2019

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 7th 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.

In the winter of 2019 ECRF purchased a 2011 GMC Sierra 2500 which is used when employees are headed in different directions on the farm as well as for travelling longer distances when picking up products or attending events. Parkland College recently purchased a CaseIH MXU135 tractor for their Ag Equipment Technician course and they have suggested that the research farm should use it during the courses off season (May-August). ECRF intends to use this tractor mainly for spraying in the coming growing seasons.

In the spring of 2019 ECRF learnt that we were the recipients of $14,625.00 from the Morris Sebulsky endowment fund through SaskCanola. Morris Sebulsky was both a professor of Agricultural Engineering and a respected farm unit operator in the Sheho, SK area. He realized the importance of agricultural research for the people of Saskatchewan and made a generous bequest to leave a lasting legacy on agricultural research. ECRF has designate the funds to go towards partial payment of a Clipper seed cleaner + screens, truck and sea-can.

ECRF Board of Directors

ECRF is led by an 8 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.

The ECRF Board recently had 4 new additions which include Brent Ulmer, Brian Ulmer, Lutz Foerster, and Wade Olynyk. Brian and Brent Ulmer farm South of Goodeve where they raise dorper sheep and red angus cattle as well as grain farm. Wade Olynyk also farms in the Goodeve area where he raises black angus cattle and grain farms. Lutz Foerster grain farms South of Theodore. ECRF is thrilled to acquire these new board members to have different ideas and backgrounds around the board room table.

The 2019 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
- Brent Ulmer- Goodeve, SK
- Brian Ulmer- Goodeve, SK
- Lutz Foerster- Theodore, SK
- Wade Olynyk- Goodeve, SK

Ex-Officio

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

Staff

- 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

<u>ECRF/Parkland College Farm Tour July 23, 2019 (attendance ~100)</u>

<u>Speaking engagements</u>

- January 17, 2019 Agri-ARM Update at the Saskatoon Crop Production Show "Is your nitrogen vanishing into thin air?" (~50 attendees)
- Febuary 6, 2019 IHARF Winter Meeting in Melville "Is your nitrogen vanishing into thin air? + Malt versus Feed Barley Management" (~150 attendees)
- July 18, 2019 Swift Current- "Feed vs Malt Barley Management" (~80 attendees)
- July 24, 2019 Melfort- "Feed vs. Malt Barley Management" (~80 attendees)
- Nov 11, 2019 ARU Saskatoon- "Getting the Most out of Your Nitrogen" (~190 attendees)
- January 16, 2020 AgriARM Update at the Crop Production Show in Saskatoon "Are we managing nitrogen well for malt barley and milling oats?"

<u>2019 Videos- Website</u>

- Post-Emergent UAN vs Melted Urea for Increasing Wheat Protein 2019
- A Introduction to Yorkton's Research Farm
- Why Did Fungicide Not Control Leaf Disease on Our Oats? 2019 (89)
- CDC Blackstrap Dry Bean Inoculation and Nitrogen Fertilization 2019 (44)
- Should feed barley be fertilized with more nitrogen than malt? 2017-2019 (86)

- Maintaining Test Weight Stability of Milling Oats 2019 (120)
- Getting the Most out of Nitrogen 2019 (217)
- Farm Tour Promo 2019 (36)

<u>2018 Videos- Website</u>

- Are Farmers Applying Enough Nitrogen and Phosphorus to Flax 2016 to 2018? (161)
- Wheat Profitability Study 2017:18 (165)
- Oats Busting Bins and Making the Grade (115)
- Inoculant Options for Faba Beans 2015-2017 (114)
- Increasing Wheat Protein with a Post Emergent Application of UAN 2018 (187)
- Control of Glyphosate Resistant Canola in Glyphosate Resistant Soybeans 2018 (107)
- Strategies for Managing Feed and Malt Barley 2017/2018 (158)
- Oat Vigour Improves with Larger Seed Size 2018 (124)
- 4R Fall Applied Urea to Spring Wheat 2018 (650)
- Farm Tour Promo 2018- (90)

<u>2017 Videos- Website</u>

- Strategies for Management of Feed and Malt Barley 2017- (69)
- Wheat Profitability 2017-(64)
- Hastening Maturity of Oats without Pre-Harvest Glyphosate 2017- (174)
- Soybean Expectations versus Results 2013-2017- (54)
- Importance of Dual Inoculation and Seeding Soybeans into Warm Soil - (78)
- Demonstrating 4R Nitrogen Principles in Canola the benefit of Agrotain and SuperU - (153)
- Effect of Seeding Date, Seeding Rate and Seed Treatment on Winter Wheat - (150)
- An Introduction to ECRF- (129)

<u>2016 Videos- Website</u>

- Evaluating Inoculant Options for Faba beans - (56)
- Flax Response to Nitrogen and Phosphorus - (130)
- Effect of Variety, and Nitrogen Rate on Oat Yield and Test Weight - (339)
- Effect of Variety, Nitrogen Rate ad Seeding Rate on Forage Corn - (78)
- Effect of Fall Cultivation on Soybeans Seeded Early, Mid, and Late May - (58)
- Effect of Preceding Legume Crop on Spring Wheat – (55)
- Effect of Nozzle Selection and Boom Height on Fusarium Head Blight - (98)
- Lentil Production in the Black Soil Zone - (240)

<u>2015 Videos -Website</u>

- Flax Studies with IHARF and NARF - (75)

- Early Defoliation of Cereals for Swath Grazing - (230)
- Canary Seed Fertility - (342)
- Soybean Stature by Row Spacing - (169)
- Manipulator Effects on Lodging in Wheat 2015 - (899)

2014 Videos - Website

- Forage Termination 2015 - (100)
- Cereal Forage by Seeding Date - (48)
- Soybean Variety by Seeding Date - (134)
- Wheat Fungicide Timing - (259)

Total website views (6,536) as of Feb. 11, 2020

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 2019 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. The Outlook location is under irrigation, they added 128.5 or 233.6 mm in precipitation depending on the trial.

Table 1. Mean monthly temperatures and long-term (1981-2010) normals for the 2019 growing seasons at 8 sites in Saskatchewan.

Location	Year	May	June	July	August	Avg. / Total
		----------------------*Mean Temperature (°C)* --------------------				
Indian Head	2019	8.9	15.7	17.4	15.8	14.4
	Long-term	***10.8***	***15.8***	***18.2***	***17.4***	***15.6***
Melfort	2019	8.8	15.3	16.9	14.9	14.0
	Long-term	***10.7***	***15.9***	***17.5***	***16.8***	***15.2***
Outlook	2019	9.9	16.0	18.0	16.2	15.0
	Long-term	***11.5***	***16.1***	***18.9***	***18.0***	***16.1***
Prince Albert	2019	9.5	15.8	17.4	15.1	14.5
	Long-term	***10.4***	***15.3***	***18.0***	***16.7***	***15.1***
Redvers	2019	9.5	16.3	18.5	16.6	15.2
	Long-term	***12***	***16***	***19***	***18***	***16.3***
Scott	2019	*9.1*	*14.9*	*16.1*	*14.4*	*13.6*
	Long-term	***10.8***	***14.8***	***17.3***	***16.3***	***14.8***
Swift Current	2019	*9.5*	*15.8*	*17.7*	*16.8*	*15.0*
	Long-term	***11***	***15.7***	***18.4***	***17.9***	***15.8***
Yorkton	2019	8.6	16	18.3	16.1	14.8
	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 2019 growing seasons at 8 sites in Saskatchewan.						
Location	**Year**	**May**	**June**	**July**	**August**	**Avg. / Total**
		---------------------------- *Precipitation (mm)* ------------------------				
Indian Head	2019	13.3	50.4	53.1	96.0	212.8
	Long-term	***51.7***	***77.4***	***63.8***	***51.2***	***241.4***
Melfort	2019	18.8	87.4	72.7	30.7	209.6
	Long-term	***42.9***	***54.3***	***76.7***	***52.4***	***226.3***
Outlook	2019	13.2	90.2	43.8	39.6	186.8
	Long-term	***42.6***	***63.9***	***56.1***	***42.8***	***205.4***
Prince Albert	2019	30.0	54.4	57.4	16.8	158.6
	Long-term	***44.7***	***68.6***	***76.6***	***61.6***	***251.5***
Redvers	2019	18.3	59.7	34.0	85.1	197.1
	Long-term	***60***	***91***	***78***	***64***	***293***
Scott	2019	12.7	97.7	107.8	18	236.2
	Long -term	***38.9***	***69.7***	***69.4***	***48.7***	***226.7***
Swift Current	2019	13.3	156	11.1	42.6	223
	Long-term	***42.1***	***66.1***	***44***	***35.4***	***187.6***
Yorkton	2019	11.1	81.6	49.1	32.2	174
	Long-term	***51***	***80***	***78***	***62***	***272***

4Rs-Fall and Spring Applied Urea on Spring Canola

Mike Hall[1] and Heather Sorestad[1]

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

Abstract/Summary:

A trial was conducted near Yorkton with the objective of demonstrating the effect of timing, placement and product on nitrogen efficiency and yield of canola. The trial was designed to compare 80 lb N/ac of side-banded urea against fall or spring broadcast applications of urea, AGROTAIN, SUPERU and ESN at the same rate of N. Broadcast applications of urea did not significantly result in less canola yield compared to side-band applications as expected. The nitrogen use efficiency of urea broadcasted in either fall or spring was high as adequate rainfall to incorporate the product was received shortly after application. However, when averaged over product, broadcast applications produced significantly more yield when applied in spring compared to fall. When averaged over timing, broadcasting AGROTAIN and SUPERU produced 3% more yield than straight urea by likely reducing nitrogen loss to volatilization and/or denitrification. In contrast, broadcasted ESN resulted in less yield compared to urea as the total release of urea may have been too late to maximize yield. The results from this study demonstrated some of the “Right Time” and “Right Product” concepts of 4 R’s nitrogen management.

Project objectives:

The objectives of this project are:

- To demonstrate poorer N efficiency of fall and spring broadcast applications of urea relative to spring banding.

- To demonstrate improved N efficiency by broadcasting products such as SUPERU, AGROTAIN and ESN over straight urea.

Project Rationale:

The average farm in western Canada is becoming larger, therefore producers are looking for ways to become more efficient. Banding urea at seeding is known to be the most effective way of reducing N losses to the environment, however it slows down seeding. Therefore broadcast applications of urea are becoming more appealing to large producers, but producers must be aware of the potential risk. Broadcast applications of urea are more prone to volatilization if not incorporated by sufficient and timely rainfall. If moisture is excessive, nitrate can be lost to leaching and denitrification. Denitrification occurs in water-logged anaerobic soils where microbes use nitrate as an oxygen source. These losses are more likely to occur with fall applications. There are a number of products available to reduce the risks of volatilization and denitrification.

SUPERU is a specialized form of urea, which provides some added protection from 3 pathways of nitrogen loss. SUPERU slows the conversion of urea to ammonia, which protects the granules from volatilization (gassing off). It also slows the conversion of ammonium to nitrate which reduces the loss of N to leaching and denitrification. AGROTAIN also provides protection from volatilization but does not reduce the risk of denitrification. Both of these products provide protection whether broadcasted in fall or spring. ESN is a polymer coated product that is best suited for fall applications. It protects the urea by slowing its release. Spring broadcast applications of ESN may result in yield loss as the release of N may be too slow.

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 setup as a Randomized Complete Block Design (RCBD) with 4 replicates. Plot size was 11 by 30 feet and seeded with a 10 foot Seedmaster drill on 12 inch spacings. Monoammonium phosphate (MAP) was seed placed at 49 lb/ac and ammonium sulphate (AS) was side banded at 62.5 lb/ac. The middle 4 rows in each plot were harvested for yield with a Wintersteiger plot combine. The following treatments were applied to DKTF94CR canola:

1. 0 Nitrogen
2. 0.5 X[a] Nitrogen- spring side banded urea
3. 0.75 X[a] Nitrogen – spring side banded urea
4. 1 X[a] Nitrogen- spring side banded urea
5. 1 X[a] Nitrogen- fall broadcast urea
6. 1 X[a] Nitrogen- fall broadcast AGROTAIN
7. 1 X[a] Nitrogen- fall broadcast SUPERU
8. 1 X[a] Nitrogen- fall broadcast ESN
9. 1 X[a] Nitrogen- spring broadcast[b] urea
10. 1 X[a] Nitrogen- spring broadcast[b] AGROTAIN

11. 1 X[a] Nitrogen- spring broadcast[b] SUPERU
12 1 X[a] Nitrogen- spring broadcast[b] ESN

[a]1X nitrogen rate was 80 lb N/ac and was based on a soil test recommendations for a modest 40 bu crop of canola. All treatments received some additional N that comes with the application of MAP and AS.
[b]Spring broadcast applications were applied by hand post seeding but prior to the 2 leaf stage.

Table 1 lists dates of operation.

Table 1. Dates of operations in 2019 for the 4Rs-Fall and Spring Applied Urea on Spring Canola trial.

Activity	Yorkton
Fall N Broadcast Application	Oct 4
Spring N Broadcast Application	June 4
Pre-seed Herbicide Application	n/a
Seeding	May 14
Emergence Counts	June 6
Insecticide Application	n/a
In-crop Herbicide Application	June 10 (Roundup 0.33 L/ac), June 18 (Roundup 0.35 L/ac), June 26 (Centurion 150 ml/ac +Amigo)
In-crop Fungicide Application	July 9 (Lance 140g)
Lodging Rating	Sept 3
Desiccant	n/a
Harvest	Sept 13

Results:

The trial established well and emergence was excellent, averaging 113 plants/m^2 which did not statistically differ between treatments (Table 3). Increasing side-banded urea from 0 to 80 lb N/ac (1X rate) significantly increased canola yield by roughly 40% (Table 3). Whether applied in spring or fall, straight urea, AGROTAIN and SUPERU provided yields similar to the same rate of N side-banded in spring. As a result, the study failed to demonstrate that side-banded urea was more N efficient than broadcast applications. Broadcast applications in fall and spring performed well as they were incorporated into the ground and protected from volatilization loss by sufficient and timely rainfall. Few significant differences between treatments 5 to 9 could be detected when the whole trial was analyzed as a single factor RCBD. However, significant differences were apparent when those treatments were analyzed as a 2 order factorial (Table 3a). Averaged across product, broadcast applications of N significantly produced 4.6% less yield when applied in fall compared to spring. Fall applied N may have performed more poorly because the potential for N losses to denitrification and leaching would be greater relative to a spring application. When averaged across timing, the use of ESN significantly resulted in 8% less yield compared to either AGROTAIN or SUPERU (Table 3a). Though not statistically significant, the yield resulting from straight urea was about 3% lower compared to using AGROTAIN or SUPERU. The relatively superior performance of AGROTAIN and SUPERU is likely the result of reduced levels of volatilization. ESN may not have performed well because the release of N might have been too slow. It takes time for the polymer coating to break down and release the urea. This is why ESN is not typically recommended for spring broadcast applications targeting yield.

Conclusions and Recommendations:

This study found N use efficiency as indicated by higher yields could be improved by broadcasting urea products in spring instead of fall. In addition, AGROTAIN and SUPERU tended to produce higher yields over straight urea. Applying all the N requirement as ESN tended to reduce yields by likely delaying the release of urea. The result from this study support the "Right Time" and "Right Product" concepts of 4 R's nitrogen management.

Supporting Information

Acknowledgements:

This project was funded through Agricultural Demonstrations of Practices and Technologies and Fertilizer Canada.

Appendices:

Table 3. Effect of Nitrogen Treatment on Emergence and Yield of Canola.		
	Emergence (plants/m^2)	**Yield (kg/ha)**
Variety		
1. 0 Nitrogen	115 a	2185.5 f
2. 0.5 X[a] Nitrogen- spring side banded urea	113.8 a	2774.8 de
3. 0.75 X[a] Nitrogen – spring side banded urea	105.5 a	3082.3 a
4. 1 X[a] Nitrogen- spring side banded urea	118.5 a	2949.3 abcd
5. 1 X[a] Nitrogen- fall broadcast urea	115.5 a	2815.5 bcde
6. 1 X[a] Nitrogen- fall broadcast AGROTAIN	123.5 a	2881.3 abcde
7. 1 X[a] Nitrogen- fall broadcast SUPERU	123.8 a	2907.8 abcde
8. 1 X[a] Nitrogen- fall broadcast ESN	118.3 a	2682.8 e
9. 1 X[a] Nitrogen- spring broadcast[b] urea	119.5 a	2956.5 abcd
10. 1 X[a] Nitrogen- spring broadcast[b] AGROTAIN	95.8 a	3046.6 ab
11. 1 X[a] Nitrogen- spring broadcast[b] SUPERU	102.8 a	3029.3 abc
12. 1 X[a] Nitrogen- spring broadcast[b] ESN	98 a	2795 cde
P-values	NS	<0.00001
LSD	NS	243.5

Table 3a. Main Effects of Broadcast Timing and Product on Yield of Canola 2019.

Main Effects	**Yield (kg/ha)**
Broadcast Timing (T)	
Fall	2821 b
Spring	2956 a
$Lsd_{0.05}$	126
Product (P)	
Urea	2886 ab
Agrotain	2964 a
SuperU	2969 a
ESN	2739 b
$Lsd_{0.05}$	178

[a]Means within a main effect followed by the same letter are not significantly different p=0.05

4Rs-Reviving Forage Stands with Nitrogen Enhancer Products applied in fall

Mike Hall[1] and Heather Sorestad[1]

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

Abstract/Summary:

A trial was established on an old hayland stand consisting of 80% smooth brome and 20% alfalfa near Yorkton. The objective was to demonstrate the effectiveness of using nitrogen enhancer products such as ESN, AGROTAIN and SUPERU applied in fall to reduce N losses and revive an old grass dominated forage stand. Despite a lack of fall rainfall to quickly incorporate products and a strong second cut yield response to added N, no yield increase from using any of the N enhancer products could be detected. However, yield was numerically higher indicating there may have been some minor benefit from using these products.

Project objectives:

To demonstrate the effectiveness of using nitrogen enhancer products in fall to revive an old grass dominated forage stands.

Project Rationale:

The intended benefit is to show producers that nitrogen fertilizer application can help rejuvenate old forage stands, and nitrogen enhancer products can improve nutrient use efficiency if fertilizer is applied at a less ideal time, such as fall or under dry conditions. While early spring application is believed to be the most effective, late fall applications may be more practical due to road bans, time constraints and wet soils. With fall applications of N, there is greater potential for N to be lost through volatilization, leaching and runoff. Nitrogen enhancer products, like AGROTAIN, SUPERU and ESN can help to reduce these losses. SUPERU is a specialized form of urea, which provides some added protection from 3 pathways of nitrogen loss. SUPERU slows the conversion of urea to ammonia, which protects the granules from volatilization (gassing off). It also slows the conversion of ammonium to nitrate which reduces the loss of N to leaching and denitrification. AGROTAIN also provides protection from volatilization but does not reduce the risk of denitrification. ESN is a polymer coated product that slows the release of urea. The use of enhancer products could further increase yields. This project will touch on some of the 4 R principals including right rate, source and time and will reinforce the importance of nutrient stewardship principles towards sustainable farming.

Methodology and Results

Methodology:

The trial was set up as a randomized complete block with 4 replicates on an old brome/alfalfa stand (alfalfa is less than 20% of the stand). Plot size was 11 by 30 feet and fertilizer treatments were broadcasted by hand. The following treatments listed in Table 1 were applied in the fall of 2018.

Table 1. Treatment List for 4Rs-Reviving Forage Stands with Nitrogen Enhancer Products applied in fall trial.

Treatment #	Application date	Rate (lb N/ac)	Nitrogen Form
1	Fall	0	None (control)
2		45	Urea
3			ESN
4			AGROTAIN
5			Super U
6		90	Urea
7			ESN
8			AGROTAIN
9			Super U

The forage stand used for this project was very deficient in all macro nutrients, so each treatment received adequate P, K and S fertilizer. The following year, each plot was harvested using a plot forage harvester. Wet weights were recorded and then converted to dry weights based on a dried subsample. Dates of operations are listed in Table 2 below.

Table 2. Dates of operations in 2019 for the 4Rs-Reviving Forage Stands with Nitrogen Enhancer Products applied in fall

Operations in 2019	Yorkton
Broadcast of Fertilizer	Oct 4, 2018
Harvest of Forage	June 26, 2019
2nd Harvest of Forage	Aug 8, 2019

Results:

The first (cut) harvest of forage had no significant differences in yield whether all treatments were analysed as a single factor RCBD or a 2 factor RCBD for treatments 2-9 (Tables 4 and 5). Forage yields were relatively low for the first cut because the spring was cool and dry. This lack of early spring growth is likely the reason differences between treatments were not apparent. Significant differences between some treatments were apparent for the second cut (Tables 4 and 5). When analysed as a 2 level factorial, increasing rate of N from 45 to 90 lb/ac significantly increased forage dry weights by from 1202 to 1538 kg/ha which is 28% (Table 5). The no fertilizer check only yielded 901 kg/ha (Table 4). Despite a significant forage yield response to added N, no significant differences between products could be detected (Table 5). However, yields were numerically lower for the unprotected urea for both the first a second cuts.

Conclusions and Recommendations:

While forage yields were numerically lower with straight urea for both the first and second cuts, no yield increases from using ESN, AGROTAIN or SUPERU could be statistically detected relative to straight urea despite conditions conducive for volatilization as rainfall was not timely after application. Only increasing rate of N from 45 to 90 lb/ac significantly increased the forage yield and this was only for the second cut. First cut yields were low and unresponsive to the added N because early spring was cool and dry.

Acknowledgements:

This project was funded through the Agricultural Demonstrations of Practices and Technologies and Fertilizer Canada.

Table 4. Significance of main effects of Nitrogen Products and Rates on Forage Dry Yield.

	1st Cut Dry Yield (Kg/ha)	**2nd Cut Dry Yield (Kg/ha)**
Nitrogen Product x Rate		
1. 0 lb N/ac	864 a	901.3 e
2. 45 lb N/ac urea	746.5 a	1136.5 de
3. 45 lb N/ac ESN	998.8 a	1223.8 cd
4. 45 lb N/ac AGROTAIN	1086 a	1163.3 de
5. 45 lb N/ac SUPERU	1025.8 a	1284.5 bcd
6. 90 lb N/ac urea	1002.3 a	1493 abc
7. 90 lb N/ac ESN	951.8 a	1566.8 ab
8. 90 lb N/ac AGROTAIN	787 a	1701 a
9. 90 lb N/ac SUPERU	1086 a	1392 bcd
P-values	NS	0.000492
LSD	NS	305.13

Table 5. Significant of a 2 level factorials main effects of Nitrogen Products (P) and Rates (R) on Forage Dry Yield		
Nitrogen Rate (lb N/ac)	**1st Cut Dry Yield (Kg/ha)**	**2nd Cut Dry Yield (Kg/ha)**
45	964	1202
90	957	1538
LSD	NS	156.7
Nitrogen Product		
Urea	874	1315
ESN	975	1395
AGROTAIN	937	1432
SUPERU	1056	1338
LSD	NS	NS
P-values		
R (rate)	NS	0.000216
P (product)	NS	NS
R*P	NS	NS

Increasing Wheat Protein with a Post Emergent Applications of UAN vs Dissolved Urea

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[7]Western Applied Research Corporation, Scott, SK
[8]Wheatland Conservation Area Inc., Swift Current, SK

Abstract/Summary:

Trials were conducted at Yorkton, Redvers, Indian Head, Swift Current, Scott, Outlook, Prince Albert and Melfort to demonstrate the potential of split applications of nitrogen to either increase yield or grain protein of spring wheat. Split applications of N at the boot stage did not tend to affect yield or protein but a latter application post-anthesis tended to increase protein and decrease yield relative to applying all the N at seeding. Dribble banding UAN at the earlier boot stage did not cause damage to the flag leaf because it was not fully emerged at the time of application. Flag leaf burn from split applications of N post-anthesis were worse with UAN compared to dissolved urea, particularly when applied as a broadcast foliar spray compared to dribble banding. However, differences in yield or protein were not usually detected between

applications UAN compared dissolved urea. In contrast, grain protein tended to be higher with broadcast applications compared to dribble band applications and this difference was large and statistically significant at Indian Head. While there were many cases were split N resulted in greater grain protein, the lower yield and extra cost of application meant few cases proved economical compared to applying all the N at seeding, even assuming a wide protein spread of 66 cents/%/bu.

Project Objectives:

The overall objective of this project was to demonstrate the potential of an additional 30 lb N/ac applied late season to increase either wheat yield or grain protein compared to applying all nitrogen (N) at seeding. The impact of nitrogen source, crop staging and application method were compared.

Specifically, the intent was to demonstrate the following concepts:

a. Dribble banded applications of UAN cause less flag leaf burn than broadcast foliar sprays post-anthesis.
b. Dribble banding UAN at the earlier boot stage causes less flag leaf burn than when applied post-anthesis.
c. Diluting dribble band applications of UAN is not necessary and may actually increase leaf burn.
d. When broadcast foliar sprays are applied post-anthesis, dissolved urea will result in less leaf burn than UAN applied as a solution of 14% nitrogen.
e. Strategies resulting in less leaf burn will produce a better yield/protein response (ie: more protein/ac).

Project Rationale:

Recently, producers have been disappointed by low levels of grain protein. When regional protein levels are low, the premiums offered for high protein wheat tend to increase. This has left producers wondering what can be done to increase protein levels in the future. Many studies, dating back the 1990s, have shown post-emergent applications of nitrogen can increase grain protein when made at late vegetative stages. Guy Lafond assessed the feasibility of applying foliar N at both the boot stage and post-anthesis for spring and winter wheat [1]. He determined that this practice had merit but the results could be variable depending on initial N supply and weather conditions. However, dribble banding at the earlier boot stage increased grain protein more consistently and reduced the potential for leaf burn. UAN (28-0-0) produces large drops that do not disperse on the leaf surface because they have a high surface tension and tend to roll off. Dilution may reduce surface tension and actually increase leaf burn [2] or increased leaf burn may just be a function of a higher volume applied.

Western Canadian research has found little reason to support the use of broadcast foliar sprays over dribble banding. Broadcast foliar sprays cause more leaf burn and since little nitrogen is actually absorbed through the leaves there is little benefit to the practice. The University of Manitoba found recovery of foliar applied 15N labelled urea (in solution) was only 4-27% compared to 32-70% with soil application. Under field conditions with foliar UAN, most of the uptake occurs after rainfall events wash the N to the soil where it is taken up through roots [3].

Despite these results, broadcast foliar sprays post-anthesis are popular in the northern United States and are practiced in Manitoba. The general recommendation is to dilute UAN 50:50 with water and spray when conditions are cool to reduce leaf burning. While foliar applications of UAN post-anthesis frequently increase protein, this practice does not always prove to be economical. Research lead by John Heard with Manitoba Agriculture evaluated the benefit of post-anthesis UAN on 15 farm sites from 2015 to 2016 [4]. The impact on protein was largely positive and statistically significant 60% of the time. On average, protein of CNHR varieties was increased 0.6% when an additional 30 lb N/ac was applied post-anthesis. However, post-anthesis UAN only proved to be economical at 2 of 15 sites and premiums for higher protein concentrations are not guaranteed.

Broadcast foliar sprays with dissolved urea, instead of UAN may prove to be more beneficial. Amy Mangin with the University of Manitoba recently found broadcast foliar sprays of dissolved urea sprayed post-anthesis not only resulted in less leaf burn but also produced greater yields and higher grain protein compared to UAN [5]. Dissolved urea is a standard product used for foliar applications in the UK and is considered to be safer on the crop than UAN. While both UAN and dissolved urea were applied at 30 lb N/ac in Mangin's study, the % N concentration of the solutions differed between the products. The UAN solution was 14%, whereas the urea solution was only 9%. This may have also contributed to the greater crop safety observed with dissolved urea. In our demonstration, dissolved urea and UAN will be compared at a 14% solution of N. Producers can create their own solution of urea on farm, however, care must be taken as dissolving urea is extremely endothermic and can freeze lines. Urea should be dissolved slowly into warm water and not into cold water pulled from a well for example. In addition, producers should only dissolve urea with less than 1% biuret. Biuret is a by-product that can cause severe leaf burning, but it is normally not a concern with urea manufactured in North American.

[1] Lafond, G and J. McKell. 1998. The Effects of Foliar Applied Nitrogen on Grain Protein Concentration in Spring and Winter Wheat. Proceedings of the Wheat Protein Symposium 298-304

[2] Stu Brandt personal communication

[3] Rawluk, C. D. L., Racz, G. J. and Grant, C. A. 2000. Uptake of foliar or soil application of 15N-labelled urea solution at anthesis and its affect on wheat grain yield and protein. Can. J. Plant Sci. 80: 331–334.

[4] Heard, J., Sabourin, B., Faroq, A. and L. Kaminski. On-farm-tests evaluate nitrogen rate, source and timing for spring wheat yield and protein. Poster.

[5]http://umanitoba.ca/faculties/afs/agronomists_conf/media/7__1_30_PM_DEC_14_MANGIN_MAC_2017_NOV23.pdf

[6] personal communication with Chris Holzapfel

Methodology:

The treatments were arranged in a Randomized Complete Block Design (RCBD) with 4 replicates. Plot size, row spacing, and fertilizer application techniques at seeding varied between locations depending on equipment. Treatments are listed in Table 1 below. UAN (28-0-0) treatments were applied either undiluted or cut in half with water to create 14-0-0. Likewise, 14-0-0 of melted urea was created by diluting 1.66 kg of 46-0-0 per US gallon of water. Urea with less than 1% biuret was used to ensure optimum crop safety. The rate used for all post-emergent applications of nitrogen provided an extra 30 lb N/ac to a base rate of 70 lb N/ac that was side-banded at seeding. These treatments were compared to base rates of 70 and 100 lb N/ac (treatments 1 and 2, no post-emergent N applied) to determine if there were responses to the post-emergent N and/or any benefits from split applying N versus simply side-banding the extra 30 lb N/ac during seeding. Comparisons between treatments 3-9 determined if N source, application method or timing influences crop safety, yield or protein responses.

Table 1. Treatment List for the Increasing Wheat Protein with a Post Emergent Applications of UAN vs Dissolved Urea Trial

Treatment #	**Seeding**	**Post emergence application**				
	Lb N/ac of Side- banded Urea	N (lb/ac)	Product	%N	method	Stage
1	70	na	na	na	na	na
2	100	na	na	na	na	na
3	70	30	UAN	14	dribble[1]	boot
4	70	30	UAN	28	dribble[2]	boot
5	70	30	UAN	14	dribble[1]	Post-anthesis
6	70	30	UAN	28	dribble[2]	Post-anthesis
7	70	30	Urea Sol'n	14	Dribble [3]	Post-anthesis
8	70	30	UAN	14	foliar[4]	Post-anthesis
9	70	30	Urea Sol'n	14	foliar[5]	Post-anthesis

[1] Sprayed with dribble band nozzle at 20 gal/ac (10 gal/ac UAN + 10 gal/ac water = 14% N solution)
[2] Sprayed with dribble band nozzle at 10 gal/ac (undiluted UAN =28% N solution)
[3] Sprayed with dribble band nozzle at 20 gal/ac (1.66 Kg of urea dissolved in 1 US gallon of water = 14% N solution)
[4] Sprayed with 02 flat fan nozzles at 20 gal/ac (10 gal/ac UAN + 10 gal/ac water = 14% N solution)
[5] Spray with 02 flat fan nozzles at 20 gal/ac (1.66 Kg of urea dissolved in 1 US gallon of water = 14% N solution)

Dates of operation are listed in Table 2 below.

Table 2. Dates of operations in 2019 for the Increasing Wheat Protein with a Post Emergent Applications of UAN vs Dissolved Urea trial								
	---------------------------Date---------------------------							
Activity	**Indian Head**	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
Pre-seed Herbicide Application	May 12 Roundup Weatherma x 540 (0.67L/ac)	May 24 Glyphosate + Heat	N/A	N/A	N/A	May Glyphosate 540 (1L/ac) + AIM (35 ml/ac)	May 7 Glyphosate	N/A
Seeding	May 14	May 24	May 15	May 23	May 7	May 14	May 8	May 13
Emergence Counts	June 3	June 26	N/a	June 13	June 5	June 11	June 17	June 12
In-crop Herbicide Application	June 17 OcTTain XL (0.45L/ac) + Simplicity GoDRI (28g/ac)	June 27 Axial July 4 Prestige XC	June 10 Badge II (500 mL/ac) + Simplicity (21 gm/ac)	June 19 Axel Extreme, MCPA, Kinetic Copron	June 10 Clodinafop (283 mL/ac) + Buctril M (0.4mL/ac)	June 26 Axial (0.5 L/ac) + Buctril M (0.4 L/ac)	June 14 Varro (200ml/ac) + Octtain XL (450ml/ac) + Agral90 (25l/100L)	June 12 Simplicity + Prestige June 25 MCPA (200ml/ac) July 3 MCPA (200ml/ac)
Boot N application	July 3	July 16	July 6	July 9	July 3	July 4	July 3	July 3
Post-anthesis N application	July 20	Aug 8	July 19	July 26	July 20	July 23	July 29	July 19
Leaf Burn Rating	July 25	Aug 16	July 22	July 19 and July 29	N/A	July 11, 18, 30 & Aug 5	N/A	July 25

In-crop Fungicide Application	July 11 Prosaro (0.325 mL/ac)	N/A	July 18 Caramba (400 mL/ac)	June 19 Pivot 418EC	July 12 Caramba (400mL/ac)	N/A	July 10 Acapella (250ml/ac)	July 11 Caramba July 14 Caramba
Lodging Rating	Aug 9	N/A	N/A	Sept 23	Sept 7	N/A	Aug 19	Sept 3
Desiccant	Aug 28 Roundup Weatherma x 540 (0.67L/ac)	N/A	N/A	Sept 5 Glyphosate	N/A	Sept 6 Heat LQ (42.8 mL/ac) + Roundup 540 (0.67 L/ac) + Merge (0.2 L/ac)	N/A	Sept 3 Roundup Transorb (0.66l/ac)
Harvest	Sept 6	Oct 6	Sept 24	Sept 23	Sept 7	Sept 22	Aug 21	Sept 16

Soil test Nitrate levels for each location are presented in Table 5. Swift Current had very high background levels and levels were relatively high at Redvers. Soil N was low at Outlook. The remaining sites had more typical levels of soil N in the 30 to 50 lb/ac range.

Table 5. Soil Test Nitrate Levels for each location (lb N/ac).

Nitrate Levels (lbs NO_3-N/ac)	Indian Head	Melfort	Outlook	Prince Albert	Redvers	Scott	Swift Current	Yorkton
0-15cm (0-6in)	16	18	6	15	29	14	42	14
15-30cm (6-12in)				10				
15-60cm (6-24in)	33	17	9		42	18	186	18
Total 0-60cm (0-24in)	49	35	15	37.5[1]	71	32	228	32
Total 0-30cm (0-12in)				25				

[1]Estimation (25 lb N/ac*1.5)

Dates of application for post-emergent applications of N are given in Table 6 along with temperature at the time of application and rainfall pattern after application. It is recommended that post-emergent applications of N occur at temperatures below 20°C to reduce leaf burning. For the most part, applications did not occur when temperatures were excessively hot. Sufficient rainfall to move N applied applied at the boot stage was received within a week at Melfort, Outlook, Redvers, Scott and Yorkton. Sufficient rainfall was received within two weeks at Indian Head and Redvers. At Swift Current, sufficient rainfall was not received for over a month. After the post-anthesis application, sufficient rainfall was not received within 2 weeks and in many cases was considerably later.

Table 6. Date of Post-Emergent Nitrogen Application, Temperature and Amount of Rain after Post-Emergent Nitrogen Application.						
	Date of Application		**Temperature During Application**		**Next Significant Rainfall after Post-emergent N Application**	
	Boot	Post-Anthesis	Boot	Post-Anthesis	Boot	Post-Anthesis
Indian Head	July 3	July 20	18-20ºC	17-18ºC	July 13 – 17 (30mm)	Aug 9- 12 (61mm)
Melfort	July 16	Aug 8	20.9º C	19-20ºC	July 17-18 (29.3mm)	Aug 22-23 (15mm)
Outlook	July 6	July 19	16.3º C	15.5ºC	July 14-16 (22.4mm) + Irrigation July 9 and 11 (20.5mm)	Aug 22 (22.8mm) + Irrigation Aug 1 (12.5mm)
Prince Albert	July 9	July 26	19ºC	22ºC	July 17-19 (24.3 mm)	Sept 2 (16.2 mm)
Redvers	July 3	July 20	18-20 ºC	19-21ºC	July 9 (21.3mm)	Aug 12 (20.3mm)
Scott	July 4	July 23	17.9º C	15.7ºC	July 11-12 (12mm) & July 19-20 (28.7mm)	Aug 7-8 (31.6mm)
Swift Current	July 3	July 29	18ºC	18-22ºC	Aug 11-12 (35.4mm)	Aug 11-12 (35.4mm)
Yorkton	July 3	July 19	20ºC	14ºC	July 6 (20.7mm)	Aug 25-27 (20.2)

General Emergence, Yield and Protein Comparisons between locations

Wheat emergence was reported from all locations except Outlook. Average stands of 402 plants/m^2 were on the high side at Swift Current and plant populations of 180 and 172/m^2 were on the low side at Melfort and Redvers, respectively. Average plant populations of 214, 205, 229 and 252/m^2 were at satisfactory levels at Prince Albert, Indian Head, Scott and Yorkton, respectively. Increasing the rate of side-banded urea from 70 to 100 lb N/ac (trt 1 vs 2) tended to decrease emergence modestly at most locations which is fairly typical (data not shown).

Average wheat yields and grain proteins varied between locations (Tables 7 and 8). Sites with higher yields tended to have lower proteins. Wheat yields were highest at Outlook under irrigation, averaging 7507 kg/ha (111 bu/ac) with a grain protein of 12.5%. At Yorkton, Redvers and Melfort yields were relatively high averaging 5780, 5041 and 5179 kg/ha with grain proteins of 12.4, 14.9, and 11.5%, respectively. Swift Current, Scott, Prince Albert and Indian Head had lower yields averaging 3185, 3938, 3753 and 3316 kg/ha and relatively higher proteins averaging 16.9, 14.6, 14.4, 16.0 %, respectively.

Effect of N management on Leaf Burn, Yield and Protein

Increasing side-banded N from 70 to 100 lb/ac increased yield and grain protein at all locations except Redvers, where yield decreased by 8.3% and Swift Current, where protein dropped by 0.9%. Both the loss in yield and protein were unexpected and can only be attributed to experimental variation. However, when averaged across locations, increasing the rate of side-banded urea from 70 to 100 lb N/ac increased yield and protein by 199 kg/ha (2.96 bu/ac) and 0.2%, respectively (Tables 7, 8 and Figure 1). On average, split applications of N at the boot stage did not tend to effect grain yield or protein relative to placing all the N down at seeding (treatment 2 -100 lb N/ac side-banded urea). However, a latter application post-anthesis produced 0.29% more protein and resulted in 2.7% less yield compared to treatment 2. This is not usual as latter season applications of N are more likely to cause increases in protein over increases in yield. For either of the boot or post-anthesis timings, dribble banding diluted UAN (14%N) resulted in smaller yield reductions and protein increases compared straight UAN (28% N). The reason for this is unclear as 30 lb N/ac was applied in both cases. If straight UAN (28 %N) was resulting in more protein due to greater crop injury and subsequent reductions in yield it was not apparent based on visual observations of leaf burn which did not significantly or consistently differ between concentrations of UAN (Table 9).

While split applications post-anthesis tended to result in higher grain protein but lower yield, the relative impact between the different split applications on leaf burn, yield and grain protein differed between locations. Dribble band applications of N at the boot stage did not cause leaf burn of the flag because it was not fully emerged at the time of spraying. For post-anthesis applications, UAN tended to cause more leaf burn than dissolved urea and broadcast foliar spray applications of N tended to cause more leaf burn than dribble band applications.

UAN (14% N) caused more leaf burn than dissolved urea (14% N) when dribble banded post-anthesis at Indian Head, Melfort, Prince Albert and Yorkton (Table 9). UAN also caused significantly more flag leaf burn than dissolved urea when applied as a broadcast foliar spray application at Indian Head, Outlook, Prince Albert, Scott and Yorkton. However, these differences did not significantly affect yield or protein at most locations except for Outlook, where grain protein was significantly higher when dribble banding UAN instead of dissolved urea.

The tendency for broadcast applications to cause more leaf burn that dribble band applications was more apparent with UAN compared to dissolved urea. For UAN, broadcast foliar spray applications caused significantly more leaf burn than dribble banding at Indian Head, Outlook and Prince Albert. In contrast, broadcast foliar spray application of dissolved urea only significantly caused more leaf burn than dribble banding at Prince Albert. Broadcast foliar spray applications of UAN or urea did not tend to affect yield compare to dribble band applications but did tend to increase grain protein. This difference was large and statistically significant at Indian Head.

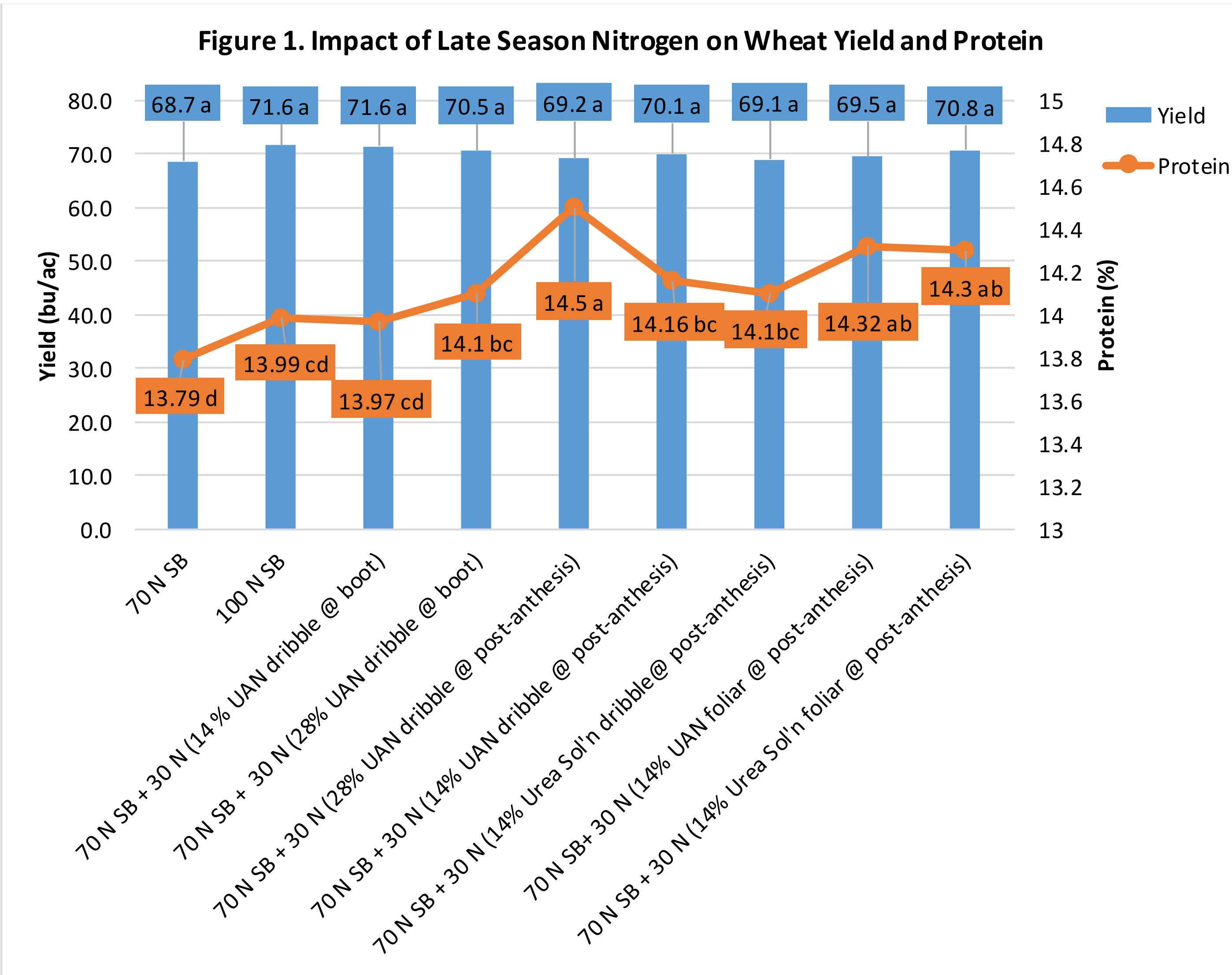

Figure 1. Impact of Late Season Nitrogen on Wheat Yield and Protein
Yield (bu/ac)
Protein (%)
Yield
Protein
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
15
14.8
14.6
14.4
14.2
14
13.8
13.6
13.4
13.2
13
68.7 a
71.6 a
71.6 a
70.5 a
69.2 a
70.1 a
69.1 a
69.5 a
70.8 a
13.79 d
13.99 cd
13.97 cd
14.1 bc
14.5 a
14.16 bc
14.1bc
14.32 ab
14.3 ab
70 N SB
100 N SB
70 N SB + 30 N (14 % UAN dribble @ boot)
70 N SB + 30 N (28% UAN dribble @ boot)
70 N SB + 30 N (28% UAN dribble @ post-anthesis)
70 N SB + 30 N (14% UAN dribble @ post-anthesis)
70 N SB + 30 N (14% Urea Sol'n dribble@ post-anthesis)
70 N SB+ 30 N (14% UAN foliar @ post-anthesis)
70 N SB + 30 N (14% Urea Sol'n foliar @ post-anthesis)

Economic Analysis

As discussed earlier, many of the split applications of N post-anthesis resulted in higher grain protein compared to applying all the N at seeding (trt 2), but they also tended to produce lower yields. As a result of lower yields and additional costs associated with a split application, there were very few cases where a split application of N proved to be more economical than just putting all the N down at seeding, even when assuming a large protein premium spread of 66 cent/%/bu. The following discussion lays the case for this conclusion.

Table 10 shows an economic analysis based on grain yields and protein averaged over all locations. Gross ($/ac) for each treatment are based on the yield (bu/ac) for the treatment multiplied by a base price of $6.75/bu. A protein premium ($/ac) relative to treatment 1 was calculated using a protein spread of 66 cents/%/bu. The cost of N ($/ac) for each treatment assumed $0.50/ lb N. Where applicable the extra cost of making a split application was assumed to be $5/ac. The last column of table 10 shows the summation of Gross ($/ac) plus any protein premium ($/ac) minus the cost of N ($/ac) minus the cost of making an extra pass for the split application. These values can now be used to make fair economic comparisons between treatments.

Based on these assumptions, increasing the rate of side-banded N from 70 to 100 lb/ac increased gross returns by $14.02/ac ($442.75/ac - $428.73/ac –difference between treatments 1 and 2) when averaged across locations (Table 10). Only 2 of the 7 treatments where 30 lb N/ac was split applied to a base rate of 70 lb N/ac of side-banded urea gave greater economic returns compared to simply side-banding all the N (100 lb/ac) at seeding (treatment 2). Where greater economic returns existed, the difference was less than $4/ac which would hardly justify the extra effort of a split application. However, the relative economics between treatments varied among sites.

Table 11 compares the economics between treatments for each location. None of the split applications of N proved more economical then just side-banding all the N (100 lb/ac) at seeding for Yorkton, Scott, Melfort and Indian Head. Even though foliar applications resulted in substantially higher protein at Indian Head, the lower associated yield with those treatments resulted in lower economic returns. At the remaining sites, there were some split applications of N that were more economic. At Outlook, dribble banding UAN (28% N) post-anthesis resulted in substantial economic gains because protein was significantly higher with this treatment. The reason for the protein bump is unclear; however, this trend was also apparent at Prince Albert, Redvers and Swift Current. At Prince Albert, the split application treatments which were more profitable generally benefited from higher yields, not increased protein. At Swift Current, the economic returns for the 100 lb N/ac side-band check (treatment 2) were unexpectedly low due to a very low protein level, so comparisons against this check are questionable. However, a broadcast foliar spray of dissolved urea post-anthesis produced relatively high yield, protein and returns. At Redvers, yield was unexpectedly low with the 100 lb N/ac side-band check. Again, this makes comparisons against this check questionable. However, economic returns of split applications did not look much better than the 70 lb N/ac side-band check which had the benefit of lower input costs and less intensive management (i.e. one less pass with the sprayer). Overall, split applications of N were largely uneconomical even though a large protein spread (66 cents/%/bu) was assumed at each location regardless of protein level.

Conclusions and Recommendations:

Split applications of N at the boot stage did not tend to affect yield or protein but a latter application post-anthesis tended to increase protein and decrease yield relative to applying all the N at seeding. Dribble banding UAN at the earlier boot stage did not cause damage to the flag leaf because it was not fully emerged at the time of application. Flag leaf burn from split applications of N post-anthesis were worse with UAN compared to dissolved urea, particularly when applied as a broadcast foliar spray compared to dribble banding. However, differences in yield or protein were not usually detected between applications UAN compared dissolved urea. In contrast, grain protein tended to be higher with broadcast applications compared to dribble band applications and this difference was large and statistically significant at Indian Head. While there were many cases were split N resulted in greater grain protein, the lower yield and extra cost of application meant few cases proved economical compared to applying all the N at seeding, even assuming a wide protein spread of 66 cents/%/bu.

Acknowledgements:

This project was funded through the Saskatchewan Wheat Development Commission.

Appendices:

Table 7. Main Effect of Nitrogen Rate, Post Emergent Nitrogen Rate, Post Emergent Nitrogen Product, Post Emergent Application Method, Post Emergent Application Timing on wheat yield at Indian Head, Melfort, Outlook, Prince Albert, Redvers, Scott, Swift Current and Yorkton in 2019.

	Yield								
	I.H.	**Melfort**	**Outlook**	**P.A.**	**Redvers**	**Scott**	**S.C.**	**Yorkton**	**All Sites**
	---------------------------------kg/ha---------------------------------								
1) 70 lb N/ac side banded	3330bc	5179 bc	7213 a	3538 a	5179 a	3830 a	3038 a	5611 a	4615 a
2) 100 lb N/ac side banded	3598 a	5566 a	7909 a	3544 a	4754 a	4018 a	3263 a	5856 a	4814 a
3) 70 lb N/ac side banded + 30 lb N/ac of 14 % UAN dribble banded @ boot	3422 ab	5331 ab	7489 a	3936 a	5144 a	3857 a	3242 a	6056 a	4810 a
4) 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ boot	3388 b	5111 bc	7795 a	3600 a	5202 a	3858 a	3239 a	5729 a	4740 a
5) 70 lb N/ac side banded + 30 lb N/ac of 14% UAN dribble banded @ post-anthesis	3226 bcd	5071 cd	7623 a	3623 a	5206 a	4002 a	3251 a	5688 a	4711 a
6) 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ post-anthesis	3378 bc	4837 d	7722 a	3720 a	5020 a	3759 a	3055 a	5715 a	4651 a
7) 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea dribble banded @ post-anthesis	3188 cd	5123 bc	7199 a	3846 a	4942 a	3950 a	3177 a	5716 a	4643 a
8) 70 lb N/ac side banded + 30 lb N/ac of 14% UAN broadcast foliar sprayed @ post-anthesis	3266 bc	5161 bc	7182 a	4026 a	4918 a	4110 a	3075 a	5636 a	4672 a
9) 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea broadcast foliar sprayed @ post-anthesis	3045 d	5232 bc	7437 a	3952 a	5012 a	4059 a	3325a	6017 a	4760 a
P-values	0.000593	0.000462	NS	NS	NS	NS	NS	NS	NS
L.S.D.	197.8129	243.635	NS	NS	NS	NS	NS	NS	NS

Table 8. Main Effect of Nitrogen Rate, Post Emergent Nitrogen Rate, Post Emergent Nitrogen Product, Post Emergent Application Method, Post Emergent Application Timing on wheat protein at Indian Head, Melfort, Outlook, Prince Albert, Redvers, Scott, Swift Current and Yorkton in 2019.

	Protein								
	I.H.	**Melfort**	**Outlook**	**P.A.**	**Redvers**	**Scott**	**S.C.**	**Yorkton**	**All Sites**
	------------------------------------%----------------------------------								
1. 70 lb N/ac side banded	15.55 c	11.28 a	12.03 c	13.68 a	14.38 e	14.48 cde	16.90 a	12.08 a	13.80 d
2. 100 lb N/ac side banded	15.85 bc	11.48 a	12.18 bc	14.55 a	14.45 de	14.73 ab	16.05a	12.65 a	13.99 cd
3. 70 lb N/ac side banded + 30 lb N/ac of 14 % UAN dribble banded @ boot	15.63 c	11.45 a	12.30 bc	14.15 a	14.65 cde	14.65bc	16.50 a	12.40 a	13.97 cd
4. 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ boot	15.65 c	11.30 a	12.70 bc	13.98 a	14.83 bcd	14.90 a	16.70 a	12.65 a	14.09 bc
5. 70 lb N/ac side banded + 30 lb N/ac of 14% UAN dribble banded @ post-anthesis	16.00 b	11.45 a	12.85 b	14.30 a	14.95 abc	14.53 cd	16.78 a	12.45 a	14.16 bc
6. 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ post-anthesis	15.75 c	11.43 a	13.83 a	14.98 a	15.28 a	14.63 bcd	17.50 a	12.63 a	14.50 a
7. 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea dribble banded @ post-anthesis	16.03 b	11.60 a	12.00 c	14.50 a	15.10 ab	14.63bcd	16.55 a	12.43 a	14.11 bc
8. 70 lb N/ac side banded + 30 lb N/ac of 14% UAN broadcast foliar sprayed @ post-anthesis	16.60 a	11.40 a	12.53 bc	14.60 a	15.20 ab	14.33 e	17.53 a	12.38 a	14.32 ab
9. 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea broadcast foliar sprayed @ post-anthesis	16.78 a	11.70 a	12.13 bc	14.50 a	14.98 abc	14.50 cde	17.50 a	12.33 a	14.30 ab
P-values	<0.00001	NS	0.000523	NS	0.001682	0.000092	NS	NS	
L.S.D.	0.34	NS	0.72	NS	0.43	0.18	NS	NS	

Table 9. Main Effect of Nitrogen Rate, Post Emergent Nitrogen Rate, Post Emergent Nitrogen Product, Post Emergent Application Method, Post Emergent Application Timing on wheat flag leaf burn at Indian Head, Melfort, Outlook, Prince Albert, Redvers, Scott, Swift Current and Yorkton in 2019.

	Flag Leaf Burn							
	I.H.	**Melfort**	**Outlook**	**P.A.**	**Redvers**	**Scott**	**S.C.**	**Yorkton**
	----------------------------------%----------------------------------							
1. 70 lb side banded	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2. 100 lb side banded	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3. 70 lb side banded + 30 lb N/ac of 14 % UAN dribble banded @ boot	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4. 70 lb side banded + 30 lb N/ac of 28% UAN dribble banded @ boot	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5. 70 lb side banded + 30 lb N/ac of 14% UAN dribble banded @ post-anthesis	22.9 b	9.0 ab	1.8 c	11.3 b	N/A	59.4 ab	N/A	35.1 a
6. 70 lb side banded + 30 lb N/ac of 28% UAN dribble banded @ post-anthesis	19.9 b	11.5 a	10.5 b	11.7 b	N/A	50 b	N/A	36.4 a
7. 70 lb side banded + 30 lb N/ac of 14% Dissolved Urea dribble banded @ post-anthesis	12.8 c	3.4 bc	8.6 b	4.6 c	N/A	53 ab	N/A	23 b
8. 70 lb side banded + 30 lb N/ac of 14% UAN broadcast foliar sprayed @ post-anthesis	31.9 a	3.5 bc	26.8 a	17.5 a	N/A	62.5 a	N/A	36.4 a
9. 70 lb side banded + 30 lb N/ac of 14% Dissolved Urea broadcast foliar sprayed @ post-anthesis	11.4 c	5.7 abc	12.1 b	10.4 b	N/A	50 b	N/A	18.2 b
P-values	<0.00001	0.0060	<0.00001	<0.00001	N/A	<0.00001	N/A	<0.00001
L.S.D.	5.5	6.3	3.3	5.7	N/A	11.2	N/A	8.9

N/A: flag leaf burn ratings were collected but not applicable

Table 10. Economics based on yield and protein averaged over all locations.							
	Yield (bu/ac)	**Gross $/ac**[1]	**% grain protein**	**$ protein premium/ac**[2]	**Cost of N ($/ac)**[3]	**Split Application Cost ($/ac)**	**Gross ($/ac) + protein premium – Cost of N and split application**
1) 70 lb N/ac side banded	68.7	463.46	13.80	0.00	35	0	428
2) 100 lb N/ac side banded	71.6	483.42	13.99	9.25	50	0	443
3) 70 lb N/ac side banded + 30 lb N/ac of 14 % UAN dribble banded @ boot	71.6	483.03	13.97	8.00	50	5	436
4) 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ boot	70.5	476.06	14.09	13.56	50	5	435
5) 70 lb N/ac side banded + 30 lb N/ac of 14% UAN dribble banded @ post-anthesis	70.1	473.15	14.16	16.97	50	5	435
6) 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ post-anthesis	69.2	467.08	14.50	32.25	50	5	444
7) 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea dribble banded @ post-anthesis	69.1	466.26	14.11	14.05	50	5	425
8) 70 lb N/ac side banded + 30 lb N/ac of 14% UAN broadcast foliar sprayed @ post-anthesis	69.5	469.18	14.32	24.06	50	5	438
9) 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea broadcast foliar sprayed @ post-anthesis	70.8	478.04	14.30	23.63	50	5	447

[1]bu/ac*$6.75/bu
[2]$ protein premium/ac relative to treatment 1 and based on 66 cents/%/bu
[3]Cost of N - application rate lb N/ac by $0.5/lb N

Table 11. Gross Returns ($/ac) + Protein Premium ($/ac) – Cost of N and split application for all locations ($/ac)									
	$/ac								
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**	**All sites**
1) 70 lb N/ac side banded	299	485	689	320	485	350	270	529	428
2) 100 lb N/ac side banded	**322**	**520**	**756**	**336**	**431**	**363**	**250**	**571**	**443**
3) 70 lb N/ac side banded + 30 lb N/ac of 14 % UAN dribble banded @ boot	291	489	717	359	475	339	258	572	436
4) 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ boot	289	459	779	317	490	348	264	552	435
5) 70 lb N/ac side banded + 30 lb N/ac of 14% UAN dribble banded @ post-anthesis	283	463	772	331	497	349	268	537	435
6) 70 lb N/ac side banded + 30 lb N/ac of 28% UAN dribble banded @ post-anthesis	291	438	857	366	494	328	270	550	444
7) 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea dribble banded @ post-anthesis	280	476	666	362	476	348	253	539	425
8) 70 lb N/ac side banded + 30 lb N/ac of 14% UAN broadcast foliar sprayed @ post-anthesis	307	469	702	386	479	352	273	528	438
9) 70 lb N/ac side banded + 30 lb N/ac of 14% Dissolved Urea broadcast foliar sprayed @ post-anthesis	288	492	699	374	478	353	299	564	447

Maintaining Test Weight Stability of Milling Oats

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Abstract/Summary:

Studies were conducted in Yorkton, Indian Head and Melfort to demonstrate the impact of seeding date, variety choice and nitrogen rate on yield and test weight of oats. While increasing nitrogen increased oat yield it significantly decreased test weight. Test weight is an important grading factor and oats below 245 g/0.5L will be discounted at Grain Millers. Oats with test weights below 230 g/0.5L will be rejected. Seeding oats early is generally recommended to maximize yield and test weights. However, yields and test weights were not always higher with early seeding in this study. This would indicate that seeding early does not guarantee environmental conditions will always be conducive for greater yield and test weight. As anticipated, increasing rates of N from 40 to 120 kg/ha reduced test weights at Indian Head and Yorkton. Moreover, Summit clearly maintained higher test weights than CS Camden at equivalent rates of N at all sites. This means the yield of Summit can be pushed with higher rates of N and with less risk of being discounted on the basis of test weight compared to CS Camden. It is hard to recommend an N rate that would be appropriate for every producer. However, 80 kg N/ha (71 lb N/ac) generally did not result in rejection for milling and often produced economic

returns which were close to the maximum possible. To minimize the risk of rejection due to low test weight, Summit should be grown instead of CS Camden.

Project objectives:

The objectives of this study are to demonstrate the following:

- Test weights and other quality factors for milling oats tend to worsen with delayed seeding and increasing nitrogen rates.
- Test weight stability can vary between varieties. Seeding early and managing nitrogen is particularly critical for a low test weight variety such as CS Camden compared to Summit

Project Rationale:

The majority of Saskatchewan's oats are sold into the milling market making quality a top priority. To achieve milling quality, producers need to seed early and manage nitrogen to maintain adequate test weights. This is particularly important for lower test weight varieties. Now that preharvest glyphosate is no longer an accepted harvest aid option for some milling oats, crops should be seeded earlier to ensure oats can be harvested before weathering reduces quality.

Studies conducted at Indian Head, Melfort and Canora by Agriculture Canada examined the impact of seeding date, nitrogen (N) rate and cultivar on oat yield and milling quality [1]. The researchers found oats should be seeded mid-May with an N rate between 40 and 80 kg/ha. If seeding was delayed to early June, only 40 kg N/ha should be applied to maintain oat quality. The specific effects of higher N rate on oat quality were lower test weight, kernel size and groat yield, fewer plump seeds and more thin seeds. These observations were also later supported by Lafond et al. in 2013 [2].

Test weight stability as N is added can differ between varieties. Summit and CS Camden are both recommended varieties by Grain Millers. CS Camden is the higher yielding variety but it has lower test weights. According to the Saskatchewan Seed Guide, tests weights average 256 and 242 g/0.5L for Summit and CS Camden, respectively [3]. Millers generally prefer tests weights over 245 g/0.5L. Recent studies lead by Bill May found Summit had good test weight stability with increasing rates of nitrogen and was similar to the check variety Stride at Yorkton. In contrast, test weights of CS Camden were poorer than those of the check variety Stride when tested at Indian Head[4] and were at border line levels for acceptance as milling oats.

The yield of Summit can be pushed by higher rates of N with less risk of reducing test weights to discounted levels compared to CS Camden.

[1] 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.

[2] Lafond, G., May, W. and C. Holzapfel. 2013. Row Spacing and Nitrogen Fertilizer Effect

on No-Till Oat Production. Agron. J. 105: 1-10.

[3] Varieties of Grain Crops 2018. Government of Saskatchewan.

[4] May, B Yield Response and Test Weight Stability of Oat to Fertilizer N. Adopt 201504418

Methodology and Results

Methodology:

Trials were established at Yorkton, Melfort and Indian Head as a split-split-plot with 3 factors and 4 replicates. The main-plot factor contrasted early May (early) vs early June (late) seeding dates. The sub-plot factors were Variety and the sub-subplot was Nitrogen rate. The varieties CS Camden and Summit were compared at nitrogen rates of 40, 80 and 120 kg N/ha. Treatments are listed in Table 1. Plots at Yorkton were 11 by 30 feet and seeded with a 10 foot SeedMaster drill on 12 inch row spacing. The middle 4 rows of each plot was harvested with a Wintersteiger plot combine. At Indian Head the plots were seeded with an 8 opener SeedMaster on 12 inch row spacing and the centre four rows were harvested. Plots were handled similarly at Melfort. Other macro nutrients apart from nitrogen were applied so as to be non-limiting.

Table 1. Treatment List for Maintaining Acceptable Test Weights for Milling Oats.

Trt #	Seeding Date	Variety	Kg N/ha
1	Early May (early)	CS Camden	40
2	Early May (early)	CS Camden	80
3	Early May (early)	CS Camden	120
4	Early May (early)	Summit	40
5	Early May (early)	Summit	80
6	Early May (early)	Summit	120
7	Early June (late)	CS Camden	40
8	Early June (late)	CS Camden	80
9	Early June (late)	CS Camden	120
10	Early June (late)	Summit	40
11	Early June (late)	Summit	80
12	Early June (late)	Summit	120

Table 2. Dates of operations in 2019.			
Operations in 2019	**Indian Head**	**Melfort**	**Yorkton**
Pre-seeding Herbicide Application	May 12 Roundup Weathermax 540 (0.67L/ac) all plots	May 24 Glyphosate540 (0.5L/ac) + Heat LQ (21mL/ac) + Merge (400mL)	n/a
Early May Seeding Date	May 3	May 14	May 10
Early June Seeding Date	May 29	June 12	May 31
Emergence Counts	May 28 & June 10	June 18 & July 3	May 30 & June 17
In-crop Herbicide Application	June 13 (early May seeding) and June 26 (early June seeding) Prestige XC A (0.17 l/ac) + Prestige XC B (0.8 l/ac)	July 4 Prestige XC (A@ 0.13L/ac + B@0.6L/ac)	June 10 (Frontline- early May seeding) June 25 (MCPA-both seedings) July 3 (MCPA-early June seeding
Fungicide Application	July 3 (early May seeding) and July 9 (early June seeding) Trivepro A (0.4 l/ac) + Trivepro B (0.12 l/ac)	July 12 Acapella @ (325mL/ac)	July 3 (Caramba 280ml/ac – early May seeding) July 14 (Caramba 400ml/ac-early June seeding)
Lodging	August 27 (early May seeding) and September 4 (early June seeding)	Sept 13	Sept 3
Harvest	August 29 (early May seeding) and September 8 (early June seeding)	Oct 7	Sept 8 (early May + rep 1 of early June seeding) Sept 16 (reps 2,3 & 4 of early June seeding)

Results:

Soil N was at moderate levels at Indian Head and Melfort and somewhat lower at Yorkton (Table 4).

Table 4. Soil Test Nitrate Levels for each location.			
Nitrate Levels (lbs NO_3-N/ac)	**Indian Head**	**Melfort**	**Yorkton**
0-15cm (0-6in)	13.4 lb/ac	15 lb/ac	14 lb/ac
15-30cm (6-12 in)		15 lb/ac	
15-60cm (6-24 in)	30.3 lb/ac		18 lb/ac
Total 0-60cm (0-24 in)	43.7 lb/ac		32 lb/ac
Total 0-60cm (0-12in)		30 lb/ac	

Plant emergence was excellent at Yorkton and Indian Head for both seeding dates. Emergence at Indian Head was somewhat higher when seeding early compared to late (316 vs 257 plants/m^2) (Table 6). In contrast, fewer plants (278 vs 339 plants/m^2) emerged when seeding oat early compared to late at Yorkton. At Melfort, emergence was substantially lower with the early seeding date. Only 95 plants/m^2 emerged when oats were seeded early due to dry soil conditions. More soil moisture was available when seeding late allowing for a better stand establishment of 275 plants/m^2. Emergence tended to decline somewhat at all locations as the rate of side-banded nitrogen was increased which is not unusual. The goal was to achieve similar emergence rates between varieties and this was somewhat accomplished at Yorkton and Indian Head with CS Camden having only 8% higher emergence than Summit at both locations. In contrast, the relative emergence of Summit was considerably poorer at Melfort. Only 158 plants/m^2 emerged for Summit compared to 213 plants/m^2 for CS Camden, a difference of 26%. However, the lower emergence of Summit did not appear to be detrimental to yield as it still yielded more than CS Camden. Differences in emergence rates likely had only modest effects on oat yield and quality.

Past research has found oat yield and grain test weight are more likely to be higher with earlier seeding. Early seeding (May 14) did result in 2.9% more yield at Melfort compared to late seeding on June 12, but the difference was insignificant (Tables 8 and 9). At Yorkton, seeding early (May 10) produced 6.2% less yield than seeding late (May 31), which is the opposite of expectations but the difference was not statistically significant. At Indian Head, there was a significant interaction between seeding date and variety. While seeding early (May 3) did result in higher yield for CS Camden, Summit produced its highest yield when seeded late (May 29) (Table 10a). It is uncertain why this would occur. Again, test weight was expected to be higher with earlier seeding and this only occurred significantly at Indian Head (Tables 11 and 12). At Melfort and Yorkton, test weights were numerically higher for the late seeding date with the difference being statistically significant at Melfort. While seeding early should increase the likelihood of harvesting quality grain before weathering, it does not seem to guarantee yields and test weights will be higher.

Increasing N was anticipated to increase oat yield and reduce test weights. For the most part this was observed in this study. On average, raising N rate from 40 to 120 kg N/ha significantly increased yield by 18 and 34% at Yorkton and Melfort, respectively (Tables 8 and 9). At Indian Head, yield response to added N was a little unusual as a significant interaction between seeding date and nitrogen rate were detected. For the early seeding date, yield peaked at 80 Kg N/ha and declined with 120 Kg N/ha (Table 10b). When seeded late, oat yield increased with added N but at a modest and insignificant rate. Yield potential was moderate at Indian Head and soil N levels were moderate with 44 lb N/ac in the top 24 inches of soil (Table 4). This may account for the low yield response to added N. As anticipated, test weights were significantly reduced by increasing N at Indian Head and Yorkton (Tables 8 and 9). However, test weights were unaffected by rate of N at Melfort.

Test weights for Summit were expected to be significantly higher than CS Camden at the same rate of applied N and this was certainly the case for all sites (Table 11 and 12). Overall, test weights were low at Indian Head with Summit and CS Camden producing average test weights of 243.7 and 231.9 g/0.5 l, respectively. At Grain Millers in Yorkton, milling oats are discounted with tests weights below 245 g/0.5l and are rejected below 230 g/0.5l. Test weights were much higher at Yorkton and Melfort. At Yorkton, Summit again had a significantly higher test weight of 260.8 g/0.5l versus 251.9 g/0.5l for CS Camden. At Melfort, Summit produced a higher test weight of 265.9 g/0.5l compared to 261 g/0.5l for CS Camden. However, there was strong variety by seeding date interaction at Melfort. When seeded early the difference in test weights was greater with Summit and Camden having test weights of 263.2 and 255.3 g/0.5l, respectively. When seeded late, test weights were more similar with Summit and Camden having test weights of 268.6 and 266.7 g/0.5l, respectively.

Whether seeded early or late, Summit was less likely to be discounted or rejected than CS Camden on the basis of test weight as N rates were increased at all sites (Table 13). When seeded early at Indian Head, CS Camden would have been discounted at all nitrogen rates. In contrast, Summit would not have been discounted until 120 kg N/ha were applied. When seeded late at Indian Head, test weights were even lower and discounts would have been worse. CS Camden would have been rejected at N rates of 80 kg/ha and above. In contrast, Summit would not have been rejected at any rate of N. At Yorkton, test weights were much higher (Table 13). While none of the treatments would have produced oats with test weights low enough to be discounted, Summit maintained higher test weights than CS Camden at all rates of N. When seeded early, CS Camden came close to being discounted with a test weight of 246.0 g/0.5L when fertilized with 120 kg N/ha. In comparison, Summit produced a much higher test weight of 254.5 g/0.5L at this rate of N. When seeded late, tests weight were higher and did not come close to discount levels even at the highest rate of N. With 120 kg/ha of added N, CS Camden produced a test weight of 254.2 g/0.5L but again Summit produced an even higher test weight of 261.8 g/0.5L. At Melfort, test weights were very high (254 g/0.5l +) and no treatment resulted in a test weight low enough to trigger a discount. Nitrogen rate did not influence test weight however, Summit consistently had higher test weights compared to CS Camden at every nitrogen rate within a seeding date. Seeding late at Melfort increased test weight by 3.2% when averaged over nitrogen rate and variety. The results from all the sites clearly indicate that Summit can maintain higher tests weights than CS Camden when yields are pushed with higher rates of N.

The following economic assessments below have been made assuming $3.23/bu for Oats and $0.50/lb N. Based on information supplied by Grain Millers, oats were discounted as follows:

- $0.02/bu for test weights between 245 and 240 g/0.5l.
- $0.04/bu for test weights between 240 and 235 g/0.5l
- $0.08/bu for test weights between 235 and 230 g/0.5l.
- Rejection for test weights below 230 g/05l.

At Melfort, Summit had higher test weights than CS Camden, particularly when seeded early. However, test weights were never low enough to discount the oats. As N had the largest significant effect on yield, the economic analysis is based on yields and test weights for each rate of N averaged over seeding date and variety (Table 14). The highest rate of N (120 kg/ha or 107 lb/ac) provided the greatest gross return. The gross returns from Melfort were higher than any of the other sites. However, test weights were high and unaffected by N rate which is not typical and was not the case for Indian Head and Yorkton.

At Indian Head there were interactions with the yield data and every factor had a significant effect on test weight. As a result, the economic analysis had to be done for every individual treatment (Tables 15a-d). Overall, economic returns were smaller at Indian Head compared to Melfort as yields were lower and fairly unresponsive to added N. Moreover, test weights were lower and, in many cases, this resulted in discounts and even rejection of oats for milling. When seeded early (Tables 15a and b), 80 kg/ha (71 lb/ac) of N was most economical for both varieties and both provided similar returns. However, there was clearly more risk to growing CS Camden as it was discounted at every rate of N due to low test weight. In contrast, test weights for Summit were higher and did not reach discount levels until the highest rate of N was applied. When seeded late (Tables 15c and d), test weights were lower which is in keeping with past research. This resulted in rejection of CS Camden for milling at N rates of 80 kg/ha (71 lb/ac) and above. Again, Summit test weights were higher but discounts were received at every rate of N. For both varieties the most economical rate of N was only 40 kg/ha (36 lb/ac) when seeded late.

For Yorkton, the economical analysis has been averaged over seeding date, as seeding date did not significantly affect yield or test weights (Table 16 a and b). Yields were more responsive to added N at Yorkton compared to Indian Head and yields were also higher, though not as high as Melfort. While test weights for CS Camden were less than Summit, discounts based on low test weight did not occur regardless of variety and rate of N. For Summit, the most economical rate of N was 80 kg/ha (71 lb/ac) whereas, 120 kg/ha (107 lb/ac) of N was most economical for CS

Camden. However, the difference in the rate of return between those two rates of N was very small for both varieties.

Conclusions and Recommendations:

Seeding early is recommended for milling oats to help maximize yield and test weights. However, yields and test weights were not always higher with early seeding in this study. This would indicate that seeding early does not guarantee environmental conditions will always be conducive for greater yield and test weight. As anticipated, increasing rates of N from 40 to 120 kg/ha reduced test weights at Indian Head and Yorkton. Moreover, Summit clearly maintained higher test weights than CS Camden at equivalent rates of N at all locations. This means the yield of Summit can be pushed with higher rates of N and with less risk of being discounted on the basis of test weight compared to CS Camden. It is hard to recommend an N rate that would be appropriate for every producer. However, 80 kg N/ha (71 lb N/ac) generally did not result in rejection for milling and often produced economic returns which were close to the maximum possible. To minimize the risk of rejection due to low test weight, Summit should be grown instead of CS Camden. However, if lodging had been an issue in this study CS Camden may have performed relatively better as its lodging resistance is higher compared to Summit. While seeding late did not guarantee higher test weights, it is still a good practice as early seeding will likely favor harvest under ideal conditions.

Acknowledgements:

This project was funded through the Agricultural Demonstrations of Practices and Technologies.

Appendices:

Table 5. Significance of seeding date, variety, and nitrogen fertilizer rate effects on oat emergence at multiple locations in 2019.

	Emergence		
	Indian Head	**Melfort**	**Yorkton**
Effect	---------------------------p-values [Z]	-------------------------	
Seeding Date (D)	0.051407	0.00096	0.003077
Variety (V)	NS	0.002381	0.024532
D x V	NS	NS	NS
Nitrogen rate (R)	0.005921	NS	NS
D x R	NS	NS	NS
V x R	NS	NS	NS
D x V x R	NS	NS	NS

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

Table 6. Main effects of seeding date, variety, and nitrogen fertilizer rate on oat emergence at multiple locations in 2019.

Main effect	**Emergence**		
	Indian Head	**Melfort**	**Yorkton**
Seeding Date	----------------------------------	plant/m^2	----------------------------------
Early May (early)	316	95	278
Early June (late)	257	275	339
LSD	NS	44	22
Variety			
CS Camden	298	213	320
Summit	274	158	297
LSD	NS	26	19
kg N/ha			
40	305	198	312
80	277	191	310
120	277	167	303
LSD	18	NS	NS

Table 7. Seeding Date by Variety by N fertilizer rate interactions on oat emergence at multiple locations in 2019.			
Main effect	**Emergence**		
	Indian Head	**Melfort**	**Yorkton**
D × V x R	---------------- plant/m^2 --------------		
Early May – CS Camden – 40 Kg N/ha	352	167	282
Early May – CS Camden – 80 Kg N/ha	305	127	290
Early May– CS Camden – 120 Kg N/ha	319	95	281
Early May - Summit– 40 kg N/ha	327	75	283
Early May- Summit– 80 Kg N/ha	298	68	264
Early May - Summit– 120 Kg N/ha	293	42	268
Early June– CS Camden – 40 Kg N/ha	277	308	343
Early June– CS Camden – 80 Kg N/ha	268	305	373
Early June– CS Camden – 120 Kg N/ha	268	274	351
Early June- Summit– 40 kg N/ha	263	241	341
Early June- Summit– 80 Kg N/ha	238	266	314
Early June- Summit– 120 Kg N/ha	228	258	313
L.S.D			
R means for same D and V	37	57	50
V means for same D and same or different R	53	60	49
D means for same or different V and R	79	83	62

Table 8. Significance of seeding date, variety, and nitrogen fertilizer rate effects on oat yield at multiple locations in 2019.

	Yield		
	Indian Head	**Melfort**	**Yorkton**
Effect	--------------------------p-values [Z] ------------------------		
Seeding Date (D)	NS	NS	NS
Variety (V)	NS	NS	0.048403
D x V	0.005152	NS	NS
Nitrogen rate (R)	0.012454	<0.00001	<0.00001
D x R	0.014263	0.036837	NS
V x R	NS	NS	NS
D x V x R	NS	NS	NS

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

Table 9 Main effects of seeding date, variety, and nitrogen fertilizer rate on oat yield at multiple locations in 2019.

Main effect	**Yield**		
	Indian Head	**Melfort**	**Yorkton**
Seeding Date	---------------------------------- kg/ha ----------------------------------		
Early May (early)	4477	7073	6439
Early June (late)	4563	6876	6859
LSD	NS	NS	NS
Variety			
CS Camden	4474	6950	6531
Summit	4566	6999	6767
LSD	NS	NS	180
kg N/ha			
40	4391	5821	5999
80	4607	7277	6854
120	4562	7826	7094
LSD	124	356	198

Table 10. Seeding Date by Variety by N fertilizer rate interactions on oat yield at multiple locations in 2019.

Main effect	Yield		
	Indian Head	**Melfort**	**Yorkton**
D × V x R	---------------- kg ha^{-1} --------------		
Early May – CS Camden – 40 Kg N/ha	4364	5704	5565
Early May – CS Camden – 80 Kg N/ha	4724	7474	6578
Early May– CS Camden – 120 Kg N/ha	4586	8035	6871
Early May - Summit– 40 kg N/ha	4153	6377	5785
Early May- Summit– 80 Kg N/ha	4606	7580	6803
Early May - Summit– 120 Kg N/ha	4432	7269	7030
Early June– CS Camden – 40 Kg N/ha	4330	5583	6133
Early June– CS Camden – 80 Kg N/ha	4421	6948	6817
Early June– CS Camden – 120 Kg N/ha	4419	7954	7220
Early June- Summit– 40 kg N/ha	4717	5619	6512
Early June- Summit– 80 Kg N/ha	4678	7105	7221
Early June- Summit– 120 Kg N/ha	4812	8046	7254
L.S.D			
R means for same D and V	247	712	395
V means for same D and same or different R	286	819	410
D means for same or different V and R	371	995	816

Table 10a. Yield for the Seeding Date by Variety interaction for Indian Head	
D x V	**IHARF Yield**
	-------------------------- kg/ha ---------------------------
Early May - CS Camden	4557.8
Early May - Summit	4396.8
Early June – CS Camden	4389.7
Early June - Summit	4735.4
L.S.D	
V1D1-V2D1	204.2
V1D1-V1D2 or V1D1-V2D2	245.7

Table 10b. Yield Means for the Seeding Date by N Rate Interaction for Indian Head	
D x R	**IHARF Yield**
	--------------------------- kg/ha ----------------------------
Early May – 40 kg N/ha	4258.3
Early May – 80 kg N/ha	4664.9
Early May – 120 kg N/ha	4508.9
Early June – 40 kg N/ha	4523.1
Early June – 80 kg N/ha	4549.3
Early June– 120 kg N/ha	4615.3
L.S.D	
R means for same D	175.0
D means for same or different R	234.0

Table 11. Significance of seeding date, variety, and nitrogen fertilizer rate effects on oat test weight at multiple locations in 2019.

	Test Weight		
	Indian Head	**Melfort**	**Yorkton**
Effect	---------------------------------p-values ^{z}	---------------------------------	
Seeding Date (D)	0.027556	0.001008	NS
Variety (V)	0.00692	<0.00001	0.000625
D x V	NS	0.00011	NS
Nitrogen rate (R)	0.001932	NS	0.00295
D x R	NS	NS	NS
V x R	NS	0.049721	NS
D x V x R	NS	NS	NS

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

Table 12. Main effects of seeding date, variety, and nitrogen fertilizer rate on oat test weight at multiple locations in 2019.			
Main effect	**Test Weight**		
	Indian Head	**Melfort**	**Yorkton**
Seeding Date	---------------------------------- g/0.5L ----------------------------------		
Early May (early)	241.2	259.3	253.7
Early June (late)	234.4	267.6	259.1
LSD	5.4	2.06	NS
Variety			
CS Camden	231.9	261.0	251.9
Summit	243.7	265.9	260.8
LSD	7.2	0.83	3.3
Kg N/ha			
40	240.3	264.0	259.5
80	236.9	262.8	255.5
120	236.1	263.6	254.1
LSD	2.3	NS	3.0

Table 13. Seeding Date by Variety by N fertilizer rate interactions on oat test weight at multiple locations in 2019.			
Main effect	**Test Weight**		
	Indian Head	**Melfort**	**Yorkton**
<u>D × V x R</u>	---------------- g/0.5L --------------		
Early May – CS Camden – 40 kg N/ha	239.0	255.7	253.0
Early May – CS Camden – 80 kg N/ha	237.0	253.8	248.2
Early May– CS Camden – 120 kg N/ha	235.0	256.4	246.0
Early May - Summit– 40 kg N/ha	247.3	265.2	263.1
Early May- Summit– 80 kg N/ha	245.8	264.0	257.3
Early May - Summit– 120 kg N/ha	243.0	260.6	254.5
Early June– CS Camden – 40 kg N/ha	231.0	266.5	255.5
Early June– CS Camden – 80 kg N/ha	222.8	265.5	254.6
Early June– CS Camden – 120 kg N/ha	226.5	268.0	254.2
Early June- Summit– 40 kg N/ha	244.0	268.6	266.4
Early June- Summit– 80 kg N/ha	242.0	267.9	262.0
Early June- Summit– 120 kg N/ha	240.0	269.3	261.8
<u>LSD</u>			
R means for same D and V	4.6	NS	6.0
V means for same D and same or different R	10.8	NS	6.8
D means for same or different V and R	10.0	NS	14.3

Table 14. Oat Economics for Melfort 2019, Averaged Over Seeding Date and Variety

Lb N/ac	Bu/ac	Test wt (g/0.5 l)	$ N/ac (@ $0.5/lb N)	$Gross/ac (@3.23/bu)	$Discount/ac	$Gross/ac-($N/ac+$Discount/ac)
36	153	262.6	18	494	0.00	476
71	191	263.6	35.5	617	0.00	582
107	205	264.2	53.5	662	0.00	609

Table 15a. Summit Oat Economics for Indian Head 2019 – Seeded Early

Lb N/ac	Bu/ac	Test wt (g/0.5 l)	$ N/ac (@ $0.5/lb N)	$Gross/ac (@3.23/bu)	$Discount/ac	$Gross/ac-($N/ac+$Discount/ac)
36	109	247.5	18	352	0	334
71	121	245.4	35.5	390	0	354
107	116	243.2	53.5	375	2.32	319

Table 15b. CS Camden Oat Economics for Indian Head 2019 – Seeded Early

Lb N/ac	Bu/ac	Test wt (g/0.5 l)	$ N/ac (@ $0.5/lb N)	$Gross/ac (@3.23/bu)	$Discount/ac	$Gross/ac-($N/ac+$Discount/ac)
36	115	239.0	18	370	4.58	347
71	124	237.0	35.5	401	4.96	360
107	121	235.0	53.5	390	4.83	331

Table 15c. Summit Oat Economics for Indian Head 2019 – Seeded Late

Lb N/ac	Bu/ac	Test wt (g/0.5 l)	$ N/ac (@ $0.5/lb N)	$Gross/ac (@3.23/bu)	$Discount/ac	$Gross/ac-($N/ac+$Discount/ac)
36	124	244.0	18	400	2.47	379
71	123	242.0	35.5	397	2.46	359
107	126	240.0	53.5	408	2.53	352

Table 15d. CS Camden Oat Economics for Indian Head 2019 – Seeded Late

Lb N/ac	Bu/ac	Test wt (g/0.5 l)	$ N/ac (@ $0.5/lb N)	$Gross/ac (@3.23/bu)	$Discount/ac	$Gross/ac-($N/ac+$Discount/ac)
36	114	231.0	18	367	9.09	340
71	116	222.8	35.5	374	reject	?
107	116	226.6	53.5	374	reject	?

Table 16a. Summit Oat Economics for Yorkton 2019 – Averaged over Seeding Date						
Lb N/ac	Bu/ac	Test wt (g/0.5 l)	$ N/ac (@ $0.5/lb N)	$Gross/ac (@3.23/bu)	$Discount/ac	$Gross/ac-($N/ac+$Discount/ac)
36	161	264.7	18	521	0	503
71	184	259.8	35.5	594	0	558
107	187	258.3	53.5	604	0	550

Table 16b. CS Camden Oat Economics for Yorkton 2019 – Averaged over Seeding Date						
Lb N/ac	Bu/ac	Test wt (g/0.5 l)	$ N/ac (@ $0.5/lb N)	$Gross/ac (@3.23/bu)	$Discount/ac	$Gross/ac-($N/ac+$Discount/ac)
36	154	254.4	18	496	0	478
71	176	251.6	35.5	568	0	533
107	185	250.6	53.5	598	0	544

Grain Millers- Oat Variety Trial (Yorkton) 2019

Mike Hall[1] and Heather Sorestad[1]

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Project objectives:

The objective of this study is to compare yield and quality of oat varieties which are either recommended or under review by Grain Millers.

Project Rationale:

As new oat varieties continue to emerge in the market place, farmers need to stay up to date on the newest genetics. This trial will show producers a local comparison of Zone 2 recommended varieties for Grain Millers as well as varieties under review.

Methodology:

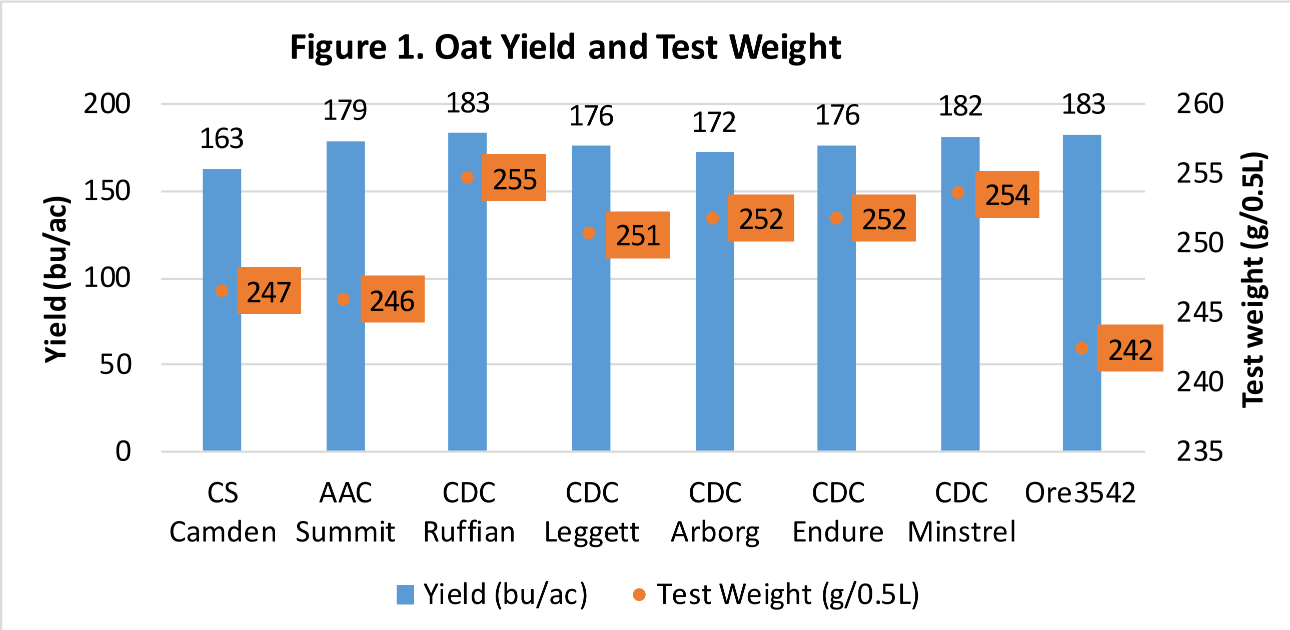
The trial was established as a Randomized Complete Block Design (RCBD) with 4 replications. Plots were 11 by 30 ft and were seeded with a 10 ft wide Seedmaster drill with 12 inch row spacings. Monoammonium phosphate (MAP) and urea were side banded at seeding at 59 lb/ac and 152 lb/ac, respectively. Oats were seeded to target 300 seeds/m^2 with corrections for vigour and thousand kernel weight taken into account. The middle 4 rows by 30 ft were harvested for yield with a Wintersteiger plot combine. The trial compared the yield and quality of oat varieties listed in Table 1.

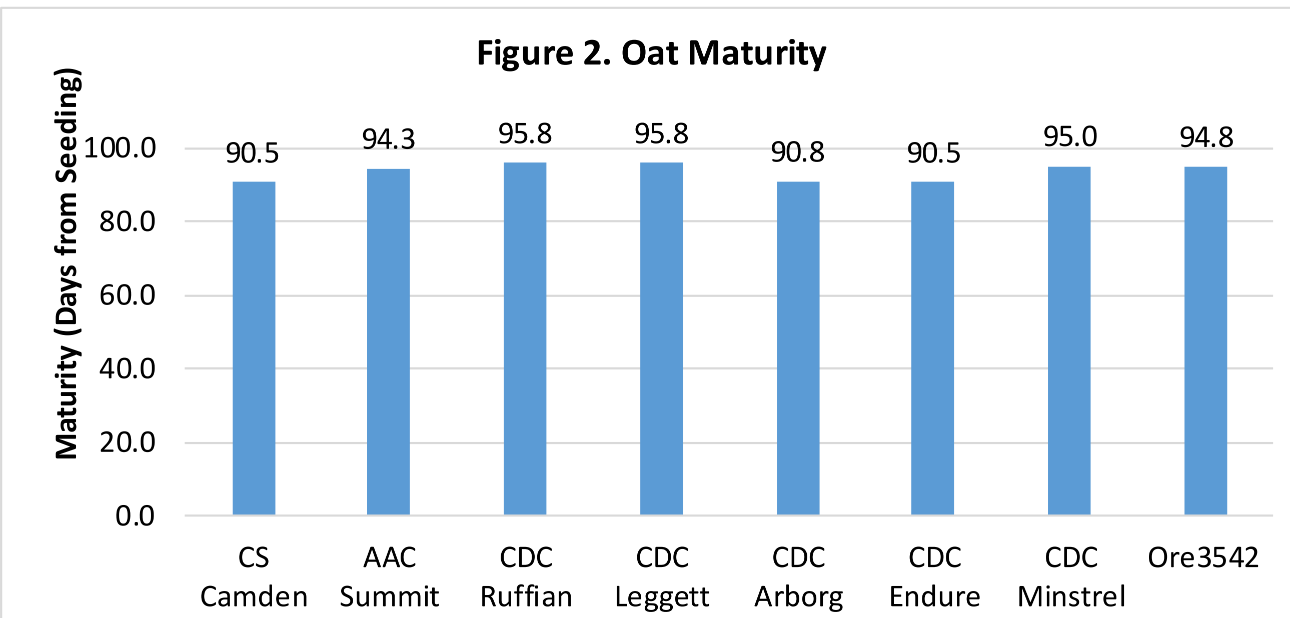
Table 1. Oat Variety Treatments		
Trt	**Oat Variety**	**Status with Grain Millers**
1	CS Camden	Recommended
2	AAC Summit	Recommended
3	CDC Ruffian	Recommended
4	CDC Leggett	Recommended
5	CDC Minstrel	Recommended
6	CDC Arborg	Under review
7	CDC Endure	Under review
8	Ore3542M	Under review

Table 2. Dates of operations in 2019 for the Grain Millers- Oat Variety Trial (Yorkton) 2019	
Operations in 2019	Yorkton
Seeded trial	May 13
Emergence counts	June 4
In-crop herbicide application: Frontline	June 10
In-crop herbicide application: MCPA	June 25
Fungicide application: Caramba (280ml/ac)	July 3
Maturity rating	Aug 13
Lodging rating	Sept 3
Harvest	Sept 4 and 6

Results:

Emergence was excellent averaging 298 plants/m^2 across varieties. No significant differences were detected between varieties for emergence or test weight (Table 4). All varieties had test weights which would have been accepted by Grain Millers, however Ore3542 had a discount test weight of 242 g/0.5l (Table 4). The test weight for AAC Summit was lower than expected. Oat yields were excellent averaging 177 bu/ac. CS Camden was statistically the lowest yielding variety at 162.8 bu/ac which would not have been expected (Table 4 & Figure 1). Numerically, CDC Ruffian had the highest yield at 183 bu/ac (Table 4 & Figure 1). CDC Leggett and CDC Ruffian had the highest incidence of lodging (Table 4) but the degree of lodging was not high enough to affect yield. CS Camden, CDC Arborg and CDC Endure matured significantly earlier, averaging 5 days earlier than the other varieties (Table 4 & Figure 2).





Conclusions and Recommendations:

CDC Ruffian was numerically the highest yielding variety however, it also suffered the second highest level of lodging. The 2019 trial year had below average rainfall which reduced lodging incidence, but in a wet year CDC Ruffian and CDC Leggett may experience lodging problems. If Manipulator gets approved for oats, CDC Ruffian may become a prime candidate for application to aid in maintaining high yields. This year's data indicates that Ore3542 may have low test weight challenges especially if a producer increases nitrogen rates beyond 70 lb N/ac.

Acknowledgements:

This project was funded through Grain Millers.

Appendices:

Table 4. Significance of main effects of Oat Varieties on Emergence, Maturity, Lodging, Test Weight and Yield.

	Emergence (plants/m^2)	**Lodging (1-10)**	**Maturity (Days from Seeding)**	**Yield (bu/ac)**	**Test Weight g/0.5L**
Variety					
1. CS Camden	308 a	1.4 cd	90.5 b	162.8 c	246.5 a
2. AAC Summit	275 a	1.8 c	94.25 a	179 ab	245.9 a
3. CDC Ruffian	288 a	2.3 b	95.75 a	183.3 a	254.7 a
4. CDC Leggett	304 a	3 a	95.75 a	175.8 ab	250.6 a
5. CDC Arborg	308 a	1.3 d	90.75 b	172 b	251.8 a
6. CDC Endure	296 a	1.8 c	90.5 b	176.3 ab	251.8 a
7. CDC Minstrel	281 a	1.6 cd	95 a	181.5 a	253.5 a
8. Ore3542	325 a	1.5 cd	94.75 a	182.5 a	242.4 a
P-values	NS	<0.00001	0.00054	0.0027	NS
LSD	NS	0.41	2.84	9.21	NS

Malt versus Feed Barley (Resubmission with variety change)

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Abstract/Summary:

Trials were conducted at Yorkton, Indian Head, Swift Current, Scott, Outlook, Prince Albert, Melfort and Redvers to compare the yield response of the malt variety AAC Synergy and the feed variety CDC Austenson to added N and seeding rate. Seeding rates of 200 and 300 seeds/m^2 were assessed at N levels of 80, 120 and 160 lb/ac, includes soil+applied (residual NO_3-N + fertilizer) N. The relative yields of the malt variety AAC Synergy and feed variety CDC Austenson varied between locations; however, when averaged across locations, yields were equal between the varieties, indicating there may be little reason to grow a feed variety over AAC Synergy. However, it should be noted that the bushel weight of CDC Austenson was significantly higher than AAC Synergy which is an important criteria for feed. Increasing seeding rate did not increase yield, decrease protein or improve any quality factors for malt barley; however, increasing N did increase protein and tended to decrease % plump. In many cases it was not possible to compare the optimum rate of N between the feed and malt varieties.

At 5 locations, the yield of both varieties was unresponsive to increasing N levels above 80 lb/ac (soil + applied N). This means the economic level of N for these sites was below 80 lb/ac for both the feed and malt barley varieties. At Yorkton, the most economic level of N for both varieties would have been above 160 lb/ac as yield was highly responsive to added N and protein levels remained relatively low. A fair comparison of the most economic rate of N was only possible at Scott, where the most economic N rate for the malt and feed varieties was 155 and 123 lb/ac, respectively. While there is more risk associated with applying too much N to malt barley, there is little evidence to suggest the most economic rate of N is higher for feed than malt.

Project objectives:

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

Project Rationale:

Growing barley for malt can be a gamble because if rejected, a large amount of yield is potentially lost compared to growing a feed variety. Work by AgriProfits would suggest that feed, rather than malt varieties, should be grown if the chance of making malt is less than 50%. However, this recommendation is not going to be applicable when the newer, higher yielding malt varieties become widely accepted by maltsters. AC Metcalfe is a popular variety for maltsters; however, there are a number of feed varieties which yield 15 to 20% higher. According the 2018 Saskatchewan Seed Guide, the popular feed variety CDC Austenson yields from 118 to 121% of AC Metcalfe. The malt variety AAC Synergy, which is gaining traction in the market, is more comparable to CDC Austenson as it also yields 118% of AC Metcalfe. If a widely selected malt variety can produce similar yields to the best feed varieties, then there would be little reason to grow a feed variety. Yields of feed varieties are not likely to stay ahead of malt varieties as funding for feed variety development is decreasing. The Saskatchewan Barley Development Commission wants to get the message out that newer malt barley varieties can yield as well as feed varieties. As this becomes the case, producers will need to be aware they can grow malt varieties without sacrificing feed yields if their grain is rejected for malt. Those who continue to grow feed varieties will be forfeiting potential economical opportunities with the maltsters.

Producers need to be aware of the importance of seeding rate and nitrogen management for malt and feed varieties. Higher seeding rates have been found to both 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 resulted in a plant stand of around 220 plants/m^2. Lower seeding rates increase tillering which can lead to more variable maturity and non-uniform kernels which is undesirable to maltsters. Increasing the seeding rate to 300 seeds/m^2 may slightly reduce kernel plumpness but produces more uniform kernels which is an acceptable 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 often somewhat higher than it is for malt.

Managing nitrogen is particularly important for malt barley where protein levels must not exceed 12.5%. 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 not a concern. This project was intended to illustrate those differences by demonstrating basic agronomic practices for newer malt varieties and to help barley producers stay competitive in a changing market.

Methodology:
Trials were established at all eight AgriARM research sites across all the major soil zones of Saskatchewan. Locations included Yorkton, Redvers, Indian Head, Swift Current, Scott, Outlook, Prince Albert and Melfort.

Each trial was designed as a 3 order factorial with 4 replicates. Plot size and row spacing varied between locations depending on equipment. The first factor compared AAC Synergy (malt variety) vs the Feed variety CDC Austenson. Based on past research the yield for the newer malt varieties should be comparable to the popular feed variety (CDC Austenson) for a given input level. The second factor evaluated seeding rates of 200 and 300 seeds/m^2. Both varieties should yield better at the higher seeding rate (300 seeds/m^2) and the higher seeding rate should improve the kernel uniformity and improve the chance of the malt variety making the grade. The 3rd factor examines nitrogen rate. The impact nitrogen rate has on protein levels, yield, and selection for malt were determined from these treatments. Table 1 lists the treatments that were established and dates of operations are included in Table 2.

Table 1. Treatment List for Malt versus Feed Barley (Resubmission with variety change) Trial

Trt #	Variety	Seeds/m^2	Lb N/ac soil + Fertilizer
1	AAC Synergy (Malt)	200	80
2	AAC Synergy (Malt)	200	120
3	AAC Synergy (Malt)	200	160
4	AAC Synergy (Malt)	300	80
5	AAC Synergy (Malt)	300	120
6	AAC Synergy (Malt)	300	160
7	CDC Austenson	200	80
8	CDC Austenson	200	120
9	CDC Austenson	200	160
10	CDC Austenson	300	80
11	CDC Austenson	300	120
12	CDC Austenson	300	160

Table 2. Dates of operations in 2019 for the Malt versus Feed Barley Management (Resubmission with variety and N change)

	------------------------Date------------------------							
Activity	**Indian Head**	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
Pre-seed Herbicide Application	May 12 Roundup Weathermax 540 (0.67 L/ac)	May 24 Glyphosate 540 (0.5 L/ac) + Heat LQ (21 mL/ac)	N/A	N/A	N/A	May 19 Glyposate 540 (1L/ac) + AIM (35mL/ac)	May 13 (glyphosate)	n/a
Seeding	May 6	May 14	May 14	May 23	May 4	May 14	May 14	May 7
Emergence Counts	May 28	June 18	N/A	June 12	June 3	June 5	June 3	May 28 and May 29
In-crop Herbicide Application	June 13 Prestige XC A (0.17 L/ac) + Prestige XC B (0.8 L/ac) + Axial BIA (0.5 L/ac)	June 27 Axial (0.5 L/ac) July 4 Prestige XCA (0.13 L/ac)+ Prestige B (0.6 L/ac)	June 13 Infinity (0.33L/ac) + Assert (0.67L/ac) + pH adjuster (155 g/ac)	June 27 Stellar	June 10 Buctril M (0.4L/ac)	June 26 Axial (0.5 L/ac) + Buctril M (0.4L/ac) @10gpa	June 20 Liquid Achieve (200ml/ac + Infinity (330ml/ac) + Turbo Charge (500ml/100L spray volume)	June 10 Axial + Frontline June 25 (MCPA)
In-crop Fungicide Application	July 4 Trivepro A (0.4 L/ac) + Trivepro B (0.12 L/ac)	N/A	July 23 Caramba (400 mL/ac)	N/A	N/A	June 13 Propel (200 mL/ac) @gpa	July 10 Aceplla	July 3 Acapella
Lodging Rating	N/A	Sept 4	Completed as treatments matured individually	N/A	N/A	Aug 26	Aug 19	Sept 3
Harvest	Aug 16	Sept 18	Sept 24	Sept 16	Aug 19	Sept 18	Aug 22	Sept 4

Results:

Table 5 lists soil test results from each location. Levels of soil N were high at Melfort, Redvers and Swift Current. Soil N tested low at Outlook.

Table 5. Soil Test Nitrate Levels for each location.

Nitrate Levels (lbs NO_3-N/ac)	**Indian Head**	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
0-15cm (0-6in)	15 lb/ac	23 lb/ac	6 lb/ac	20 lb/ac	34 lb/ac	14 lb/ac	17 lb/ac	14 lb/ac
15-30cm (6-12in)		22 lb/ac		15 lb/ac				
15-60cm (6-24in)	27 lb/ac		9 lb/ac		51 lb/ac	18 lb/ac	66 lb/ac	18 lb/ac
Total 0-60cm (0-24in)	42 lb/ac	67.5 lb/ac	15 lb/ac		85 lb/ac	32 lb/ac	83 lb/ac	32 lb/ac
Total 0-30cm (0-12in)				35 lb/ac				

As expected, increasing seeding rate from 200 to 300 seeds/m^2 significantly increased plant emergence at all reporting locations (Table 6). Emergence data was not available from Outlook. When averaged across locations, 200 and 300 seeds/m^2 resulted in plant populations of 158 and 211/m^2, respectively; however, emergence varied between locations (Table 7). Plant densities were lower at Melfort and Prince Albert, averaging 84 and 125/m^2 when seeding 200 seeds/m^2 and 111 and 164/m^2 when seeding 300 seeds/m^2, respectively. Stand establishment at the remaining sites was as expected. The goal was to produce similar emergence rates for AAC Synergy and CDC Austenson and this was essentially achieved. Emergence between varieties did statistically differ by 10% at Yorkton, however, this difference is unlikely to have favored or hindered one variety over the other. Increasing N rates significantly decreased emergence at Melfort, Prince Albert, Redvers, Scott and Swift Current but not at Indian Head or Yorkton (Table 7). The impact was quite large at Melfort, where increasing N levels from 80 to 160 lb/ac (includes soil N) decreased emergence from 117 to 69 plants/m^2, respectively. The impact was also relatively large at Prince Albert, where emergence was decreased from 162 to 126 plant/m^2 in response to increasing N levels from 80 to 160 lb/ac.

Barley grain yields varied between locations. The highest yielding sites were Outlook and Yorkton averaging 7734 and 7308 kg/ha, respectively. Soil moisture reserves were good at Yorkton and Outlook was under irrigation. The lowest yielding site was Swift Current averaging 3146 kg/ha. Prince Albert was the second lowest yielding site at 4350 kg/ha and the remaining sites produced yields in the range of 5000 kg/ha.

Averaged across location, the yield of AAC Synergy and CDC Austenson were within 0.16% of each other. While yields were virtually identical overall, their ranking did vary substantially between locations even though the same seedlot was used at all locations. The malt variety AAC Synergy significantly yielded 2.6, 5.1 and 11.9% more grain than the feed variety CDC Austenson at Indian Head, Redvers and Swift Current, respectively (Table 9 and 10). In contrast, CDC Austenson was significantly higher yielding by 9.5 and 16.7% at Melfort and Prince Albert, respectively. Yields did not statistically differ between varieties at Outlook, Scott or Yorkton.

Yield differences between seeding rates were minor and none were significant at the 5% level of confidence (Table 9 and 10). However, the lower seeding rate at Redvers resulted in 3.7% more yield at the 6.3% level of confidence. Numerically, the lower seeding rate resulted in 7% more yield at Swift Current. Lower seeding rates tend to be more beneficial if conditions are dry due to less interplant competition. This was certainly the case for many locations in early spring. Overall, seeding rate had little effect on yield when considering all locations.

Increasing nitrogen levels from 80 to 160 lb/ac, which includes soil N (0-24 inches), significantly increased yield at Melfort, Scott and Yorkton by 13, 18 and 24%, respectively (Table 9 and 10). At Redvers, added N significantly reduced yield by 7%. For the remaining sites, yield was unresponsive to added N and no significant differences were detected.

Treatment means for quality factors are listed in tables 12 to 14. Data for test weight % plump, protein, and germination were combined together using site for replication to determine if seeding rate or rate of N impacted those variables. Only N rate significantly increased protein content of grain. On average, N levels of 80, 120 and 160 lb/ac resulted in grain proteins of 11.8, 12.6, and 13.1 percent, respectively. Increasing seeding rate did not significantly reduce protein or % plumps, however there was a trend for % plumps to decrease from 91.8 to 90.2% as N rates were increased from 80 to 160 lb N/ac. When averaged over location, the bushel weights for AAC Synergy and CDC Austenson were 48.7 lb/W bu (314 g/0.5l) and 50.4 lb/W bu (325 g/0.5l), respectively. For feed barley bushel weight should be above 48 lb/W bu.

Malt barley grain protein was based off of a bulked sample from the 4 replicates for each treatment. While the data cannot be analyzed statistically, grain protein tended to increase with added N at all locations (Table 12). However, the level of grain protein and the response to N level differed substantially between locations. Malsters typically want barley with a protein content between 11 and 12.5%. Even at the lowest level of N, % protein was too high for the grain to be selected for malt at Prince Albert and Swift Current. This likely occurred because the yield potential at these sites was relatively low. High yields are needed to produce starchy kernels which dilutes the protein. The remaining sites all had at least one treatment which produced grain protein within acceptable limits for malt. The highest level of N which still provided an acceptable level of grain protein varied between the remaining locations. When averaged across seeding rates, the highest N level which produced grain with an acceptable protein concentration for malt was 80 lb N/ac at Indian Head (12.3% protein), 120 lb N/ac at Redvers (11.7% protein) and 160 lb/ac at Melfort, Scott and Yorkton resulting in average grain proteins of 10, 12.5 and 11.4, respectively. Determining the highest N level for Outlook was difficult as % grain protein hovered at the end of the acceptable range regardless of N level. However, the highest level of N that produced acceptable levels of grain protein is not necessarily the most economical rate of N.

The most economic rate of N for AAC Synergy (malt) and CDC Austenson (feed) was determined using their yield responses to added N (averaged over seeding rate) and the prices of $4.68/bu for malt and $3.70/bu for feed. The optimum rate of N was the point at which $1/ac of additional N (at 50 cents/lb) produced $1/ac of additional revenue. However, the optimum N rate for malt also had to take into consideration that grain protein above 12.5% would result in rejection for malt.

Based on the above criteria, the most economic level of N for Scott was 155 lb/ac for malt (AAC Synergy) and 123 lb/ac for feed (CDC Austenson) (Figure 1). At Melfort, the most economic rate of N for feed was 116 lb/ac (Figure 2). Calculating the most economic rate of N for malt was questionable as the response curve was linear. This means the rate of return is same for every pound of added N which is not likely. Unfortunately, it was not possible to determine the most economic rate of N for either variety at the rest of the sites. At Yorkton, rates of N tested did not go high enough to determine the most economic rate for either variety (Figure 3). The yield response to N was very steep and very similar for both varieties at Yorkton. This means the most economic rate of N was somewhere beyond the level of 160 lb/ac. Even for malt, additional N would have been economical at Yorkton as protein was only 11.35% at the 160 lb N/ac level. For the remaining sites, N levels tested did not go low enough and the optimum level of N for both feed and malt was below 80 lb/ac. At Swift Current, Prince Albert and Outlook, even the lowest level of N at 80 lb/ac would not have produced malt as protein levels were above 12.5% (Figures 4, 5 and 6). Moreover, yields for both malt and feed were unresponsive to levels of N beyond 80 lb/ac. While an N level of 80 lb/ac did result in acceptable levels of grain protein at Indian Head and Redvers, further increases in N did not significantly increase yield of feed or malt (Figures 7 and 8). Thus the most economic level of N at Swift Current, Prince Albert, Outlook, Indian Head and Redvers was somewhere below 80 lb/ac for both AAC Synergy (malt) and CDC Austenson (feed).

Figure 1. Scott- Yield/Protein of AAC Synergy vs Yield of CDC Austenson 2019

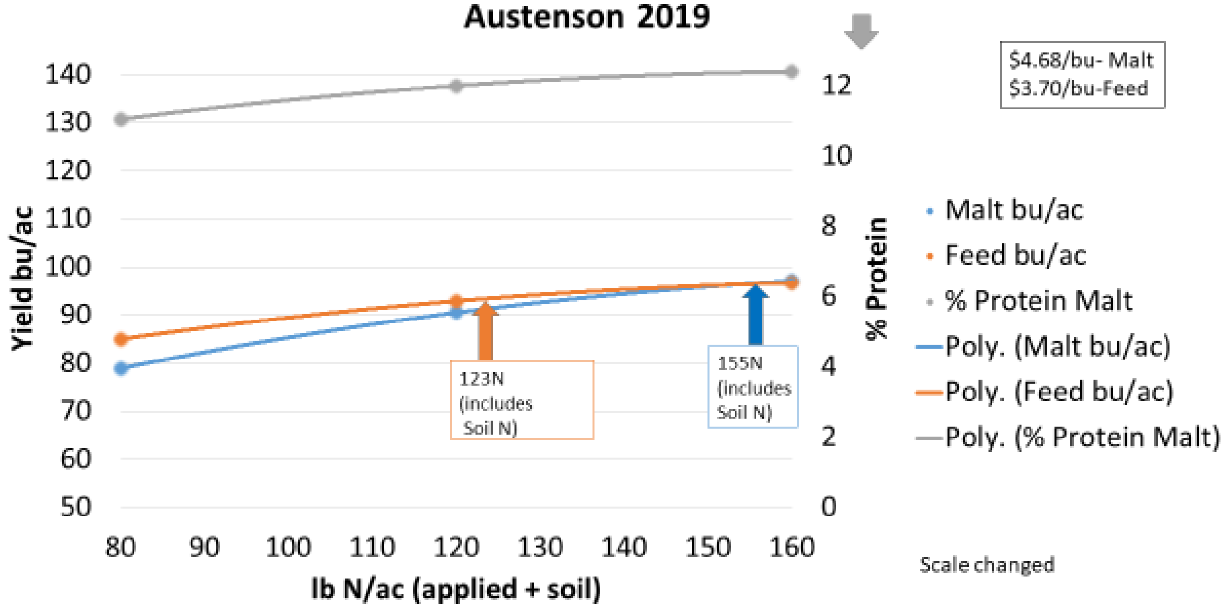


Figure 2. Melfort Yield/Protein of AAC Synergy vs Yield of CDC Austenson 2019

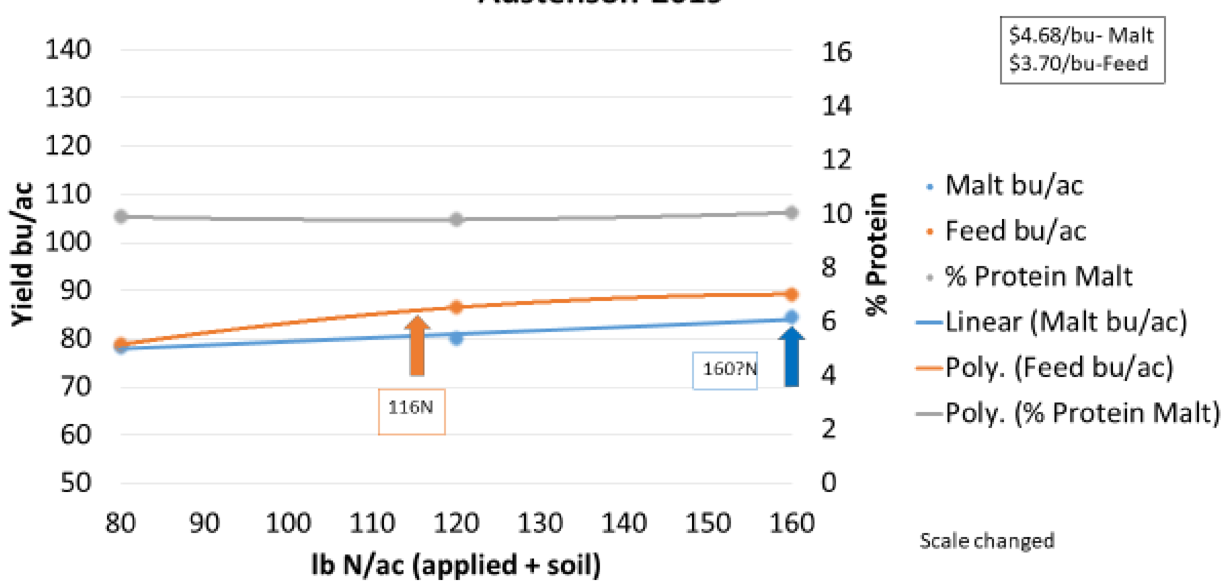


Figure 3. Yorkton- Yield/Protein of AAC Synergy vs Yield of CDC Austenson 2019

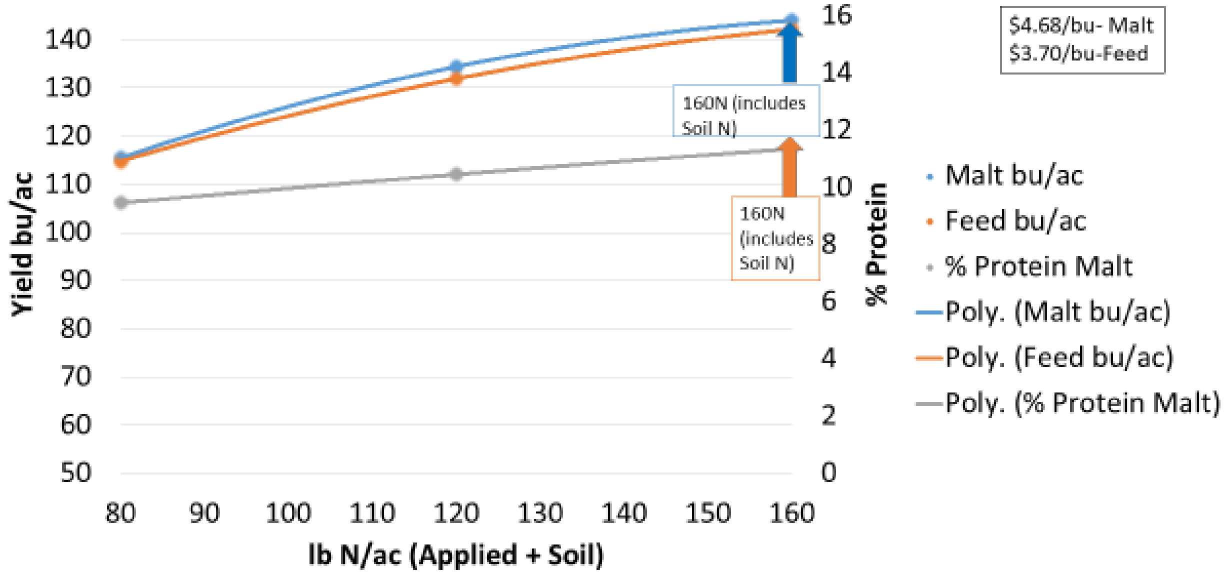


Figure 4. Swift Current- Yield/Protein of AAC Synergy vs Yield of CDC Austenson 2019

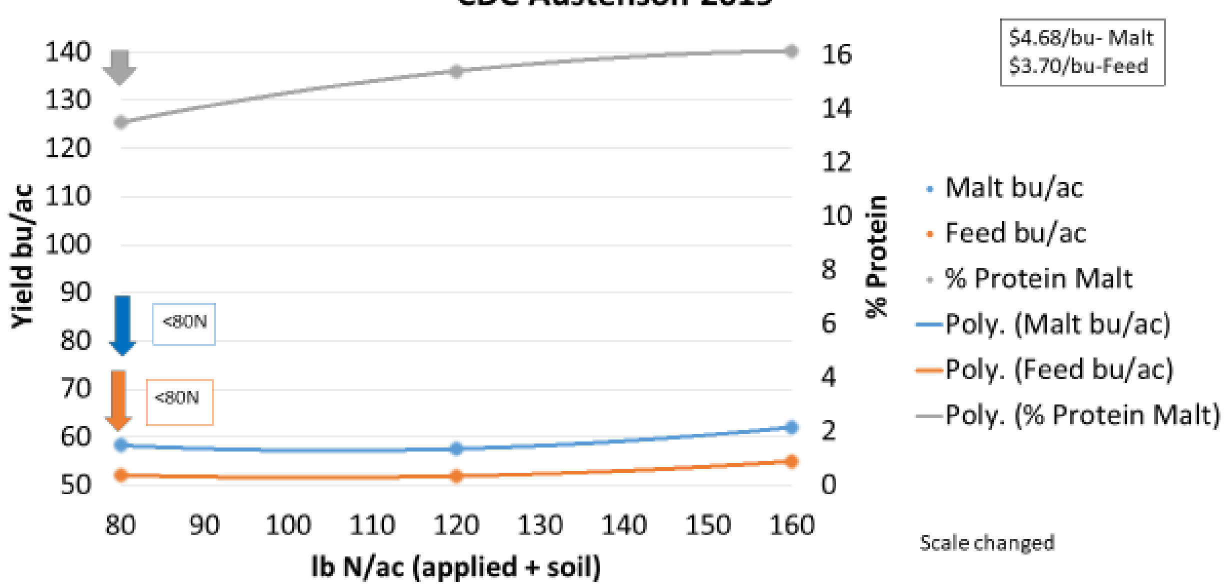


Figure 5. Prince Albert- Yield/Protein of AAC Synergy vs Yield of CDC Austenson 2019

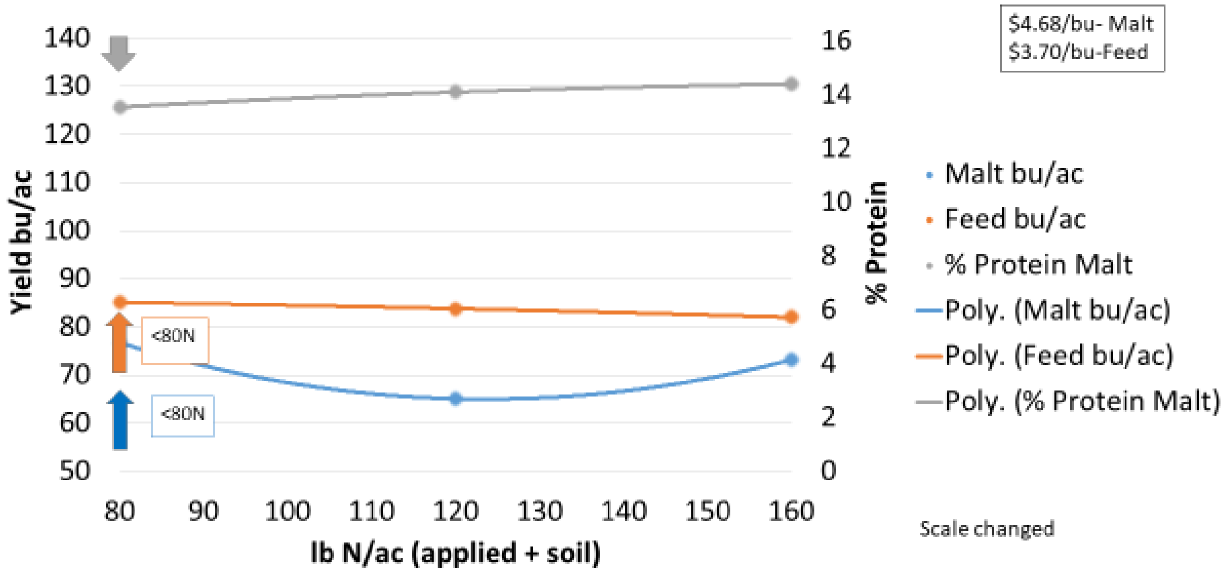


Figure 6. Outlook Yield/Protein of AAC Synergy vs Yield of CDC Austenson 2019

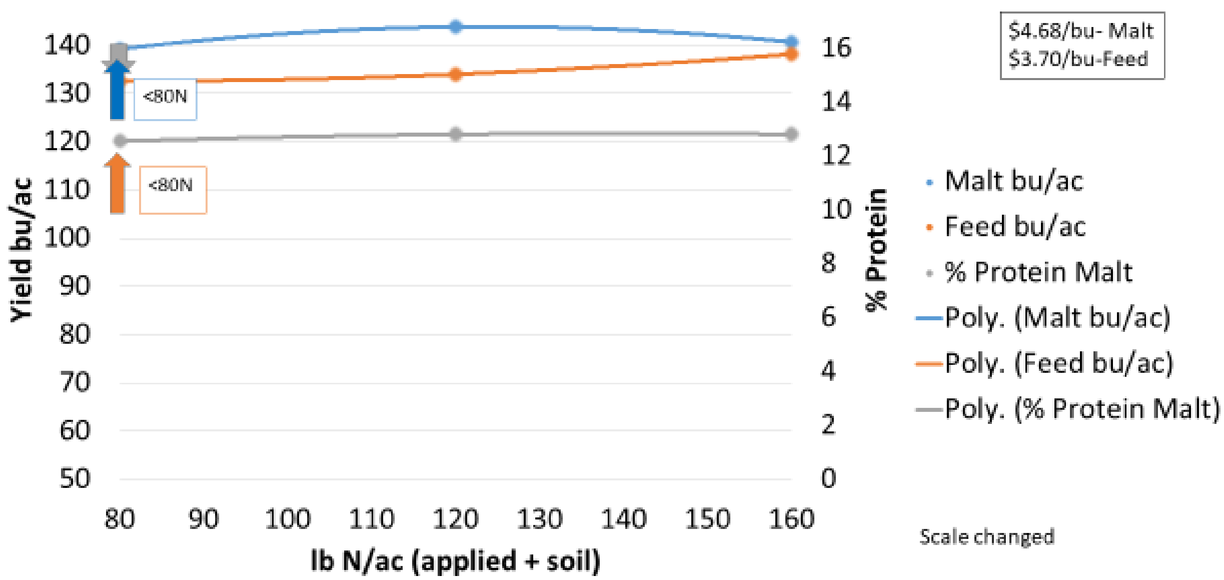


Figure 7, Indian Head Yield/Protein of AAC Synergy vs Yield of CDC Austenson 2019

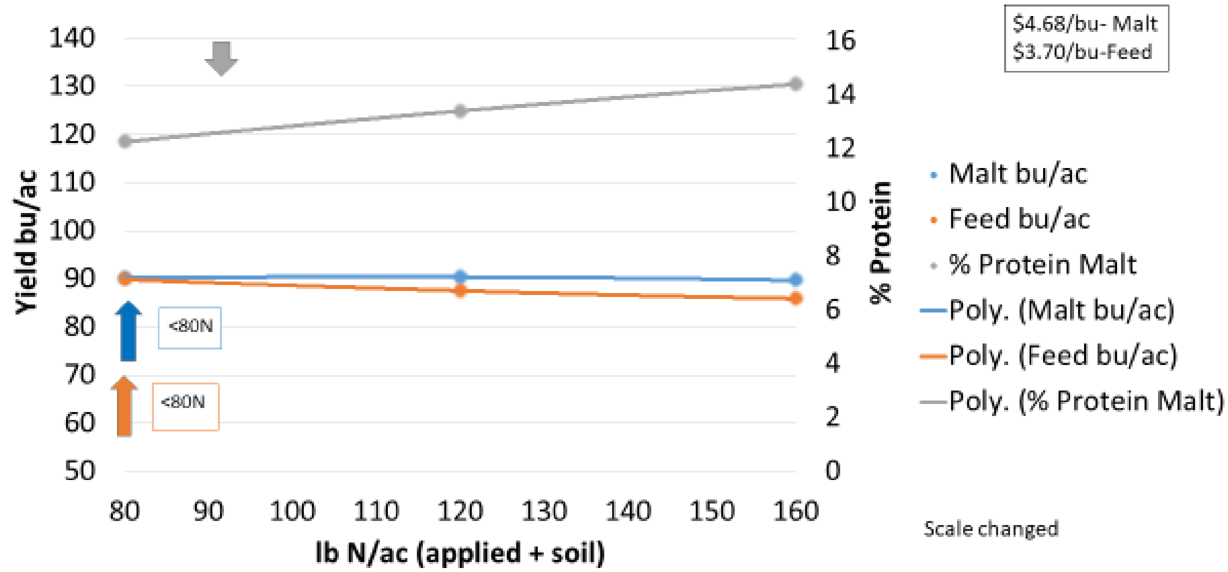
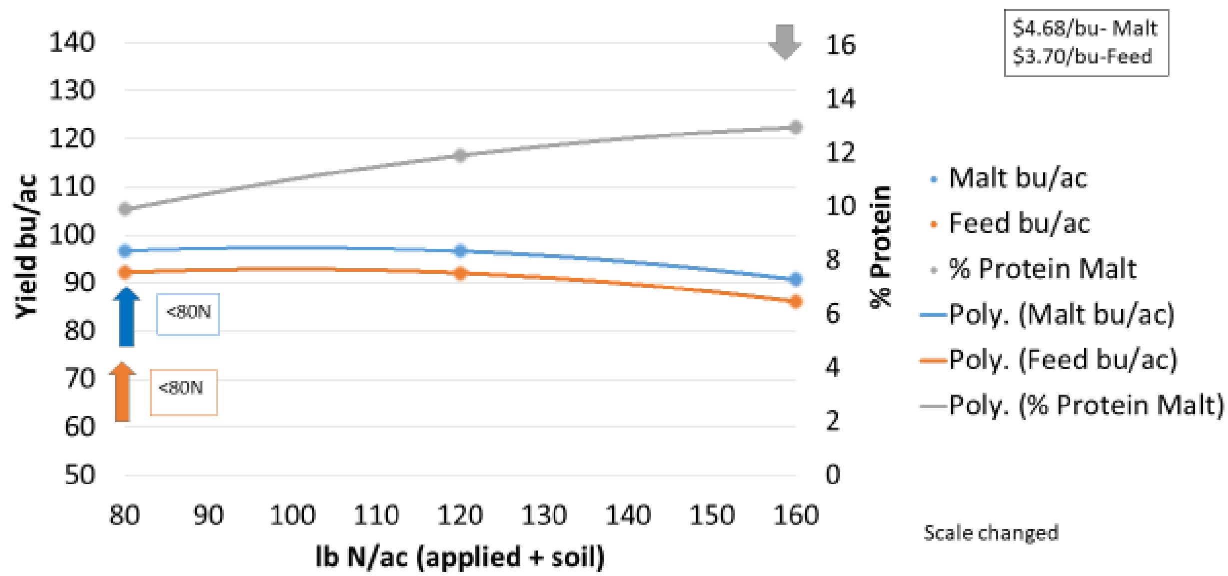


Figure 8. Redvers- Yield/Protein of AAC Synergy vs Yield of CDC Austenson 2019



Conclusions and Recommendations:

The yield difference between the malt variety AAC Synergy and feed variety CDC Austenson did vary between locations. However, when averaged across location, there was little yield difference between the varieties. There may be little reason to grow a feed variety over AAC Synergy which has a similar yield to the best feed varieties. However, it should be noted that the bushel weight of CDC Austenson was significantly higher than AAC Synergy which is an important criteria for feed. AAC Synergy was gaining acceptance with maltsters but recently Canada Malt has decided to no longer accept this variety. Increasing seeding rate did not increase yield, decrease protein or improve any quality factors for malt barley. However, increasing N did increase protein and tended to decrease % plump. In many cases it was not possible to compare the optimum level of N between the feed and malt varieties. At 5 locations, the yield of both varieties was unresponsive to increasing N levels above 80 lb/ac (soil + applied N). This means the economic level of N for these sites was below 80 lb/ac for both the feed and malt barley varieties. At Yorkton, the most economic level of N for both varieties would have been above 160 lb/ac as yield was highly responsive to added N and protein levels remained relatively low. A fair comparison of the most economic rate of N was only possible at Scott, where the most economic N rate for the malt and feed varieties were 155 and 123 lb/ac, respectively. While there is more risk associated with applying too much N to malt barley, there was little evidence to suggest the most economic rate of N is higher for feed than malt.

Acknowledgements:

This project was funded through the Agricultural Demonstrations of Practices and Technologies and Saskatchewan Barley Development Commission.

Appendices:

Table 6. Significance of variety, seeding rate and nitrogen fertilizer effects on barley emergence at multiple locations in 2019.

	Emergence							
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
Effect	---p-values [Z] ---------------------------------------							
Variety (V)	NS	NS	N/A	NS	NS	NS	NS	0.004129
Seeds/m^2 (S)	<0.00001	0.000374	N/A	0.00123	<0.00001	<0.00001	<0.00001	<0.00001
V x S	NS	NS	N/A	NS	NS	NS	NS	NS
Nitrogen rate (R)	NS	<0.00001	N/A	0.038526	0.075299	0.035497	0.020234	NS
V x R	0.00213	NS	N/A	NS	0.038526	NS	NS	NS
S x R	NS	NS	N/A	NS	0.012684	NS	NS	0.032719
V x S x R	NS	0.049375	N/A	NS	NS	NS	NS	NS

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

Table 7. Main effects of variety, seeding rate and nitrogen rate on barley emergence at multiple locations in 2019.								
Main effect	**Emergence**							
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
Variety	------------------------------------ plants/m^2 ------------------------------------							
AAC Synergy	268	95.2	N/A	147	189	186	188	213
CDC Austenson	259	99.7	N/A	141	179	194	186	235
LSD	NS	NS	N/A	NS	NS	NS	NS	14.2
Seeds/m^2								
200	226	83.8	N/A	125	158	160	158	193
300	301	111	N/A	164	210	221	216	254
LSD	15.4	14.2	N/A	22.8	12	9.4	12.7	14.2
lbs N/ac								
80	267	117	N/A	162	191	197	198	225
120	263	106	N/A	145	186	191	189	225
160	260	69	N/A	126	175	182	175	221
LSD	NS	17.9	N/A	28.6	14.5	11.9	16	NS

Table 8. Variety by Seeding rate by N fertilizer rate interactions on barley emergence at multiple locations in 2019.								
Main effect	**Emergence**							
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
V × S x R	-- plant/m^2 --							
AAC Synergy – 200 seeds/m2 – 80 lbs N/ac	236	84 bcd	N/A	137	348	165	174	174
AAC Synergy – 200 seeds/m2 – 120 lbs N/ac	217	111 abc	N/A	147	348	160	160	184
AAC Synergy– 200 seeds/m2 – 160 lbs N/ac	233	54 d	N/A	115	281	151	156	189
AAC Synergy – 300 seeds/m2 – 80 lbs N/ac	338	127 ab	N/A	182	475	218	215	254
AAC Synergy – 300 seeds/m2 – 120 lbs N/ac	281	112 abc	N/A	163	381	215	214	246
AAC Synergy – 300 seeds/m2 – 160 lbs N/ac	302	85 bcd	N/A	138	429	207	210	234
CDC Austenson – 200 seeds/m2 – 80 lbs N/ac	214	124 ab	N/A	139	297	162	171	196
CDC Austenson – 200 seeds/m2 – 120 lbs N/ac	240	74 cd	N/A	97	339	164	155	200
CDC Austenson – 200 seeds/m2 – 160 lbs N/ac	217	57 d	N/A	114	285	155	134	218
CDC Austenson – 300 seeds/m2 – 80 lbs N/ac	280	134 a	N/A	190	408	244	232	278
CDC Austenson – 300 seeds/m2 – 120 lbs N/ac	317	127 ab	N/A	172	414	226	225	271

CDC Austenson – 300 seeds/m2 – 160 lbs N/ac	287	83 bcd	N/A	137	406	214	201	244
L.S.D.	50.5	46.8	N/A	75.0	74.8	31.0	41.9	46.9

Table 9. Significance of variety, seeding rate and nitrogen fertilizer effects on barley grain yield at multiple locations in 2019.

	Yield							
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
Effect	--------------------	--------------------	--------------------	p-values [Z]	--------------------	--------------------	--------------------	
Variety (V)	0.006068	0.029177	NS	0.005565	0.015619	NS	0.006621	NS
Seeds/m^2 (S)	NS	NS	NS	NS	0.063075	NS	NS	NS
V x S	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen rate (R)	NS	0.045437	NS	NS	0.012684	<0.00001	NS	<0.00001
V x R	NS	NS	NS	NS	NS	NS	NS	NS
S x R	NS	NS	NS	NS	NS	NS	NS	NS
V x S x R	NS	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 10. Main effects of variety, seeding rate and nitrogen rate on barley grain yield at multiple locations in 2019.								
Main effect	**Yield**							
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
Variety	---------- Kg ha^{-1} ----------							
AAC Synergy	5048	4537	7909	4014	5302	4975	3323	7354
CDC Austenson	4916	4969	7559	4685	5046	5126	2968	7261
LSD	92.6	390	NS	467	208	NS	253	NS
Seeds/m^2								
200	5001	4817	7660	4288	5270	5073	3249	7349
300	4963	4689	7807	4411	5078	5029	3041	7265
LSD	NS	NS	NS	NS	NS	NS	NS	NS
lbs N/ac								
80	5046	4416	7613	4532	5288	4590	3090	6449
120	4984	4845	7778	4171	5284	5136	3068	7457
160	4916	4998	7810	4346	4950	5427	3279	8016
LSD	NS	490	NS	NS	261	216	NS	195

Table 11. Variety by Seeding rate by N fertilizer rate interactions on barley yield at multiple locations in 2019.								
Main effect	**Yield**							
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
V × S x R	-- Kg ha^{-1} --							
1. AAC Synergy – 200 seeds/m2 – 80 lbs N/ac	5114	4242	7263	4278	5450	4473	3307	6378
2. AAC Synergy – 200 seeds/m2 – 120 lbs N/ac	5102	4819	8287	3840	5624	5107	3208	7579
3. AAC Synergy– 200 seeds/m2 – 160 lbs N/ac	5032	4868	7875	4212	5149	5382	3627	8146
4. AAC Synergy – 300 seeds/m2 – 80 lbs N/ac	4994	4531	8333	4312	5381	4362	3220	6559
5. AAC Synergy – 300 seeds/m2 – 120 lbs N/ac	5030	4158	7816	3453	5198	5034	3246	7471
6. AAC Synergy – 300 seeds/m2 – 160 lbs N/ac	5014	4602	7881	3991	5011	5492	3330	7988
7. CDC Austenson – 200 seeds/m2 – 80 lbs N/ac	5046	4442	7259	4495	5266	4777	3058	6412
8. CDC Austenson – 200 seeds/m2 – 120 lbs N/ac	4938	5209	7159	4413	5143	5273	3087	7446
9. CDC Austenson – 200 seeds/m2 – 160 lbs N/ac	4775	5320	8119	4491	4990	5426	3209	8133
10. CDC Austenson – 300 seeds/m2 – 80 lbs N/ac	5029	4449	7596	5042	5057	4747	2774	6447
11. CDC Austenson – 300 seeds/m2 – 120 lbs N/ac	4867	5192	7852	4979	5171	5131	2733	7331
12. CDC Austenson – 300 seeds/m2 – 160 lbs N/ac	4843	5204	7367	4690	4650	5407	2949	7797

L.S.D.	305	1284	1735	1539	685	566	833	510

Table 12. Quality Parameters for Malt Barley								
Treatment	**Sprouted %**	**Plump %**	**Thins %**	**Foreign %**	**Peeled/Broken %**	**Moisture %**	**Protein %**	**Germ %**
Indian Head								
1. AAC Synergy – 200 seeds/m2 – 80 lbs N/ac	0	94	0.6	0	1	12.1	12.4	100
2. AAC Synergy – 200 seeds/m2 –120lbs N/ac	0	92.4	0.7	0	0.8	11.9	13.6	100
3. AAC Synergy – 200 seeds/m2 – 160s lb N/ac	0	92.8	0.6	0	0.8	12	14.4	100
4. AAC Synergy – 300 seeds/m2 – 80 lbs N/ac	0	95.1	0.6	0	0.8	12.2	12.1	100
5. AAC Synergy – 300 seeds/m2 – 120 lbs N/ac	0	93.6	0.6	0	1	12	13.2	100
6. AAC Synergy – 300 seeds/m2 – 160 lbs N/ac	0	92.4	0.7	0	0.5	12	14.4	100
Melfort								
1. AAC Synergy – 200 seeds/m2 – 80 lbs N/ac	0.3	98.2	0.2	0.2	5.4	10.4	10.3	99
2. AAC Synergy – 200 seeds/m2 – 120 lbs N/ac	0	98.4	0.1	0.3	3.8	10.4	9.7	97
3. AAC Synergy – 200 seeds/m2 – 160 lbs N/ac	0	98.4	0.2	0.2	2.6	10.4	9.8	97
4. AAC Synergy – 300 seeds/m2 – 80 lbs N/ac	0	98.1	0.1	0.2	5.8	10.4	9.5	100
5. AAC Synergy – 300 seeds/m2 – 120 lbs N/ac	0	98.2	0.1	0.1	5	10.4	9.9	99
6. AAC Synergy – 300 seeds/m2 – 160 lbs N/ac	0	98.5	0.1	0.1	3.9	10.4	10.3	97

Table 12 Continued. Quality Parameters for Malt Barley								
Treatment	**Sprouted %**	**Plump %**	**Thins %**	**Foreign %**	**Peeled/Broken %**	**Moisture %**	**Protein %**	**Germ %**
Outlook								
1. AAC Synergy – 200 seeds/m2 – 80 lbs N/ac	0	98.7	0.1	0	25.2	14.8	12.4	96
2. AAC Synergy – 200 seeds/m2 – 120 lbs N/ac	0	98.2	0.1	0	25.2	15.0	12.4	94
3. AAC Synergy – 200 seeds/m2 – 160 lbs N/ac	0	98.4	0.1	0	22.9	14.9	12.8	98
4. AAC Synergy – 300 seeds/m2 – 80 lbs N/ac	0	98.2	0.1	0	21.5	14.8	12.7	97
5. AAC Synergy – 300 seeds/m2 – 120 lbs N/ac	0	98.0	0.2	0.1	24.8	15.0	13.2	98
6. AAC Synergy – 300 seeds/m2 – 160 lbs N/ac	0	97.6	0.2	0	21.2	15.3	12.8	96
Prince Albert								
1. AAC Synergy – 200 seeds/m2 – 80 lbs N/ac	16.3	98.8	0.2	0.3	1.5	14.5	14.0	98
2. AAC Synergy – 200 seeds/m2 – 120 lbs N/ac	14.8	98.4	0.2	1.7	1.6	14.7	14.3	83
3. AAC Synergy – 200 seeds/m2 – 160 lbs N/ac	11.2	98.4	0.2	0.7	1.6	15.2	14.6	92
4. AAC Synergy – 300 seeds/m2 – 80 lbs N/ac	12.4	98.2	0.1	0.3	1.0	15.3	13.1	93
5. AAC Synergy – 300 seeds/m2 – 120 lbs N/ac	18.9	98.1	0.2	0.3	2.0	14.0	13.9	83
6. AAC Synergy – 300 seeds/m2 – 160 lbs N/ac	23.6	98.4	0.3	0.5	1.3	14.1	14.2	99

Table 12 Continued. Quality Parameters for Malt Barley								
Treatment	**Sprouted %**	**Plump %**	**Thins %**	**Foreign %**	**Peeled/Broken %**	**Moisture %**	**Protein %**	**Germ %**
Redvers								
1. AAC Synergy – 200 seeds/m2 – 80 lbs N/ac	0.4	95	0.3	0	2.8	10.5	10.2	100
2. AAC Synergy – 200 seeds/m2 – 120 lbs N/ac	0	91	0.8	0	2.0	10.6	11.6	99
3. AAC Synergy – 200 seeds/m2 – 160 lbs N/ac	0	89	0.9	0	3.3	10.8	13.0	99
4. AAC Synergy – 300 seeds/m2 – 80 lbs N/ac	0.5	92	0.5	0	2.0	10.6	9.6	99
5. AAC Synergy – 300 seeds/m2 – 120 lbs N/ac	0	90	0.9	0	3.7	10.9	12.2	100
6. AAC Synergy – 300 seeds/m2 – 160 lbs N/ac	0	85	2.1	0	3.2	10.7	12.9	98
Scott								
1. AAC Synergy – 200 seeds/m2 – 80 lbs N/ac	0.1	98.4	0.1	0	3.2	11.5	10.9	99
2. AAC Synergy – 200 seeds/m2 – 120 lbs N/ac	0.1	98.4	0.1	0	2.7	12.9	11.8	98
3. AAC Synergy – 200 seeds/m2 – 160 lbs N/ac	0.1	96.8	0	0.1	2.5	13.5	12.2	99
4. AAC Synergy – 300 seeds/m2 – 80 lbs N/ac	0.1	98	0	0	4.4	12	11.2	100
5. AAC Synergy – 300 seeds/m2 – 120 lbs N/ac	0	97.2	0.1	0	2.9	12.3	12.2	100
6. AAC Synergy – 300 seeds/m2 – 160 lbs N/ac	0.1	97.1	0.2	0	3	13.4	12.6	98

Table 12 Continued. Quality Parameters for Malt Barley								
Treatment	**Sprouted %**	**Plump %**	**Thins %**	**Foreign %**	**Peeled/Broken %**	**Moisture %**	**Protein %**	**Germ %**
Swift Current								
1. AAC Synergy – 200 seeds/m2 – 80 lbs N/ac	0	61.2	8.2	0.5	4.0	11.2	13.5	100
2. AAC Synergy – 200 seeds/m2 – 120 lbs N/ac	0	51.0	10.0	0.6	3.9	11.0	15.5	100
3. AAC Synergy – 200 seeds/m2 – 160 lbs N/ac	0	53.6	9.2	0.4	4.5	11.1	15.9	100
4. AAC Synergy – 300 seeds/m2 – 80 lbs N/ac	0	51.2	12.4	0.5	4.5	11.0	13.5	100
5. AAC Synergy – 300 seeds/m2 – 120 lbs N/ac	0	41.6	15.5	0.4	3.9	10.8	15.3	100
6. AAC Synergy – 300 seeds/m2 – 160 lbs N/ac	0	45.2	14.2	0.5	3.6	11.4	16.4	100
Yorkton								
1. AAC Synergy – 200 seeds/m2 – 80 lbs N/ac	2.8	99.1	0.1	0.1	1.4	15.2	9.6	99
2. AAC Synergy – 200 seeds/m2 – 120 lbs N/ac	1.4	98.0	0.1	0.1	4.3	15.3	10.3	97
3. AAC Synergy – 200 seeds/m2 – 160 lbs N/ac	0.3	98.2	0.1	0.1	3.5	15.2	11.1	95
4. AAC Synergy – 300 seeds/m2 – 80 lbs N/ac	3.5	98.6	0.1	0.1	3.0	15.1	9.3	96
5. AAC Synergy – 300 seeds/m2 – 120 lbs N/ac	0.4	97.5	0.2	0.1	3.9	15.1	10.6	99
6. AAC Synergy – 300 seeds/m2 – 160 lbs N/ac	0.7	96.5	0.3	0.1	3.4	15.3	11.6	97

Table 13. Thousand Kernel Weights for Malt and Feed Barley								
Treatments	**Indian Head**	**Melfort**	**Outlook**	**Redvers**	**Prince Albert**	**Scott**	**Swift Current**	**Yorkton**
Thousand Kernel Weights (g)								
1. AAC Synergy (Malt); 200 seeds/m^2; 80 lbs/ac N	47.5	49.9	53.6	48.6	52.1	49.0	34.5	52.2
2. AAC Synergy (Malt); 200 seeds/m^2; 120 lbs/ac N	47.5	53.0	54.2	45.5	50.6	51.6	34.4	53.3
3. AAC Synergy (Malt); 200 seeds/m^2; 160 lbs/ac N	45.8	52.8	53.7	45.1	50.7	49.8	33.1	51.8
4. AAC Synergy (Malt); 300 seeds/m^2; 80 lbs/ac N	47.2	49.5	51.8	45.7	51.2	50.2	29.6	52.4
5. AAC Synergy (Malt); 300 seeds/m^2; 120 lbs/ac N	46.8	51.0	51.3	45.0	50.1	49.2	30.8	51.7
6. AAC Synergy (Malt); 300 seeds/m^2; 160 lbs/ac N	46.6	52.4	51.9	43.2	50.8	49.8	28.7	53.3
7. CDC Austenson (Feed); 200 seeds/m^2; 80 lbs/ac N	37.5	51.3	53.6	46.5	50.7	51.8	29.2	58.1
8. CDC Austenson (Feed); 200 seeds/m^2; 120 lbs/ac N	44.5	52.8	55.8	43.8	54.3	51.4	28.1	55.3
9. CDC Austenson (Feed); 200 seeds/m^2; 160 lbs/ac N	43.5	51.7	54.9	45.3	51.8	50.6	32.0	54.9
10. CDC Austenson (Feed); 300 seeds/m^2; 80 lbs/ac N	45.5	50.8	52.8	44.1	51.6	50.2	29.5	53.4
11. CDC Austenson (Feed); 300 seeds/m^2; 120 lbs/ac N	45.1	51.2	53.2	44.4	51.0	50.6	23.4	54.9
12. CDC Austenson (Feed); 300 seeds/m^2; 160 lbs/ac N	43.6	52.3	53.2	43.5	50.6	48.8	28.6	51

Table 14. Test Weights for Malt and Feed Barley								
Treatments	**Indian Head**	**Melfort**	**Outlook**	**Redvers**	**Prince Albert**	**Scott**	**Swift Current**	**Yorkton**
Test Weight (g/0.5 L)								
1. AAC Synergy (Malt); 200 seeds/m^2; 80 lbs/ac N	315.8	323.6	310.8	319.3	316.4	316.0	288.2	316.9
2. AAC Synergy (Malt); 200 seeds/m^2; 120 lbs/ac N	315.5	331.1	314.3	319.3	319.4	319.0	286.5	325.3
3. AAC Synergy (Malt); 200 seeds/m^2; 160 lbs/ac N	314.8	331.2	311.5	314.5	316.0	323.5	287.2	328.1
4. AAC Synergy (Malt); 300 seeds/m^2; 80 lbs/ac N	315.8	322.1	312.1	314.5	305.8	317.5	266.5	316.6
5. AAC Synergy (Malt); 300 seeds/m^2; 120 lbs/ac N	315.5	327.9	311.6	315.0	300.5	320.3	281.5	325.5
6. AAC Synergy (Malt); 300 seeds/m^2; 160 lbs/ac N	316.5	334.7	312.5	312.5	318.9	323.0	283.4	328.3
7. CDC Austenson (Feed); 200 seeds/m^2; 80 lbs/ac N	325.8	341.2	327.0	333.3	330.0	332.5	290.4	336.0
8. CDC Austenson (Feed); 200 seeds/m^2; 120 lbs/ac N	319.3	346.8	326.3	328.3	324.0	335.0	280.5	335.7
9. CDC Austenson (Feed); 200 seeds/m^2; 160 lbs/ac N	319.5	344.6	326.1	327.3	324.3	337.5	284.8	339.5
10. CDC Austenson (Feed); 300 seeds/m^2; 80 lbs/ac N	326.3	342.0	326.3	329.5	328.1	337.0	284.3	335.7
11. CDC Austenson (Feed); 300 seeds/m^2; 120 lbs/ac N	323.5	344.9	327.4	328.0	330.3	333.5	257.1	336.5
12. CDC Austenson (Feed); 300 seeds/m^2; 160 lbs/ac N	319.3	345.2	324.3	323.5	330.4	334.5	277.2	336.0

Enhanced Fertilizer Management for Optimizing Yield and Protein in Field Pea

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Objectives:

The project objectives were simply to evaluate, across a range of Saskatchewan environments, the yield and protein response of yellow field pea to various rates and combinations of nitrogen (N), phosphorus (P) and sulphur (S) fertilizer.

Rationale:

Field peas are the most widely adapted pulse crop in Saskatchewan and are important to many growers for both the rotational benefits associated with legumes and as a key option for maintaining diversity in crop rotations. Furthermore, with increasing consumer demand for plant-based protein there are emerging opportunities for growers to receive premiums for high protein pulse crops and we anticipate increased interest in exploring potential management options to more consistently achieve high protein levels. Experience with non-legume crops suggests that N fertility is one of relatively few management decisions that can consistently affect grain protein concentrations.

Field peas can benefit from N fixation whereby symbiotic relationships with Rhizobium leguminosarum bacteria allow atmospheric N2 to be converted to available forms and utilized by the crop. The maximum benefit to this process is generally achieved when mineral N (soil + fertilizer) levels are low; therefore, N fertilization in field pea production is not normally recommended unless soil residual levels are extremely low (i.e. < 11 kg NO3-N/ha). In northwest Alberta, Clayton et al. (2004) found that, regardless of inoculant form, N fertilizer rates ranging from 0-80 kg N/ha (side-banded urea) increased vegetative growth but did not affect seed yield at 4/6 site-years and seed protein was not affected in any cases. At one site where there was a response, N fertilization increased grain yield with either no inoculant or seed-applied (peat or liquid) formulations but decreased yield when combined with granular inoculant. The highest yields, by a large margin, were achieved with no N fertilizer and granular inoculant. At the other site where there was an N fertilizer effect, increased yield with N fertilizer only occurred when no inoculant (regardless of form) was applied. Another, extensive, Alberta study showed that application of N fertilizer (20, 40, or 60 kg N/ha) increased pea yield in 24% of 58 trials by an average of 9% (McKenzie et al. 2001). When residual NO3-N was less than 20 kg N/ha, increases occurred 33% of the time with an overall average benefit of 11%. Although protein was affected by the addition of N fertilizer at more than 36% of the sites, the response was more frequently negative than it was positive (21% versus 16%). In early work with a single site-year at Saskatoon, Sosuiski et al. (1974) were not able to measure yield but increased field pea seed protein by 2% over the control with 55 kg N/ha as ammonium-nitrate (33.5-0-0).

Focussing on P, field peas are not considered to be particularly responsive to fertilization; however, responses to modest rates have been documented in low P soils. Over a three-year period on low P soils (10-18 kg NaHCO3 extractable P) near Outlook, Melfort, and Saskatoon, Henry et al. (1994) increased pea yields by approximately 15% with 35 kg P2O5/ha as side-banded monoammonium phosphate at one of three locations but observed negative responses to seed-placed P rates exceeding 35 kg P2O5/ha at the other two locations. In a series of 21 trials using Triple Super Phosphate (0-45-0) as a P source, Karamanos et al. (2003) found that field peas responded to P when modified Kelowna extractable P was less than 10 ppm and that the response was greater in loam versus clay soils and with side-banded versus seed-placed fertilizer. Many producers strive to apply P fertilizer rates that are sufficient to offset nutrients removed in the harvested grain. It is estimated that field peas removed approximately 0.6-0.8 lb P2O5/bu or 31-38 lb P2O5/ac (35-43 kg P2O5/ha) in a 50 bu/ac (3400 kg/ha) crop (Canadian Fertilizer Institute 1998).

Relatively few studies have evaluated field pea response to S fertilization. McKenzie et al. (2001) reported that yield increases with potassium and S fertilizer application occurred at only 3 of 44 trials in Alberta and found no correlation between the observed responses and soil test levels. Under low yielding, drought conditions at Swift Current in 2017, lentil yields were significantly increased with sulphate S fertilizer with the best results achieved using ammonium sulphate (21-0-0-24) at a rate of 20 kg S/ha (Nybo et al. 2017). While the treatments were also evaluated on field peas, yields were extremely low and no benefit was observed. A 50 bu/ac (3400 kg/ha) field pea crop will take up approximately 12-16 kg S/ha (Canadian Fertilizer

Institute 1998). In general, S fertilizer responses are be more likely to occur in coarse textured soils with low organic matter and low residual S.

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Materials and Methods

In early 2019, Agri-ARM and Saskatchewan Pulse Growers agronomists developed and initiate a comprehensive field pea fertility study at multiple Saskatchewan locations. The locations were Swift Current (dry Brown), Outlook (Brown), Scott (Dark Brown), Indian Head (thin Black), Yorkton (Black), and Melfort (moist Black). The treatments were an assortment of fertilizer applications selected to test the yield and protein responses to varying P and S rates in addition to several N fertilization strategies. To represent both extremes we also included an unfertilized control and an ultra-high fertility treatment. The P and S sources were monoammonium phosphate (11-52-0) and ammonium sulphate (21-0-0-24), respectively. With the exception of treatments 12-13 where polymer coated urea (ESN; 44-0-0) was used, the N source was urea (46-0-0). All fertilizer was side-banded with the exception of the extra urea in Treatment 11 which was applied as a surface broadcast during the late vegetative crop stages. All treatments received the full, label-recommended rate of granular inoculant. The fertilizer treatments are listed below in Table 1.

Table 1. Field pea fertilizer treatment descriptions.

#	kg N-P_2O_5-K_2O-S/ha
1	0-0-0-0 (no fertilizer)
2	17-0-0-10 (0 P)
3	17-20-0-10 (20 P)
4	17-40-0-10 (40 P / 10 S)
5	21-60-0-10 (60 P)
6	26-80-0-10 (80 P)
7	17-40-0-0 (0 S)
8	17-40-0-5 (5 S)
9	22-40-0-15 (15 S)
10	40-40-0-10 (40 N as MAP/AS/urea)
11[Z]	17.2-40-0-10 + 40 N in-crop broadcast urea
12[Y]	40-40-0-10 * (40 N as MAP/AS/ESN)
13[Y]	40-80-0-15 * (ultra high fertility / ESN)

[Z] In-crop N broadcast approximately 4-5 weeks after emergence, prior to canopy closure and 1st flowers

[Y] ESN (44-0-0) instead of urea as the supplemental N source in Trt #12 and 13

*All fertilizer side-banded except for the 40 kg N/ha as in-crop urea in Trt #11

Selected agronomic information is provided in Table 2 of the Appendices. Seeding equipment varied across locations to a certain extent but all sites utilized no-till drills with side-band capabilities and the field peas were always direct-seeded into cereal stubble. All sites used the same seed source (variety CDC Spectrum) with target seeding rates of 100 viable seeds/m2, adjusted for seed size and percent germination. Seed treatments were used to mitigate the risk of root diseases and pea leaf weevil at all locations. Seeding dates ranged from as early as May 7 at Yorkton to May 22 at Melfort with seeding for the remaining sites completed between May 9-14. Weeds were controlled using registered pre- and post-emergent herbicide options. Insecticides were not required at any locations. Foliar fungicides were applied preventatively at all sites except for Swift Current where the risk of disease was low. Pre-harvest herbicides and/or desiccants were applied at the discretion of individual site managers and the plots were straight combined as soon as possible after it was fit to do so. Seed yields were corrected for dockage and to a uniform moisture content of 16%. Seed protein concentrations were determined for each plot using an NIR instrument. To aid in the interpretation of results, composite soil samples were collected from each location prior to seeding to be analyzed for residual nutrients and other basic qualities. Similarly, precipitation amounts and temperatures for each location were recorded at nearby Environment Canada stations.

The specific response data evaluated were seed yield and seed protein concentrations. Data were analyzed using the Mixed procedure of SAS with the effects of location (L), fertilizer treatment (F), and the L x F interaction considered fixed and replicated effects (nested within locations) considered random. Individual treatment means were separated using Tukey's studentized range test. Heterogeneity in variance estimates amongst individual locations was permitted and improved model convergence for both response variables. Contrasts were used to compared the unfertilized (1) to fertilized (2-13) treatments and normal fertility (4) to the treatments where extra N was applied (10, 11, and 12). Orthogonal contrasts were used to test whether the specific responses to increasing P and S rates were linear, quadratic, or not significant. All responses were considered significant at $P \leq 0.05$ but values ≤ 0.10 were also generally highlighted as noteworthy trends.

Results and Discussion:

Soil test results are provided in Table 5 of the Appendices. Soil pH ranged from 5.9-8.1 while organic matter levels ranged from 2.3-9.6% and all values were considered reasonably representative of their corresponding regions. Residual nitrate was variable, below 50 kg/ha at 5/6 locations (0-60 cm) but with a range of 21-202 kg NO3-N/ha. The site with the higher than usual residual nitrate levels was Swift Current while the lowest N levels were at Outlook and Indian Head (21-27 kg NO3-N/ha). Residual P levels were always low, ranging from 4-5 ppm at Indian Head and Outlook to a maximum of 11 ppm at Scott. Both potassium (K) and sulphur (S) levels were high at all locations and neither of these nutrients were expected to be limiting at any locations based on soil test results alone. Potassium responses were not evaluated in the current project.

Seed Yield

When seed yield data were averaged across all locations, the effect of fertilizer treatment and location were both highly significant ($P < 0.001$) but a significant F x L interaction ($P < 0.001$) indicated that the fertilizer effect varied with environment (Table 6). The highest yields were achieved at Scott (6022 kg/ha), followed by Yorkton and Outlook (4833-4918 kg/ha), Indian Head (4326 kg/ha), Melfort (3807 kg/ha), and Swift Current (2845 kg/ha). Looking at the averaged fertilizer responses, yields were lowest in the unfertilized control (Trt. #1) as expected while the highest yields were achieved with balanced but not excessive fertility package of 17-40-0-10 kg N-P2O5-K2O-S/ha as side-banded monoammonium phosphate and ammonium sulfate (Trt. #4). Statistically, yields did not significantly differ amongst any of the fertilized treatments where a minimum of 20 kg P2O5/ha was applied. The quadratic response to P rate (Table 7; $P = 0.002$) considered along with the treatment means indicated that the maximum benefit was achieved at approximately 40 kg P2O5/ha when averaged across locations. While there was no indication of a response to S fertilizer when averaged across locations, the contrasts did show a tendency for lower yields when additional N fertilizer (beyond what was supplied by the P and S fertilizer products) was applied ($P = 0.062$; Tables 6 and 7). The magnitude of this reduction was small at only 163 kg/ha or 3.5%.

Again, the F x L interaction tells us that the response varied across locations. Overall tests of fertility effects for individual locations suggested that yield responses occurred at Indian Head, Outlook, and Scott ($P < 0.001$) with trends observed at Swift Current and Yorkton ($P = 0.072$-0.074) and no response at Melfort. At Indian Head, P fertilizer rate had the greatest impact with a strong linear response detected ($P < 0.001$). There was a slight tendency for lower yields when supplemental N fertilizer (beyond what is provided by P and S products) was applied ($P = 0.094$). At Melfort, despite the lack of a significant F-test, the orthogonal contrasts indicated a quadratic response to P rate ($P = 0.048$) but no other impacts. At Outlook, although there was a relatively strong discrepancy between the unfertilized versus fertilized treatments ($P < 0.001$), it was difficult to attribute the response to any individual nutrients. Phosphorus appeared to have the largest and most consistent effect on yield; however, the corresponding orthogonal contrasts were marginally significant at best (P-linear, $P = 0.095$) and most of the benefit appeared to be achieved with the relatively low rate of 20 kg P_2O_5/ha. It appears that most of the yield gains with fertilization at Outlook could be attributed to the low rate (17 kg N/ha) of background N provided in all the treatments combined the first 20 kg P_2O_5/ha. At Scott, there was a highly significant quadratic P response ($P = 0.007$) with most of the benefit realized at the lowest rate of 20 kg P_2O_5/ha. The contrast testing the effects of extra N was also significant ($P = 0.002$) and appeared to mostly be due to a negative impact of side-banding supplemental urea. Of the N treatments evaluated, this was the most likely to increase mineral N levels early and potentially impede rhizobial colonization and subsequent N fixation; however, nodule assessments were beyond the scope of this project. At Swift Current, the quadratic orthogonal contrast for seed yield also suggested a benefit to P fertilization but, again, with most of the benefit realized at the lowest rate (20 kg P_2O_5/ha). At Yorkton, there was no evidence of a P response specifically ($P = 0.302$-0.773) but the comparison between the control and all fertilized treatments was significant ($P = 0.011$) and, somewhat unexpectedly (considering the soil test results), the linear orthogonal contrast for S rate was also significant ($P = 0.030$).

Seed Protein Concentration

When seed protein data were averaged across all locations, the effect of fertilizer treatment on its own was not significant ($P = 0.270$) but protein levels were affected by location ($P < 0.001$) and, again, the F x L interaction ($P < 0.001$) indicated that the fertilizer effect on protein varied with environment (Table 8). Average seed protein concentrations of individual locations ranged from 19.9-24.7%. Averaged across all locations, seed protein concentrations ranged from 22.2-22.9% with, as indicated by the F-tests, no significant differences amongst individual treatments. The only contrast that was significant was an overall linear increase in protein with increasing P rate ($P = 0.046$; Table 9). It is worth specifically noting that supplemental N fertilizer did not impact field pea seed protein when averaged across locations ($P = 0.738$).

Similar to seed yield, the significant F x L interaction indicated that the protein response to fertilizer was not always consistent depending on the environment. The overall F-tests for individual locations indicated that the protein responses were greatest at Indian Head and Swift Current ($P < 0.001$-0.026), followed by Outlook and Scott ($P = 0.054$-0.083) and then Melfort and Yorkton ($P = 0.533$-0.978). At Indian Head, no differences between individual treatments were significant according to the multiple comparisons test but the comparison between the control versus fertilized treatments was and appeared to be due to a slight decline in protein with fertilizer application ($P < 0.001$). At Swift Current, the opposite occurred whereby the lowest protein concentrations were observed in the unfertilized control. Protein also increased linearly with P rate at this location ($P < 0.001$). At Outlook, P rate also appeared to have a positive effect on protein; however, this appeared to be mostly due to the comparatively high values observed at the 80 kg P_2O_5/ha rate. At Scott, there was slight positive impact of extra N on protein detected; however, this mostly appeared to be associated with the side-banded urea where yields were also lowest; therefore, the effect may have been more a result of reduced yield as opposed to enhanced N uptake/availability. At Yorkton, there was evidence of a slight negative impact of extra N on grain protein ($P = 0.038$) and no significant responses or noteworthy trends were observed at Melfort.

Economic and Practical Implications for growers

While it is difficult to assign a specific monetary value, the economic benefits associated with this research could conceivably arise from either enhanced yields through better fertilizer management or reduced fertilizer costs with no reduction in yield. The benefits will vary with environment and also as a function of the current practices of individual growers. For example, some growers may currently be under fertilizing their field peas, losing yield and further depleting soil reserves (i.e. phosphorus) and the results from this work may help them justify the higher costs of enhanced fertility. In contrast, other producers may be fertilizing excessively and can potentially utilize these results to reduce their fertilizer investment (i.e. starter N, S in non-limiting soils) without negatively impacting yields. Since P fertilizer provided the most consistent responses, marginal economic returns were calculated for each P rate assuming $6.25/bu for yellow peas and two monoammonium phosphate prices ($550 and 750/Mt). The results from this exercise are provided in Table 10 of the Appendices. Average across all locations, the most economical P rate was 40 kg P_2O_5/ha. This was also the most economical rate at both Indian Head and Melfort. At Outlook, Scott, and Swift Current the most economical P rate was 20 kg P_2O_5/ha while at Yorkton the P response was not significant, therefore the control was considered to be the most profitable. Notably, the most profitable P rate treatment for each individual site and on average was unchanged regardless of whether the P fertilizer price was $550/Mt or $750/Mt.

From a broader agronomic perspective, our results support the use of soil tests and suggest that, of the major nutrients, phosphorus is the most likely to be limiting field pea productivity and can provide sizeable yield benefits when applied as fertilizer. Soil test results did not indicate that a response to S was likely at any individual locations and this was mostly true; however, there was some evidence of a small response to S even with high soil test levels at 1/6 sites (Yorkton). All nutrients have potential to be limiting and this result is not inconsistent with broader recommendations for S which indicate that soil test results are often variable and high residual S levels do not necessarily indicate that deficiencies cannot occur, at least on a site-specific basis. There was no benefit to additional N (beyond what is supplied with modest rates of P and S fertilizers) for either yield or protein, regardless of formulation. Any responses to N that did occur were small and/or negative.

Conclusions and Recommendations:

Overall, the locations provided a range of yield potentials and were representative of the major field pea producing regions of Saskatchewan while the observed fertilizer responses were largely consistent with past research and current recommendations for western Canada. Soil test P levels for all sites were considered low (≤ 11 ppm, Olsen) and there was evidence of a statistically significant response at 4/6 locations, or 67% of the time. For the responsive sites, the yield increase with P ranged from 11-31% and, when averaged across all six locations, yields were increased by up to 12% with P fertilization and the optimal rate was 40 kg P_2O_5/ha. While responses were occasionally linear with top yields realized at the highest P rate, yield increases beyond the 20 kg P_2O_5/ha rate were never statistically significant and it is unlikely that rates exceeding approximately 40 kg P_2O_5/ha would be justified under most conditions. An important exception could be when the objective of the producer is for long-term building of residual P levels. Some of the literature cited earlier indicated yield increases of approximately 15% at responsive sites and suggested that responses were likely when soil test levels were below 10 ppm (modified Kelowna extractable P). Sulphur responses have been elusive in past research and this was also true in the current project. Past work has also shown that responses to S are poorly correlated with soil test results. Consequently, if deficiencies have been observed in the past for either field peas or other crops, applying a small amount of S may be justifiable; however, it is unlikely that S deficiency has been an important yield limiting factor for many field pea producers in Saskatchewan. Focussing on N, past research has found that N fertilization can frequently increase vegetative growth in field peas but positive yield responses are less likely, especially when combined with adequate rhizobial inoculation. Negative protein responses to N fertilization are at least as probable as positive responses. Our results did not show any benefits to N fertilization and, unless residual levels are extremely low or a nodulation failure is suspected, Saskatchewan field pea producers are advised to avoid applying any more N fertilizer than what is provided by any P or S fertilizer products being utilized.

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Appendices:

Table 1. Selected agronomic information and dates of operations in 2019 for field pea fertility trials at Indian Head, Melfort, Outlook, Scott, Swift Current, and Yorkton, Saskatchewan.

Activity	Indian Head	Melfort	Outlook	Scott	Swift Current	Yorkton
Pre-seed Herbicide	890g glyphosate/ha (May 6)	667g glyphosate/ha + 18g saflufenacil/ha (May 21)	890g glyphosate/ha (May 6)	1134g glyphosate/ha + 21g carfentrazone/ha (May 19)	890g glyphosate/ha (May 4)	n/a
Seeding	May 9	May 22	May 9	May 12	May 14	May 7
Row Spacing	30 cm	30 cm	25 cm	25 cm	21 cm	30 cm
In-crop Herbicide	15g imazamox/ha + 15g imazethapyr/ha (June 12)	20g imazamox/ha + 424g bentazon/ha + 71g quizalofop/ha (July 5)	20g imazamox/ha + 424g bentazon/ha (June 5)	15g imazamox/ha + 15g imazethapyr/ha + 167g sethoxydim/ha (June 13)	20g imazamox/ha + 424g bentazon/ha (June 12)	20g imazamox/ha + 424g bentazon/ha (June 6) 89g clethodim/ha (June 6)
In-crop Nitrogen	June 28 (as per protocol)	July 11 (as per protocol)	June 27	June 10	May 14	June 27
Foliar Fungicide	74g fluxapyroxad/ha + 148g pyraclostrobin/ha (July 7)	201g picoxystrobin/ha (July 12)	74g fluxapyroxad/ha + 148g pyraclostrobin/ha (July 18)	74g fluxapyroxad/ha + 148g pyraclostrobin/ha (July 15)	n/a	201g picoxystrobin/ha (July 5)
Pre-harvest Herbicide / Desiccant	890g glyphosate/ha (August 8)	890g glyphosate/ha + 50g saflufenacil/ha (September 16)	410g diquat/ha (August 20)	410g diquat/ha (August 20)	n/a	n/a
Harvest	August 17	September 23	August 22	August 29	August 20	August 26

n/a – not applicable

Table 2. Selected soil test results for field pea fertility trials at Indian Head, Melfort, Outlook, Scott, Swift Current, and Yorkton Saskatchewan in 2019.

Attribute/Nutrient [Z]	Indian Head	Melfort	Outlook	Scott	Swift Current	Yorkton
pH	7.9	6.0	8.1	5.9	6.5	7.0
S.O.M. (%)	4.7	9.6	2.3	3.5	2.6	6.5
NO_3-N (kg/ha)	27	37 (0-30 cm)	21	47	202	44
Olsen-P (ppm)	4	9	5	12	8	9
K ppm (ppm)	573	473	158	201	229	291
S (kg/ha)	60	85 (0-30 cm)	60 (0-30 cm)	116	47	125

[Z] NO_3-N and S are for 0-60 cm depth (unless otherwise indicated) – all other attributes are for 0-15 cm

Table 3. Tests of fixed effects and individual fertility treatment means for field pea yield at six Agri-ARM facilities in 2019. Data were analyzed using the Mixed procedure of SAS. Treatment means within a column and location means within a row followed by the same letter do not significantly differ (Tukey's studentized range test, $P \leq 0.05$).

Source / Treatment	Indian Head	Melfort	Outlook	Scott	S. Current	Yorkton	Average
Overall F-test				p-value			
Fertilizer Treatment (F)	<0.001	0.439	<0.001	<0.001	0.074	0.072	<0.001
Location (L)	–	–	–	–	–	–	<0.001
F x L	–	–	–	–	–	–	<0.001
kg N-P_2O_5-K_2O-S/ha				Seed Yield (kg/ha)			
1) 0-0-0-0 (no fertilizer)	4085 b	3763 a	3595 b	5546 bc	2701 a	4422 a	4019 C
2) 17-0-0-10 (0 P)	3994 b	3683 a	4377 ab	5625 bc	2375 a	4973 a	4171 BC
3) 17-20-0-10 (20 P)	4287 ab	3515 a	4912 ab	6202 a	3090 a	4751 a	4460 AB
4) 17-40-0-10 (40 P / 10 S)	4487 ab	4210 a	4897 ab	6137 a	3111 a	5082 a	4654 A
5) 21-60-0-10 (60 P)	4310 ab	4157 a	5004 ab	6168 a	2855 a	5269 a	4627 A
6) 26-80-0-10 (80 P)	4628 a	3484 a	5054 ab	6268 a	3078 a	5018 a	4588 A
7) 17-40-0-0 (0 S)	4437 ab	3548 a	5472 a	6181 a	2806 a	4494 a	4490 AB
8) 17-40-0-5 (5 S)	4289 ab	3742 a	4782 ab	6150 a	2908 a	4641 a	4419 AB
9) 22-40-0-15 (15 S)	4340 ab	3838 a	5218 ab	6244 a	2611 a	4952 a	4534 A
10) 40-40-0-10 (urea)	4390 ab	3923 a	5366 a	5340 c	2911 a	4932 a	4477 AB
11) 17-40-0-10 + 40 N in-crop	4186 ab	3948 a	5067 ab	5953 ab	2824 a	4978 a	4493 AB
12) 40-40-0-10 (ESN)	4374 ab	4038 a	4628 ab	6204 a	2859 a	4912 a	4502 AB
13) 40-80-0-15 (ultra high fert)	4429 ab	3644 a	5558 a	6266 a	2861 a	5049 a	4634 A
S.E.M.	127.4	253.6	288.1	124.8	181.7	207.8	84.2
Location Average	4326 C	3807 D	4918 B	6022 A	2845 E	4883 B	–
S.E.M.	95.6	113.3	119.5	95.3	102.1	105.9	–

Table 4. Group comparison and orthogonal contrast results for field pea grain yield at six Agri-ARM facilities in 2019. Data were analyzed using the Mixed procedure of SAS. P-values ≤0.05 are considered significant while P-values in the 0.05-0.10 range indicate trends.

Contrast	Indian Head	Melfort	Outlook	Scott	S. Current	Yorkton	Average
	-- p-value --						
1) No fertilizer [(1)] vs. rest [(2-13)]	0.005	0.847	<0.001	<0.001	0.339	0.011	<0.001
2) P rate – linear	<0.001	0.743	0.095	<0.001	0.019	0.302	<0.001
3) P rate – quadratic	0.319	0.048	0.408	0.007	0.032	0.773	0.002
4) S rate – linear	0.815	0.206	0.597	0.640	0.586	0.030	0.275
5) S rate – quadratic	0.994	0.232	0.066	0.414	0.056	0.458	0.743
6) No extra N [(4)] vs extra N [(10-12)]	0.094	0.379	0.697	0.002	0.173	0.512	0.062

Table 5. Tests of fixed effects and individual fertility treatment means for field pea protein concentrations at six Agri-ARM facilities in 2019. Data were analyzed using the Mixed procedure of SAS. Treatment means within a column and location means within a row followed by the same letter do not significantly differ (Tukey's studentized range test, *P* ≤ 0.05).

Source / Treatment	Indian Head	Melfort	Outlook	Scott	S. Current	Yorkton	Average
Overall F-test				p-value			
Fertilizer Treatment (F)	0.026	0.978	0.054	0.083	<0.001	0.533	0.270
Location (L)	–	–	–	–	–	–	<0.001
F x L	–	–	–	–	–	–	<0.001
kg N-P_2O_5-K_2O-S/ha				Seed Protein (%)			
1) 0-0-0-0 (no fertilizer)	24.4 a	20.9 a	19.7 a	23.6 a	24.0 b	22.0 a	22.4 A
2) 17-0-0-10 (0 P)	23.8 a	21.2 a	19.7 a	23.9 a	24.1 b	22.0 a	22.4 A
3) 17-20-0-10 (20 P)	24.1 a	21.1 a	19.5 a	23.4 a	24.9 ab	21.8 a	22.5 A
4) 17-40-0-10 (40 P / 10 S)	24.0 a	20.7 a	19.3 a	23.4 a	24.7 ab	22.7 a	22.5 A
5) 21-60-0-10 (60 P)	24.0 a	20.9 a	19.9 a	23.8 a	24.6 ab	22.1 a	22.5 A
6) 26-80-0-10 (80 P)	24.1 a	20.9 a	22.1 a	23.6 a	25.1 a	21.5 a	22.9 A
7) 17-40-0-0 (0 S)	24.0 a	21.1 a	20.1 a	23.8 a	24.8 ab	21.2 a	22.5 A
8) 17-40-0-5 (5 S)	24.0 a	20.7 a	20.9 a	23.6 a	24.9 ab	21.4 a	22.6 A
9) 22-40-0-15 (15 S)	24.0 a	21.0 a	19.5 a	23.8 a	24.7 ab	21.8 a	22.5 A
10) 40-40-0-10 (urea)	23.8 a	21.2 a	18.8 a	24.1 a	24.8 ab	21.7 a	22.4 A
11) 17-40-0-10 + 40 N in-crop	24.1 a	21.2 a	20.5 a	23.8 a	24.6 ab	22.0 a	22.7 A
12) 40-40-0-10 (ESN)	23.9 a	20.8 a	18.7 a	23.6 a	24.9 ab	21.3 a	22.2 A
13) 40-80-0-15 (ultra high fert)	24.1 a	21.1 a	19.6 a	23.6 a	25.2 a	21.8 a	22.6 A
S.E.M.	0.16	0.34	0.68	0.19	0.19	0.43	0.16
Location Average	24.0 B	21.0 D	19.9 E	23.7 B	24.7 A	21.8 C	–
S.E.M.	0.12	0.15	0.22	0.13	0.13	0.17	–

Table 6. Group comparison and orthogonal contrast results for field pea grain protein at six Agri-ARM facilities in 2019. Data were analyzed using the Mixed procedure of SAS. P-values ≤0.05 are considered significant while P-values in the 0.05-0.10 range indicate trends.

Contrast	Indian Head	Melfort	Outlook	Scott	S. Current	Yorkton	Average
				p-value			
7) No fertilizer (1) vs. rest (2-13)	<0.001	0.838	0.780	0.453	<0.001	0.630	0.532
8) P rate – linear	0.252	0.392	0.015	0.835	<0.001	0.607	0.046
9) P rate – quadratic	0.401	0.469	0.031	0.136	0.274	0.144	0.233
10) S rate – linear	0.705	0.929	0.270	0.713	0.420	0.101	0.728
11) S rate – quadratic	0.904	0.282	0.642	0.049	0.623	0.206	0.745
12) No extra N (4) vs extra N (10-12)	0.485	0.370	0.991	0.023	0.962	0.038	0.738

Table 7. Marginal economic returns at varying rates of monoammonium phosphate. A yellow field pea price of \$230/Mt was assumed and fertilizer prices of both \$550/Mt and \$750/Mt were considered. The bold/italicized values represent the most profitable P rate for each location. The values presented do not take into account all production expenses. At Yorkton, the control was selected as the most profitable treatment regardless of actual values because the P response was not significant at this location. Furthermore, these values do not take into account any longer term benefits associated with maintaining or building soil P over the long-term.

Location	0 kg P_2O_5/ha	20 kg P_2O_5/ha	40 kg P_2O_5/ha	60 kg P_2O_5/ha	80 kg P_2O_5/ha
	---------------------	\$/ha with \$550/Mt monoammonium phosphate			---------------------
Indian Head	\$914.95	\$960.73	***\$985.19***	\$924.48	\$975.98
Melfort	\$843.71	\$783.87	***\$921.74***	\$889.43	\$713.91
Outlook	\$1,002.69	***\$1,103.90***	\$1,079.12	\$1,083.47	\$1,073.57
Scott	\$1,288.59	***\$1,399.42***	\$1,363.18	\$1,350.12	\$1,351.68
Swift Current	\$544.07	***\$686.51***	\$669.98	\$591.17	\$620.90
Yorkton	***\$1,139.23***	\$1,067.02	\$1,121.50	\$1,144.17	\$1,065.32
Avg	\$955.50	\$1,000.36	***\$1,023.45***	\$997.10	\$966.82
	---------------------	\$/ha with \$750/Mt monoammonium phosphate			---------------------
Indian Head	\$914.95	\$953.17	***\$970.07***	\$902.22	\$946.16
Melfort	\$843.71	\$776.31	***\$906.62***	\$867.17	\$684.09
Outlook	\$1,002.69	***\$1,096.34***	\$1,063.99	\$1,061.20	\$1,043.75
Scott	\$1,288.59	***\$1,391.86***	\$1,348.06	\$1,327.85	\$1,321.85
Swift Current	\$544.07	***\$678.95***	\$654.85	\$568.90	\$591.08
Yorkton	***\$1,139.23***	\$1,059.46	\$1,106.37	\$1,121.91	\$1,035.50
Avg	\$955.50	\$992.80	***\$1,008.33***	\$974.84	\$936.99

Dry Bean Inoculant and Fertilizer Strategies for Solid Seeded Production

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Abstract/Summary:
A study was initiated to evaluate the efficacy of a peat and granular dry bean inoculant, manufactured and retailed in the USA, with and without fertilizer nitrogen (N) additions. An additional aspect of the study was to evaluate the potential of CDC Blackstrap as a suitable variety for dry land, solid seeded production. The trial was conducted under natural rainfed conditions at Scott, Redvers, Yorkton and Indian Head. An additional trial was conducted under irrigation at Outlook to serve as a production reference. Peat formulation inoculant was seed applied at 3.1 gm/kg of seed either by itself, with a dilute molasses as a sticking agent or with a commercially applied polymer coating. The granular inoculant was applied at either 4.8 kg/ha or 4.0 kg/ha depending upon the row spacing used. All trials were seeded to establish a plant population of 35 plants/m^2 in a solid seeded system using 25cm (10") or 30cm (12") row spacing. Nitrogen fertilizer treatments were applied at rates so that total available N (soil N plus fertilizer N) equaled 80 lb N/ac. Inoculation failed

to provide a yield advantage over un-inoculated dry bean at 4 of 5 locations. At the 5th location yields were very low and variable, with inoculant treatment inconsistences. No inoculant response was obtained when data were combined across locations. However, all trial locations obtained significantly higher yields when fertilizer N was applied. The un-inoculated treatment at the irrigated site was high yielding compared to dry land sites, this is partly attributed to high levels of indigenous *rhizobia* populations from numerous preceding dry bean productions. In general, the observed dry land production of CDC Blackstrap was encouraging. Fertilized treatments resulted in an average of 690 kg/ha (614 lb/ac) greater seed yield than unfertilized treatments under dry land conditions. This study was viewed during field events at all five trial locations, has or will appear in videos created by ECRF & ICDC, and been presented at extension events. Total exposure to producer and agronomists is estimated to be > than 600 in number.

Project objectives:

The objective of this study is:

- To demonstrate the efficacy of commercial dry bean inoculant formulations alone or in conjunction with fertilizer nitrogen and
- To evaluate the potential for solid seeded dry bean production under dry land conditions in the non-irrigated areas of Saskatchewan

Project Rationale:

Inoculation of pulse crops is widely accepted as a sound agronomic practice. Further, a multitude of trials conducted across western Canada, and globally, have demonstrated the benefit of rhizobia inoculants. For most pulses a wide selection of inoculation formulations (eg. peat, liquid, granular, encapsulated) are available and commonly used. Agronomists recommend the use of inoculants as standard agronomic practice for field pea, lentil, chickpea, soybean and faba bean in Saskatchewan.

The outlier within the pulse crop types with respect to inoculant use occurs with dry bean. If an inoculant formulation which is easy to apply, and available, a portion of dry bean producers have been willing to treat their dry bean seed. Others have simple bypassed inoculants in favor of using commercial fertilizer to meet their crops nitrogen demands (Hnatowich – personal observations and experience). The reason for this is that field dry bean (Phaseolus vulgaris L.) is considered a poor di-nitrogen fixer (N-fixation) and unable to meet crop demand for N to obtain optimal yield through this means. Because of the inconsistency and uncertainty of inoculant response fertilizer nitrogen additions in dry bean production are recommended. In Saskatchewan the current recommendation for non-irrigated dry bean production is to inoculate the crop and also use 55 kg/ha (50 lb/acre) starter nitrogen, broadcast or side-banded (Government of Saskatchewan).

The large multinational inoculant companies have been inconsistent in producing a dry bean inoculant for western Canada due to limited acreage and market demand. Recently, the leading Canadian inoculant manufactures have discontinued manufacturing dry bean inoculant; therefore, Saskatchewan dry bean producers would be entirely reliant upon N fertilizer additions to meet crop demands. However, a USA manufacturer has indicated a willingness to provide dry bean inoculant formulations for exploratory evaluation as to its efficacy under Saskatchewan conditions.

At present, virtually all Saskatchewan dry bean production occurs within a confined area associated to the Lake Diefenbaker region. This production occurs under irrigation and is produced using wide row production. This type of production requires specialized equipment and in-field operations (ex. access to irrigation, row planters, inter-row cultivation, under-cutters, bean combines). This defined production system has developed because historic dry bean varieties produced pods that developed very low on the plant that prevented direct combining, or swathing, such as occurs in other pulse crops. This obviously has restricted acreage expansion of this commodity. However, the Crop Development Centre at the University of Saskatchewan recently released a Black market class dry bean, CDC Blackstrap. This variety tends to produce pods higher on the plant that may be suitable for direct combining, is small seeded so adaptable to existing on-farm seeders, and is high yielding and early maturing. Therefore it may be adaptable for solid seeded production under dry land conditions.

Methodology:
Trials were established five Agri-ARM facilities in Saskatchewan – ICDC (Outlook), WARC (Scott), SERF (Redvers), ECRF (Yorkton) and IHARF (Indian Head). Each trial was established in a factorial RCBD design with four replications. The factors evaluated were inoculation and N fertilization. Dry Bean inoculant formulations were obtained from Verdisian Life Sciences based in Cary, North Carolina. They included a peat formulation (N Charge, intended for on-seed applications) and a granular formulation (PRIMO GX2, applied in-furrow at seeding). All inoculant treatments were applied without fertilizer N additions or with fertilizer N additions such that total N (soil test N + fertilizer N applications) equaled 80 lbs N/ac.

Trail treatments are shown in Table 1. All inoculants were applied at the manufactures recommended rates. The N Charge peat had a guaranteed titre of 2 x 10e8 cfu/gm and applied for all on-seed treatments at 3.1 gm/kg of seed. The peat formulation contained a self-sticking agent but a damp application method of inoculation was used such that 2 ml of water was applied to each kg seed to assist adhesion. With the molasses application a dilute solution of 60 ml molasses mixed with 240 ml water and then 2 ml of solution was used in substitution for the 2 ml water for damp application. Seed applied inoculant treatments, applied on-site, were treated immediately prior to seeding, allowing sufficient time to dry in order to prevent seed bridging while planting. The polymer was applied with the N Charge utilizing a commercial applicator, application occurred on May 10. The granular inoculant PRIMO GX2 had a guaranteed titre of 1 x 10e8 cfu/gm and was applied at either 4.8 kg/ha (25 cm or 10” row spacing) or 4.0 kg/ha (30 cm or 12” row spacing). Granular treatments were applied with the seed in-furrow.

Times of the various field operations and crop assist products used at each trial location are shown in Table 2. CDC Blackstrap, a Black market class dry bean, was used at all trial locations. A target plant population of 35 plants/m^2 was attempted, with seeding rate adjusted to account for 99% seed germination, seed size and an assumed 90% emergence. Soil test N results from each site are shown in Table 3. Fertilizer N applied at each trial location was determined on the basis of the soil test N results. Plant population (where obtained) was determined after such a time that no further plants were observed emerging. Maturity was deemed at 90% pod colour change. *Sclerotinia* (white mold) was evaluated at maturity using the following rating;

0 – no symptoms apparent
1 – 1-3 small independent lesions on leaf or stems
2 – At least 1 coalescence of lesions with moderate mycelial growth
3 – Mycelial development or wilt involving up to 25% of foliage
4 – Extensive mycelial growth or wilt involving up to 50% of foliage
5 – Plant death

At all locations dry bean plants were directly harvested with small plot combines. Plot grain samples were cleaned and yields adjusted to 16% moisture.

Growing Season Weather

Mean monthly temperatures and precipitation amounts for trial locations are listed in Table 4 and 5. The 2019 season was cooler than the long-term average at all sites. Rainfall was below average for all sites except Scott. Irrigation applied to the Outlook site included 8 mm in May, 27.5 mm in June, 45.5 mm in July and 12.5 mm in August.

Table 1. Inoculant and fertilizer treatments.

Trt #	Inoculant	Formulation	Total N (soil + fertilizer)
1	Control	n/a	0 lbs N/ac
2	N Charge	Peat on-seed	0 lbs N/ac
3	N Charge	Peat on-seed + molasses	0 lbs N/ac
4	N Charge	Pretreated Polymer Peat on-seed	0 lbs N/ac
5	PRIMO GX2	Granular	0 lbs N/ac
6	N Charge + PRIMO GX2	Peat on-seed + Granular	0 lbs N/ac
7	Control	n/a	80 lbs N/ac
8	N Charge	Peat on-seed	80 lbs N/ac
9	N Charge	Peat on-seed + molasses	80 lbs N/ac
10	N Charge	Pretreated Polymer Peat on-seed	80 lbs N/ac
11	PRIMO GX2	Granular	80 lbs N/ac
12	N Charge + PRIMO GX2	Peat on-seed + Granular	80 lbs N/ac

Table 2. Times of operations and crop input products utilized by location.

Activity	Location				
	Outlook	**Scott**	**Redvers**	**Yorkton**	**Indian Head**
Pre-seed Herbicide Application	NA	May 19 Glyphosate 540 (0.7 L/ac) + AIM (35 ml/ac)	May 23 Glyphosate 540 (1 L/ac) + AIM (35 ml/ac)	NA	May 27 Roundup Weathermax 540 (0.67 L/ac)
Seeding	May 23	May 24	May 27	May 23	May 17
Row Spacing	25 cm (10")	25 cm (10")	30 cm (12")	30 cm (12")	30 cm (12")
Emergence Counts	June 11	June 5	NC	June 14	July 4
In-crop Herbicide Application	June 26 Viper ADV (400 ml/ac) + Basagran Forte (145 ml/ac) + UAN	June 26 Viper ADV (400 ml/ac) + Basagran Forte (145 ml/ac) + UAN	June 6 Centurion (75 ml/ac) + Amigo (200 ml/ac) July 1 Viper ADV (400 ml/ac)	May 24 Roundup Transorb (0.5L/ac) June 26 Centurion (150 ml/ac) + Amigo July 2 Viper ADV (400 ml/ac) + Basagran Forte (145 ml/ac) + UAN	July 12 Viper ADV (400 ml/ac) + Basagran Forte (145 ml/ac) + UAN + Equinox (100 ml/ac + Merge)
In-crop Fungicide Application	July 27 Priaxor (180 ml/ac)	NA	NA	July 22 Acapela (350 ml/ac)	NA
Harvest	Sept 20	Oct 7	Sept 17	Oct 7	Oct 12

NA = not applied

NC = observation not captured

Table 3. Soil test results from each trial location.

Nitrate Levels (lbs NO_3-N/ac)	**Outlook**	**Scott**	**Redvers**	**Yorkton**	**Indian Head**
0-15cm (0-6in)	10 lb/ac	12 lb/ac	20 lb/ac	14 lb/ac	12 lb/ac
15-30cm (6-12in)	7 lb/ac				
15-60cm (6-24in)	12 lb/ac	30 lb/ac	24 lb/ac	15 lb/ac	15 lb/ac
Total 0-60cm (0-24in)	29 lb/ac	42 lb/ac	44 lb/ac	29 lb/ac	27 lb/ac

Results:

Individual site treatment agronomic results and associated statistics for each treatment are shown in the Appendix. For clarity of data interpretation, results of factorial analyses for each trial location are presented in Tables 6 through 10.

Treatment of dry bean seed with rhizobium inoculant generally failed to provide a yield response at any trial location excepting Indian Head (Table 10). At Indian Head some treatments appeared to be influencing yield, with or without fertilizer N additions. However no clear explanation of response is apparent. The N Charge peat is statistically higher yielding than the control but N Charge + molasses and N Charge polymer treatments are not. It is not thought that the addition of a sugar source or the commonly adopted polymer technology should adversely affect the rhizobium inoculant. The granular and dual inoculant treatments also appear to positively influence yield. Treatment effects on yield for Indian Head are illustrated in Figure 1. It is apparent that the yields obtained at Indian Head were very low and statistical analyses indicated a high coefficient of variation (CV). A higher CV in dry bean trials in Saskatchewan, compared to other pulse, cereals or oilseed crops, is not unusual. These results exhibit a variability between inoculant treatments and their variation may be a result of the very low yields obtained. Yield obtained may also be a reflection of differing plant populations between treatments. Indian Head results have not been rejected, as a consequence of its higher CV, based on personal experience in dry bean trials and because of the strong significant influence of fertilizer N additions. This site location exhibits the same N fertilizer response as all other locations and Figure 1 clearly illustrates that fertilizer N applications increase and influence yield to a far greater extent than did inoculation.

Inoculation of dry bean failed to positively influence dry bean yield at any remaining trial location. The reason for the inability of the inoculant to influence dry bean yield cannot be definitively answered within the limited observations/measurements undertaken within the scope of this trial. Given the inherent soil N fertility as revealed by soil testing procedures it is not thought that the N levels at any site would be sufficiently high to inhibit rhizobia infection and possible N-fixation. However the author suggests that the following are possible reasons;

1. Rhizobia strain specificity is known to occur within dry bean. Meaning that it is possible that the strain of rhizobium leguminosarum bv. Phaseoli simply failed to form a symbiotic

relationship with CDC Blackstrap dry bean. While developing commercial inoculant formulations the author did experience this phenomena. A specific rhizobium strain might generally work in one market class type of dry bean but not in others. Further, specificity was also found within market classes such that the strain might result in acceptable N-fixation in one variety but not others.

2. The rhizobium within the inoculants may not have been adaptable to Saskatchewan soil conditions. This regional adaptability is also known and is the reason inoculant companies often screen soils for effective indigenous rhizobium strains to be used within their sales market region and where production of the pulse commodity is highest.

Inoculation may have failed to influence dry bean yield in 2019 but the application of fertilizer N certainly did. All trial locations obtained significant yield responses to the addition of fertilizer N. This response highlights the inefficiency of the inoculant formulations evaluated. With respect to seed yield, results from all sites indicate that supplemental fertilizer N is required to optimize dry bean yield. At Outlook, the trial was irrigated and yields obtained at this location generally doubled those obtained at the remaining dry land locations. The Outlook location has a long-term history of dry bean production with the field on which the trial was conducted having had dry beans produced numerable times. Though not part of the trial protocol, plant roots were exhumed from all unfertilized and fertilized control treatments and nodules were found on all. Moreover, the red colour exhibited upon cutting nodules suggest they were performing active biological N-fixation. These bacteria were from indigenous populations likely built up from previous dry bean production and likely contributed to the high unfertilized yield obtained at Outlook. However, even these indigenous populations did not suffice to provide maximum yields and a fertilizer N response occurred.

In general, inoculation did not directly influence any other agronomic measurement, at any trial location. Nitrogen fertilizer additions tended to decrease individual seed weight and increased plant height. Sclerotinia (white mold) was not an issue at any site in 2019

The result of inoculation and N fertilizer additions on dry bean yield averaged across all 5 trial locations is shown in Figure 2.

A summary of the combined all site analyses, and for the 4 dry land trials alone, for CDC Blackstrap seed yield is presented in Table 11. Yield results indicate that, for all sites, the average yield response to N fertilizer was 521 kg/ha (464 lb/ac). However, an objective of this project was to demonstrate dry bean production away from the traditional irrigated production and into dry land production. Therefore if we exclude the Outlook site the average yield response to N fertilizer increases to 690 kg/ha (614 lb/ac). Presently, Black dry beans are being purchased at \$0.75/kg (\$0.34/lb) so the gross return of the fertilizer additions is approximately \$518/ha or \$209/ac, easily an economic return for the fertilizer investment. The result of inoculation and N fertilizer additions on dry bean yield averaged across only the 4 dry land trial locations is shown in Figure 3.

Some general observations and thoughts regarding the dry land production trials can be made;

• All sites were solid seeded and direct combined. While harvest loss assessment was beyond the scope of the study (given the finances), all sites report that harvest losses were deemed minimal.

• Direct combining of dry beans is likely only possible at this time with the Black market class variety CDC Blackstrap which is a Type II plant structure with pods that may initiate high enough on the plant stem to facilitate direct combining or swathing.

• Seed weights obtained at WARC (Scott) were very low and might limit market acceptance, additional work should be conducted in this region in order to ascertain if this is a function of the trialing season or potentially problematic to the region.

• It is reasonable to believe rolling of the dry beans after seeding will assist harvest management by facilitating pod clearance. On heavy textured, such as at Indian Head, rolling can be a challenge for dry bean. Seed bed conditions need be ideal and packing pressure be light enough to minimize possible compaction issues.

Table 6. ICDC (Outlook) Dry Bean Yield & Agronomic Observations as Influenced by N Fertilizer and Inoculant.

Treatment	**ICDC**						
	Yield		**Seed weight (gm/1000)**	**Maturity (days)**	**White Mold (0 – 5)**	**Height (cm)**	**Plant Stand (plants /m²)**
	kg/ha	**lb/ac**					
Nitrogen Fertilizer Application (lbs N/ac)							
0	2651	2365	225	105	0	37	29
80	3142	2802	225	107	0	39	31
Fertilizer LSD (0.05)	247	220	NS	0.4	NS	1.7	NS
CV (%)	14.5	14.5	2.0	0.6	0	7.4	22.1
Inoculant							
Control	2829	2523	225	106	0	38	30
N Charge peat	3008	2683	225	106	0	39	29
N Charge peat + molasses	3046	2717	225	106	0	38	31
N Charge polymer	2868	2558	226	106	0	39	29
PRIMO GX2 granular	2782	2481	224	106	0	37	29
N Charge + PRIMO GX2	2846	2538	228	106	0	38	31
Inoculant LSD (0.05)	NS	NS	NS	NS	NS	NS	NS
Nitrogen Fertilizer x Inoculation							
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS

NS = not significant

Table 7. WARC (Scott) Dry Bean Yield & Agronomic Observations as Influenced by N Fertilizer and Inoculant.

Treatment	WARC						
	Yield		Seed weight (gm/1000)	Maturity (days)	White Mold (0 – 5)	Height (cm)	Plant Stand (plants /m^2)
	kg/ha	lb/ac					
Nitrogen Fertilizer Application (lbs N/ac)							
0	1324	1181	169	103	0.04	27	18
80	1983	1768	161	99	0.25	34	14
Fertilizer LSD (0.05)	112	100	2.7	1.0	0.2	2.0	2.8
CV (%)	11.5	11.5	2.8	1.7	229	11.1	30.6
Inoculant							
Control	1666	1486	168	102	0.25	29	18
N Charge peat	1617	1442	165	101	0.13	31	15
N Charge peat + molasses	1663	1483	164	101	0.13	30	15
N Charge polymer	1686	1503	164	101	0.13	34	17
PRIMO GX2 granular	1674	1493	165	102	0.25	30	13
N Charge + PRIMO GX2	1613	1439	165	101	0	30	17
Inoculant LSD (0.05)	NS	NS	NS	NS	NS	NS	NS
Nitrogen Fertilizer x Inoculation							
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

Table 8. SERF (Redvers) Dry Bean Yield & Agronomic Observations as Influenced by N Fertilizer and Inoculant.

Treatment	SERF						
	Yield		Seed weight (gm/1000)	Maturity (days)	White Mold (0 – 5)	Height (cm)	Plant Stand (plants /m²)
	kg/ha	lb/ac					
Nitrogen Fertilizer Application (lbs N/ac)							
0	1381	1229	198	97	0	28	25
80	1746	1554	191	96	0	31	28
Fertilizer LSD (0.05)	121	108	5.2	NS	NS	1.2	NS
CV (%)	13.2	13.2	4.6	1.4	0	7.1	24.7
Inoculant							
Control	1695	1509	197	97	0	30	30
N Charge peat	1570	1397	199	96	0	29	25
N Charge peat + molasses	1558	1386	196	96	0	29	29
N Charge polymer	1593	1418	195	97	0	29	24
PRIMO GX2 granular	1450	1290	189	95	0	30	23
N Charge + PRIMO GX2	1514	1348	193	97	0	29	27
Inoculant LSD (0.05)	NS	NS	NS	NS	NS	NS	NS
Nitrogen Fertilizer x Inoculation							
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

NC = Observation Not Captured

Table 9. ECRF (Yorkton) Dry Bean Yield & Agronomic Observations as Influenced by N Fertilizer and Inoculant.

Treatment	ECRF						
	Yield		Seed weight (gm/1000)	Maturity (days)	White Mold (0 – 5)	Height (cm)	Plant Stand (plants /m^2)
	kg/ha	lb/ac					
Nitrogen Fertilizer Application (lbs N/ac)							
0	973	866	200	105	0	41	32
80	1885	1677	210	105	0	46	39
Fertilizer LSD (0.05)	166	148	3.6	NS	NS	2.3	4.5
CV (%)	19.8	19.8	3.0	1.5	0	8.9	21.4
Inoculant							
Control	1372	1221	203	105	0	44	35
N Charge peat	1447	1288	207	105	0	44	30
N Charge peat + molasses	1266	1127	206	104	0	41	34
N Charge polymer	1341	1194	204	104	0	43	39
PRIMO GX2 granular	1454	1294	205	105	0	43	40
N Charge + PRIMO GX2	1694	1508	206	105	0	48	39
Inoculant LSD (0.05)	NS	NS	NS	NS	NS	3.9	NS
Nitrogen Fertilizer x Inoculation							
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

Table 10. IHARF (Indian Head) Dry Bean Yield & Agronomic Observations as Influenced by N Fertilizer and Inoculant.

Treatment	IHARF						
	Yield		Seed weight (gm/1000)	Maturity (days)	White Mold (0 – 5)	Height (cm)	Plant Stand (plants /m^2)
	kg/ha	lb/ac					
Nitrogen Fertilizer Application (lbs N/ac)							
0	174	155	220	110	0	22	22
80	998	890	224	113	0	30	23
Fertilizer LSD (0.05)	70	62	NS	0.2	NS	1.0	NS
CV (%)	20.3	20.3	12.9	0.4	0	6.3	19.9
Inoculant							
Control	484	432	228	110	0	25	20
N Charge peat	620	553	214	111	0	26	26
N Charge peat + molasses	533	475	211	111	0	26	23
N Charge polymer	526	469	227	112	0	27	18
PRIMO GX2 granular	641	572	215	112	0	27	21
N Charge + PRIMO GX2	712	635	239	112	0	25	27
Inoculant LSD (0.05)	121	108	NS	0.4	NS	NS	4.5
Nitrogen Fertilizer x Inoculation							
LSD (0.05)	S	S	NS	NS	NS	NS	NS

S = Significant

NS = Not Significant

Table 11. Dry Bean Combined Site Yields: Effect of Inoculation and N Fertilization, 2019.

Location/Treatment	**All 5 Sites**		**4 Dry Land Sites Only**	
	Yield		**Yield**	
Trial Site	**kg/ha**	**lb/ac**	**kg/ha**	**lb/ac**
ICDC – Outlook	2896	2583	-	-
WARC – Scott	1653	1475	1653	1475
SERF – Redvers	1563	1391	1563	1391
ECRF – Yorkton	1429	1272	1429	1272
IHARF – Indian Head	586	523	586	523
Location LSD (0.05)	113	101	92	144
CV (%)	17.4	17.4	15.5	15.5
Nitrogen Fertilizer Application (lbs N/ac)				
0	1365	1217	963	858
80	1886	1681	1653	1472
Fertilizer LSD (0.05)	72	64	81	72
Inoculant				
Control	1589	1416	1305	1162
N Charge peat	1620	1444	1314	1170
N Charge peat + molasses	1616	1440	1255	1118
N Charge polymer	1568	1398	1286	1146
PRIMO GX2 granular	1675	1493	1305	1162
N Charge + PRIMO GX2	1686	1502	1383	1232
Inoculant LSD (0.05)	NS	NS	NS	
Location x Nitrogen Fertilizer Application Interaction				
LSD (0.05)	S	S	S	S
Location x Inoculant Interaction				
LSD (0.05)	NS	NS	NS	NS
Nitrogen Fertilizer Application x Inoculant Interaction				
LSD (0.05)	NS	NS	NS	NS
Location x Nitrogen Fertilizer Application x Inoculant Interaction				
LSD (0.05)	NS	NS	NS	NS

S = Significant

NS = Not Significant

Figure 1. Dry Bean Yield Response to Inoculation & N Fertilization – Indian Head, 2019

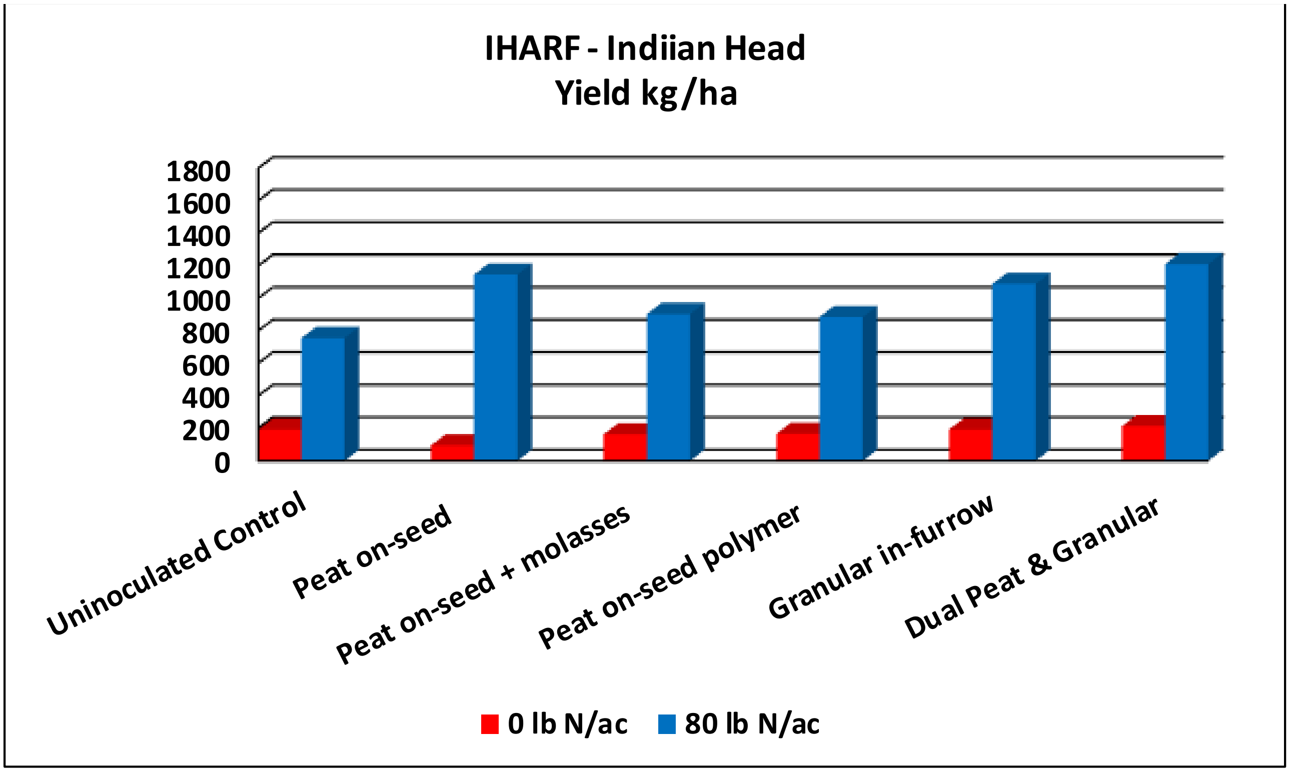


Figure 2. Combined 5 Site Dry Bean Yield, Effect of Inoculation and N Fertilization, 2019.

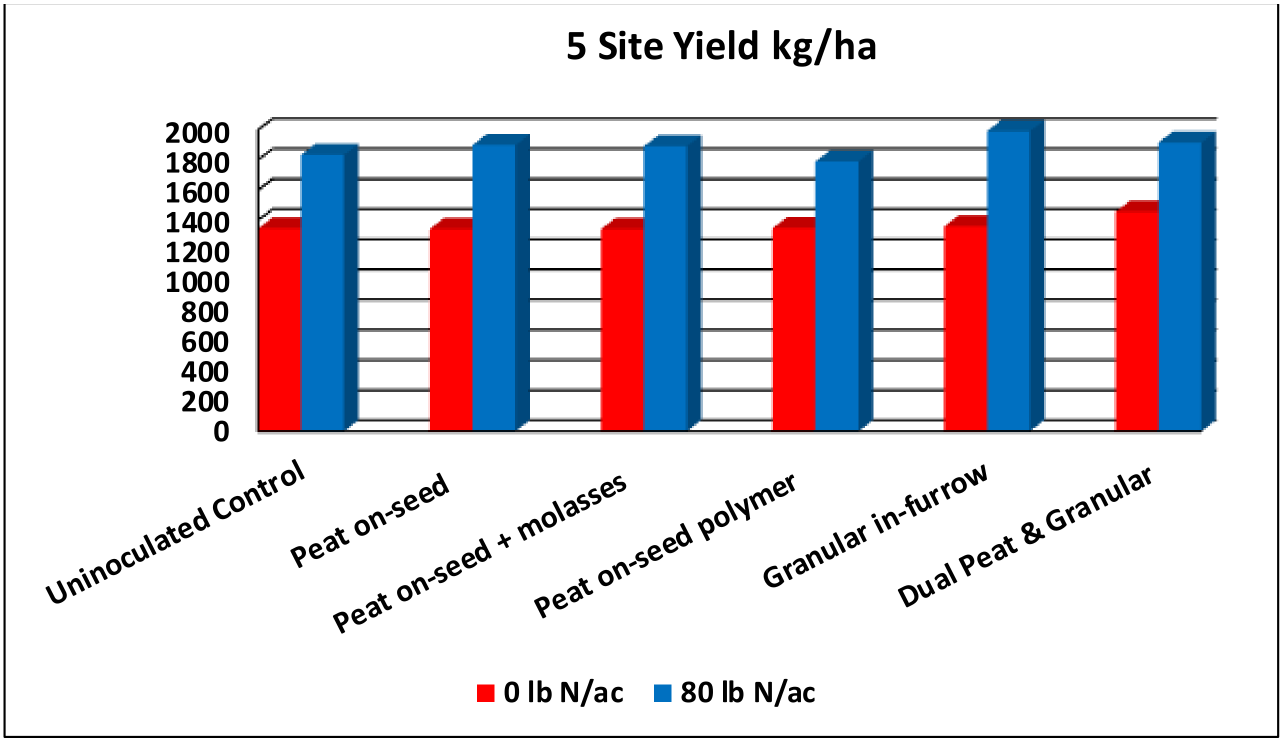
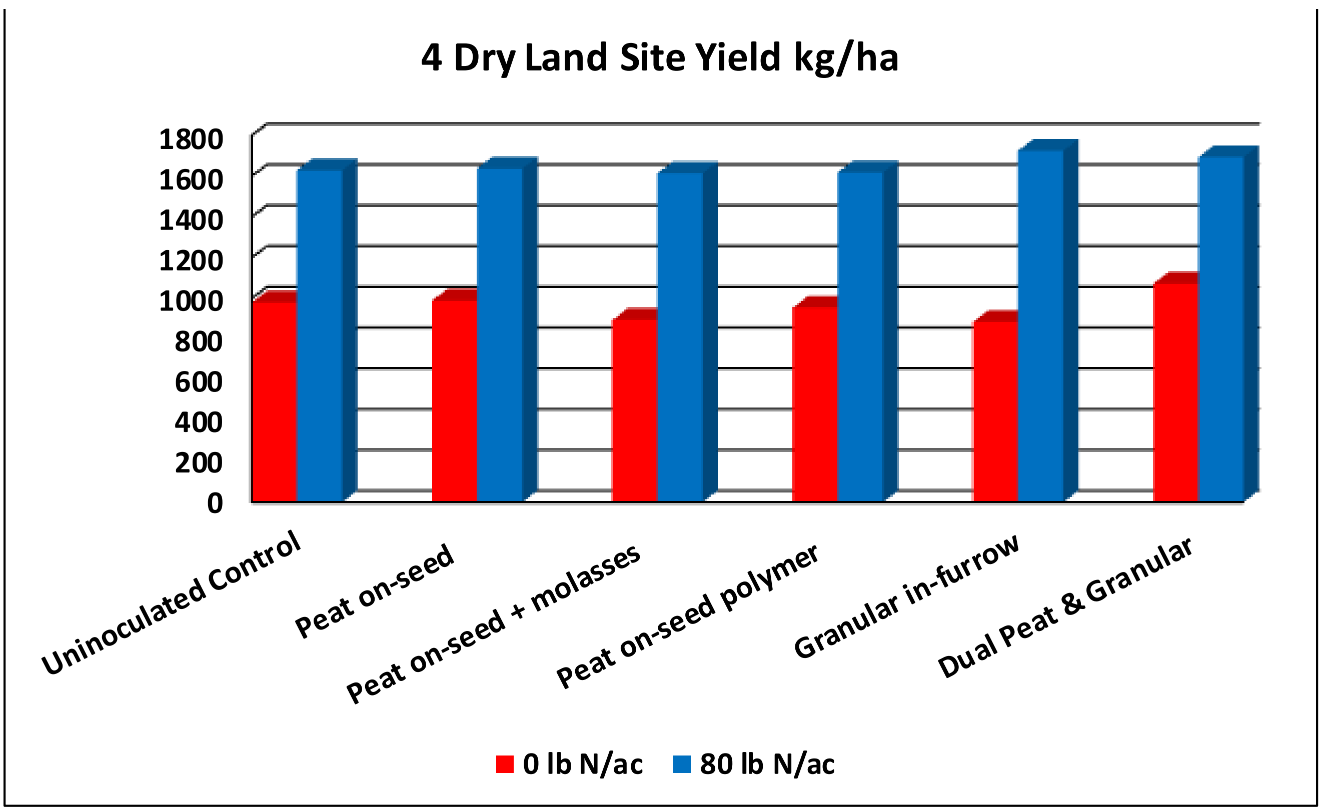


Figure 3. Combined 4 Dry Land Site Dry Bean Yield, Effect of Inoculation and N Fertilization, 2019.



Conclusions and Recommendations:

Inoculation failed to provide yield or agronomic benefits to dry beans in this trial. It is suspected that the strain of rhizobium leguminosarum bv. Phaseoli provided in the inoculant formulations used in the study were either inefficient in forming an effective symbiotic relationship with the CDC Blackstrap variety used in the study or the strain was unable to thrive and multiply under Saskatchewan soil/climatic conditions. Application of fertilizer N, such that the combination of soil available N (0-60cm depth) plus fertilizer N (nutrient) equaled 80 lb N/ac significantly increased grain yield and tended to produce taller plants which may facilitate harvest management. It is recommended that producers view N fertilizer as their primary nutrient source for dry bean production. An inoculant, if available, can be used as an insurance but is unlikely to provide optimal N-fixation to optimize yield goals.

This study demonstrated the feasibility of producing CDC Blackstrap dry bean under dry land conditions utilizing a solid seeded production system. Should further investigations also demonstrate this potential then dry bean production could expand considerably beyond the present acreage. This pulse could be an alternative for the moister regions of the province where root diseases have impacted other pulse crops.

Additional research projects such as the following are suggested;

- Further N fertilizer studies are warranted, rates should continue beyond those used in this study. Within these studies sclerotinia should be closely assessed, as well as pod clearance.
- Seeding rate trials would have merit and value.
- Seeding date trials should be geographically evaluated with attention to soil temperatures, plant populations and pod clearance.
- Further regional adaptability trials should be considered, certainly the entire black soil zone of Saskatchewan should be assessed.
- As dry beans are poor competitors until canopy closure, weed control options under solid seeded production should be assessed.
- Within all trials where dry bean is either direct combined or swathed, harvest losses and seed quality should be assessed.
- Should dry bean inoculants be made available then;
  - Producers should view such products sceptically unless regional independent third-party efficacy results are provided. Regardless, N fertilizer supplementation will be required.
  - Consideration should be given to secure funding for organizations such as Agri-ARM facilities to maintain an annual pulse inoculant trials for suitable pulses within their local whereby all commercial and pre-commercial inoculant products can be compared for efficacy.
- An economic investigation either by the Ministry of Agriculture or the University of Saskatchewan Ag, Econ., should be undertaken to investigate such aspects as crop insurance/risk

management options, lack or perceived lack, of buyer interest within Saskatchewan, production contracts and marketing agreements presently available, market barriers to possible low quality dry bean, accessibility and availability of CDC varieties (closed loop systems?), etc.

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Appendices

Individual trial location agronomic responses and associated statistical results for individual treatments are shown in Tables 12 through 16.

Table 12. ICDC (Outlook) Dry Bean Yield & Agronomic Observations, RCBD Analyses, 2020.

Trt	Description	Yield kg/ha	Yield lbs/ac	Seed Weight (gm/1000)	Maturity (days)	White Mold (0 – 5)	Height (cm)	Plant Stand (plants/m2)
1	Uninoculated – 0 N/ac	2601	2320	224	106	0	37	29
2	N Charge peat – 0 N/ac	2947	2629	224	105	0	36	27
3	N Charge peat + molasses – 0 N/ac	2769	2470	227	105	0	38	28
4	N Charge polymer – 0 N/ac	2531	2258	227	105	0	38	28
5	PRIMO GX2 granular – 0 N/ac	2480	2212	223	105	0	36	30
6	N Charge + PRIMO GX2 – 0 N/ac	2579	2300	227	105	0	38	32
7	Uninoculated – 80 N/ac	3056	2726	226	107	0	38	32
8	N Charge peat – 80 N/ac	3069	2737	226	107	0	42	31
9	N Charge peat + molasses – 80 N/ac	3323	2964	222	107	0	39	35
10	N Charge polymer – 80 N/ac	3205	2859	224	107	0	40	30
11	PRIMO GX2 granular – 80 N/ac	3083	2750	226	107	0	39	28
12	N Charge + PRIMO GX2 – 80 N/ac	3112	2776	228	107	0	38	30
	LSD (0.05)	NS*	NS*	NS	0.0001		NS	NS
	CV (%)	14.5	14.5	2.0	0.6		7.4	22.1

NS = not significant

NS* = not significant at P<0.05 but significant at P<0.10

Table 13. WARC (Scott) Dry Bean Yield & Agronomic Observations, RCBD Analyses, 2020.

Trt	Description	Yield kg/ha	Yield lbs/ac	Seed Weight (gm/1000)	Maturity (days)	White Mold (0 – 5)	Height (cm)	Plant Stand (plants/m2)
1	Uninoculated – 0 N/ac	1334	1190	171	103	0	26	18
2	N Charge peat – 0 N/ac	1298	1157	170	104	0	28	19
3	N Charge peat + molasses – 0 N/ac	1243	1109	169	104	0	26	15
4	N Charge polymer – 0 N/ac	1352	1206	167	104	0.3	32	20
5	PRIMO GX2 granular – 0 N/ac	1325	1182	171	104	0	27	13
6	N Charge + PRIMO GX2 – 0 N/ac	1391	1241	165	102	0	27	20
7	Uninoculated – 80 N/ac	1999	1783	164	100	0.5	32	18
8	N Charge peat – 80 N/ac	1937	1728	160	98	0.3	35	12
9	N Charge peat + molasses – 80 N/ac	2083	1858	160	98	0.3	35	15
10	N Charge polymer – 80 N/ac	2020	1801	161	99	0	35	15
11	PRIMO GX2 granular – 80 N/ac	2023	1804	159	99	0.5	34	13
12	N Charge + PRIMO GX2 – 80 N/ac	1835	1637	165	100	0	34	13
	LSD (0.05)	273	244	6.7	2.5	NS	4.9	NS
	CV (%)	11.5	11.5	2.8	1.7	229	11.1	30.6

NS = not significant

Table 14. SERF (Redvers) Dry Bean Yield & Agronomic Observations, RCBD Analyses, 2020.

Trt	Description	Yield kg/ha	Yield lbs/ac	Seed Weight (gm/1000)	Maturity (days)	White Mold (0 – 5)	Height (cm)	Plant Stand (plants/m2)
1	Uninoculated – 0 N/ac	1525	1357	197	97	0	28	30
2	N Charge peat – 0 N/ac	1371	1221	209	97	0	28	21
3	N Charge peat + molasses – 0 N/ac	1403	1248	199	97	0	29	27
4	N Charge polymer – 0 N/ac	1376	1224	197	96	0	28	23
5	PRIMO GX2 granular – 0 N/ac	1197	1065	189	96	0	28	22
6	N Charge + PRIMO GX2 – 0 N/ac	1415	1260	199	98	0	27	27
7	Uninoculated – 80 N/ac	1866	1661	196	98	0	32	29
8	N Charge peat – 80 N/ac	1769	1574	190	96	0	31	30
9	N Charge peat + molasses – 80 N/ac	1713	1524	193	96	0	30	31
10	N Charge polymer – 80 N/ac	1811	1612	193	98	0	31	26
11	PRIMO GX2 granular – 80 N/ac	1703	1515	189	95	0	31	25
12	N Charge + PRIMO GX2 – 80 N/ac	1613	1436	186	96	0	31	28
	LSD (0.05)	296	264	NS*	NS		3.0	NS
	CV (%)	13.2	13.2	4.6	1.4		7.1	24.7

NS = not significant

NS* = not significant at P<0.05 but significant at P<0.10

NC = observation not captured

Table 15. ECRF (Yorkton) Dry Bean Yield & Agronomic Observations, RCBD Analyses, 2020.

Trt	Description	Yield kg/ha	Yield lbs/ac	Seed Weight (gm/1000)	Maturity (days)	White Mold (0 – 5)	Height (cm)	Plant Stand (plants/m2)
1	Uninoculated – 0 N/ac	851	757	197	104	0	39	32
2	N Charge peat – 0 N/ac	1195	1064	206	106	0	43	23
3	N Charge peat + molasses – 0 N/ac	773	688	204	104	0	38	32
4	N Charge polymer – 0 N/ac	925	823	195	104	0	41	39
5	PRIMO GX2 granular – 0 N/ac	824	733	198	105	0	39	37
6	N Charge + PRIMO GX2 – 0 N/ac	1272	1132	199	104	0	46	32
7	Uninoculated – 80 N/ac	1894	1686	210	105	0	48	37
8	N Charge peat – 80 N/ac	1698	1511	208	105	0	45	37
9	N Charge peat + molasses – 80 N/ac	1759	1566	207	104	0	43	37
10	N Charge polymer – 80 N/ac	1757	1564	212	103	0	45	39
11	PRIMO GX2 granular – 80 N/ac	2084	1855	211	105	0	48	43
12	N Charge + PRIMO GX2 – 80 N/ac	2116	1883	213	106	0	50	39
	LSD (0.05)	408	363	8.7	NS		5.6	NS*
	CV (%)	19.8	19.8	3.0	1.5		8.9	21.4

NS = not significant

NS* = not significant at P<0.05 but significant at P<0.10

Table 16. IHARF (Indian Head) Dry Bean Yield & Agronomic Observations, RCBD Analyses, 2020.

Trt	Description	Yield kg/ha	Yield lbs/ac	Seed Weight (gm/1000)	Maturity (days)	White Mold (0 – 5)	Height (cm)	Plant Stand (plants/m2)
1	Uninoculated – 0 N/ac	212	189	215	110	0	21	20
2	N Charge peat – 0 N/ac	94	84	217	110	0	21	23
3	N Charge peat + molasses – 0 N/ac	163	145	221	110	0	21	24
4	N Charge polymer – 0 N/ac	166	148	236	110	0	23	19
5	PRIMO GX2 granular – 0 N/ac	194	173	213	110	0	23	22
6	N Charge + PRIMO GX2 – 0 N/ac	213	190	222	110	0	20	28
7	Uninoculated – 80 N/ac	756	674	242	111	0	30	18
8	N Charge peat – 80 N/ac	1146	1023	210	113	0	30	29
9	N Charge peat + molasses – 80 N/ac	903	806	200	113	0	31	22
10	N Charge polymer – 80 N/ac	885	790	219	113	0	30	18
11	PRIMO GX2 granular – 80 N/ac	1089	971	216	113	0	31	20
12	N Charge + PRIMO GX2 – 80 N/ac	1211	1080	257	113	0	30	26
	LSD (0.05)	171	153	NS	0.6		2.3	6.4
	CV (%)	20.3	20.3	12.9	0.4		6.3	19.9

NS = not significant

Can Farm-saved Seed Wheat (Triticum aestivum L.) Perform as well as Certified Seed in Saskatchewan?

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[4]Northeast Agriculture Research Foundation, Melfort, SK
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[8]Wheatland Conservation Area Inc., Swift Current, SK

Abstract/Summary:

In 2019, trials were conducted at Yorkton, Redvers, Indian Head, Swift Current, Scott, Outlook, Prince Albert and Melfort to compare the vigor and yield performance of various lots of farm-saved wheat seed relative to the same varieties of certified seed. Seed lots were compared with and without seed treatment to determine the impact of seed treatment on seed lots of differing quality. Positive effects of seed treatment on emergence, seedling vigor, and grain protein were observed at Swift Current. However, there were a couple instances at Yorkton and Indian Head where seed treatment adversely affected yield. In most instances seed treatment did not affect emergence, seedling vigor, yield, or grain protein of wheat.

Overall, seed quality was very good for both farm saved seed and certified seed lots. However, levels of seed borne disease tended to be more variable on farm-saved seed. One seed lot of farm-saved seed had total *Fusarium* levels beyond acceptable levels. Despite this, the overall vigor of farm-saved seed seed lots were no different from certified seed. Few significant differences in emergence, seedling vigor, yield, or grain protein were observed between planting farm-saved seed and certified seed. As a result, growing farm-saved seed would have been more economical because of the added cost of purchasing certified seed.

While the study found there were no production risks from growing farm-saved seed in 2019, there is still value in purchasing certified seed as this assures quality (true to type) for end users and allows for the introduction of better genetics to help the farm stay competitive.

Project objectives:

- To compare the vigor and yield performance of various lots of farm-saved wheat seed relative to the same varieties of certified seed.
- To determine the degree to which seed treatment can improve the vigor and yield potential of farm-saved and certified seed lots of wheat.

Project Rationale:

While the yield loss from growing saved seed from hybrid crops such as canola[1] has been well documented, little research has compared yields between certified and farm-saved seed for wheat in western Canada. Producers of cereal grains are free to retain seed for planting on their own farm. This retained seed is commonly referred to as "farm-saved seed" (FSS). Despite the guaranteed quality of certified seed, a phone survey of 800 producers in 2004 determined approximately 70 to 80% of cereal acres in western Canada were seeded with farm-saved seed[2]. Producers cited "reduced costs" and "knowing what is in the seed" as reasons preferring FSS. Farm-saved seed is typically a cheaper seed source than certified seed. A 13-year study in Alberta between 2003 and 2016 found the average price premium for certified wheat seed over FSS was $3.75/bu[3], even when assuming a 1.5 bu/ac yield benefit from using a new variety of certified seed. To be fair, the Canadian Seed Growers' Association does not mention higher yields when discussing "the certified advantage".[4] Certified seed is valuable because it is "true to type" meaning it has retained all the genetic benefits developed by the breeder. This helps with "quality assurance" for the end users which is of increasing importance as the industry moves toward a value chain model. In addition, to be "certified", seed must meet high standards of germination and freedom from impurities, which are determined by an officially recognized third-party agency[5]. Finally, it is important to support a system that ensures the development of new varieties to keep Canadian wheat producers globally competitive. The exact form of this support is currently under debate.

Many producers believe they are capable of producing quality FSS which is comparable to certified seed. Producers will typically grow FSS for 2-3 years and then purchase certified seed to introduce better genetics to the farm. This may prove to be true for many producers in Saskatchewan as past study with winter wheat in central Oklahoma found FSS could often perform as well as certified seed. However, the relative comparison changed between years in their study. In 2003, they observed 9 out of 19 farm-saved seed lots were inferior for grain production compared to the best certified seed source. In contrast, only 2 out of 27 farm-saved samples were inferior in 2004 and only 4 out of 17 were inferior in 2005.[6] The authors concluded "that if farmers use quality control measures similar to those required for certified seed, farm-saved wheat seed can produce forage and grain yield comparable to that of certified seed" [6]. To ensure quality seed is being planted, seed must be sent away for testing.

There are a number of seed labs, which offer vigor testing and disease screening to help producers determine the suitability of a seed lot for seeding. Vigor tests are superior to the standard germination test as they will give a better indication of crop emergence and strength under adverse conditions. A fungal screen can determine the presence of a number of seedborne pathogens that can also affect seed vigor. Low vigor seed lots with high fungal screens can be retested to determine if seed treatment can improve vigor[7]. Seed treatment will often improve the vigor of a seed lot by 10%. However, the level of seedborne disease may help to determine if locating a better seed lot would be advisable.

The quality of farm-saved seed lots are likely to be more variable than certified seed which must meet exacting standards. The intent of this proposal is to randomly compare the vigor and yield potential of FSS relative to certified seed in Saskatchewan over the next 3 years. The intent is to sample as many FSS and certified seed lots as possible. In the first year of this study, 24 different seed lots of FSS were compared against the same varieties of 24 different seed lots of certified seed.

[1]Clayton, G.W., Brandt, S., Johnson, E.N., O'Donovan, J.T., Harker, K.N., Blackshaw, R.E., Smith, E.G., Kutcher, H.R., Vera, C., and M. Hartman. 2009. Comparison of Certified and Farm-Saved Seed on Yield and Quality Characteristics of Canola. Agron. J. 101: 1581-1588

[2]https://www.cropweek.com/presentations/2005/ssga.pdf

[3]Overview of Certified Seed and Farm-saved Seed, March 2018. Economics and Competitiveness Branch. Alberta Government.
https://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/econ15976/$FILE/Overview%20of%20Certified%20Seed%20and%20Farmer%20Saved%20Seed%20II.pdf

[4]The Certified Advantage
https://seedgrowers.ca/farmers/the-certified-advantage/

[5]What is Canadian Certified Seed?
http://seedgrowers.ca/seed-growers/what-is-canadian-certified-seed/

[6]Edwards, J.T. and E. G. Krenzer Jr. 2006. Quality of Farm-saved Wheat Seed is Variable in the Southern Great Plains. Online. Crop Management doi:10.1094/CM-2006-0531-01-RS

[7]What is a Fungal ScreenTM for Cereals? 20/20 Seed Labs
https://www.2020seedlabs.ca/what-is-a-fungal-screen-for-cereals/

Methodology:

The trial was setup as a 2 by 3 by 2 factorial in a randomized complete block design with 4 replicates. The plot size, row spacing, and fertilizer application techniques for seeding varied between locations depending on equipment used. The combined factorial treatments are listed in Table 1 below. The targeted seeding rate and date were 300 seeds/m^2 within the first three weeks in May. The ideal seeding depth was targeted at 1 inch. Seed treatment was applied shortly before seeding. Seed treatments varied between location and the exact product used can be found in Table 2 along with dates of operation. Nitrogen, phosphorus, potassium and sulphur were applied at each location as based on soil test results and agronomist's experience. Soil test results for each site are found in Table 5.

Table 1. Treatment list for 2019 "Can Farm-saved Seed Wheat (Triticum aestivum L.) perform as well as Certified Seed in Saskatchewan?" Trial

Trt #	Seed treatment	Variety pairing	Seed type
1	Untreated	A	Certified
2	Untreated	A	Farm-saved Seed
3	Untreated	B	Certified
4	Untreated	B	Farm-saved Seed
5	Untreated	C	Certified
6	Untreated	C	Farm-saved Seed
7	Treated	A	Certified
8	Treated	A	Farm-saved Seed
9	Treated	B	Certified
10	Treated	B	Farm-saved Seed
11	Treated	C	Certified
12	Treated	C	Farm-saved Seed

Table 2. Dates of operations in 2019 for the "Can Farm-saved Seed Wheat Perform as well as Certified Seed in Saskatchewan" trial								
Activity	**---Date---**							
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
Pre-seed Herbicide Application	May 12 Glyphosate	May 24 Glyphosate (540 0.5L/ac) + Heat LQ (21mL/ac) + Merge (400mL/ac)	N/A	N/A	N/A	May 19 Glyphosate 540 (1L/ac) + AIM (35 ml/ac)	May 13 RT540 (0.67 L/ac)	N/A
Seeding & Seed treatment applied	May 7 & Raxil PRO	May 23 & Cruiser Vibrance Quattro (325mL/ 100kg seed)	May 14 & Cruiser Vibrance Quatro (325 ml/100 kg seed)	May 23 & Raxil PRO (325mL/100 kg seed)	May 6 & Raxil PRO	May 14 & CruiserMax x Cereal	May 16 & Cruiser Vibrance Quattro (325 ml/100kg seed)	May 7 and 8 & CruiserMax x Vibrance
Emergence Counts	June 4	June 21	June 14	June 12	June 5	June 5	June 7	May 30
Vigour Rating	June 4	July 12	June 20	July 11	N/A	June 27		June 12 and June19
In-crop Herbicide Application	June 17 OcTTain + Simplicity	June 27th Axial (0.5L/ac) July 4 Prestige XC (A@ 0.13L/ac & B@	June 10 Badge II & Simplicity 21 gm/ac	June 27 Stellar A (florasulam 2.5g/L, fluroxypyr 100 g/L) @ 1L/ha) + B (MCPA 600	June 10 Buctril M + Clodinafop	June 26 Axial (0.5L/ac) + Buctril M (0.4L/ac) @ 10gpa	June 12 Varro (200ml/ac) + Octane (450ml/ac) + Agral90 (0.25 l/ac)	June 12 Prestige, June 25 MCPA, July 3 MCPA

		0.6L/ac)		g/L) @ 900 mL/ha				
In-crop Fungicide Application	July 9 Prosaro	N/A	July 15 Caramba (400 mL/ac)	N/A	July 12 Caramba	N/A	N/A	July 3 Acapela (200ml/ac)
Lodging Rating	N/A	Oct 9	N/A	N/A	N/A	Aug 26	Aug 20	Sept 3
Desiccant	Aug 28 Glyphosate	N/A	N/A	Sept 5 Glyphosate (1.67L/ha)	N/A	Sept 6 Heat LQ (41.8 mL/ac) + Roundup 540 (0.67L/ac) + Merge (0.2L/ac) @10gpa	N/A	Sept 3 Roundup Transorb (0.66 L/ac)
Harvest	Sept 6	Oct 9	Sept 24	Oct 1	Aug 29	Sept 16	Aug 27	Sept 16

Results:

Table 5. Soil Test Nitrate Levels for each location.								
Nitrate Levels (lbs NO_3-N/ac)	**Indian Head**	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
0-15cm (0-6in)	16 lb/ac	9 lb/ac	8 lb/ac	17 lb/ac	29 lb/ac	14 lb/ac	28 lb/ac	14 lb/ac
15-30cm (6-12in)		10 lb/ac		12 lb/ac				
15-60cm (6-24in)	39 lb/ac		10 lb/ac		42 lb/ac	18 lb/ac	225 lb/ac	18 lb/ac
Total 0-60cm (0-24in)	55 lb/ac		18 lb/ac		71 lb/ac	32 lb/ac	253 lb/ac	32 lb/ac
Total 0-30 cm (0-12in)		19 lb/ac		29 lb/ac				

Site Establishment

Overall, sites were well established but wheat seedling emergence, yield and grain protein varied substantially between locations. While seeding rates for each seed lot were based on 1000 kernel weight and vigor to achieve 300 live seeds/m^2, crop emergence varied substantially between locations. Crop emergence at Indian Head, Melfort, Outlook, Redvers, Scott, Swift Current, Yorkton and Prince Albert averaged 355, 180, 204, 234, 229, 191 277 and 82 plants/m^2, respectively. The very poor emergence rate at Prince Albert was the result of poor soil moisture conditions. Overall wheat yields varied from a high of 6081 kg/ha (90 bu/ac) at Yorkton to a low of 2128 kg/ha (32 bu/ac) at Swift Current. The rest of the sites yielded well, even Prince Albert where crop emergence was low. Average yields were 3931, 5470, 4296, 3796, 4395 and 4794 kg/ha at Indian Head, Melfort, Outlook, Prince Albert, Redvers and Scott, respectively. Not surprisingly, average grain protein was very high at Swift Current (19.9%) were yield was very low. Protein was also relatively high at Indian Head (15%). For the remaining sites, grain protein ranged within 12 to 14%.

Effects of Seed Treatment

The seed treatment used varied between locations (Table 2). Raxil PRO was used at Indian Head, Prince Albert, and Redvers. Cruiser Vibrance Quattro was used at Melfort, Outlook, and Swift Current. CruiserMaxx Vibrance was used at Yorkton and CruiserMaxx Cereals was use at Scott. In most cases, seed treatment did not significantly affect emergence, plant vigor, wheat yield or grain protein. However, there were a few instances where seed treatments had significant effects. Seed treatment proved to have beneficial effects at Swift Current, where emergence (Tables 6 and 7) and plant vigor based on visual assessments (Tables 9 and 10) were significantly increased. While the use of seed treatment did not significantly affect yield (Tables 12 and 13) at Swift Current, it did significantly increase grain protein (Tables 15 and 16). Why protein increased is not clear. In contrast, some negative effects of seed treatment were observed at Redvers, Yorkton, and Indian Head. Seed treatment significantly reduced emergence from 243 to

225 plants/m^2 at Redvers (Table 7) and significantly reduced yield at Yorkton by 3.2% (Table 13). At Indian Head, there was a significant interaction between variety and seed treatment as seed treatment only significantly reduced the yield of the farm-saved seed for the variety C comparison (Table 14). In the absence of disease pressure or conditions conducive to disease development, the author has noted detrimental effects of seed treatment. This may be the result of uneven application of product to seed. The germination of seeds receiving excessive amounts of seed treatment can be adversely affected. Seed treatment is typically applied at research farms in small batches using a cement mixer at most locations. While every effort is made to apply the seed treatment evenly to seed, the result was not likely as uniform as can be accomplished by a commercial seed treater. However, seed treatment for the most part did not significantly affect yield in this study.

Varietal Comparisons

In total, the study compared 24 different seed lots of certified seed against 24 different seed lots of FSS. To be fair, comparisons between certified and FSS were grouped together by variety to create 3 varietal comparisons at each of the 8 locations. The varieties used in the varietal comparisons varied between locations. Locations chose varieties based on local grower preference. AAC Brandon was a very popular hard red spring (HRS) variety in Saskatchewan and was used in 13 of the 24 varietal comparisons. It was present at all locations except Swift Current where durum varieties Transcend, AAC Spitfire, and CDC Fortitude were used for the varietal comparisons. Transcend was also used at Redvers. AAC Elie was a fairly popular HRS variety and was present at 4 locations. Cardale was present at 2 locations and Stettler only at one. A complete list of the varietal comparisons along with seed quality results are found in Table 18. In order to be as representative of the industry as possible, each varietal comparison between certified and FSS used a different seed lot. A seed lot for a variety at one location was never used again for a comparison at another site. Determining differences between varietal comparisons was not an objective of this study and the few significant differences that were detected are not of any interest and will not be discussed. The relative performance of certified seed against FSS is the main comparison of interest and will be discussed next.

Certified vs FSS

Large differences in emergence rates between FSS and certified seed lots were not expected, as seeding rates were adjusted for each seed lot based on 1000 kernel weight and vigor to achieve 300 live seeds/m^2 at each location. Averaged across location, this resulted in comparable emergence rates of 223 and 215 plants/m^2 for FSS and certified seed lots, respectively. However, emergence did vary greatly between sites (Table 7). As noted earlier, overall emergence rates were quite low at Prince Albert. Emergence rates between FSS and certified seed lots did not statistically differ at Yorkton, Prince Albert and Melfort. For the remaining sites there were interactions where emergence did differ between FSS and certified seed for some of the varietal comparisons. However, these differences are not necessarily related to seed vigor as inaccuracies in seeding rate to deliver the same number of seeds/m^2 for each seed lot could also account for small differences. However, the magnitude of these differences were not of agronomic significance. Overall, emergence between FSS and certified seed were comparable.

Based on visual ratings, seedling emergence from certified seed appeared more vigorous at Yorkton (Table 10). While the vigor difference was statistically significant it was only minor and did not result in any detectable yield or protein differences later on. At Indian Head there was a significant interaction. While certified seed appeared more vigorous for one of AAC Brandon varietal comparisons, FSS appeared more vigorous for the AAC Elie varietal comparison. Again, treatments which appeared more vigorous did not translate into improved yield or protein differences. Overall, there were few differences in observed seedling vigor between certified and FSS and none of the difference that were observed resulted in greater yields.

In the majority of cases, yield and grain protein did not significantly differ between certified and FSS seed lots (Tables 12, 13, 15 and 16). When averaged across location, certified seed yielded 4362 kg/ha (64.9 bu/ac) with a grain protein of 14.20%. FSS was virtually identical, averaging 4361 kg/ha (64.9 bu/ac) with a grain protein of 14.25%. There were a few instances where yield did differ between certified and FSS seed lots. At Indian Head, certified AAC Elie (C-varietal comparison) was significantly lower yielding by 7%, but only for the untreated seed comparison (Table 14). At Scott, averaged over seed treatment, certified AAC Elie (B-varietal comparison) significantly yielded 9% more grain with 1% higher protein (13.04% vs 12.0%) compared to FSS. Certified AAC Elie may have performed better as it had a higher vigor germination test result of 97% compared to 92% for the FSS (Table 18). Moreover, the emergence for the certified AAC Elie was in a more ideal range averaging 279 plants/m^2 compared to only 200 plants/m^2 for FSS. These differences may have contributed to the better performance of the certified AAC Elie in this instance. At Outlook, there was an interaction involving the protein data. The grain protein of the certified AAC Brandon was almost significantly lower than the grain protein of the FSS (12.58% vs 13.18%) for the A-varietal comparison. In contrast, the opposite result occurred for the B-varietal comparison where certified AAC Brandon produced significantly higher grain protein compared to FSS (13.2% vs 11.34%). Though not statistically significant, the differences in grain protein were a reflection of yield differences. When certified AAC Brandon had higher grain protein than FSS it also had lower yield and vice versa. The difference in performance of AAC Brandon seed types between the A and B varietal comparisons at Outlook cannot be explained in terms of seed quality. The vigor and fungal screens were all good and essentially the same between the four seed lots. Overall, yield and protein did not frequently differ between certified and FSS seed lots considering all 8 locations. This is not surprising as the quality of seed in terms of germination, vigor and fungal screens were very good for both seed types in the vast majority of cases (Table 18).

<u>Seed Lot Quality</u>

The average germination for the certified and FSS was 97% and 96.8%, respectively. Percent vigor was also excellent for both and averaged 93.1% for certified and 93.3% for FSS. Overall, germination and vigor were virtually identical between seed lots and did not differ significantly based on a paired T-test. The 5 seed borne pathogenic fungi which were screened for included:

- *Cochliobolis sativus* – Seedling blight, foot and root rot or spot blotch (leaf blight)
- *Fusarium graminearum* – Head blight
- *Fusarium* spp. – Seedling blight, root and crown rot, and head blight

- *Pyrenophora* spp. – Leaf blight (leaf stripe, net blotch and tan spot), and seedling blight (oats)
- *Septoria* spp. – Leaf blotch

According to the 20/20 Seed Labs Inc. website, seed treatment may not provide sufficient control if infection with any one disease is higher than 8% or if the total disease of 3 or more pathogens is more than 12%. Only one seed lot of FSS used at Prince Albert exceeded these criteria. The rest of the seed lots were in good condition.

On average, the fungal screens found certified and FSS had 1.63 and 2.44% total *Fusarium* species, respectively. This difference did not prove to be statistically significant (paired T test $p=0.28$). Total % *Fusarium* species did vary more between seed lots of FSS. One seed lot of FSS used at Prince Albert had 18% total *Fusarium* species (Table 15). Despite the high fungal screen for this seed lot, the vigor was still 92% and the performance of this seed lot did not significantly differ from its certified counterpart in terms of either yield or protein. This may not have been the case if the seed had been planted under cold wet conditions. *Fusarium graminearum* (head blight) was detected in 5 seed lots ranging from 0.5 to 1.5%. These levels of *Fusarium graminearum* are not of agronomic significance unless *Fusarium* head blight is already present in stubble. *Cochliobolis sativus* (seedling blight, foot and root rot, or spot blotch) was found in 2 seed lots at 0.5% which is also of no agronomic significance. For the most part, seed lots of FSS were mostly of good quality and comparable to certified. Recent years have been relatively dry which is good for producing quality seed. This may change as the study will continue for 2 more years.

Conclusions and Recommendations:

Positive effects of seed treatment on emergence, seedling vigor, and grain protein were observed at Swift Current. In contrast, there were a couple instances were yield was significantly reduced by seed treatment at Yorkton and Indian Head. However, seed treatment did not affect emergence, seedling vigor, yield, or grain protein of wheat in most cases.

Fungal screening of seed lots found only somewhat higher levels of seed borne disease on FSS. However, there was one seed lot of FSS with total *Fusarium* levels beyond acceptable levels. Despite this, the overall vigor of FSS seed lots were comparable to certified seed and few significant differences in emergence, seedling vigor, yield, or grain protein were observed between the seed types. In the few cases where differences were significant, the observation did not consistently favor the use of either certified or FSS. The results from this study would indicate that producers using FSS that is 1 to 3 years removed from certified were achieving yields and grain protein similar to those using certified seed in 2019. The quality of seed used by producers in 2019 was good for both seed types.

Growing FSS was more economical in this study because there was no yield or protein advantage to growing certified seed which is typically more expensive. However, there is value in purchasing certified seed, to assure quality (true to type) for end users and to introduce better genetics to the farm to stay competitive. Certified seed should be purchased at a premium as these assurances have value and there is value in supporting a system where new genetics can be developed and brought to the farm to keep Canadian producers globally competitive. Exactly how this support will continue is currently under debate. This study does not suggest that there is no value in purchasing certified seed only that there were no production risks to growing FSS during 2019. Growing FSS for a couple years between purchasing new certified varieties with better genetics may prove to have little production risk. This would currently appear to be the approach of many producers as approximately 70 to 80% of cereal acres in western Canada were seeded with FSS in 2004 based on a phone survey of 800 producers. Initial results from this study would indicate that wheat producers who use quality control measures similar to those required for certified seed can produce grain yield and protein comparable to that of certified seed. This study will continue for 2 more years before final conclusions are made.

The trial was toured at Swift Current on July 9 during WCA directors and staff tour (20 attendees) and on July 30 during Swift Current Crop Club tour (12 attendees). The trial was also promoted on Swift Current's Facebook page and CKSW's weekly program "Walk the Plots" reaching thousands of listeners in southwest Saskatchewan. The trial was toured at Outlook during their July 11 CSIDC Field Day which 200 producers and agronomists attended. Indian Head toured the trial during their Indian Head Crop Management Field Day on July 16 (125 attendees).

Supporting Information

Acknowledgements:

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Appendices:

Table 6. Significance of seed treatment, variety, and type effects on wheat emergence at multiple locations in 2019.

	Emergence							
	I.H.	**Melfort**	**Outlook**	**P.A.**	**Redvers**	**Scott**	**S.C.**	**Yorkton**
Effect	-------------------------------------- p-values [z] -----------------------------------							
Seed Treatment (S)	NS	NS	NS	NS	0.014	NS	<0.00001	NS
Variety (V)	NS	NS	0.013	NS	0.075	0.075	0.0034	NS
S x V	NS	NS	NS	NS	0.016	NS	NS	NS
Type (T)	NS	NS	0.010	NS	0.01	0.00065	0.088	NS
S x T	NS	NS	NS	NS	NS	NS	NS	NS
V x T	0.028	NS	NS	NS	0.00087	<0.00001	0.0017	NS
S x V x T	NS	NS	NS	NS	0.063	NS	NS	NS

Table 7. Main effects of seed treatment, variety, and type of seed on wheat emergence at multiple locations in 2019.									
Main effect	**Emergence**								
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**	**All Sites Average**
Seed Treatment	---------- plants/m² ----------								
Untreated	358 a	177 a	212 a	78 a	243 a	232 a	165 b	277 a	218
Treated	352 a	184 a	196 a	85 a	225 b	226 a	217 a	276 a	220
LSD	NS	NS	NS	NS	14.4	NS	14.7	NS	--
Varietal comparison									
A	360 a	173 a	219 a	84 a	242 a	222 a	192 ab	272 a	220
B	351 a	189 a	168 b	81 a	222 a	239 a	206 a	279 a	217
C	355 a	179 a	224 a	80 a	237 a	226 a	174 b	279 a	219
LSD	NS	NS	41.3	NS	NS	NS	18.5	NS	--
Type									
Farm-saved	349 a	179 a	225 a	90 a	243 a	241 a	185 a	272 a	223
Certified	361 a	181 a	182 b	73 a	224 b	217 b	197 a	281 a	215
LSD	NS	NS	32.8	NS	14.4	13.0	NS	NS	--

Table 8. Main effects of seed treatment, variety, and type of seed on wheat emergence at multiple locations in 2019.

Main effect	**Emergence**								
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**	**All Sites Average**
Main Effects	plant/m²								
1. Untreated A Certified	349 a	167 a	243 ab	75 a	250 abc	223 cd	174 cde	271 a	219
2. Untreated A Farm-saved Seed	379 a	179 a	218 abc	84 a	266 ab	227 cd	148 de	270 a	221
3. Untreated B Certified	369 a	167 a	203 abc	106 a	240 abcd	284 a	180 cd	288 a	230
4. Untreated B Farm-saved Seed	348 a	190 a	124 c	54 a	239 abcd	208 cd	170 cde	263 a	200
5. Untreated C Certified	338 a	185 a	273 a	85 a	276 a	209 cd	130 e	273 a	221
6. Untreated C Farm-saved Seed	368 a	172 a	212 abc	65 a	186 e	240 bc	186 bcd	298 a	216
7. Treated A Certified	354 a	172 a	211 abc	82 a	227 bcde	227 cd	233 ab	272 a	222
8. Treated A Farm-saved Seed	357 a	173 a	206 abc	94 a	225 bcde	212 cd	213 abc	273 a	219
9. Treated B Certified	348 a	198 a	212 abc	88 a	209 cde	274 ab	217 abc	278 a	228
10. Treated B Farm-saved Seed	338 a	200 a	134 b	75 a	202 de	191 d	258 a	286 a	211
11. Treated C Certified	335 a	184 a	211 abc	106 a	258 ab	229 cd	174 cde	250 a	218
12. Treated C Farm-saved Seed	380 a	175 a	200 abc	67 a	228 bcde	225 cd	208 bc	297 a	223
L.S.D	52.8	NS	108.1	NS	47.4	42.7	48.3	NS	--

Table 9. Significance of seed treatment, variety, and type effects on wheat Vigour at multiple locations in 2019.

	Vigour							
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
Effect	---------- p-values [Z] ----------							
Seeding Treatment (S)	NS	NS	NS	NS	NS	NS	0.0006	NS
Variety (V)	NS	NS	0.0011	NS	NS	NS	0.0065	NS
S x V	NS	NS	NS	NS	NS	NS	NS	NS
Type (T)	0.023	NS	NS	NS	NS	NS	NS	0.014
S x T	NS	NS	NS	NS	NS	NS	NS	NS
V x T	0.00001	NS	NS	NS	NS	NS	NS	NS
S x V x T	NS	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 10. Main effects of seed treatment, variety, and type of seed on wheat yield at multiple locations in 2019.									
Main effect	**Vigour**								
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**	**All Sites Average**
Seed Treatment	---------- 1-10 ----------								
Untreated	8.4 a	7.9 a	9.1 a	6.3 a	NS	5.9 a	8.5 b	7.3 a	7.7
Treated	8.1 a	7.8 a	9.3 a	7.0 a	NS	6.0 a	9.5 a	7.5 a	7.9
LSD	NS	NS	NS	NS	NS	NS	0.52	NS	--
Varietal comparison									
A	8.1 a	8.0 a	8.5 b	6.4 a	NS	6.2 a	9 a	7.3 a	7.7
B	8.4 a	7.7 a	9.6 a	6.9 a	NS	5.6 a	9.6 a	7.3 a	7.9
C	8.3 a	7.8 a	9.5 a	6.7 a	NS	5.9 a	8.5 b	7.6 a	7.8
LSD	NS	NS	0.64	NS	NS	NS	0.65	NS	--
Type									
Farm-saved	8.0 a	7.9 a	9.3 a	6.6 a	NS	5.9 a	8.8 a	7.2 b	7.7
Certified	8.5 a	7.8 a	9.2 a	6.7 a	NS	5.9 a	9.2 a	7.5 a	7.8
LSD	0.36	NS	NS	NS	NS	NS	NS	0.23	--

Table 11. Main effects of seed treatment, variety, and type of seed on wheat yield at multiple locations in 2019.									
Main effect	**Vigour**								
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**	**All Sites Average**
Main Effects	-- (1-10) --								
1. Untreated A Certified	7.3 cd	7.8 a	8.5 a	5.5 a	Na	6.5 a	8.5 abc	6.9 c	7.3
2. Untreated A Farm-saved Seed	9.3 a	8.3 a	8.3 a	5.8 a	Na	6.3 a	8.5 abc	7.1 abc	7.7
3. Untreated B Certified	9.0 a	7.5 a	10.0 a	6.8 a	Na	5.8 a	9.3 ab	7.3 abc	8.0
4. Untreated B Farm-saved Seed	8.5 ab	7.8 a	9.3 a	6.9 a	Na	5.5 a	9.5 ab	7.4 abc	7.8
5. Untreated C Certified	8.3 abc	8.5 a	9.5 a	7.0 a	Na	5.5 a	7.3 c	7.3 abc	7.6
6. Untreated C Farm-saved Seed	8.3 abc	7.5 a	9.3 a	5.8 a	Na	5.8 a	8.3 bc	7.8 a	7.5
7. Treated A Certified	7.0 d	7.5 a	8.5 a	6.9 a	Na	5.8 a	9.5 ab	7.5 abc	7.5
8. Treated A Farm-saved Seed	8.8 ab	8.5 a	8.8 a	7.5 a	Na	6.3 a	9.5 ab	7.6 abc	8.1
9. Treated B Certified	8.3 abc	8.3 a	9.8 a	5.6 a	Na	5.5 a	9.5 ab	7.0 bc	7.7
10. Treated B Farm-saved Seed	7.8 bcd	7.3 a	9.5 a	8.4 a	Na	5.8 a	10.0 a	7.6 abc	8.1
11. Treated C Certified	8.5 ab	7.8 a	9.3 a	7.8 a	Na	6.5 a	9.0 ab	7.5 abc	8.1
12. Treated C Farm-saved Seed	8.3 abc	7.3 a	10.0 a	6.1 a	Na	6.0 a	9.5 ab	7.7 ab	7.8
L.S.D	1.2	NS	1.7	NS	Na	NS	1.7	0.76	--

Table 12. Significance of seed treatment, variety, and type effects on wheat yield at multiple locations in 2019.

	Yield							
	I.H.	**Melfort**	**Outlook**	**P.A**	**Redvers**	**Scott**	**S.C.**	**Yorkton**
Effect	-- p-values [Z] ------------------------------------							
Seeding Treatment (S)	NS	NS	NS	NS	NS	NS	NS	0.011
Variety (V)	Ns	NS	NS	NS	0.0074	<0.00001	NS	NS
S x V	0.0029	NS	NS	NS	NS	NS	NS	NS
Type (T)	NS	NS	NS	NS	NS	NS	NS	NS
S x T	NS	NS	NS	NS	NS	NS	NS	NS
V x T	NS	NS	NS	NS	NS	0.0045	NS	NS
S x V x T	0.0064	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 13. Main effects of seed treatment, variety, and type of seed on wheat yield at multiple locations in 2019.									
Main effect	**Yield**								
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**	**All Sites Average**
Seed Treatment	---------- kg/ha ----------								
Untreated	3951 a	5529 a	4286 a	3681 a	4393 a	4799 a	2139 a	6179 a	4370
Treated	3910 a	5412 a	4306 a	3912 a	4397 a	4788 a	2116 a	5982 b	4353
LSD	NS	NS	NS	NS	NS	NS	NS	152	--
Varietal comparison									
A	3942 a	5571 a	4180 a	3841 a	4450 a	5098 a	2147 a	6119 a	4419
B	3889 a	5385 a	4430 a	3728 a	4503 a	4755 b	2187 a	5999 a	4360
C	3961 a	5455 a	4277 a	3821 a	4232 b	4527 c	2048 a	6124 a	4306
LSD	NS	NS	NS	NS	180	157	NS	NS	--
Type									
Farm-saved	3922 a	5520 a	4344 a	3620 a	4419 a	4843 a	2131 a	6086 a	4361
Certified	3939 a	5420 a	4247 a	3973 a	4371 b	4745 a	2124 a	6076 a	4362
LSD	NS	NS	NS	NS	143	NS	NS	NS	--

Table 14. Main effects of seed treatment, variety, and type of seed on wheat yield at multiple locations in 2019.									
Main effect	**Yield**								
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**	**All Sites Average**
Main Effects	kg/ha								
1. Untreated A Certified	3979 ab	5571 a	4485 a	3584 a	4462 a	5253 a	2220 a	6113 ab	4458
2. Untreated A Farm-saved Seed	3855 b	5443 a	3864 a	3934 a	4407 a	5155 ab	2179 a	6147 ab	4373
3. Untreated B Certified	3864 b	5550 a	4164 a	3280 a	4627 a	4832 bc	2175 a	6202 ab	4337
4. Untreated B Farm-saved Seed	3839 b	5465 a	4593 a	3912 a	4426 a	4558 cd	2261 a	6179 ab	4404
5. Untreated C Certified	3930 b	5681 a	4384 a	3666 a	4194 a	4378 d	1967 a	6156 ab	4295
6. Untreated C Farm-saved Seed	4240 a	5463 a	4225 a	3713 a	4242 a	4619 cd	2033 a	6279 a	4352
7. Treated A Certified	4023 ab	5627 a	4245 a	3689 a	4525 a	4950 abc	2087 a	6089 ab	4404
8. Treated A Farm-saved Seed	3911 b	5643 a	4128 a	4156 a	4408 a	5037 ab	2104 a	6127 ab	4439
9. Treated B Certified	3836 b	5229 a	4545 a	3414 a	4463 a	5077 ab	2213 a	5878ab	4332
10. Treated B Farm-saved Seed	4018 ab	5295 a	4417 a	4306 a	4495 a	4555 cd	2100 a	5739 b	4366
11. Treated C Certified	3902 b	5466 a	4244 a	4089 a	4245 a	4569cd	2126 a	6075 ab	4340
12. Treated C Farm-saved Seed	3772 b	5210 a	4256 a	3818 a	4248 a	4544 cd	2066 a	5986 ab	4238
L.S.D	267.5	NS	NS	NS	471.3	410.3	NS	500.5	---

Table 15. Significance of seed treatment, variety, and type effects on wheat protein at multiple locations in 2019.

	Protein							
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**
Effect	------------------------------------ p-values [z] -----------------------------------							
Seeding Treatment (S)	NS	NS	NS	NS	NS	NS	0.02	NS
Variety (V)	NS	NS	0.012	NS	NS	NS	NS	NS
S x V	NS	NS	NS	NS	NS	NS	NS	0.045
Type (T)	NS	NS	0.006	NS	NS	NS	NS	NS
S x T	NS	NS	NS	NS	NS	NS	NS	0.048
V x T	NS	NS	<0.00001	NS	NS	0.007	NS	NS
S x V x T	NS	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 16. Main effects of seed treatment, variety, and type of seed on wheat protein at multiple locations in 2019.

Main effect	**Protein**								
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**	**All Sites Average**
Seed Treatment	-- % --								
Untreated	15.02 a	13.24 a	12.68 a	13.77 a	13.30 a	12.78 a	19.66 b	13.30 a	14.23
Treated	15.00 a	13.10 a	12.57 a	13.70 a	13.43 a	12.53 a	20.07 a	13.25 a	14.21
LSD	NS	NS	NS	NS	NS	NS	0.35	NS	---
Varietal comparison									
A	15.04 a	13.17 a	12.88 a	13.69 a	13.29 a	12.73 a	19.93 a	13.30 a	14.26
B	14.98 a	13.18 a	12.27 c	13.54 a	13.53 a	12.53 a	19.71 a	13.41 a	14.15
C	15.00 a	13.17 a	12.73 b	13.96 a	13.29 a	12.71 a	19.96 a	13.18 a	14.25
LSD	NS	NS	0.4	NS	NS	NS	NS	NS	---
Type									
Farm-saved	15.04 a	13.18 a	12.86 a	13.58 a	13.40 a	12.78 a	19.79 a	13.27 a	14.25
Certified	14.98 a	13.17 a	12.38 b	13.88 a	13.34 a	12.53 a	19.94 a	13.33 a	14.20
LSD	NS	NS	0.34	NS	NS	NS	NS	NS	---

Table 17. Main effects of seed treatment, variety, and type of seed on wheat yield at multiple locations in 2019.									
Main effect	**Protein**								
	Indian Head	**Melfort**	**Outlook**	**Prince Albert**	**Redvers**	**Scott**	**Swift Current**	**Yorkton**	**All Sites Average**
Main Effects	-- % --								
1. Untreated A Certified	15.2 a	13.1 a	12.6 a	13.4 a	13.1 a	12.9 a	19.6 a	13.6 a	14.19
2. Untreated A Farm-saved Seed	14.9 a	13.2 a	13.5 a	13.7 a	13.3 a	12.8 ab	19.8 a	13.5 a	14.34
3. Untreated B Certified	15.1 a	13.2 a	13.4 a	13.2 a	13.5 a	13.0 a	19.7 a	13.4 ab	14.31
4. Untreated B Farm-saved Seed	15.0 a	13.3 a	11.4 b	14.0 a	13.5 a	12.4 ab	19.4 a	13.4 ab	14.05
5. Untreated C Certified	15.1 a	13.4 a	12.6 a	14.0 a	13.5 a	12.6 ab	19.4 a	13.2 ab	14.23
6. Untreated C Farm-saved Seed	14.9 a	13.3 a	12.6 a	14.3 a	13.0 a	13.0 a	20.1 a	13.0 ab	14.28
7. Treated A Certified	15.0 a	13.2 a	12.6 a	13.7 a	13.5 a	12.3 ab	20.3 a	12.8 b	14.18
8. Treated A Farm-saved Seed	15.1 a	13.2 a	12.8 a	14.0 a	13.3 a	12.9 a	20.1 a	13.4 ab	14.35
9. Treated B Certified	14.9 a	13.1 a	13.0 a	13.5 a	13.4 a	13.1 a	19.8 a	13.5 a	14.29
10. Treated B Farm-saved Seed	15.0 a	13.2 a	11.3 b	13.5 a	13.7 a	11.7 b	19.9 a	13.4 ab	13.96
11. Treated C Certified	15.0 a	13.1 a	13.1 a	13.7 a	13.4 a	12.9 a	20.0 a	13.1 ab	14.29
12. Treated C Farm-saved Seed	15.0 a	12.8 a	12.7 a	13.8 a	13.3 a	12.4 ab	20.4 a	13.4 ab	14.23
L.S.D.	NS	NS	1.11	NS	NS	1.11	NS	0.61	---

Table 18 Discovery Seed Labs. Seed Quality Results					
	Years from Certified	**Germination**	**Vigour**	**Thousand Kernel Weights**	**Fungal Screen**
Indian Head					
a. Certified AAC Brandon	-	98	99	33.8	0%
b. Certified AAC Brandon	-	99	98	41.8	0.5% total fus
c. Certified AAC Elie	-	98	94	36.6	0%
a. Farm-saved AAC Brandon	2	99	96	41.1	0.5% total fus
b.Farmer- Saved AAC Brandon	2	99	95	41.7	2% total fus
c.Farm-saved AAC Elie	2	99	97	35.4	2% total fus
Melfort					
a. Certified AAC Brandon	-	98	96	40.5	0.5% total fus
b. Certified AAC Brandon	-	96	92	38.1	2% total fus; 0.5% F.gram
c. Certified AAC Brandon	-	97	94	44.8	3% total fus
a. Farm-saved AAC Brandon	?	97	98	39.8	7.5% total fus
b. Farmer- Saved AAC Brandon	3	99	97	39.8	1% total fus
c. Farmer- Saved AAC Brandon	2	99	96	37.2	1% total fus
Outlook					
a. Certified AAC Brandon	-	99	93	40.0	1% total fus
b. Certified AAC Brandon	-	99	91	34.8	0%
c. Certified Cardale	-	99	92	36.0	0.5% total fus
a.Farm-saved AAC Brandon	2	99	93	33.0	1.5% total fus
b. Farmer- Saved AAC Brandon	2	98	92	32.1	0%
c. Farm-saved Cardale	2	99	92	37.0	0%
Prince Albert					

a. Certified Cardale	-	96	89	39.1	2.5% total fus; 0.5% F. gram.; 1% Coch.
b. Certified AAC Elie	-	77	74	39.3	4% total fus
c. Certified AAC Brandon	-	99	99	39.4	3.5% total fus
a. Farm-saved Cardale	1	94	95	35.9	0
b. Farm-saved AAC Elie	1	95	90	43	5.5% total fus
c. Farm-saved AAC Brandon	3	88	92	40.4	18.5% total fus; 1.5% F. gram.
Redvers					
a. Certified AAC Brandon	-	97	89	40.1	1.5% total fus
b. Certified AAC Brandon	-	98	97	39.3	2.5% total fus; 1% F. gram.
c. Certified Transcend Durum	-	94	89	45.0	1.5% total fus
a. Farm-saved AAC Brandon	3	99	95	40.5	0.5% F. gram.
b. Farm-saved AAC Brandon	2	98	93	39.0	2% total fus; 0.5% F. gram.
c. Farm-saved Transcend Durum	2	97	86	43.0	0%
Scott					
a. Certified AAC Brandon	-	98	92	38.9	3% total fus
b. Certified AAC Elie	-	98	97	39.3	2% total fus
c. Certified Stettler	-	97	97	34.7	0.5% total fus
a. Farm-saved AAC Brandon	2	96	96	39.2	3% total fus
b. Farm-saved AAC Elie	2	92	92	33.2	0%
c. Farm-saved Stettler	2	99	94	40.2	1.5% total fus
Swift Current					

a. Certified Transcend Durum	-	98	84	43.5	0%
b. Certified AAC Spitfire Durum	-	98	92	47.1	0.5% total fus
c. Certified CDC Fortitude Durum	-	98	96	38.1	0.5% total fus
a. Farm-saved Transcend Durum	3	97	93	47.1	0%
b. Farm-saved AAC Spitfire Durum	1	95	93	38.6	0%
c. Farm-saved CDC Fortitude Durum	3	93	84	40.3	0.5% total fus
Yorkton					
a. Certified AAC Brandon	-	99	96	38.8	6% total fus
b. Certified AAC Brandon	-	99	97	34.3	0%
c. Certified AAC Elie	-	99	98	40.7	3.5% total fus; 0.5% Coch
a. Farm-saved AAC Brandon	2	99	95	40.5	6.5% total fus
b. Farm-saved AAC Brandon	2	98	89	43.1	3.5% total fus
c. Farm-saved AAC Elie	2	96	97	40.1	1.5% total fus