AgriScience Program - Projects Component

Final Performance Report

This template covers the annual performance reporting for the final year of the project and two additional questions to satisfy the final performance reporting requirements.

Section A: Annual Performance Reporting

This section is the same as previous Annual Reports completed to date, and is intended to capture only those results that were achieved during the final year of the project.

Name of Recipient: Canadian Field Crop Research Alliance (CFCRA)	
Project Title: Breeding, genomics, and agronomy research to improve oat yield and quality	
Project Number: ASP-001	**Final Period Covered by the Report**: 2022/04/01 to 2023/03/31
Project Start Date: 2018/04/01	**Project End Date**: 2023/03/31

1. Performance Measures – Project Level

In the performance measures table below, please provide the results and achievements that were finalized during this final reporting period, that combines all the CA and CRDA activities. Do not include results that are not final. Please see Annex A for a description of each performance measure.

Performance Measure		**Results Achieved**	Provide a brief description of each final result achieved during the reporting period.
1.	Number of highly qualified personnel (HQP) working on funded activities (HQP refers exclusively to current Master and PhD students)	0	
2.	Training/knowledge transfer events		
	2.1 Number of training/knowledge transfer events organized by the recipient	1	1. Ottawa Oat Day (OOD) – July 19, 2022; Ottawa Research & Development Centre, Ottawa, ON.
	2.2 Number of presentations made in training/knowledge transfer events	15	1. Weikai Yan: "Oat Breeding through Visual Selection and Genomic Selection at ORDC" oral presentation presented at the 2022 OOD

Performance Measure		Results Achieved	Provide a brief description of each final result achieved during the reporting period.
			2. Wubishet Bekele: "Genomics-assisted Breeding of Oat" oral presentation presented in the 2022 OOD 3. Guoqi Wen, Baoluo Ma: "Using Electrical Signals to Quantify Oat Agronomic Traits and Plant Health under Drought Stress" oral talk presented in the 2022 OOD 4. Mehri Hadinezhad: "Oats: Nutritious Whole Grains" oral talk presented in the 2022 OOD 5. "Oat and Hulless Barley Breeding at Agriculture and Agri-Food Canada." Oral talk Presented to CROPDIVA by Charlene Wight 6. "A behind the scenes look at breeding and producing oats," interview of Weikai Yan by Laura Ferrier of GFO for an article to be published in Ontario Grain Farmer Magazine 7. "New oat cultivars offer boost in yield, quality and resistance, " interview of Weikai Yan by Melanie Epp of GFO 8. "Oat Varieties Developed for Canada's Diverse Growing Conditions: Breeding Project Update," interview of Weikai Yan by POGA 9. "Breeding for specifically adapted oat," "Speaking of Oats" Webinar by Weikai Yan to international oat workers 10. "How to deal with G by E," tele-lecture to northwestern Agri-Forest University, China 11. "Head-to-head comparison of GS and VS," presented by Weikai Yan to the TUGBAOT international meeting 12. "2022 Oat variety update," presented by Weikai Yan to MB-CSGA 13. "Oat coordinator's report" presented to OCCC by Weikai Yan 14. "Oat variety released during 2018-2023", presented at the AGA of grain producers in Saguenay-Lac-St-Jean QC by Geneviève Telmosse 15. "Oat variety development and agronomy results", presented at the Annual Regional Field Crop Day in Saguenay-Lac-St-Jean QC by Geneviève Telmosse
3.	Number of participants at training/knowledge transfer events	280	
4.	Number of new knowledge transfer products developed		
5.	Number of papers published in peer reviewed journals	7	1. Exploring the relationships between biomass production, nutrient acquisition, and phenotypic traits: testing oat genotypes as a cover crop. BL Ma, B De Haan, Z Zheng, AG Xue,

Performance Measure		Results Achieved	Provide a brief description of each final result achieved during the reporting period.
			Y Chen, NDG de Silva, H Byker, ..., Journal of Plant Nutrition 45 (19), 2931-2944 2. Genome analysis in Avena sativa reveals hidden breeding barriers and opportunities for oat improvement. NA Tinker, CP Wight, WA Bekele, W Yan, EN Jellen, NT Renhuldt, ... Communications Biology 5 (1), 474 7 3. AAC Excellence oat. W Yan, J Fregeau-Reid, B DeHaan, S Thomas, M Hayes, R Martin, ... Canadian Journal of Plant Science 102 (3), 776-780 1 4. AAC Reid oat. W Yan, J Fregeau-Reid, B DeHaan, S Thomas, M Hayes, R Martin, ...Canadian Journal of Plant Science 102 (3), 781-784 1 5. Mega-environment analysis and breeding for specific adaptation. W Yan, KT Nilsen, A Beattie, Crop Science 63 (2): 480-494 6. Yao E, et al. (2022) GrainGenes: a data-rich repository for small grains genetics and genomics. *Database*, Volume 2022, 2022, baac034. https://doi.org/10.1093/database/baac034 7. Blake VC, et al. (2022) GrainGenes: Tools and Content to Assist Breeders Improving Oat Quality. Foods. 2022 Apr; 11(7): 914.https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8998097/
6.	Number of new technologies (new products, practices, processes and systems) that are developed		
7.	Number of new technologies (new products, practices, processes and systems) that are assessed under research conditions		
8.	Number of new technologies (new products, practices,		

Performance Measure		Results Achieved	Provide a brief description of each final result achieved during the reporting period.
	processes and systems) that are demonstrated on-farm or in-plant		
9.	Number of new technologies (new products, practices, processes and systems) that attain Intellectual Property (IP) protection.	4	1. OA1655-1 (For ME1, tendered by SeCan) 2. OA1655-2 (for ME3, tendered by SeCan, Quaker proved) 3. OA1658-1 (For ME2, tendered by SeCan) 4. OA1675-1GS (For ME2, to be tendered)
10.	Number of new technologies (new products, practices, processes and systems) that are utilized	5	1. OA1609-7 (SeCan) 2. OA1644-13 (AAC Dehaan) (SeCan, Quaker proved) 3. OA1627-1 (AAC Hunt) (SeCan) 4. OA1623-5 (AAC Wight) (SeCan) 5. OA1613-5 (AAC Wallace) (William Houde)

2. Activity-level Information

In this section, please complete one table for each activity. For activities with both a CA and CRDA component, please integrate the results into one table.

CA Activity Number: 1B / CRDA Activity Number: 1A
Name of Activity: Breeding, genomics, and agronomy research to improve oat yield and quality
Principal Investigator: Weikai Yan
Summary of Activity Please provide a high-level summary of this activity that includes an introduction, objectives, methodology, deliverables, results and discussion. Technical language can be used in this section.

INTRODUCTION

Oat is an important, multi-purpose cereal in Canada that is grown for grain, straw, forage, or land cover. Oat grain is regarded as a healthy human food, largely due to the presence of beta-glucan (BGL) and other soluble fibers in the oat groat, which have been implicated in reduced risk of heart disease, lowered blood pressure, and lowered risk of type-II diabetes. Grain yield, groat content (i.e., milling yield), and BGL content are key targets for improvement. Protein, test weight, and kernel weight are considered secondary targets for improvement. Additionally, oat millers require a groat oil content of less than 8% to meet the FDA healthy food labeling requirements. To achieve high and stable yield and quality, lodging resistance is required under high-yielding environments, and resistance to crown rust is required in some production regions. Our nation-wide multi-discipline research team proposes to improve these characters through breeding, genomics, and agronomy. There are seven objectives in this proposed project: 1) developing new oat cultivars with improved grain yield and quality; 2) identifying optimal agronomic practices to achieve high and stable grain yield and quality; 3) enhancing the current oat breeding procedures in both the Ottawa and Brandon programs with genomic selection; 4) improving the ability to deploy appropriate rust resistance genes through a survey of Pc gene profiles in existing cultivars, and Pc gene effectiveness in western and eastern Canada; 5) enhancing genetic diversity in North American oat breeding programs through a joint testing and genotyping network that promotes germplasm exchange and provides information about adaptation; and 6) developing a multi-faceted approach to data and knowledge management that enhances all objectives of this project and benefits world-wide pre-competitive oat research. Collectively, these six objectives share the same ultimate goal to improve Canadian oat grain yield and quality. The expected impacts on the Canadian field crop sector include: 1) increased income for Canadian oat growers, 2) increased profit of Canadian/American oat processors, 3) increased health of oat consumers, 4) increased resilience of Canadian agriculture against biotic and abiotic stresses and adaptation to climate change, and 5) enhanced Canadian soil and environmental conservation due to the planting of more oats in rotation with other crops. Through these outcomes, this project addresses the following AAFC priorities: 1) to enhance Canadian environmental sustainability in the face of climate change, and 2) to enhance knowledge and technology transfer activities and thereby the resiliency and productivity of the agriculture.

OBJECTIVES

Objective #1: Cultivar development

• By 2023, to release at least one new cultivar for subregion1, with ≥11% higher grain yield than the mean of check cultivars AAC Bullet and AAC Roskens while keeping the groat level of the check cultivars (≥72%) (High b-glucan is not required for oat grain not used for milling).

• By 2023, to release at least one new cultivar for subregion2, with ≥11% higher yield than the mean of check cultivars AC Rigodon, Dieter, and Synextra while keeping the beta-glucan (≥4.2%) and groat (≥72%) levels of the check cultivars.

• By 2023, to release at least one cultivar for subregion2, with ≥5.0% beta-glucan while keeping the yield and groat levels of the check cultivars AC Rigodon, Dieter, and Synextra.

Objective #2: Agronomic research to develop oat production guide

• Cultivar and region-specific production guide on N rate and method and planting density if there are genotype by treatment and region by treatment interactions.

• Scientific manuscripts reporting the research

Objective #3: Genomic selection

• GS derived lines from this project are at an advanced stage of performance testing, and GS lines from the GFII project could be recommended as varieties.

• Scientific report on the relative efficiency of GS vs. visual selection.
• Recommendation on the use of GS in future oat breeding within Ottawa and Brandon oat breeding programs.
• Genotype and phenotype database, and highly predictive GS models for ongoing use.

Objective #4: Pyramiding crown rust resistance using gene markers

• 2018: data on crown rust response of two populations (10W60 and 15F082)
• 2018: Genotype data of the two populations
• 2019: Selectable markers for PcTX, Pc59, and/or Pc61.
• By 2022, >10 crown rust resistant lines
• By 2022, >1 oat line carrying ≥3 Pc genes

Objective #5: Crown rust pathogen virulence and host resistance gene survey

• Report on the crown rust rating of the oat crown rust differential lines tested in Ottawa and Morden (Yan, Menzies)
• Survey report of oat field in eastern Canada and western Canada and publish the annual survey report (Menzies and Xue)
• Report of reactions of newly released oat cultivars and promising lines to different crown rust races (Menzies)

Objective #6: North American joint oat breeding and testing

Yearly data of grain yield, agronomic traits, grain quality, any diseases, and compositional quality for c. 240 new breeding lines from 4 breeding programs at 5 locations (Ottawa, Brandon, Saskatoon, Lacombe, and Fargo) (Yan, Mitchell Fetch, Beattie, and McMullen)

Objective #7: Oat Data and Knowledge Management

All interim database deliverables were populated and enhanced until project completion. An overall project report describing project accomplishments in knowledge management is published.

MILESTONES

Objective #1: Cultivar development (yearly)

1) About 50 new crosses
2) About 300 F4:5 or F6:7 lines, to be tested in next year's Home Test.
3) Yield and quality data of c. 400 breeding lines from Home Test.
4) Yield and quality results of c. 60 breeding lines tested in the Preliminary Test.
5) Yield and quality data of c. 30 breeding lines tested in the registration test.
6) Up to 2 oat lines supported for registration

Objective #2: Agronomic research to develop oat production guide

2018/2019: Data and summary of the 1st year Exp1.
2019/2020: 2nd year data pf Exp1 and summary across two years for Exp1
2020/2021: 3rd year data for Exp1, summary across years, crop guide on optimal N.
2021/2022: first year data of for Exp2 and Exp3
2022/2023: 2nd year data for Exp2&3 and final summary, production guide on N application and planting density.

Objective #3: Genomic selection

Each year starting from year 1 (2018/19):
-GBS markers for about 2000 new breeding lines (about 1000 from each of Ottawa and Brandon);
-900 lines from training population genotypes and phenotyped, added to database, and used to update GS predictions for both breeding programs.
-80 lines from each of Ottawa and Brandon selected based on GS and increased in New Zealand
Each year starting from year 2 (2019/20):
-80 GS-selected lines from each breeding program are tested in performance tests together with selections from regular breeding streams.

-Evaluation of the performance of GS breeding streams, and overall performance of breeding programs relative to common checks.

Objective #5: Crown rust survey (annually)

• Report on the crown rust rating of the oat crown rust differential lines tested in Ottawa and Morden

• Report Survey results of oat field in eastern Canada and western Canada

• Report of reactions of key oat cultivars and promising lines to different crown rust races

Objective #6: North American joint oat breeding and testing

• Yearly data of grain yield, agronomic traits, grain quality traits, and diseases for c. 240 new breeding lines from 4 breeding programs at 5 locations and compositional quality from at least one location.

• Genotypes and phenotypes of ENCORE incorporated to train and evaluate GS.

Objective #7: Oat Data and Knowledge Management

• 2018: Formal linkages and curational arrangements with T3/Oat, GrainGenes, ORI, and POOL.

• 2019: POOL is up-to-date with recent germplasm from major North American programs and queries in POOL provide a gateway to relevant data in T3/Oat and GrainGenes.

• 2020: Rust gene nomenclature is up-to-date and QTL survey is complete.

• 2021: Rust genes and QTL can be queried on the oat genome sequence to find candidate genes or develop better markers.

• 2022: Simple or advanced queries available for in-depth knowledge on Canadian oat varieties.

• 2023: Useful queries are available for breeders to interrogate germplasm from crop wild relatives.

RESULTS

Executive Summary by Objective

Objective #1: Cultivar development (Yan, Hadinezhad, MacEachern, Morasse/Telmosse, Mountain/Byker, Nilsen, Tinker, Bekele). 1) Four new cultivars were supported for registration, and three of them were tendered by SeCan: OA1655-1 supported by OCCC (for ME1, tendered by SeCan); OA1658-1 supported by OCCC (for ME2, tendered by SeCan); OA1655-2 supported by PGDC (for ME3, Quaker approved milling oat, tendered by SeCan), OA1675-1GS supported by RGCQ (for ME2, to be tendered). OA1675-1GS was selected through genomic selection (GS) at the Observation nursery stage in 2017, preceded by one-year visual selection and followed by 5 years of yield trials. OA1655-1 was selected by visual selection (VS) and was also among the 60 GS predicted winners in 2017. **2)** 40 lines were tested in various registration trials, and several 2nd year entries (e.g., OA1689-4VS, OA1689-10GS, OA1684-3, OA1682-8) and 1st year entries (e.g., OA1689-11, OA1689-20, OA1708-1, OA1725-1VS) showed promise. **3)** 60 lines were tested in the Preliminary Test in conjunction with ENCORE, and several lines (OA1721-2GGM, OA1721-4, OA1734-1,4,5) showed promise. **4)** 300 lines, including 120 VS lines, 120 GS lines, and 40 GC (genomically predicted poor) lines, were tested in the 2022 Home Test. Several promising VS and GS lines were identified from the Normandin and Harrington locations (ME2), and several promising VS and GC lines were identified from the Ottawa location (ME1). **5)** 1060 lines were tested in the Observation nursery, and 186 lines will be advanced to the 2023 Home Test. **6)** 13000 lines were grown in the hill nursery, and 600 lines were selected for further observation. **7)** 88 new crosses were made in Apr 2022, and a selected set of crosses are being advanced in the greenhouse. **8)** Breeder Seed was produced for OA1613-5 (AAC Wallace), OA1623-5 (AAC Wight), OA1644-13 (AAC Dehaan), and OA1627-1 (AAC Hunt). OA1444-5-19, a line supported by OCCC in 2021, showed good yield, rust resistance, and quality but was found to have off types. So 50 panicles were selected and sent to New Zealand for purification and increase; Breeder Seed will be produced in 2023. **9)** Plant Breeder's Rights (PBR) test was conducted for all supported lines in the last two years and PBR applications were filed. **10)** AAC Excellence, released in 2019, was listed No. 1 in the 2023 Quebec oat variety recommendation list. AAC Reid, released in 2019, continued to show superior yield, quality, resistance to multiple diseases (crown rust, BYDV, and Powdery mildew), and resistance to lodging, and is on its way to replacing AAC Bullet as the most popular cultivar in ME1.

Objective #2: Agronomic research to develop oat production guide (Ma, Mountain/Byker, Hall, Entz, Morasse/Telmosse, Leach, Kobuta, Semach) 1) Three field experiments were conducted as planned in the beginning of the year. 2) Experiment 1 aimed at determining site-specific most economic rate of N (MERN) was conducted for the 3rd year at Normandin, Yorkton, Lacombe, and Beaverlodge, because the grain yield responses of the oat varieties were highly variable in the 2nd year, possibly due to the severe drought. To obtain more data and draw more reliable conclusions, we proposed and got approval from CFCRA to redo Exp. 1, instead of starting the previously planned Experiment 2 at these locations in 2022. 3) Experiment 2 aimed at determining the best N fertilizer type, rate, and application methods was conducted at Ottawa, New Liskeard, and Melfort. Preliminary analysis of comprehensive results led to the following conclusions: a) The MERN varied by site and year, but averaged 127 kg ha-1 across Canada based on the 2022 grain price ($400/tonne) and nitrogen prices ($2200/tonne), to achieve the maximum yield of 6240 kg ha^{-1} in eastern Canada and 5560 kg ha^{-1} in western Canada. b) As a result of the increased costs of grain and nitrogen fertilizer from 2018 to 2022, MERN decreased by 6.3% from 136 kg ha^{-1} to 127 kg ha^{-1} in eastern Canada and from 141 kg ha^{-1} to 127 kg ha^{-1} in western Canada. c) Nitrogen application before or at planting was often efficient to increase oat yield, but there are potential benefits to split application when sufficient rainfall is forecasted in the early season. The impact of environmentally smart N on oat production is inconclusive due to limited data. 4) Experiment 3 aimed at determining the optimum seeding rate was conducted for the 2nd year at Beaverlodge, Lacombe, Yorkton, Melfort, Regina, Winnipeg, Ottawa, New Liskeard, and Normandin. The results show that under normal rainfall conditions, oat yields were highest at average seeding rates of 420 seeds m^{-2}, higher than the OMAFRA-recommended seeding rate of 200-300 seeds m^{-2}, in eastern Canada. 5) Yield was highly correlated with the number of seeds $panicle^{-1}$ or seeds m^{-2} and was less associated with kernel weight. 6) Lodging was found to be significantly increased by increased seeding rates ($p \leq 0.01$) and strongly associated with plant height. 7) Seed protein and β-glucan were not significantly affected by seeding rate, but it tended to increase with increasing N application.

Objective #3: Genomic selection (Tinker, Bekele): 1) The Rapture-based oat genotyping assay continues to perform well. A total of 3500 training and breeding lines were genotyped in 2022. 2) for the

ORDC breeding program, 3100 single seed-derived lines from 13 crosses were grown in the greenhouse, genotyped, and selected based on GS models. 60 GS lines, 20 GC lines, and 60 VS lines were increased in New Zealand and will enter the 2023 Home Test. The performance of GS lines in the 2022 Home Test has been described above under Objective #1 ("Cultivar Development"). 3) for the BRDC program, for the first time in the west, 3 GS lines showed enough merit to be admitted as first year entries into the 2023 Western Cooperative Oat Registration. In addition, 9 GS lines were advanced from the PRELP into the BOAT/ENCORE, and we expect more to be advanced from the EGYT into the PRELP pending the arrival of final quality data. In addition, ~1000 early generation new test lines were screened and increased in NZ, the selected top 80 GS lines were harvested and will be advanced to the 2023 EGYT.

Objective #4: crown rust study (Yan): This objective was eliminated from the original proposal due to reduced budget. Nevertheless, many lines from crosses using parents carrying Pc94 and Pc genes from MNBT1021-1 and TX1948 were selected, which showed significantly better crown rust resistance and higher yield at Ottawa than AAC Reid, which is currently the most crown-rust resistant cultivar.

Objective #5: Crown rust test and survey (Menzies, Yan) : 1) 452 oat lines tested in HT, Preliminary, and Registration trials were screened for crown rust resistance at Winchester ON and for crown rust and smut resistance at Morden MB in 2022, and lines with better resistance than AAC Reid have been identified. There was a moderate amount of crown rust pressure at Morden but good disease rating was obtained at Ottawa and Winchester. 2) 153 fields of common and wild oats were assessed for crown rust infection in Manitoba, with 150 of these fields having crown rust infected plants. Samples were collected from crown rust infected plant in 75 fields. Twenty five samples of crown rust infected plants from fields in Ontario were collected. Single pustule isolates have been made from the crown rust infected plants, and these single pustule isolates are undergoing virulence assessment on an oat crown rust differential set. 3) it was observed that Pc94 was clearly defeated at Ottawa in 2022; cultivars carrying Pc94 (such as Leggett) showed a MS crown rust response. Lines derived from OA1426-2 (Pc genes unknown) showed resistance at the early stage but became susceptible during grain filling; these lines may be classified as late-rusting lines. Powdery mildew was observed for the first time in the Winchester ON trials and AAC Reid was identified as the only resistant cultivar.

Objective #6: North American joint oat breeding and testing (ENCORE) (Nilsen, Beattie, Hadinezhad, Yan) : 210 oat lines from three breeding programs were tested in ENCORE at Ottawa ON, Brandon MB, Lacombe AB, and Saskatoon SK, with two replicates. Data of grain yield, agronomic traits, grain and nutritional quality traits, and diseases were obtained at all locations. These lines were also genotyped for GBS markers by the genomics group. The phenotypic data will be shared with the genomic selection group and the GBS marker data will be shared with the breeders.

Objective #7: Oat Data and Knowledge Management (Wight, Tinker) : 1) Participation in weekly conference calls with the T3/Oat and GrainGenes teams (USDA-ARS) continued. (2) Breeders were asked once more to send their recent pedigree data for inclusion in the T3/Oat database. (3) Molecular genetic maps continue to be uploaded to GrainGenes as they are produced by the oat research community. (4) The MS Access database created to hold all of the information regarding mapped oat genes and QTL (Quantitative Trait Loci) was used to produce the final version of the inventory. The associated analyses and manuscript are currently being reviewed by authors. The consensus oat map of Bekele et al. (2018) was used to align >2300 genes and QTL with the most recent release of the OT3098 genome sequence.

DISCUSSION

Reduced work in 2020 due to the COVID-19 pandemic adversely affected all aspects of this activity. Nevertheless, new cultivar release was not affected owing to a healthy breeding pipeline. Four new cultivars were supported for registration by OCCC, RGCQ, or PGDC, and three of these were tendered by SeCan in this fiscal year. OA1655-1 was released for ME1. Across 18 trials conducted in 2021 and 2022, it yielded 8% higher than AAC Reid and showed good agronomic and quality traits. OA1658-1 was released for ME2. Across 71 trials, it yielded 9% higher and showed significantly better test weight, groat content, kernel weight, and plumpness than AAC Nicolas. OA1655-2 was released for ME3. It yielded the same as Morgan across the 2021 and 2022 WCORT trials but showed much higher beta-glucan content and significantly better kernel weight, plumpness, and groat content. Quaker has approved it as a preferred milling oat.

OA1675-1GS was released for ME2; it yielded the same as AAC Nicolas but had much higher beta-glucan content, kernel weight, and test weight. These results exceed the project target. Releasing cultivars for all three mega-environments of Canada is an unprecedented success of the ORDC oat breeding program and a proof of our concept and methodology "to breed for specific adaptation".

The agronomic studies were more affected by the Pandemic as the planned studies were not conducted at several locations in 2020. This does affect the completeness of data even though amendments were made in 2021 and 2022. Nevertheless, important information has been obtained on MERN and optimum seeding rates. Since the studies generated massive data, full data processing, analysis, and writing up will take more time than we expected.

The GS prediction was effective for yield at Normandin QC and Harrington PE but it was negative for yield at Ottawa in 2022. This strongly suggests that mega-environment specific GS models, particularly for yield in ME1, must be developed and utilized in the future. Multiple cohorts of genomic selection (GS) up to the present indicate that GS was not more effective than visual selection (VS) in developing high-yielding cultivars. This is because cultivars are defined by many traits other than yield and these traits are often unfavorably associated. Therefore, GS models for all key traits must be developed and utilized in the prediction if GS is to be used as an alternative to VS. A more rational approach would be to combine GS with VS prior to yield trials. We propose to use VS for observable traits, which are literally countless, and to use GS for traits that are important but cannot be easily observed or measured (e.g., yield and compositional quality). Cost efficiency has to be investigated for adding GS to the current breeding system; hopefully the additional cost will be justified by improved selection accuracy.

Issues

- Describe any challenges or concerns in achieving the results and deliverables of this activity during the reporting period. How were they overcome or how do you plan to overcome?
- Describe any potential changes to the work plan and the budget during the reporting period. How were or how will they be managed?

- Prolonged rainfall during harvest led to severe pre-harvest sprouting and the loss of the Home Test and the Preliminary test at New Liskeard ON in 2022. This is unfortunate but also within the scope of expectation. Our multi-location test strategy plus relatively low selection intensity at the Home Test and Preliminary Test stages were designed to cover such exceptions. According to our long time study, New Liskeard belongs to oat mega-environment 2 and has similar cultivar responses to those in Quebec and the Maritimes. It is believed that the selected lines based on data from Normandin QC and Harrington PE, and from Princeville QC to a less extent (Preliminary test only), should have included those that would perform best at New Liskeard.
- Due to the retirement of Dr. Allen Xue, some planned oat disease work was cancelled in 2022. The fund previously allocated to Dr. Xue was used to grow a Registration test and a crown rust screening nursery at Winchester ON. Since Winchester is a hot spot for crown rust, highly informative data were obtained, which were better than what can be expected if the nursery were grown at Ottawa.

Key Achievements

A key achievement represents a significant achievement or tangible result that could potentially be applied either by farmers or industry or the science community. In one to three paragraphs, please provide key achievements that meet one of the following criteria:

1) The item has commercial potential (all testing and piloting has been completed);
2) The item has been commercialized; or
3) The item has been adopted by the sector.

Examples of tangible results could include increased sustainability (beneficial management practice), reduced costs, improved productivity or increased profitability. Please note that the information provided will be used for communication purposes only.

If no key achievements have been realized at this stage, please leave this section blank.

1. OA1655-1 was released for ME1 and tendered by SeCan. Across 18 trials conducted in 2021 and 2022, it yielded 8% higher than AAC Reid, which is currently the best cultivar in ME1. This line was selected through visual selection. It was also among the 60 lines selected through genomic prediction in 2017, a proof of usefulness of genomic selection.
2. OA1658-1 was released for ME2 and tendered by SeCan. Across 71 trials, it yielded 9% higher and showed significantly better test weight, groat content, kernel weight, and plumpness than AAC Nicolas, which is one of the most popular cultivars in ME2.
3. OA1655-2 was released for ME3 and tendered by SeCan. It yielded the same as AC Morgan, one of the highest yielding cultivars in ME3, but showed significantly higher beta-glucan content, kernel weight, plumpness, and groat content. It was approved by Quaker as a preferred milling oat. Developing cultivars for ME3 was not a target of this project; this development is another proof our “breeding for specific adaptation” concept and methodology.
4. OA1675-1GS was released for ME2; it yielded the same as AAC Nicolas but had much better beta-glucan, kernel weight, and test weight. This line was discarded by visual selection for its relatively tall plant height in 2017 but was picked up by genomic prediction of yield and beta-glucan.
5. The N-fertilizer studies led to the determination of optimum N rates.
6. The planting density study revealed an optimum seeding rate that is higher than previously recommended.

Section B: Final Performance Reporting

The following three questions are supplemental to the standard APR questions, to gather additional information as required for the final year of performance reporting.

3. Results Variance

The table below presents the performance measure targets initially identified in the project’s work plan, as well as the results achieved by this project as reported in previous Annual Performance Reports. The targets and results achieved include all the CA and CRDA activities. To easily see whether there is a variance between the targets set and the results achieved over the life of the project, you may add the value in the Previous Results column to the results achieved this year (as recorded in the table at the beginning of this document) and note the sum in the Total Results column.

Performance Measure		**Targets** (as set out in the CA work plan)	**Previous Results** (as reported in previous APRs)	**Total Results** (previous results + results achieved this year)
1.	Number of highly qualified personnel (HQP) working on funded activities (HQP refers exclusively to current Master and PhD students)			
2.	Training/knowledge transfer events			
	2.1 Number of training/knowledge transfer events organized by the recipient	5	3	4
	2.2 Number of presentations made in training/knowledge transfer events		24	39
3.	Number of participants at training/knowledge transfer events	300	586	866
4.	Number of new knowledge transfer products developed	1	13	13
5.	Number of papers published in peer reviewed journals	5	34	41
6.	Number of new technologies (new products, practices, processes and systems) that are developed	3	5	5
7.	Number of new technologies (new products, practices, processes and systems) that are assessed under research conditions	2	15	15
8.	Number of new technologies (new products, practices, processes and systems) that are demonstrated on-farm or in-plant			
9.	Number of new technologies (new products, practices, processes and systems) that attain Intellectual Property (IP) protection. plant breeder rights	4	14	18
10.	Number of new technologies (new products, practices, processes and systems) that are utilized	4	10	15

Please provide a brief explanation of the variance for any performance measures for which the **total results achieved** are less than the target set.

4. Knowledge and Technology Transfer (KTT)

What is your target audience for sharing information about the results of your project? Describe your strategy and success in reaching this target audience.
For cultivar development and genomic selection, the target audience are seed companies (seed growers), oat growers, and oat millers. For the agronomic studies, the target audience are oat growers. Our approaches to reach them included 1) running an annual Ottawa Oat Day, 2) advertising officially supported oat cultivars through the IPO of AAFC, 3) interacting with seed companies and millers, 4) reporting to growers' meetings (MS-CSGA, AGA), and 5) testing promising lines in Quaker's oat area test. We were successful to have three of the four newly released cultivars tendered by SeCan and to have one of them approved by Quaker a preferred milling oat.

5. Gender-Based Analysis Plus (GBA+)

To the best of your knowledge, how many of the HQP who are working on the project meet the GBA+ categories outlined below? Please indicate the total number for each category. If a HQP fits in more than one category, please count them in as many of the categories as appropriate. Only indicate a number and not the names of the individuals.

	Female	Indigenous peoples	Visible minority	LGBTQ2+	Person with disability
Number of HQP	8	0	5	0	0

Annex A

Performance Measures Table	
Performance Measures	**Description**
1. Number of highly qualified personnel (HQP) working on funded activities	This only includes individuals who are registered in Master or PhD programs and are working on activities that receive funding through the Canadian Agricultural Partnership. They are only counted in their first year working on projects. For each reported HQP, please provide the following: the name of the student, level of degree, field of study and name of the academic institution.
2. Training/knowledge transfer events	
2.1. Number of training/knowledge transfer events organized by the recipient	This includes events completed in the reporting year that were organized under the project to share results of the activities with audiences who may use that knowledge in the future. Examples could include training events, scientific meetings, symposia, conferences, workshops, industry meetings, field days or webinars. Annual General Meetings do not normally qualify for this category as they are considered to be part of normal day-to-day business. For each reported item, please provide the following: name of the event, name of the organizer and organization, location, and year/month/day.
2.2. Number of presentations made in training/knowledge transfer events	This includes oral presentations and poster presentations at events that are not organized by the recipient, for example, conferences, symposiums or training events. For each reported item, please provide the following: name of presenter, title of presentation, name of the event, location, and year/month/day.
3. Number of participants at training/knowledge transfer events	This includes individuals who attend the events listed and who may use that knowledge in the future.
4. Number of new knowledge transfer products developed	New knowledge could include, but is not limited to: 1) newly acquired knowledge that differs significantly from previously acquired knowledge; 2) existing knowledge that is enhanced to meet different requirements; 3) existing knowledge that is applied in different situations. These are knowledge transfer materials created under the project that have been disseminated to transfer information to audiences who may use that knowledge in the future. Examples could include brochures, factsheets, flyers, guides, articles in trade magazines, technical bulletins and social media items. Only the number of products developed should be reported, not the number of copies that were printed and disseminated. For each reported item, please provide the following: author(s), title of the item, type of the reported item (e.g. brochure), name of the trade magazine/publisher and page number(s) if applicable, and year/month/day.

5. Number of papers published in peer reviewed journals	This includes scientific papers that are published in peer reviewed journals. Papers that are not yet published (ex. manuscripts in preparation, under review or accepted) should not be reported. For each reported item, please provide the following: author(s), year of publication, article title, title of journal, volume (issue), and page number(s). If the item is a book or a book chapter, add name of publisher. If the item is an article for conference proceedings, add title of published proceedings, location, and year/month/day.
6. Number of new technologies (new products, practices, processes and systems) that are developed	A new technology could include, but is not limited to: 1) a newly created technology that differs significantly from existing technologies; 2) an existing technology that is modified to meet different requirements; 3) an existing technology that is tested in different situations. New products are goods and services that differ significantly in their characteristics or intended uses from products previously produced and used. Examples could include equipment, software, novel foods or consumer goods. New practices are new agronomic techniques or methods that can be applied directly by producers. New processes are the set of operations performed by equipment in which variables are monitored or controlled to produce an output in labs or processing facilities. New systems are the set of detailed methods, procedures and routines created to carry out a specific activity, perform a duty, or solve a problem. Development consists of the creation of a new product, the generation of a new practice, or the demonstration of utility of a new process or system. This category does not include new varieties. New varieties are only reported under ‘Number of new technologies that attain Intellectual Property protection’ and/or ‘Number of new technologies that are utilized’. Gene sequences, breeding lines and populations are not eligible under this category. To avoid duplication, for any new technologies, only set a target that represents the last stage in the innovation process. For example, a new technology is either developed, or assessed, or demonstrated or utilized.
7. Number of new technologies (new products, practices, processes and systems) that are assessed under research conditions	See the definition of new technologies under #6. Are assessed: when new technologies are evaluated or tested under research conditions. This category does not include new varieties. New varieties are only reported under ‘Number of new technologies that attain Intellectual Property protection’ and/or ‘Number of new technologies that are utilized’. Gene sequences, breeding lines and populations are not eligible under this category.

	To avoid duplication, for any new technologies, only set a target that represents the last stage in the innovation process. For example, a new technology is either developed, or assessed, or demonstrated or utilized
8. Number of new technologies (new products, practices, processes and systems) that are demonstrated on-farm or in-plant	See the definition of new technologies under #6. Are demonstrated: when new technologies are presented to the sector by experiments, prototypes, examples or pilot on-farm or in-plant. This category does not include new varieties. New varieties are only reported under 'Number of new technologies that attain Intellectual Property protection' and/or 'Number of new technologies that are utilized'. Gene sequences, breeding lines and populations are not eligible under this category. To avoid duplication, for any new technologies, only set a target that represents the last stage in the innovation process. For example, a new technology is either developed, or assessed, or demonstrated or utilized.
9. Number of new technologies (new products, practices, processes and systems) that attain Intellectual Property (IP) protection	See the definition of new technologies under #6. Examples for IP protection could include, but are not limited to: plant breeder rights, patents filed, registered trademarks and copyrights, and registered germplasms and released varieties (excluding breeding lines and gene sequences). For each new variety, please provide the registration number, the variety name, and year/month/date.
10. Number of new technologies (new products, practices, processes and systems) that are utilized	See the definition of new technologies under #6. Are utilized: when new technologies are adopted or implemented for use within the sector. Examples may include, but are not limited to: a signed license agreement, a signed letter of intent, a new product that is available on the market, and a new practice which is adopted by farmers. Gene sequences, breeding lines and populations are not eligible under this category. To avoid duplication, for any new technologies, only set a target that represents the last stage in the innovation process. For example, a new technology is either developed, or assessed, or demonstrated or utilized.