
Seed size (S)	0.037	0.0031	Na	Ns	0.039
Seeding Rate (R)	<0.0001	0.0001	Na	0.0018	Ns
S x R	Ns	0.0042	Na	Ns	Ns

[z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability
[1]Treatments 1-9 used in factorial analysis (3 seed sizes by 3 seeding rates). Seeding depth for all treatments was shallow.

Table 2. Main effect means of seed size and seeding rate on oat emergence, biomass, maturity, test weight and yield at Yorkton in 2018[1].

Main effect	**Emergence (plants/m²)**	**Oat Biomass (Kg/ha dry)**	**Maturity (days)**	**Test Weight (g/0.5 l)**	**Yield (kg/ha)**
Seed Size					
Large (42 mg/seed)	185 b	154 a	Na	256.1 a	6701b
Small (26 mg/seed)	162 a	130 a	Na	255.4 a	6189 a
Unscreened (41 mg/seed)	187 b	184 b	Na	255.1 a	6530 ab
LSD	21	29		3.42	397
Seeding Rate					
100 seeds/m²	109 a	112 a	Na	259.3 b	6632 a
200 seeds/m²	182 b	171 b	Na	253.1 a	6359 a
300 seeds/m²	243 c	184 b	Na	254.1 a	6429 a
LSD	21	29		3.42	397

[1]Treatments 1-9 used in factorial analysis (3 seed sizes by 3 seeding rates). Seeding depth for all treatments was shallow.

Table 3. Means for seed size by seeding rate interactions on oat emergence, biomass, maturity, test weight and yield at Yorkton in 2018[1].					
Main effect	**Emergence (plants/m²)**	**Oat Biomass (Kg/ha dry)**	**Maturity (days)**	**Test Weight (g/0.5 l)**	**Yield (kg/ha)**
S x R					
Large Seed size – 100 seeds/m²	112	130	Na	259.0	7008
Large Seed size – 200 seeds/m²	178	141	Na	254.9	6441
Large Seed size – 300 seeds/m²	264	191	Na	254.4	6655
Small Seed size – 100 seeds/m²	107	102	Na	259.1	6131
Small Seed size – 200 seeds/m²	163	169	Na	253.1	6304
Small Seed size – 300 seeds/m²	217	118	Na	254.1	6131
Unscreened Seed – 100 seeds/m²	108	104	Na	260.0	6758
Unscreened Seed – 200 seeds/m²	205	204	Na	251.5	6332
Unscreened Seed – 300 seeds/m²	249	243	Na	253.8	6501
L.S.D.	36	50		5.9	688

[1]Treatments 1-9 used in factorial analysis (3 seed sizes by 3 seeding rates). Seeding depth for all treatments was shallow.

Table 4. Seed size and seeding rate effects on oat emergence, biomass, maturity, test weight and yield at Indian Head in 2018[1].					
Main effect	**Emergence (plants/m^2)**	**Oat Biomass (Kg/ha dry)**	**Maturity (days)**	**Test Weight (g/0.5 l)**	**Yield (kg/ha)**
Effect	---------------p-values ^{z} ---------------				
Seed size (S)	0.056	<0.0001	0.0005	Na	Ns
Seeding Rate (R)	<0.0001	<0.0001	<0.0001	Na	Ns
S x R	Ns	Ns	Ns	Na	Ns

^{z} p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability
[1]Treatments 1-9 used in factorial analysis (3 seed sizes by 3 seeding rates). Seeding depth for all treatments was shallow.

Table 5. Main effect means of seed size and seeding rate on oat emergence, biomass, maturity, test weight and yield at Indian Head in 2018[1].					
Main effect	**Emergence (plants/m^2)**	**Oat Biomass (Kg/ha dry)**	**Maturity (days)**	**Test Weight (g/0.5 l)**	**Yield (kg/ha)**
Seed Size					
Large (42 mg/seed)	215.0 a	243.3 b	87.2 a	Na	4434 a
Small (26 mg/seed)	207.1 a	174.2 a	87.7 b	Na	4367 a
Unscreened (41 mg/seed)	231.0 a	254.8 b	87.0 a	Na	4550 a
LSD	Ns	32.5	0.32		Ns
Seeding Rate					
100 seeds/m^2	122.2 a	155.5 a	89.6 c	Na	4591 a
200 seeds/m^2	214.1 b	232.8 b	87.0 b	Na	4416 a
300 seeds/m^2	316.9 c	284.0 c	85.4 a	Na	4344 a
LSD	19.8	32.5	0.32		Ns

[1]Treatments 1-9 used in factorial analysis (3 seed sizes by 3 seeding rates). Seeding depth for all treatments was shallow.

Table 6. Means for Seed Size by Seeding rate interactions on oat emergence, biomass, maturity, test weight and yield at Indian Head in 2018[1].					
Main effect	**Emergence (plants/m^2)**	**Oat Biomass (Kg/ha dry)**	**Maturity (days)**	**Test Weight (g/0.5 l)**	**Yield (kg/ha)**
S x R					
Large Seed size – 100 seeds/m^2	116	164	89.8	Na	4695
Large Seed size – 200 seeds/m^2	215	244	86.6	Na	4314
Large Seed size – 300 seeds/m^2	315	322	85.1	Na	4292
Small Seed size – 100 seeds/m^2	124	118	89.8	Na	4464
Small Seed size – 200 seeds/m^2	193	181	87.5	Na	4402
Small Seed size – 300 seeds/m^2	305	224	85.9	Na	4236
Unscreened Seed – 100 seeds/m^2	127	185	89.3	Na	4615
Unscreened Seed – 200 seeds/m^2	235	274	86.8	Na	4532
Unscreened Seed – 300 seeds/m^2	331	306	85.1	Na	4505
L.S.D.	34	56	0.56		Ns

[1]Treatments 1-9 used in factorial analysis (3 seed sizes by 3 seeding rates). Seeding depth for all treatments was shallow.

Table 7. Seed size and seeding depth effects on oat emergence, biomass, maturity, test weight and yield at Yorkton in 2018[1].					
Main effect	**Emergence (plants/m^2)**	**Oat Biomass (Kg/ha dry)**	**Maturity (days)**	**Test Weight (g/0.5 l)**	**Yield (kg/ha)**
Effect	---------------------------------------p-values [Z] -------------------------------------				
Seed size (S)	0.0095	0.076	Na	0.0096	0.15
Seeding Depth (D)	Ns	Ns	Na	0.12	0.14
S x D	Ns	0.068	Na	Ns	Ns

[Z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability
[1]Treatments 2, 5, 8, 10, 11, 12 used in factorial analysis (3 seed sizes by 2 seeding depths). Seeding rate for all treatments is (200 seeds/m^2).

Table 8. Main effect means of seed size and seeding depth on oat emergence, biomass, maturity, test weight and yield at Yorkton in 2018[1].					
Main effect	**Emergence (plants/m^2)**	**Oat Biomass (Kg/ha dry)**	**Maturity (days)**	**Test Weight (g/0.5 l)**	**Yield (kg/ha)**
Seed Size					
Large (42 mg/seed)	179 ab	162 a	Na	256.6 b	6785
Small (26 mg/seed)	163 a	136 a	Na	255.5 b	6444
Unscreened (41 mg/seed)	197 b	187 a	Na	250.8 a	6302
LSD	21	Ns		3.7	Ns
Seeding Depth					
Shallow (1”)	182 a	170 a	Na	253.1 a	6359
Deep (3”)	177 a	154 a	Na	255.5 a	6661
LSD	Ns	Ns		Ns	Ns

[1]Treatments 2, 5, 8, 10, 11, 12 used in factorial analysis (3 seed sizes by 2 seeding depths). Seeding rate for all treatments is (200 seeds/m^2).

Table 9. Means for Seed Size by Seeding Depth interactions on oat emergence, biomass, maturity, test weight and yield at Yorkton in 2018[1].					
Main effect	**Emergence (plants/m^2)**	**Oat Biomass (Kg/ha dry)**	**Maturity (days)**	**Test Weight (g/0.5 l)**	**Yield (kg/ha)**
S x D					
Large Seed size – Shallow	178	141	Na	254.9	6441
Large Seed size – Deep	180	183	Na	258.4	7128
Small Seed size – Shallow	179	164	Na	253.1	6304
Small Seed size – Deep	163	109	Na	257.9	6584
Unscreened Seed – Shallow	204	204	Na	251.5	6332
Unscreened Seed – Deep	190	169	Na	250.1	6272
L.S.D.	30	Ns		5.2	NS

[1]Treatments 2, 5, 8, 10, 11, 12 used in factorial analysis (3 seed sizes by 2 seeding depths). Seeding rate for all treatments is (200 seeds/m^2).

Table 10. Seed size and seeding depth effects on oat emergence, biomass, maturity, test weight and yield at Indian Head in 2018[1].					
Main effect	**Emergence (plants/m^2)**	**Oat Biomass (Kg/ha dry)**	**Maturity (days)**	**Test Weight (g/0.5 l)**	**Yield (kg/ha)**
Effect	-----------------p-values [Z] -----------------				
Seed size (S)	0.037	0.055	0.0072	Na	Ns
Seeding Depth (D)	0.10	0.007	0.001	Na	Ns
S x D	Ns	0.059	Ns	Na	Ns

[Z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability
[1]Treatments 2, 5, 10, 11 used in factorial analysis (2 seed sizes by 2 seeding depths). Seeding rate for all treatments is (200 seeds/m^2).

Table 11. Main effect means of seed size and seeding depth on oat emergence, biomass, maturity, test weight and yield at Indian Head in 2018[1].					
Main effect	**Emergence (plants/m^2)**	**Oat Biomass (Kg/ha dry)**	**Maturity (days)**	**Test Weight (g/0.5 l)**	**Yield (kg/ha)**
Seed Size					
Large	207 a	204 a	87.2 a	Na	4308
Small	180 b	172 a	87.9 b	Na	4346
LSD	26	34	0.52		Ns
Seeding Depth					
Shallow (1”)	204 a	212 b	87.1 a	Na	4358
Deep (3”)	183 a	163 a	88.1 b	Na	4296
LSD	26	34	0.52		Ns

[1]Treatments 2, 5, 10, 11 used in factorial analysis (2 seed sizes by 2 seeding depths). Seeding rate for all treatments is (200 seeds/m^2).

Table 12. Means for Seed Size by Seeding Depth interactions on oat emergence, biomass, maturity, test weight and yield at Indian Head in 2018[1].					
Main effect	**Emergence (plants/m²)**	**Oat Biomass (Kg/ha dry)**	**Maturity (days)**	**Test Weight (g/0.5 l)**	**Yield (kg/ha)**
S x D					
Large Seed size – Shallow	215	244	86.6	Na	4314
Large Seed size – Deep	199	163	87.8	Na	4302
Small Seed size – Shallow	193	181	87.5	Na	4402
Small Seed size – Deep	167	163	88.4	Na	4290
L.S.D.	NS	48	0.74		Ns

[1]Treatments 2, 5, 10, 11 used in factorial analysis (2 seed sizes by 2 seeding depths). Seeding rate for all treatments is (200 seeds/m^2).

Malt versus Feed Barley Management

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[4]Northeast Agriculture Research Foundation, Melfort, SK
[5]South East Research Farm, Redvers, SK
[6]Irrigation Crop Diversification Centre, Outlook, SK
[7]Western Applied Research Corporation, Scott, SK

Abstract/Summary:
A study was conducted at 7 locations across Saskatchewan to determine the effect of seeding rate (200 vs 300 seeds/m^2) and nitrogen rate (50, 75 and 100 lb N/ac) on the yield of the malt variety CDC Bow and the feed variety CDC Austenson. Treatment effects on grain quality for malt were also measured. Increasing seeding rate increased inter-plant competition for moisture and reduced yield at the dryland sites since precipitation was well below average at all locations; however, the effects on yield were rarely significant at individual sites. Increasing seeding rate only resulted in more yield at Outlook under irrigation. When averaged across locations, increasing seeding rate decreased thousand kernel weight. However, it did not decrease kernel plumpness which is of more concern to malsters. No other quality parameters were influenced by seeding rate. While the yield response to added nitrogen was similar between the varieties, CDC Austenson was 8% higher yielding than CDC Bow when averaged over treatments and location. However, the yield difference between varieties varied from as low as 1.9% at Prince Albert to

as high as 11% at Redvers. Increasing nitrogen significantly increased protein. For most sites, protein stayed below the maximum limit even at the highest nitrogen rate of 100 lb N/ac. The exception to this was at Scott where acceptable protein levels for malt were exceeded even with 50 lb N/ac. As a result, the economic analysis for growing CDC Bow for malt or feed against CDC Austenson for feed were made at 100 lb N/ac for all locations except Scott where comparisons were made at 50 lb N/ac. The economic analysis was based on yields obtained for these nitrogen rates and pricing obtained from Saskatchewan Crop Planning Guide. The 2017 values were $5.44 and $3.22/bu for malt and feed barley, respectively. In 2018, the prices used narrowed to $4.68 and $3.70/bu for malt and feed barley, respectively. Based on 2017 and the narrower 2018 pricing, the likelihood of achieving malt with CDC Bow has to be greater than 10 or 27%, respectively to justify growing it instead of CDC Austenson for feed. The values would be a little higher if one considers the yield of the feed variety CDC Austenson could have been pushed higher with increasing N beyond 100 lb/ac at most sites. While the chance of obtaining malt may be high for some producers, one must recognize that only 20% of malting barley is actually selected according to the Canadian Grain Commission. However, as even higher yielding malt varieties such as AAC Synergy gain acceptance in the market place, there may be little reason to grow feed varieties in the future.

Project Objectives:

The objectives of this project are:

- To demonstrate that newer malt varieties can provide comparable yield to the best feed varieties
- To demonstrate the importance of adequate plant populations for yield and malt acceptance
- To demonstrate the differences in N management for malt versus feed barley

Project Rationale:

Malt barley breeders have been developing new varieties which have increased yields to compete with higher yielding feed varieties. As higher yielding malt varieties come into the market place, producers must be aware that continuing to grow feed varieties may result in missed opportunities with maltsters. The past recommendation was to grow a feed variety if a producer only makes malting quality 50% of the time. However, as higher yielding malt barley varieties become accepted, feed barley does not appear as rewarding. Producers need to be aware of the importance of seeding rate and nitrogen management for malt and feed varieties. Higher seeding rates of 300 seeds/m^2 maximize yield and improve acceptance for malt. Work by John O'donovan determined 300 seeds/m^2 was the optimum seeding rate for malt barley. This typically results in a plant stand around 220 plants/m^2. Increased tillering resulting from lower seeding rates leads to uneven maturity and non-uniform kernels which is undesirable to maltsters. Increasing seeding rates to 300 seeds/m^2 may slightly reduce kernel plumpness, but produces more uniform kernels which is a better trade-off. Using a higher seeding rate also has the advantage of hastening maturity by 2 to 3 days and slightly lowers protein. For feed barley, the optimum seeding rate is somewhat higher than it is for malt.

Managing nitrogen is particularly important for malt barley because protein levels must stay between 11-12.5% to be accepted. High protein barley means there is less carbohydrate for the malting process which may result in cloudy beer. Nitrogen rates for feed barley can be higher as high protein is desirable. In order to determine how much N to apply to new malt varieties, producers will need to consider the likelihood of being selected for malt and the price differential that can occur if malt is not met. This project will demonstrate basic agronomic practices for newer malt versus feed varieties to help barley producers stay competitive in a changing market.

Methodology and Results

Methodology:

Below is a list of the treatments that were established at Yorkton, Prince Albert, Indian Head, Melfort, Redvers, Outlook and Scott. The treatments were a 3 order factorial arranged in a 4 replicate RCBD. The first factor compared the malt variety CDC Bow against the feed variety CDC Austenson. The second factor contrasted seeding rates of 200 and 300 seeds/m^2. The 3rd factor examines increasing nitrogen rates of 50, 75 and 100 lb N/ac.

Treatment List

1) CDC Bow (Malt); 200 seeds/m2; 50 lb N/ac
2) CDC Bow (Malt); 200 seeds/m2; 75 lb N/ac
3) CDC Bow (Malt); 200 seeds/m2; 100 lb N/ac
4) CDC Bow (Malt); 300 seeds/m2; 50 lb N/ac
5) CDC Bow (Malt); 300 seeds/m2; 75 lb N/ac
6) CDC Bow (Malt); 300 seeds/m2; 100 lb N/ac
7) CDC Austenson (Feed); 200 seeds/m2; 50 lb N/ac
8) CDC Austenson (Feed); 200 seeds/m2; 75 lb N/ac
9) CDC Austenson (Feed); 200 seeds/m2; 100 lb N/ac
10) CDC Austenson (Feed); 300 seeds/m2; 50 lb N/ac
11) CDC Austenson (Feed); 300 seeds/m2; 75 lb N/ac
12) CDC Austenson (Feed); 300 seeds/m2; 100 lb N/ac

Plot sized varied across locations based on seeding and spraying equipment. Dates of operations for all sites are found in Table 1.

Table 1. Dates of operations in 2018 for the Malt versus Feed Barley Management at Yorkton

	--Date--						
Activity	**Indian Head**	**Melfort**	**Outlook**	**Redvers**	**Prince Albert**	**Scott**	**Yorkton**
Pre-seed Herbicide Application	May 11 (Weathermax 540)	May 18 (Glyphosate 540)		May 8 (Glyphosate and Buctril M)		May 19 (Glyphosate and AIM)	None
Seeding	May 7	May 15	May 22	May 6		May 19	May 9
Emergence Counts	May 29	June 4		May 20	June 15	June 13	May 28
In-crop Fungicide Application	June 5 (Quilt)	July 13 (Caramba)	none	none	none	none	June 21 (Twinline)
In-crop Herbicide Application	June 7 (Buctril M and Axial BIA)	June 6 (Buctril M)	July 21 (Buctril M and Assert)	May 28 (Infinity)	June 13 (Curtail M)	June 8 (Buctril M and Axial)	(Prestige and Axial in separate passes)
Lodging Ratings		Aug 20		Aug 18		July 27 and Aug 23	
Harvest	Aug 9	Aug 20	Aug 15	Aug 13	Sept 10	Sept 8	August 17

Results:
Spring residual soil nitrate levels are presented in Table 2. Nitrate levels were relatively high at Redvers, moderate at Yorkton, Prince Albert, Melfort and Outlook and low at Indian Head, and Scott.

Table 2. Soil Test Nitrate Levels for each location.							
Nitrate Levels (lb NO_3-N/ac)	**Yorkton**	**Melfort**	**Redvers**	**Scott**	**Prince Albert**	**Indian Head**	**Outlook**
0-15 (0-6)	10	10	31	8	25	5.5	15
15-30 (6-12)	15	10			17		11
15-60 (6-24)			45	9		8	
30-60 (12-24)							12
Total (0-24)	37.5[a]	30[a]	76	17	42	13.5	38

[a]Estimated value for 0 to 24 inches based on 0-12 sample.

Tables 3-11 show the complete analysis for all locations are found in the appendices.

The target seeding rates for CDC Bow and CDC Austenson were either 200 or 300 seeds/m^2 depending on the treatment. Averaged across location, 200 and 300 seeds/m^2 resulted in plant emergence of 183 and 241 plants/m^2, respectively. However, this did vary between locations with populations being relatively low at Scott and Prince Albert compared to the other locations (Table 3). For the most part, emergence was very similar for CDC Bow and CDC Austenson at each location and emergence tended to decline modestly with increasing nitrogen rate.

Overall, the feed barley variety CDC Austenson yielded significantly more than the malt barley variety CDC Bow at all locations, except Prince Albert (Tables 4 and 5). When averaged across seeding rate, nitrogen rate, and location, CDC Austenson yielded 8% more than CDC Bow and this difference in yield was maintained as rates of applied N were increased (Figure 1). However, the yield difference between varieties varied from as little as 1.9% at Prince Albert to as high as 11% at Redvers. Yield differences between the varieties were more modest at Prince Albert, Indian Head and Scott compared to the other locations (Figures 2 and 3). Indian Head was very dry and yields were low. Prince Albert had little precipitation up until the end of June which resulted in reduced yields. Scott also had low yields due to a significant hail and wind storms. Sites receiving more rainfall or irrigation were more responsive to added nitrogen (as expected) and had larger yield differences between the varieties. The overall yield difference of 8% between varieties is consistent with variety results published in 2018 Saskatchewan Seed Guide. In this guide, yields of CDC Austenson and CDC Bow are compared to AC Metcalfe. From these relative comparisons it can be inferred that CDC Austenson should be yielding between 4 to 9% more than CDC Bow depending on the region.

Figure 1. Yield Response of CDC Bow and CDC Austenson to Added Nitrogen Rate, Averaged over Seeding Rate and Location

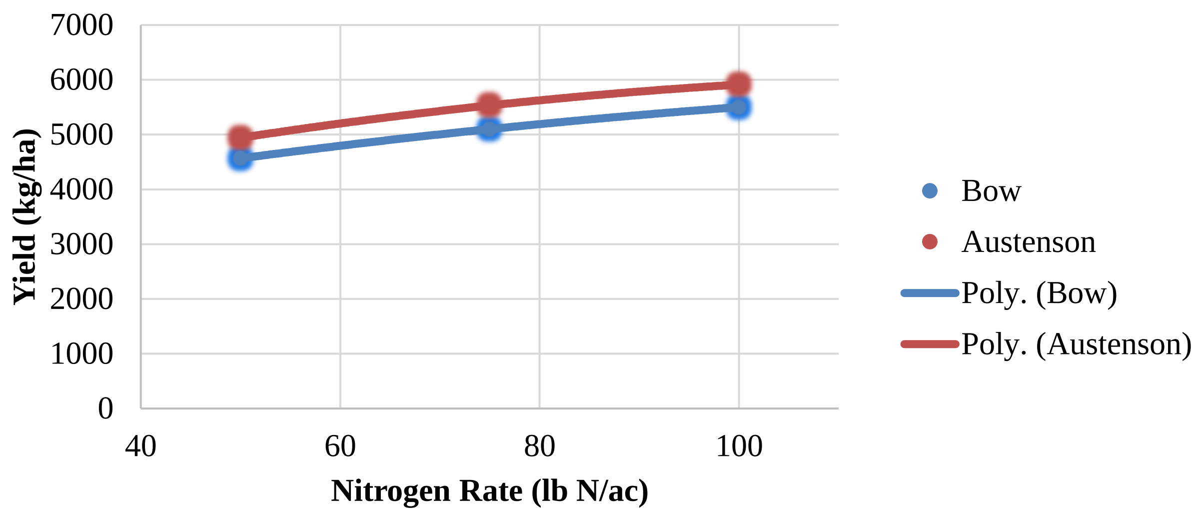


Figure 2. Yield Response of CDC Bow and CDC Austenson to Nitrogen Rate Averaged over Seeding Rate

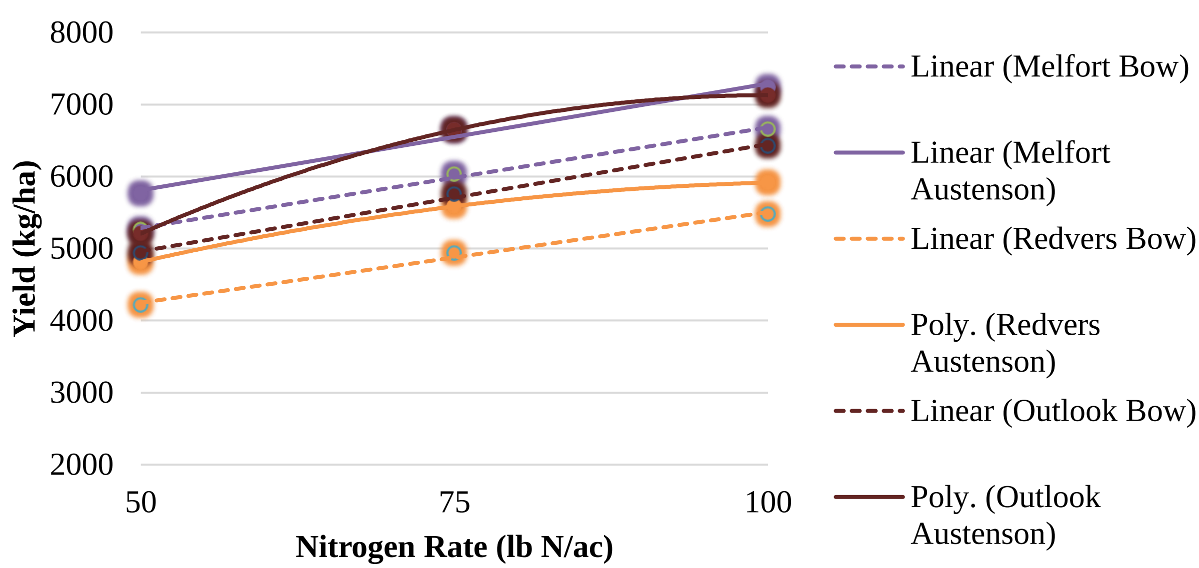
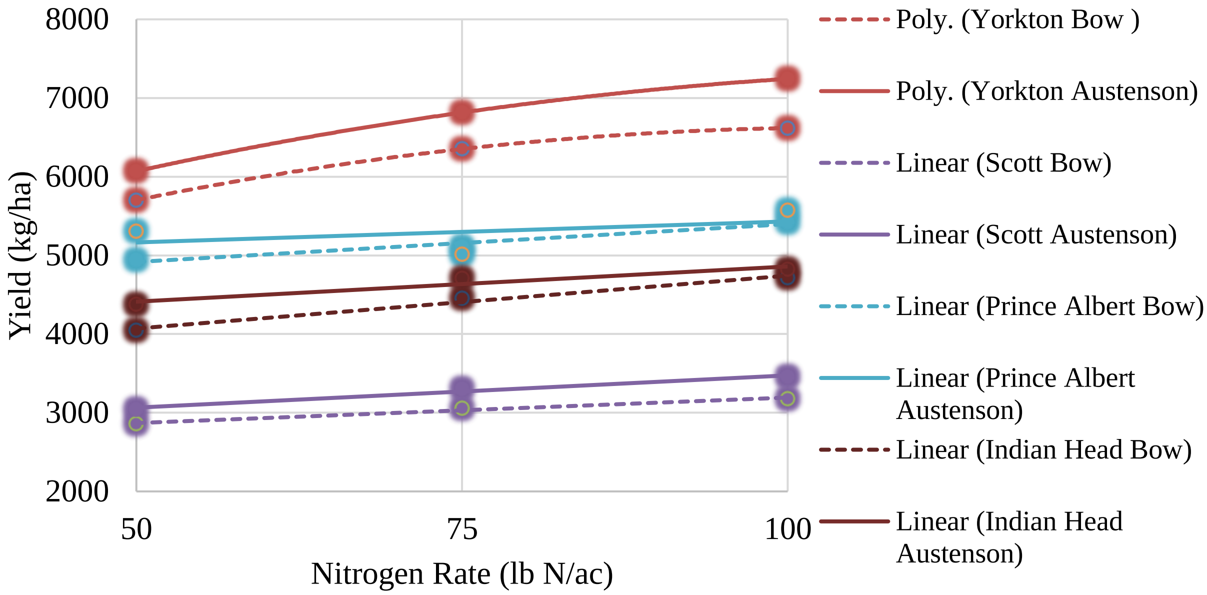


Figure 3. CDC Bow and CDC Austenson's Yield Response to Nitrogen Rate Averaged over Seeding Rate



Increasing seeding rate from 200 to 300 seeds/m^2, tended to reduce yield at all locations except Outlook; however, for most individual sites the response was not significant. The effect was almost statistically significant at Prince Albert ($p=0.062$) and was statistically significant at Scott (Table 4). Increasing seeding rate decreased yield by 4.4 and 3.8 % at Scott and Prince Albert, respectively. Conditions were dry at most locations. As a result, increasing seeding rates increased inter-plant competition for soil moisture and reduced yield at all dryland sites. The only site where increasing plant populations increased yield was under irrigation at Outlook. Inter-plant competition for moisture as seeding rate was increased did not limit yield at this site.

The selection of barley for malt is based on measuring a number of parameters such as germination, sprouting, moisture content, peeled and broken kernels, plumpness and protein. The treatment results for these parameters are listed by location in Table 7 and are based on one bulk sample from the 4 replicates. Germination must exceed 95% and this was achieved regardless of seeding or nitrogen rate at all locations. Levels of sprouting were low at all locations and within acceptable limits as conditions prior to harvest were dry. Moisture content should be no higher than 13.5% otherwise storage may become an issue. Grain moisture was excessively high at Prince Albert, but harvesting later could have addressed this issue. Peeled and broken kernels should be less than 5% as they interfere with the uniformity of germination during malting. This was only exceeded at Outlook and could have been addressed by adjusting combine settings. Malsters are also looking for plump kernels of uniform size. A plump kernel contains more starch and gives a higher percent of extract. The exact requirement may vary with the malster, but barley selected for malt typically has around 92% plump seed. This level was exceeded at every location regardless of treatment with the exception of CDC Bow seeded at 300 seeds/m^2 and with 100 lb N/ac at Yorkton. Protein must be between 11 and 12.5% to be accepted for malt.

This varied greatly with nitrogen rate and location. By using site as replication, the plumps, protein, thousand kernel weight, and test weight data was statistically analysed. Kernel plumpness and protein did not significantly differ between seeding rates. However, kernel plumpness did significantly decrease from 96.3 to 95.1% and protein significantly increased from 11.1 to 12.0% as nitrogen rate was increased from 50 to 100 lb N/ac (data not shown). Thousand kernel weight (Table 8) and test weights (Table 9) were also measured, although malsters place less value on these parameters. Increasing seeding rate was found to significantly reduce thousand kernel weight from 49.5 to 48.8 grams however, test weights were unaffected. This decrease in thousand kernel weight is not agronomically significant. Increasing nitrogen did not significantly impact either thousand kernel weight or test weight.

The exact amount of nitrogen required to maximize yield and still provide an acceptable level of protein varied greatly between locations. Applying 100 lb N/ac proved to be the best nitrogen rate for maximizing yield and maintaining protein levels below the maximum allowable limit of 12.5% at all locations, except Scott. Scott's yields were low and protein levels were too high for malt even with only 50 lb N/ac. The reason for the high protein level is uncertain but may have been related to poor yields caused by extreme wind and hail events. At Melfort, Redvers and Outlook, nitrogen rates should have been increased beyond 100 lb N/ac as yields were still increasing sharply and protein levels were low. This was particularly true at Outlook as even the highest rate of N did not result in protein levels above the 11% minimum (Table 7).

Table 10 and 11 shows the economic analysis used to determine the value of growing CDC Bow for malt vs CDC Austenson for feed based on 2017 and 2018 pricing, respectively. As seeding rate had little effect on the yield or protein of barley, the economic comparison of growing the feed variety CDC Austenson against the malt variety CDC Bow is based on yields averaged over seeding rate and prices obtained from the Saskatchewan Crop Planning Guide. For the black soil zone in 2017, the guide used prices of $5.44 and $3.22/bu for malt and feed barley, respectively. In 2018, the guide used a narrower range of $4.68 and $3.70/bu for malt and feed, respectively. The Crop Planning Guide calculates total variable expenses for malt and feed barley to be $252.22 and $206.75/ac, respectively in 2018. However, the economic analysis for this study will assume production costs are equal as fertility and chemical costs for our comparisons did not differ between the varieties in our study. Economic comparisons were made at 100 lb N/ac at all sites except Scott where the comparison was made at 50 lb N/ac because further increases in N just continued to increase protein levels beyond acceptable levels for malt.

When averaged over seeding rate, CDC Austenson yielded more than CDC Bow at every location. However, the gross returns for selling CDC Bow for malt were greater than selling CDC Austenson for feed regardless of location and whether 2017 or 2018 pricing was used (Tables 10 and 11). Selling CDC Austenson for feed generated more income than selling CDC Bow for feed at every location as yield for CDC Austenson was always higher. The probability for making malt that is required to justifying growing CDC Bow instead of CDC Austenson was determined by comparing the relative value of selling CDC Bow for malt or feed against selling CDC Austenson for feed. To justifying growing CDC Bow, the required probability for making malt varied from as low as 1% at Prince Albert and as high as 16% at Outlook based on 2017 pricing (Table 10). When considering the narrower pricing difference of 2018, the required probability of making malt needed to justify growing CDC Bow jumped to 2% at Prince Albert and 41% at Outlook (Table 11). Based on these results, there was virtually no reason to grow CDC Austenson at Prince Albert because the yield difference between varieties was very small. CDC Bow essentially provided the same feed returns with the possibility of selling for higher returns as malt. Based on results from Outlook, growing CDC Bow for malt should only be considered if the chance of obtaining malt is very high (over 41%) or the price differential between malt and feed is high. This is because CDC Austenson was considerably higher yielding (+11%) than CDC Bow at Outlook. When averaged across all locations, there needed to be more than a 10% or 27% chance of making malt to justifying growing CDC Bow over CDC Austenson based on 2017 and 2018 pricing, respectively. These probabilities may be a little low when considering feed yields could have been pushed higher with rates of N beyond 100 lb/ac. However, the required probability of making malt to justify growing the malt variety CDC Bow would still be low.

Conclusions and Recommendations:

The first objective of this study was to demonstrate that newer malt varieties could provide yields comparable to the best feed variety CDC Austenson. This was not achieved when comparing with CDC Bow. When averaged across location CDC Austenson yielded 8% more than CDC Bow. To justify growing CDC Bow the chance of making malt had to be better than 10% based on 2017 pricing and 27%, based on the narrower price difference of 2018. When the price differential between malt and feed barley is fairly high, many areas could justify taking a chance on growing CDC Bow for malt as the downside for selling CDC Bow for feed is fairly small compared to the upside of making malt. However, producers need to have a realistic expectation for making malt to choose between the varieties. According to the Canadian Grain Commission, only 20% of malting barley production in Saskatchewan is actually selected each year for malting. Future study should compare AAC Synergy versus CDC Austenson as yield difference between these two varieties should be minimal based on variety information in Saskatchewan Seed Guide. The Saskatchewan Barley Development Commission is also impressed by AAC Synergy as it yielded better than expected under the dry conditions of 2018. When malt varieties provide comparable yields to the best feed varieties and are widely accepted by malsters, there will be little reason to grow feed varieties.

The 2nd objective was to demonstrate the benefit of higher seeding rates for yield and malt quality. For the most part this was not demonstrated at the dryland farming sites because soil moisture was limiting. Increasing seeding rate from 200 to 300 seeds/m^2 increased inter-plant competition for moisture and decreased yield, although for most individual sites the response was not significant. The only exception to this occurred under irrigation at Outlook. At Outlook yields increased with increasing seeding rate. Increasing seeding rate had no significant effect on malt quality parameters in this study. It was found to decrease thousand kernel weight slightly, but malsters are more concerned with kernel plumpness. These results may have differed under more typical, or wetter, conditions

The 3rd objective was to demonstrate how nitrogen management differed between malt and feed varieties. This was somewhat accomplished, but differences would have been clearer if an additional, higher, rate of N was included in the study. While the feed variety CDC Austenson was higher yielding, its response to added nitrogen was very similar to the malt variety CDC Bow. When averaged across location, the protein of malt barley was nearing the borderline of

12.5% protein with 100 lb N/ac. This means there was not much room to increase the yield of CDC Bow without risking rejection for malt based on excessive protein. However, the yield and economic benefit of growing CDC Austenson for feed could have been pushed higher with rates beyond 100 lb N/ac at most sites. In other words, target nitrogen rates for CDC Austenson should be higher than CDC Bow.

Supporting Information

Acknowledgements:

This project was funded through the Saskatchewan Barley Development Commission and Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement. Adopt signs were posted during annual tours.

Appendices:

Table 3. Main effects of variety, seeding rate and nitrogen rate on barley emergence at multiple locations in 2018.

Main effect	**Emergence**						
	Yorkton	**Melfort**	**Redvers**	**Scott**	**Prince Albert**	**Indian Head**	**Outlook**
Variety	---------- plants m^{-2} ----------						
CDC Bow	230 a	262 a	212 a	193 b	180 a	249 a	215 a
CDC Austenson	228 a	255 a	239 b	170 a	151 a	235 a	209 a
LSD	NS	NS	15.9	10	NS	NS	NS
Seeds/m^2							
200	195 a	222 a	194 a	158 a	139 a	190 a	183 a
300	262 b	296 b	257 b	204 b	193 b	294 b	241 b
LSD	16.4	15.3	15.9	10	21.6	14.7	21.8
lb N/ac							
50	231 a	271 a	229 a	190 b	169 a	246 a	211
75	231 a	253 a	225 a	180 ab	163 a	238 a	218
100	224 a	253 a	224 a	173 a	166 a	242 a	207
LSD	NS	NS	NS	12.6	NS	NS	NS

Table 4. Significance of variety, seeding rate and nitrogen fertilizer effects on barley yield at multiple locations in 2018.

	Yield						
	Yorkton	**Melfort**	**Redvers**	**Scott**	**Prince Albert**	**Indian Head**	**Outlook**
Effect	---p-values ^{Z} ---------------------------------------						
Variety (V)	0.0003	<0.0001	<0.0001	<0.0001	Ns	0.0005	0.0002
Seeds/m^2 (S)	Ns	Ns	Ns	0.0084	0.062	Ns	Ns
V x S	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Nitrogen rate (R)	<0.0001	<0.0001	<0.0001	<0.0001	0.014	<0.0001	<0.0001
V x R	Ns	Ns	Ns	Ns	Ns	Ns	Ns
S x R	Ns	Ns	Ns	Ns	Ns	Ns	Ns
V x S x R	Ns	Ns	Ns	Ns	Ns	Ns	Ns

^{Z} p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability

Table 5. Main effects of variety, seeding rate and nitrogen rate on barley yield at multiple locations in 2018.

Main effect	**Yield**						
	Yorkton	**Melfort**	**Redvers**	**Scott**	**Prince Albert**	**Indian Head**	**Outlook**
Variety	---------- kg ha^{-2} ----------						
CDC Bow	6224 a	5984 a	4876 a	3031 a	5156 a	4406 a	5706 a
CDC Austenson	6710 b	6550 b	5438 b	3270 b	5256 a	4635 b	6328 b
LSD	247	223	202	104	Ns	123	310
Seeds/m^2							
200	6544 a	6310 a	5160 a	3221 a	5308 a	4535 a	5870 a
300	6390 a	6224 a	5153 a	3079 b	5105 a	4506 a	6164 a
LSD	Ns	Ns	Ns	104	NS	Ns	Ns
lb N/ac							
50	5886 a	5111 a	4515 a	2952 a	5123 a	4210 a	5072 a
75	6584 b	6341 b	5261 b	3179 b	5061 a	4582 b	6201 b
100	6931 c	6950 c	5694 c	3319 c	5497 b	4770 c	6778 c
LSD	311	280	254	131	271	155	390

Table 6. Variety by Seeding rate by N fertilizer rate interactions on barley yield at multiple locations in 2018.

Main effect	Yield						
	Yorkton	Melfort	Redvers	Scott	Prince Albert	Indian Head	Outook
V × S x R	--- Kg ha^{-2} ---						
CDC Bow – 200 seeds/m2 – 50 lb N/ac	5786	5249	4095	2867	5096	4091	4773
CDC Bow – 200 seeds/m2 – 75 lb N/ac	6260	6110	4982	3034	5159	4443	5512
CDC Bow – 200 seeds/m2 – 100 lb N/ac	6636	6690	5424	3336	5523	4807	6178
CDC Bow – 300 seeds/m2 – 50 lb N/ac	5618	5272	4338	2848	4785	4000	5101
CDC Bow – 300 seeds/m2 – 75 lb N/ac	6444	5963	4893	3072	5058	4468	5996
CDC Bow – 300 seeds/m2 – 100 lb N/ac	6601	6623	5525	3027	5320	4628	6675
CDC Austenson – 200 seeds/m2 – 50 lb N/ac	6254	5806	4751	3102	5455	4205	5196
CDC Austenson – 200 seeds/m2 – 75 lb N/ac	7051	6545	5813	3443	5163	4742	6580
CDC Austenson – 200 seeds/m2 – 100 lb N/ac	7277	7462	5898	3547	5450	4924	6981
CDC Austenson – 300 seeds/m2 – 50 lb N/ac	5887	5718	4876	2992	5158	4545	5219
CDC Austenson – 300 seeds/m2 – 75 lb N/ac	6580	6745	5358	3167	4866	4674	6715
CDC Austenson – 300 seeds/m2 – 100 lb N/ac	7211	7026	5931	3367	5446	4721	7278
L.S.D.	816	735	667	345	711	406	1021

Table 7. Quality Parameters for Malt Barley								
Treatment	**Sprouted %**	**Plump %**	**Thins %**	**Foreign %**	**Peeled/Broken %**	**Moisture %**	**Protein %**	**Germ %**
Yorkton								
1. CDC Bow – 200 seeds/m2 – 50 lb N/ac	0	96.1	0.4	0.1	4.1	12.7	10.2	100
2. CDC Bow – 200 seeds/m2 – 75 lb N/ac	0	93.7	0.6	0.1	4.3	12.6	10.5	100
3. CDC Bow – 200 seeds/m2 – 100s lb N/ac	0	92.4	0.9	0.1	4.3	12.7	12.3	98
4. CDC Bow – 300 seeds/m2 – 50 lb N/ac	0	95	0.4	0.1	2.9	12.6	9.8	100
5. CDC Bow – 300 seeds/m2 – 75 lb N/ac	0	92	1.2	0.1	2	12.6	10.9	98
6. CDC Bow – 300 seeds/m2 – 100 lb N/ac	0	88	2.7	0.1	2.3	12.6	11.4	100
Melfort								
1. CDC Bow – 200 seeds/m2 – 50 lb N/ac	0.0	96.4	0.2	0.2	2.7	9.1	10.4	100.0
2. CDC Bow – 200 seeds/m2 – 75 lb N/ac	0.0	95.2	0.2	0.2	1.9	8.9	10.6	99.0
3. CDC Bow – 200 seeds/m2 – 100 lb N/ac	0.0	93.0	0.4	0.3	1.6	9.2	10.8	99.0
4. CDC Bow – 300 seeds/m2 – 50 lb N/ac	0.1	98.2	0.1	0.1	4.4	8.9	10.1	100.0
5. CDC Bow – 300 seeds/m2 – 75 lb N/ac	0.1	95.5	0.3	0.2	2.8	9.0	10.8	99.0
6. CDC Bow – 300 seeds/m2 – 100 lb N/ac	0.0	95.4	0.2	0.1	3.1	9.1	11.3	98.0

Table 7 Continued. Quality Parameters for Malt Barley								
Treatment	**Sprouted %**	**Plump %**	**Thins %**	**Foreign %**	**Peeled/Broken %**	**Moisture %**	**Protein %**	**Germ %**
Scott								
1. CDC Bow – 200 seeds/m2 – 50 lb N/ac	0	96	0.2	0	0.9	10.6	13.1	100
2. CDC Bow – 200 seeds/m2 – 75 lb N/ac	0	95	0.2	0.1	0.9	10.5	13.5	98
3. CDC Bow – 200 seeds/m2 – 100 lb N/ac	0	95	0.2	0	0.4	10.6	13.4	98
4. CDC Bow – 300 seeds/m2 – 50 lb N/ac	0	96	0.1	0.05	0.8	10.5	12.6	99
5. CDC Bow – 300 seeds/m2 – 75 lb N/ac	0	96	0.1	0.05	0.6	10.5	13.3	99
6. CDC Bow – 300 seeds/m2 – 100 lb N/ac	0	94	0.2	0	0.5	10.5	13.7	99
Prince Albert								
1. CDC Bow – 200 seeds/m2 – 50 lb N/ac	0.2	98	0.2	0.1	0.3	17.8	11.6	96
2. CDC Bow – 200 seeds/m2 – 75 lb N/ac	0.2	98.4	0.2	0.1	0.3	18.4	11.3	98
3. CDC Bow – 200 seeds/m2 – 100s lb N/ac	0.2	98.2	0.2	0.1	0.2	18.1	12.2	97
4. CDC Bow – 300 seeds/m2 – 50 lb N/ac	0.2	98.4	0.1	0.1	0.2	17.7	11.7	99
5. CDC Bow – 300 seeds/m2 – 75 lb N/ac	0.1	98.2	0.1	0	0.2	17.7	12.1	98
6. CDC Bow – 300 seeds/m2 – 100 lb N/ac	0.1	98	0.1	0	0.3	18.1	12.5	98

Table 7 Continued. Quality Parameters for Malt Barley								
Treatment	**Sprouted %**	**Plump %**	**Thins %**	**Foreign %**	**Peeled/Broken %**	**Moisture %**	**Protein %**	**Germ %**
Indian Head								
1. CDC Bow – 200 seeds/m2 – 50 lb N/ac	0.2	95.6	0.2	0.4	1.1	9.6	10.7	100
2. CDC Bow – 200 seeds/m2 – 75 lb N/ac	0	95.1	0.2	0.1	1	9.7	11.5	99
3. CDC Bow – 200 seeds/m2 – 100 lb N/ac	0	95.7	0.2	0.1	0.8	9.8	12.6	100
4. CDC Bow – 300 seeds/m2 – 50 lb N/ac	0	95.3	0.2	0.2	3.6	9.7	10.3	99
5. CDC Bow – 300 seeds/m2 – 75 lb N/ac	0	93.6	0.2	0.2	3	9.7	11.3	100
6. CDC Bow – 300 seeds/m2 – 100 lb N/ac	0	93.2	0.2	0.2	2.8	9.6	12.3	100
Outlook								
1. CDC Bow – 200 seeds/m2 – 50 lb N/ac	0	98.8	0.1	0.1	8	10.9	9.5	98
2. CDC Bow – 200 seeds/m2 – 75 lb N/ac	0	99.0	0.1	0.1	6.4	10.9	9.5	98
3. CDC Bow – 200 seeds/m2 – 100 lb N/ac	0	99.0	0.1	0.1	4.4	11	10.6	96
4. CDC Bow – 300 seeds/m2 – 50 lb N/ac	0	98.8	0.1	0.1	5.9	10.8	9.6	95
5. CDC Bow – 300 seeds/m2 – 75 lb N/ac	0	99.1	0.1	0.1	5.7	10.9	9.5	100
6. CDC Bow – 300 seeds/m2 – 100 lb N/ac	0	98.9	0.1	0.1	6	11	10.5	97

Table 7 Continued. Quality Parameters for Malt Barley								
Treatment	**Sprouted %**	**Plump %**	**Thins %**	**Foreign %**	**Peeled/Broken %**	**Moisture %**	**Protein %**	**Germ %**
Redvers								
1. CDC Bow – 200 seeds/m2 – 50 lb N/ac	0	98.3	0.1	0.05	0.2	12.3	10.4	100
2. CDC Bow – 200 seeds/m2 – 75 lb N/ac	0	98.4	0.1	0.05	0.7	12.4	10.5	100
3. CDC Bow – 200 seeds/m2 – 100 lb N/ac	0	98	0.1	0	0.8	12.1	11.7	100
4. CDC Bow – 300 seeds/m2 – 50 lb N/ac	0	98	0.1	0	0.4	12.3	9.7	100
5. CDC Bow – 300 seeds/m2 – 75 lb N/ac	0	98.4	0.1	0	0.5	12.2	10.8	100
6. CDC Bow – 300 seeds/m2 – 100 lb N/ac	0	97.6	0.1	0.05	0.2	12.1	11.9	99

Table 8. Thousand Kernel Weights for Malt and Feed Barley							
Treatments	**Yorkton**	**Melfort**	**Redvers**	**Scott**	**Prince Albert**	**Indian Head**	**Outlook**
Thousand Kernel Weights (g)							
1. CDC Bow (Malt); 200 seeds/m^2; 50 lb/ac N	48.5	48.4	50.8	44.6	52.8	45.4	49.9
2. CDC Bow (Malt); 200 seeds/m^2; 75 lb/ac N	46.9	47.7	52.2	43.6	56.4	45.4	50.2
3. CDC Bow (Malt); 200 seeds/m^2; 100 lb/ac N	46.7	47.0	52.9	45.2	56.0	46.0	50.8
4. CDC Bow (Malt); 300 seeds/m^2; 50 lb/ac N	48.3	44.5	50.3	44.4	56.0	45.2	49.5
5. CDC Bow (Malt); 300 seeds/m^2; 75 lb/ac N	47.7	48.7	49.4	43.8	56.8	44.9	49.4
6. CDC Bow (Malt); 300 seeds/m^2; 100 lb/ac N	47.6	48.1	50.6	44.6	56.4	44.8	50.9
7. CDC Austenson (Feed); 200 seeds/m^2; 50 lb/ac N	50.8	50.5	49.5	47.6	56.4	43.2	51.5
8. CDC Austenson (Feed); 200 seeds/m^2; 75 lb/ac N	50.3	50.3	49.4	47.8	57.6	43.7	53.8
9. CDC Austenson (Feed); 200 seeds/m^2; 100 lb/ac N	50.6	49.4	49.6	48.8	55.2	43.5	53.4
10. CDC Austenson (Feed); 300 seeds/m^2; 50 lb/ac N	48.2	49.8	49.4	48.2	54.8	44.2	51.2
11. CDC Austenson (Feed); 300 seeds/m^2; 75 lb/ac N	43.7	50.5	49.1	46.4	52.8	42.9	52.3
12. CDC Austenson (Feed); 300 seeds/m^2; 100 lb/ac N	48.0	50.0	48.3	47.8	55.2	41.9	53.0

Table 9. Test Weights for Malt and Feed Barley

Treatments	Yorkton	Melfort	Redvers	Scott	Prince Albert	Indian Head	Outlook
Test Weight (g/0.5 l)							
1. CDC Bow (Malt); 200 seeds/m^2; 50 lb/ac N	333	330	332	327	305.6	328	313
2. CDC Bow (Malt); 200 seeds/m^2; 75 lb/ac N	332	328	335	328	311.4	325	309
3. CDC Bow (Malt); 200 seeds/m^2; 100 lb/ac N	328	325	334	329	310.1	325	309
4. CDC Bow (Malt); 300 seeds/m^2; 50 lb/ac N	328	333	329	329	308.7	328	320
5. CDC Bow (Malt); 300 seeds/m^2; 75 lb/ac N	330	330	330	329	310.5	326	309
6. CDC Bow (Malt); 300 seeds/m^2; 100 lb/ac N	329	328	336	328	314.3	326	309
7. CDC Austenson (Feed); 200 seeds/m^2; 50 lb/ac N	343	346	335	335	326.3	334	322
8. CDC Austenson (Feed); 200 seeds/m^2; 75 lb/ac N	342	344	336	336	319.8	330	322
9. CDC Austenson (Feed); 200 seeds/m^2; 100 lb/ac N	342	339	333	334	320.1	327	320
10. CDC Austenson (Feed); 300 seeds/m^2; 50 lb/ac N	339	344	336	337	321.8	336	322
11. CDC Austenson (Feed); 300 seeds/m^2; 75 lb/ac N	337	348	333	334	323.8	330	322
12. CDC Austenson (Feed); 300 seeds/m^2; 100 lb/ac N	337	345	334	336	320.2	325	313

Table 10. Economic Analysis for Growing CDC Bow for Malt over CDC Austenson for Feed[1]								
	Yorkton	**Melfort**	**Prince Albert**	**Indian Head**	**Outlook**	**Redvers**	**Scott**	**All sites**
	---------------------bu/ac----------------							
CDC Bow -100 lb N/ac (averaged over seeding rate)	123.1	123.8	100.8	87.7	119.5	101.8	Na	
CDC Austenson -100 lb N/ac (averaged over seeding rate)	134.7	134.7	101.3	89.7	132.6	110.0	Na	
CDC Bow -50 lb N/ac (averaged over seeding rate)	Na	Na	Na	Na	Na	Na	53.1	
CDC Austenson -50 lb N/ac (averaged over seeding rate)	Na	Na	Na	Na	Na	Na	56.7	
	--------------------$/ac--------------------							
Gross $ selling CDC Bow for malt	670	673	549	477	650	554	289	552
Gross $ selling CDC Bow for feed	396	399	325	283	385	328	171	327
Gross $ selling CDC Austenson for feed	434	434	326	289	427	354	183	349
Value of selling CDC Bow for malt over CDC Austenson for feed	236	240	222	188	223	200	106	202
Value of selling CDC Austenson for feed over CDC Bow for feed	37	35	2	6	42	26	12	23
	-------------------- %--------------------							
Percent chance of making malt that is required to justify growing CDC Bow over CDC Austenson	14	13	1	3	16	12	10	10

[1]Economic analysis is based on 2017 selling price for malt and feed barley of $5.44 and $3.22/bushel, respectively.

Table 11. Economic Analysis for Growing CDC Bow for Malt over CDC Austenson for Feed[1]								
	Yorkton	**Melfort**	**Prince Albert**	**Indian Head**	**Outlook**	**Redvers**	**Scott**	**All sites**
	--------------------bu/ac---------------							
CDC Bow -100 lb N/ac (averaged over seeding rate)	123.1	123.8	100.8	87.7	119.5	101.8	Na	
CDC Austenson -100 lb N/ac (averaged over seeding rate)	134.7	134.7	101.3	89.7	132.6	110.0	Na	
CDC Bow -50 lb N/ac (averaged over seeding rate)	Na	Na	Na	Na	Na	Na	53.1	
CDC Austenson -50 lb N/ac (averaged over seeding rate)	Na	Na	Na	Na	Na	Na	56.7	
	-------------------$/ac-------------------							
Gross $ selling CDC Bow for malt	576	579	472	411	559	476	249	475
Gross $ selling CDC Bow for feed	455	458	373	325	442	377	197	375
Gross $ selling CDC Austenson for feed	498	498	375	332	491	407	210	402
Value of selling CDC Bow for malt over CDC Austenson for feed	78	81	97	79	69	70	39	73
Value of selling CDC Austenson for feed over CDC Bow for feed	43	40	2	7	48	30	13	26
	-------------------- %-------------------							
Percent chance of making malt that is required to justify growing CDC Bow over CDC Austenson	36	33	2	8	41	30	25	27

[1]Economic analysis is based off a 2018 selling price for malt and feed barley of $4.68 and $3.70/bushel, respectively.

Control of Glyphosate Resistant Canola in Glyphosate Resistant Soybeans

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Abstract/Summary:

Trials were established at Yorkton, Indian Head, Melfort and Outlook to demonstrate the benefit of layering herbicide for the control of glyphosate resistant (GR) canola volunteers in a glyphosate resistant soybean crop. The trials were established as a factorial design with 4 replicates. The first factor compared an in-crop application of glyphosate alone against glyphosate + Viper ADV. The second factor contrasted pre-seed applications of glyphosate alone and glyphosate tank mixed with either Blackhawk, Authority Charge, Express SG or Heat LQ. The benefit of layering herbicide could not be demonstrated at all locations. An in-crop application of Viper ADV alone was sufficient to maximize control of GR canola volunteers and maximize yield at Yorkton, Indian Head and Melfort. Layering with pre-seed tank mixes did little to improve control of volunteers or increase soybean yield as canola populations were low at Indian Head and the initial flush at Melfort and Yorkton emerged after the pre-seed herbicides had been applied. The situation was different at Outlook under irrigation, as a healthy population of volunteers was present when pre-seed herbicides were applied and canola continued to flush throughout the year. As a result, layering of herbicide was extremely beneficial at Outlook. On average, pre-seed tank mixes alone provided 60% control of GR canola volunteers and increased soybean yield by 36%. However, layering pre-seed tank mixes with an in-crop application of Viper ADV further improved volunteer control to 90% and increased soybean yield by 68%. While differences between pre-seed tank mixes were significant at times, no consistent conclusion can be made regarding the relative efficacy of the products.

Project Objectives:

The objectives of this project are:

1. to demonstrate the efficacy of specific pre and post-emergent herbicide options for the control of glyphosate resistant canola volunteers in glyphosate resistant soybeans.
2. to demonstrate improved control of glyphosate resistant canola volunteers by layering pre and post-emergent herbicides
3. to encourage the use of herbicides with differing modes of action to delay the development of herbicide resistance.

Project Rationale:

Glyphosate resistant (GR) soybeans dominate the market due to convenience and improved weed control over traditional soybeans. Volunteer GR canola is the major weed appearing in GR soybean acres in Saskatchewan. Producers must use herbicides in addition to glyphosate for control of GR volunteer canola to minimize soybean yield losses. This is an added cost, but combining herbicides with different modes of action can delay weed resistance to herbicides. In addition, “layering” of pre and post-emergence herbicides provides the greatest control of GR canola volunteers which emerge early and over an extended period of time. The herbicides in this demonstration are registered in Saskatchewan to control volunteer canola in soybean crops. This study will demonstrate the efficacy of various pre- and post-emergence herbicides alone and in combination.

Methodology and Results

Methodology:
Trials were located on land that has had a history of glyphosate resistant canola within the last two years and were established as a factorial design with 4 replicates. Plot size varied at each location based on equipment. The first factor compared an in-crop application of glyphosate alone against glyphosate + Viper ADV. The second factor contrasted pre-seed applications of glyphosate alone and glyphosate tank mixed with either Blackhawk, Authority Charge, Express SG or Heat LQ. Table 1 lists the treatments established. Greater detail regarding herbicide rates are listed below the table.

Every treatment consisted of a pre-seed and post-emergence (in-crop) herbicide application. Treatment 1 consists of glyphosate applied pre and post-emergence. This is the "check" as glyphosate resistant canola will not be controlled by this treatment. Treatment 2 evaluates the addition of Viper ADV post-emergence. This treatment does not benefit from any pre-seed control of the volunteer canola. Treatments 3, 4, 5 and 6 consist of pre-seed applications of Blackhawk, Authority Charge, Express SG and Heat LQ, respectively tank mixed with glyphosate. All of these treatments only have glyphosate applied in-crop so that the control of glyphosate resistant canola volunteers by the pre-seed herbicides can be assessed. Treatments 7, 8, 9 and 10 also consist of pre-seed applications of Blackhawk, Authority Charge, Express SG and Heat LQ, respectively. However, unlike treatments 3 to 6, Viper ADV has been added as an in-crop herbicide. These last four treatments are layering pre-seed and post-emergence herbicides and should provide the best control of glyphosate resistant canola volunteers.

Table 1. Treatment List of Control of Glyphosate Resistant Canola in Glyphosate Resistant Soybean			
Treatment	**Control of GR Volunteer Canola**	**Post-emergence (in-crop)**	**Pre-seed Herbicide**
1	No control	Glyphosate only	Glyphosate only
2	In-crop control only	Glyphosate + Viper ADV	Glyphosate only
3	Early control	Glyphosate only	Glyphosate + Blackhawk
4	Early control	Glyphosate only	Glyphosate + Authority Charge
5	Early control	Glyphosate only	Glyphosate + Express SG
6	Early control	Glyphosate only	Glyphosate + Heat LQ
7	Early + in-crop control	Glyphosate + Viper ADV	Glyphosate + Blackhawk
8	Early + in-crop control	Glyphosate + Viper ADV	Glyphosate + Authority Charge
9	Early + in-crop control	Glyphosate + Viper ADV	Glyphosate + Express SG
10	Early + in-crop control	Glyphosate + Viper ADV	Glyphosate + Heat LQ

Detailed Treatment List

1. Post-emergence:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)

   Pre-seed:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)

2. Post-emergence:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)
    - ***Viper ADV****-0.4 l/ac* (imazamox/bentazon)
    - ***BASF 28% UAN****-0.81 l/ac*

   Pre-seed:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)

3. Post-emergence:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)

   Pre-seed:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)
    - ***BlackHawk****-0.3 l/ac (2,4-D ester + pyraflufen-ethyl)*

4. Post-emergence:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)

   Pre-seed:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)
    - ***Authority Charge***
        i. ***Aim****-18.75 ml/ac* (carfentrazone)
        ii. ***Authority****-118 ml/ac* (sulfentrazone)

5. Post-emergence:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)

   Pre-seed:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)
    - ***Express SG****-4 g/ac* (tribenuron)

6. Post-emergence:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)

   Pre-seed:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)
    - ***Heat LQ****-21.4 ml/ac* (saflufenacil)

7. Post-emergence:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)
    - ***Viper ADV****-0.4 l/ac* (imazamox/bentazon)
    - ***BASF 28% UAN****-0.81 l/ac*

   Pre-seed:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)
    - ***BlackHawk****-0.3 l/ac (2,4-D ester + pyraflufen-ethyl)*

8. Post-emergence:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)
    - ***Viper ADV****-0.4 l/ac* (imazamox/bentazon)
    - ***BASF 28% UAN****-0.81 l/ac*

   Pre-seed:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)
    - ***Authority Charge***
        i. ***Aim****-18.75 ml/ac* (carfentrazone)
        ii. ***Authority****-118 ml/ac* (sulfentrazone)

9. Post-emergence:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)
    - ***Viper ADV****-0.4 l/ac* (imazamox/bentazon)
    - ***BASF 28% UAN****-0.81 l/ac*

   Pre-seed:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)
    - ***Express SG****-4 g/ac* (tribenuron)

10. Post-emergence:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)
    - ***Viper ADV****-0.4 l/ac* (imazamox/bentazon)
    - ***BASF 28% UAN****-0.81 l/ac*

   Pre-seed:
    - ***Roundup transorb****-0.67 l/ac* (glyphosate)
    - ***Heat LQ****-21.4 ml/ac* (saflufenacil)

Table 2 lists the dates various operations occurred at each site.

Table 2. Dates of operations in 2018 for the Control of Glyphosate Resistant Canola in Glyphosate Resistant Soybeans				
	----------------------------Date-----------------------------			
Activity	**Indian Head**	**Melfort**	**Outlook**	**Yorkton**
Broadcasted canola	n/a	n/a	May 18	n/a
Pre-seed Herbicide Application	May 15	May 23	May 24 glyphosate & May 29 (other herbicides)	May 20
Seeding	May 14	May 28	May 29	May 22
Emergence Counts	June 13	June 19	June 21	
Control of volunteer canola 14 days after seeding	n/a	June 11	June 12	June 6
In-crop Fungicide Application	n/a	July 27 (Priaxor)		n/a
In-crop Herbicide Application	June 15	July 6	July 5	June 12
Control of volunteer canola 14 days after post emergence application	n/a	June 20	July 19	June 25
Control of volunteer canola 21 days after post emergence application	July 6	July 27	July 26	July 3
Control of volunteer canola 56 days after post emergence application	Aug 10	Aug 31	Aug 31	Aug 7
Harvest	Sept 11	Oct 19	Oct 5	

Results:
Tables 3 to 14 showing the complete analysis for the study can be found in the Appendices.

Trials were well established with soybean emergence averaging 54.5, 54.5, 58.8 and 51.7 plants/m^2 at Yorkton, Melfort, Indian Head and Outlook, respectively. A heavy population of volunteer glyphosate resistant (GR) canola was present at Outlook and Yorkton. At Melfort there was a mixture of glyphosate and liberty canola volunteers, but the liberty volunteers were not a problem as they were controlled in every treatment by glyphosate. At Indian Head there were very few canola volunteers. Ratings for the control of volunteer canola were taken 14 days after seeding, and 14, 21 and 56 days after post-emergent herbicide. The discussion below focuses on ratings taken 14 days after seeding and 56 days after post-emergent herbicide. Ratings from 14 and 21 days after post-emergent herbicide have been omitted from the report as the 56 day rating provides all the information needed for comparison.

When rated 14 days after seeding, the pre-seed herbicides Blackhawk, Authority Charge, Express SG and Heat LQ provided significant and substantial control of volunteer canola at Outlook (Tables 3 and 4, Figure 1). Pre-seed control was much lower at Melfort and Yorkton as the main flush of volunteer canola occurred after pre-seed herbicides were applied. Ratings were not taken at this time from Indian Head because volunteers were not present at this time.

When rated 56 days after post-emergent herbicides were applied, the control of canola volunteers by pre-seed herbicide tank mixes was still significant at Outlook (Tables 6, 7 Figure 2). At this location, pre-seed herbicide tank mixes significantly reduced canola dockage from 42.1% to 13.6-20.6% (Table 9, 10 and Figure 3) and significantly increased soybean yield from 1480 kg/ha to 2184-2644 kg/ha (Table 13 and Figure 4) depending on herbicide tank mixed with glyphosate. Additionally, yield increases associated with the application of Blackhawk or Authority Charge were significantly higher than those of Express SG or Heat LQ. At Yorkton, pre-seed tank mixes were still only providing modest control of volunteers by the 56 day rating and no control could be detected at Melfort (Table 7 and Figure 2). As a result, pre-seed tank mixes did not significantly reduce canola dockage (Table 10 and Figure 3) or increase soybean yield (Table 13 and Figure 4) at either site. Results were somewhat similar at Indian Head, but percent control ratings at 56 days were based off plants counts and not visual comparisons, as there were still very few volunteers by this time. Like Yorkton and Melfort, no significant differences in control of volunteers or soybean yield resulted from the application of a pre-seed tank mix at Indian Head with the exception of Heat LQ. Heat LQ provided significantly less control than glyphosate alone (Table 7 and Figure 2) which in turn resulted in significantly less soybean yield (Table 13 and Figure 4). The reason for this is unclear. Overall, pre-seed herbicides controlled volunteer canola and increased soybean yield at Outlook, but had little affect at the other locations.

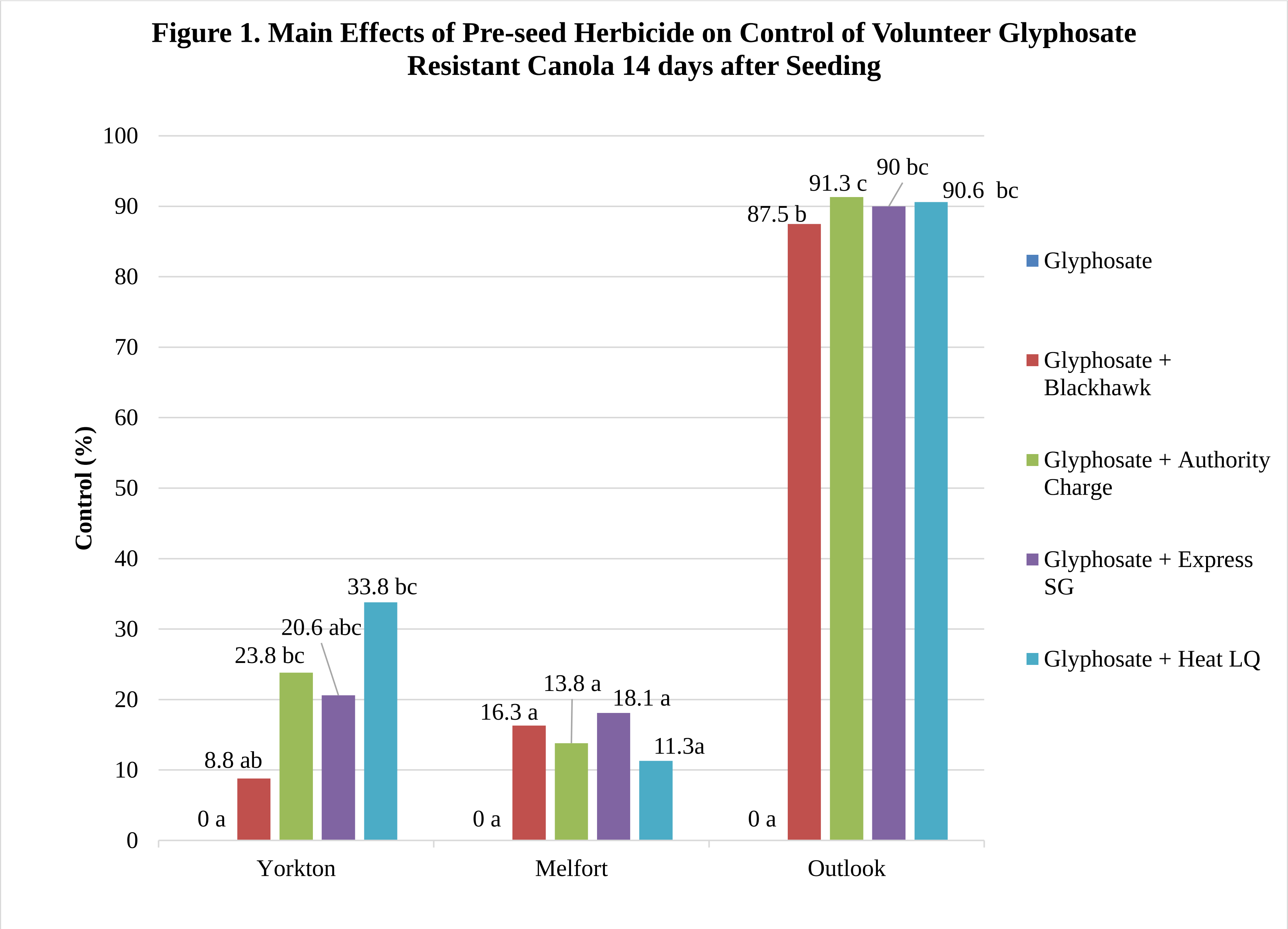


Figure 1. Main Effects of Pre-seed Herbicide on Control of Volunteer Glyphosate Resistant Canola 14 days after Seeding
Control (%)
100
90
80
70
60
50
40
30
20
10
0
0 a
8.8 ab
23.8 bc
20.6 abc
33.8 bc
0 a
16.3 a
13.8 a
18.1 a
11.3a
0 a
87.5 b
91.3 c
90 bc
90.6 bc
Yorkton
Melfort
Outlook
Glyphosate
Glyphosate + Blackhawk
Glyphosate + Authority Charge
Glyphosate + Express SG
Glyphosate + Heat LQ

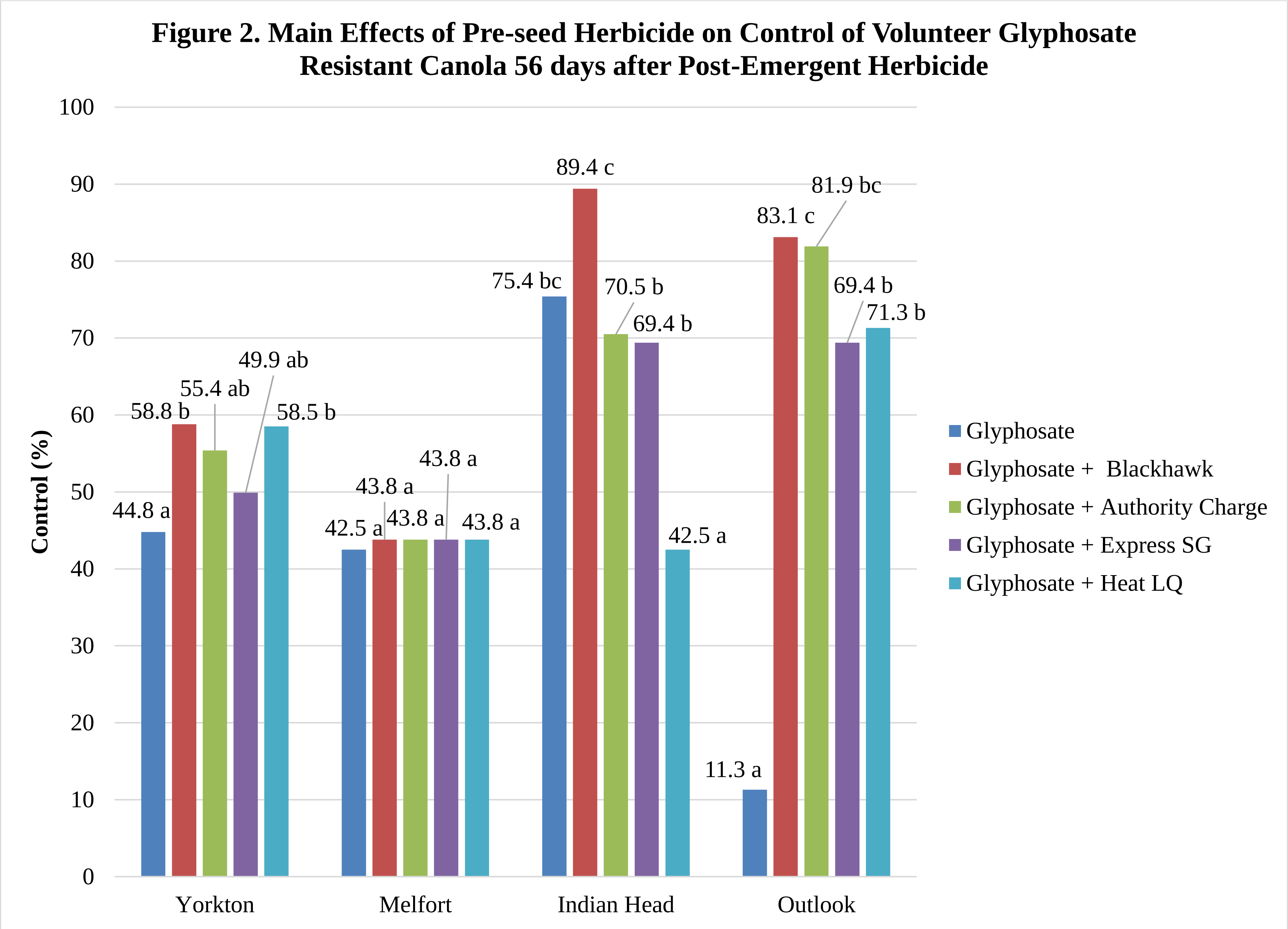


Figure 2. Main Effects of Pre-seed Herbicide on Control of Volunteer Glyphosate Resistant Canola 56 days after Post-Emergent Herbicide
Control (%)
100
90
80
70
60
50
40
30
20
10
0
44.8 a
58.8 b
55.4 ab
49.9 ab
58.5 b
42.5 a
43.8 a
43.8 a
43.8 a
43.8 a
75.4 bc
89.4 c
70.5 b
69.4 b
42.5 a
11.3 a
83.1 c
81.9 bc
69.4 b
71.3 b
Yorkton
Melfort
Indian Head
Outlook
Glyphosate
Glyphosate + Blackhawk
Glyphosate + Authority Charge
Glyphosate + Express SG
Glyphosate + Heat LQ

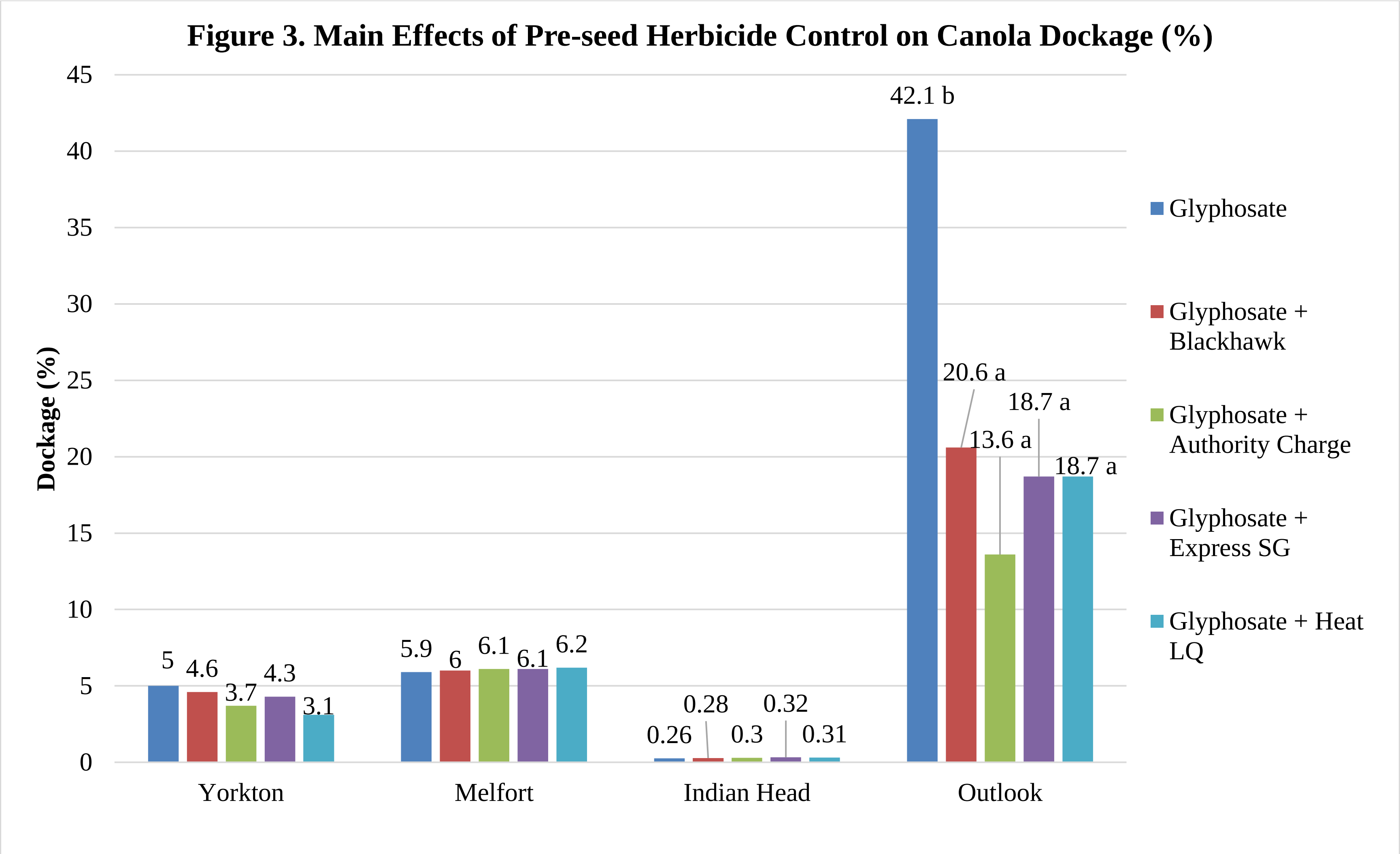


Figure 3. Main Effects of Pre-seed Herbicide Control on Canola Dockage (%)
Dockage (%)
45
40
35
30
25
20
15
10
5
0
5
4.6
3.7
4.3
3.1
5.9
6
6.1
6.1
6.2
0.26
0.28
0.3
0.32
0.31
42.1 b
20.6 a
13.6 a
18.7 a
18.7 a
Yorkton
Melfort
Indian Head
Outlook
Glyphosate
Glyphosate + Blackhawk
Glyphosate + Authority Charge
Glyphosate + Express SG
Glyphosate + Heat LQ

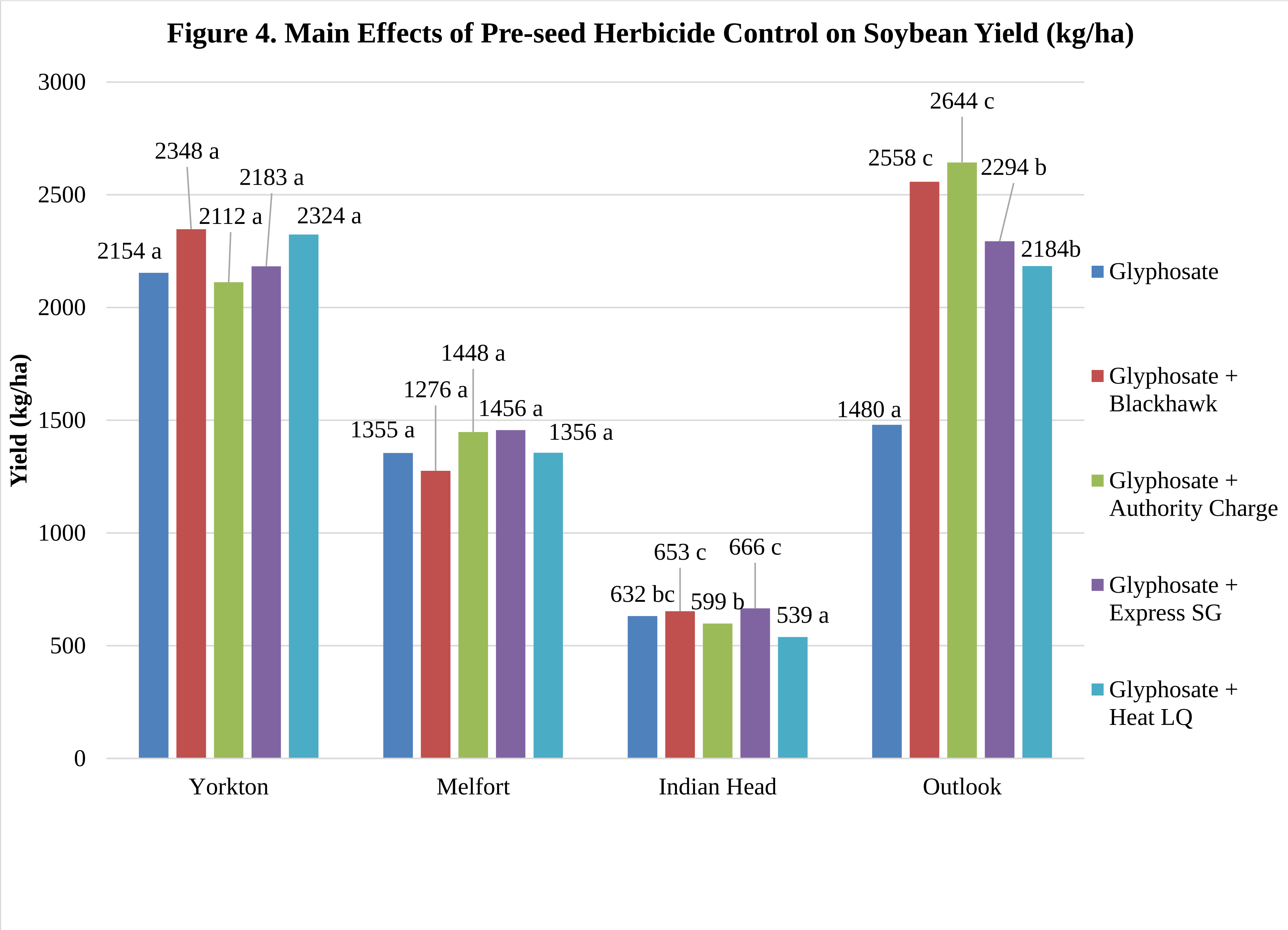


Figure 4. Main Effects of Pre-seed Herbicide Control on Soybean Yield (kg/ha)
Yield (kg/ha)
3000
2500
2000
1500
1000
500
0
2154 a
2348 a
2112 a
2183 a
2324 a
1355 a
1276 a
1448 a
1456 a
1356 a
632 bc
653 c
599 b
666 c
539 a
1480 a
2558 c
2644 c
2294 b
2184b
Yorkton
Melfort
Indian Head
Outlook
Glyphosate
Glyphosate + Blackhawk
Glyphosate + Authority Charge
Glyphosate + Express SG
Glyphosate + Heat LQ

An in-crop application of Viper ADV significantly increased the control of volunteer canola (Tables 6 and 7, Figure 5) at all locations and decreased canola dockage at all sites excepting Indian Head (Tables 9 and 10, Figure 6). Dockage was not reduced at Indian Head as there was little volunteer canola present at that site. When averaged across pre-seed herbicides, the in-crop application of Viper ADV significantly increased soybean yield by 28 and 23% at Yorkton and Outlook, respectively (Table 13 and Figure 7). Viper ADV did not increase yields at Melfort or Indian Head. The lack of a yield response was not surprising for Indian Head as there were few canola volunteers. However, a yield response was expected at Melfort as Viper ADV provided excellent control of volunteers. The lack of yield response at Melfort could be attributed the poor vigour and seed quality from lack of moisture.

The benefit of layering pre-seed and in-crop herbicides for the control of volunteer GR canola could not be demonstrated at Yorkton, Melfort or Indian Head. Viper ADV was very efficacious at these locations, providing over 85% control (Table 8). Moreover, Viper ADV alone reduced canola dockage from 7.6% down to 1.2% at Yorkton and from 11.2% down to 0.6% at Melfort (Table 11). Layering with a pre-seed herbicide tank mix did not significantly improve the control of volunteers (Table 8), further reduce canola dockage (Table 11) or increase soybean yield (Table 14). In contrast, the best control of volunteer canola at Outlook was achieved by layering Viper ADV with a pre-seed herbicide tank mix. The check, sprayed pre-seed and in-crop with glyphosate alone, provided no control of canola, resulted in 44.8% dockage and produced a soybean yield of only 1524 kg/ha (Tables 8, 11 and 14). On average, a pre-seed tank mix without an in-crop application of Viper ADV provided 60% control of volunteers, reduced canola dockage down to 24.3% and increased yield to 2075 kg/ha. Layering Viper ADV with a pre-seed tank mix improved control of volunteers to 90%, further reduced dockage to 11.5% and maximized yield at 2570 kg/ha. Layering herbicide at Outlook increased soybean yield by 68%!

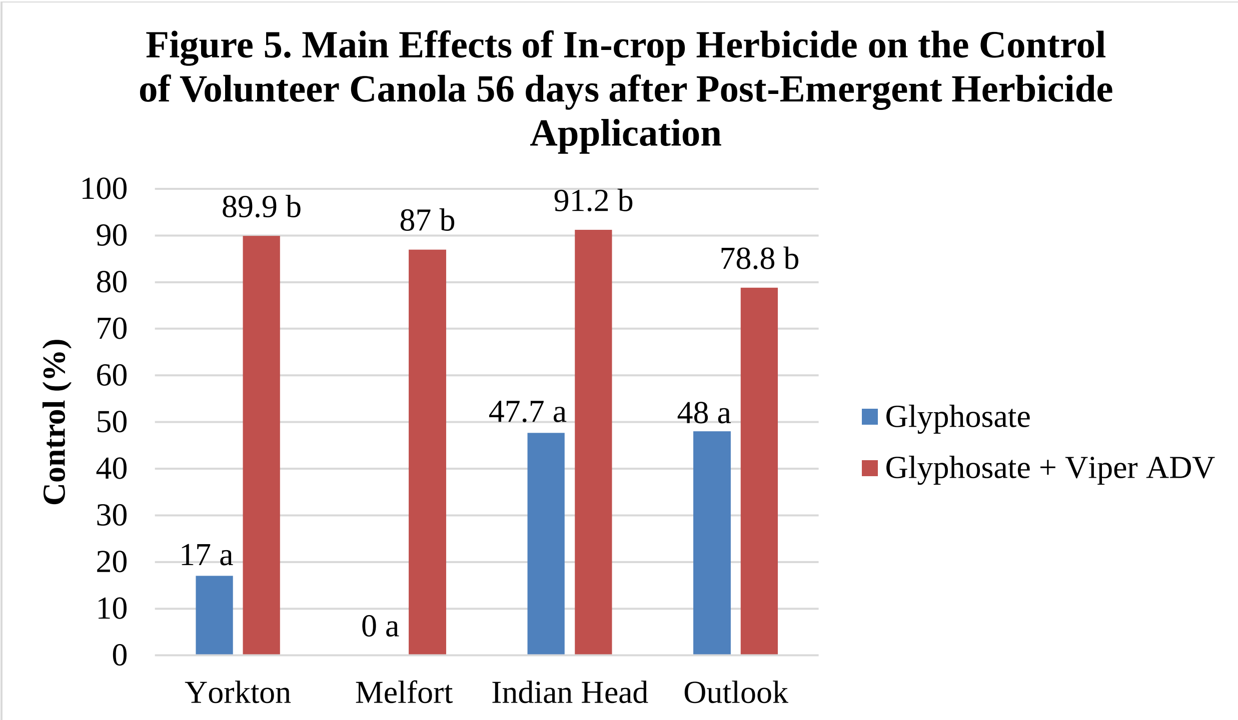


Figure 5. Main Effects of In-crop Herbicide on the Control of Volunteer Canola 56 days after Post-Emergent Herbicide Application
Control (%)
100
90
80
70
60
50
40
30
20
10
0
89.9 b
87 b
91.2 b
78.8 b
47.7 a
48 a
17 a
0 a
Yorkton
Melfort
Indian Head
Outlook
Glyphosate
Glyphosate + Viper ADV

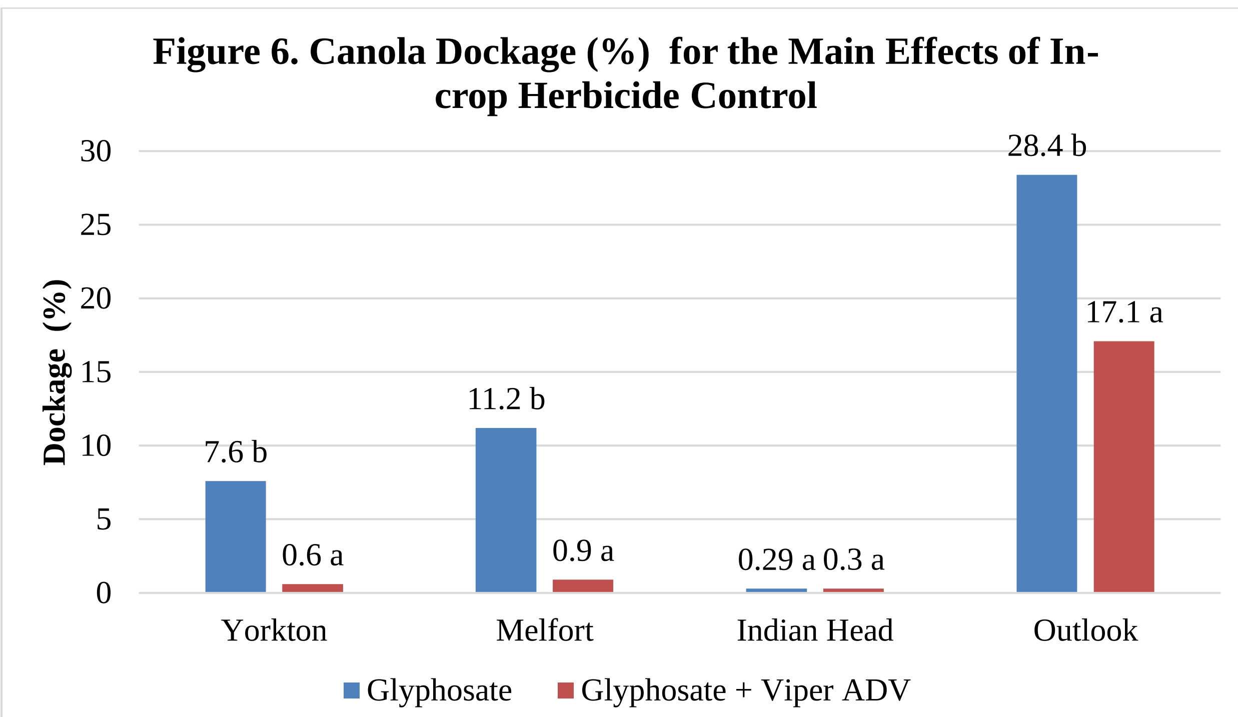
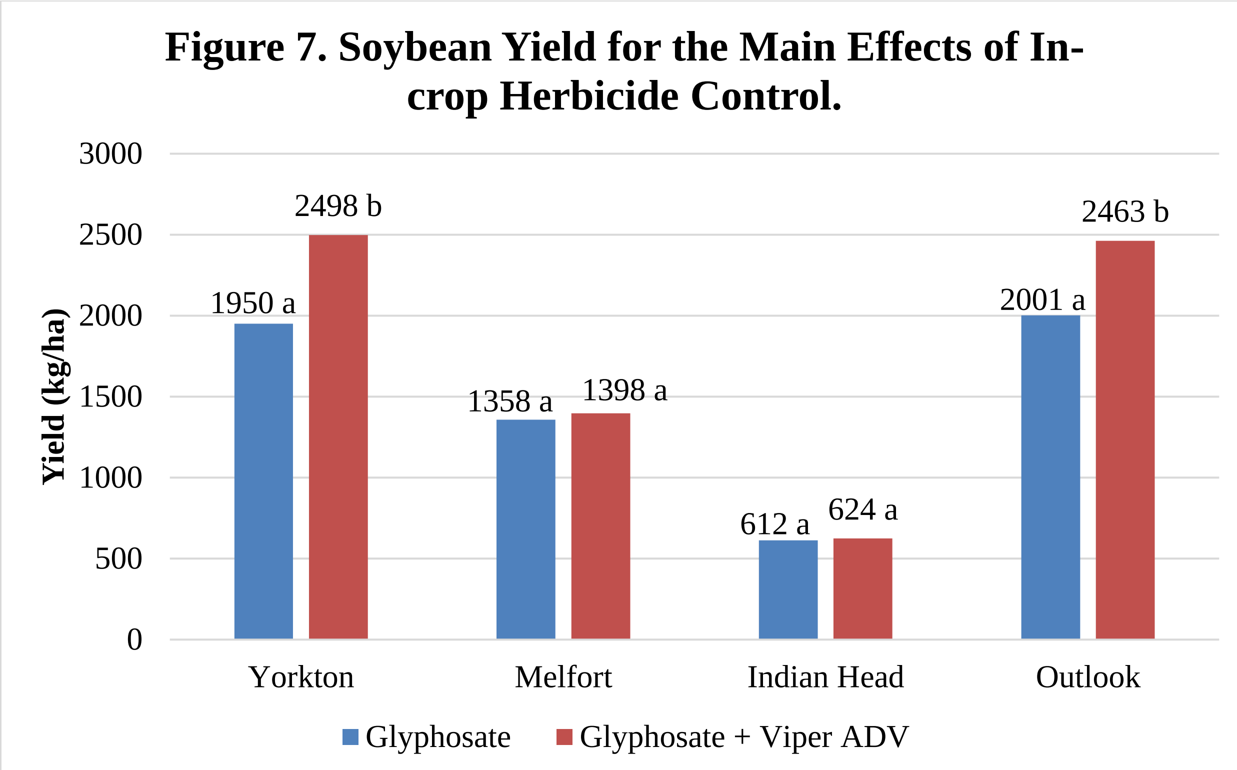


Figure 6. Canola Dockage (%) for the Main Effects of In-crop Herbicide Control
Dockage (%)
30
25
20
15
10
5
0
28.4 b
17.1 a
11.2 b
7.6 b
0.6 a
0.9 a
0.29 a
0.3 a
Yorkton
Melfort
Indian Head
Outlook
Glyphosate
Glyphosate + Viper ADV



Conclusions and Recommendations:

An in-crop application of Viper ADV without a pre-seed tank mix provided sufficient control of GR canola volunteers and maximized yield at Yorkton, Melfort, and Indian Head because volunteers flushed late at Yorkton and Melfort and populations were low at Indian Head. In contrast, layering pre-seed herbicide tank mixes with an in-crop application of Viper ADV was extremely beneficial at Outlook under irrigation. At this location populations of canola volunteers were very heavy and there were multiple flushes. On average, pre-seed tank mixes alone provided 60% control of GR canola volunteers and increased soybean yield by 36%. However, layering pre-seed tank mixes with an in-crop application of Viper ADV further improved volunteer control to 90% and increased soybean yield by 68%. Layering of herbicides with different application timings and modes of action can increase control of canola volunteers and increase soybean yield. While differences between pre-seed tank mixes were significant at times, no consistent conclusion can be made regarding the relative efficacy of the products.

<u>Supporting Information</u>

Acknowledgements:

This project was funded through the Saskatchewan Pulse Growers and Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement. Adopt signs were posted during annual tours.

Appendices:

Table 3. Significance of In-crop control (Viper ADV) and Pre-seed Tank Mixes on Control of Volunteer GR Canola 14 days after seeding (multiple locations 2018).				
	Control 14 days after Seeding (%)			
	Yorkton	**Melfort**	**Indian Head**	**Outlook**
Effect	------------------------ p-values ^{Z} -------------------------			
In-crop control Viper ADV (V)	0.0266	Ns	n/a	<0.0001
Pre-seed control (P)	0.0599	Ns	n/a	<0.0001
V x P	Ns	Ns	n/a	Ns
^{Z} p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability				

Table 4. Main Effect Means for In-crop Control (Viper ADV) and Pre-seed control on Volunteer GR Canola 14 days after seeding (multiple locations 2018).				
Main effect	**Control 14 days after Seeding**			
	Yorkton	**Melfort**	**Indian Head**	**Outlook**
In-crop control	--------------------------------- % ---------------------------			
Glyphosate	26.0 b	13.8 a	n/a	69.8 a
Glyphosate + Viper ADV	8.8 a	10.0 a	n/a	74.0 b
LSD	15.0	Ns	n/a	2.0
Pre-seed control				
Glyphosate	0 a	0 a	n/a	0 a
Glyphosate + Blackhawk	8.8 ab	16.3 a	n/a	87.5 b
Glyphosate + Authority Charge	23.8 bc	13.8 a	n/a	91.3 c
Glyphosate + Express SG	20.6 abc	18.1 a	n/a	90.0 bc
Glyphosate + Heat LQ	33.8 bc	11.3 a	n/a	90.6 bc
LSD	23.8	Ns	n/a	3.1

Table 5. Means for the Interaction between In-crop control and Pre-seed control on Volunteer GR Canola 14 days after seeding (multiple locations 2018).				
Main effect	**Control 14 days after Seeding**			
	Yorkton	**Melfort**	**Indian Head**	**Outook**
V × P	------------------------------- %-------------------------------			
1.Glyphosate – Glyphosate	0.0	0.0	n/a	0.0
3.Glyphosate – Glyphosate + Blackhawk	12.5	10.0	n/a	85.0
4.Glyphosate – Glyphosate + Authority Charge	42.5	8.8	n/a	90.0
5.Glyphosate – Glyphosate + Express SG	27.5	30.0	n/a	86.3
6.Glyphosate – Glyphosate + Heat LQ	47.5	20.0	n/a	87.5
2.Glyphosate + Viper ADV– Glyphosate	0.0	0.0	n/a	0.0
7.Glyphosate + Viper ADV – Glyphosate + Blackhawk	5.0	22.5	n/a	90.0
8.Glyphosate + Viper ADV – Glyphosate + Authority Charge	5.0	18.8	n/a	92.5
9.Glyphosate + Viper ADV – Glyphosate + Express SG	13.8	6.3	n/a	93.8
10.Glyphosate + Viper ADV – Glyphosate + Heat LQ	20.0	2.5	n/a	93.8
L.S.D	33.7	Ns	n/a	4.4

Table 6. Significance of In-crop control (Viper ADV) and Pre-seed Tank Mixes on Control of Volunteer GR Canola 56 days after Post-emergent Herbicide Application (multiple locations in 2018).

Control 56 days after Post-emergent Herbicide Application (%)				
	Yorkton	**Melfort**	**Indian Head**	**Outlook**
Effect	--------------------- p-values [z] ---------------------			
In-crop control Viper ADV (V)	<0.0001	<0.0001	<0.0001	<0.0001
Pre-seed control (P)	0.0711	Ns	0.0002	<0.0001
V x P	Ns	Ns	0.0146	Ns

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

Table 7. Main Effect Means for In-crop Control (Viper ADV) and Pre-seed control on Volunteer GR Canola 56 days after Post-emergent Herbicide Application (multiple locations in 2018).

Main effect	**Control 56 days after Post-Emergent Herbicide Application**			
	Yorkton	**Melfort**	**Indian Head**	**Outlook**
In-crop control	--------------------------------------- % ---------------------			
Glyphosate	17.0 a	0.0 a	47.7 a	48.0 a
Glyphosate + Viper ADV	89.9 b	87.0 b	91.2 b	78.8 b
LSD	7.1	3.5	11.1	7.0
Pre-seed control				
Glyphosate	44.8 a	42.5 a	75.4 bc	11.3 a
Glyphosate + Blackhawk	58.8 b	43.8 a	89.4 c	83.1 c
Glyphosate + Authority Charge	55.4 ab	43.8 a	70.5 b	81.9 bc
Glyphosate + Express SG	49.9 ab	43.8 a	69.4 b	69.4 b
Glyphosate + Heat LQ	58.5 b	43.8 a	42.5 a	71.3 b
LSD	11.2	NS	17.6	11.1

Table 8. Means for the Interaction between In-crop control and Pre-seed control on Volunteer GR Canola 56 days after Post-emergent Herbicide Application (multiple locations in 2018).

Main effect	**Control 56 days after Post-Emergent Herbicide Application**			
	Yorkton	**Melfort**	**Indian Head**	**Outook**
V × P	------------------------------- %------------------------------			
1.Glyphosate – Glyphosate	3.8	0.0	59.5	0.0
3.Glyphosate – Glyphosate + Blackhawk	28.8	0.0	83.8	70.0
4.Glyphosate – Glyphosate + Authority Charge	18.8	0.0	48.5	70.0
5.Glyphosate – Glyphosate + Express SG	12.5	0.0	40.0	50.0
6.Glyphosate – Glyphosate + Heat LQ	21.3	0.0	6.5	50.0
2.Glyphosate + Viper ADV– Glyphosate	85.8	85	91.3	22.5
7.Glyphosate + Viper ADV – Glyphosate + Blackhawk	88.8	87.5	95.0	96.3
8.Glyphosate + Viper ADV – Glyphosate + Authority Charge	92.0	87.5	92.5	93.8
9.Glyphosate + Viper ADV – Glyphosate + Express SG	87.3	87.5	98.8	88.8
10.Glyphosate + Viper ADV – Glyphosate + Heat LQ	95.8	87.5	78.5	92.5
L.S.D	15.8		24.9	15.7

Table 9. Significance of In-crop control (Viper ADV) and Pre-seed Tank Mixes on Canola Dockage (multiple locations in 2018).

	Dockage (%)			
	Yorkton	**Melfort**	**Indian Head**	**Outlook**
Effect	------------------------ p-values [Z] --------------------------			
In-crop control Viper ADV (V)	<0.0001	<0.0001	Ns	0.0024
Pre-seed control (P)	Ns	Ns	Ns	<0.0001
V x P	Ns	Ns	Ns	Ns

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

Table 10. Main Effect Means for In-crop Control (Viper ADV) and Pre-seed control on Canola Dockage (multiple locations in 2018).

Main effect	**Dockage**			
	Yorkton	**Melfort**	**Indian Head**	**Outlook**
In-crop control	--------------------------------------- % ----------------------------			
Glyphosate	7.6 b	11.2 b	0.29 a	28.4 b
Glyphosate + Viper ADV	0.6 a	0.9 a	0.30 a	17.1 a
LSD	1.0	2.2	Ns	6.9
Pre-seed control				
Glyphosate	5.0 a	5.9 a	0.26 a	42.1 b
Glyphosate + Blackhawk	4.6 a	6.0 a	0.28 a	20.6 a
Glyphosate + Authority Charge	3.7 a	6.1 a	0.30 a	13.6 a
Glyphosate + Express SG	4.3 a	6.1 a	0.32 a	18.7 a
Glyphosate + Heat LQ	3.1 a	6.2 a	0.31 a	18.7 a
LSD	NS	NS	NS	10.9

Table 11. Means for the Interaction between In-crop control and Pre-seed control on Canola Dockage (multiple locations in 2018).

Main effect	Dockage			
	Yorkton	**Melfort**	**Indian Head**	**Outlook**
V × P	------------------------------- %------------------------------			
1.Glyphosate – Glyphosate	8.8	11.2	0.24	44.8
3.Glyphosate – Glyphosate + Blackhawk	8.7	11.5	0.25	26.7
4.Glyphosate – Glyphosate + Authority Charge	7.1	11.9	0.30	15.0
5.Glyphosate – Glyphosate + Express SG	7.9	10.7	0.33	27.0
6.Glyphosate – Glyphosate + Heat LQ	5.8	10.9	0.31	28.5
2.Glyphosate + Viper ADV– Glyphosate	1.2	0.6	0.28	39.5
7.Glyphosate + Viper ADV – Glyphosate + Blackhawk	0.6	0.5	0.30	14.6
8.Glyphosate + Viper ADV – Glyphosate + Authority Charge	0.3	0.4	0.30	12.2
9.Glyphosate + Viper ADV – Glyphosate + Express SG	0.8	1.5	0.30	10.4
10.Glyphosate + Viper ADV – Glyphosate + Heat LQ	0.3	1.6	0.31	8.9
L.S.D	2.3	5.0	NS	15.4

Table 12. Significance of In-crop control (Viper ADV) and Pre-seed Tank on Soybean yield (multiple locations in 2018).

	Yield (kg/ha)			
	Yorkton	**Melfort**	**Indian Head**	**Outlook**
Effect	------------------------------------- p-values ^{Z} --			
In-crop control Viper ADV (V)	<0.0001	Ns	Ns	<0.0001
Pre-seed Herbicide (P)	Ns	Ns	<0.0001	<0.0001
V x P	Ns	Ns	Ns	0.0014

^{Z} p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability

Table 13. Main Effect Means for In-crop Control (Viper ADV) and Pre-seed control on Soybean Yield (multiple locations 2018).

Main effect	**Yield**			
	Yorkton	**Melfort**	**Indian Head**	**Outlook**
In-crop control	--------------------------------------- kg ha^{-2} ------------------------------			
Glyphosate	1950 a	1358 a	612 a	2001 a
Glyphosate + Viper ADV	2498 b	1398 a	624 a	2463 b
LSD	200	NS	Ns	117
Pre-seed control				
Glyphosate	2154 a	1355 a	632 bc	1480 a
Glyphosate + Blackhawk	2348 a	1276 a	653 c	2558 c
Glyphosate + Authority Charge	2112 a	1448 a	599 b	2644 c
Glyphosate + Express SG	2183 a	1456 a	666 c	2294 b
Glyphosate + Heat LQ	2324 a	1356 a	539 a	2184 b
LSD	316	NS	45.7	184

Table 14. Means for the Interaction between In-crop control and Pre-seed control on Soybean Yield (multiple locations in 2018).				
Main effect	**Yield**			
	Yorkton	**Melfort**	**Indian Head**	**Outook**
V × P	------------------------------- Kg ha^{-2} -----------------------------			
1.Glyphosate – Glyphosate	1855	1358	602	1524 a
3.Glyphosate – Glyphosate + Blackhawk	2051	1259	648	2231 c
4.Glyphosate – Glyphosate + Authority Charge	1913	1362	598	2388 cd
5.Glyphosate – Glyphosate + Express SG	1799	1481	688	1974 bc
6.Glyphosate – Glyphosate + Heat LQ	2133	1329	523	1890 b
2.Glyphosate + Viper ADV– Glyphosate	2453	1352	663	1436 a
7.Glyphosate + Viper ADV – Glyphosate + Blackhawk	2645	1293	658	2886 e
8.Glyphosate + Viper ADV – Glyphosate + Authority Charge	2311	1534	600	2901 e
9.Glyphosate + Viper ADV – Glyphosate + Express SG	2567	1431	645	2614 d
10.Glyphosate + Viper ADV – Glyphosate + Heat LQ	2516	1384	556	2479 cd
L.S.D	447	Ns	64.7	261

Increasing Wheat Protein with a Post Emergent Application of UAN

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Abstract/Summary:

A study was conducted at seven locations across Saskatchewan to determine if wheat yield and/or protein could be increased by applying 30 lb N/ac of UAN at pre-boot or post-anthesis. UAN was subsequently applied in addition to base rates of 70 or 100 lb N/ac of side-banded urea. The in-crop N was either dribble banded pre-boot or post-anthesis or foliar sprayed post-anthesis. Leaf burning was most severe with the foliar spray application and dribble banding pre-boot resulted in the least amount of crop damage. On average, the supplemental application of 30 lb N/ac increased grain protein by 0.8 and 0.6% when applied to base rates of 70 and 100 lb N/ac, respectively. This supports the hypothesis that supplemental N can increase grain protein

more when N deficiency is greater. While applying supplemental N increased protein it did not increase either yield or protein compared to side banding that additional 30 lb N/ac at seeding, in some instances split applications resulted in less yield and/or protein. In this study, nitrogen use efficiency was better when all the nitrogen was side-banded at seeding. However, if a crop has been fertilized below its potential, a late season application of 30 lb N/ac can increase protein by 0.8%; this protein increase alone will only prove to be economical when the protein spreads are at historical highs, therefore the need for N should be identified early enough that yield can also be increased.

Project Objectives:

The objectives of this project are:

- To demonstrate the potential of post-anthesis applied UAN (30 lb/ac N) to increase wheat grain protein.
- To demonstrate that improvements in grain protein with in-season nitrogen (N) are more likely to occur for more nitrogen deficient wheat (ie: base levels of 70 and 100 lb/ac of N for comparison).
- To demonstrate greater crop safety (less leaf burn) and potentially greater wheat yields when post-anthesis N is applied in a dribble band vs foliar broadcast (flat fan) sprays.
- To demonstrate the potential for a better yield and protein response to post-emergent N when applied earlier in the season (pre-boot versus anthesis)
- To demonstrate the overall risks and benefits of split-applications versus applying all N at seeding. Split-applications may decrease lodging and increase grain protein; however, the separate applications increase cost and applying the entire amount of N up front may provide greater yield potential. An economic analysis of the two practices will be performed.

Project Rationale:

Post-emergent application of N fertilizer is one of the only options to increase grain protein during the growing season. Often it is most economical when yield potential is high and soil N is inadequate to maintain high protein levels. Split applications of N have the benefit of supplying higher levels of N without the increased risk of lodging that comes with supplying all the nitrogen at seeding. However, split applications may cause a nitrogen deficiency in high yielding wheat before the second application. Dribble banding mid-season is the most effective way to apply liquid nitrogen while minimizing leaf burn. Dribble banding also minimizes N lost to volatilization. Foliar broadcast sprays can cause significant leaf burning. UAN can be diluted with water 50:50 to reduce leaf burn when foliar spraying. Leaves are not good at absorbing sufficient amounts of nitrogen; absorbing only 4-27%. Foliar sprayed UAN is mostly absorbed through the roots after rainfall events wash the N into the soil. Foliar broadcast spray applications of UAN post-anthesis frequently increase protein, but this practice does not always prove to be economical.

Recently, most work has been targeting the post-anthesis stage for increasing protein in wheat. However, applying N at the boot stage instead of post-anthesis stage has been shown to be more consistent at increasing protein, but it is highly dependent on N supply and weather conditions. The boot application time has a higher probability of response, reduced potential for leaf burn, increased likelihood of precipitation, potential for increased yield and growth stages are easily identifiable.

Methodology and Results

Methodology:

The demonstration was setup as a factorial with 4 replicates. The first factor contrasted total nitrogen applied which was either 100 or 130 lb/ac. The second factor contrasted 4 different means of applying the last 30 lb N/ac. The last 30 lb N/ac was either applied as side-banded urea at seeding, UAN dribble banded at pre-boot or post anthesis, or UAN foliar sprayed at post anthesis. An extra treatment of "70 lb N/ac as side-banded urea" was added to the factorial design so that the impact of late in-crop applications of 30 lb N/ac on a base rate of 70 N could be determined. All treatments applied are listed below in Table 1. Plot size varied between locations based on equipment size.

Table 1. Treatment List of Nitrogen Application Rates and Timings		
Treatment #	Side-banded Urea at Seeding	In-season Nitrogen Application
1	70 lb N/ac	
2	100 lb N/ac	
3	130 lb N/ac	
4	70 lb N/ac	30 lb N/ac pre-boot surface dribble-band UAN[1,3]
5	100 lb N/ac	30 lb N/ac pre-boot surface dribble-band UAN[1,3]
6	70 lb N/ac	30 lb N/ac post-anthesis foliar spray UAN[2,4]
7	100 lb N/ac	30 lb N/ac post-anthesis foliar spray UAN[2,4]
8	70 lb N/ac	30 lb N/ac post-anthesis surface dribble-band UAN[2,3]
9	100 lb N/ac	30 lb/ac N post-anthesis surface dribble-band UAN[2,3]

[1]Applied late-herbicide timing, pre-boot stage
[2]Applied 7-10 days post-anthesis
[3]Sprayed with dribble band nozzle at 20 ga/ac (10 ga/ac UAN + 10 ga/ac water)
[4]Sprayed with 02 flat fan nozzles at 20 ga/ac (10 ga/ac UAN + 10 ga/ac water)

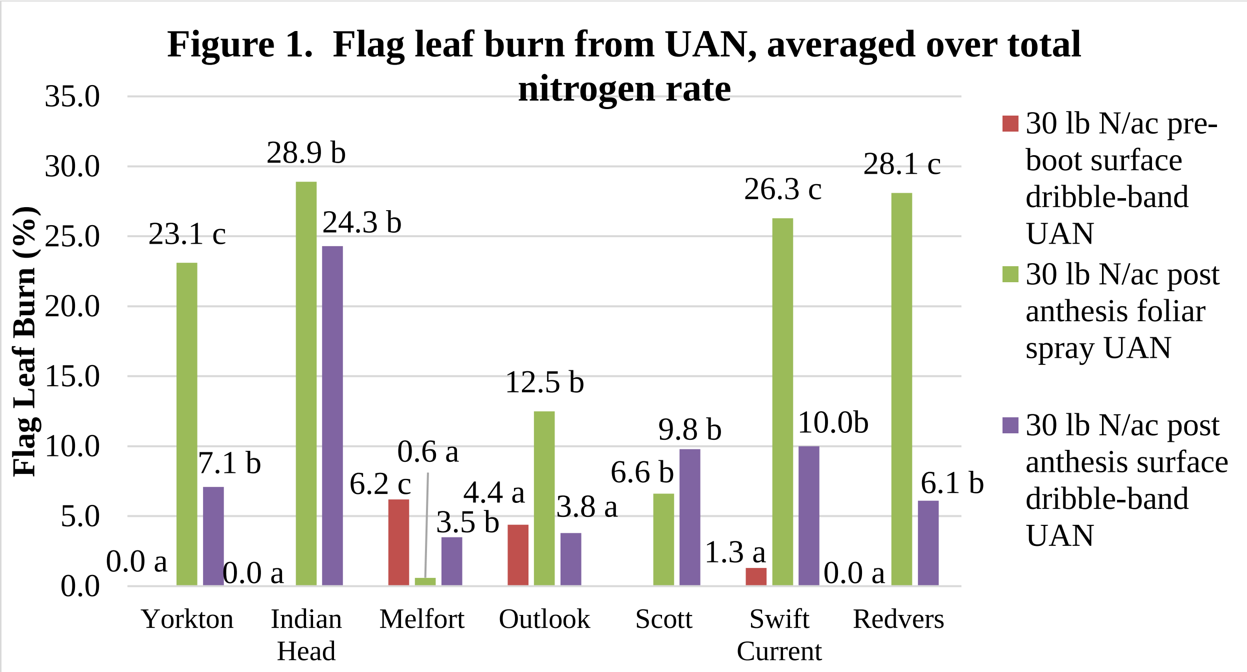
Table 2. Dates of operations in 2018 for the Increasing Wheat Protein with Post Application of UAN							
	--**Date**--						
Activity	**Indian Head**	**Melfort**	**Outlook**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
Pre-seed Herbicide Application	May 11 (Roundup Weathermax 540)	May 18 (Glyphosate & Heat LQ)			May 16 (Glyphosate and Aim)	May 15 (Credit & AIM)	
Seeding	May 8	May 5	May 22	May 8	May 19	May 23	May 4
Emergence Counts	May 25	June 7	June 7	May 30	June 8	June 12	May 24
Dribble banded UAN at pre-boot (trt 4 and 5)	June 23	July 6	July 9	June 20	June 28	June 26	June 13
In-crop Fungicide Application	June 25 (Quilt) July 5 (Prosaro)	July 13 (Caramba)		N/a	July 27 (Headline)	N/a	June 25 (Caramba)
In-crop Herbicide Application	June 7 (Buctril M/Simplicity GoDRI)	June 14 (Prestige XC)	June 13 (Buctril M/Simplicity Go Dry)	May 28	June 18 (Butril M and Axial)	June 19 (Tracos and Octain)	June 6 Prestige followed later with Axial
Dribble band UAN at 7-10 days post-anthesis	July 12	July 24	July 25	July 13	July 19	July 16	July 5
Foliar spray UAN at 7-10 days post-anthesis	July 12	July 24	July 25	July 13	July 19	July 16	July 5
Leaf Burn: % of flag leaf damaged by UAN	July 20	Aug 6	July 27		July 5, 12, 26 and Aug 2	July 25	July 13
Lodging Ratings	Aug 12	Sept 20	Aug 9	Aug 20		N/a	
Pre-harvest Herbicide Application	Aug 9 (Roundup Weathermax 540)				Sept 8	N/a	N/a
Harvest	Aug 14	Oct 4	Aug 17	Aug 21	Sept 28	Aug 27	Aug 29

Results:

Tables 3 to 14 show the complete analysis for the study can be found in the appendices.

Crop emergence was lower at Scott, Swift Current and Melfort where average populations were 188, 172 and 202 plants/m^2, respectively (data not shown). At Swift Current, increasing nitrogen rate at seeding from 70 to 100 lb N/ac significantly reduced emergence from 187 to 157 plants/m^2. This trend was also apparent at Melfort where increasing N reduced emergence from 222 to 181 plants/m^2, respectively. Crop emergence was higher at Yorkton, Indian Head, Outlook and Redvers where average populations were 375, 240, 302 and 303 plants/m^2, respectively (data not shown). At these locations, increasing nitrogen rates at seeding had little effect on emergence. Lodging was very low at all sites and no treatment difference were detected (data not shown).

Significant leaf burn from the application of UAN was observed at all locations when evaluated 1 to 2 weeks after the post-anthesis application (Table 9). As expected, dribble banding UAN pre-boot resulted in significantly less flag leaf burn than dribble banding post-anthesis at Yorkton, Indian Head, Swift Current and Redvers (Table 10 and Figure 1). This is because the flag leaf was not fully emerged when applications occurred pre-boot. When applied post-anthesis, foliar sprayed UAN resulted in more leaf burn than dribble banding at Yorkton, Indian Head, Outlook, Swift Current and Redvers because of increased coverage on foliage. In this study, all in-crop UAN was diluted 1:1 with water with the intention of reducing leaf burning. However, in practice, dribble band applications of UAN are not typically diluted with water and how doing so might affect leaf burn uncertain. It is conceivable that dilution might even make dribble bands more damaging by reducing surface tension and decreasing the number of drops that roll off leaf surfaces (Stu Brandt personal communication). That being said, foliar spray applications were still more injurious in this study than dribble band applications, when both were applied post anthesis.



The yield and % protein data for this study have been analysed in two ways. First, as single factor RCBD (Tables 5 and 8) so that treatment 1 can be part of the statistical comparisons and secondly as a two order factorial (trts 2-9) to gain greater power to separate main effect means (Tables 3-6). The main effect comparison are total N (100 vs 130 lb/ac), when averaged over method of applying supplemental N and method of applying supplemental N, when averaged over total N.

Results were fairly similar between locations. Yield and protein increased numerically at all locations as the rate of side-banded urea was increased from 70 to 130 lb N/ac at seeding (Tables 5 and 8). Overall, the main effect of increasing total nitrogen from 100 to 130 lb /ac increased yield and protein at all locations with yield differences being statistically significant at Indian Head, Melfort and Redvers (Tables 3, 4 and Figure 2) and protein differences being significant at all locations except Swift Current (Tables 6, 7 and Figure 3). When averaged across location and method of applying supplemental N, increasing total N from 100 to 130 lb/ac increased protein levels by 0.8%.

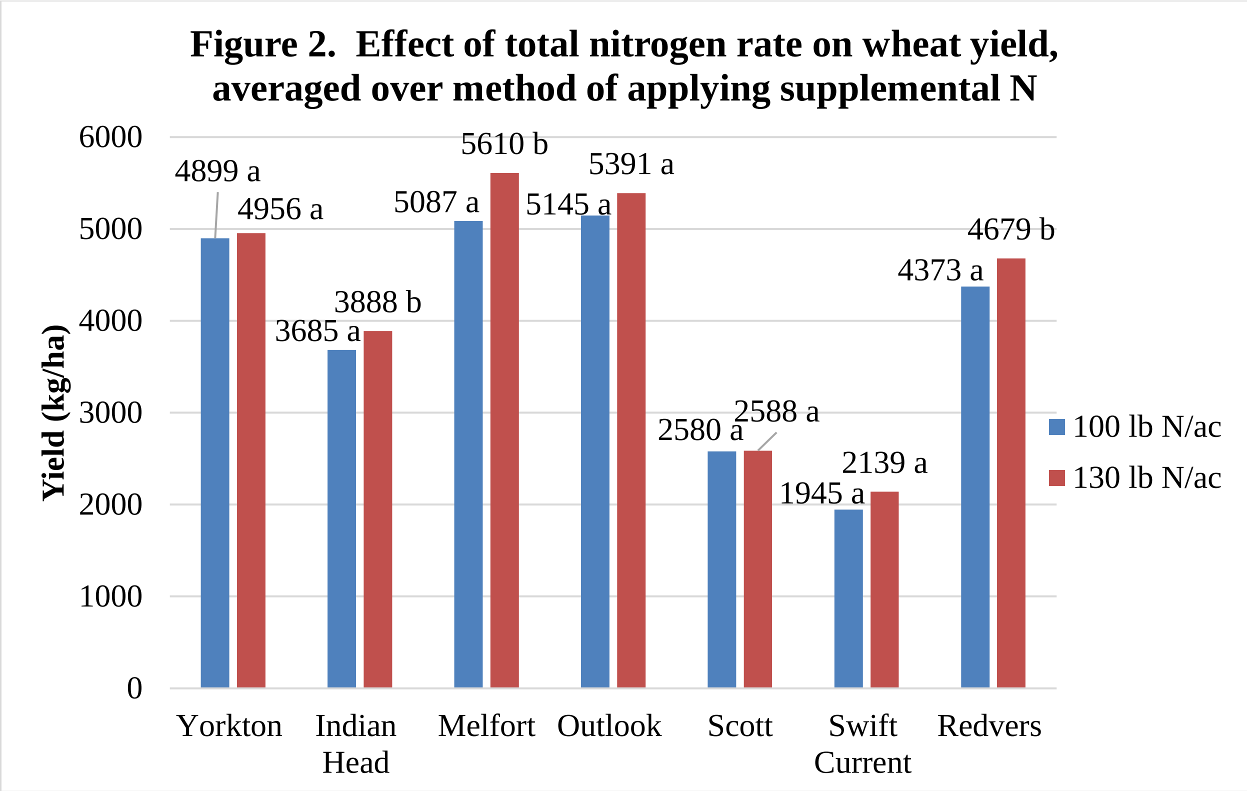


Figure 2. Effect of total nitrogen rate on wheat yield, averaged over method of applying supplemental N
Yield (kg/ha)
6000
5000
4000
3000
2000
1000
0
4899 a
4956 a
3685 a
3888 b
5087 a
5610 b
5145 a
5391 a
2580 a
2588 a
1945 a
2139 a
4373 a
4679 b
Yorkton
Indian Head
Melfort
Outlook
Scott
Swift Current
Redvers
100 lb N/ac
130 lb N/ac

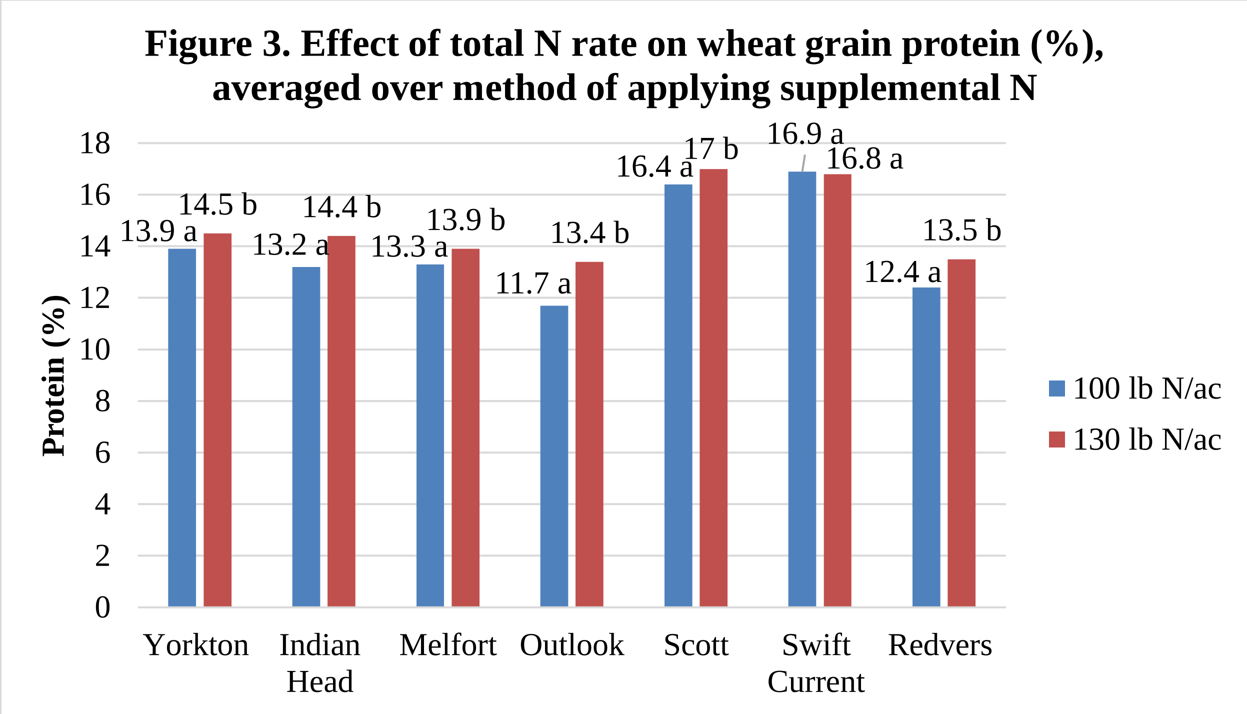
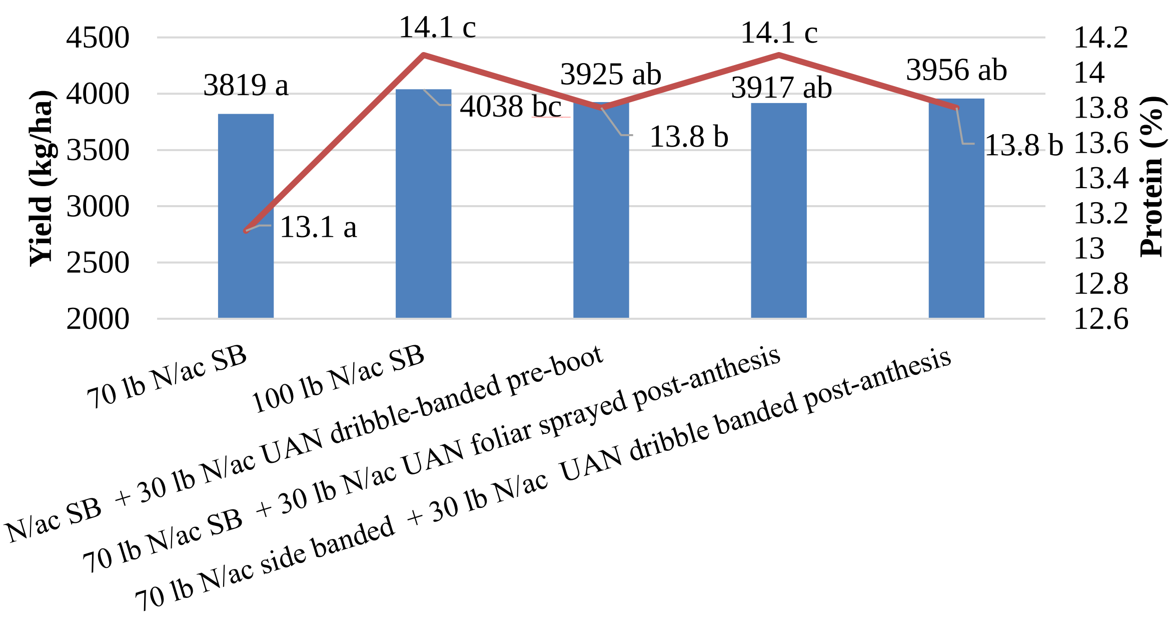
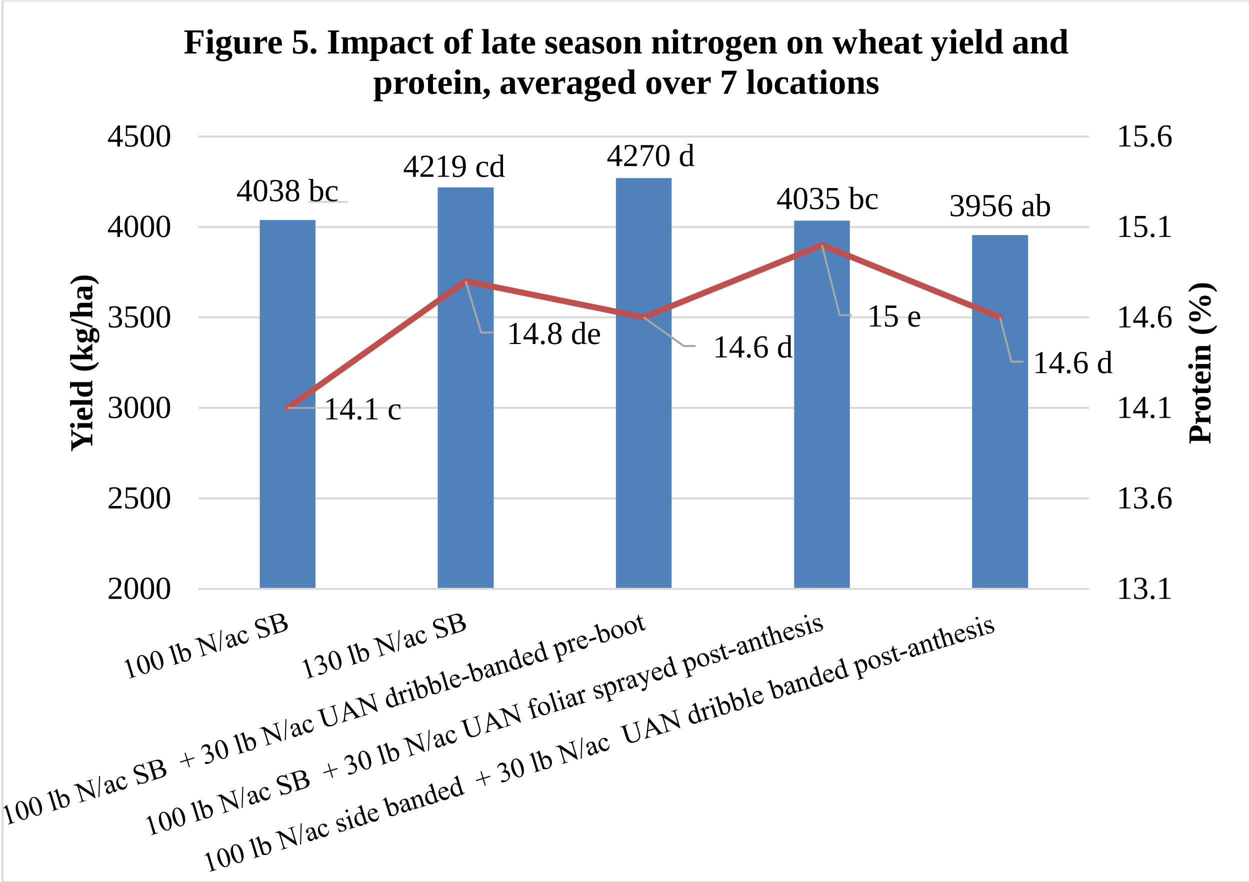


Figure 3. Effect of total N rate on wheat grain protein (%), averaged over method of applying supplemental N
Protein (%)
18
16
14
12
10
8
6
4
2
0
13.9 a
14.5 b
13.2 a
14.4 b
13.3 a
13.9 b
11.7 a
13.4 b
16.4 a
17 b
16.9 a
16.8 a
12.4 a
13.5 b
Yorkton
Indian Head
Melfort
Outlook
Scott
Swift Current
Redvers
100 lb N/ac
130 lb N/ac

A late season application of 30 lb N/ac tended to increase yield and often significantly increased percent grain protein. However, late season applications of N did not increase yield or protein relative to side-banding the whole amount of nitrogen at seeding. In other words, it was better to place all the nitrogen down at seeding instead of split applying it. When averaged over location, a late season application of 30 lb N/ac to a base rate of either 70 or 100 lb N/ac of side banded urea, increased yield somewhat and significantly increase grain protein (Tables 5 and 8, Figures 4 and 5). Most of the yield increases were not statistically significant, except for a 6% yield increase from dribble banding UAN at the pre-boot stage to a base rate of 100 lb N/ac (Figure 5). Applications of UAN at the pre-boot are more likely to show a yield increase because the staging is earlier, and less likely to burn the flag leaf. On average, a late season application of 30 lb N/ac significantly increased protein by 0.8% when applied to a base rate of 70 lb N/ac and by 0.6% when applied to a base rate of 100 lb N/ac. This supports the hypothesis that greater protein gains can be achieved from applying late season N to a more N deficient crop of wheat. The protein responses in this study from a late season application of 30 lb N/ac is very similar to the results of past studies conducted by John Heard, Amy Mangin, Ross MacKenzie and Guy Lafond which have typically observed protein increases of 0.5 to 1% in western Canada.

Figure 4. Impact of late season nitrogen on wheat yield and protein, averaged over total N and locations





While an extra 30 lb N/ac applied in late season did increase protein, it did not significantly increase yield or protein when compared to side-banding all the N at seeding for any location (Tables 3, 4, 6, 8 Figures 6 and 7). It was more efficient to place all the nitrogen down at seeding instead of split applying it, especially since split applications actually resulted in either less yield or protein in some instances. Even when yield and protein were considered together as kg/ha of protein, split applications never provided a statistically significant advantage over applying the whole amount of nitrogen down at seeding (Tables 13 and 14 Figure 8). The nitrogen from split applications was less efficient as it may have been lost to the atmosphere, stranded on the soil surface or caused crop injury. When comparing between applications of UAN averaged over location, foliar sprays resulted in greater grain protein (Figures 4 and 5). However, this bump in protein may have been partly due to the tendency for lower yield caused by greater leaf burn from foliar spray applications compared to dribble bands. In the end, none of the late season applications provided any yield or protein benefit compared to side-banding all the nitrogen at seeding. It should be acknowledged that our results may have differed under wet conditions where there would be greater potential for denitrification losses in side- or mid-row banded N and less potential for the volatilization losses and/or leaf-burn associated with the in-crop applications.

When averaged over location and method of application, 30 lb N/ac applied in late season to a base rate of 70 lb N/ac increased grain protein from 13.1 to 13.9% and yield from 3819 to 3932 kg/ha. This is 0.8% protein increase on roughly a 58 bu/ac crop of wheat. The economics of this situation can be explored by referring to Figure 9. In Figure 9 there are two tables showing the protein spread (cents/%/bu) required to break even from the cost of applying 30 lb N/ac of UAN plus the cost of application. The left and right hand tables assume a protein increase of 0.5 and 1.0% resulting from the late season application of UAN. This covers the range of results that might be expected based on both the current demonstration and previously reported responses. In each table you will note the spread required to cover costs increases as the price of N increases and it decreases as the yield of wheat increases. Based on the results for this study we would require a spread between roughly 35 and 60 cents/%/bu to breakeven depending of the price of nitrogen. This would be achievable for some years, but predicting those high protein spreads in advance may be difficult. Of course, the most economic scenario in this study was to put all the nitrogen down at seeding, as split applications could not improve yield or protein over this approach.

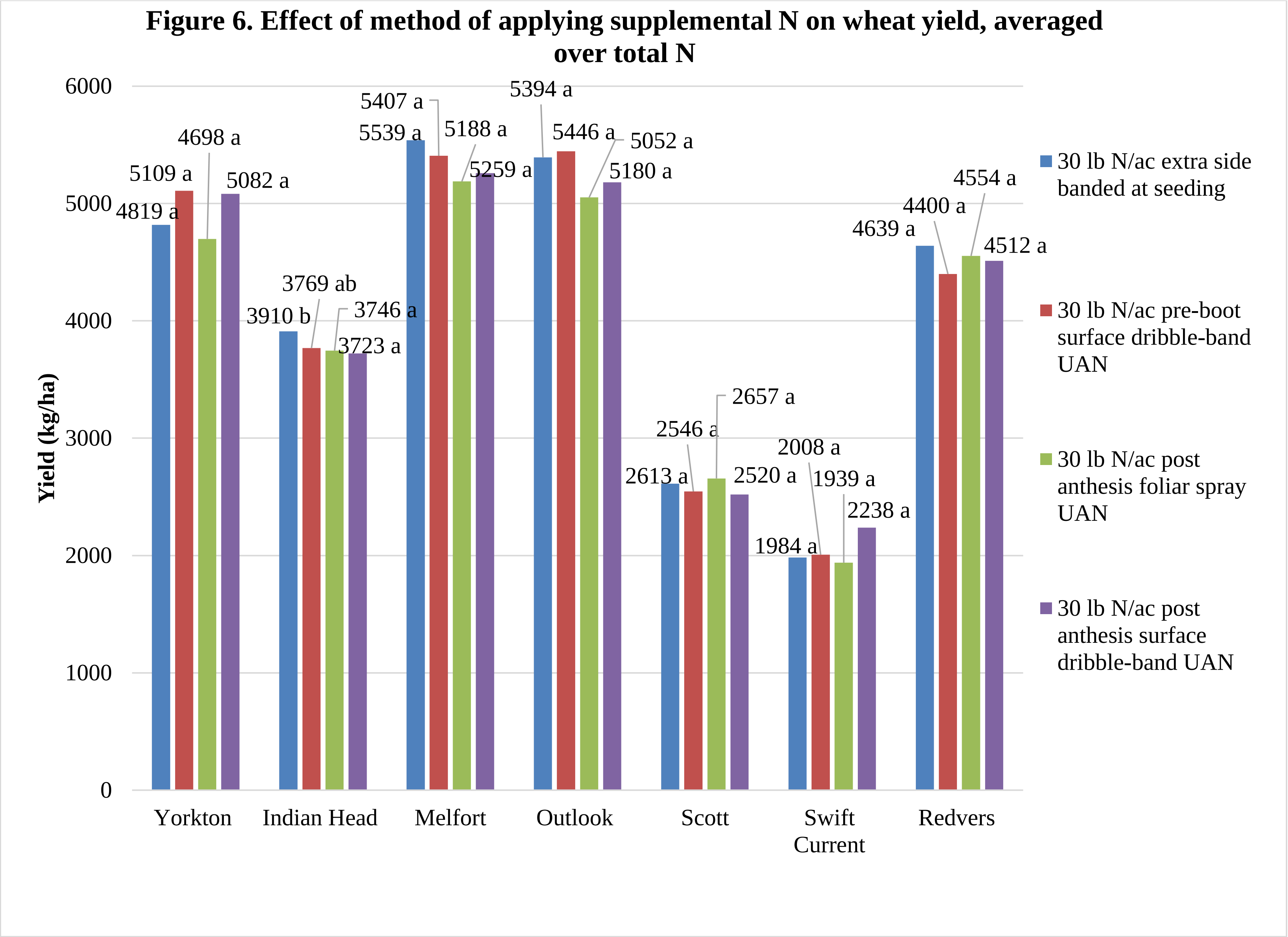


Figure 6. Effect of method of applying supplemental N on wheat yield, averaged over total N
Yield (kg/ha)
6000
5000
4000
3000
2000
1000
0
4819 a
5109 a
4698 a
5082 a
3910 b
3769 ab
3746 a
3723 a
5539 a
5407 a
5188 a
5259 a
5394 a
5446 a
5052 a
5180 a
2613 a
2546 a
2657 a
2520 a
1984 a
2008 a
1939 a
2238 a
4639 a
4400 a
4554 a
4512 a
Yorkton
Indian Head
Melfort
Outlook
Scott
Swift Current
Redvers
30 lb N/ac extra side banded at seeding
30 lb N/ac pre-boot surface dribble-band UAN
30 lb N/ac post anthesis foliar spray UAN
30 lb N/ac post anthesis surface dribble-band UAN

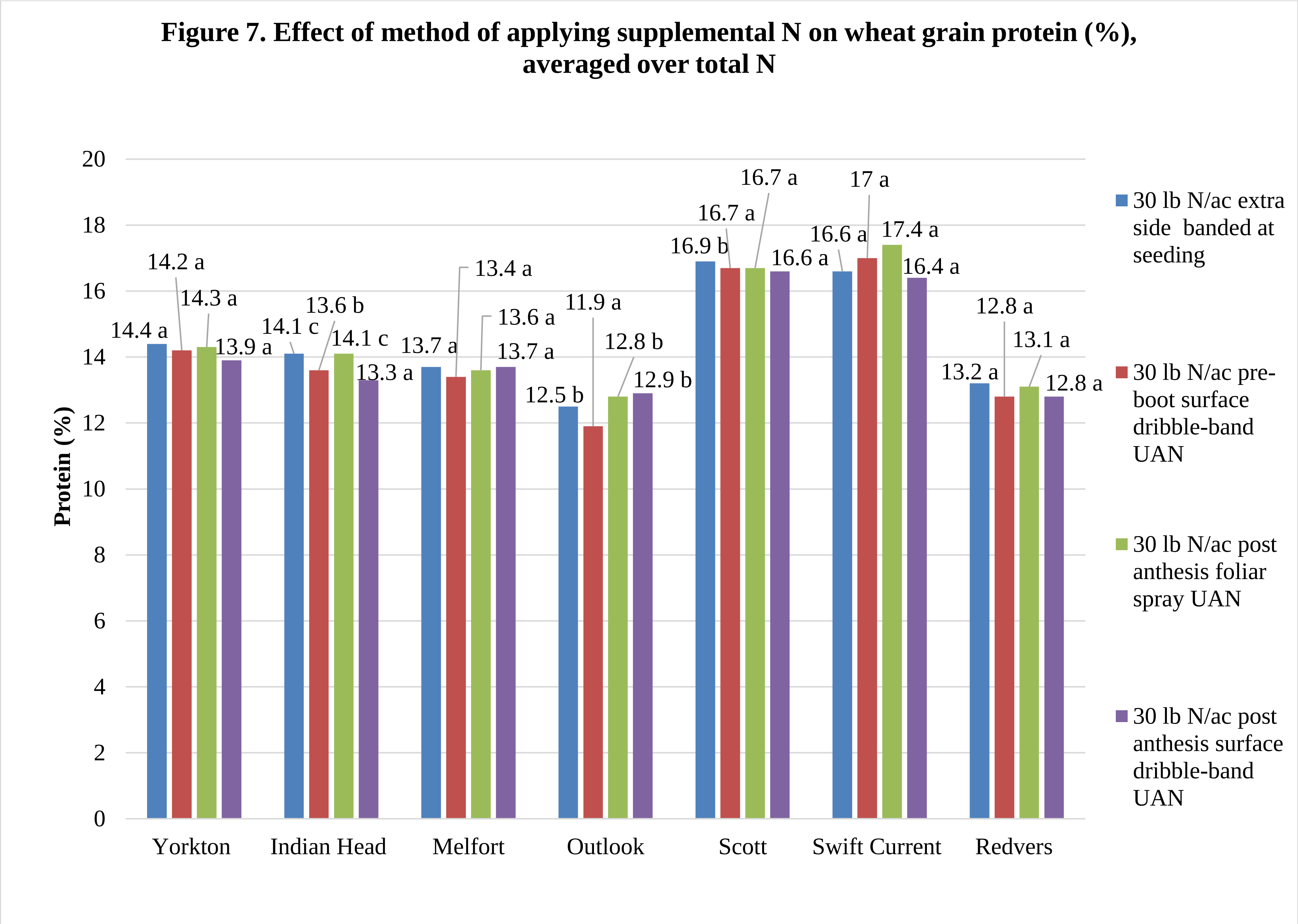


Figure 7. Effect of method of applying supplemental N on wheat grain protein (%), averaged over total N
Protein (%)
0
2
4
6
8
10
12
14
16
18
20
Yorkton
Indian Head
Melfort
Outlook
Scott
Swift Current
Redvers
14.4 a
14.2 a
14.3 a
13.9 a
14.1 c
13.6 b
14.1 c
13.3 a
13.7 a
13.4 a
13.6 a
13.7 a
12.5 b
11.9 a
12.8 b
12.9 b
16.9 b
16.7 a
16.7 a
16.6 a
16.6 a
17 a
17.4 a
16.4 a
13.2 a
12.8 a
13.1 a
12.8 a
30 lb N/ac extra side banded at seeding
30 lb N/ac pre-boot surface dribble-band UAN
30 lb N/ac post anthesis foliar spray UAN
30 lb N/ac post anthesis surface dribble-band UAN

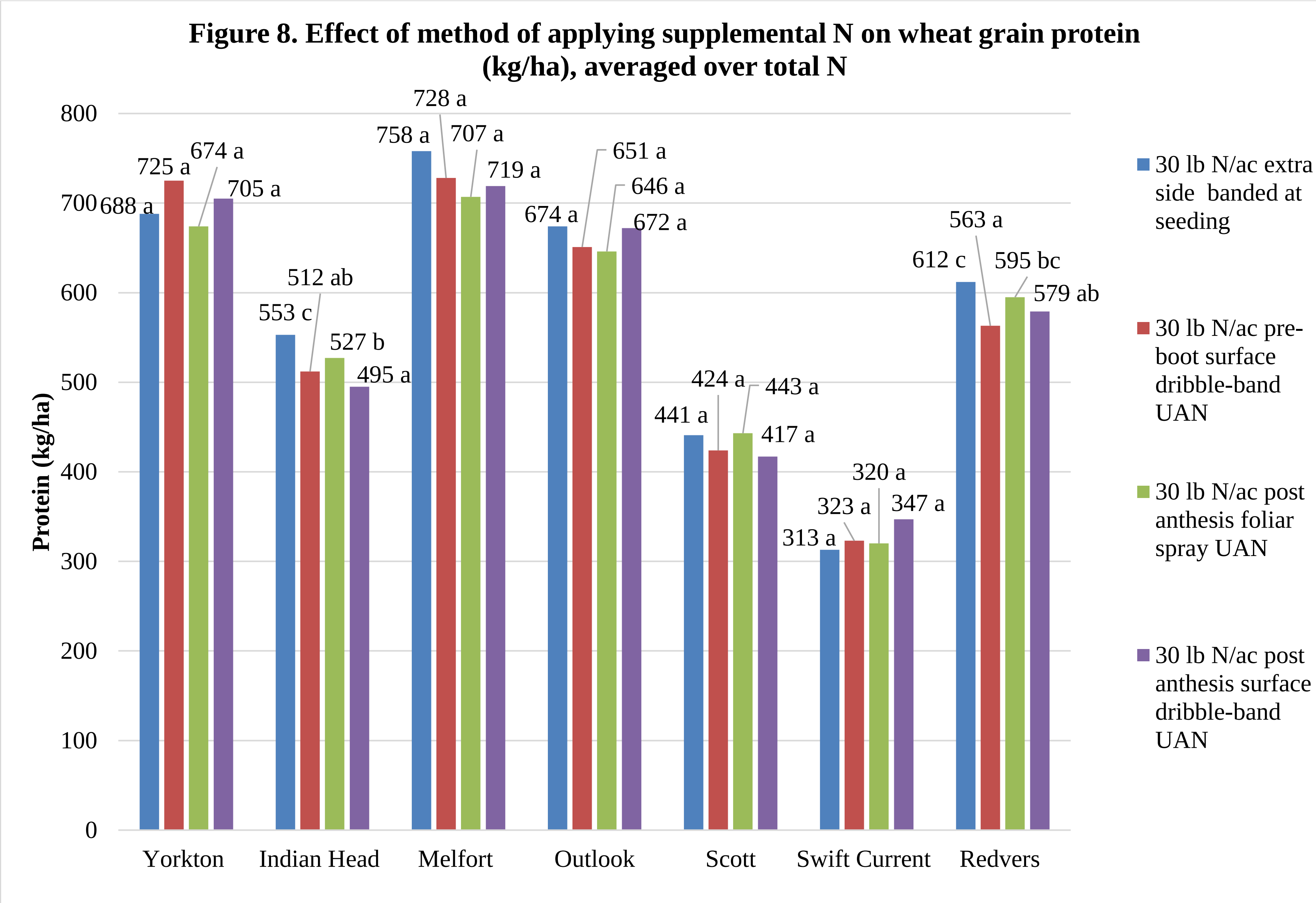


Figure 8. Effect of method of applying supplemental N on wheat grain protein (kg/ha), averaged over total N
Protein (kg/ha)
800
700
600
500
400
300
200
100
0
688 a
725 a
674 a
705 a
553 c
512 ab
527 b
495 a
758 a
728 a
707 a
719 a
674 a
651 a
646 a
672 a
441 a
424 a
443 a
417 a
313 a
323 a
320 a
347 a
612 c
563 a
595 bc
579 ab
Yorkton
Indian Head
Melfort
Outlook
Scott
Swift Current
Redvers
30 lb N/ac extra side banded at seeding
30 lb N/ac pre-boot surface dribble-band UAN
30 lb N/ac post anthesis foliar spray UAN
30 lb N/ac post anthesis surface dribble-band UAN

Figure 9. Spread (cents/%/bu) required to cover the cost of 30 lbs N/ac of UAN + $5/ac cost of application.

Protein spread 66 cents/%/bu (February 2018)

Crop Yield (bu/ac)	40	50	60	70
Protein Increase (%)	0.5	0.5	0.5	0.5
$N/lbs				
0.3	70	56	47	40
0.35	78	62	52	44
0.4	85	68	57	49
0.45	93	74	62	53
0.5	100	80	67	57
0.55	108	86	72	61
0.6	115	92	77	66
0.65	123	98	82	70

Crop Yield (bu/ac)	40	50	60	70
Protein Increase (%)	1	1	1	1
$N/lbs				
0.3	35	28	23	20
0.35	39	31	26	22
0.4	43	34	28	24
0.45	46	37	31	26
0.5	50	40	33	29
0.55	54	43	36	31
0.6	58	46	38	33
0.65	61	49	41	35

Conclusions and Recommendations:

Wheat yield and grain protein increased with added nitrogen in this study. Applying an additional 30 lb N/ac late in the season to base rates of 70 and 100 lb N/ac of side-banded urea significantly increased grain protein by 0.8% and 0.6%, respectively when averaged over location and method of application. This supports the hypothesis that split applications provide greater protein increases with more N deficient wheat. However, split applications did not increase wheat yield or protein relative to side-banding all the N at seeding. In terms of nitrogen use efficiency, it was frequently better to place all the nitrogen down at seeding in this study. Nitrogen from split applications was less efficient as it was likely stranded at the soil surface due to dry conditions or lost to volatilization. Late season applications of UAN can also result in leaf burn and potentially even reduce yields. Reduced yield may account for some of the observed increase in protein from late season UAN applications as foliar spray applications with higher levels of leaf burn also had somewhat higher protein; however, there was one site where, at the post-anthesis stage, foliar applied UAN did appear to be more effective for increasing protein than dribble banding. Pre-boot dribble band applications of UAN typically caused the least amount of crop injury. This study concludes that late season nitrogen can be used to increase protein, but doing so was never advantageous over simply side-banding the extra nitrogen at seeding under the conditions encountered. However, if a crop has been under fertilized for its potential, late season supplemental N can provide a protein boost of 0.8%. This will increase net returns, but only when protein spreads are at historical highs. If increasing protein with a late season application of N is desired, every effort should be made to reduce leaf burn. As expected, pre-boot dribble banding UAN was safer on the crop than foliar sprays post anthesis in this study. Spraying should not occur at temperatures above 20^{o}C. Diluting 50:50 with water may reduce leaf burn with foliar applications but the effects of dilution with dribble-banding are uncertain. For example, dilution also doubles the total solution application volume required and reduces surface tension of the UAN which could result in greater potential for leaf burn in dribble-band applications. With foliar applications the objective is to get as much product as possible retained on the leaves while, dribble-band applications are specifically targeting the soil surface. Recent studies have also shown that melted urea may be safer on the crop than UAN. Care must be taken not to freeze lines when dissolving urea as it is an endothermic reaction. Moreover, only urea low in biuret should be used otherwise severe leaf burning will occur.

Supporting Information

Acknowledgements:

This project was funded through the Saskatchewan Wheat Development Commission and Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement. Adopt signs were posted during annual tours.

Appendices:

Table 3. Significance of main effects and interactions for total N applied and method of applying supplemental N (30 lb N/ac) on wheat yield at multiple locations in 2018.							
Yield							
	Yorkton	**Indian Head**	**Melfort**	**Outlook**	**Scott**	**Swift Current**	**Redvers**
Effect	------------------------------- p-values [z]-------------------------------------						
Total nitrogen (N)	Ns	0.0010	<0.0001	Ns	Ns	Ns	0.0044
Method (M)	Ns	0.0865	0.0159	Ns	Ns	Ns	Ns
N x M	Ns	0.0019	<0.0001	Ns	Ns	Ns	0.0150

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

Table 4. Main effect means for total nitrogen applied and method of applying supplemental nitrogen (30 lb N/ac) on wheat yield (kg ha^{-2}) at multiple locations in 2018.

Main effect	Yield						
	Yorkton	Indian Head	Melfort	Outlook	Scott	Swift Current	Redvers
Total Nitrogen Applied	---------- kg ha^{-2} ----------						
100 lb N/ac	4899 a	3685 a	5087 a	5145 a	2580 a	1945 a	4373 a
130 lb N/ac	4956 a	3888 b	5610 b	5391 a	2588 a	2139 a	4679 b
LSD	Ns	110	156	Ns	Ns	Ns	199
Method of applying supplemental N							
30 lb N/ac extra side banded at seeding	4819 a	3910 b	5539 b	5394 a	2613 a	1984 a	4639 a
30 lb N/ac pre-boot surface dribble-band UAN	5109 a	3769 ab	5407 ab	5446 a	2546 a	2008 a	4400 a
30 lb N/ac post anthesis foliar spray UAN	4698 a	3746 a	5188 a	5052 a	2657 a	1939 a	4554 a
30 lb N/ac post anthesis surface dribble-band UAN	5082 a	3723 a	5259 a	5180 a	2520 a	2238 a	4512 a
LSD	Ns	156	221	Ns	Ns	Ns	Ns

Table 5. Means for total nitrogen applied by method of applying supplemental nitrogen on wheat yield (Kg ha^{-2}) at multiple locations in 2018.

Main effect	**Yield**							
	Yorkton	**Indian Head**	**Melfort**	**Outlook**	**Scott**	**Swift Current**	**Redvers**	**All Sites Average**
	------------ Kg ha^{-2} ------------							
1. 70 lb N/ac side banded as urea at seeding	4788 a	3498 a	4997 a	4730 a	2469 a	2184 a	4070 a	3819 a
2. 100 lb N/ac side banded as urea at seeding	4678 a	3865 cd	5295 bc	5388 a	2574 a	2065 a	4401 ab	4038 bc
3. 130 lb N/ac side banded as urea at seeding	4960 a	3955 d	5783 d	5400 a	2652 a	1904 a	4877 c	4219 cd
4. 70 lb N/ac sided banded as urea at seeding + 30lb N/ac pre-boot surface dribble-band UAN[1,3]	4860 a	3633 abc	4980 a	5218 a	2565 a	1883 a	4340 ab	3925 ab
5. 100 lb N/ac side banded as urea at seeding + 30lb N/ac pre-boot surface dribble-band UAN[1,3]	5359 a	3905 d	5835 d	5673 a	2526 a	2133 a	4461 ab	4270 d
6. 70 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis foliar spray UAN[2,4]	4798 a	3583 ab	4943 a	5097 a	2674 a	1902 a	4423 ab	3917 ab
7. 100 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis foliar spray UAN[2,4]	4598 a	3909 d	5433 bc	5006 a	2641 a	1977 a	4684 abc	4035 bc
8. 70 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis surface dribble-band UAN[2,3]	5260 a	3661 abc	5131 ab	4875 a	2506 a	1932 a	4329 ab	3956 ab
9. 100 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis surface dribble-band UAN[2,3]	4905 a	3785 abcd	5389 bc	5484 a	2533 a	2544 a	4695 abc	4191 cd
L.S.D	Ns	227.0	291.1	Ns	Ns	Ns	400.7	189

Table 6. Significance of main effects and interactions for total N applied and method of applying supplemental N (30 lb N/ac) on wheat protein at multiple locations in 2018.							
	Protein (%)						
	Yorkton	**Indian Head**	**Melfort**	**Outlook**	**Scott**	**Swift Current**	**Redvers**
Effect	------------------p-values[z]------------------						
Total nitrogen (N)	0.0055	<0.0001	0.0003	<0.0001	<0.0001	Ns	<0.0001
Method (M)	Ns	<0.0001	Ns	0.0014	0.0055	Ns	Ns
N x M	0.0029	<0.0001	0.0002	<0.0001	<0.0001	Ns	Ns

Table 7. Main effect means for total nitrogen applied and method of applying supplemental Nitrogen (30 lb/ac) on wheat protein (%) at multiple locations in 2018.

Main effect	**Protein**						
	Yorkton	**Indian Head**	**Melfort**	**Outlook**	**Scott**	**Swift Current**	**Redvers**
Total Nitrogen Applied	-- % -----------------------------------						
100 lb N/ac	13.9 a	13.2 a	13.3 a	11.7 a	16.4 a	16.9 a	12.4 a
130 lb N/ac	14.5 b	14.4 b	13.9 b	13.4 b	17.0 b	16.8 a	13.5 b
LSD	0.36	0.19	0.32	0.35	0.11	Ns	0.33
Method of applying supplemental N							
30 lb N/ac extra side banded at seeding	14.4 a	14.1 c	13.7 a	12.5 b	16.9 b	16.6 a	13.2 a
30 lb N/ac pre-boot surface dribble-band UAN	14.2 a	13.6 b	13.4 a	11.9 a	16.7 a	17.0 a	12.8 a
30 lb N/ac post anthesis foliar spray UAN	14.3 a	14.1 c	13.6 a	12.8 b	16.7 a	17.4 a	13.1 a
30 lb N/ac post anthesis surface dribble-band UAN	13.9 a	13.3 a	13.7 a	12.9 b	16.6 a	16.4 a	12.8 a
LSD	Ns	0.28	Ns	0.49	0.16	Ns	Ns

Table 8. Means for total nitrogen applied by method of applying supplemental N on wheat protein (%) at multiple locations in 2018.								
Main effect	**Protein**							
	Yorkton	**Indian Head**	**Melfort**	**Outook**	**Scott**	**Swift Current**	**Redvers**	**All Sites**
	-- % -----------------------------------							
1.-70 lb N/ac sided banded as urea at seeding	12.9 a	12.3 a	12.3 a	10.4 a	15.8 a	16.4 a	11.6 a	13.1 a
2.-100 lb N/ac side banded as urea at seeding	14.1 bc	13.7 cd	13.4 bc	11.8 b	16.7 b	16.5 a	12.7 bc	14.1 c
3. 130 lb N/ac side banded as urea at seeding	14.6 c	14.6 e	14.0 c	13.3 cd	17.1 c	16.7 a	13.7 d	14.8 de
4. 70 lb N/ac sided banded as urea at seeding + 30lb N/ac pre-boot surface dribble-band UAN[1,3]	14 bc	13.0 b	13.2 b	11.0 a	16.4 b	16.9 a	12.3 ab	13.8 b
5. 100 lb N/ac side banded as urea at seeding + 30lb N/ac pre-boot surface dribble-band UAN[1,3]	14.5 c	14.1 d	13.7 bc	12.8 c	16.9 bc	17.1 a	13.3 cd	14.6 d
6. 70 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis foliar spray UAN[2,4]	14.2 c	13.5 c	13.2 b	12.0 b	16.4 b	17.4 a	12.5 b	14.1 c
7. 100 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis foliar spray UAN[2,4]	14.5 c	14.7 e	14.0 c	13.6 d	17.0 bc	17.5 a	13.7 d	15.0 e
8. 70 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis surface dribble-band UAN[2,3]	13.4 ab	12.4 a	13.3 b	12.0 b	16.3 b	16.9 a	12.2 ab	13.8 b
9. 100 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis surface dribble-band UAN[2,3]	14.4 c	14.1 d	14.0 c	13.9 d	16.9 bc	15.9 a	13.4 cd	14.6 d
L.S.D	0.80	0.39	0.64	0.65	0.26	Ns	0.73	0.27

Table 9. Significance of main effects and interactions for total N applied and method of applying supplemental N (30 lb N/ac) on flag leaf burn (%) at multiple locations in 2018.

	Flag leaf burn (%)						
	Yorkton	**Indian Head**	**Melfort**	**Outlook**	**Scott**	**Swift Current**	**Redvers**
Effect	---------------------------------- p-values z ------------------------------------						
Total nitrogen (N)	Ns	Ns	Ns	Ns	Ns	0.0059	Ns
Method (M)	<0.0001	<0.0001	0.0004	0.0014	<0.0001	<0.0001	<0.0001
N x M	Ns	Ns	Ns	Ns	0.0717	0.0965	Ns

Table 10. Main effect means for total nitrogen applied and method of applying supplemental nitrogen (30 lb N/ac) on flag leaf burn (%) at multiple locations in 2018.

Main effect	Flag leaf burn						
	Yorkton	Indian Head	Melfort	Outlook	Scott	Swift Current	Redvers
Total Nitrogen Applied	-- % ------------------------------------						
100 lb N/ac	8.5 a	14.4 a	2.9 a	5.6 a	10.8 a	13.4 b	8.8 a
130 lb N/ac	6.6 a	12.2 a	2.3 a	5.3 a	9.2 a	5.3 a	8.4 a
LSD	Ns	Ns	Ns	Ns	Ns	5.5	Ns
Method of applying supplemental N							
30 lb N/ac extra side banded at seeding	0 a	0 a	0 a	1.3 a	0 a	0 a	0 a
30 lb N/ac pre-boot surface dribble-band UAN	0 a	0 a	6.2 c	4.4 a	omitted	1.3 a	0 a
30 lb N/ac post anthesis foliar spray UAN	23.1 c	28.9 b	0.6 a	12.5 b	6.6 b	26.3 c	28.1 c
30 lb N/ac post anthesis surface dribble-band UAN	7.1 b	24.3 b	3.5 b	3.8 a	9.8 b	10 b	6.1 b
LSD	4.27	7.7	2.8	5.3	3.4	7.8	2.2

Table 11. Means for total nitrogen applied by timing of supplemental nitrogen on flag leaf burn (%) at multiple locations in 2018.

Main effect	Flag leaf burn						
	Yorkton	Indian Head	Melfort	Outlook	Scott	Swift Current	Redvers
	-- % ---------------------------------						
1. 70 lb N/ac sided banded as urea at seeding	0	0	0	1.3	0	0	0
2. 100 lb N/ac side banded as urea at seeding	0	0	0	1.3	0	0	0
3. 130 lb N/ac side banded as urea at seeding	0	0	0	1.3	0	0	0
4. 70 lb N/ac sided banded as urea at seeding + 30lb N/ac pre-boot surface dribble-band UAN[1,3]	0	0	6.8	5.0	27.5	2.5	0
5. 100 lb N/ac side banded as urea at seeding + 30lb N/ac pre-boot surface dribble-band UAN[1,3]	0	0	5.7	3.8	20.0	0	0
6. 70 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis foliar spray UAN[2,4]	26.3	31.4	1.3	13.8	6.4	32.5	28.8
7. 100 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis foliar spray UAN[2,4]	20	26.5	0	11.3	6.9	20.0	27.5
8. 70 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis surface dribble-band UAN[2,3]	7.8	26.3	3.8	2.5	9.5	18.8	6.3
9. 100 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis surface dribble-band UAN[2,3]	6.5	22.2	3.3	5.0	10.0	1.3	6.0
L.S.D	Ns	Ns	Ns	Ns	4.9	Ns	Ns

Table 12. Significance of main effects and interactions for total N applied and method of applying supplemental N (30 lb N/ac) on protein (kg/ha) at multiple locations in 2018.

	Protein (kg/ha)						
	Yorkton	**Indian Head**	**Melfort**	**Outlook**	**Scott**	**Swift Current**	**Redvers**
Effect	-------------------------------- p-values [z] --------------------------------------						
Total nitrogen (N)	Ns	<0.0001	<0.0001	<0.0001	Ns	Ns	<0.0001
Method (M)	Ns	<0.0001	Ns	Ns	Ns	Ns	0.0178
N x M	Ns	<0.0001	<0.0001	<0.001	0.0704	Ns	Ns

Table 13. Main effect means for total nitrogen applied and method of applying supplemental nitrogen (30 lb N/ac) on protein (kg/ha) at multiple locations in 2018.

Main effect	**Protein**						
	Yorkton	**Indian Head**	**Melfort**	**Outlook**	**Scott**	**Swift Current**	**Redvers**
Total Nitrogen Applied	-- kg/ha -----------------------------------						
100 lb N/ac	680 a	485 a	675 a	600 a	424 a	312 a	543 a
130 lb N/ac	717 a	558 b	781 b	721 b	438 a	340 a	631 b
LSD	Ns	12.4	32.7	49.9	Ns	Ns	21.4
Method of applying supplemental N							
30 lb N/ac extra side banded at seeding	688 a	553 c	758 a	674 a	441 a	313 a	612c
30 lb N/ac pre-boot surface dribble-band UAN	725 a	512 ab	728 a	651 a	424 a	323 a	563 a
30 lb N/ac post anthesis foliar spray UAN	674 a	527 b	707 a	646 a	443 a	320 a	595 bc
30 lb N/ac post anthesis surface dribble-band UAN	705 a	495 a	719 a	672 a	417 a	347 a	579 ab
LSD	Ns	17.5	Ns	Ns	Ns	Ns	30.2

Table 14. Means for total nitrogen applied by method of applying supplemental nitrogen on protein (kg/ha) at multiple locations in 2018.

Main effect	Protein							
	Yorkton	Indian Head	Melfort	Outook	Scott	Swift Current	Redvers	All Sites Average
	-- kg/ha ----------------------------							
1. 70 lb N/ac sided banded as urea at seeding	614 a	429 a	614 a	492 a	390 a	341 a	471 a	479 a
2. 100 lb N/ac side banded as urea at seeding	656 a	530 d	707 bc	633 bcd	429 a	324 a	559 bc	548 c
3. 130 lb N/ac side banded as urea at seeding	721 a	575 e	808 d	715 de	453 a	302 a	665 e	606 d
4. 70 lb N/ac sided banded as urea at seeding + 30lb N/ac pre-boot surface dribble-band UAN[1,3]	678 a	473 bc	656 ab	574 ab	421 a	302 a	531 b	519 b
5. 100 lb N/ac side banded as urea at seeding + 30lb N/ac pre-boot surface dribble-band UAN[1,3]	773 a	550 de	799 d	727 de	426 a	344 a	594 cd	602 d
6. 70 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis foliar spray UAN[2,4]	682 a	482 c	651 ab	609 bc	437 a	311 a	550 b	532 b
7. 100 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis foliar spray UAN[2,4]	666 a	572 e	763 cd	682 cde	448 a	329 a	639 e	586 d
8. 70 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis surface dribble-band UAN[2,3]	703 a	455 b	684 b	584 ab	408 a	309 a	530 b	525 b
9. 100 lb N/ac side banded as urea at seeding + 30 lb/ac N post-anthesis surface dribble-band UAN[2,3]	707 a	535 d	753 cd	761 e	426 a	385 a	628 de	599 d
L.S.D	Ns	24.7	61.7	96.0	Ns	Ns	40.4	28.8

Evaluating Inoculant Options for Faba Beans

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Abstract/Summary:
A three year study was initiated in 2015 to investigate the effect of two rhizobia inoculant formulations, peat based on-seed and granular in-furrow, on yield and growth of faba bean across differing soil/climatic regions of Saskatchewan. Trials were established annually at Swift Current (brown soil zone) and Outlook (brown-dark brown transitional soil zone); Scott (dark brown soil zone) and Melfort, Yorkton, Indian Head and Redvers (black soil zone). Two faba bean varieties, a tannin and a zero tannin, were treated either with a peat based on-seed formulation (Nodulator brand by BASF) at the recommended rate of application (1.2 kg inoculant for 982 kg seed) or a granular in-furrow formulation (TagTeam brand by Monsanto BioAg) at 0.5X, 1.0X or 2.0X recommended application rates based upon row spacing used at each cooperating test site.

Additional treatments included a dual inoculation combining the peat based inoculant applied at all three granular application rates. The peat based formulation was applied immediately prior to seeding using a damp inoculation method, granular products were applied at seeding.

Significant responses with respect to faba bean seed yield, at any individual test location over the three years of trialing, were few (2 of 15 site years). However, combined site analyses indicated an overall faba bean seed yield increase of approximately 230 kg/ha (3.5 bu/ac). This greatest yield response occurred with the peat based inoculant formulation by itself or in combination with a granular application, however the dual inoculation treatments were not statistically greater yielding in comparison to the peat based solo application. Inoculation had no statistically significant effect on seed protein, N content, total seed N uptake or seed test weight. Inoculation did not statistically influence vegetative biomass, tissue N content or total biomass N uptake but did result in an increase in plant height.

The overall minimal response cannot be attributed to soil providing adequate N for faba bean yield as the majority of sites were low in soil N according to spring soil testing procedures. Although mineralized N being released throughout the growing season is expected again the amounts of N removed in biomass and seed suggests that soil N sources would unlikely provide the quantities measured. Rather it is more likely that indigenous populations of Rhizobium leguminosarum were present at most trial locations and formed effective nodulation and subsequent biological nitrogen fixation to come close in optimizing faba bean growth and seed yield production. All sites involved in the trial have had an extended history of pulse crops within their rotations. While most pulses within their respective rotations have been field pea and/or lentil the Rhizobium leguminosarum inoculants applied are able to infect and provide nitrogen fixation in faba bean. Results from this trial suggest that inoculation of faba bean is still recommended, but producers can choose an inoculant formulation based on cost and convenience for their operation. A single dose of inoculant is sufficient to provide optimal faba bean seed yield.

Objectives:

To determine the effects of two inoculants at different rates and in combination on Faba bean grown in various soil/climatic zones of Saskatchewan.

Project Rationale:

Interest in growing faba beans has increased among farmers, especially as a way to maintain pulses in the crop rotation without the disease issues of alternative pulse options, i.e. field pea or lentil. Although faba beans are not resistant to Aphanomyces, which currently infests many pea and lentil fields, they do have a higher tolerance to the level of infection from the disease as well as other root rot pathogens susceptible (Lamari and Bernier, 1985 and van Leur et al., 2008). Along with increased disease tolerance, faba beans are very efficient in fixing nitrogen (N) through Rhizobium symbiosis compared to other cultivated legumes and derives most of its' N required through atmospheric N fixation (Bremer et al., 1988). Farmers struggling to grow field peas or lentils because of disease issues could substitute faba beans in the rotation if faba beans perform well agronomically and economically.

Previous studies completed on faba bean agronomics focused on determining the best production practices for the crop, i.e. seeding date, rates, depth, and row spacing are among the more popular topics (Jensen et al. 2010). Although some studies have focused on determining which species of Rhizobium bacteria colonize and infect the plant roots to form symbiotic relationships to carry out atmospheric N fixation (Slattery et al. 2004), there is no comprehensive study to determine the best commercially available inoculant option for faba bean. Current research suggests Rhizobium leguminosarum bv. viciae is the dominant species of Rhizobium that infect field peas, lentil and faba bean roots, forming nodules and which carry out N fixation (Evans et al. 1996). Unfortunately there is a lack of information regarding which strains of Rhizobium leguminosarum bv. viciae are in the new faba bean-specific inoculants. There are strains of indigenous faba bean –specific rhizobium in Western Canadian soils (Laguerre et al. 2003), however, these are not well defined in the literature.

Successful nodulation of the crop is extremely important to ensure the crop reaches maximum yield potential; therefore farmers need to inoculate their faba bean seed. The objective of this experiment is to develop recommendations for commercially available inoculants registered for faba beans, allowing farmers to select the best option and rate to maximize yield. Our experiment will test faba bean inoculants available to the market at varying rates and combinations. Determining which inoculant product and /or combinations will help producers achieve the greatest amount of economic return will hopefully give producers a more robust knowledge of faba bean production. As a result, encouraging them to be more comfortable when deciding to incorporate this new crop into their rotations.

Methodology and Results

Methodology:

2015

The trial was established at all test locations as described below for 2016-17 however the tannin variety FB9-4 was used in the first year of the trial as opposed to the tannin variety CDC SSNS-1 used in years 2016 and 2017. The variety FB9-4 utilized across all locations in the trial initiation year resulted in serious seeding issues at the majority of site locations. The Thousand Kernel Weight (TKW) of 805 grams associated with the FB9-4's caused significant plugging at numerous sites. The plugging of seed occurred at the venturI, distributor, within hoses or in the opener depending upon the seeder being used to establish the trial. In an attempt to minimize plugging NARF seeded their FB9-4's plots twice – at a half rate per operation but still experienced difficulties. Consequently plant stand was compromised and less than desirable. The Snowdrop variety due to the randomized nature of the experimental design was also adversely affected as plugging may not have been detected until several plots had been seeded.

Due to plugging issues, plant counts were conducted after plant emergence and certain plots, at most sites, reduced to micro-plots. This may have been defined as reduction in plot length or width (e.g. plant counts & harvested area conducted on 6 m^2 compared to normal 12 m^2 area or normal 8 row plots reduced to 4-5 rows that did not plug). It cannot be disallowed that variation in plot sizes within a trial did not result in error of any agronomic parameters measured.

Consequently the decision was made to change the tannin faba bean variety to the smaller seeded CDC CCNS-1 for the remaining years of trialing.

2016 & 2017

A consistent treatment protocol was observed and followed at all participating trial locations. Inoculants as indicated, their formulation and method of application was consistent across all sites. Two inoculants, Nodulator peat seed treatment (BASF) and TagTeam (Monsanto BioAg) a granular inoculant, were utilized in the study. Granular TagTeam inoculant treatments were metered through boxes or pre-weighed and applied through a cone on the seeder, granular inoculant was positioned within the seed row. The amount of granular inoculant (1x rate) was applied based on the manufactures recommended rate for the row spacings used at each trial location. Peat based Nodulator inoculant treatments were applied by damp inoculation method of applying 2.0 ml water to a kg of seed, adding 1.22 gm inoculant (recommended rate of 1.2 kg per 982 kg of seed), and mixing well in either a large plastic bag or plastic container. Seed-placed peat inoculant was applied to seed immediately prior to seeding. If seed treatments were utilized they were applied to the seed first and seed was fully dried prior to peat based inoculant application. Seed was treated with a registered seed treatment product for Faba bean at each location, excepting Indian Head. Supplemental fertilizer as 11-52-0 was applied at all locations at rates of 20 – 30 kg P2O5/ha and either side- banded or seed-placed depending upon location. Where required other supplemental nutrients were applied in quantities so as not be a yield limiting factor. Two faba bean varieties were evaluated in the trial to evaluate if they differed to inoculation treatments, varieties chosen were the zero tannin “Snowdrop” and the tannin variety “CDC SSNS-1.” Target plant populations of both varieties was 43 – 58 plants/m^2 (approximately 4 – 5 plants/ft^2), seeding rate was determined factoring seed size, germination and assuming 90% emergence for each variety. Faba bean varieties were centrally sourced by ICDC and the required quantities of each variety shipped to cooperating Agri-ARM facilities. At all sites plots were maintained weed free by herbicide burn-off prior to seeding, post herbicide applications and when required by hand weeding. Most sites received an in-season fungicide application for disease prevention. Harvest at all locations was accomplished with a small plot combine in a straight cut operation. At some locations Reglone was applied in a desiccation application, at other locations natural dry down occurred.

What did differ between locations was such practical aspects of date of seeding, method of seeding (direct vs worked), plot size, harvest date, etc., variables that would be expected to differ among a multi-organizational study such as this. Response data from all site-years were combined for mixed model analyses with the effects of site-year, variety, inoculant treatment and possible interactions were considered fixed and the effects of replicate (within site-year) considered random. All treatment means (both individual site-years and multi-site combined means) were separated by LSD testing analyses. All treatment effects and differences between means were considered significant at $P \leq 0.05$.

This study was established in a randomized complete block design with four replications. Treatments were factorial in design with two faba bean varieties and eight inoculant rates and/or formulations, treatments are shown in Table 1. Agronomic and pertinent site establishment information is shown in Table 2.

Results of spring soil sampling are shown in Table 3. The Melfort trial site in 2016 was situated on ground that would be expected to interfere with inoculant performance. The remaining sites soil test N levels would not have been expected to mask or inhibit an inoculant response bases of spring soil test sampling.

All trial sites, other than Outlook, were reliant on annual in-season precipitation to maintain plant growth and development. The Outlook location has irrigation capacity however 2016 received only a single application of 12.5 mm due to the above normal precipitation throughout the growing season, in 2017 a total of 162.5 mm of supplemental irrigation was applied. In general, all sites received above normal precipitation throughout the 2016 growing season, in particular Swift Current. The Swift Current trial site received a total of 438 mm of rainfall from May 1 to September 30, greatly exceeding long-term norms. High precipitation consequently resulted in high yield potentials being established at the majority of test locations. The opposite rainfall situation occurred in 2017 with most sites experiencing drought, particularly Swift Current.

Table 1. Variety and Inoculant Treatments.

Treatments	Faba bean Variety	Inoculants
1	Snowdrop	Un-inoculated check
2	Snowdrop	Nodulator peat for Faba Beans
3	Snowdrop	0.5x rate TagTeam Granular for Faba bean
4	Snowdrop	1x rate TagTeam Granular for Faba bean
5	Snowdrop	2x rate TagTeam Granular for Faba bean
6	Snowdrop	Nodulator peat for Faba Beans + TagTeam granular for Faba Beans at 0.5x
7	Snowdrop	Nodulator peat for Faba Beans + TagTeam granular for Faba Beans at 1x
8	Snowdrop	Nodulator peat for Faba Beans + TagTeam granular for Faba Beans at 2x
9	CDC SSNS-1	Un-inoculated check
10	CDC SSNS-1	Nodulator peat for Faba Beans
11	CDC SSNS-1	0.5x rate TagTeam Granular for Faba bean
12	CDC SSNS-1	1x rate TagTeam Granular for Faba bean
13	CDC SSNS-1	2x rate TagTeam Granular for Faba bean
14	CDC SSNS-1	Nodulator peat for Faba Beans + TagTeam granular for Faba Beans at 0.5x
15	CDC SSNS-1	Nodulator peat for Faba Beans + TagTeam granular for Faba Beans at 1x
16	CDC SSNS-1	Nodulator peat for Faba Beans + TagTeam granular for Faba Beans at 2x

Table 2. General Site Agronomic Information of 2016 & 2017 Faba Bean Inoculant Trial.

Agronomic's	**Indian Head**	**Swift Current**	**Melfort**	**Yorkton**	**Outlook**	**Redvers**	**Scott**
Previous crop	Cereal	Cereal	Cereal	Cereal	Cereal	Cereal	Cereal
Tillage System	No-till	No-till	No-till	No-till	Tillage	No-till	No-till
Row spacing	30 cm	22.5 cm	30 cm	25 cm	25 cm	25 cm	25 cm

Table 3. Soil Test Information by Site, 2015 – 2017.

Soil Test Criteria	Indian Head	Swift Current	Melfort	Yorkton	Outlook	Redvers	Scott
	2015						
NO_3-N (0-60 cm)	12 kg ha^{-1}	39 kg ha^{-1} (0-30 cm)	62 kg ha^{-1}	24 kg ha^{-1} (0-30 cm)	53 kg ha^{-1}	39 kg ha^{-1} (0-45 cm)	40 kg ha^{-1}
PO_4-P (0-15 cm)	7 kg ha^{-1}	17 kg ha^{-1}	34 kg ha^{-1}	40 kg ha^{-1}	16 kg ha^{-1}	30 kg ha^{-1}	47 kg ha^{-1}
K (0-15 cm)	673 kg ha^{-1}	>415 kg ha^{-1}	>1000 kg ha^{-1}	>1000 kg ha^{-1}	649 kg ha^{-1}	595 kg ha^{-1}	569 kg ha^{-1}
SO_4-S (0-60 cm)	11 kg ha^{-1}	24 kg ha^{-1} (0-30 cm)	47 kg ha^{-1}	25 kg ha^{-1} (0-30 cm)	>179 kg ha^{-1}	41 kg ha^{-1}	57 kg ha^{-1}
OM % (0-15 cm)	5.2		12.4				
pH (0-15 cm)	8.0	6.8	5.8	7.4	8.0	7.6	
	2016						
NO_3-N (0-60 cm)	18 kg ha^{-1}	27 kg ha^{-1} (0-30 cm)	112 kg ha^{-1} (0-30 cm)	25 kg ha^{-1} (0-30 cm)	49 kg ha^{-1}	42 kg ha^{-1}	39 kg ha^{-1}
PO_4-P (0-15 cm)	8 kg ha^{-1}	13 kg ha^{-1}	22 kg ha^{-1}	25 kg ha^{-1}	18 kg ha^{-1}	27 kg ha^{-1}	62 kg ha^{-1}
K (0-15 cm)	>1200 kg ha^{-1}	>600 kg ha^{-1}	>600 kg ha^{-1}	>600 kg ha^{-1}	388 kg ha^{-1}	531 kg ha^{-1}	613 kg ha^{-1}

Table 3. Continued.

SO_4-S (0-60 cm)	20 kg ha^{-1}	>100 kg ha^{-1} (0-30 cm)	20 kg ha^{-1} (0-30 cm)	>70 kg ha^{-1} (0-30 cm)	>180 kg ha^{-1}	37 kg ha^{-1}	30 kg ha^{-1}
OM % (0-15 cm)	5.1		11.5		2.4		
pH (0-15 cm)	7.9	5.9	5.9	7.8	7.6	7.6	
	2017						
NO_3-N (0-60 cm)	16 kg ha^{-1}	38 kg ha^{-1} (0-30 cm)	63 kg ha^{-1} (0-30 cm)	27 kg ha^{-1}	72 kg ha^{-1}	24 kg ha^{-1} (0-45cm)	52 kg ha^{-1}
PO_4-P (0-15 cm)	11 kg ha^{-1}	20 kg ha^{-1}	18 kg ha^{-1}	18 kg ha^{-1}	16 kg ha^{-1}	8 kg ha^{-1}	71 kg ha^{-1}
K (0-15 cm)	>1200 kg ha^{-1}	>800 kg ha^{-1}	476 kg ha^{-1}	522 kg ha^{-1}	186 kg ha^{-1}	303 kg ha^{-1}	>800 kg ha^{-1}
SO_4-S (0-60 cm)	63 kg ha^{-1}	45 kg ha^{-1} (0-30 cm)	31 kg ha^{-1} (0-30 cm)	45 kg ha^{-1} (0-30 cm)	>140 kg ha^{-1}	>184 kg ha^{-1}	671 kg ha^{-1}
OM % (0-15 cm)	4.9	2.7	9.0	4.2	2.6	3.5	4.5
pH (0-15 cm)	7.6	6..0	6.1	7.2	8.2	7.7	6.0

Results:

Faba bean grain yield collected from each site with acceptable CV's (<15) for each treatment are outlined for 2015, 2016 and 2017 in Tables 4, 5 and 6, respectively. In 2017, the final year of the trial the sites at Swift Current were adversely influenced by drought such that average treatment yields were only 381 kg/ha (5.7 bu/ac). The Scott location had high yields an unacceptable CV, the reason for the high yield variation is not apparent. The Melfort 2017 trial had seeding difficulties with the seeder used resulting in non-uniform stand establishment and excessive variation between and within treatments. Over the three years of the trial the majority of sites failed to achieve a positive yield response to inoculation. Combined summary of results is shown in Table 5. Overall, the tannin variety faba bean was higher yielding than the zero tannin but both responded, or failed to respond, to inoculation treatments in a similar fashion. Bare, un-inoculated faba bean produced the lowest yields. Yields were greatest whenever faba bean was treated with an on-seed peat based inoculant. The granular inoculation treatments, while numerically higher yielding, were not greatly higher than the un-inoculated. The relative failure of the granular inoculant to provide yields equal to a peat on-seed inoculant application is concerning and unexplainable. The granular and peat inoculants utilized with this study are produced by two different manufactures. It is highly probable that the strain of Rhizobia leguminosarum used within these products differs. Therefore it cannot be discounted that the strain used within the peat based formulation was superior to the strain within the granular formulation and accounts for the yield performance differences identified in Table 5. Additionally it should be noted that the net effect on enhancing faba bean yield with inoculation was modest. The maximum yield benefit obtained to inoculation across 15 site years of data was 236 kg/ha (3.5 bu/ac).

All trial sites used within this study have an extended history of pulse production, either with field pea and/or lentil. As Rhizobia leguminosarum bacteria are able to infect pea, lentil and faba bean and provide biological nitrogen fixation to occur it is possible that, with extended pulse inclusion within rotations, the background “indigenous” levels of Rhizobia leguminosarum in these soils is now high, resulting in diminishing yield responses to annual inoculation. In a recent Alberta study Lopetinski et. al. (2014) failed to obtain a faba bean yield response to inoculation in a six site-year study. In field pea McKenzie et. al., 2001 found an inoculant yield response in field pea at only 9 of 22 sites in Alberta. The average response to whenever peat based inoculant was applied (with or without granular applications) resulted in a 6.0% yield response which would provide an economic benefit. Although these results suggest that indigenous populations of Rhizobia leguminosarum may now be high through an extended history of pulse production in Saskatchewan, no commercial test is presently available to predict the likelihood of an inoculation response. Consequently this study suggests that producers continue to apply an inoculant to ensure the presence of adequate numbers of Rhizobia leguminosarum for faba bean production.

Table 5 shows the influence of variety and inoculation on seed protein, seed N percentage and seed N uptake, test weight, plant height, plant tissue N, plant biomass and total N uptake in biomass. The tannin variety faba bean contained higher seed N and therefore protein, higher seed N uptake and test weight compared to the zero tannin faba bean. Inoculation treatments had no influence on any of these factors excepting plant height, which increased with all inoculant treatments. All sites other than Melfort in 2016 had residual soil N levels that would not be expected to supply the N quantities measured in seed and biomass tissue. These overall lack of inoculation responses further suggests that faba beans within the confines of these test sites were being assisted by effective indigenous soil rhizobia thereby restricting, or limiting, positive fresh inoculation effects.

Table 4. Sites included in summary analyses.

Variety	Inoculant	2015 Site Yield (kg/ha)			
		Indian Head	Swift Current	Melfort	Yorkton
Snowdrop	Check	1045 f	712 g	2729 bcde	2109 a
Snowdrop	Nod peat	3286 c	1020 bcde	2637 cde	2082 a
Snowdrop	0.5X TT	1197 f	1031 bcde	2403 e	2149 a
Snowdrop	1.0X TT	1130 f	1110 bcde	2644 cde	2249 a
Snowdrop	2.0X TT	1493 e	1143 abc	2498 de	2097 a
Snowdrop	Nod + 0.5X TT	3085 c	1081 bcde	2552 de	2008 a
Snowdrop	Nod + 1.0X TT	3169 c	1122 bc	2634 cde	2118 a
Snowdrop	Nod + 2.0X TT	3140 c	1285 a	2986 abcde	2104 a
FB9-4	Check	1854 d	716 g	2912 abcde	2007 a
FB9-4	Nod peat	4946 a	1010 cde	3244 ab	2221 a
FB9-4	0.5X TT	1728 de	852 fg	3268 ab	2039 a
FB9-4	1.0X TT	1868 d	973 def	3417 a	2132 a
FB9-4	2.0X TT	1957 d	964 ef	3255 ab	2249 a
FB9-4	Nod + 0.5X TT	4623 ab	1105 bcde	3058 abcd	1790 a
FB9-4	Nod + 1.0X TT	4580 ab	1165 ab	3141 abc	2069 a
FB9-4	Nod + 2.0X TT	4359 b	1119 bcd	3076 abcd	2044 a
	Pr > F	0.0001	0.0001	0.001	0.918
	CV	7.1	10.1	14.2	14.7

Table 4. Continued

Variety	Inoculant	2016 Site Yield (kg/ha)						
		Indian Head	Swift Current	Melfort	Yorkton	Outlook	Redvers	Scott
Snowdrop	Check	3227 a	5728 bcdef	3816 a	4163 a	6581 a	5160 a	4998 a
Snowdrop	Nod peat	3503 a	6025 ab	3832 a	4350 a	6775 a	5321 a	4992 a
Snowdrop	0.5X TT	2987 a	5890 abcd	3951a	4326 a	6734 a	5026 a	5350 a
Snowdrop	1.0X TT	3222 a	5912 abcd	3754 a	4229 a	6727 a	5311 a	5299 a
Snowdrop	2.0X TT	3227 a	5964 abc	5358 a	3843 a	6627 a	5683 a	5360 a
Snowdrop	Nod + 0.5X TT	3220 a	5854 abcde	4202 a	4193 a	6777 a	5351 a	5340 a
Snowdrop	Nod + 1.0X TT	3371 a	6460 a	4114 a	3894 a	6482 a	4781 a	5325 a
Snowdrop	Nod + 2.0X TT	3353 a	6183 ab	3659 a	4223 a	6736 a	5441 a	5453 a
CDC SSNS-1	Check	3029 a	5143 f	3532 a	3408 a	7109 a	4389 a	5431 a

CDC SSNS-1	Nod peat	3205 a	5216 f	3688 a	4117 a	7053 a	4562 a	5203 a
CDC SSNS-1	0.5X TT	2982 a	5342 def	3503 a	4021 a	6887 a	4984 a	5259 a
CDC SSNS-1	1.0X TT	3019 a	5646 bcdef	3468 a	4063 a	7258 a	4950 a	5244 a
CDC SSNS-1	2.0X TT	3282 a	5395 cdef	3715 a	3706 a	7268 a	4821 a	5225 a
CDC SSNS-1	Nod + 0.5X TT	3251 a	5255 ef	3772 a	3833 a	7223 a	4456 a	5342 a
CDC SSNS-1	Nod + 1.0X TT	3216 a	5396 cdef	4107 a	4063 a	7313 a	4398 a	5152 a
CDC SSNS-1	Nod + 2.0X TT	3253 a	5351 def	3558 a	4296 a	7304 a	4767a	5210 a
	Pr > F	0.052	0.005	0.128	0.441	0.835	0.059	0.805
	CV	6.6	7.5	11.2	12.4	4.1	11.8	6.2

Table 4. Continued

Variety	Inoculant	2017 Site Yield (kg/ha)			
		Indian Head	**Redvers**	**Outlook**	**Yorkton**
Snowdrop	Check	1729 de	4543 a	3572 a	5203 a
Snowdrop	Nod peat	1777 de	4300 a	3634 a	5717 a
Snowdrop	0.5X TT	1702 e	3970 a	3799 a	5401 a
Snowdrop	1.0X TT	1780 cde	4249 a	3574 a	5891 a
Snowdrop	2.0X TT	1709 e	4082 a	3540 a	5927 a
Snowdrop	Nod + 0.5X TT	1699 e	4285 a	3419 a	5541 a
Snowdrop	Nod + 1.0X TT	1761 de	3859 a	3577 a	5438 a
Snowdrop	Nod + 2.0X TT	1693 e	4470 a	3539 a	5704 a
CDC SSNS-1	Check	2041 ab	3941 a	3841 a	5280 a
CDC SSNS-1	Nod peat	1981 ab	4223 a	3679 a	5766 a
CDC SSNS-1	0.5X TT	2098 a	3853 a	3591 a	5107 a
CDC SSNS-1	1.0X TT	2048 ab	3940 a	3777 a	5498 a
CDC SSNS-1	2.0X TT	2001 ab	4352 a	3405 a	5472 a
CDC SSNS-1	Nod + 0.5X TT	2077 a	4037 a	3698 a	5678 a
CDC SSNS-1	Nod + 1.0X TT	1901 bcd	4352 a	3623 a	5435 a
CDC SSNS-1	Nod + 2.0X TT	1951 abc	4532 a	3646 a	5541 a
	Pr > F	0.0001	0.139	0.970	0.601
	CV	6.5	9.1	10.6	9.1

Table 5. Combined Site Factorial Analyses for Faba Bean Grain Yield (kg/ha), 2015-17.

Treatment	**15 Site Year Summary Yield (kg/ha)**
Variety	
Zero Tannin	3782 b
Tannin	3931 a
Inoculation	
Check	3719 c
Nod peat	3952 a
0.5X TT	3758 bc
1.0X TT	3815 b
2.0X TT	3790 bc
Nod + 0.5X TT	3955 a
Nod + 1.0X TT	3925 a
Nod + 2.0X TT	3940 a
Pr > F (p-value)	
Variety (V)	0.0001
Inoculation (I)	0.0001
V x I	0.125

Table 6. Combined Site Analyses for Faba Bean Seed Quality and In-season Agronomic Observations, 2015-17.

Treatment	**Seed Protein (%)**	**Seed N (%)**	**Seed N Uptake (kg/ha)**	**Seed Test Weight (kg/hl)**	**Height (cm)**	**Tissue N (%)**	**Plant Biomass (T/ha)**	**N Biomass Uptake (kg/ha)**
Variety								
Zero Tannin	27.0 b	4.4 b	189 b	81.6 b	103 a	3.2 a	7.1 a	228 a
Tannin	28.1 a	4.6 a	205 a	82.3 a	103 a	3.2 a	7.1 a	228 a
Inoculation								
Check	27.6 a	4.5 a	197 a	82.1 a	100 b	3.2 a	6.9 a	222 a
Nod peat	27.5 a	4.5 a	199 a	82.0 a	103 a	3.2 a	7.4 a	241 a
0.5X TT	27.6 a	4.4 a	194 a	81.9 a	103 a	3.2 a	7.1 a	231 a
1.0X TT	27.7 a	4.5 a	199 a	81.8 a	103 a	3.2 a	7.2 a	234 a
2.0X TT	27.4 a	4.4 a	194 a	81.4 a	102 a	3.2 a	7.1 a	231 a
Nod + 0.5X TT	27.4 a	4.4 a	197 a	81.9 a	104 a	3.2 a	7.1 a	220 a
Nod + 1.0X TT	27.6 a	4.5 a	196 a	82.1 a	102 a	3.2 a	7.3 a	231 a
Nod + 2.0X TT	27.7 a	4.5 a	200 a	82.3 a	104 a	3.2 a	6.8 a	215 a
Pr > F (p-value)								
Sites	10	9	9	9	15	14	10	8
Variety (V)	0.01	0.01	0.01	>.01	0.97	0.87	0.86	0.98
Inoculation (I)	0.41	0.07	0.59	0.30	0.01	0.90	0.32	0.23
V x I	0.97	0.67	0.42	0.63	0.91	0.13	0.47	0.76

Conclusion and Recommendations:

The overall minimal response of faba bean to inoculation was somewhat unexpected. In general inoculation provided a modest yield response that would cover the cost of a recommended rate of inoculant application. The peat based formulation was sufficient in providing optimal yields, equal or greater, than that of the granular inoculant. These results suggest that producers can make their faba bean inoculant formulation decision based on cost and convenience to their operation. Results of this trial suggest that it still be recommended that an inoculant be applied with faba beans as a small yield response is expected and for insurance as no valid method of predicting viable and sufficient background levels of indigenous rhizobia might be present to assist in faba bean growth and development.

Supporting Information

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To Demonstrate the Effect of Macro and Micro Nutrients on the Yield and Development of Canaryseed

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Abstract/Summary:

This study was conducted at five locations, Indian Head, Melfort, Yorkton, Swift Current and Scott in 2014. It continues earlier work from 2012 and 2013. In 2014 grain yield responded to N fertilizer at all locations; however, the response was not large at all locations except Scott. Grain yield was increased by chloride at 3 out of the five locations and test weight was also affected by chloride. Grain yield responded to zinc at Scott. It is suspected that the response to chloride may be related to local differences in field elevation/drainage and the potential for leaching of the soil profile; further study needs to be undertaken to confirm this observation. In conclusion, apply

chloride in the form of potash fertilizer when growing canaryseed and only use moderate amounts of N fertilizer.

Objectives:
To demonstrate the effect of macro and micro nutrients on canaryseed and provide professionals providing extension on canaryseed production in Saskatchewan with up to date information on the benefits of macro and micro nutrients for canaryseed.

Project Rationale:
Canaryseed producers are becoming aware that chloride is an import nutrient to apply and that large amounts of nitrogen are not required for canaryseed production. This project will help to demonstrate to canaryseed growers the importance of a complete nutrient management package in canaryseed.

Methodology and Results

Methodology:
Experimental Design: Single factor RCBD
Replicates: 4
Plot Size: 13’ x 35’ (Conservapak)
Cultivar: CDC Bastia
Seeding Rate: 35 kg/ha
Locations: Indian Head, Swift Current, Melfort, Scott, Yorkton, Redvers

Table 1 Nutrients applied in each treatment

Treatment	N	P_2O_5	K_2O	Cl	S	Copper	Zinc	Combination of Micro’s
	---------- kg/ha ----------							
1	0							
2	15		20	18.1				
3	30		20	18.1				
4	30	30	20	18.1				
5	30	30	20	18.1	15			
6	60	30	20	18.1	15			
7	60	30			15			
8	60	30	20	18.1	15	3		
9	60	30	20	18.1	15		3	
10	60	30	20	18.1	15			Yes
11	90	30	20	18.1	15			Yes

Weed Control: An application of granular Avadex is the recommended treatment for wild oats. If you have old stock of Mataven, it is fairly safe. Puma super is not registered and please consult with Bill May if you wish to use it. Canaryseed has good tolerance to the broadleaf herbicides Buctril M, Curtail M, Trophy and Prestige. If you need to use something else please consult with Bill May.

Data Collection: (Each site is responsible)

1. Soil test: Take 2 cores from each plot of treatments 1 and 7 (0 kg/ha Cl) with 0-15 and 15- 60 cm increments and then bulk the 2 cores together. Each site should have 8 samples (1 per plot) per sample depth, for a total of 16 samples per site. The samples will be air dried and ground if possible: A Minimum of 200 grams ground sample will first be sent to Indian Head so they can all be sent together to the Swift Current S.C. Lab for analysis. 0-15 cm: N, P, K, S , Cl, Zn, Cu, texture, organic matter content, pH, EC. 15-60 cm: N & C
   Request samples to be returned after analysis and archive until project is complete. Any leftover soil after preparing samples for analysis, hold until S.C. Lab samples (200g) are returned.
2. Plant density (2 x 1m row per plot, # plants/unit area)
3. Panicle density (2 x 1m row per plot, # panicles/unit area)
4. Plant height (2 per plot)
5. Lodging (0-10, 0 = upright, 10 = flat)
6. Monitor leaf disease. Rate and control if required. (McFadden Scale 0-11)
7. Monitor aphids, and control if required. (Economic thresh hold approximately 10 aphids on 50 per cent of the stems prior to the soft dough stage)
8. Days to maturity (Julian date)
9. Grain yield
10. Random grain moisture
11. Dockage
12. 1000 Kernel weight
13. Test weigh

Results:

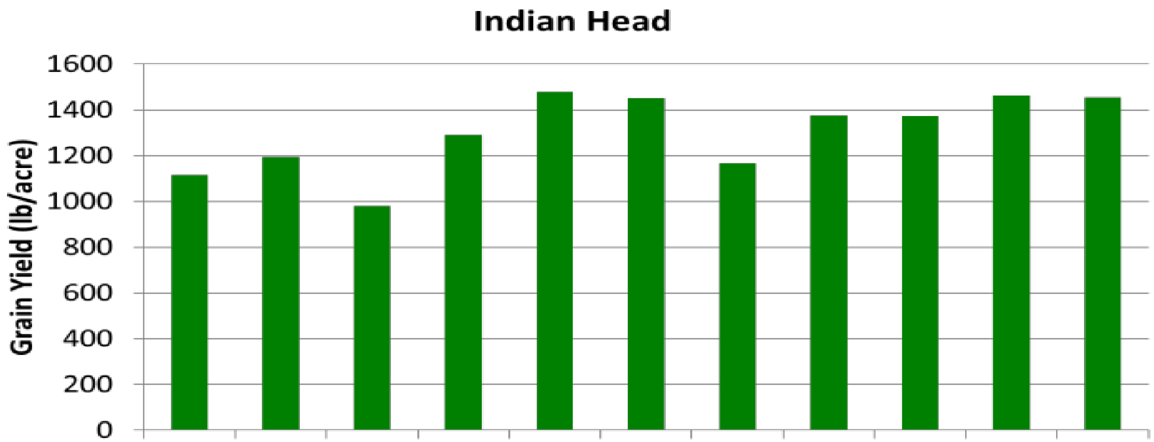
The nutrients applied in each treatment are layout in Table 1. At Indian Head the differences in grain yield from the treatments could not be separated statistically (Fig1 and Table 2). After examining the data it became it appears that the Cl response varied depending on the elevation. When the low elevation was separated from the high elevation there appears to be a chloride response at the higher elevation but not the lower elevations (Fig 2). This makes sense since chloride is mobile and will flow with the water. In the spring the elevation of each plot will be used to improve the statistical analysis of the site. Figure 3 shows the difference in vegetative growth of the canaryseed from the applied nutrients. This difference in vegetative growth does not always result in a difference in grain yield. Plant density varied among the fertilizer treatments, but there does not appear to be any clear trend and panicle density was not affected (Table 1). The addition of P in treatment 4 resulted in an increase in the height of the canaryseed. Interestingly the presence of copper appeared to increase lodging as did increasing the N rate to 90 from 60 kg ha-1. Test weight was lowest for treatment 7 which received no chloride. In addition increasing the N rate to 90 from 60 kg ha-1, (Treatments 10 vs 11) decreased the test weight.

At Swift Current, the application of 15 kg N ha-1 combined with 18 kg Cl ha-1 increased the grain yield and removing Cl, treatment 7, reduced grain yield below the unfertilized check, treatment 1 (Figure 4). The plant density varied among the fertilizer treatments (Table 3). No discernable pattern can be observed and the panicle density was not affected by the fertilizer treatments. Height, lodging, leaf disease and maturity were also not affected by the fertilizer treatments.

At Melfort the addition of N fertilizer up to 30 kg/ha increased yield and N levels above 30 kg/ha did not increase yield and may have actually been slightly negative (Figure 5). The only other measured variable at Melfort that was affected by the fertilizer treatments was plant height (Table 4). Height increased in treatment 5 when S was added and increased even more when the Cl was removed (Treatment 7). The addition of micronutrients resulted in a height that was similar to all the treatments except the unfertilized check.

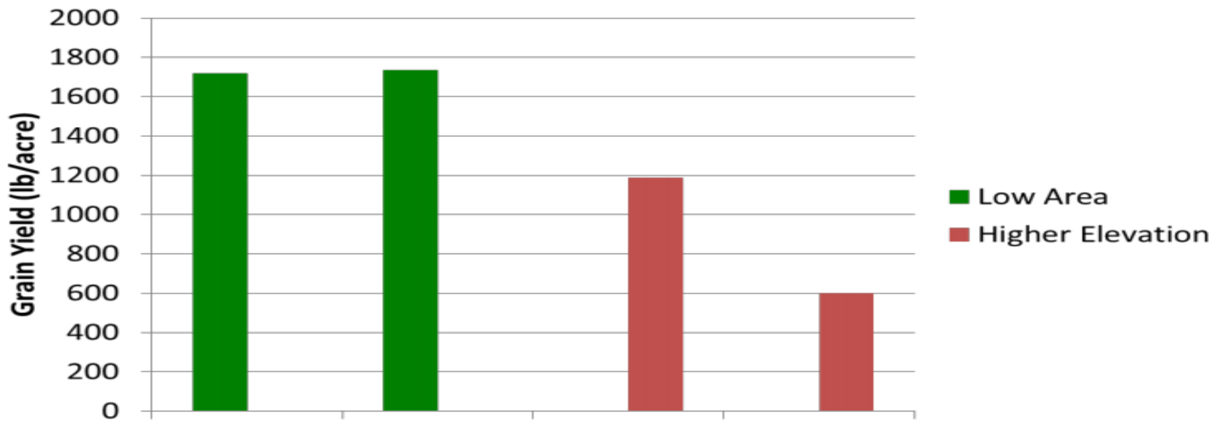
At Scott there was a strong yield response to N up to the highest rate of 90 kg/ha (Figure 6). In addition there appears to be a grain yield response to Zinc at Scott in 2014. The effects of the fertilizer treatments observed in the grain yield were also observed in the panicle density, height and test weight but not the kernel weight (Table 5). This indicates that the panicle density was the yield component affected most by the fertilizer treatments. Interestingly the removal of chloride in treatment 7 lowered the test weight of the canaryseed as it did at Indian Head.

At Yorkton, the addition of 15 kg N/ha combined with 18 kg Cl/ha increased the grain yield and removing Cl, treatment 7, reduced grain yield back to the level of the unfertilized check. The application of N above 15 kg N/ha had little effect on grain yield. At Yorkton test weight followed the same trend as grain yield (Table 6). Test weight increased when N and Chloride were applied and decreased when the chloride was removed. The soil test results have not yet returned from the lab and need to be incorporated.



N	0	15	30	30	30	60	60	60	60	60	90
P	0	0	0	30	30	30	30	30	30	30	30
CL		18	18	18	18	18	0	18	18	18	18
S					15	15	15	15	15	15	15
Cu								3			
Zinc									3		
Cu, Z, Mg, B										Yes	Yes

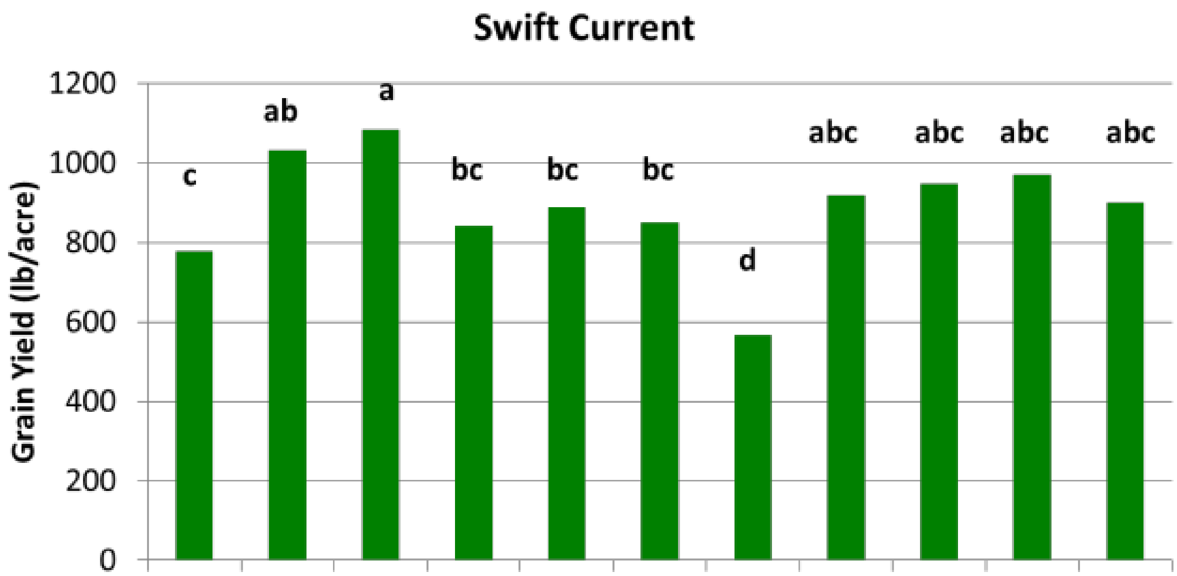
Figure 1. The grain yield response of canaryseed at Indian Head in 2014.



N	60	60	60	60
P	30	30	30	30
CL	18	0	18	0
S	15	15	15	15

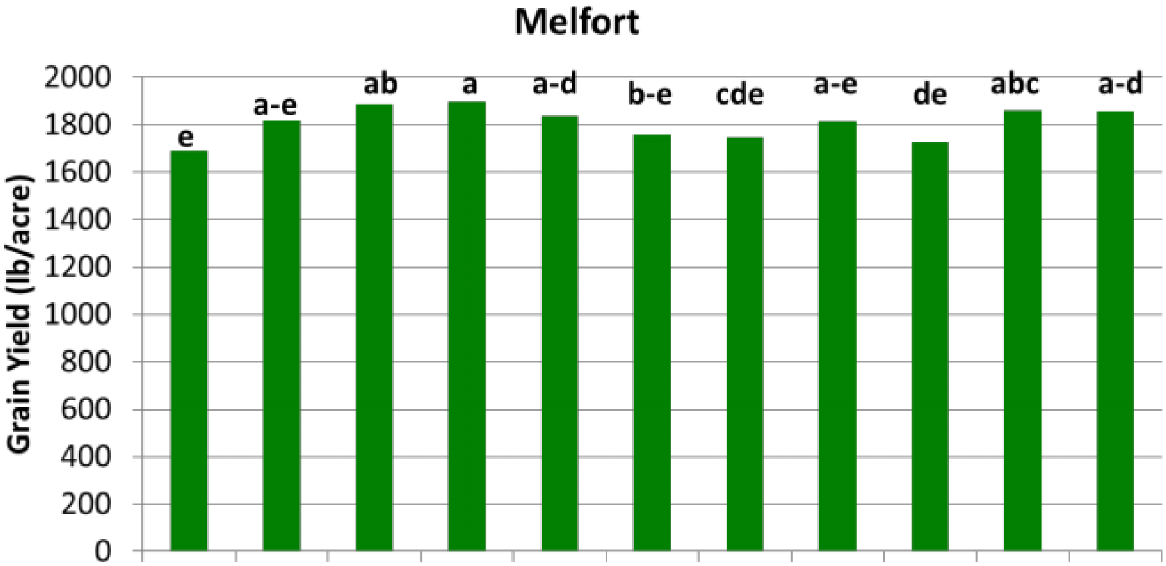
Figure 2. The grain yield of canaryseed separated by elevation at Indian Head in 2014.

Figure 3. Visual response of canaryseed to the applied nutrients at Indian Head in 2014.



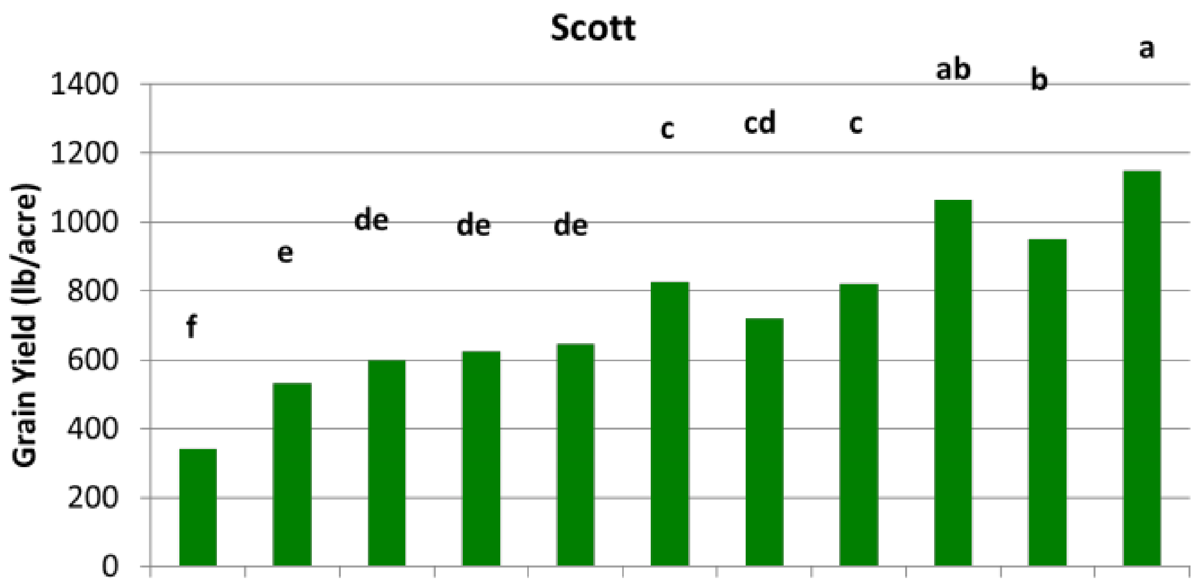
N	0	15	30	30	30	60	60	60	60	60	90
P	0	0	0	30	30	30	30	30	30	30	30
CL		18	18	18	18	18	0	18	18	18	18
S					15	15	15	15	15	15	15
Cu								3			
Zinc									3		
Cu, Z, Mg, B										Yes	Yes

Figure 4. The grain yield response at Swift Current in 2014.



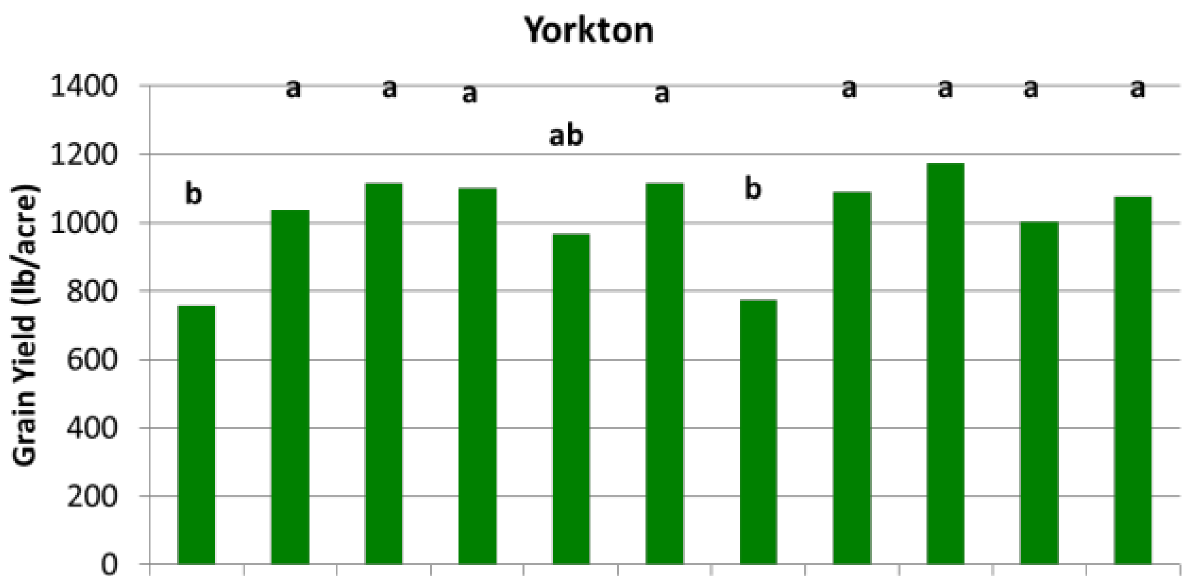
N	**0**	**15**	**30**	**30**	**30**	**60**	**60**	**60**	**60**	**60**	**90**
P	**0**	**0**	**0**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**
CL		**18**	**18**	**18**	**18**	**18**	**0**	**18**	**18**	**18**	**18**
S					**15**	**15**	**15**	**15**	**15**	**15**	**15**
Cu								**3**			
Zinc									**3**		
Cu, Z, Mg, B										**Yes**	**Yes**

Figure 5. The grain yield response at Melfort in 2014



N	0	15	30	30	30	60	60	60	60	60	90
P	0	0	0	30	30	30	30	30	30	30	30
CL		18	18	18	18	18	0	18	18	18	18
S					15	15	15	15	15	15	15
Cu								3			
Zinc									3		
Cu, Z, Mg, B										Yes	Yes

Figure 6. The grain yield response at Scott in 2014



N	0	15	30	30	30	60	60	60	60	60	90
P	0	0	0	30	30	30	30	30	30	30	30
CL		18	18	18	18	18	0	18	18	18	18
S					15	15	15	15	15	15	15
Cu								3			
Zinc									3		
Cu, Z, Mg, B										Yes	Yes

Figure 7. The grain yield response at Yorkton in 2014

Table 2. The effect of macro and micro nutrients on the yield and development of canaryseed at Indian Head in 2014

Treatments	Plant Density /m2		Panicle Density /m2		Average Height cm		Lodge 0-10		Grain Yield kg/ha		Test Weight g/ 0.5 L		Kernel weight g/1000 K	
1	176.3	abc	229.2	a	104.5	bc	3.0	de	1251.9	a	374.9	a	8.2	a
2	237.9	a	267.4	a	103.4	bc	3.8	cde	1342.6	a	373.3	abc	8.4	a
3	153.4	bc	223.5	a	96.4	c	2.0	e	1100.9	a	375.3	a	8.2	a
4	147.2	bc	258.8	a	112.9	ab	3.3	de	1451.0	a	374.4	ab	8.2	a
5	231.3	a	267.0	a	119.6	a	4.3	cd	1662.3	a	375.1	a	8.2	a
6	187.0	abc	250.6	a	120.3	a	3.8	cde	1631.9	a	372.5	abc	8.3	a
7	201.4	abc	252.6	a	118.3	a	3.5	de	1312.8	a	362.3	e	8.3	a
8	162.8	bc	260.4	a	118.5	a	5.5	bc	1546.6	a	368.8	cd	8.0	a
9	206.7	ab	276.8	a	117.4	a	4.3	cd	1543.6	a	369.7	bcd	8.3	a
10	148.0	bc	311.3	a	117.6	a	6.3	b	1645.7	a	371.5	abc	8.3	a
11	136.6	c	259.6	a	119.6	a	8.3	a	1632.5	a	365.5	d	8.3	a
LSD P=.05	65.3		59.0		10.4		1.8		426.0		4.9		0.2	
Standard Deviation	45.3		40.8		7.2		1.3		294.6		3.4		0.2	
CV	25.0		15.7		6.4		28.9		20.1		0.9		1.9	
Treatment Prob(F)	0.0324		0.2726		0.0002		0.0001		0.1400		0.0046		0.7378	

Means followed by same letter do not significantly differ (P=.05, LSD)

Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Table 3. The effect of macro and micro nutrients on the yield and development of canaryseed at Swift Current in 2014.

Treatments	Plant Density Plants/m2		Panicle Density /m2		Average Height cm		Lodge 0-10		Leaf Disease 0-11		Maturity DAYTO		Grain Yield kg/ha	
1	394.2	a	751.3	a	66.4	a	0.0	a	0.0	A	95.8	a	873.8	c
2	304.0	b	801.6	a	68.3	a	0.0	a	0.0	A	95.0	a	1158.1	ab
3	366.9	ab	844.3	a	68.5	a	0.0	a	0.0	A	95.0	a	1218.7	a
4	407.9	a	813.6	a	62.0	a	0.0	a	0.0	A	96.0	a	946.2	bc
5	359.3	ab	772.1	a	65.5	a	0.0	a	0.0	A	94.3	a	997.5	bc
6	405.7	a	716.3	a	66.5	a	0.0	a	0.0	A	95.8	a	955.6	bc
7	359.8	ab	768.8	a	65.6	a	0.0	a	0.0	A	96.3	a	638.1	d
8	387.7	a	738.2	a	66.6	a	0.0	a	0.0	A	95.3	a	1030.9	abc
9	397.5	a	841.0	a	68.8	a	0.0	a	0.0	A	94.8	a	1065.3	abc
10	311.1	b	746.9	a	69.4	a	0.0	a	0.0	A	95.5	a	1090.0	abc
11	348.3	ab	769.9	a	67.1	a	0.0	a	0.0	A	96.3	a	1010.5	abc
LSD P=.05	66.0		122.7		6.3		0.0		0.0		1.4		220.4	
Standard Deviation	45.7		85.0		4.3		0.0		0.0		1.0		152.6	
CV	12.5		10.9		6.5		0.0		0.0		1.0		15.3	
Treatment Prob(F)	0.0282		0.4915		0.5544		1.0000		1.0000		0.1334		0.0013	

Means followed by same letter do not significantly differ (P=.05, LSD)
Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Table 4. The effect of macro and micro nutrients on the yield and development of canaryseed at Melfort in 2014.

Treatments	Plant Density /m2	Panicle Density /m2	Average Height cm	Lodge 0-10	Grain Yield kg/ha	Test Weight g/ 0.5 L	Kernel weight g/1000 K
1	366.5 a	652.8 a	122.3 d	3.0 A	1897.6 e	338.3 a	10.3 a
2	408.8 a	529.3 a	125.0 cd	2.0 A	2042.6 a-e	351.8 a	10.8 a
3	440.5 a	707.8 a	125.0 cd	2.4 A	2120.1 ab	342.8 a	10.5 a
4	401.8 a	589.0 a	124.8 cd	1.3 A	2130.1 a	348.0 a	10.7 a
5	357.5 a	564.0 a	125.8 bc	2.2 A	2063.8 a-d	341.2 a	10.3 a
6	358.0 a	616.5 a	126.0 bc	2.8 A	1976.5 b-e	345.6 a	10.6 a
7	383.5 a	677.5 a	129.3 a	2.1 A	1961.7 cde	342.5 a	10.2 a
8	379.5 a	625.5 a	128.5 ab	3.9 A	2039.1 a-e	346.2 a	10.6 a
9	399.8 a	692.3 a	127.3 abc	4.0 A	1939.1 de	343.6 a	11.0 a
10	382.0 a	519.0 a	127.0 abc	3.8 A	2091.0 abc	344.6 a	10.0 a
11	331.0 a	610.3 a	128.3 ab	3.9 A	2083.7 a-d	341.8 a	10.3 a
LSD P=.05	67.46	178.36	3.03	2.1	151.3	11.0	1.4
Standard Deviation	46.72	123.52	2.10	1.4	104.8	7.6	1.0
CV	12.21	20.03	1.66	50.6	5.2	2.2	9.6
Treatment Prob(F)	0.1473	0.4323	0.0023	0.1355	0.0499	0.5278	0.9470

Means followed by same letter do not significantly differ (P=.05, LSD)

Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Table 5. The effect of macro and micro nutrients on the yield and development of canaryseed at Scott in 2014.

Treatments	Plant Density /m2	Panicle Density /m2	Average Height cm	Lodge 0-10	Leaf Disease 0-11	Grain Yield kg/ha	Test Weight g/ 0.5 L	Kernel weight g/1000 K
1	101.4 a	209.6 f	78.3 e	0.0 a	2.0 a	383.9 f	356.6 d	7.5 a
2	128.0 a	235.7 ef	85.0 d	0.0 a	2.0 a	598.8 e	362.5 bc	7.3 a
3	129.9 a	253.4 def	90.0 d	0.0 a	2.0 a	671.8 de	363.5 abc	7.6 a
4	128.9 a	278.5 cde	101.7 bc	0.0 a	2.0 a	702.1 de	366.8 ab	7.9 a
5	128.9 a	290.8 bcd	98.3 c	0.0 a	2.0 a	725.1 de	366.7 ab	7.6 a
6	127.0 a	284.0 cde	105.0 ab	0.0 a	2.0 a	927.7 c	367.0 a	7.9 a
7	108.3 a	281.0 cde	108.3 a	0.0 a	2.0 a	807.7 cd	360.3 cd	7.8 a
8	119.1 a	307.6 bc	108.3 a	0.0 a	2.0 a	922.8 c	367.3 a	8.1 a
9	130.9 a	382.9 a	108.3 a	0.0 a	2.0 a	1195.9 ab	367.7 a	7.6 a
10	114.2 a	324.8 bc	110.0 a	0.0 a	2.0 a	1067.9 b	366.9 ab	7.5 a
11	120.6 a	336.1 ab	106.7 ab	0.0 a	2.0 a	1288.6 a	366.9 a	8.2 a
LSD P=.05	31.1	48.7	6.1	0.0	0.0	138.6	4.3	0.6
Standard Deviation	21.5	33.6	3.6	0.0	0.0	95.9	3.0	0.4
CV	17.7	11.6	3.6	0.0	0.0	11.4	0.8	5.2
Treatment Prob(F)	0.5874	0.0001	0.0001	1.0000	1.0000	0.0001	0.0001	0.0973

Means followed by same letter do not significantly differ (P=.05, LSD)

Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Table 6. The effect of macro and micro nutrients on the yield and development of canaryseed at Yorkton in 2014

Treatments	Plant Density /m2		Panicle Density /m2		Lodge 0-10		Grain Yield kg/ha		Test Weight g/ 0.5 L		Kernel weight g/1000 K	
1.0	475.4	a	405.0	a	8.3	a	851.3	b	351.0	Ef	8.1	a
2.0	469.5	a	415.8	a	6.8	a-d	1165.6	a	363.2	Ab	8.1	a
3.0	437.0	a	409.0	a	5.3	d	1254.8	a	363.0	Ab	8.0	a
4.0	467.5	a	442.4	a	5.8	cd	1237.6	a	364.9	A	8.3	a
5.0	459.6	a	440.9	a	5.5	cd	1086.8	ab	361.2	a-d	8.2	a
6.0	393.2	a	471.9	a	8.0	ab	1253.5	a	356.6	Cde	8.2	a
7.0	434.5	a	425.2	a	6.5	a-d	871.6	b	347.3	F	8.1	a
8.0	390.3	a	382.9	a	6.3	bcd	1225.6	a	362.7	Abc	8.3	a
9.0	421.8	a	436.0	a	7.3	abc	1319.9	a	358.2	Bcd	8.1	a
10.0	458.7	a	423.2	a	7.3	abc	1127.7	a	358.5	Bcd	8.1	a
11.0	407.5	a	440.5	a	7.3	abc	1208.8	a	356.3	De	8.0	a
LSD P=.05	107.4		81.0		1.8		238.5		6.2		0.2	
Standard Deviation	74.4		56.1		1.2		165.2		4.3		0.2	
CV	16.99		13.16		18.41		14.42		1.2		1.99	
Treatment Prob(F)	0.7189		0.7059		0.0243		0.0038		0.0001		0.3771	

Means followed by same letter do not significantly differ (P=.05, LSD)

Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Conclusions and Recommendations:

- N Fertilizer: response at all 5 locations
- Optimum amount ranged from 15 to 90 kg/ha
- Chloride: response at 3 of 5 locations
- Test weight appears to be affected by a lack of Chloride
- Zinc: response at 1 out of 5 locations
- Still need to incorporate soil test results

Apply Chloride in the form of potash fertilizer when growing canaryseed and only use moderate amounts of N fertilizer.

Supporting Information:

Acknowledgements:
This project was funded through the Agricultural Demonstration of Practices and Technologies (ADOPT). The ADOPT trials were posted with signs and funding was acknowledged during presentations and in PDF's of the presentations.

The Test Weight Stability and Yield Response of New and Established Oat Cultivars to Fertilizer N

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Abstract/Summary:
Oat growers are looking for ways to increase their yield and maintain the quality of the oats they grow. Many are using high N rates with varying degrees of success. Research indicates that some cultivars have a more stable test weight than other cultivars as the nitrogen fertilizer fate is increased. In addition new cultivars are available that growers have not had a chance to see evaluated in their own area. The demonstration consisted of four cultivars and four nitrogen rates in an RCBD with four replications at Indian Head, Yorkton, Melfort and Redvers in 2014 and 2015. The experiment was successfully carried out at three locations in 2014, Indian Head, Yorkton and Melfort and all locations in 2015. In 2014 seeding could not be completed due to excessive soil moisture and rain at Redvers. In 2014 there was no interaction among the cultivars for their response to nitrogen fertilizer at all three locations. This indicates that the cultivars all responded in a similar manor to the application of nitrogen fertilizer. However both 2015and 2016 at 2 out of 4 locations there was an interaction between the cultivars and their response to

applied N. In general, as the amount of applied N increased lodging increased. In all eleven site-years (a location in a specific year) trials conducted over the three years, grain yield increased as the N rate increased. At three site years, Indian Head 2014 and Redvers 2015 and 2015 only 60 kg N/ha was needed to maximize yield (Tables 3, 7 and 11). Two site years, Indian Head 2015 and Yorkton 2016, required 80 kg N/ha to maximize yield (Tables 6 and 8). At six site years, Yorkton in 2014 and 2015, Melfort in 2014, 2015, and 2016 and Indian Head in 2016, 120 kg N/ha was required to maximize yield (Tables 1, 2, 4, 5, 9 and 10). The test weight of the cultivars differed in their response to the addition of N fertilizer at 2 out of 4 locations in 2015 and 1 out of 4 locations in 2016. The test weight declined as the N rate increased at Indian Head in 2014 and 2015, Yorkton in 2014 and 2016, Melfort in 2015 and 2016 and Redvers in 2015 and 2016 but not at Melfort in 2014, Yorkton in 2015 and Indian Head in 2016 (Tables 1-11). . There does not appear to be a strong correlation between cultivars with high yield potential and a low test weight. There does appear to be a relationship between lodging increasing as N rates increased and test weight decreasing. A combined analysis is now required to further investigate this relationship. In addition the combined analysis will let us look at the cultivars overall stability in test weight as the N rate increases.

Methodology and Results

Methodology:

Experimental Design: 2 factors, N rate and cultivar in a RCBD design.
Plot Size: 35 x 13 feet
Reps: 3

Treatment Factors
1) Cultivars
Four cultivars (cultivars picked for each location based on two popular and two new cultivars with potential)

Cultivars chosen for each location.			
Indian Head	**Melfort**	**Redvers**	**Yorkton**
Stride	Stride	Stride	Stride
CDC Ruffian	CDC Minstrel	Justice	CDC Dancer
CS Camden	AC Morgan	Souris	Summit
CDC Big Brown	CDC Seabiscuit	CDC Morrison	Triactor

2) Nitrogen Rate (kg N ha-1)

I) 40
II) 60
III) 80
IV) 120

Data Collection

1. Soil test: 0-6 inches, 6-24 inches, N bulked across reps, P, K, and S bulked across the test
2. Plant density
3. Lodging, (1-10, 1= upright and10=flat)
4. grain yield
5. test weight
6. thin kernels

Results:
The experiment was successfully carried out at all four locations Indian Head, Yorkton, Redvers and Melfort in 2014, 2015 and 2016. The only exception was at Redvers in 2014 when seeding could not be completed due to excessive soil moisture and rain. In 2014 there was no interaction among the cultivars for their response to nitrogen fertilizer at all three locations; which means that cultivars all responded in a similar manor to the application of nitrogen fertilizer. In 2015 and 2016 there were significant interactions between the cultivars and their response to N fertilizer. Plant density differed among the cultivars tested at 9 out of 11 site-years. As the nitrogen rate increased, plant density decreased at only Yorkton in 2015 and 2016 (Tables 4 and 8). In fact at Yorkton in 2015, the cultivars differed in the effect N rate had on their plant density (Table A4, Appendix 1). The plant density of all the cultivars tended to decrease as the N fertilizer rate increased but they varied in the levels that were statistically different.

In 2014, as the amount of applied N increased lodging increased, especially at Indian Head (Tables 1- 3). At Yorkton and Melfort, the lodging increased when the N rate increased from 80 to 120 kg/ha; however, at Indian Head there was an increase in lodging each time the N rate increased. In 2015 lodging increased as the N rate increase at Melfort and Redvers (Tables 5 and 7). Again the increase in lodging at Melfort was between 80 and 120 kg N/ha. While Redvers had lodging that was similar to the lodging observed at Indian Head in 2014 with lodging increasing every time the level of N increase. At Yorkton in 2015 lodging decreased as the N rate increased (Table 4). In addition the cultivars reacted differently to increasing N at three of the locations in 2015, Yorkton, Melfort and Redvers (Tables 4, 5 and 7). Unexpectedly lodging decreased for three of the four cultivars at Yorkton in 2015 as the N rate increased (Table A4). At Melfort in 2015 lodging was low with a very small increase in the lodging of CDC Seabiscuit and Stride as the N rate increased from 80 to 120 kg N/ha while the lodging of AC Morgan and CDC Ministrel did not change did not change (Table A5). At Redvers very little lodging occurred in CDC Morrison while the lodging of the other three cultivars tended to increase as the N rate increased (Table A7). At Yorkton in 2015, Triactor again had the lowest level of lodging; however, summit had the highest level of lodging among the four cultivars. The lodging in Souris was higher than the other cultivars at Redvers in 2015. At Yorkton 2014, the cultivars Summit and Triactor had lower lodging than both Stride and CDC dancer (Table 1). At Melfort in both 2014 and 2015 and Indian Head in 2014 the cultivars did not differ in lodging. At Indian Head in 2015 stride had slightly more lodging than the other three cultivars (Table 6). In 2016 lodging increased as the N rate increased at Melfort and Redvers (Tables 9 and 11). At Yorkton lodging similar to Triactor. The lodging of Stride and CDC Dancer increased as the N rate increased.

In all eleven site-years (a location in a specific year) trials conducted over the three years, grain yield increased as the N rate increased. At three site years, Indian Head 2014 and Redvers 2015 and 2015 only 60 kg N/ha was needed to maximize yield (Tables 3, 7 and 11). Two site years, Indian Head 2015 and Yorkton 2016, required 80 kg N/ha to maximize yield (Tables 6 and 8). At six site years, Yorkton in 2014 and 2015, Melfort in 2014, 2015, and 2016 and Indian Head in 2016, 120 kg N/ha was required to maximize yield (Tables 1, 2, 4, 5, 9 and 10). At Indian Head in 2014 and Redvers in 2015, the cultivars did not differ in their grain yield (Tables 3 and 7). At Indian Head in 2015, Stride had a grain yield that was below the other three cultivars (Table 6) while in 2016 both Stride and CDC Ruffian had a lower yield than CDC Big Brown. At Yorkton, Triactor had the highest grain yield in all three years (Tables 2, 4 and 8). In 2014 CDC Dancer had a higher yield than Summit and Stride; however, in 2015 and 2016 CDC Dancer had the lowest yield at Yorkton. At Melfort, AC Morgan had the highest yield of all the cultivars in all years (Tables 2, 5, and 9). In 2014 at Melfort that other cultivars had similar grain yields while in 2015 CDC Seabiscuit out yielded CDC Minstrel and Stride and CDC Minstrel out yielded Stride. In 2016, CDC Seabiscuit had a yield that was lower than CDC Minstrel. At Yorkton in 2016 the yield of all the cultivars increased as the N rate increased except for CDC Dancer (Table A8).

In 2014 the test weight of the cultivars did not vary in their response to the addition of N fertilizer. The test weight of the cultivars differed in their response to the addition of N fertilizer at 2 out of 4 locations in 2015 and 1 out of 4 locations in 2016. The test weight declined as the N rate increased at Indian Head in 2014 and 2015, Yorkton in 2014 and 2016, Melfort in 2015 and 2016 and Redvers in 2015 and 2016 but not at Melfort in 2014, Yorkton in 2015 and Indian Head in 2016 (Tables 1-11). The decrease in test weight was small at Yorkton in 2014 (from 259 to 253 g/0.5L) and Indian Head in 2015 (from 253 to 250 g/0.5L) as the N rate increased from 40 to 120 kg N/ha. At Indian Head in 2014 there was a larger decrease in test weight, from 264 to 246 g/0.5L as the N rate was increased from 40 to 120 kg N/ha. At Melfort in 2015 there was a large decrease in the test weight of CDC Seabiscuit as the N rate increased (Table A5). In addition the test weight of Stride decreased as the N rate increased while the test weight of AC Morgan and CDC Minstrel had decreases of less than 4 g/0.5L. At Redvers in 2015 the test weight of all the cultivars except Souris declined as the N rate increased (Table A7). The decrease in test weight as the N rate increased was greater than 10 g/0.5L for both Leggett and Stride. At Redvers in 2016 the test weight of Souris and Stride both decreased as the N rate increased. (Table A11)

Over the two years the effect increasing of N fertilizer was consistent on plump seed but not thin seed and groat yield. The percentage of plump seed tended to decrease as the N rate increased (Tables 1- 7).

Conclusions and Recommendation:

Grain yield increased as the N rate increased at all 11 site-years with grain yield maximized at the highest N rate at 6 site years. There does not appear to be a strong correlation between cultivars with high yield potential and a low test weight. There does appear to be a relationship between lodging increasing as N rates increased and test weight decreasing. A combined analysis is now required to further investigate this relationship. In addition the combined analysis will let us look at the cultivars overall stability in test weight as the N rate increases.

Supporting Information

Acknowledgements:

This project was funded through the Agricultural Demonstration of Practices and Technologies (ADOPT). ADOPT signs were posted at the various trial locations and the demonstration was toured at different locations. Data was posted on websites and in annuals reports.

Appendices:

Table 1: Effect of Cultivar and Nitrogen Rate on Oat Yield and Development at Yorkton in 2014

	Plant Density Plants/m^2	Lodging 1-10	Yield Kg/ha	Test weight g/0.5L	Plump seed %	Thin Seed %	Groat Yield %
Cultivar							
Stride	272.7 a	4.2 b	5960.9 c	266.0 a	96 ab	0.5 B	72.9 c
CDC Dancer	271.4 a	5.6 a	6512.6 b	257.0 c	96 bc	0.7 B	75.6 a
Summit	269.0 a	2.6 c	6194.8 c	260.8 b	96 a	0.6 B	74.5 b
Triactor	253.8 a	2.9 c	7049.3 a	242.4 d	95 c	1.3 A	72.4 c
Nitrogen Rate (kg/ha)							
40	268.5 a	3.5 b	5741.6 c	259.2 a	97 a	0.6 A	73.9 a
60	268.2 a	3.4 b	6309.8 b	257.6 ab	96 b	0.8 A	73.9 a
80	268.8 a	3.7 b	6642.0 b	256.6 b	96 bc	0.8 A	73.9 a
120	261.3 a	4.8 a	7024.2 a	252.8 c	95 c	0.9 A	73.8 a

Table 2. Yield response and test weight stability of oat to fertilizer N at Melfort in 2014

	Plant Density /m2		Lodge Belgian 0-5		Grain yield kg/ha		Grain yield bu/ac		Test Wt g/0.5 L		Plump %		Thin %		TKW g/1000 k	
Cultivar																
Stride	284.8	b	0.2	a	6714.3	b	175.8	b	282.89	a	88.216	A	2.288	a	32.7	d
CDC Minstrel	328.3	a	0	a	6874.6	b	180	b	276.31	ab	90.388	A	2.368	a	36.11	c
AC Morgan	295.6	b	0	a	7496.6	a	196.3	a	273.86	b	90.244	A	1.203	b	37.36	b
CDC Seabiscuit	277.8	b	0.3	a	6819.1	b	178.6	b	264.92	c	90.475	A	1.611	b	39.48	a
Nitrogen Rate																
40 kg/ha	294.7	a	0.05	b	6575.5	d	172.2	d	276.29	a	90.716	A	1.834	a	36.83	a
60 kg/ha	293.4	a	0.05	b	6850.6	c	179.4	c	275.44	a	90.635	A	1.936	a	36.93	a
80 kg/ha	305.3	a	0.05	b	7103.9	b	186	b	272.04	a	89.113	B	1.866	a	36	b
120 kg/ha	292.9	a	0.35	a	7374.6	a	193.1	a	274.2	a	88.859	B	1.833	a	35.9	b

Table 3. Yield response and test weight stability of oat to fertilizer N at Indian Head

	Plant Density	Lodge	Grain yield	Test Wt	Plump seed	Thin Seed	Groat yield	Wild Oat
	/m2	(1-10)	kg/ha	g/0.5 L	%	%	%	g/50g
Cultivar								
Stride	241 a	6.8 a	3726.8 a	261.9 a	80 b	2.2 a	70 bc	0.252 a
Pinnacle	222 a	6.6 a	4028.7 a	248.29 c	93 a	1.2 b	71 b	0.264 a
CDC Orrin	229 a	6.6 a	4125.3 a	256.08 b	93 a	1.4 b	70 c	0.25 a
CDC Big Br	229 a	5.8 a	4038.7 a	260.52 ab	91 a	2.6 a	73 a	0.216 a
Nitrogen Rate (kg/ha)								
40 kg/ha	229 a	3.8 d	3426.4 b	264.31 a	92 a	1.5 b	72 a	0.26 a
60 kg/ha	231 a	5.8 c	4144.7 a	261.07 a	91 a	1.5 b	71 b	0.191 a
80 kg/ha	234 a	7.4 b	4051.8 a	255.62 b	90 a	1.8 b	71 c	0.313 a
120 kg/ha	227 a	8.8 a	4296.6 a	245.79 c	85 b	2.6 a	70 d	0.219 a

Table 4. Yield response and test weight stability of oat to fertilizer N at Yorkton in 2015

	Plant Density /m2	Lodging 0-10	Grain yield kg/ha	Grain yield bu/ac	Test Wt g/0.5 L	Plump %	Thin %	Groat Yield %
Cultivar								
Stride	184.9 c	4.3 b	4446.1 b	115.6 b	259.1 b	89.9 b	1.8 bc	73.6 c
CDC Dancer	212.0 ab	3.8 b	4165.5 c	108.3 c	268.3 a	91.7 a	1.6 c	82.4 a
Summit	219.6 a	5.2 a	4362.1 b	113.4 b	261.5 ab	91.4 a	1.9 ab	80.2 b
Triactor	199.6 bc	2.8 c	5168.6 a	134.4 a	241.0 c	89.4 b	2.1 a	72.6 d
Nitrogen Rate								
40 kg/ha	218.0 a	4.2 ab	3744.7 d	97.4 d	257.9 a	91.1 a	1.7 a	76.9 b
60 kg/ha	215.1 a	4.6 a	4273.9 c	111.1 c	256.5 a	91.2 a	1.8 a	77.0 b
80 kg/ha	196.8 b	3.8 bc	4686.4 b	121.9 b	262.6 a	90.2 b	2.0 a	77.2 b
120 kg/ha	186.3 b	3.4 c	5437.1 a	141.4 a	252.9 a	89.8 b	1.8 a	77.8 a
Interaction p value	0.0183	0.0008						

Table 5. Yield response and test weight stability of oat to fertilizer N at Melfort in 2015

	Plant Density /m2	Lodging 0-10	Grain yield kg/ha	Grain yield bu/ac	Test Wt g/0.5 L	Plump %	Thin %	Groat Yield %
Cultivar								
Stride	205.3 c	1.1 a	4923.4 d	128.0 d	254.2 a	89.3 C	1.8 a	71.4 c
CDC Minstrel	233.8 ab	1.0 a	5252.5 c	136.6 c	241.1 c	97.8 A	1.1 b	73.0 b
AC Morgan	245.1 a	1.0 a	5831.4 a	151.6 a	246.7 b	95.2 B	0.9 b	70.4 d
CDC Seabiscuit	214.3 bc	1.3 a	5544.2 b	144.2 b	232.1 d	95.3 B	1.5 a	74.0 a
Nitrogen Rate								
40 kg/ha	224.6 a	1.0 b	4549.9 d	118.3 d	246.9 a	95.4 A	1.1 a	71.9 a
60 kg/ha	220.6 a	1.0 b	5111.9 c	132.9 c	245.0 ab	94.7 ab	1.2 a	72.0 a
80 kg/ha	230.7 a	1.0 b	5631.2 b	146.4 b	242.8 b	94.1 B	1.5 a	72.2 a
120 kg/ha	222.5 a	1.4 a	6258.4 a	162.7 a	239.3 c	94.9 ab	1.3 a	72.6 a
Interaction p value		0.051			0.012			

Table 6. Yield response and test weight stability of oat to fertilizer N at Indian Head in 2015

	Plant Density /m2	Lodging 1-10	Grain yield kg/ha	Grain yield bu/ac	Test Wt g/0.5 L	Plump %	Thin %	Groat Yield %
Cultivar								
Stride	201.26 b	1.9 a	3649.6 b	96	254.614 b	87.6 C	1.42 a	72.13 b
CDC Ruffian	213.56 b	1.3 b	4253.19 a	111	248.414 c	96.53 A	0.54 c	74.77 a
CS Camden	209.77 b	1 b	4520.38 a	118	246.309 c	93.84 B	0.86 b	71.94 b
CDC Big Brown	250.47 a	1.3 b	4400.69 a	115	260.498 a	96.94 A	0.86 b	75.12 a
Nitrogen Rate								
40 kg/ha	227.3 a	1.1 a	3651.41 c	96	253.24 a	93.35 A	0.95 a	72.75 b
60 kg/ha	234.58 a	1.4 a	4118.68 b	108	253.991 a	93.08 A	0.96 a	73.17 b
80 kg/ha	219.3 a	1.3 a	4503.69 a	118	252.338 ab	93.94 A	1.01 a	73.94 a
120 kg/ha	193.88 a	1.6 a	4550.08 a	119	250.266 b	94.54 A	0.76 a	74.11 a

Table 7. Yield response and test weight stability of oat to fertilizer N at Redvers in 2015														
	Plant Density /m2		Lodging 1-10		Grain yield kg/ha		Grain yield bu/ac	Test Wt g/0.5 L		Plump %		Thin %		Groat Yield %
Cultivar														
Stride	163	c	1.6	b	4416.6	a	115.7	248.5	a	64.1	b	4.7	b	68.9 c
Leggett	247	b	2	b	4542.3	a	118.9	244.6	b	77.1	a	3.9	b	70.1 ab
Souris	278	a	4.7	a	4490.5	a	117.6	236.0	c	64.2	b	8.6	a	70.7 a
CDC Morrison	261	ab	1.1	c	4602.8	a	120.5	247.5	a	72.3	a	4.0	b	69.5 bc
Nitrogen Rate														
40 kg/ha	231.8	a	1.4	c	4154.4	b	108.8	248.9	a	77.4	a	3.4	b	69.7 a
60 kg/ha	237.8	a	1.7	bc	4466.0	a	116.9	244.6	b	67.2	b	6.0	a	69.4 a
80 kg/ha	238.1	a	2.2	b	4667.6	a	122.2	243.9	b	66.0	b	5.9	a	70.0 a
120 kg/ha	241.4	a	3.3	a	4764.2	a	124.8	239.2	c	67.3	b	5.3	a	70.1 a
Interaction p value			0.006					0.09						

Table 8. Yield response and test weight stability of oat to fertilizer N at Yorkton in 2016										
Description	Plant Density		Lodge		Grain yield		Grain yield		Test Wt	
Rating Unit	/m2		1-10		kg/ha		bu/acre		g/0.5 L	
Cultivar										
Stride	296.6	ab	2.44	b	3738.1	b	97.9	b	257.2	a
CDC Dancer	267.8	b	3.24	a	3179	c	83.2	c	246.4	c
Summit	311.8	a	1.27	c	4032.3	a	105.6	a	252.1	b
Triactor	266.6	b	1.27	c	4027.4	a	105.5	a	240.2	d
Nitrogen Rate (kg/ha)										
40 kg/ha	292.3	a	1.52	b	3426.9	b	89.7	b	254	a
60 kg/ha	309.7	a	1.42	b	3490.7	b	91.4	b	253.4	a
80 kg/ha	281.7	ab	2.23	a	4069.4	a	106.6	a	246.4	b
120 kg/ha	259.1	b	2.83	a	3989.8	a	104.5	a	242.1	c
Interaction p value			0.0284		0.0168		0.0168			

Table 9. Yield response and test weight stability of oat to fertilizer N at Melfort in 2016										
Description	Plant Density		Lodge Belgium (0-5)		Grain yield		Grain yield		Test Wt	
Rating Unit	/m2				kg/ha		bu/acre		g/0.5 L	
Cultivar										
Stride	220.02	ab	3.26	a	7257.65	bc	190	bc	249.98	a
Minstrel	211.61	b	1.36	b	7454.44	ab	195.2	ab	234.45	b
AC Morgan	234.38	a	0.25	c	7638.15	a	200	a	251.08	a
Seabiscuit	207.1	b	2.89	a	7153.18	c	187.3	c	235.96	b
Nitrogen Rate (kg/ha)										
40 kg/ha	217.25	ab	0.54	c	7177.41	b	187.9	b	247.64	a
60 kg/ha	206.08	b	2.02	b	7377.46	ab	193.2	ab	242.81	b
80 kg/ha	234.38	a	1.34	bc	7352.95	ab	192.5	ab	242.98	b
120 kg/ha	215.41	b	3.44	a	7595.59	a	198.9	a	238.03	c
Interaction p value										

Table 10. Yield response and test weight stability of oat to fertilizer N at Indian Head in 2016											
Description	Plant Density		Lodge		Grain yield		Grain yield		Test Wt	
Rating Unit	/m2		1-10		kg/ha		bu/acre		g/0.5 L	
Cultivar										
Stride	245.65	b	3.9	a	4136.2	b	108.3	b	261.386	A
CDC Ruffian	247.6	b	2.8	b	4221.5	b	110.5	b	247.546	D
CS Camden	301.84	a	2.8	b	4262.1	ab	111.6	ab	252.308	C
CDC Big Brown	184.65	c	2.3	c	4426.1	a	115.9	a	256.83	B
Nitrogen Rate (kg/ha)										
40 kg/ha	241.24	a	2.6	b	3460.6	d	90.6	d	254.179	A
60 kg/ha	242.88	a	2.8	b	4058.7	c	106.3	c	255.519	A
80 kg/ha	241.86	a	3.4	a	4436	b	116.2	b	254.542	A
120 kg/ha	253.75	a	3	b	5090.8	a	133.3	a	253.83	A

Table 11. Yield response and test weight stability of oat to fertilizer N at Redvers in 2016										
Description	Plant Density		Lodge		Grain yield		Grain yield		Test Wt	
Rating Unit	/m2		(1-10)		kg/ha		bu/acre		g/0.5 L	
Cultivar										
Stride	216.64	a	4.94	b	5848.8	b	153.2	b	245.83	a
Justice	204.33	a	6.56	a	6459	a	169.1	a	249.61	a
Souris	212.43	a	5.31	b	6266	a	164.1	a	238.72	b
CDC Morrison	222.07	a	2	c	5178.9	c	135.6	c	232.39	c
Nitrogen Rate (kg/ha)										
40 kg/ha	218.69	a	3.66	c	5589.3	b	146.4	b	246.33	a
60 kg/ha	211.82	a	4.5	b	5987.5	a	156.8	a	243.21	ab
80 kg/ha	211.82	a	5.16	ab	6051.9	a	158.5	a	239.13	bc
120 kg/ha	213.15	a	5.5	a	6124	a	160.4	a	237.88	c
Interaction p value					0.0478		0.0478		0.0106	

Appendix 1: N rate – Cultivar Interactions

Table A1: N rate and cultivar interactions on Oat Yield at Yorkton in 2014

Description		Plant Density		Lodging		Yield		Test Wt		Wild Oat		Plump Seed		Thin Seed		Groat Yield	
Rating Unit		/m2		1-10		Kg/ha		g/0.5L		g/50g		%		%		%	
Cultivar	N Rate																
CDC Dancer	40 kg/ha	252.95	a	5.3	b	6244.1	bc	258.40	de	0.00	a	96	abc	0.7	c	75.7	ab
CDC Dancer	60 kg/ha	277.56	a	4.0	bc	6387.4	bc	261.09	cde	0.04	a	96	abc	0.6	c	75.8	ab
CDC Dancer	80 kg/ha	275.84	a	5.3	b	6565.7	bc	257.37	e	0.00	a	96	bc	0.5	c	76.3	a
CDC Dancer	120 kg/ha	279.28	a	8.0	a	6853.3	b	251.07	f	0.00	a	95	c	0.9	bc	74.7	b
Stride	40 kg/ha	283.46	a	3.3	bc	5027.0	d	268.87	a	0.00	a	97	a	0.4	c	73.2	cd
Stride	60 kg/ha	274.11	a	4.3	bc	5908.1	c	266.60	ab	0.00	a	96	abc	0.5	c	73.1	d
Stride	80 kg/ha	275.84	a	4.0	bc	6238.0	bc	265.15	abc	0.00	a	96	bc	0.6	c	72.3	d
Stride	120 kg/ha	257.38	a	5.3	b	6670.3	bc	263.35	bcd	0.00	a	95	bc	0.5	c	72.9	d
Summit	40 kg/ha	285.19	a	2.5	c	5301.4	d	263.67	bcd	0.01	a	97	ab	0.4	c	74.3	bc
Summit	60 kg/ha	266.49	a	2.3	c	5956.1	c	261.18	cde	0.01	a	96	abc	0.6	c	74.4	bc
Summit	80 kg/ha	274.11	a	3.0	bc	6702.1	bc	260.97	cde	0.00	a	96	abc	0.7	c	74.5	b
Summit	120 kg/ha	250.25	a	2.8	bc	6819.5	b	257.46	e	0.00	a	96	abc	0.7	c	74.9	b
Triactor	40 kg/ha	252.46	a	3.0	bc	6393.7	bc	245.72	g	0.00	a	96	abc	0.8	bc	72.3	d
Triactor	60 kg/ha	254.68	a	3.3	bc	6987.5	b	241.57	gh	0.01	a	95	bc	1.5	a	72.3	d
Triactor	80 kg/ha	249.51	a	2.5	c	7062.2	b	242.94	gh	0.00	a	95	c	1.3	ab	72.5	d
Triactor	120 kg/ha	258.37	a	3.0	bc	7753.6	a	239.26	h	0.00	a	95	c	1.7	a	72.6	d
LSD P=.05		34.02		1.50		534.98		3.653		0.030		1.0		0.4		0.98	
CV		8.92		27.34		5.82		1.0		0.69		0.71		36.66		0.92	
Treatment Prob(F)		0.3481		0.0001		0.0001		0.0001		0.5521		0.0001		0.0001		0.0001	

Table A2: N rate and cultivar interaction on Oat Yield at Melfort in 2014

Description		Plant Density		Lodge Belgian		Grain Yield		Grain Yield		Test Wt		Plump		Thin		TKW	
Rating Unit		/m2		0-5		Kg/ha		Bu/ac		g/0.5L		%		%		g/1000g	
Cultivar	N Rate																
AC Morgan	40 kg/ha	292	a	0	b	7100.5	b-e	185.9	b-e	280.0	abc	90.4	abc	1.31	bc	36.9	cde
AC Morgan	60 kg/ha	298	a	0	b	7204.3	bcd	188.7	bcd	277.0	abc	90.7	abc	1.26	bc	37.9	bc
AC Morgan	80 kg/ha	291	a	0	b	7654.3	ab	200.4	ab	269.8	abc	89.7	abc	1.05	c	37.2	cde
AC Morgan	120 kg/ha	301	a	0	b	8027.3	a	210.2	a	268.6	abc	90.1	abc	1.19	bc	37.5	cd
CDC Minstrel	40 kg/ha	317	a	0	b	6404.0	f	167.7	f	282.0	a	91.9	a	2.23	abc	37.0	cde
CDC Minstrel	60 kg/ha	342	a	0	b	6713.3	c-f	175.8	c-f	279.4	a	90.2	abc	2.99	a	37.0	cde
CDC Minstrel	80 kg/ha	340	a	0	b	7024.0	c-f	183.9	c-f	266.2	a	90.5	abc	2.36	abc	35.0	e
CDC Minstrel	120 kg/ha	314	a	0	b	7357.0	bc	192.7	bc	264.0	a	89.0	abc	1.9	abc	35.5	de
CDC Seabiscuit	40 kg/ha	297	a	0.2	ab	6443.8	ef	168.7	ef	262.1	bc	91.6	ab	1.37	bc	40.7	a
CDC Seabiscuit	60 kg/ha	256	a	0.2	ab	6653.8	def	174.2	def	270.1	abc	90.7	abc	1.71	abc	39.9	a
CDC Seabiscuit	80 kg/ha	280	a	0.2	ab	6995.8	c-f	183.2	c-f	260.6	c	90.3	abc	1.53	bc	39.5	ab
CDC Seabiscuit	120 kg/ha	276.8	a	0.6	ab	7183.3	bcd	188.1	bcd	266.8	abc	89.3	abc	1.83	abc	37.8	bc
Stride	40 kg/ha	272	a	0	b	6353.8	f	166.4	f	285.0	a	88.9	abc	2.43	ab	32.8	f
Stride	60 kg/ha	277	a	0	b	6831.0	c-f	178.9	c-f	280.2	abc	90.9	ab	1.79	abc	32.9	f
Stride	80 kg/ha	309	a	0	b	6741.8	c-f	176.5	c-f	284.4	ab	86.1	c	2.53	ab	32.4	f
Stride	120 kg/ha	280	a	0.8	a	6930.8	c-f	181.5	c-f	281.9	abc	87.0	bc	2.40	abc	32.8	f
LSD P=.05		49.77		0.444		417.7		10.9		12.7		2.7		0.78		1.5	
CV		11.74		248.3		4.19		4.19		3.25		2.09		29.38		2.84	
Treatment Prob(F)		0.0577		0.0117		0.0001		0.0001		0.0032		0.0056		0.0001		0.0001	

Table A3: N rate and cultivar interactions on Oat Yield at Indian Head in 2014

Description		Plant Density		Lodge		Grain Yield		Test Wt		Wild Oat		Plump Seed		Thin Seed		Groat Yield	
Rating Unit		/m2		1-10		Kg/ha		g/0.5L		g/50g		%		%		%	
Cultivar	N Rate																
CDC Big Brown	40 kg/ha	243.60	a	2.3	f	3330.3	b	268.3	ab	0.19	a	93	a	2.2	bc	75.2	a
CDC Big Brown	60 kg/ha	233.76	a	5.5	b-f	4165.0	ab	262.8	abc	0.29	a	92	a	2.2	bc	72.5	b
CDC Big Brown	80 kg/ha	228.84	a	7.3	a-d	4486.8	ab	260.7	a-d	0.11	a	92	a	2.3	bc	72.3	bc
CDC Big Brown	120 kg/ha	209.56	a	8.0	abc	4172.8	ab	250.3	de	0.13	a	87	ab	3.6	a	70.8	b-f
CDC Orrin	40 kg/ha	237.04	a	5.0	c-f	3355.2	b	261.1	abc	0.34	a	94	a	1.2	cd	70.2	c-f
CDC Orrin	60 kg/ha	229.25	a	5.5	b-f	4224.8	ab	260.3	a-d	0.16	a	95	a	0.9	cd	69.9	def
CDC Orrin	80 kg/ha	225.15	a	6.8	a-e	4133.9	ab	256.0	cde	0.20	a	93	a	1.5	cd	70.1	c-f
CDC Orrin	120 kg/ha	223.51	a	9.0	ab	4787.5	a	246.9	e	0.04	a	92	a	2.0	bcd	69.0	f
Pinnacle	40 kg/ha	210.79	a	3.5	ef	3614.8	ab	258.8	a-d	0.10	a	94	a	0.9	cd	72.1	bcd
Pinnacle	60 kg/ha	218.59	a	5.5	b-f	4440.1	ab	253.3	cde	0.08	a	95	a	0.7	d	71.5	b-e
Pinnacle	80 kg/ha	232.94	a	7.5	a-d	3808.8	ab	247.9	e	0.49	a	92	a	1.2	cd	69.5	ef
Pinnacle	120 kg/ha	225.15	a	10.0	a	4251.3	ab	233.2	f	0.16	a	89	a	2.0	bcd	69.0	f
Stride	40 kg/ha	222.69	a	4.3	def	3405.4	b	269.1	a	0.15	a	87	ab	1.6	cd	71.2	b-f
Stride	60 kg/ha	241.96	a	6.8	a-e	3749.1	ab	267.8	ab	0.08	a	81	b	2.0	bcd	71.0	b-f
Stride	80 kg/ha	248.93	a	8.0	abc	3777.7	ab	257.9	bcd	0.22	a	81	b	2.3	bc	70.2	c-f
Stride	120 kg/ha	251.39	a	8.3	abc	3974.9	ab	252.8	cde	0.31	a	72	c	3.0	ab	69.4	ef
LSD P=.05		13.9		2.2		760.3		6.6		1.61		5		0.8		1.4	
CV		9.81		23.46		13.37		1.81		46.96		4.0		31.89		1.37	
Prob(F)		0.3123		0.0001		0.0070		0.0001		0.0818		0.0001		0.0001		0.0001	

Table A4: N rate and cultivar interactions on Oat Yield at Yorkton in 2015

Description		Plant Density		Lodging		Yield		Yield		Test Wt		Plump Seed		Thin Seed		Groat Yield	
Rating Unit		/m2		1-10		Kg/ha		Bu/ac		g/0.5L		%		%		%	
Cultivar	N Rate																
CDC Dancer	40 kg/ha	214.0	bcd	4.5	b-e	3484.5	h	90.6	h	262.7	b	92.8	a	1.7	b-e	82.1	ab
CDC Dancer	60 kg/ha	229.8	abc	4.9	a-d	4021.6	fg	104.6	fg	264.7	b	92.4	ab	1.6	de	82.5	a
CDC Dancer	80 kg/ha	210.3	b-e	3.5	efg	4254.1	ef	110.6	ef	286.1	a	91.6	abc	1.5	de	82.8	a
CDC Dancer	120 kg/ha	194.0	d-g	2.4	gh	4901.9	c	127.5	c	259.8	bc	89.8	de	1.5	e	82.2	ab
Stride	40 kg/ha	200.3	c-f	4.9	a-d	3763.2	gh	97.8	gh	262.3	b	90.4	cde	1.6	b-e	73.5	ef
Stride	60 kg/ha	193.0	d-g	5.1	abc	4204.3	ef	109.3	ef	259.2	bc	90.1	cde	1.7	a-e	73.5	ef
Stride	80 kg/ha	175.8	fg	3.5	efg	4527.3	de	117.7	de	259.5	bc	89.1	e	2.2	a	73.2	fg
Stride	120 kg/ha	170.8	fg	3.6	d-g	5289.5	b	137.5	b	255.6	bcd	89.8	de	1.6	b-e	74.4	e
Summit	40 kg/ha	247.5	a	5.8	ab	3473.4	h	90.3	h	264.6	b	92.3	ab	1.6	cde	80.0	d
Summit	60 kg/ha	238.5	ab	6.0	a	4091.7	fg	106.4	fg	260.8	bc	92.0	ab	1.9	a-e	79.7	d
Summit	80 kg/ha	182.0	efg	5.1	abc	4473.7	de	116.3	de	261.9	b	90.9	bcd	2.0	a-e	80.0	cd
Summit	120 kg/ha	210.5	b-e	3.8	def	5409.5	b	140.7	b	258.7	bc	90.3	cde	2.0	a-e	81.2	bc
Triactor	40 kg/ha	210.1	b-e	1.7	h	4257.6	ef	110.7	ef	242.2	cde	89.1	e	2.0	a-d	72.2	g
Triactor	60 kg/ha	199.3	d-g	2.4	gh	4778.3	cd	124.2	cd	241.2	de	90.1	cde	2.1	ab	72.2	g
Triactor	80 kg/ha	219.0	a-d	3.1	fgh	5490.7	b	142.8	b	243.0	cde	89.2	e	2.2	a	72.7	fg
Triactor	120 kg/ha	170.0	g	3.9	c-f	6147.7	a	159.8	a	237.6	e	89.2	e	2.1	abc	73.5	ef
LSD P=.05		29.88		1.358		354.772		9.224		17.2365		1.558		0.503		1.15	
CV		10.44		23.82		5.57		5.57		4.77		1.23		19.67		1.06	
Treatment Prob(F)		0.0001		0.0001		0.0001		0.0001		0.0002		0.0001		0.03		0.0001	

Table A5: N rate and cultivar interaction on Oat Yield at Melfort in 2015																	
Description		Plant Density		Lodge Belgian		Grain Yield		Grain Yield		Test Wt		Plump		Thin		Groat Yield	
Rating Unit		/m2		0-5		Kg/ha		Bu/ac		g/0.5L		%		%		%	
Cultivar	N Rate																
AC Morgan	40 kg/ha	245.8	a	1.0	c	5007.9	fg	130.2	fg	248.2	c	95.3	bc	0.8	fg	70.2	e
AC Morgan	60 kg/ha	243.8	a	1.0	c	5591.8	de	145.4	de	247.2	cd	95.0	bc	0.7	g	70.3	e
AC Morgan	80 kg/ha	251.3	a	1.0	c	6107.5	bc	158.8	bc	246.9	cde	94.8	bc	1.0	d-g	70.4	e
AC Morgan	120 kg/ha	239.5	a	1.0	c	6618.4	a	172.1	a	244.4	cde	95.8	bc	0.9	efg	70.6	de
CDC Minstrel	40 kg/ha	235.8	a	1.0	c	4520.7	h	117.5	h	244.1	cde	98.0	a	1.0	d-g	72.3	bc
CDC Minstrel	60 kg/ha	215.0	a	1.0	c	4760.9	gh	123.8	gh	241.3	ef	97.5	a	1.2	c-g	72.3	bc
CDC Minstrel	80 kg/ha	255.0	a	1.0	c	5556.2	de	144.5	de	237.0	fg	97.4	a	1.4	a-e	73.2	ab
CDC Minstrel	120 kg/ha	229.5	a	1.0	c	6172.3	abc	160.5	abc	241.9	def	98.4	a	0.7	g	74.0	a
CDC Seabiscuit	40 kg/ha	199.5	a	1.0	c	4666.8	gh	121.3	gh	237.9	fg	96.0	b	1.2	c-g	73.8	a
CDC Seabiscuit	60 kg/ha	212.0	a	1.0	c	5467.9	def	142.2	def	236.4	fg	95.9	bc	1.3	b-f	74.2	a
CDC Seabiscuit	80 kg/ha	220.3	a	1.0	c	5614.1	de	146.0	de	232.3	g	94.3	c	1.9	a	73.9	a
CDC Seabiscuit	120 kg/ha	225.3	a	2.0	a	6427.9	ab	167.1	ab	221.8	h	95.0	bc	1.8	abc	74.1	a
Stride	40 kg/ha	217.5	a	1.0	c	4004.3	i	104.1	i	257.5	a	91.5	d	1.5	a-d	71.2	cde
Stride	60 kg/ha	211.5	a	1.0	c	4627.1	gh	120.3	gh	255.0	ab	88.7	e	1.9	ab	71.2	cde
Stride	80 kg/ha	196.3	a	1.0	c	5247.2	ef	136.4	ef	254.9	ab	88.4	e	1.8	ab	71.4	cde
Stride	120 kg/ha	195.8	a	1.5	b	5814.9	cd	151.2	cd	249.3	bc	88.2	e	1.9	ab	71.7	cd
LSD P=.05		47.0		0.5		470.0		12.2		5.8						1.3	
CV		14.7		30.3		6.1		6.1		1.7		1.99t		21.85t		1.3	
Treatment Prob(F)		0.2063		0.0052		0.0001		0.0001		0.0001		0.0001		0.0001		0.0001	

Table A6: N rate and cultivar interactions on Oat Yield at Indian Head in 2015															
Description		Plant Density		Lodge		Grain Yield		Test Wt		Plump Seed		Thin Seed		Groat Yield	
Rating Unit		/m2		1-10		Kg/ha		g/0.5L		%		%		%	
Cultivar	N Rate														
CDC Big Brown	40 kg/ha	244.0	a	1.3	b	3796.6	e-h	259.7	ab	95.7	abc	1.1	a-d	74.4	b
CDC Big Brown	60 kg/ha	255.1	a	1.0	b	4639.3	ab	261.9	a	97.2	ab	0.7	c-f	75.1	ab
CDC Big Brown	80 kg/ha	261.2	a	1.5	b	4891.4	ab	259.5	ab	97.2	ab	1.1	a-e	75.7	a
CDC Big Brown	120 kg/ha	241.6	a	1.5	b	4275.4	b-f	260.9	ab	97.8	a	0.5	ef	75.3	ab
CDC Ruffian	40 kg/ha	234.2	ab	1.0	b	3904.8	d-g	248.7	def	95.8	abc	0.6	c-f	74.4	b
CDC Ruffian	60 kg/ha	239.1	a	1.5	b	4006.9	c-f	249.5	def	96.8	ab	0.5	def	74.5	b
CDC Ruffian	80 kg/ha	223.1	abc	1.3	b	4620.4	abc	250.8	de	96.5	ab	0.6	def	75.3	ab
CDC Ruffian	120 kg/ha	157.9	d	1.3	b	4480.7	bcd	244.7	fg	97.0	ab	0.4	f	75.0	ab
CS Camden	40 kg/ha	202.6	a-d	1.0	b	3695.5	fgh	248.3	d-g	95.0	abc	0.7	c-f	70.9	f
CS Camden	60 kg/ha	207.9	a-d	1.0	b	4498.0	a-d	247.6	d-g	92.9	cd	1.0	b-f	71.7	def
CS Camden	80 kg/ha	220.2	a-d	1.0	b	4770.8	ab	246.1	efg	93.7	bc	0.9	b-f	72.2	cde
CS Camden	120 kg/ha	208.3	a-d	1.0	b	5117.2	a	243.2	g	93.7	bc	0.9	b-f	73.0	c
Stride	40 kg/ha	228.4	abc	1.3	b	3208.7	h	256.3	bc	87.0	ef	1.4	ab	71.4	ef
Stride	60 kg/ha	236.2	a	2.3	a	3330.5	gh	257.0	abc	85.4	f	1.6	a	71.4	ef
Stride	80 kg/ha	172.7	bcd	1.5	b	3732.2	e-h	252.9	cd	88.3	ef	1.5	ab	72.6	cd
Stride	120 kg/ha	167.7	cd	2.5	a	4327.0	b-e	252.3	cd	89.6	de	1.2	abc	73.2	c
LSD P=.05		62.6		0.7		629.7		5.4		3.6		0.6		1.0	
CV		20.1		37.7		10.5		1.5		2.7		47.5		1.0	
Prob(F)		0.0406		0.002		0.0001		0.0001		0.0001		0.004		0.0001	

Table A7: N rate and cultivar interactions on Oat Yield at Redvers in 2015

Description		Plant Density		Lodge		Grain Yield		Test Wt		Plump Seed		Thin Seed		Groat Yield	
Rating Unit		/m2		1-10		Kg/ha		g/0.5L		%		%		%	
Cultivar	N Rate														
CDC Morrison	40 kg/ha	249.5	abc	1.0	e	4177.1	bc	250.8	abc	74.9	abc	3.8	bcd	69.3	a-d
CDC Morrison	60 kg/ha	258.4	abc	1.0	e	4407.5	bc	246.9	bcd	68.6	a-e	5.0	bcd	68.5	cd
CDC Morrison	80 kg/ha	283.5	ab	1.0	e	4771.7	ab	247.5	bcd	71.0	a-d	4.0	bcd	69.9	abc
CDC Morrison	120 kg/ha	253.9	abc	1.2	e	5054.8	a	244.8	de	74.8	abc	3.3	cd	70.3	ab
Leggett	40 kg/ha	241.6	bc	1.4	de	4119.3	c	251.8	ab	82.4	a	2.5	d	70.0	abc
Leggett	60 kg/ha	245.1	abc	1.4	de	4458.7	abc	245.3	cd	74.7	abc	4.5	bcd	69.3	a-d
Leggett	80 kg/ha	228.3	c	1.6	de	4535.1	abc	243.3	def	72.8	a-d	5.2	bc	69.8	abc
Leggett	120 kg/ha	273.1	ab	3.9	b	5056.1	a	238.2	fg	78.6	ab	3.6	bcd	71.1	a
Souris	40 kg/ha	280.0	ab	2.3	cd	4227.2	bc	239.0	fg	77.9	ab	4.3	bcd	70.3	abc
Souris	60 kg/ha	285.4	a	4.6	ab	4579.6	abc	234.2	g	60.9	cde	11.1	a	70.5	ab
Souris	80 kg/ha	266.2	abc	7.1	a	4632.4	abc	236.2	g	58.6	de	11.0	a	71.0	a
Souris	120 kg/ha	280.5	ab	5.8	ab	4522.9	abc	234.5	g	59.5	de	9.9	a	70.9	ab
Stride	40 kg/ha	156.0	d	1.0	e	4094.1	c	254.2	a	74.3	abc	3.1	cd	69.1	bcd
Stride	60 kg/ha	162.4	d	1.0	e	4418.4	bc	251.8	ab	64.4	b-e	4.8	bcd	69.4	a-d
Stride	80 kg/ha	174.2	d	1.4	de	4731.1	ab	248.6	a-d	61.6	cde	4.9	bcd	69.3	a-d
Stride	120 kg/ha	158.0	d	3.8	bc	4422.9	bc	239.3	efg	56.1	e	6.6	ab	67.9	d
LSD P=.05															
CV															
Prob(F)															

Table A8. Yield response and test weight stability of oat to fertilizer N at Yorkton in 2016

		Plant Density /m2		Lodge 1-10		Grain yield kg/ha		Grain yield bu/acre		Test Wt g/0.5 L	
Treatment											
Stride	40	300.7	a-d	1.34	de	3460.9	e-h	90.6	e-h	262.6	a
Stride	60	308.6	abc	1.36	cde	3661	def	95.9	def	263.1	a
Stride	80	283.5	b-f	3.9	ab	4068	bcd	106.5	bcd	253.7	bc
Stride	120	293.8	b-e	4.15	a	3762.6	cde	98.5	cde	249.4	bcd
CDC Dancer	40	244.6	def	2.23	cd	2982.8	h	78.1	h	253.9	b
CDC Dancer	60	277.1	b-f	2.43	bc	3141.5	gh	82.3	gh	252.2	bcd
CDC Dancer	80	302.2	a-d	3.94	ab	3457.9	e-h	90.5	e-h	241.1	efg
CDC Dancer	120	247.5	c-f	4.92	a	3133.9	gh	82.1	gh	238.4	fg
Summit	40	317.9	ab	1.51	cde	3755.6	c-f	98.3	c-f	255.1	b
Summit	60	358.3	a	1	e	3257.5	fgh	85.3	fgh	256.6	ab
Summit	80	305.1	a-d	1.11	e	4530.8	ab	118.6	ab	250.5	bcd
Summit	120	265.7	b-f	1.5	cde	4585.3	a	120.1	a	246.4	cde
Triactor	40	306.1	a-d	1.11	e	3508.4	efg	91.9	efg	244.5	def
Triactor	60	294.8	a-e	1.11	e	3902.7	cde	102.2	cde	241.6	ef
Triactor	80	236.2	ef	1.11	e	4221.1	abc	110.5	abc	240.3	efg
Triactor	120	229.3	f	1.82	cde	4477.1	ab	117.2	ab	234.2	g
LSD P=.05		63.52		0.917 - 1.861		499.4		13.08		7.32	
CV		15.61		24.54t		9.39		9.39		2.06	
Treatment Prob(F)		0.0139		0.0001		0.0001		0.0001		0.0001	

Table A9. Yield response and test weight stability of oat to fertilizer N at Melfort in 2016

		Plant Density /m2		Lodge 1-10		Grain yield kg/ha		Grain yield bu/acre		Test Wt g/0.5 L	
Treatment											
Stride	40	208.74	bc	1.1	cde	7077	cd	185.3	cd	257.18	a
Stride	60	224.33	bc	4.94	ab	7624.58	abc	199.7	abc	248.95	b
Stride	80	224.74	bc	3.19	bc	7069.5	cd	185.1	cd	253.8	ab
Stride	120	222.28	bc	4.63	ab	7259.51	bcd	190.1	bcd	239.98	cd
Minstrel	40	211.2	bc	0.2	e	7351.53	a-d	192.5	a-d	237.68	cde
Minstrel	60	204.23	bc	1.21	cde	7305.06	bcd	191.3	bcd	233.5	def
Minstrel	80	216.13	bc	0.9	cde	7351.42	a-d	192.5	a-d	233.58	def
Minstrel	120	214.9	bc	4.64	ab	7809.73	ab	204.5	ab	233.05	ef
AC Morgan	40	241.14	ab	0.2	e	7374.62	a-d	193.1	a-d	255	ab
AC Morgan	60	198.08	c	0.43	de	7476.87	a-d	195.8	a-d	250.3	b
AC Morgan	80	268.62	a	0.2	e	7810	ab	204.5	ab	250.93	ab
AC Morgan	120	229.66	bc	0.2	e	7891.12	a	206.6	a	248.09	b
Seabiscuit	40	207.92	bc	1.01	cde	6906.5	d	180.9	d	240.7	c
Seabiscuit	60	197.67	c	2.9	bc	7103.35	cd	186	cd	238.5	cde
Seabiscuit	80	228.02	bc	2.06	bcd	7180.87	cd	188	cd	233.63	def
Seabiscuit	120	194.8	c	6.97	a	7421.99	a-d	194.4	a-d	231	f
LSD P=.05		37.155		1.477 - 3.693		572.99		15		6.509	
CV		11.95		46.08t		5.45		5.45		1.88	
Treatment Prob(F)		0.0328		0.0001		0.0312		0.0312		0.0001	

Table A10. Yield response and test weight stability of oat to fertilizer N at Indian Head in 2016

		Plant Density /m2		Lodge 1-10		Grain yield kg/ha		Grain yield bu/acre		Test Wt g/0.5 L	
Treatment											
Stride	40	234	c	3.8	ab	3309	i	86.6	i	263	a
Stride	60	250	c	4	ab	3869	fgh	101.3	fgh	262	a
Stride	80	239	c	4.3	a	4325	de	113.3	de	263	a
Stride	120	260	bc	3.8	ab	5042	ab	132	ab	258	a-d
CDC Ruffian	40	253	c	2.5	de	3523	hi	92.3	hi	246	fg
CDC Ruffian	60	242	c	2.5	de	4088	ef	107.1	ef	250	d-g
CDC Ruffian	80	244	c	3.5	abc	4428	de	115.9	de	248	efg
CDC Ruffian	120	251	c	2.8	cde	4847	bc	126.9	bc	245	g
CS Camden	40	304	a	2	e	3349	i	87.7	i	252	b-g
CS Camden	60	287	ab	2.8	cde	4060	efg	106.3	efg	250	c-g
CS Camden	80	303	a	3.3	bcd	4381	de	114.7	de	249	efg
CS Camden	120	313	a	3.3	bcd	5259	a	137.7	a	259	abc
CDC Big Brown	40	174	d	2.3	e	3662	ghi	95.9	ghi	256	a-e
CDC Big Brown	60	193	d	2	e	4218	def	110.4	def	259	ab
CDC Big Brown	80	181	d	2.8	cde	4610	cd	120.7	cd	259	a-d
CDC Big Brown	120	191	d	2.3	e	5215	ab	136.6	ab	254	b-f
LSD P=.05		29.835		0.77		399.97		10.47		8.4014	
CV		8.55		18.23		6.59		6.59		2.32	
Treatment Prob(F)		0.0001		0.0001		0.0001		0.0001		0.0001	

Table A11. Yield response and test weight stability of oat to fertilizer N at Redvers in 2016

		Plant Density /m2		Lodge 1-10		Grain yield kg/ha		Grain yield bu/acre		Test Wt g/0.5 L	
Treatment											
Stride	40	223.51	a	3.75	e	5453.3	fg	142.8	fg	256.6	a
Stride	60	214.07	a	4.5	de	6045.6	cde	158.3	cde	249.73	abc
Stride	80	218.59	a	5.25	cde	6252.1	bcd	163.7	bcd	243.9	bcd
Stride	120	210.38	a	6.25	abc	5644.1	efg	147.8	efg	233.08	efg
Justice	40	202.18	a	5.13	cde	6224.1	bcd	163	bcd	252.68	ab
Justice	60	221.46	a	6	bcd	6513.2	abc	170.6	abc	249.45	abc
Justice	80	187.01	a	7.63	a	6185.6	bcd	162	bcd	248.75	abc
Justice	120	206.69	a	7.5	ab	6913.1	a	181	a	247.55	bc
Souris	40	219.82	a	3.75	e	5823.1	def	152.5	def	243.65	cd
Souris	60	210.79	a	5.5	cd	6235.9	bcd	163.3	bcd	241.55	cde
Souris	80	223.92	a	5.75	cd	6557.9	ab	171.7	ab	236.05	d-g
Souris	120	195.21	a	6.25	abc	6447	abc	168.8	abc	233.63	efg
CDC Morrison	40	229.25	a	2	f	4856.6	h	127.2	h	232.4	fg
CDC Morrison	60	200.95	a	2	f	5155.1	gh	135	gh	232.1	fg
CDC Morrison	80	217.77	a	2	f	5212	gh	136.5	gh	227.8	g
CDC Morrison	120	240.32	a	2	f	5491.8	fg	143.8	fg	237.25	def
LSD P=.05		32.065		1.533		493.04		12.91		8.829	
CV		10.53		22.88		5.83		5.83		2.57	
Treatment Prob(F)		0.1777		0.0001		0.0001		0.0001		0.0001	

Winter Cereal Variety Trial 2018

Mike Hall[1] and Heather Sorestad[1]

[1]East Central Research Foundation, Yorkton, SK.

Abstract/Summary:

A trial was conducted near Yorkton Saskatchewan in 2018 to evaluate currently available winter wheat and hybrid fall rye varieties. The trial was designed as a randomized complete block design with four replications. The winter cereal establishment was poor in the fall resulting in poor levels of winter survival. Winter survival for winter wheat ranged from 30 to 50% whereas hybrid fall rye ranged from 60 to 74%. However, yields were still decent with yields averaging 3979 kg/ha and 3519 kg/ha for winter wheat and hybrid fall rye, respectively. The yield of hybrid fall rye was also greatly reduced by very high levels of ergot. Wildfire was the highest yielding winter wheat variety and CDC Chase and Flourish were the lowest. Between hybrid fall rye varieties, Brasetto was significantly lower yielding than Bono or Gatano. The results from this trial should be "taken with a grain of salt" because the yields were also greatly affected by glyphosate drift from the neighboring farmer.

Objectives and Rationale

Project Objectives:

To demonstrate the adaptation of new winter cereal varieties in East central Saskatchewan.

Project Rationale:

Producing winter cereals can help spread out the work load for producers. Winter kill can be an issue for winter wheat, but fall rye is more resistant. Producers need to be aware of the yield performance of currently available varieties of winter wheat and fall rye.

Methodology and Results

Methodology:

The trial was setup as a randomized complete block design with four replications. Plots were 11 by 30 ft. Seeding took place with a 10ft SeedMaster drill on 12 inch wide row spacing. At seeding monoammonium phosphate (MAP) was applied at 49lb/ac and urea at 163 lb/ac. Another 54lb/ac of urea was broadcasted the following spring in 2018. The middle 4 rows by 30ft were harvested with a Wintersteiger plot combine from each plot to minimize edge effects. Treatments are listed in Table 1 and dates of operations are listed in Table 2.

Table 1. Treatment List for Winter Cereal Variety Trial

Variety	**Seeding Rate (lb/ac)**
1. Moats – winter wheat	91
2. Elevate – winter wheat	137
3. Gold Rush – winter wheat	88
4. CDC Chase – winter wheat	104
5. Flourish – winter wheat	130
6. Emerson – winter wheat	93
7. Pintail – winter wheat	103
8. Gateway – winter wheat	111
9. Buteo – winter wheat	114
10. Wildfire – winter wheat	103
11. Brasetto - hybrid fall rye	62
12. Bono - hybrid fall rye	63
13. Gatano - hybrid fall rye	61

Table 2. Dates of operations in 2018 for the Winter Cereal Variety Trial 2018

Operations in 2018	Yorkton
Seeded winter Cereals	September 28
Broadcasted 0.57 lb/plot of urea	May 8
In-crop herbicide: Prestige	May 29
Harvested	Aug 29

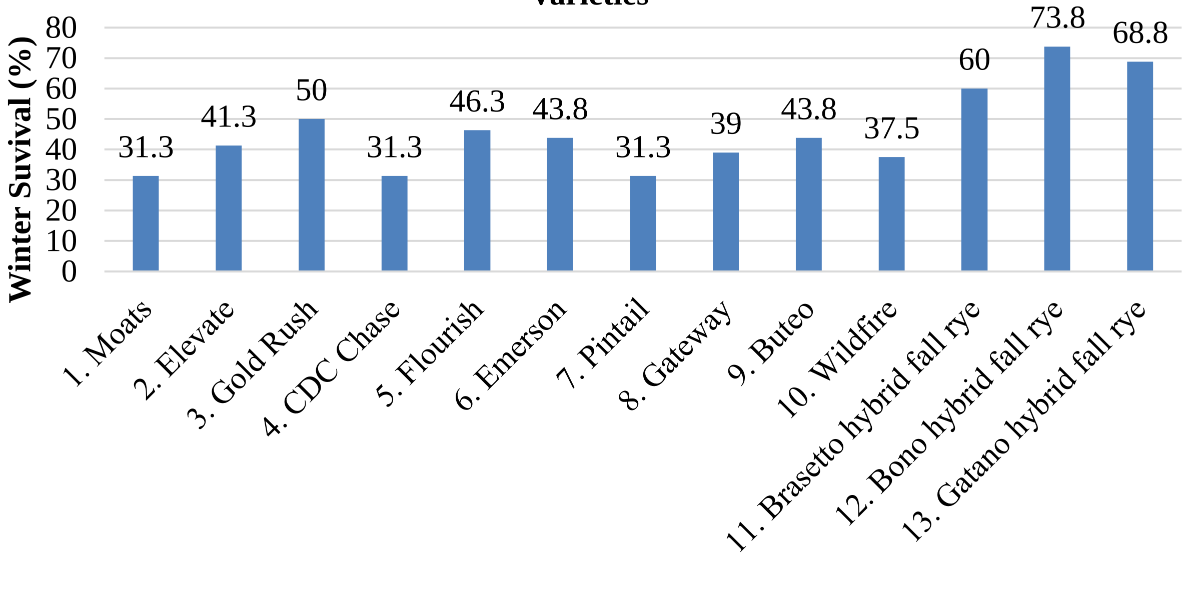
Results:

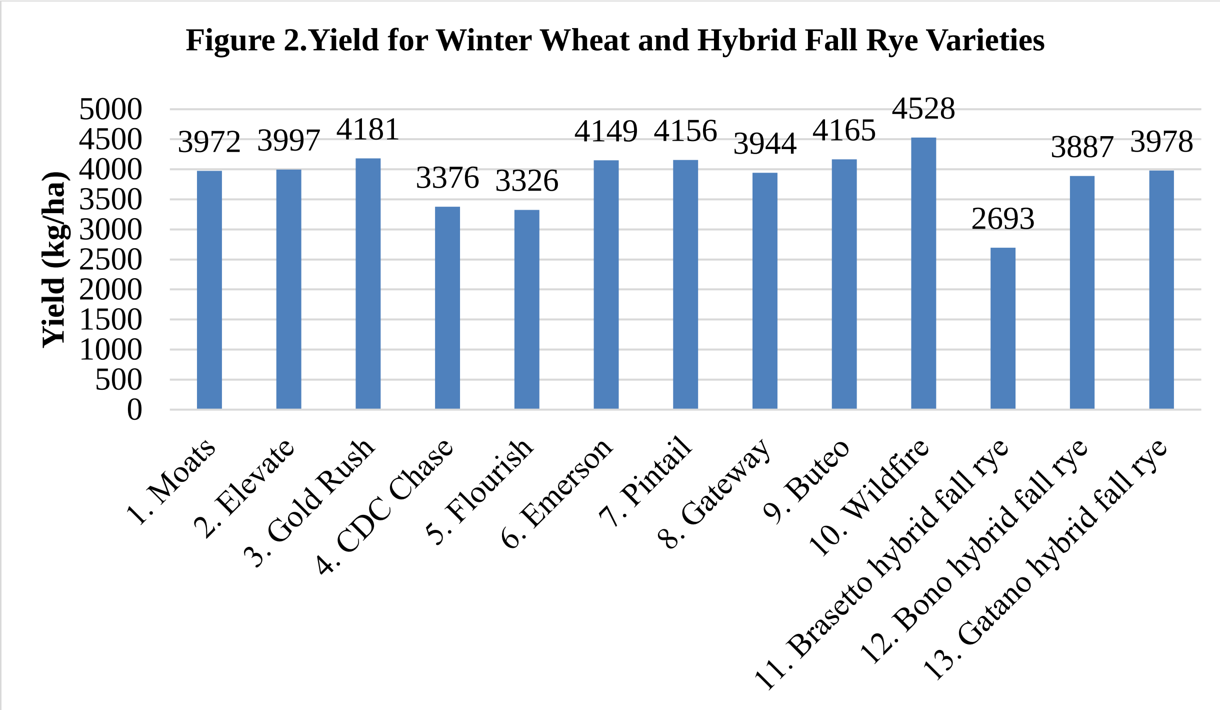
The fall of 2017 was fairly dry resulting in less than ideal conditions for germination. The winter cereals did eventually germinate and emerge, but winter wheat only partially developed a second leaf and fall rye only had two fully emerged leaves going into the winter. The less than ideal stages of growth in fall impacted winter survival. In the spring, only 30 to 50% of the winter wheat and 60 to 74% of the hybrid fall rye survived the winter (Figure 1 and Table 3). Although the winter survival ratings were relatively poor, yields were still better than expected as winter cereals were able to compensate for thin stands by tillering

The average yield for winter wheat was 3979 kg/ha and 3519 kg/ha for hybrid fall rye. While yields were decent, it should be noted that yield from neighbouring spring wheat trials were more than 30% higher yielding. The yield potential of the winter cereals were affected by poor winter survival, glyphosate drift from a neighbouring producer and in the case for hybrid fall rye, very high levels of ergot. While not significantly different, Wildfire had one of the worst winter survival ratings, yet it yielded 13% higher than the average winter wheat yield (Table 3, Figures 1 and 2). CDC Chase and Flourish were the poorest yielding varieties, yielding 15 - 16% less than the average winter wheat variety. CDC Chase had a relatively poor winter survival which may account for the poor yield. Flourish had a relatively good rating but was still poor yielding. Between the hybrid fall rye varieties, Brasetto was significantly lower yielding (24%). The winter survival was also somewhat lower for Brasetto.

Lodging was recorded and although Buteo had significantly more lodging compared to other varieties, the lodging was minimal and would not have influence yield greatly for any winter cereal.

Figure 1. Winter Survival for Winter Wheat and Hybrid Fall Rye Varieties





Conclusions and Recommendations:

The ideal time for seeding winter cereals is prior to September 15th into moist soil. Ideally winter cereals should be in the 3-4 leaf stage going into the winter. In this study, winter cereals were seeded into dry soil on September 28th. While fall rye established 2 leaves before winter, winter wheat established little more than 1. As a result, winter kill was fairly high for all cereals however, hybrid fall rye survive better than winter wheat. Winter cereals were able to compensate and produce decent yields by tillering. However, winter cereal yields were considerably lower than spring wheat yields from neighbouring trials. Despite better winter survival, hybrid fall rye was lower yielding than winter wheat. This was likely due to very high levels of ergot associated with the hybrid fall rye. Bono and Gatono were the highest yielding hybrid fall rye varieties. Wildfire was the highest yield winter wheat variety with CDC Chase and Flourish being the lowest yielding.

Supporting Information

Acknowledgements:

This project was funded through the Western Winter Wheat Initiative.

Appendices:

Table 3. Significance of main effects of Fall rye and Winter Wheat Varieties on Winter Survival, Lodging and Yield.

	Winter Survival (%)	Lodging (1-9)	Yield (kg/ha)
Variety			
1. Moats	31.3 a	1 a	3972 bcd
2. Elevate	41.3 ab	1 a	3997 bcd
3. Gold Rush	50.0 bc	1 a	4181 cd
4. CDC Chase	31.3 a	1 a	3376 abc
5. Flourish	46.3 bc	1.1 a	3326 ab
6. Emerson	43.8 ab	1 a	4149 bcd
7. Pintail	31.3 a	1 a	4156 bcd
8. Gateway	39.0 ab	1 a	3944 bcd
9. Buteo	43.8 ab	1.4 b	4165 cd
10. Wildfire	37.5 ab	1 a	4528 d
11. Brasetto hybrid fall rye	60.0 cd	1 a	2693 a
12. Bono hybrid fall rye	73.8 d	1 a	3887 bcd
13. Gatano hybrid fall rye	68.8 d	1 a	3978 bcd
P-values	<0.0001	0.0338	0.0105
LSD	14.7	0.2	836.5

Oats: Busting Bins and Making the Grade with Agronomy Basics

Mike Hall[1] and Heather Sorestad[1]

[1]East Central Research Foundation, Yorkton, SK.

Abstract/Summary:

A study was conducted in Yorkton, Saskatchewan to determine if oat yield and quality could be improved through agronomic basics. The basic agronomic factors which were analyzed were seeding date (early vs late), seeding rate (200, 300 and 400 seeds/m^2) and nitrogen rate (70 vs 120 kg N/ha). While early seeded oat are typically higher yielding the opposite occurred in this study. Seeding early resulted in significantly lower yields due to floral blast. Oats seeded later flowered under cooler temperature and were unaffected by blast. Oats are often unresponsive to nitrogen beyond 80 kg/ha and increasing rates of N typically decrease test weights. In this study, increasing N from 70 to 120 kg/ha increased the yield of early seeded oats by 15% whereas, the yield of late seeded oats was only increased by 4%. In part, increasing N was more beneficial with early seeded oats because it significantly reduced blast from 26.9% down to 13.9%. Past research would indicate that higher seeding rates tend to maximize yield and increase test weights. In this study, increasing seeding rate tended to decrease yield and reduce test weights of early seeded oats due to increased blast. However, increasing seeding rate did increase test weights of late seeded oats but had no effect on yield. High seeding rates and low nitrogen increased blast and decreased yield of early seeded oats. This created some very unexpected results. The "best" treatment should have been early seeded oats at 400 seeds/m^2 with 70 kg/ha

of N and the “worst” treatment should have been late seeded oats at 200 seeds/m^2 with 120 kg/ha of N. Ironically, the “best” treatment yielded 5041 kg/ha of oats whereas, the “worst” treatment produced 6406 kg/ha. This occurred because seeding early at high seeding rates and low nitrogen rates severely increased blast in this study. Following best practices reduces risks to oat production, but may not always provide the best results under certain environmental conditions.

Objectives and Rationale

Project Objectives:

The objective of the proposed trial is to demonstrate the relative contributions of the most basic management decisions to oat yield and quality. The factors that will be directly evaluated are seeding date, seeding rate and nitrogen (N) fertilizer rate.

Project Rationale:

While the large volumes of grain that can be produced may deter some growers, oats can be a very profitable cereal option for the cooler, wetter regions of Saskatchewan, especially if milling grades can be consistently achieved. Oats are an excellent crop option which is relatively inexpensive to grow and can add diversity to grain operations. While not a particularly high input crop, oats are quite responsive to management and there are a number of basic factors that can have a large impact on yield and quality. Before seeking out additional inputs that increase costs and may come with a relatively low probability of response, both current and new oat growers alike should ensure that they have secured all the ‘low hanging fruit’ for maximizing yields and quality with this crop. Ways to maximize yields while maintaining lower margins are seeding date, seeding rate and nitrogen rate.

Methodology and Results

Methodology:

At Yorkton, plots were 11 by 30 ft and seeded with a 10ft SeedMaster drill on 12 inch row spacing. The middle 4 rows of each plot were harvested with a Wintersteiger plot combine. The trial was established as a 3 order factorial. The first factor contrasted seeding dates of May 10 and June 5. The second factor compared seeding rates of 200, 300 and 400 seeds/m2. The last factor assessed nitrogen (N) rates of 70 and 120 kg/ha. The combination of these factors (2 x 3 x 2) produced 12 treatments which are listed in Table 1.

Table 1. Treatment List for Oats: Busting Bins and Making Grade with Agronomy Basics			
trt #	Seeding date	Seeds/m2	kg N/ha
1	Early (May 10)	200	70
2	Early (May 10)	200	120
3	Early (May 10)	300	70
4	Early (May 10)	300	120
5	Early (May 10)	400	70
6	Early (May 10)	400	120
7	Late (June 5)	200	70
8	Late (June 5)	200	120
9	Late (June 5)	300	70
10	Late (June 5)	300	120
11	Late (June 5)	400	70
12	Late (June 5)	400	120

Dates of operations are listed in Table 2.

Table 2. Dates of operations in 2018 for the Oats: Busting Bins and Making the Grade with Agronomy Basics	
Operations in 2018	Yorkton
Early Seeding	May 10
Late Seeding	June 5
Plant Emergence	May 28
Fungicide: Caramba	June 25
Pre-seed Burnoff Herbicide: Pardner	June 4
In-crop Herbicide: MCPA	
Harvest for Early Seeding	Sept 5
Harvest for Late Seeding	

Results:

Tables 3 to 8 showing the complete analysis can be found in the appendices.

The oat crop emerged well with seeding rates of 200, 300 and 400 seeds/m^2 producing plant stands of 186, 267, and 300 plants/m^2, respectively (Table 4). When averaged over seeding rate, increasing nitrogen rate from 70 to 120 kg/ha decreased emergence by 10% (263 vs 239 plants/m^2). Surprisingly, the increase in nitrogen did not significantly increase lodging. Lodging was very minor in this study and not substantially affected by any treatment.

Based on past research conducted in Saskatchewan and Manitoba we had several expectations regarding the results for this demonstration. Oats seeded early were expected to have higher test weights and yield[1,2]. While not statistically significant, the early seeded oats (May 10th) in this study yielded 4.5% less than late seeded oats (June 5th) on average (Table 4). Early seeded oats yielded less because of floral blast (floral abortion). This occurs when oats are flowering during hot temperatures. The late seeded oats may have flowered during cooler temperatures and did not suffer from blast. Test weight was slightly higher for early seeded oats, but the difference was not significant (Table 4). However, test weights for early and late seeded oats averaged well above the minimum requirement of 235 g/0.5l. Nevertheless, it is best for producers to aim for tests weights well above the minimum requirement.

Oats are generally not expected to respond substantially to nitrogen rates beyond 70 kg/ha and increasing rates of N are expected to decrease test weights[2]. Past research has shown the yield of oats are optimized between 40 and 80 kg N/ha[2]. In this study, there was an interaction between seeding date and nitrogen rate. Oats were very responsive to added N beyond 70 kg/ha when seeded early but not when seeded late. As nitrogen rate was increased from 70 to 120 kg N/ha the yield of oats seeded early increased by 15% (5690 vs 6569 kg/ha) whereas, the yield of late seeded oats only increased by 4% (6287 vs 6540 kg/ha) (Table 5 and Figure 1). In part, increasing N was more beneficial with early seeded oats because it significantly reduced blast from 26.9% down to 13.9% (Table 7). The higher rate of N either gave the crop more resilience against blast or it simply delayed flowering into cooler temperatures. In this study, test weights were reduced somewhat with added N but the difference was not significant (Table 4). Again, test weights were at very good levels for both rates of nitrogen.

Past research has found yield is optimized around 350 seeds/m^2 and that increasing seeding rates can result in higher test weights[3]. In this study, increasing seeding rate did not affect yield of late seeded oats, and it did significantly reduced the yield of early seeded oats (Table 4 and Figure 2). This was the opposite of expectation and could once again be accounted for by higher levels of blast. For early seeded oats, increasing seeding rate from 200 to 400 seeds/m^2 increased blast from 8 to 31%, respectively. Higher seeding rates would have increased inter-plant competition for moisture and perhaps this added stress made the blast worse. Alternatively, higher seeding rates caused the plants to flower earlier when temperatures were possibly higher. Contrary to past research, test weights were declining with increasing seeding rate and this may have also been related to increasing blast. However, increasing seeding rate did increase test weight for the late seeded oats which were unaffected by blast. The reason test weights tend to go up with seeding rate is unclear. It could be related how smaller or different sized seed packed together or related to less space between the hull and groat. However, the reason has not been studied in great detail.

Floral blast was a problem for the early seeded oats and this created some unusual results. Blast became more problematic as seeding rate was increased and nitrogen was reduced. Increasing seeding rate and reducing nitrogen rate may have increased blast by increasing interplant competition for resources or simply caused flowering to occur earlier when temperatures were warmer. The extremes in blast are apparent in Figure 3. Blast was much worse for oats seeded at the highest rate with the lowest rate of nitrogen. Blast with early seeded oats created some very unexpected results. The “best” treatment should have been early seeded oats at 400 seeds/m^2 with 70 kg/ha of N and the “worst” treatment should have been late seeded oats at 200 seeds/m^2 with 120 kg/ha of N. Ironically, the “best” treatment resulted in 5041 kg/ha of oats whereas, the “worst” treatment produced 6406 kg/ha.

Figure 1. Effect of nitrogen rate on yield of oat seeded early and late, averaged over seeding rate.

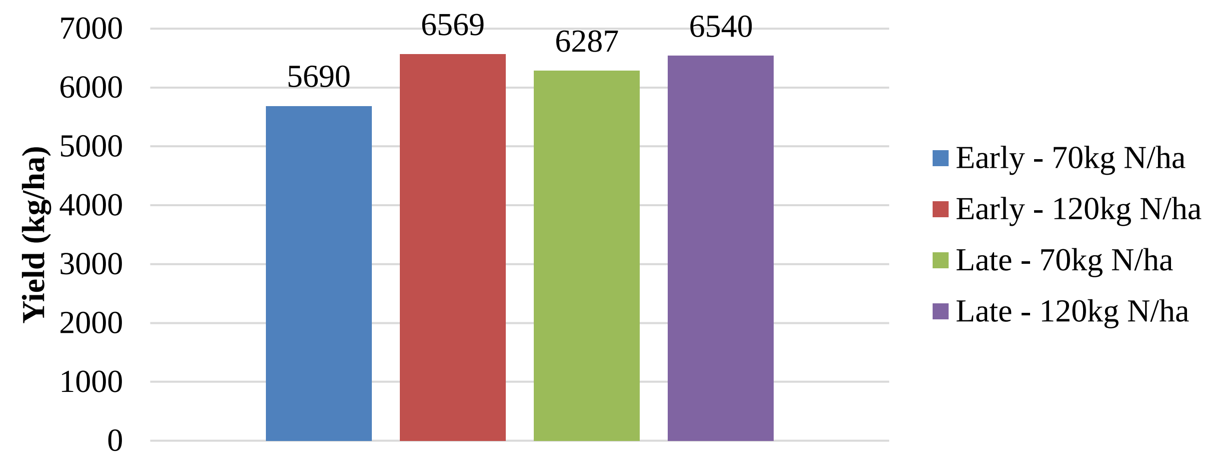


Figure 2. Effect of seeding rate on early and late seeded oats, averaged over nitrogen rate.

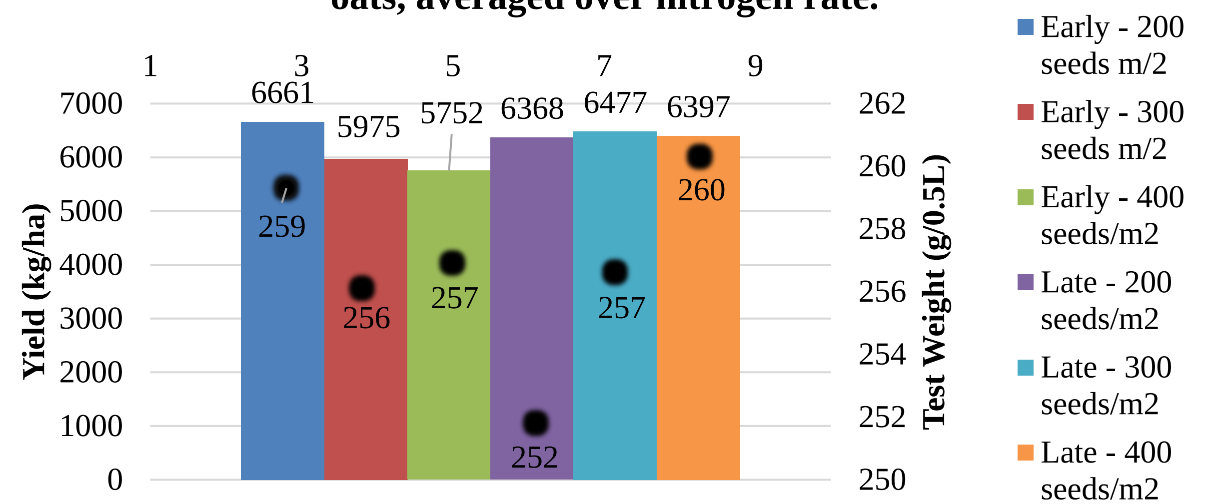


Figure 3. Floral blast increases with low nitrogen rates and higher seeding rates.

[1]**May, W., Mohr, R., Lafond, G., Johnston, A. and C. Stevenson. 2004a.** Early seeding dates improve oat yield and quality in the eastern prairies. Can. J. Plant Sci. **84:** 431-442.

[2]**May, W., Mohr, R., Lafond, G., Johnston, A. and C. Stevenson. 2004b.** Effect of nitrogen, seeding date and cultivar on oat quality and yield in the eastern Canadian Prairies. Can. J. Plant Sci. **84:** 1025-1036.

[3]**May, W., Shirtliffe, S., McAndrew, D., Holzapfel, C. and G. Lafond. 2009.** Management of wild oat (*Avena sativa* L.) in tame oat (*Avena sativa* L.) with early seeding dates and high seeding rates. **89:** 763-773.

Conclusions and Recommendations

This study shows that following "best" practices for oat production does not guarantee the best results as environment can greatly influence the outcome. While not supported in this study due to blast issues, early seeding should be a recommended practice and tends to optimize yield and test weight. While early seeding may not allow for the pre-seed control of wild oats it does help to ensure the crop is harvested under ideal conditions. This is particularly important since oats treated with pre-harvest glyphosate as a harvest aid are no longer accepted by some millers. Increasing seeding rate is recommended to optimize yield and increase test weights. While the opposite was true for early seeded oats in this study due to blast, increasing seeding rates did increase test weights for late seed oats which responded more typically without blast issues. Early seeded oats did significantly respond to N rates beyond 70 kg/ha, but this again was related to higher levels of blast with lower N. Late seeded oats were less responsive to increasing N as expected. However, past studies at the Yorkton farm has found oats to be responsive to N rates much higher than is typically applied by producers. This only occurs if lodging is not an issue.

Supporting Information

Acknowledgements:

This project was funded through Grain Millers at Yorkton.

Appendices:

Table 3. Significance of main effects and interactions for Seeding Date, Seeding Rate and Nitrogen Rate on oat Yield, Emergence, Lodging, Thins and Test Weight.

	Yield (kg/ha)	**Emergence (plants/m^2)**	**Lodging (0-10)**	**Thins**	**Test Weight (g/0.5L)**
Effect	----------p-values^z----------				
Seeding Date (D)	Ns	Ns	0.0101	Ns	Ns
Seeding Rate (R)	Ns	<0.0001	Ns	0.0268	0.08
Nitrogen Rate (N)	<0.0001	Ns	Ns	Ns	Ns
D*R	0.052	Ns	Ns	Ns	0.0024
D*N	0.0055	0.0366	Ns	Ns	Ns
R*N	0.0235	0.0392	Ns	Ns	Ns
D*R*N	Ns	0.0121	Ns	Ns	Ns

Table 4. Main effect means for Seeding Date, Seeding Rate and Nitrogen Rate on oat yield, emergence, lodging, thins and test weight.

	Yield (kg/ha)	**Emergence (plants/m^2)**	**Lodging (0-10)**	**Thins**	**Test Weight (g/0.5L)**
Seeding Date					
Early	6129 a	241 a	2.6 b	1.0 a	257 a
Late	6414 a	261 a	0.3 a	0.9 a	256 a
LSD	Ns	Ns	1.3	Ns	Ns
Seeding Rate					
200 seeds/m^2	6514 a	186 a	1.2 a	1.0 b	256 a
300 seeds/m^2	6226 a	267 b	1.5 a	1.0 b	256 a
400 seeds/m^2	6074 a	300 c	1.5 a	0.7 a	259 a
LSD	Ns	23.8	Ns	0.2	Ns
Nitrogen Rate					
70 kg N/ha	5988 a	263 a	1.3 a	0.9 a	258 a
120 kg N/ha	6554 b	239 a	1.6 a	1 a	256 a
LSD	208	Ns	Ns	Ns	Ns

Table 5. Main effect means for Seeding Date, Seeding Rate and Nitrogen Rate on oat yield, emergence, lodging, thins and test weight.

D x R x N	Yield (kg/ha)	Emergence (plants/m^2)	Lodging (0-10)	Thins	Test Weight (g/0.5L)
1. Early May—200 seeds/m^2—70 kg N/ha	6324	179	2.0	1.0	258
2. Early May—200 seeds/m^2—120 kg N/ha	6997	174	2.5	0.9	261
3. Early May—300 seeds/m^2—70 kg N/ha	5705	277	2.5	1.0	259
4. Early May—300 seeds/m^2—120 kg N/ha	6246	258	3.0	1.2	254
5. Early May—400 seeds/m^2—70 kg N/ha	5041	326	2.5	0.8	257
6. Early May—400 seeds/m^2—120 kg N/ha	6464	231	3.0	0.8	257
7. Late May—200 seeds/m^2—70 kg N/ha	6331	208	0.2	1.0	252
8. Late May—200 seeds/m^2—120 kg N/ha	6405	182	0.2	1.3	251
9. Late May—300 seeds/m^2—70 kg N/ha	6416	264	0.3	0.7	260
10. Late May—300 seeds/m^2—120 kg N/ha	6538	268	0.4	0.9	254
11. Late May—400 seeds/m^2—70 kg N/ha	6115	325	0.2	0.7	259
12. Late May—400 seeds/m^2—120 kg N/ha	6678	319	0.3	0.7	261
LSD	Ns	60.8	Ns	Ns	Ns

Table 6. Significance of main effects and interactions for seeding rate and nitrogen rate on floral blast of early seeded oats.	
	Floral Blast (%)
Effect	----------------------------------p-values^{z}----------------------------------
Seeding Rate (R)	0.0108
Nitrogen Rate (N)	0.0297
R*N	Ns

Table 7. The main effects of seeding rate and nitrogen rate on floral blast of early seeded oats	
Seeding Rate (seeds/m2) (R)	**Floral Blast (%)**
200	8.1 a
300	21.8 ab
400	31.4 b
LSD	14.1
Nitrogen Rate (kg N/ha) (N)	
70	26.9 a
120	13.9 b
LSD	11.5

Table 8. Interaction of seeding rate and nitrogen rate on floral blast of early seeded oats	
R*N (Early May)	**Floral Blast (%)**
1. 200 seeds/m^2—70 kg N/ha	10.3 a
2. 200 seeds/m^2—120 kg N/ha	6.0 a
3. 300 seeds/m^2—70 kg N/ha	28.0 bc
4. 300 seeds/m^2—120 kg N/ha	15.5 a
5. 400 seeds/m^2—70 kg N/ha	42.5 c
6. 400 seeds/m^2—120 kg N/ha	20.3 a
LSD	19.9

Wheat Profitability- ECRF Site Only

Mike Hall[1] and Heather Sorestad[1]

[1]East Central Research Foundation/Parkland College, Yorkton, SK.

Abstract/Summary:
Trials were conducted near Yorkton Saskatchewan in 2017 and 2018 to evaluate how levels of management can enhance wheat profitability over different classes of wheat. The trial was developed by the Northeast Agriculture Research Foundation and it was set up as a 2 factor Randomized Complete Block Design with 4 replications. The first factor contrasted wheat variety and the second factor assessed management level. Between the two CPRS varieties, yield did not significantly vary in either year. However, SY Rowyn had significantly higher grain protein than AAC Ryley in both years. In 2017, yields did not significantly differ between CWRS varieties however, Carberry was lower yielding in 2018 which would be expected based on variety data published in the Saskatchewan seed guide. AAC Cameron VB produced lowest grain protein in both years. When averaged across variety, each incremental increase in management significantly increased yield in both years, but protein levels were maximized with enhanced management. On average, enhanced management increased yield by 11% and intensive management increased yield by 22% compared to conventional management. The economic return for each variety under different levels of management depends on the price which can be secured. This can vary significantly between varieties, even within the same class. To help

producers determine economic returns a table was developed based on the results from this study and different prices. When the value of higher levels of grain protein are taken into consideration, enhanced management often provided greater economic returns for CWRS and CPRS varieties. While intensive management continued to improve yield it rarely resulted in greater economic returns. The exception to this was the ethanol variety AC Andrew which was likely responding mostly to the higher rate of N supplied with intensive management.

Objectives and Rationale

Project Objectives:

- To enhance wheat profitability by incorporating some or all components of intensive wheat management.
- To identify how wheat classes and varieties are affected by enhanced wheat management.
- To identify how interactions of wheat genetic characteristics respond to varying soil and climate conditions across Saskatchewan.

Project Rationale:

Profitability of wheat has declined relative to oilseeds and pulses. However, wheat remains as an important crop in our rotations. Recent developments in wheat production technologies like plant growth regulators present opportunities to enhance yield with increased fertilizer application or higher seed rates without the complications that they have promoted in the past like increased lodging. Fusarium head blight (FHB) presents new challenges for wheat growers in knowing how best to utilize genetic resistance in combination with fungicides to minimize losses. This study will examine how yield and quality of wheat responds to varying levels of management across a diversity of wheat varieties. Improved understanding of how genetic differences interact with management strategies will allow growers to select the most appropriate management strategies to employ with differing wheat varieties and classes. To ensure that results are applicable to a wide range of soils and climate we will conduct trials over 3 years at locations representative of the driest to wettest areas of the province with cool and short to relatively warm, long growing seasons.

Methodology and Results

Methodology:

The trial will consist of 3 levels of management across 6 cultivars selected from 3 wheat classes that represent the range of wheat yields, Fusarium head blight resistances, lodging resistances and protein contents provided in spring wheat cultivars of all classes currently recommended for production in Saskatchewan. Wheat cultivars chosen were Carberry, AAC Cameron VB, CDC Utmost VB, AC Andrew, SY Rowyn and AAC Ryley. All vary between class, relative yield, protein, lodging resistance and Fusarium resistance.

The trial will utilize a 4 replicate factorial design with plots sizes varying across sites to accommodate equipment at each site.

Management levels will be based on a conservative approach that targets average yields (Conventional Management); a more aggressive approach that targets higher than average yield with increased seed rates, moderately higher fertility and fungicides for FHB control (Enhanced Management); and a highly aggressive and riskier approach that attempts to achieve the full yield potential of this crop (Intensive Management).

Conventional Management : No seed treatment, seed rate of 200 viable seeds/m^2, N and P fertilizer applied at replacement rates for a 50 bu/ac (75 lb/ac N plus 25 lb/ac of P_2O_5) CWHRS wheat yield. No PGR, no fungicide.

Enhanced management: No seed treatment, seed rate of 300 viable seeds/m^2, N and P fertilizer applied at replacement rates for a 65 bu/ac (98 lb/ac N plus 33 lb/ac of P_2O_5) CWHRS wheat yield. No PGR, fungicide (Caramba or Proline 480SC) for FHB applied at 75% head emergence to 50% flowering.

Intensive management: Cruiser Maxx seed treatment, seed rate of 360 viable seeds/m^2, N and P fertilizer applied at replacement rates for an 80 bu/ac (120 lb/ac N plus 40 lb/ac of P_2O_5) CWHRS wheat yield. PGR (Manipulator 620) at 1-2 node stage, fungicide (Acapela) at flag leaf, fungicide (Caramba or Proline 480SC) for FHB at 75% head emergence to 50% flowering.

Table 1. Dates of operations in 2017 and 2018 for the Wheat Profitability trial.

Operations	2017	2018
Seeded wheat	May 11	May 7
Emergence Counts	May 30	May 28
In-crop herbicide	June 1 (Frontline/Simplicity)	? (Prestige/Axial)
Manipulator applied at 1-2 node stage (trts 13-18)	June 20	June 13
Fungicide: Acapela applied to trts 13-18	July 5	June 29
Fungicide: Caramba applied to trts 7-18	July 9-13	July 2
Days to Maturity		Aug 7
Harvest	August 31	?

Results:

Tables 2 to 7 showing the complete analysis for the study are found in the appendices. This study was developed by the Northeast Agriculture Research Foundation out of Melfort and ECRF/Parkland College is one of five Agri-Arm sites participating in the study. The final report for the three year study will not be available until 2020. This report is based on the data obtained solely from Yorkton during the growing seasons of 2017 ad 2018.

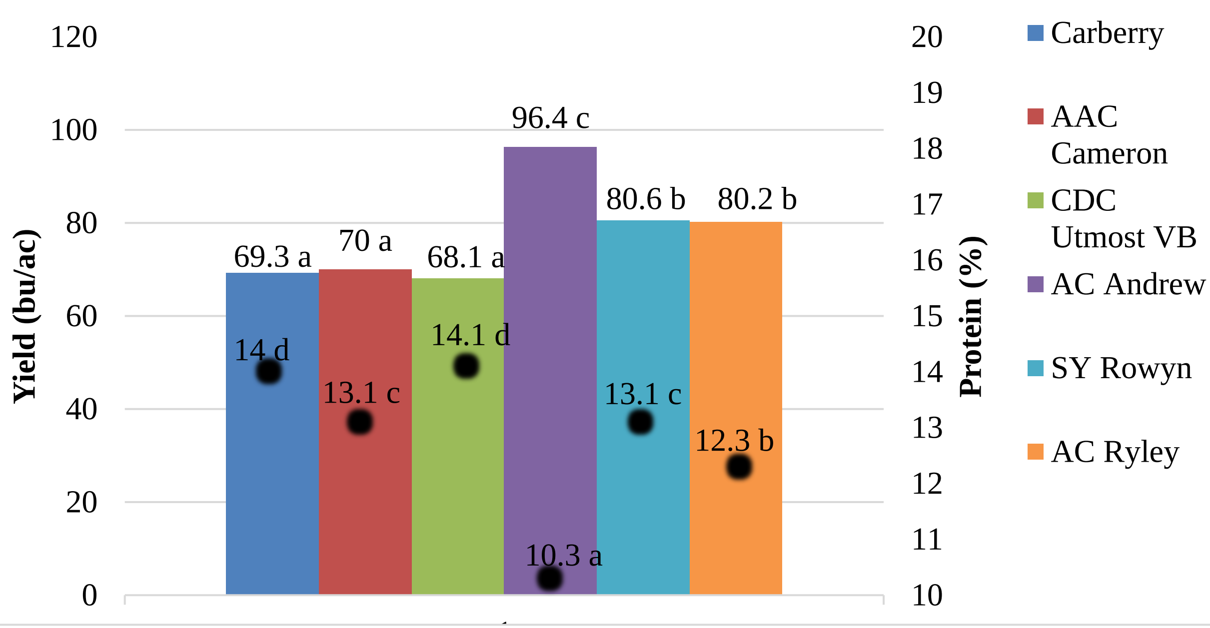
Seeding targets of 200, 300 and 360 seeds/m^2 resulted in average plant stands of 221, 272 and 348 plant/m^2 in 2017, respectively and 179, 248 and 300 plants/m^2 in 2018, respectively (Table 4 and 5). In 2017, emergence varied significantly between varieties which was not desired.

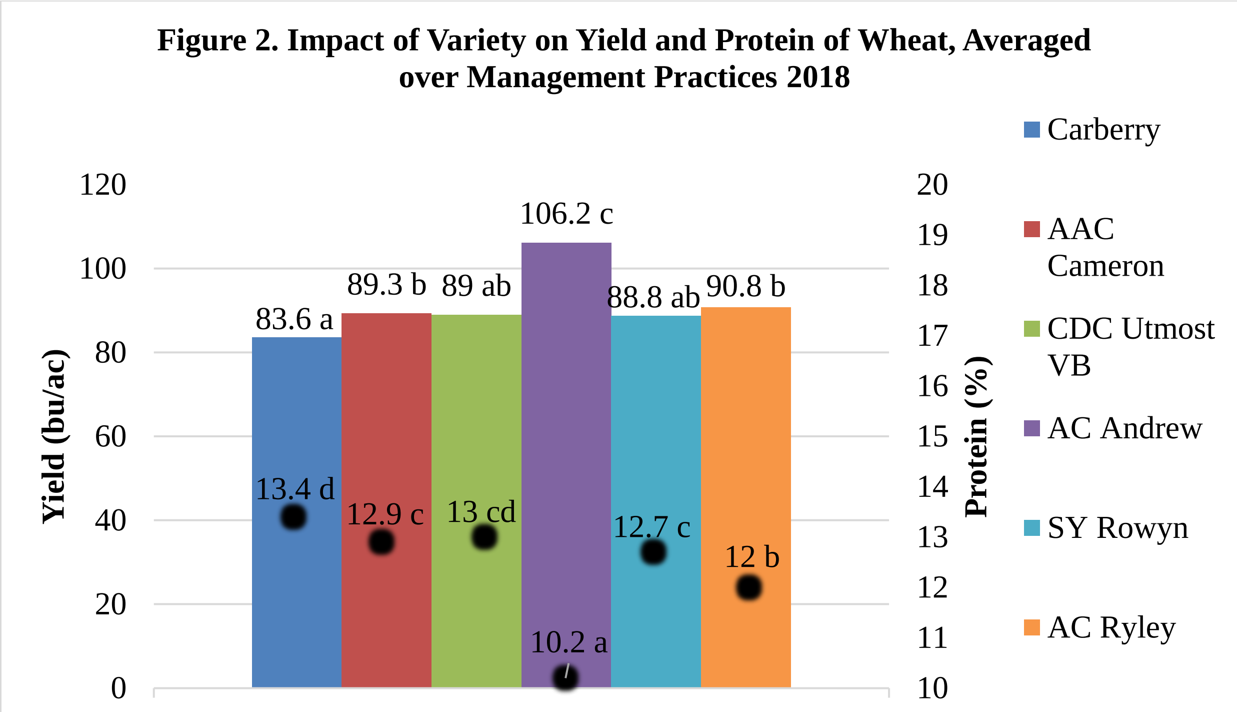
Emergence for AAC Cameron VB was substantially higher than most of the other varieties in that year. In 2018, emergence did not vary significantly between varieties.

Fusarium head blight was present in both years. In 2018, Fusarium damaged kernels (FDK) for the marginally resistant varieties Carberry and SY Rowyn were significantly less than that found in the other varieties rated as intermediate to marginally susceptible to Fusarium (Table 4 and 5). The exception to this was AAC Cameron VB, which had the lowest level of FDK despite a rating of intermediate. Increasing level of management did not significantly impact the level of FDK found in the grain in 2018. In 2017, enhanced management did significantly reduce FDK but oddly this was not the case for intensive management. Overall, FDK levels were relatively low, but were high enough for some varieties to result in down grading from number 1.

In 2017 and 2018 there were no significant interactions between variety and management level for either the grain protein or yield data (Tables 2 and 3). In other words, varieties responded to management level in similar ways. When averaged across management level, AC Andrew was by far the highest yielding variety with the lowest grain protein in both years (Tables 4, 5 and Figures 1 and 2). This makes sense as AC Andrew was bred to produce a lot of starch for the ethanol market. When averaged over both years, AC Andrew yielded 29% and 19% more than the CWRS and CPRS varieties, respectively. Between the two CPRS varieties, yield did not significantly vary in either year. However, SY Rowyn had significantly higher grain protein than AAC Ryley in both years (Figure 1, 2, Table 4 and 5). In 2017, yields did not significantly differ between CWRS varieties however, Carberry was lower yielding in 2018 which would be expected based on variety data published in the Saskatchewan seed guide. AAC Cameron VB produced lowest grain protein in both years.

Figure 1. Impact of Variety on Yield and Protein of Wheat, Averaged over Management Practices 2017





When averaged across variety, each incremental increase in management significantly increased yield in both years, but protein levels were maximized with enhanced management (Figure 3 and 4). When averaged across years, enhanced management increased yield by 11% and intensive management increased yield by 22% compared to conventional management Figure 3 and 4).

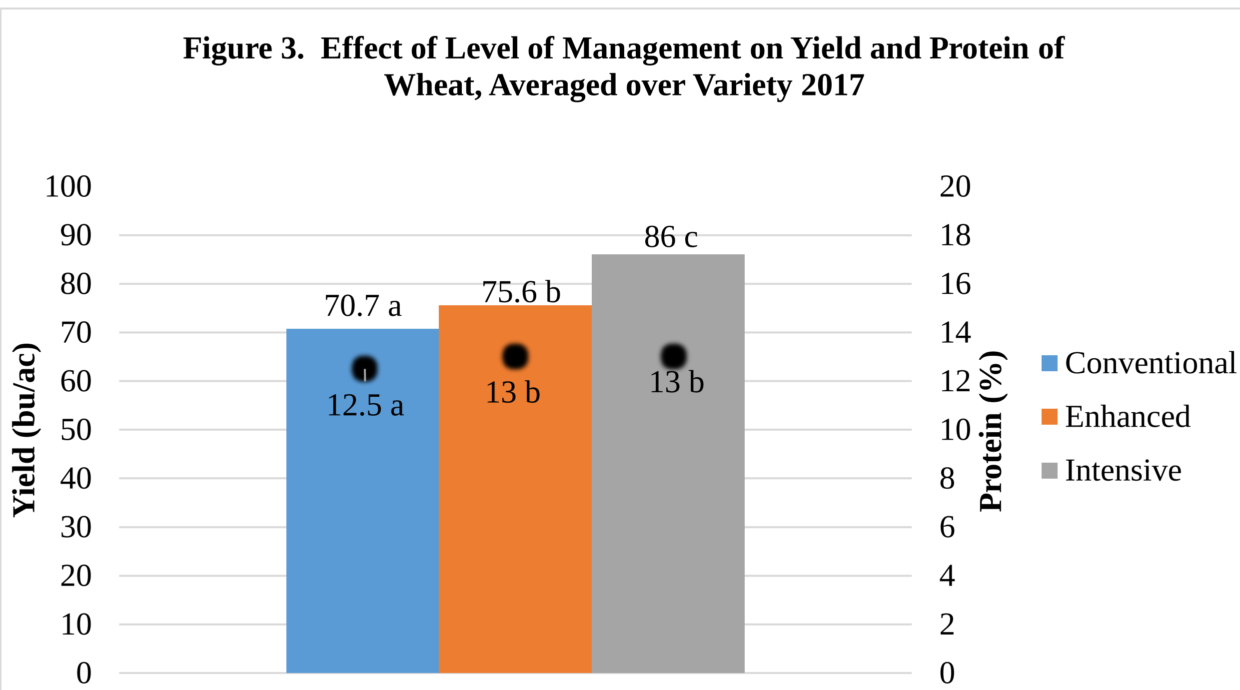
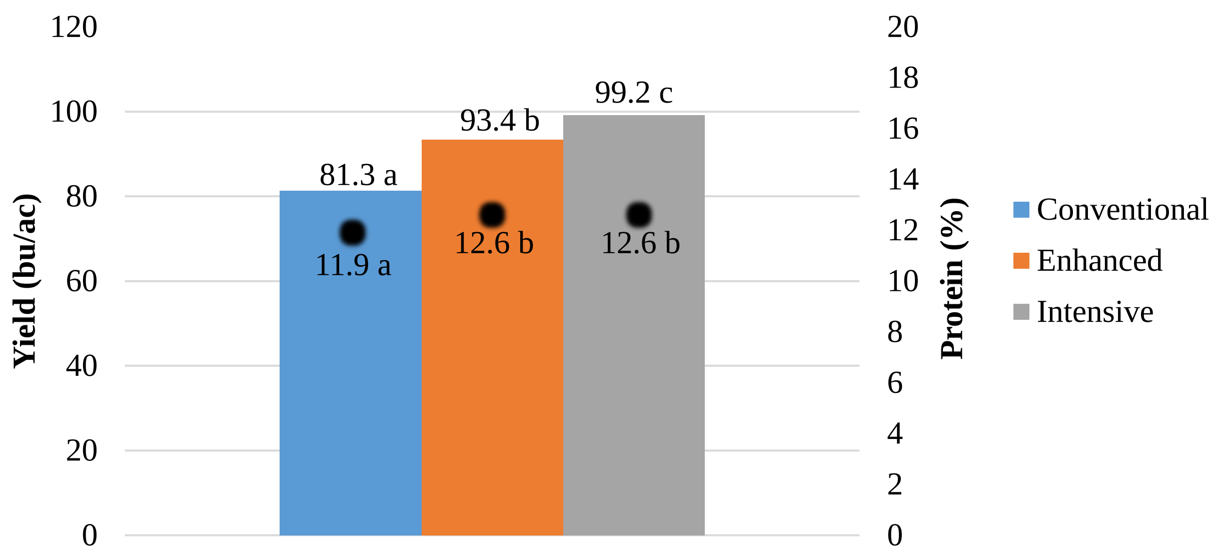


Figure 4. Effect of Level of Management on Yield and Protein of Wheat, Averaged over Variety 2018



In order to make an economic comparison between the levels of management, NARF's data on variable costs of production (Table 6) was borrowed when creating Table 7. Seed, fertilizer and chemical costs increase as management intensifies.

Calculating costs of production are fairly straightforward, however, determining a price for the commodity can vary significantly. The economic returns between varieties and level of management will change depending on the price that can be secured for each variety. Price can even vary substantially within a variety class if that variety is of special interest to a particular company. For example, P&H has offered a substantial premium for SY Rowyn over AAC Ryley. Table 7 contains the average yield and protein for each variety which were achieved under conventional, enhanced and intensive management in 2017 and 2018 at Yorkton. The assumed variable cost for each level of management are also presented in the table based on NARF's calculations. Profit over variable costs equals the bu/ac multiplied by $/bu, minus the variable cost for each level of management being considered. For example, Carberry yields 70.1 bu/ac when conventionally managed and produced 82 dollars/ac in profit if we assume a price of 4 dollars per bushel. Not surprisingly, profit rises as the price per bushel rises. If the value of the crop is low (ie $4/bu), increasing the level of management drastically reduced profit for most varieties. The profit of AC Andrew was reduced to a lesser extent because it was very responsive to intensifying management. If the assumed value of the crop is high (ie: $8/bu), increasing management increased profitability for CDC Utmost VB, AC Andrew, SY Rowyn and AAC Ryley. Profitability was unchanged for Carberry and AAC Cameron. However, this has assumed the price per bushel stays the same as management increases and this is not likely accurate. The table shows that protein has also been increasing with management for many of the varieties. If protein spreads are wide it is not unreasonable to expect the price per bushel to be 50 cents higher when moving from conventional to enhanced management. In this case, diagonal comparisons should be considered instead of making comparisons down the table. For example, when assuming a price of $6/bu, Carberry delivered a profit of $223/ac when conventionally managed. Assuming the price stays the same, enhanced management will result in a profit of only $205/ac. In other words, enhanced management resulted in a $18/ac loss when assuming the price stays at $6/bu. However, this is not realistic as enhanced management also increased protein by 1.1%. It is more probable that $6.5/bu would be received with enhanced management. In this case $242/ac would be received which has now increased profitability by $19 instead of a $18 loss. Making diagonal comparisons for AC Andrew would not make sense as it is an ethanol variety and a premium will not be paid for higher protein. When making diagonal comparisons between the $6 and $6.5, an argument for the enhanced level of management can be made for CDC Utmost VB, SY Rowyn and AAC Ryley. For Carberry and AAC Cameron VB enhanced management resulted in virtually the same economic returns as conventional. If we make diagonal comparisons between conventional and intensive management, it would only further improve profitability for CDC Utmost VB. These examples above show how the table can be used by individual producers to assess economic returns for each variety and level of management. Conclusions will differ based on the price per bushel which can be secured by each variety.

Conclusions and Recommendations

It should be stressed that this is only two site years from Yorkton and the final results for the much larger study will not be available from the Northeast Agriculture Research Foundation until 2020. The study is limited as there is confounding between multiple factors. The impact of each individual input cannot be isolated. To do so would simply make the trial unreasonably large. However, it is evident that not every input is pulling its weight and applying everything has not been economical. Unfortunately, the impact of each input is going to change with environmental conditions. The enhanced level of management for the CWRS and CPRS varieties often provide greater economic returns over conventional management when the value of higher protein was taken into consideration. It is likely the best approach as it hedges against severe yield loss should heavy disease pressure become an issue. While intensive management continued to increase yield it rarely increased economic returns over enhanced management. For the ethanol variety AC Andrew, returns were highest for intensive management once we got above $5.5/bu. However, a large part of that increase likely came from added N. Manipulator likely did not provide an economic benefit in this study as lodging was not an issue. Moreover, while not impossible, it is unlikely that the double spray of fungicide provided a significantly benefit. Removing Manipulator and Acapela at flag from the intensive management would likely have improved the economic returns under the conditions of our study. In conclusion, intensifying management certainly produced more yield, but not necessarily more profit. While the value of increasing management depends on the price that can be obtained for the commodity, there was little evidence that moving from enhanced to intensive management would prove economic based on the results obtained from this study.

Supporting Information

Acknowledgements:

Funding provided by the Agricultural Development Fund (ADF) and the Saskatchewan Wheat Development Commission.

Appendices

1.

Table 2. Significance of variety and level of management on wheat emergence, yield, protein and FDK 2017.				
	------------------------------------p-values ^{Z}--			
	Emergence (plants/m^2)	**Yield (bu/ac)**	**Protein (%)**	**FDK (%)**
Variety (A)	0.0010	0.0001	0.0001	0.0189
Management (B)	0.0001	0.0001	0.0188	0.0449
A*B	0.0047	Ns	Ns	Ns

Table 3. Significance of variety and level of management on wheat emergence, yield, protein and FDK 2018**.**				
	-------------------------------------p-values [Z]---------------------------------------			
	Emergence (plants/m^2)	**Yield (bu/ac)**	**Protein (%)**	**FDK (%)**
Variety (A)	Ns	0.0001	0.0001	0.0001
Management (B)	0.0001	0.0001	0.0001	Ns
A*B	Ns	Ns	Ns	0.0257

Table 4. Main Effects of Variety and Level of Management on Emergence, Yield, Protein and FDK on wheat 2017.				
Main Effects	**Emergence (plants/m^2)**	**Yield (bu/ac)**	**Protein (%)**	**FDK (%)**
Variety (A)				
Carberry (cwrs)	243	69.3 a	14.0 d	0.1
AAC Cameron VB (cwrs)	333	70.0 a	13.1 c	0.1
CDC Utmost VB (cwrs)	302	68.1 a	14.1 d	0.2
AC Andrew (cwsws)	275	96.4 c	10.3 a	0.2
SY Rowyn (cprs)	287	80.6 b	13.1 c	0.2
AAC Ryley (cprs)	244	80.2 b	12.3 b	0.2
$Lsd_{0.05}$	44.3	5.7	0.61	0.10
Management (B)				
Conventional	221	70.7 a	12.5 a	0.2
Enhanced	272	75.6 b	13.0 b	0.1
Intensive	348	86.0 c	13.0 b	0.2
$Lsd_{0.05}$	31.3	4.0	0.43	0.07
Interactions	76.7	NS	NS	Ns

Table 5. Main Effects of Variety and Level of Management on Emergence, Yield, Protein and FDK of Wheat 2018.				
Main Effects	**Emergence (plants/m^2)**	**Yield (bu/ac)**	**Protein (%)**	**FDK (%)**
Variety (A)				
Carberry (cwrs)	251	83.6 a	13.4 d	0.05
AAC Cameron VB (cwrs)	243	89.3 b	12.9 c	0.03
CDC Utmost VB (cwrs)	245	89.0 ab	13.0 cd	0.14
AC Andrew (cwsws)	240	106.2 c	10.2 a	0.17
SY Rowyn (cprs)	240	88.8 ab	12.7 c	0.02
AAC Ryley (cprs)	238	90.8 b	12.0 b	0.33
$Lsd_{0.05}$	Ns	5.7	0.48	0.05
Management (B)				
Conventional	179	81.3 a	11.9 a	0.13
Enhanced	248	93.4 b	12.6 b	0.10
Intensive	300	99.2 c	12.6 b	0.13
$Lsd_{0.05}$	13	4.0	0.34	Ns
Interactions	Ns	Ns	Ns	Ns

Table 6. Variable Cost of Production per acre under Conventional, Enhanced, and Intensive Levels of Management			
	CWRS		
Input	**Conventional**	**Enhanced**	**Intensive**
Seed	25	38	45
N fertilizer	36	47	57
P fertilizer	16	21	25
Herbicide	62	62	62
Caramba	-	19	19
Acapela	-	-	12
Manipulator	-	-	15
Cruiser Vibrance	-	-	13
Machinery	24	24	24
Labour	19	19	19
Insurance	6	6	6
Misc.	5	5	5
Interest	5	5	5
Total	**198**	**246**	**307**

Table 7. Profit ($/ac) over variable costs for wheat varieties under different levels of management and price per bushel (Yorkton 2017-18)

					$/bushel								
Variety	**Management**	**bu/ac**	**protein**	**variable cost $/ac**	**4**	**4.5**	**5**	**5.5**	**6**	**6.5**	**7**	**7.5**	**8**
Carberry	Conventional	70.1	13.1	198	82	117	153	188	223	258	293	328	363
	Enhanced	75.1	14.2	246	54	92	129	167	205	242	280	317	355
	Intensive	84.1	13.9	308	28	70	112	154	196	238	280	323	365
AAC Cameron VB	Conventional	73.9	12.8	198	98	135	172	209	246	283	319	356	393
	Enhanced	78.3	13.2	246	67	106	146	185	224	263	302	341	381
	Intensive	86.8	13.0	308	39	82	126	169	213	256	299	343	386
CDC Utmost VB	Conventional	68.1	13.2	198	74	109	143	177	211	245	279	313	347
	Enhanced	78.2	13.9	246	67	106	145	184	223	262	302	341	380
	Intensive	89.3	13.5	308	49	94	139	183	228	273	317	362	407
AC Andrew	Conventional	89.4	10.0	198	160	204	249	294	339	383	428	473	517
	Enhanced	102.0	10.1	246	162	213	264	315	366	417	468	519	570
	Intensive	112.3	10.6	308	141	198	254	310	366	422	478	535	591
SY Rowyn	Conventional	76.1	12.2	198	106	144	182	220	258	297	335	373	411
	Enhanced	85.5	13.2	246	96	139	181	224	267	310	352	395	438
	Intensive	92.6	13.3	308	62	109	155	201	247	294	340	386	433
AAC Ryley	Conventional	78.4	11.6	198	116	155	194	233	272	311	351	390	429
	Enhanced	87.8	12.1	246	105	149	193	237	281	324	368	412	456
	Intensive	90.3	12.7	308	53	98	143	189	234	279	324	369	414