1. **Project title and reporting period.**

   Breeding milling oat varieties with improved agronomic, quality and disease traits for Saskatchewan oat producers
   20180260
   April 1, 2019 – June 30, 2024

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

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

   None.

4. **Abstract/Summary:** *An outline of overall project objectives, methods, key findings and conclusions for use in publications and in the Ministry database (Maximum of 500 words or one page in lay language).*

   Oat is considered a healthy cereal due to a number of nutritional compounds found within the grain. These include beta-glucan, a soluble fiber that has been shown to reduce the risk of heart disease, polyphenolic avenanthramides which have anti-inflammatory effects that may protect against coronary heart disease, and a protein profile that provides a better balance of essential amino acids than other cereals and which can be consumed by most people suffering from celiac disease. As a result of these desirable attributes, oat remains a significant Canadian crop that has been seeded on an average of 3.6 million acres over the past five years. The direct impact of the oat industry on the Canadian economy amounted to $1.4 billion and 7,000 jobs annually since 2018, with an indirect impact of $4.2 billion. Oat varieties are an important foundation of the Canadian oat industry and developing improved varieties will help support the continued growth of the industry. To this end, there were three main goals of this project, including: 1) breed improved milling oat varieties, 2) evaluate and improve the nutritional quality of oat varieties and, 3) produce 'hairless' oat germplasm than can be incorporated into future varieties.

   Each year an average of 53 crosses were made to create 214 early generation populations that were advanced through the program, 2,495 advanced lines were evaluated, 4,728 lines were screened for crown rust, stem rust, smut and FHB, and 42,740 molecular-marker data points were obtained for genes related to crown rust resistance. Nutritional quality information related to beta-glucan, total dietary fiber, protein and fat was obtained on an average of 10,861 lines. Finally, a total of six crosses were made with the hairless groat variety VAO-51 in order to incorporate this trait into elite breeding lines adapted to western Canada. These populations are currently advancing through the breeding program and visual selection of hairless groat lines will begin in the fall of 2024.

   A total of 24 lines were advanced into the western cooperative oat registration trial (WCORT) over the course of this project. Among these lines, 13 lines (OT3110, OT3112, OT3113, OT3116, OT3117, OT3118, OT3119, OT3121, OT3123, OT3124, OT3126, OT3130 and OT3132) showed groat percentage similar to, or better than, the WCORT

check variety Summit, while 17 lines (OT3111, OT3112, OT3113, OT3114, OT3116, OT3117, OT3118, OT3120, OT3121, OT3122, OT3124, OT3126, OT3128, OT3129, OT3131, OT3132, and OT3133) contained beta-glucan equal to or greater than the WCORT check variety CS Camden. Additionally, 14 lines (OT3112, OT3113, OT3114, OT3115, OT3118, OT3119, OT3121, OT3125, OT3126, OT3127, OT3129, OT3130, OT3131 and OT3133) showed protein content similar to, or better than, Summit and 12 lines (OT3110, OT3113, OT3114, OT3115, OT3117, OT3120, OT3122, OT3126, OT3127, OT3128, OT3129 and OT3131) contained total fat at the low levels shown by the WCORT check variety AC Morgan.

The most significant accomplishments of the project were the registration of two new milling oat varieties. CDC Anson has very good crown rust resistance, strong yield potential similar to CS Camden, very short and strong straw, moderate maturity, excellent kernel weight and plumps, low thins, a groat percentage equal to Summit, beta-glucan similar to CDC Morrison, protein less than Summit and fat similar to Summit. CDC Byer also has very good crown rust resistance, yield potential better than CS Camden, short and strong straw, moderate maturity, excellent plumps and low thins, a groat percentage better than CS Camden, beta-glucan higher than CS Camden, protein equal to Summit and fat similar to AC Morgan. Overall, both varieties should provide the milling industry a significant improvement over current varieties.

5. Key Messages: *Key outcomes and/or extension messages and their importance for producers/industry (3-5 bullet points <u>in lay language</u>)*

- Two new milling oat varieties, CDC Anson and CDC Byer, were bred and registered through this project. These varieties variety should be good replacements for growers currently using Summit or CS Camden, and they should be in strong demand by millers and food companies due to their combination of high groat percentage, plumps and beta-glucan content,
- The significant number of breeding lines assessed for important quality attributes has resulted in significant progress with 71% of CDC lines entering the western Canadian oat registration trials (WCORT) containing beta-glucan content equal to or better than the best check, while 58% and 50% have protein and fat content, respectively, equal to or better than the best checks. This should provide increased value to end-users when some of these lines are released as future varieties,
- Crosses were made during the course of this project using the VAO-51 donor line to incorporate the hairless (i.e. low trichome) groat trait into the CDC breeding program. The value of this trait to growers and millers will be assessed when good performing lines are produced in suitable volumes in future years.

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

Oat is considered a healthy cereal due to 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 Canada, the European Union and the United States. Oat grain also contains several 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, providing a better balance of essential amino acids. Although soy, pea and wheat protein are commonly used for plant-based protein products, oat is increasingly considered a viable protein alternative. This is not only due to the nutritional benefits of oat, but also because it is able to be consumed by most people suffering from celiac disease and is thus considered to be gluten-free. This has supported the growth of gluten-free products developed from companies such as MGM Seeds (Saskatoon) and Avena Foods (Regina).

As a result of these desirable attributes, oat remains a significant western Canadian crop that has been seeded on an average of 3.6 million acres since 2018. Due to the low input costs and competitive nature of oat it has also

become the second most widely grown organic crop in Canada at 280,000 acres, only behind wheat at 360,000 acres. Over the past five years, 50% of the 3.9 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 1,225,000 MT, with western Canada being home to Richardson Milling, Grain Millers, Patterson Global Foods, Ardent Mills, Canadian Oats Milling, Emerson Milling, MGM Seeds and Avena Foods, or about 90% of milling production. The direct impact of the oat industry on the Canadian economy amounted to $1.4 billion and 7,000 jobs annually since 2018, with an indirect impact of $4.2 billion.

Western Canada currently holds a strong position in supplying the North American oat market due to the continued decline in U.S. oat acres, down to 2.5 million acres in 2023, and our proximity to the main US oat distribution hub in Minneapolis, MN. Raw oat exports have increased from 1.64 million MT in 2016 to 1.79 million MT in 2020, with the US accounting for 85% of the market. Similarly, the US accounts for 85% of the 518,000 MT of oat products exported from Canada in 2020, up from 419,000 MT in 2016. In addition to the long-term, stable U.S. export market, three other markets hold promise to increase demand for Canadian oat. Firstly, Mexico has been the second largest importer of Canadian oat since 2016 (6% of total exports) and in 2020/21 imported a record 170,000 MT. The strong ties of Mexico to Canadian oat production, due in part to the marketing efforts by the Prairie Oat Growers Association (POGA) and ownership of Canadian Oat Milling (Namo, Alberta) by Grupo Vida bode well for Canadian producers. Secondly, POGA is working to gain market access to China for Canadian oat. Imports of oat to China increased from 3,000 T in 2001 to a high of 500,000 T in 2017, and in 2020/21 sat at 320,000 MT. Most of China's imports are sourced from Australia and the market is worth about $100M. 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 western 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 grower's 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 project is part of our effort to build on past oat variety successes through continued focus on improving agronomics, milling and nutritional quality, and disease resistance. Additionally, we expanded 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.

7. 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) Produce improved milling oat varieties	A total of 263 crosses were created to generate 1,068 early generation milling oat populations and 12,475 advanced milling oat lines were grown and evaluated from 2019-23 for agronomic performance and reaction to various diseases. Physical grain quality traits were also evaluated. **CDC Anson** (**OT3112**) was registered with CFIA in 2022 and **CDC Byer** (**OT3115**) was registered with CFIA in 2023.
b) Nutritional quality evaluation	54,304 milling oat samples were collected from 2019-2023 field trials, ground, scanned by NIT/NIR, and evaluated for a combination of traits including beta-glucan, protein and fat. A total of 103,261 analyses were conducted, including 16,118 beta-glucan, 1,032 protein and 1,068 fat analyses. Of the 24 lines that were entered into the WCORT trials from 2019-2024, 17 lines contained beta-glucan equal to or greater than the WCORT check variety CS Camden. Fourteen lines showed protein content similar to the WCORT check variety Summit and 12 lines contained total fat at the low levels shown by the WCORT check variety AC Morgan.
c) Produce 'hairless' groat milling oat lines	Six crosses were made from 2019-23 with the hulless, hairless groat variety VAO-51 in order to incorporate this trait into elite breeding lines adapted to western Canada. These populations are currently at the preliminary yield trial generation. Hand dehulling is required to prevent breakage of groat trichomes, so selection of reduced groat hair lines will commence at advanced generations when there are fewer lines to assess and after they have already been selected for easier to measure traits.

8. Methodology: *Specify project activities undertaken during entire project period. Include approaches, experimental design, tests, materials, sites, etc.*

Breeding Objectives and Targets

Objectives and targets related to agronomics, physical grain quality, nutritional grain quality and disease resistance desired in future oat varieties were 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

Forty to sixty bi-parental or three-way crosses were made in the greenhouse (University of Saskatchewan). Parental lines were 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 were used to introduce this trait into elite breeding germplasm. Selection for the trait was based on visual examination of the grain.

Progeny populations were advanced from the F1-F5 generations using a bulk breeding strategy in combination with single seed descent. Bulk populations were 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 (400) from each population were selected in the field based on maturity, height and disease (if present) and further selected based on physical seed quality and/or molecular markers.

F6 hill populations were 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) were grown in a modified augmented design in Saskatoon with 50% culling in the field and a further 50% culling based on nutritional and physical grain quality. Field selection was based on maturity, height, lodging resistance, leaf diseases (if present) and overall appearance. Nutritional quality traits (i.e. protein, fat) were evaluated using NIT predictions while beta-glucan was evaluated using wet chemistry. Physical grain quality assessed included test weight, plumpness/thins, thousand kernel weight, and groat percentage. Lines were subjected to crown rust evaluation in Guelph, ON.

Selected F8 lines were 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 or Clavet Research Farm. No selection was done in the field. Lines were evaluated for yield along with the nutritional and physical grain quality characteristics mentioned for the MPs. All lines were subjected to crown rust evaluation in Guelph, ON and smut evaluation in St. Paul Minnesota.

Advanced F9 lines were 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 were evaluated as in the PBYTs, except total dietary fibre (TDF) was also evaluated using wet chemistry, barley yellow dwarf virus (BYDV) was evaluated in Champaign, Illinois, adult plant resistance (APR) to crown rust was evaluated in St. Paul, MN and stem rust resistance was screened in Morden, MB.

Selected lines were then advanced for two years of testing in the Western Cooperative Oat Registration Trial (WCORT) 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 were then registered and tendered for sale to producers in Canada.

Germplasm Exchange

The CDC oat breeding program conducted 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 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. V. Chabot (Sollio, St-Hyacinthe, QC)
Dr. S. Harrison (Louisiana State University, Baton Rouge, LA)
Dr. A. Ceplitis (Lantmannen, Sweden)
Dr. P. Richter (General Mills)

Molecular Marker-Assisted Selection (MMAS)

Molecular marker-assisted selection (MMAS) was conducted on the F5 and F6 space-planted generation and lines at the F6 and F7 single seed descent generations. 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 *Pc45*, *Pc91*, *Pc94*, *PcAS* and APR crown rust resistance genes, the leaf blotch resistance gene (AVLB651) and the low acid detergent lignin trait.

Nutritional Quality Evaluation

For nutritional quality evaluation, clean whole grain oat samples were 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 was 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 were analyzed with the NIRS DS2500 Analyser (Foss North America, Eden Prairie, MN) to predict beta-glucan content. Grain quality predictions were 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 were prepared for chemical laboratory analysis by grinding 20 g of groats to pass through a 0.5 mm screen using a Retsch ZM 200 Ultra Centrifugal Laboratory Mill (ATS Scientific Inc, Burlington, ON). The resulting wholemeal samples were then analyzed for Total Dietary Fibre (TDF), oil, protein and beta-glucan. TDF percentage was measured on samples using the Ankom Automated Dietary Fiber Analyzer (Ankom Technology, Macedon, NY)

in accordance to AOAC method 991.43. Oil percentage was quantified by the official method AOCS Am 5-04 using hexane as the solvent in the automated Ankom XT15 Fat Extractor (Ankom Technology, Macedon, NY). Protein percentage was 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 was 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).

9. Results and discussion: *Describe research accomplishments during the entire project period under each objective 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.*

OBJECTIVE 1

Crossing and Early Generations

A total of 263 new crosses were made in the greenhouse during the 2019-23 winter, summer and fall crossing blocks. Sub-categories of crosses included introductions, crown rust resistance, adult plant crown rust resistance, leaf blotch resistance, stem rust resistance, high beta-glucan content, high protein content, reduced tertiaries, yield, hairless groat, and general.

Two hundred and sixteen (216) F2 generation populations, 94 F3 generation populations and 207 F4 generation populations were grown as bulk plots in Saskatoon during the summers of 2019-23.

One hundred and twenty-two (122) F5 and 212 F6 space-planted populations were grown in Saskatoon in the summers of 2019-23.

One hundred and sixty-seven (167) F6 hill and F6 single-seed descent (SSD) hill populations were grown in Saskatoon in the summers of 2019-23.

Two hundred and sixty-two (262) F7 hill and F7 SSD hill populations were grown in Saskatoon in the summers of 2019-23.

Winter Nursery Increases

Over the winters of 2019-24 the following populations were grown for seed increase at the winter nursery:

97 F1 row populations.
51 F2 bulk increase populations.
226 F3 bulk increase populations.
93 F4 bulk increase populations.
221 F5 bulk increase populations.

Advanced Generations

Preliminary Oat MicroPlots (POMP)

A total of 9,625 lines were evaluated at the POMP stage as un-replicated plots in Saskatoon in the summers of 2019-23.

Preliminary Oat Yield Trials (POYT)

2,421 lines were tested at the POYT stage in two replication tests grown at the Kernen Crop Research Farm (KCRF), the Goodale Research Farm and either Melfort or Codette, SK in the summers of 2019-23.

Standard Oat Yield (SOYT) and ENCORE Trials

Four hundred and twenty-nine (429) lines were tested at the SOYT/ENCORE stage in two or three replicate tests grown at 5-6 locations (Codette, Goodale, KCRF, SK; Lacombe, AB; Brandon, Portage-la-Prairie, Ft. Whyte, Roblin, MB; and Ottawa, ON) in the summers of 2019-23.

Twenty-four milling lines were advanced to the Western Co-operative Oat Registration test (WCORT) from 2019-24 (Table 1). General characteristics of the lines were as follows:

OT3110: R CRR, R Smut, Yld>Arborg, Tlr, Ltr, weaker, G Grain, <Thins, Grt%=Summit, BG<Summit, Fat=Dancer, Prot<Summit
OT3111: S CRR, S Smut, Yld>Arborg, Tlr, Erlr, ok Lodging, G Grain, <Thins, Grt%=Summit, BG=Camden, Fat<Summit, Prot<Summit
OT3112: Pc94 CRR, I Smut, Yld<Arborg, VS, erlr, strong, lower TWT, good Grain otherwise, Grt%>Summit, BG>Camden, Fat<Summit, Prot=Summit
OT3113: Pc94 CRR, R Smut, Yld<Arborg, S, Erlr, strong, lower TWT, good Grain otherwise, Grt%<Summit, BG=Camden, Fat=Dancer, Prot=Summit
OT3114: R CRR, I SRR, MR BYDV, S Smut, Yld≥Arborg, ok HT, ok Mat, stronger, lower TWT, good grain otherwise, moderate tertiaries, Grt%<Summit, BG>Camden, Fat=Dancer, Prot=Summit
OT3115: MR CRR, S SRR, R Smut, Yld>Arborg, Shrtr, ok Mat, stronger, good grain, moderate tertiaries, Grt%<Summit, BG=Summit, Fat=Dancer, Prot=Summit
OT3116: MS CRR, I SRR, I Smut, Yld=Arborg, ok HT, ok Mat, strong, good grain, moderate tertiaries, Grt%=Summit, BG=Camden, Fat<Summit, Prot<Summit
OT3117: MS CRR, I SRR, MR Smut, Yld<Arborg, ok HT, ok Mat, very strong, very good grain, higher tertiaries, Grt%=Summit, BG=Camden, Fat=Dancer, Prot<Summit
OT3118: R CRR, S SRR, S BYDV, R Smut, Yld=Arborg, shrt, Ltr, stronger, 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, stronger, >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, stronger, >TWT, >TKW, ok PLP, <Thins, moderate tertiaries, Grt%<Summit, BG=Camden, Fat=Dancer, Prot<Summit
OT3121: I CRR, S SRR, R Smut, Yld>Arborg, Tlr, erlr, ok TWT, >TKW, ok PLP, >er Thins, Grt%=Summit, BG>Camden, Fat<Camden, Prot=Summit
OT3122: I CRR, S SRR, R Smut, Yld>Arborg, Tlr, ok Mat, stronger, ok TWT, >>TKW, ok PLP, ok Thins, Grt%<Summit, BG>Camden, Fat>Dancer, Prot<Summit
OT3123: Pc94 CRR, S SRR, R Smut, Yld=Arborg, Tlr, erlr, stronger, >TWT, <erTKW, ok PLP, <Thins, Grt%=Summit, BG>Summit, Fat>Summit, Prot<Summit
OT3124: Pc94 CRR, S SRR, R Smut, Yld>Arborg, g HT, ok Mat, ok TWT, >TKW, >PLP, <THINS, Grt%>Summit, BG=Camden, Fat>Dan, Prot<Summit
OT3125: MR CRR, I SRR, R Smut, >>YLD, shrtr, strg, ok Mat, >TWT, >>TKW, >>PLP, <<THINS, ok MY, Wht, BG=Sum, Fat<Leg, ok Prot
OT3126: I CRR, S SRR, R Smut, >YLD, Tlr, strg, erlr, >TWT, >>TKW, >>PLP, <<THINS, >erMY, Wht, BG>Leg, Fat=Dan, ok Prot
OT3127: I CRR, S SRR, S Smut, >>>YLD, Tlr, strgr, erlr, >TWT, >>TKW, >>PLP, <<THINS, ok MY, Wht, BG=Leg, Fat=Dan, ok Prot
OT3128: Pc94, MR-I SRR, R Smut, >YLD, shrt, strg, erlr, ok TWT, >TKW, >>PLP, <<THINS, ok MY, Wht, BG>Leg, Fat=Dan, <erProt
OT3129: I CRR, S SRR, S Smut, >>>YLD, ok HT, strg, erlr, ok TWT, >TKW, >PLP, ok THINS, <erMY, Wht, BG>Leg, Fat=Dan, >erProt

OT3130: MS CRR, S SRR, R Smut, YLD=Endure, Tlr, strgr, ok Mat, >erTWT, >TKW, >PLP, <THINS, >MY, Wht, BG<Endure, Fat=Endure, ok Prot
OT3131: MS CRR, S SRR, R Smut, YLD=Endure, shrtr, strgr, Ltr, >erTWT, ok TKW, >>PLP, <<THINS, ok MY, Wht, BG=Endure, Fat=Dan, >erProt
OT3132: S CRR, S SRR, S Smut, YLD>Endure, ok HT, strgr, ok Mat, >erTWT, >TKW, >>PLP, <THINS, >>MY, Wht, BG=Endure, Fat=Endure, <Prot
OT3133: Pc94, S SRR, R Smut, YLD=Endure, ok HT, strgr, ok Mat, <TWT, >>TKW, >>PLP, <<THINS, ok MY, Wht, BG=Endure, Fat=Sum, >erProt

Data collected on these lines from the 2019-23 WCORT are provided in Appendices A-E.

Table 1. Summary of lines advanced to the 2019-24 WCORT.

Coop#	CDC#	Pedigree
OT3110	SA160212	MN07104/CDC Ruffian
OT3111	SA161030	04G48-OA07/OT3073
OT3112 (CDC Anson)	SA162676	OT3068/CS Camden
OT3113	SA162689	OT3068/CS Camden
OT3114	SA170850	CDC Norseman/OT3071
OT3115 (CDC Byer)	SA172419	OT3073/OT3076
OT3116	SA172370	OT3071/OT3063
OT3117	SA172371	OT3071/OT3063
OT3118	SA181287	OT3068/CDC Arborg//09P09-BV
OT3119	SA182041	OT3076/OT3090
OT3120	SA180245	OT3071/SD090780
OT3121 (being registered)	SA191208	CDC Endure/CDC Arborg
OT3122	SA191217	CDC Endure/CDC Arborg
OT3123	SA191314	OT3076/SA130027
OT3124	SA191167	OT3076/SA110685
OT3125	SA200043	OT2119/OT3100
OT3126	SA200069	OT2119/OT3102
OT3127	SA200847	CDC Endure/CDC Arborg
OT3128	SA200898	CDC Endure/OT3098
OT3130	SA210204	SW140712/CDC Arborg
OT3131	SA210036	SW141022/CDC Endure
OT3132	SA210983	OT5003/CDC Endure
OT3133	SA210783	OT3104/OT3100

Plant Breeders Rights (PBR) Trials

CDC Anson (**OT3112**) received PBR from CFIA on November 28, 2023 (#6948).

CDC Byer (**OT3115**) completed first year PBR trials in 2023. The second and final year PBR trials will be conducted in 2024.

Variety Registration

CDC Anson (**OT3112**) was officially registered with CFIA on June 30, 2022 (#9652). Data collected on CDC Anson from the WCORT is provided in Appendix F.

CDC Byer (**OT3115**) was officially registered with CFIA on August 18, 2023 (#9969). Data collected on CDC Byer from the WCORT is provided in Appendix G.

Miscellaneous Trials

The oat tests listed in Table 2 were planted from 2019-23 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. Thirty-nine lines grown in these collaborative tests were used in the 2019-23 crossing blocks 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 from 2019-23.

Test	Coordinating Organization	Entries	Reps	Sites
WCORT	AAFC-Brandon (Nilsen)	170	3	1
UMOPN	University of Minnesota (Kianian)	172	3	1
UEOPN	University of Minnesota (Kianian)	119	3	1
ENCORE	AAFC-Ottawa (Yan)	1,044	2	1
SW Oat	Lantmannen (Ceplitis)	857	1	1
Canterra Oat	Canterra (Badea)	94	3	1
ES3301-SKT	Coop Federee (Chabot)	144	3	1
Quaker Area Trial	PepsiCo (Beattie)	100	3	1
SACGC-Oat	CDC/Sask. Ag. and Food (Kowalchuk)	58	3	1
QION	Louisiana State University (Harrison)	606	1	1

Disease Nurseries

A total of 23,638 lines were evaluated at the following disease nurseries: University of Saskatchewan (Saskatoon, SK; Dr. Randy Kutcher) for crown rust (2,746 lines) and stem rust (4,455), University of Guelph (Guelph, ON; Dr. Duane Falk) for crown rust (10,048 lines), AAFC-Morden (Morden, MB; Drs. Tom Fetch, Jim Menzies and Xiben Wang) for crown rust, stem rust, smut and FHB (1,094 lines), University of Minnesota (Minneapolis, MN; Dr. Shahryar Kianian) for crown rust (469 lines), University of Minnesota (Minneapolis, MN; Dr. Ruth Dill-Macky) for smut (2,572 lines), Murphy et al. (Ft. Whyte, MB; Keith Murphy) for crown rust and stem rust (942 lines) and University of Illinois (Urbana, IL; Dr. Juan Arbelaez) for BYDV (1,312 lines).

Molecular Marker-Assisted Selection (MMAS)

A total of 213,702 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.

OBJECTIVE 2

The Grain Quality Lab completed 103,261 analyses over the 2019-24 period. 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 the 24 lines entered into the WCORT from 2019-24, 13 lines (OT3110, OT3112, OT3113, OT3116, OT3117, OT3118, OT3119, OT3121, OT3123, OT3124, OT3126, OT3130 and OT3132) showed groat percentage similar to, or better than, the WCORT check variety Summit, while 17 lines (OT3111, OT3112, OT3113, OT3114, OT3116, OT3117, OT3118, OT3120, OT3121, OT3122, OT3124, OT3126, OT3128, OT3129, OT3131, OT3132, and OT3133) contained beta-glucan equal to or greater than the WCORT check variety CS Camden. Additionally, 14 lines (OT3112, OT3113, OT3114, OT3115, OT3118, OT3119, OT3121, OT3125, OT3126, OT3127, OT3129, OT3130, OT3131 and OT3133) showed protein content similar to, or better than, Summit and 12 lines (OT3110, OT3113, OT3114, OT3115, OT3117, OT3120, OT3122, OT3126, OT3127, OT3128, OT3129 and OT3131) contained total fat at the low levels shown by the WCORT check variety AC Morgan.

Table 3. Summary of analyses conducted at the CDC Grain Quality lab from 2019-24.

Oat Field Trial	NIT	NIR	BG	TDF	Moisture	Protein	Oil	ADL	Totals
Validation	99	84	84	84	84	84	84	84	721
SOYT/ENCORE	1,561	1,319	1,591	956	1,380	948	984	85	9,262
Exchange Trials	2,634	2,125	2,666	613	0	0	0	0	8,364
POYT	5,023	4,207	4,951	1,551	0	0	0	106	16,797
POMP	6,762	4,947	2,242	600	0	0	0	212	15,186
Misc. MP Trials	1,360	140	1,000	360	0	0	0	0	3,220
Misc. Yield Trials	280	0	96	0	9	0	0	18	463
F6 Hill Trials	13,356	1,739	1,636	0	0	0	0	0	18,470
F7 Hill Trials	21,754	2,894	1,736	0	0	0	0	0	28,689
Misc. Hill Trials	1,505	432	98	0	0	0	0	0	2,089
Totals:	54,304	17,887	16,118	4,164	1,473	1,032	1,068	505	103,261

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)

OBJECTIVE 3

The following crosses were made over the course of this project using the parent VAO-51 as the donor of the hairless (i.e. low trichome) groat trait. These populations have now reached the POYT generation of testing.

VAO-51 x SW130720
VAO-51 x OT3106
VAO-51 x SA161984
VAO-51 x AAC Douglas
VAO-51 x OA1655-2
VAO-51 x CDC Anson

Figure 1 shows the difference in groat trichome content between VAO-51 (Figure 1A) and typical oat lines (Figure 1B). Selection of groat trichome content will be done visually. To determine if visual evaluation could be done on mechanically threshed panicles, or if hand threshing is necessary to prevent excessive breakage of the groat trichomes, both methods were compared (Figure 1). Minimal breakage occurs, or at least not enough to make selection of low trichome groats difficult, with the normal mechanical threshing machinery used at the CDC (Figure 1B). We have now determined that hand-dehulling of oat grain is required to preserve the groat trichomes since mechanical dehulling using the Codema removes the trichomes. Assessing groat hairiness by hand dehulling is slow, especially if observing multiple groats per line is desired. As such, our strategy will be to assess groat hairiness once there are fewer lines (i.e. at the POYT generation) which have already been selected for other important traits.

A.

B.

Figure 1. Images of groats from the low trichome donor line VAO-51 (A) and typical oat lines, as represented by CDC Dancer (B). The top row of groats in (B) were threshed mechanically while the lower row of groats were threshed by hand.

10. Conclusions and Recommendations: *Highlight significant conclusions based on the findings of this project, with emphasis on the project objectives specified above. Provide recommendations for the application and adoption of the project findings.*

The significant number of breeding lines evaluated for agronomic, disease and quality traits over the course of this project has produced meaningful dividends. A high percentage of the lines entering the variety registration trials meet or exceeds the check varieties for many of the quality-related traits important to end-users. Specifically, 54% of the lines show groat percentage similar or better than the best WCORT check (Summit), 71% contain beta-glucan

content equal to or better than the best WCORT check (CS Camden), while 58% and 50% have protein or fat content, respectively, equal to the best WCORT check (Summit and AC Morgan, respectively).

The ultimate successful output from this work was the registration of **CDC Anson** (**OT3112**) with CFIA in 2022 and **CDC Byer** (**OT3115**) with CFIA in 2023. In both cases marketing rights were awarded to FP Genetics. CDC Anson has very good crown rust resistance, strong yield potential similar to CS Camden, very short and strong straw, moderate maturity, excellent kernel weight and plumps, low thins, a groat percentage equal to Summit, beta-glucan similar to CDC Morrison, protein less than Summit and fat similar to Summit. CDC Byer also has very good crown rust resistance, yield potential better than CS Camden, short and strong straw, moderate maturity, excellent plumps and low thins, a groat percentage better than CS Camden, beta-glucan higher than CS Camden, protein equal to Summit and fat similar to AC Morgan. Overall, both varieties should provide the milling industry a significant improvement over current varieties.

With respect to incorporation of the hairless (i.e. low trichome) groat trait into the breeding program, six crosses were made during the course of this project using the VAO-51 donor line. It was crossed with elite germplasm from the CDC, AAFC-Brandon, AAFC-Ottawa and Lantmannen, and populations have been advanced as far as the POYT generation. Visual selection for low trichome groat lines, which is time-consuming and laborious, will commence in 2024 on advanced generations in which there are fewer lines to assess. It will still be several years before advanced lines containing this trait will be available, but at that point evaluation of related characteristics like dehulling efficiency can be assessed.

11. Is there a need to conduct follow up research? *Detail any further research, development and/or communication needs arising from this project.*

The work outlined under this project will continue. Further improvements to the agronomic, disease and quality traits described in this project will be incorporated into future oat varieties. Crosses to incorporate the hairless groat trait will continue and in 2024 visual selection for lines showing groats with fewer trichomes will begin.

12. Patents/ IP generated/commercialized products: *List any products developed from this research.*

CDC Anson (**OT3112**) was registered with CFIA in 2022 and marketing rights were provided to FP Genetics. Breeder seed was produced in 2021 and provided to FP for Select Seed production in 2022.

CDC Byer (**OT3115**) was registered with CFIA in 2023 and marketing rights were provided to FP Genetics. Breeder seed was produced in 2022 and provided to FP for Select Seed production in 2023.

13. List technology transfer activities: *Include presentations to conferences, producer groups or articles published in science journals or other magazines.*

Field Tours:

1. Cerela Oat Field Tour (Saskatoon, SK, July 22, 2019).
2. PepsiCo Oat Tour (Saskatoon, SK, July 23, 2019).
3. CDC Oat Field Day (Saskatoon, SK, July 24, 2019).
4. FP Genetics Barley and Oat Field Tour (Saskatoon, SK, July 30, 2019).
5. Secan Barley and Oat Field Tour (Saskatoon, SK; August 6, 2019).
6. Richardson Milling Field Tour (Kelburn Farm, MB, July 28, 2020).
7. CDC Oat Industry Field Day (Saskatoon, SK, July 19, 2022).
8. CDC 50th Anniversary Field Tour (Saskatoon, SK, July 20, 2022).
9. Richardson Oat Field Tour (Winnipeg, MB, July 26, 2022).

10. MGM Seeds Oat Field Tour (Saskatoon, SK, July 12, 2023).
11. Grain Millers Oat Field Tour (Saskatoon, SK, July 19, 2023).
12. FP Genetics Oat Field Tour (Saskatoon, SK, July 19, 2023).
13. Richardson Oat Field Tour (Kelburn, MB, July 26, 2023).
14. FP Genetics Oat Field Tour (Carmen, MB, July 27, 2023).

Presentations:

1. A.D. Beattie, 2020. CDC Oat Varieties: What's New, On Its Way and Good for Alberta Producers. Alberta Oat Growers Association's Annual General Meeting, Edmonton, AB, January 27, 2020.

2. 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

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

4. A.D. Beattie, 2022. CDC Varieties: What's New, in the Pipeline and Good for Producers. 11th Annual Dairy Info Day, Warman, SK, February 24, 2022.

5. A.D. Beattie, 2022. Update on CDC Oat Breeding and Research Activities, Prairie Oat Growers Association AGM, Saskatoon, SK, November 29, 2022.

Media:

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

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

3. Oat Scoop, Pam Yule, November 2022, pp. 3 "CDC Oat Breeding Program Progress in 2021"

4. Oat Scoop, Pam Yule, November 2023, pp. 2-4 "Update: POGA-Supported Breeding Programs and Projects"

14. List any industry contributions or support received.

Co-funding of this project was received from the Saskatchewan Ministry of Agriculture – Agriculture Development Fund and the Prairie Oat Growers Association (POGA).

15. Acknowledgements: *Include actions taken to acknowledge support by the Ministry of Agriculture and the Canadian Agriculture Partnership.*

Acknowledgement of the funding support provided by ADF for this project was mentioned at the field tours and presentations mentioned in Section 13.

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

Appendices A-G contain WCORT data collected from 2019-23 on CDC lines, as well as, summary data collected on CDC Anson and CDC Byer.

Appendix A - 2019 WCORT Data for CDC Lines

ENTRY	YIELD (Kg/Ha)	HEADING (Days)	MATURITY (Days)	HEIGHT (cm)	LODGING (1-9)	TWT (Kg/Hl)	TKW (g)	PLUMP[z] (%)	THINS[y] (%)	CODEMA GROAT[x] (%)	PROTEIN ANALYTICAL[w] (%db)	OIL ANALYTICAL[v] (%db)	BETA-GLUCAN[u] (%db)	CROWN RUST RATING	STEM RUST RATING	SMUT RATING	FHB RATING
CDC Dancer	6654	57	99	103.6	2.1	60.5	38.4	93.5	1.1	76.2	14.4	6.5	4.3				
AC Morgan	7178	59	102	102.9	1.7	59.7	42.7	95.1	0.6	72.5	15.0	6.1	4.1				
Summit	6911	57	104	92.2	1.9	60.3	38.3	91.7	1.8	75.2	15.6	7.2	4.7				
CS Camden	7118	57	98	94.4	1.4	58.4	39.5	92.2	1.6	72.1	16.3	7.3	5.1				
OT3110	**7121**	**59**	**103**	**102.0**	**2.1**	**57.9**	**40.7**	**95.1**	**1.2**	**74.7**	**14.6**	**5.8**	**4.5**	**S**	**S**	**R**	**MR**
OT3111	**7182**	**58**	**101**	**100.4**	**2.0**	**57.4**	**43.2**	**95.3**	**0.9**	**73.3**	**14.4**	**7.0**	**5.0**	**MS**	**S**	**MS**	**I**
OT3112	**7134**	**60**	**101**	**86.0**	**1.6**	**59.0**	**41.1**	**94.6**	**1.0**	**76.4**	**15.2**	**7.0**	**6.2**	**MR**	**MS**	**R**	**MR**
OT3113	**7066**	**59**	**102**	**97.7**	**1.4**	**57.9**	**43.7**	**97.3**	**0.3**	**74.6**	**16.4**	**6.0**	**5.4**	**R**	**S**	**R**	**MR**
Grand Mean	6851.8	58	101	97.9	1.7	59.1	40.2	91.6	1.8	73.5	15.7	6.8	4.9				
LSD	282.1	0.6	1.4	2.4	0.3	0.6	0.9	0.3	0.8	1.4	0.6	0.4	0.2				
C.V. %	8.9	1.4	2.7	4.9	26.7	1.5	5.7	3.3	44.2	1.7	3.2	4.4	3.3				
No. of Reps	36	17	29	32	18	12	12	6	6	6	5	5	5				

[z]Percent plump based on portion of 50 gram sample remaining on top of 5.5/64 x 3/4" sieve.

[y]Percent thin was determined by the portion of 50 gram sample passing through 5/64 x 3/4" sieve.

[x]Percent groat determined on a 50 gram sample using a Codema dehuller.

[w]Data supplied by M. Izydroczyk, Grain Research Laboratory, Canadian Grain Commission. Wholemeal samples were analyzed by Combustion Nitrogen Analysis on a LECO Model FP-428 CAN analyzer.

[v]Data supplied by M. Izydroczyk, Grain Research Laboratory, Canadian Grain Commission. Wholemeal samples were analyzed by standard procedures using AOAC 922.06.

[u]Data supplied by M. Izydorczyk, Grain Research Laboratory, Canadian Grain Commission. Standard analystical procedures were used to quantify beta-glucan

Appendix B - 2020 WCORT Data for CDC Lines

ENTRY	YIELD (Kg/Ha)	HEADING (Days)	MATURITY (Days)	HEIGHT (cm)	LODGING (1-9)	TWT (Kg/Hl)	TKW (g)	PLUMP[z] (%)	THINS[y] (%)	CODEMA GROAT[x] (%)	PROTEIN ANALYTICAL[w] (%db)	OIL ANALYTICAL[v] (%db)	BETA-GLUCAN[u] (%db)	CROWN RUST RATING	STEM RUST RATING	SMUT RATING	FHB RATING
AC Morgan	6305	54	90	104.0	2.3	58.0	37.7	79.3	4.9	70.4	15.3	6.0	4.0				
Summit	6103	51	92	95.1	2.7	58.7	34.8	80.4	5.6	74.1	15.8	7.3	4.7				
CS Camden	6452	51	87	100.0	1.9	56.9	36.7	73.9	6.0	70.1	16.9	7.0	5.0				
OT3114	**6474**	**52**	**89**	**104.7**	**1.8**	**55.5**	**37.2**	**76.1**	**7.0**	**72.0**	**16.0**	**6.7**	**5.5**	**I**	**MS**	**S**	**MR**
OT3115	**6652**	**53**	**90**	**97.7**	**2.0**	**57.3**	**35.7**	**80.8**	**5.8**	**71.9**	**15.2**	**6.1**	**5.5**	**MR**	**MS**	**MR**	**MR**
OT3116	**6697**	**55**	**91**	**105.5**	**1.6**	**57.7**	**38.6**	**85.6**	**4.1**	**72.8**	**15.2**	**7.3**	**5.2**	**S**	**MS**	**I**	**MR**
OT3117	**6019**	**54**	**91**	**104.1**	**1.6**	**58.5**	**38.4**	**81.2**	**5.3**	**72.3**	**15.9**	**6.2**	**5.4**	**S**	**I**	**MR**	**I**
Grand Mean	6193.7	52	89	100.5	2.1	58.2	37.5	81	5.0	71.8	16.1	6.3	4.9				
LSD	267.8	1.0	1.6	2.2	0.5	1.4	2.4	10.1	5.1	1.7	0.6	0.3	0.3				
C.V. %	7.2	2.3	2.6	3.5	29.7	3.2	6.8	11.6	62.4	2.0	3.4	4.0	4.9				
No. of Reps	33	18	27	33	18	11	11	6	6	6	6	5	5				

[z]Percent plump based on portion of 50 gram sample remaining on top of 5.5/64 x 3/4" sieve.

[y]Percent thin was determined by the portion of 50 gram sample passing through 5/64 x 3/4" sieve.

[x]Percent groat determined on a 50 gram sample using a Codema dehuller.

[w]Data supplied by M. Izydroczyk, Grain Research Laboratory, Canadian Grain Commission. Wholemeal samples were analyzed by Combustion Nitrogen Analysis on a LECO Model FP-428 CAN analyzer.

[v]Data supplied by M. Izydroczyk, Grain Research Laboratory, Canadian Grain Commission. Wholemeal samples were analyzed by standard procedures using AOAC 922.06.

[u]Data supplied by M. Izydorczyk, Grain Research Laboratory, Canadian Grain Commission. Standard analystical procedures were used to quantify beta-glucan

Appendix C - 2021 WCORT Data for CDC Lines

ENTRY	YIELD (Kg/Ha)	HEADING (Days)	MATURITY (Days)	HEIGHT (cm)	LODGING (1-9)	TWT (Kg/Hl)	TKW (g)	PLUMP[z] (%)	THINS[y] (%)	CODEMA GROAT[x] (%)	PROTEIN ANALYTICAL[w] (%db)	OIL ANALYTICAL[v] (%db)	BETA-GLUCAN[u] (%db)	CROWN RUST RATING	STEM RUST RATING	SMUT RATING	FHB RATING
AC Morgan	4835.4	57	87	78.6	1.6	56.6	40.3	80.3	3.3	71.5	17.2	6.5	4.4				
Summit	3824.0	53	84	76.6	1.6	60.2	39.2	84.6	2.7	76.5	18.1	7.5	4.8				
CS Camden	4638.2	54	82	76.0	1.3	55.5	39.4	83.0	2.6	70.3	19.3	7.4	5.2				
OT3118	**4551.6**	**55**	**84**	**72.8**	**1.3**	**56.1**	**42.1**	**92.6**	**1.1**	**75.3**	**18.8**	**7.8**	**4.8**	**MR**	**S**	**R**	**MR**
OT3119	**4257.9**	**55**	**85**	**70.9**	**1.3**	**58.3**	**42.5**	**91.3**	**1.3**	**72.9**	**18.5**	**8.0**	**5.3**	**MR**	**I**	**R**	**I**
OT3120	**4245.8**	**53**	**86**	**74.3**	**1.5**	**59.1**	**41.7**	**87.6**	**3.0**	**72.9**	**17.5**	**7.2**	**5.0**	**S**	**I**	**R**	**MR**
Grand Mean	4326.0	56	86	75.8	1.5	56.8	41.7	87.2	2.4	72.1	18.3	6.9	4.9				
LSD	166.9	1.0	0.9	1.6	0.4	1.2	2.0	7.6	4.0	2.3	0.7	0.7	0.3				
C.V. %	8.3	3.0	2.0	4.2	30.1	2.5	5.9	8.2	75.1	2.8	3.3	8.7	4.6				
No. of Reps	33	24	27	30	12	11	11	6	6	6	6	6	6				

[z]Percent plump based on portion of 50 gram sample remaining on top of 5.5/64 x 3/4" sieve.

[y]Percent thin was determined by the portion of 50 gram sample passing through 5/64 x 3/4" sieve.

[x]Percent groat determined on a 50 gram sample using a Codema dehuller.

[w]Data supplied by M. Izydroczyk, Grain Research Laboratory, Canadian Grain Commission. Wholemeal samples were analyzed by Combustion Nitrogen Analysis on a LECO Model FP-428 CAN analyzer.

[v]Data supplied by M. Izydroczyk, Grain Research Laboratory, Canadian Grain Commission. Wholemeal samples were analyzed by standard procedures using AOAC 922.06.

[u]Data supplied by M. Izydorczyk, Grain Research Laboratory, Canadian Grain Commission. Standard analytical procedures were used to quantify beta-glucan

Appendix D – 2022 WCORT Data for CDC Lines

ENTRY	YIELD (Kg/Ha)	HEADING (Days)	MATURITY (Days)	HEIGHT (cm)	LODGING (1-9)	TWT (Kg/Hl)	TKW (g)	PLUMP[z] (%)	THINS[y] (%)	CODEMA GROAT[x] (%)	PROTEIN ANALYTICAL[w] (%db)	OIL ANALYTICAL[v] (%db)	BETA-GLUCAN[u] (%db)	CROWN RUST RATING	STEM RUST RATING	SMUT RATING	FHB RATING
AC Morgan	6670.8	54	92	105.4	2.7	55.5	37.2	87.8	2.5	71.7	15.6	5.9	4.3				
Summit	5975.9	53	91	92.9	4.7	56.1	34.1	82.3	5.7	75.2	16.0	7.1	4.9				
CS Camden	6524.3	53	88	98.4	2.6	54.6	36.6	81.4	4.4	71.9	17.1	7.0	5.5				
CDC Endure	6904.5	54	90	104.9	4.2	55.6	39.2	94.4	1.6	75.8	15.5	6.7	5.2				
OT3121	**6944.8**	**53**	**90**	**103.4**	**2.4**	**53.4**	**37.2**	**87.8**	**3.5**	**73.5**	**15.8**	**6.4**	**5.6**	**S**	**S**	**R**	**I**
OT3122	**6757.1**	**54**	**90**	**105.5**	**3.2**	**55.8**	**40.5**	**91.3**	**2.3**	**74.2**	**15.8**	**6.5**	**5.2**	**S**	**S**	**R**	**I**
OT3123	**6651.5**	**50**	**90**	**97.6**	**2.2**	**56.3**	**37.2**	**92.2**	**1.4**	**75.7**	**15.6**	**7.3**	**4.9**	**MR**	**S**	**MS**	**MR**
OT3124	**6687.2**	**52**	**93**	**99.3**	**2.7**	**54.4**	**40.7**	**91.8**	**1.9**	**76.4**	**14.6**	**6.5**	**4.9**	**MR**	**S**	**R**	**I**
Grand Mean	6442.4	55	91	99.5	3.9	54.7	38.2	89.4	2.4	72.6	16.6	6.1	5.0				
LSD	220.1	0.4	0.7	1.7	0.8	1.0	1.6	7.4	2.6	1.3	0.5	0.3	0.2				
C.V. %	7.4	1	2	4	30	2.4	5.3	7.9	98.8	1.7	3	4.4	4.3				
No. of Reps	33	24	33	33	18	11	11	7	7	7	7	7	7				

[z]Percent plump based on portion of 50 gram sample remaining on top of 5.5/64 x 3/4" sieve.

[y]Percent thin was determined by the portion of 50 gram sample passing through 5/64 x 3/4" sieve.

[x]Percent groat determined on a 50 gram sample using a Codema dehuller.

[w]Data supplied by M. Izydroczyk, Grain Research Laboratory, Canadian Grain Commission. Wholemeal samples were analyzed by Combustion Nitrogen Analysis on a LECO Model FP-428 CAN analyzer.

[v]Data supplied by M. Izydroczyk, Grain Research Laboratory, Canadian Grain Commission. Wholemeal samples were analyzed by standard procedures using AOAC 922.06.

[u]Data supplied by M. Izydorczyk, Grain Research Laboratory, Canadian Grain Commission. Standard analytical procedures were used to quantify beta-glucan

Appendix E – 2023 WCORT Data for CDC Lines

ENTRY	YIELD (Kg/Ha)	HEADING (Days)	MATURITY (Days)	HEIGHT (cm)	LODGING (1-9)	TWT (Kg/Hl)	TKW (g)	PLUMP[z] (%)	THINS[y] (%)	CODEMA GROAT[x] (%)	PROTEIN ANALYTICAL[w] (%db)	OIL ANALYTICAL[v] (%db)	BETA-GLUCAN[u] (%db)	CROWN RUST RATING	STEM RUST RATING	SMUT RATING	FHB RATING
AC Morgan	7571.2	52	90	100.8	2.5	55.4	41.3	89.7	1.5	71.3	14.5	6.5	4.1				
Summit	6773.9	48	90	91.4	2.7	57.2	37.6	92.8	1.5	74.7	15.1	7.5	4.6				
CS Camden	7205.4	49	87	95.9	2.6	55.0	40.9	90.4	1.6	71.3	16.5	7.3	5.3				
CDC Endure	7427.0	50	87	99.6	3.2	54.7	41.3	94.3	1.4	75.2	14.9	7.2	5.2				
OT3125	**7795.5**	**52**	**89**	**91.6**	**3.1**	**54.8**	**41.9**	**91.8**	**1.9**	**73.3**	**15.0**	**7.0**	**4.8**	**S**	**S**	**R**	**I**
OT3126	**7245.3**	**50**	**86**	**90.8**	**2.4**	**57.1**	**44.5**	**95.9**	**1.3**	**73.3**	**15.2**	**6.6**	**5.0**	**S**	**S**	**R**	**MR**
OT3127	**7684.6**	**52**	**88**	**101.8**	**2.7**	**54.9**	**42.1**	**91.6**	**2.1**	**72.8**	**15.2**	**6.5**	**5.0**	**S**	**S**	**R**	**MR**
OT3128	**6903.4**	**49**	**88**	**84.3**	**1.5**	**56.6**	**39.4**	**95.3**	**0.8**	**73.0**	**16.1**	**6.3**	**5.0**	**MR**	**S**	**R**	**MR**
OT3129	**7688.6**	**50**	**87**	**93.0**	**2.8**	**54.9**	**39.7**	**86.3**	**2.8**	**72.0**	**15.8**	**6.4**	**5.1**	**S**	**S**	**R**	**I**
Grand Mean	7218.0	51	89	97.2	2.8	54.8	40.5	87.0	2.8	72.3	15.6	6.9	5.0				
LSD	287.3	0.8	0.7	2.0	0.5	0.8	1.9	7.1	1.9	1.5	0.6	0.2	0.2				
C.V. %	8.6	2.1	1.5	4.1	27.6	1.8	5.5	7.1	59.6	1.8	3.4	3.1	3.4				
No. of Reps	36	12	26	27	18	12	12	6	6	6	6	6	6				

[z]Percent plump based on portion of 50 gram sample remaining on top of 5.5/64 x 3/4" sieve.

[y]Percent thin was determined by the portion of 50 gram sample passing through 5/64 x 3/4" sieve.

[x]Percent groat determined on a 50 gram sample using a Codema dehuller.

[w]Data supplied by M. Izydroczyk, Grain Research Laboratory, Canadian Grain Commission. Wholemeal samples were analyzed by Combustion Nitrogen Analysis on a LECO Model FP-428 CAN analyzer.

[v]Data supplied by M. Izydroczyk, Grain Research Laboratory, Canadian Grain Commission. Wholemeal samples were analyzed by standard procedures using AOAC 922.06.

[u]Data supplied by M. Izydorczyk, Grain Research Laboratory, Canadian Grain Commission. Standard analytical procedures were used to quantify beta-glucan

Appendix F - WCORT Data for CDC Anson

Table 1. Grain yield for CDC Anson and checks from the 2019 and 2020 WCORT.

	Black Soil Zone		Black & Grey Zone		Brown Soil Zone		Irrigated		Combined	
Entry	**kg/ha**	**%Camden**	**kg/ha**	**%Camden**	**kg/ha**	**%Camden**	**kg/ha**	**%Camden**	**kg/ha**	**%Camden**
AC Morgan	6517	96	7804	107	5160	101	8481	96	6741	99
Summit	6375	94	7033	97	5022	99	8957	101	6506	96
CS Camden	6765	100	7275	100	5092	100	8863	100	6784	100
CDC Anson	**7068**	**104**	**7133**	**98**	**5114**	**100**	**9450**	**107**	**6958**	**103**
Station years	12		5		4		2		23	

Table 2. Agronomic characteristics for CDC Anson and checks from the 2019 and 2020 WCORT.

	Days to	Days to	Height	Lodging	Test Wt.	Kern. Wt.	Plump	Thins	Groat
Entry	**Head**	**Mature**	**(cm)**	**(1 - 9)**	**(kg/hl)**	**(mg)**	**(%)**	**(%)**	**(%)**
AC Morgan	56	96	104	2.0	58.9	40.2	87.2	2.7	71.4
Summit	54	98	94	2.3	59.5	36.6	86.0	3.7	74.7
CS Camden	54	92	97	1.7	57.7	38.1	83.0	3.8	71.1
CDC Anson	**57**	**95**	**88**	**1.7**	**57.9**	**39.1**	**89.6**	**2.9**	**75.3**
Station years	12	19	22	7	23	23	12	12	12

Table 3. Grain quality characteristics for CDC Anson and checks from the 2019 and 2020 WCORT.

	Protein			Oil			β-Glucan			TDF
	2019	**2020**	**Mean**	**2019**	**2020**	**Mean**	**2019**	**2020**	**Mean**	**2020**
Entry	**(%db)**	**(%db)**	**(%db)**	**(%db)**	**(%db)**	**(%db)**	**(%db)**	**(%db)**	**(%db)**	**(%db)**
AC Morgan	15.0	15.1	15.0	6.1	6.0	6.1	4.1	4.1	4.1	9.7
Summit	15.6	15.7	15.6	7.2	7.3	7.2	4.7	4.7	4.7	9.7
CS Camden	16.3	16.6	16.4	7.3	7.2	7.3	5.1	5.1	5.1	10.6
CDC Anson	**15.2**	**15.6**	**15.4**	**7.0**	**6.9**	**6.9**	**6.2**	**6.1**	**6.2**	**11.6**
Station years	5	6	11	5	5	11	5	5	10	4

Appendix G - WCORT Data for CDC Byer

Table 1. Grain yield for CDC Byer and checks from the 2020 and 201 WCORT.

	Black Soil Zone		Black & Grey Zone		Brown Soil Zone		Irrigated		Combined	
Entry	**kg/ha**	**%Camden**	**kg/ha**	**%Camden**	**kg/ha**	**%Camden**	**kg/ha**	**%Camden**	**kg/ha**	**%Camden**
AC Morgan	5637	96	5971	113	3664	102	8174	101	5570	100
Summit	5190	88	5067	96	3156	88	7006	87	4963	90
CS Camden	5866	100	5274	100	3594	100	8058	100	5545	100
CDC Byer	**5991**	**102**	**5747**	**109**	**3607**	**100**	**7811**	**97**	**5678**	**102**
Station years	12		4		4		2		22	

Table 2. Agronomic characteristics for CDC Byer and checks from the 2020 and 201 WCORT.

	Days to	Days to	Height	Lodging	Test Wt.	Kern. Wt.	Plump	Thins	Groat
Entry	**Head**	**Mature**	**(cm)**	**(1 - 9)**	**(kg/hl)**	**(mg)**	**(%)**	**(%)**	**(%)**
AC Morgan	56	88	91	2.0	57.3	39.0	79.8	8.0	70.9
Summit	52	88	86	2.2	59.5	37.0	82.5	8.3	75.3
CS Camden	53	84	88	1.6	56.2	38.0	78.4	8.7	70.2
CDC Byer	**54**	**88**	**86**	**1.7**	**56.9**	**37.7**	**82.7**	**2.6**	**72.3**
Station years	14	18	21	10	22	22	12	12	12

Table 3. Grain quality characteristics for CDC Byer and checks from the 2020 and 201 WCORT.

	Protein			Oil			β-Glucan			TDF
	2020	**2021**	**Mean**	**2020**	**2021**	**Mean**	**2020**	**2021**	**Mean**	**2021**
Entry	**(%db)**	**(%db)**	**(%db)**	**(%db)**	**(%db)**	**(%db)**	**(%db)**	**(%db)**	**(%db)**	**(%db)**
AC Morgan	15.3	17.2	16.3	6.0	6.5	6.2	4.0	4.4	4.2	9.5
Summit	15.8	18.1	16.9	7.3	7.5	7.4	4.7	4.8	4.8	9.6
CS Camden	16.9	19.3	18.1	7.0	7.4	7.2	5.0	5.2	5.1	10.3
CDC Byer	**15.2**	**18.4**	**16.8**	**6.1**	**6.2**	**6.1**	**5.5**	**5.4**	**5.5**	**10.1**
Station years	6	6	12	6	6	12	6	6	12	3