Government of Saskatchewan
Ministry of Agriculture

1. **Project title, ADF file number and reporting period.**

   Breeding milling oat varieties with improved agronomic, quality and disease traits for Saskatchewan oat Producers
   20180260
   July 1, 2020 – June 30, 2021

2. **Name of the Principal Investigator and contact information.**

   Aaron Beattie
   Crop Development Centre
   University of Saskatchewan
   51 Campus Drive
   Saskatoon, SK S7N 5A8
   Phone: 306-966-2102
   Fax: 306-966-5015
   Email: aaron.beattie@usask.ca

3. **Name of the collaborators and contact information**

   None.

4. **Abstract (Not more than 250 words).** *Describe in lay language the progress towards the project objectives over the last reporting period. Include any key findings and any interim conclusions. Include any deviations from the original methodology.*

Goodprogress on the objectives for project 20180260 was made in 2020-21.The 2020 year was defined by COVID-19, with the CDC operating with reduced staff between March 15 and June 1, with full resumption of normal staffing occurring on September 1. COVID-19 also affected our ability to access some AAFC sites which were used in previous years as off-site testing locations. This required the CDC to find alternative locations for these trials. Despite reduced staff and the need to work under conditions to minimize the spread of COVID-19 we were able to complete all intended activities.The 2020 growing season was defined by good soil moisture conditions at seeding, cooler-warm temperaturesand very good precipitation until mid-July, followed by very hot and dry conditions throughout the remainder of summer. From May 1-August 31 Saskatoon received 1,219 GDD (5°C base) with the 5-year average being 1,348 GDD, and received 217 mm of precipitation with the 30-year average being 216 mm. Overall, plots at Goodale, Preston, Seed Farm, and Codette SK, Lacombe, AB, and Ft. Whyte, Roblin, Portage-la-Prairie and Brandon, MB were uniform and provided good data. Harvest began on August 18 and was completed by September 15 with no frost received prior to completion. Good data was produced from most sites during the 2020 season and all material moved through the program normally. During the summer 2,672 lines were evaluated at disease nurseries coordinated by the University of Saskatchewan for crown rust, stem rust, smut, fusarium head blight and barley yellow dwarf virus. Most nurseries operate normally in 2020, except for the oat smut nursery located at the University of Minnesota, which was only able to assess a small number of lines due to COVID-19. Over the winter a total of 53,394 marker data points were collected on breeding material related to four crown rust resistance genes and one quality trait, and 20,645 analyses were conducted in the quality lab for beta-glucan, total dietary fiber, protein, oil, fatty acids and groat percentage.Sixty new crosses were made in 2020, including two crosses to incorporate

the hairless groat characteristic. One new line (**OT3112**) was registered in the past year, and three promising lines moved into the second year of registration testing in 2021.

5. Introduction: *Brief project background and rationale.*

Oat is considered a healthy cereal due to a number of nutritional compounds found within the grain, including beta-glucan. Beta-glucan is a soluble fiber that has been shown to lower plasma cholesterol and reduce the risk of heart disease. This has resulted in health claims being established in both Canada and the United States. Oat grain also contains a number of antioxidant compounds, including the polyphenolic avenanthramides, which have anti-inflammatory effects that may protect against coronary heart disease. Oat contains 12-20% protein which is rich in globulins and contains more lysine and threonine than other cereals, and provides a better balance of essential amino acids. Finally, oat is able to be consumed by most people suffering from celiac disease and is thus considered to be gluten-free.

As a result of these desirable attributes, oat remains a significant Canadian crop that has been seeded on an average of 3.1 million acres over the past 5 years, with Saskatchewan accounting for 50% of these acres. Over the past 5 years, 50% of the 3.2 million metric tonnes (MT) of oat produced annually in Canada has been exported to the U.S., destined for the food market. In addition to the export of raw oat, oat is critical to the domestic milling industry. Total annual domestic milling in Canada is close to 750,000 MT, with Saskatchewan being home to Richardson Milling (Martensville), Grain Millers (Yorkton), Ardent Mills (Saskatoon), and Avena Foods (Regina), or about half of all milling production. Forecasts indicate that domestic milling will grow to just over 900,000 MT within the next 6 years. Combined sales of oat and milled oat products were valued at almost $750 million last year. In addition, farm-gate sales of oat represent an estimated value of $450 million to growers.

Saskatchewan currently holds a strong position in supplying the North American oat market due to the steady decline in U.S. oat acres since the 1980s and our proximity to the main US oat distribution hub in Minneapolis, MN. In addition to the long-term, stable U.S. export market, two other markets hold promise to increase demand for Canadian oat. Firstly, Mexico has become the second largest importer of Canadian oat in recent years, in part due to recent marketing efforts by the Prairie Oat Growers Association (POGA), and the purchase of Canadian Oat Milling (Namo, Alberta) by Grupo Vida. Secondly, POGA is working to gain market access to China for Canadian oat. In 2017 China purchased about 500,000 MT of oat from Australia, up from just 50,000 MT in 2009, with projected growth over the next 5 years to continue at the same pace. Access to the Chinese market could become a strong export market for Canadian oat, as it is in barley where China is now the leading importer of Canadian barley (having recently surpassed the U.S.).

To build on Saskatchewan's (and Canada's) position as a supplier of premium quality oat to current U.S. markets (and developing markets in Mexico and China) require developing varieties with improved agronomic, quality and disease resistance (traits that are current breeding targets for the CDC oat breeding program). This will provide value to growers, through improved yield and harvestability which will help oat remain a viable crop within a growers rotation, and to millers/food processors, through higher selectability (i.e. good plumpness and test weight) and better nutritional profile (i.e. higher beta-glucan and protein, lower fat). In addition, the CDC is exploring new traits for incorporation into future Canadian oat varieties that may add value to the crop. For example, the CDC has begun crossing with oat lines which possess very few trichomes (i.e. 'hairs') on the groat. Oat trichomes are known to be irritating and can cause allergic reactions, in addition they form a fine dust when removed from the groat during grain handling, or when groats are dehulled and scoured, which can be hard on equipment. When speaking to several Canadian oat millers about producing a 'hairless' oat groat, there was interest in understanding if this will have benefits to the oat grower and miller in terms of less irritation, and if it will allow more efficient dehulling.

This proposal is part of our effort to maintain the viability and productivity of the CDC oat breeding program which will allow us to build on our past oat variety successes through continued focus on improving agronomics, milling and nutritional quality and disease resistance. We will also expand our efforts to increase protein content and improve stem rust resistance while also incorporating novel traits, like ‘hairless’ groats, to understand their potential impact and importance to growers and millers.

6. Objectives and the *progress towards meeting each objective*

Objectives (*Please list the original objectives and/or revised objectives if Ministry-approved revisions have been made to original objective. A justification is needed for any deviation from original objectives)*	**Progress (e.g. completed/in progress)**
a)Produceimprovedmilling oatvarieties	A total of 242 early generation milling oat populations, and 2,217 advanced milling oat lines were grown and evaluated in 2020 for agronomic performance and reaction to various diseases. Physical grain quality traits were also evaluated. One line (**OT3112**) was supported for registration at the 2021 PGDC meeting. Three lines were advanced to 2nd year registration testing and threelines were advanced to 1st year registration testing in 2021.
b)Nutritionalqualityevaluation	11,945milling oat samples were collected from 2020 field trials, ground, scanned by NIT and evaluated for a combination of traits including beta-glucan, total dietary fiber, protein, oil, and ADL. A total of 20,645 analyses were conducted, including 5,045 beta-glucan, 11,945 protein and oil analyses. This data was used to assist in decisions regarding lines to advance to 2021 trials.
c)Produce‘hairless’groatmilling oatlines	Two crosses were made in 2020 with the hulless, hairless groat variety VAO-51 in order to incorporate this trait into elite breeding lines adapted to western Canada. In addition to selecting for the hairless trait, these populations will be used for a genetic study to develop markers linked to this trait.

7. Methodology:*Specify project activities undertaken during this reporting period.Include approaches, experimental design, tests, materials, sites, etc. Please note that any significant changes from the original work plan will require written approval from the Ministry.*

Breeding Objectives and Targets

Objectives and targets related to agronomics, physical grain quality, nutritional grain quality and disease resistance desired in future oat varieties are as follows (traits are listed in priority order beneath each general category and targets are expressed relative to current best varieties to provide guidance for future, desired improvements in varieties):

1. Agronomics

Grain Yield: better than CDC Arborg
Lodging resistance: equal to or better than CDC Arborg
Maturity: equal to or earlier than CDC Arborg
Plant height: equal to or shorter than CDC Endure

2. Physical Grain Quality

Groat percentage: equal to or better than CDC Arborg
Test weight: better than CDC Arborg
Plumpness/Thins: equal to or better than CDC Endure
Thousand kernel weight: equal to or better than CDC Endure
White hull: equal to CDC Arborg or CDC Endure
Uniformity (fewer tertiary kernels): equal to CDC Dancer
Hairless: no comparator, using VAO-51

3. Nutritional Grain Quality

Beta-glucan: equal to or higher than CDC Endure
Fat: equal to or lower than CDC Endure
Protein: equal to or higher than Leggett
Total dietary fibre: equal to or greater than Leggett

4. Disease Resistance

Crown rust: equal to or better than CDC Endure (MR)
Stem rust: Intermediate reaction or better
Smut: equal to CDC Endure (R)
Fusarium head blight: MR or better
BYDV: intermediate reaction or better

Strategy

Breeding milling oat varieties will begin with bi-parental or three-way crosses made in the greenhouse (University of Saskatchewan). 40 to 60 crosses will be targeted per year. Parental lines are chosen to maximize the potential to produce progeny containing the desired agronomic, quality and disease trait package indicated above. With respect to the 'hairless' trait, a limited number of crosses with the hairless line VAO-51 will be used to introduce this trait into elite breeding germplasm. Selection for the trait will be based on visual examination of the grain.

Progeny populations will be quickly advanced from the F1-F5 generations using a bulk breeding strategy in combination with single seed descent. Bulk populations will be grown at the Saskatoon Seed Farm during the summer and either as bulk populations in our winter nursery located in Leeston, New Zealand (Southern Seed Technology Ltd.), or as single seed descent populations in the U of S greenhouse. Single F5 plant selections (300-400) from each population will be selected in the field based on maturity, height and disease (if present) and further selected based on physical seed quality and/or molecular markers. In addition, a small number of populations (2 or 3) will be selected based on genomic selection (GS) predictions.

F6 hill populations will be grown in Saskatoon in the summer with approximately 50% of hills culled in the field based on visual traits (e.g. straw strength, height, lodging) and a further 50% culled after threshing of field selected hills based on NIT-predicted seed quality (protein, beta-glucan, fat, groat percentage). Unreplicated F7 microplots (MPs) will be grown in a modified augmented design the following year in Saskatoon with 50% culling in the field and a further 50% culling based on nutritional and physical grain quality. Field selection is based on maturity, height, lodging resistance, leaf diseases (if present) and overall appearance. Nutritional quality traits (i.e. protein, fat) are evaluated using NIT predictions while beta-glucan is evaluated using wet chemistry. Physical grain quality assessed included test weight, plumpness/thins, thousand kernel weight, and groat percentage. Lines are subjected to crown rust evaluation in Guelph, ON.

Selected F8 lines are then grown the following year in two replication randomized complete block design (RCBD) preliminary yield tests (POYTs) grown at the Kernen Crop Research Farm (KCRF), AAFC-Melfort farm and the

Goodale Research Farm. No selection is done in the field. Lines are evaluated for yield along with the nutritional and physical grain quality characteristics mentioned for the MPs. All lines are subjected to crown rust evaluation in Guelph, ON and smut evaluation in St. Paul Minnesota.

Advanced F9 lines are then tested for one more year in advanced yield tests (SOYTs) as three replicate RCBD tests grown at 5-6 locations, depending on the trial (KCRF, Goodale, Melfort and Codette, SK, Brandon and Roblin, MB, Lacombe AB). Lines are evaluated as in the PBYTs, except total dietary fibre (TDF) using wet chemistry, barley yellow dwarf virus (BYDV) is evaluated in Champaign, Illinois, adult plant resistance (APR) to crown rust is evaluated in St. Paul, MN and stem rust resistance is screened in Morden, MB.

Selected lines are then advanced for two years of testing in the Western Cooperative Oat Registration Trial grown at 15 sites across Western Canada in three replication RCBD tests. If deemed to have merit by the Prairie Recommending Committee on Oats and Barley (PRCOB), lines are then registered and tendered for sale to producers in Canada.

Germplasm Exchange

The CDC oat breeding program conducts extensive germplasm exchanges with oat breeding programs within Canada and around the world in order to access new genetics that can be incorporated into future varieties targeted for Western Canada. Exchanges currently exist with:

Dr. K. Nilsen (AAFC-Brandon Research and Development Centre, Brandon, MB)
Dr. W. Yan (AAFC-Ottawa Research and Development Centre, Ottawa, ON)
Dr. C. Azar (La Coop fédérée, St-Hyacinthe, QC)
Dr. M. McMullen (North Dakota State University, Fargo, ND)
Dr. F. Kolb (University of Illinois, Champaign, IL)
Dr. S. Harrison (Louisiana State University, Baton Rouge, LA)
Dr. A. Ceplitis (Lantmannen, Sweden)
Dr. P. Richter (General Mills)

Molecular Marker-Assisted Selection (MMAS)and Genomic Selection (GS)

Molecular marker-assisted selection (MMAS) is an essential part of the CDC breeding program and is conducted on the F5 space-planted generation and lines at the F6 single seed descent generations. MMAS is conducted using the Taq-Man (ABI) marker system in combination with the ABI StepOnePlus™ Real-Time (RT)-PCR machine. MMAS is conducted for the Pc45, Pc91, Pc94 and APR crown rust resistance genes and the low acid detergent lignin trait.

Genomic selection (GS) is conducted on a small number of populations (2 or 3) using predictions models created using training populations that contain CDC and other oat germplasm relevant to Western Canada and data collected from Western Canadian trials. Selection will be based on predicted phenotypes for most traits measured in the SOYT stage of the breeding program.

Nutritional Quality Evaluation

For nutritional quality evaluation, clean whole grain oat samples are analyzed using either an Infratec 1241 Grain Analyser or Infratec Nova (Foss North America, Eden Prairie, MN) to predict grain quality traits such as groat, oil, protein, and hull lignin content. Dehulling oat grain for chemical analysis and determination of groat percentage is accomplished using a Codema Laboratory Oat Huller (Codema, LLC, Maple Grove, MN) on a 50g sample of oat grain. Post-dehulling, whole oat groat samples are analyzed with the NIRS DS2500 Analyser (Foss North America, Eden Prairie, MN) to predict beta-glucan content. Grain quality predictions are developed and monitored/validated in-house using the Foss calibration development software WinISI (version 4.6) and ODIN (version 4.42) application model maker (for use with the Infratec 1241).

Oat samples are prepared for chemical laboratory analysis by grinding 20 g of groats to pass through 0.5 mm screen using a Retsch ZM 200 Ultra Centrifugal Laboratory Mill (ATS Scientific Inc, Burlington, ON). The resulting wholemeal samples are then analyzed for Total Dietary Fibre (TDF), oil, protein and beta-glucan. TDF percentage is measured on samples using Ankom's Automated Dietary Fiber Analyzer (Ankom Technology, Macedon, NY) in accordance to AOAC method 991.43. Oil percentage is quantified by the official method AOCS Am 5-04 using hexane as the solvent in the automated Ankom's XT15 Fat Extractor (Ankom Technology, Macedon, NY). Protein percentage is determined using the AACC 46-30.01 combustion method (%Nx6.25), using a Leco FP-628 Nitrogen Analyzer (Leco Corporation, St. Joseph, MI). Beta-glucan is obtained by extracting samples in a dilute acid with the supernatant being loaded into Thermo Fisher Scientific's Gallery Discrete Photometric Analyzer for quantification using beta-glucan (high MW) test kits purchased also from Thermo Fisher Scientific (Thermo Fisher Scientific, Mississauga, ON).

8. **Results and discussion:** *Describe research accomplishments during the reporting period under relevant objectives listed under section 6. The results need to be accompanied with tables, graphs and/or other illustrations. Provide discussion necessary to the full understanding of the results. Where applicable, results should be discussed in the context of existing knowledge and relevant literature. Detail any major concerns or project setbacks.*

<u>2.1 Crossing and Early Generations</u>

A total of 60 new crosses were made in the greenhouse during the 2020 winter, summer and fall crossing blocks. Sub-categories of crosses included introductions, crown rust resistance, adult plant crown rust resistance, leaf blotch resistance, high β-glucan content, high protein content, yield, hairless groat, and general. The F1 generation from the winter and summer crossing blocks were sent to the winter nursery in Leeston, New Zealand (Southern Seed Technology, Ltd.) for seed increase over the winter of 2020-21. The F1 generation from the fall crossing block wasincreased in the greenhouse during the winter of 2020-21.

Thirty-two F2 generation populations were grown as bulk plots in Saskatoon during the summer of 2020. F3 seed harvested from these plots were subsequently sent to our New Zealand winter nursery for generation advancement over the winter of 2020-21. Thirty F3 generation populations were grown as bulk plots in Saskatoon during the summer of 2020. F4 seed harvested from these plots were subsequently sent to our New Zealand winter nursery for generation advancement over the winter of 2020-21.Forty-seven F4 generation populations were grown as bulk plots in Saskatoon during the summer of 2020. F5 seed harvested from these plots were subsequently sent to our New Zealand winter nursery for generation advancement over the winter of 2020-21.

Thirty-two F5 and 38 F6 space-planted populations were grown in Saskatoon in the summer of 2020 with 300-400 single plant selections from each population harvested and further culled based on physical seed quality and/or molecular markers to 150-200 lines per population.

Forty-nine F6 hill and F6 single-seed descent (SSD) hill populations were grown in Saskatoon in the summer of 2020. Approximately 50% of hills were culled in the field with a further 50% culled after threshing of field selected hills based on physical seed quality and NIT-based prediction of hull, total fat and protein content.

Fifty-two F7 hill and F7 SSD hill populations were grown in Saskatoon in the summer of 2020. Approximately 50% of hills were culled in the field with a further 50% culled after threshing of field selected hills based on physical seed quality and NIT-based prediction of hull, total fat and protein content.

<u>2.2 Winter Nursery Increases</u>

Over the winter of 2020-21 the following populations were grown for seed increase at the winter nursery located in Irwell, New Zealand (Southern Seed Technology, Pty.):

38 F1 row populations derived from 2020 crosses.

33 F3 bulk increase populations derived from 2019 crosses.
29 F4 bulk increase populations derived from 2019 crosses.
55 F5 bulk increase populations derived from 2018 crosses.

2.3 Advanced Generations

2.3.1 Preliminary Oat MicroPlots (POMP)

A total of 1,719 lines were evaluated at the POMP stage as un-replicated plots in Saskatoon in the summer of 2020 with 50% culling in the field and a further 50% culling based on chemical and/or physical grain quality. Field selection was based on maturity, height, lodging resistance, leaf diseases (if present) and overall appearance. Chemical quality traits evaluated included, fatty acid profile, protein content, oil content and beta-glucan content, depending on the population. Physical grain quality assessed included hull percentage, test weight, plumpness and seed weight. Lines were subjected to appropriate disease evaluation (crown rust at Guelph, ON). 449 lines were advanced to the 2021 Preliminary Oat Yield Trials (POYT).

2.3.2 Preliminary Oat Yield Trials (POYT)

423 lines were tested at the POYT stage in two replication tests grown at the Kernen Crop Research Farm (KCRF), the Goodale Research Farm and Clavet. No selection was done in the field. Lines were evaluated for yield along with the chemical and physical grain quality characteristics mentioned for the POMP. Lines were subjected to appropriate disease evaluation (crown rust at Guelph, ON and Saskatoon; oat smut at University of Minnesota). Ninety (90) lines were advanced to the 2021 Standard Oat Yield (SOYT) and ENCORE Trials.

2.3.3 Standard Oat Yield (SOYT) and ENCORE Trials

Seventy-five (75) lines were tested at the SOYT/ENCORE stage in two or three replicate tests grown at 5-6 locations, depending on the trial (Codette, Goodale, KCRF, SK; Lacombe, AB; Brandon, Portage-la-Prairie, Ft. Whyte, Roblin, MB; and Ottawa, ON). Lines were evaluated as in the POYTs. Lines were subjected to appropriate disease evaluation (crown rust in Ontario, Saskatoon, AAFC-Morden and the University of Minnesota; oat smut at the University of Minnesota; stem rust at AAFC-Morden and Ft. Whyte, FHB at AAFC-Morden, BYDV at the University of Illinois).

Three milling lines were advanced to the 2021 Western Co-operative Oat Registration test (WCORT) (Table 1). General characteristics of the lines are as follows:

OT3118: R CRR, S SRR, S BYDV, R Smut, Yld=Arborg, shrt, Ltr, strgr, lower TWT, >TKW, >PLP, <Thins, moderate tertiaries, Grt%≤Summit, BG=Camden, Fat=Summit, Prot>Summit
OT3119: R CRR, I SRR, S BYDV, R Smut, Yld≤Arborg, Shrtr, Ltr, strgr, >TWT, >TKW, >PLP, <Thins, <er tertiaries, Grt%≤Summit, BG=Summit, Fat=Summit, Prot=Summit
OT3120: S CRR, MS SRR, I BYDV, R Smut, YLD<Arborg, ok HT, Ltr, strgr, >TWT, >TKW, ok PLP, <Thins, moderate tertiaries, Grt%<Summit, BG=Camden, Fat=Morrison, Prot<Summit

Table 1. Summary of lines being advanced to the 2021 WCORT.

2021 Coop#	CDC#	Pedigree	Type	2020 SOYT#
OT3118	SA181287	OT3068/CDC Arborg//09P09-BV	milling	2020 SOYT#1-9
OT3119	SA182041	OT3076/OT3090	milling	2020 SOYT#1-13
OT3120	SA180245	OT3071/SD090780	milling	2020 SOYT#1-17

2.4 Cooperative Testing

OT3112 wasproposed for, and received, support for registration at the 2021 PGDC meeting. **OT3114**, **OT3115**and **OT3116** were advanced for a 2nd year of testing in the 2021 WCORT. All other CDC oat lines were dropped from further testing in the WCORT.

2.5 Breeder Seed Production

2.5.1 Advanced Bulk Increases

0.02 acre plots of 2020 WCORT first year (**OT3114**-**OT3117**) and second year (**OT3112** and **OT3113**) entries were grown. Approximately 250 heads were taken fromthe first year entries for potential Breeder Seed purification. Those for **OT3114**, **OT3115**and **OT3116**were threshed and will be used to plant 2021 breeder hills. The others were discarded.

2.5.2 Breeder Hills

Breeder hills are the initial stage of Breeder Seed purification produced for 2nd year cooperative testing lines. In 2020 breeder hills were produced for **OT3112** and **OT3113**. Those for **OT3113** were discarded as this line was not moved forward with registration.

2.5.3 Breeder Long Rows

Breeder long rows are the second stage of Breeder Seed purification produced for lines supported for registration that year.

No breeder long rows were grown in 2020.

2.5.4 Breeder Seed and Special Increases

0.75 acre Breeder Seed plots of **CDC Haymaker**, **CDC Endure** and **CDC Minstrel** were grown at KCRF to increase seed stock of this variety.

0.3 acre special increases were grown for no varieties.

2.6 Plant Breeders Rights (PBR) Trials

CDC Endure was granted PBR onDecember 29, 2020 (#6340).

CDC Skye was granted PBR on March 19, 2021 (#6402).

2.7 Variety Registration

No varieties wereofficially registered with CFIA in 2020.

2.8 Miscellaneous Trials

The oat tests listed in Table 2 were planted in 2020 as part of collaborative exchanges or cooperative testing. These tests continue to be a valuable resource for identifying and evaluating oat germplasm that can be used in the CDC crossing block as parents to diversity and improve the genetic base of the CDC oat breeding program. Five lines grown in these collaborative tests were used in the 2020 crossing block as parents to incorporate traits such as crown rust resistance, beta-glucan and agronomic traits.

Table 2. Collaborative or exchange test grown by the CDC in 2020.				
Test	**Coordinating Organization**	**Entries**	**Reps**	**Sites**
WCORT	AAFC-Brandon (Kirby Nilsen)	30	3	1
UMOPN	University of Minnesota (Kianian)	36	3	1
UEOPN	University of Minnesota (Kianian)	24	3	1
ENCORE	AAFC-Ottawa (Yan)	180	2	1
SW Oat	Lantmannen (Ceplitis)	208	1	1
Canterra Oat	Canterra (Badea)	13	3	1
20-ES3301-SKT	Coop Federee (Azar)	30	3	1
Quaker Area Trial	PepsiCo (Beattie)	20	3	1
SACGC-Oat	CDC/Sask. Ag. and Food (Japp)	8	3	1
QION	PepsiCo (Harrison)	73	1	1

2.9 Disease Nurseries

2,672 lines were evaluated at nurseries coordinated by the University of Saskatchewan (Saskatoon; Dr. Randy Kutcher) for crown rust (251 lines), University of Guelph (Guelph, ON; Dr. Duane Falk) for crown rust (1,073 lines), AAFC-Morden for crown rust, stem rust, smut and FHB (Morden, MB; Drs. Tom Fetch, Jim Menzies and Xiben Wang) (300 lines), University of Minnesota (Minneapolis, MN; Dr. Shahryar Kianian) for crown rust (90 lines), University of Minnesota (Minneapolis, MN; Dr. Ruth Dill-Macky) for smut (513 lines), Murphy et al. (Ft. Whyte, MB; Keith Murphy) for crown rust and stem rust (150 lines) and University of Illinois (Urbana, IL; Dr. Fred Kolb) for BYDV (324 lines). This information was obtained on lines entered in the WCORT, as well as, the SOYTs, POYTs and POMPs. This data was extremely valuable when making selection decisions.

2.10 Molecular Marker-Assisted Selection (MMAS)

A total of 53,394 marker data points was obtained on CDC oat lines harvested from the F5 and F6 space-planted generations, and lines at the F6 and F7 SSD generations. This work was completed in the Crop Molecular Genetics Lab (Peter Eckstein) at the University of Saskatchewan. Molecular marker-assisted selection (MMAS) was conducted using the Taq-Man® (ABI) marker system in combination with the ABI StepOnePlus™ Real-Time (RT)-PCR machine. MMAS was conducted for the *Pc91* crown rust resistance gene, the *Pc94* crown rust resistance gene, the *PcKM* (*Pc45*) crown rust resistance gene, APR (from MN841801) crown rust resistance and the low acid detergent lignin trait.

2.11 Quality Lab

The Grain Quality Lab completed 20,645 analyses over the 2020-21 screening year. Table 3 lists the number of lines tested for each trait at each stage in the breeding program. We continue to develop Near Infrared Reflectance Spectroscopy (NIR) and Near Infrared Transmittance Spectroscopy (NIT) calibration curves predictive of quality traits. These tools can allow us to screen more samples at earlier generations, thus providing us with other selection criteria on which to discard poor lines. To improve the correlation between predicted and actual values, all lines on which wet chemistry analysis is done are also scanned with the NIR (Foss NIRSystem DS2500) and NIT (Foss Infratec 1241 Grain Analyser and Foss NOVA). These data points are added to the database and the prediction is recalibrated. We currently have very good NIT calibration curves for protein, total oil and groat percentage which are used to cull lines at the hill plot and advanced generation stages of the program. We are currently building calibrations curves for beta-glucan.

Good progress is being made as a result of these screening efforts. Of lines entering the 2021 WCORT, two lines show groat percentage similar to, or better than, Summit (**OT3118** and **OT3119**) while two lines (**OT3118** and

Growing Forward 2
A federal-provincial-territorial initiative
Government of Saskatchewan
Ministry of Agriculture
Canada

OT3120) contain beta-glucan equal to or greater than CS Camden. Additionally, two lines show protein content similar to or better than Summit (**OT3118** and **OT3119**) and one lines (**OT3120,**) contain total fat at the low levels shown by CDC Morrison.

Table 3. Summary of analyses conducted at the CDC Grain Quality lab in 2020-21.

Oat Field Trial	NIT	NIR	BG	TDF	Moisture	Protein	Oil	ADL	Totals
Validation	18	18	18	18	18	18	18	18	162
SOYT/ENCORE	272	-	272	272	252	168	204	20	1,628
Exchange Trials	541	-	541	541	-	-	-	-	1,623
POYT	744	-	744	744	-	-	-	-	2,432
POMP	1,310	-	-	600	-	-	-	-	1,910
Misc. MP Trials	360	-	-	360	-	-	-	-	720
Misc. Yield Trials	24	-	-	-	-	-	-	-	24
F6 Hill Trials	4,091	-	1,636	-	-	-	-	-	5,727
F7 Hill Trials	4,339	-	1,736	-	-	-	-	-	6,075
Misc. Hill Trials	246	-	98	-	-	-	-	-	344
Totals:	**11,945**	**18**	**5,045**	**2,535**	**270**	**186**	**222**	**38**	**20,645**

ADL=acid detergent lignin content of hulls (wet chemical analysis)
BG=beta-glucan (Gallery Analyzer)
Moisture: measurement of groat moisture to assist with NIR calibration.
Oil= Ankom analysis
Protein=LECO analysis
NIR=near infrared reflectance spectroscopy; building calibration curve to estimate BG.
NIT=near infrared transmittance spectroscopy; estimation of total oil, protein, hull percentage.
TDF: total dietary fiber (Ankom TDF Analyzer)

9. Interim conclusions(If any).

OT3112 was supported for registration at the 2021 PGDC meeting and marketing rights were provided to FP genetics. The line shows crown rust resistance, moderate resistance to smut, moderate susceptibility to stem rust, yield potential similar to CS Camden, very short and strong straw, moderate maturity, ok test weight, excellent kernel weight, plumps and low thins, a groat percentage equal to Summit, beta-glucan similar to CDC Morrison, protein less than Summit and fat similar to Summit.

10. Listany technology transfer activities undertaken in relation to this project: *Include conference presentations, talks, papers published etc.*

Field Tours:

Richardson Milling Field Tour (Kelburn Farm, MB, July, 28, 2020).

Presentations:

A.D. Beattie, 2020. Canadian Oat Quality. Prairie Oat Growers Association Presentation to Japanese Oat Industry, Webinar, February 24, 2021.

A.D. Beattie, 2020. CDC Forage Barley and Oat Breeding: How it all Works. Saskatchewan Ministry of Agriculture Regional Services Branch, Saskatoon, SK, December 11, 2020

Media:

Oat Breeding Video, Parkland Crop Diversification Centre, January 19, 2021. https://www.youtube.com/watch?v=Hef5Z6MSvSI&t=5s

Germination Magazine, July 2, 2020, "3 Cool Things About a New Oat Breakthrough."
https://germination.ca/3-cool-things-about-a-new-oat-breakthrough/

11. Identify any changes expected to industry contributions, in-kind support, collaborations or other resources.

None.

12. Appendices: *Include any additional materials supporting the previous sections, e.g. detailed data tables, maps, graphs, specifications, literature cited, acknowledgments.*

See Supplementary File 1 (.xlsx) which contains excerpts of 2020WCORT data related to **OT3112**.