Agriculture et Agroalimentaire Canada | Agriculture and Agri-Food Canada

AgriScience Program - Projects Component

Annual Performance Report

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	**Period Covered by the Report**: 2021/04/01 to 2022/03/31
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 the reporting period, that combines all the CA and CRDA activities. Do not include results that are not final or that will continue to be developed. It is quite possible that in the first year or two, there may not be any results to report. 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)		
2.	Training/knowledge transfer events		
	2.1 Number of training/knowledge transfer events organized by the recipient		
	2.2 Number of presentations made in training/knowledge transfer events		
3.	Number of participants at training/knowledge transfer events		
4.	Number of new knowledge transfer products developed		
5.	Number of papers published in peer reviewed journals	3	1. Yan, W. (2021). A Systematic Narration of Some Key Concepts and Procedures in Plant Breeding, 12 http://dx.doi.org/10.3389/fpls.2021.724517 2. Klos, K.E., Yimer, B.A., Howarth, C.J., McMullen, M.S., Sorrells, M.E., Tinker, N.A., Yan, W., Beattie, A.D. (2021). The

	Performance Measure	Results Achieved	Provide a brief description of each final result achieved during the reporting period.
			genetic architecture of milling quality in spring oat lines of the collaborative oat research enterprise, 10(10), http://dx.doi.org/10.3390/foods10102479 3. Yan, W., Fregeau-Reid, J., DeHaan, B., Thomas, S., Hayes, M., Martin, R., Cummiskey, A., Pageau, D., Morasse, I., Orozovic, S. and Mitchell Fetch, J., 2022. AAC Reid Oat. Canadian Journal of Plant Science, (ja). DOI:10.1139/cjps-2022-0009
6.	Number of new technologies (new products, practices, processes and systems) that are developed	3	• OA1644-13 oat (suitable for ME1 & ME3) • OA1623-5 oat (suitable for ME2) • OA1627-1 oat (suitable for ME3)
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, 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.		
10.	Number of new technologies (new products, practices, processes and systems) that are utilized	5	1. AAC Chandler (OA1568-6) 2. AAC Excellence (OA1415-2) 3. AAC Reid (OA1444-4) 4. AAC Roberval (OA1436-1) 5. AAC Stature (OA1453-2)

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

I. CULTIVAR DEVELOPMENT. 1) Three new oat cultivars were supported by registration. OA1623-5 and OA1644-13, were supported for full registration by OCCC on Jan 18, 2022. They are suitable for areas 2 and 3 of Ontario (mega-environment 1 or ME1) and the other regions of eastern Canada (Mega-environment 2 or ME2), respectively. OA1627-1 was supported for registration by PGDC on March 3, 2022. 2) Among 2nd year entries in ORDC and QC registration trials, two visually selected (VS) lines (OA1655-1 and OA1658-1) and one genomics-selected (GS) line (OA1675-1GS) showed promise. OA1655-2 was tested in WCORT and Quaker and was invited for a 2nd year test by the trial coordinators. OA1634-1 will also be tested the 2nd year in WCORT. 3) Among the 1st year entries a GS line (OA1689-10GS) and several VS lines (OA1689-3VS, OA1689-4VS, OA1689-8VS, OA1684-3) showed promise and will be tested again. (4) Lines tested in the 2021 ENCORE/Preliminary Test included a GS line, several genomics-culled (GC) lines, and two VS lines. A GC line yielded among the best while the GS line yielded intermediately. Seventeen lines, including the two VS lines, will be advanced to the 2022 Registration trials for their adaptation in ME1 or ME2. (5) Among previously released cultivars, AAC Excellence (2019) has performed very well in ME2 for yield, b-glucan, test weight, kernel weight, and groat content and showed promise to become a major cultivar; AAC Reid (2019) performed very well for yield, quality, crown rust resistance, and lodging resistances, and showed promise to become a major cultivar in ME1. (6) OA1613-5, supported for registration by OCCC in Jan 2020 but not tendered by any seed company, yielded among the best in the 2021 Quebec provincial registration trials as well as in others. **II. GENOMIC SELECTION**. In addition to what has been mentioned under Cultivar Development, (1) 252 lines were genotyped and tested in the Home Test; (2) 210 lines from three breeding programs tested in ENCORE and genotyped; (3) 120 GS lines and 40 GC lines from selected 2017 and 2018 crosses were selected using updated GS models. These lines and 120 VS lines from the same selected crosses were sent to New Zealand for seed increase. **III. AGRONOMIC STUDIES**. All agronomic studies, i.e., Exp 1 at some locations and Exp 2 and 3 at other locations, were carried out as planned prior to the growing season. Data have been collected and are under analysis. VI. **PUBLICATIONS**. Several papers were published. Among these, Tinker et al. (2022) discovered a large non-reciprocal translocation from chromosome 1C to 1A in some oat genotypes, which may have important implications on oat breeding. This paper also characterized positions of major QTL in relation to known functional candidate genes, a step toward more deterministic breeding approaches. Another paper by Yan (2021) was commented by a reviewer as “a paper that should be read by all plant breeders.” **V. PANDEMIC EFFECTS**. Reduced and delayed work workplace access in 2020 led to some broken links in 2021. For example, there was not an Observation nursery, no GS lines in the Home Test, and not many promising lines selected in the Home Test. These effects will be carried over in the next few years. Nevertheless, cultivar release will not be dramatically affected.

Summary by objective

Objective #1: Cultivar development (**Yan, Hadinezhad, MacEachern, Morasse/Telmosse, Mountain/Byker, Nilsen, Tinker, Bekele**)

- **OA1644-13** was supported for registration by OCCC. It displayed good levels of yield, groat, beta-glucan, test weight, maturity, and crown rust resistance and is most adapted to ME1. This line was also tested in the Quaker Oat Area Test and proved as a preferred milling oat. It was tendered by SeCan
- **OA1623-5** was supported for registration by OCCC. It showed high yield and β-glucan content and good levels of other breeding objectives and is most adapted to ME2. It was tendered by SeCan.
- **OA1627-1** has completed two years of test in WCORT. It yielded among the best and showed exceptionally large and plump kernels and was supported for registration by PGDC. This is the first ORDC line that was supported by PGDC. It was also tendered by SeCan.
- 25 lines were tested in the ORDC registration trials. Two 2nd-yr entries (**OA1655-1** and **OA1658-1**) showed promise. **OA1675-1GS** has been tested for two years in the QC provincial oat registration trials and demonstrated good yield and milling quality relative to official checks. **OA1655-2** and **OA1634-1** yielded well in WCORT and will be tested again. OA1655-2 and OA1658-1 were invited for a 2nd year test in Quaker OAT.
- 66 lines, including a GS line, four GC lines, and two VS lines, were tested in the Preliminary Test in conjunction with ENCORE. The GS line yielded only intermediately. One GC line yielded among the best but had low test weight. Seventeen lines including the two VS lines will be advanced to the ORDC or QC registration trials in 2022.
- 252 lines were tested in 2021 Home Test at four locations with two replicates (Ottawa, New Liskeard, Normandin QC, and Harrington PE). No GS lines were included due to reduced work in 2020.

- No regular Observation nursery was grown because no hill plot nursery was grown in 2020. However, 13 F3:4 lines derived from 5 F2 individuals from the cross 19S45 (OA1613-5/BY685), looked unexpectedly and surprisingly uniform both within and between lines and all appeared high yielding (The parent BY685 being a tall, weak, rusty Chinese naked oat line brought by Dr. Bo Zhang of China Academy of Sciences). These 13 lines will be tested for yield and adaptation in 2022.
- 77 new crosses were made in Jan 2021, which are now in F3 in the greenhouse.
- Breeder or pre-Breeder Seed was produced for OA1584-1 (AAC Zip), OA1609-7, OA1623-5, OA1644-13, OA1627-1, and OA1644-5-19. Plant Breeder's Rights (PBR) test was conducted for these lines.
- AAC Excellence released in 2019 continues to show superior yield and quality in Quebec (ME2).
- AAC Reid released in 2019 continues to show superior yield, quality, resistance to crown rust, and resistance to lodging in southern Ontario (ME10.

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 2nd year at Normandin, Yorkton, Lacombe, and Beaverlodge. However, the grain yield responses of the oat varieties were highly variable, possibly due to the extremely severe drought. To obtain more data and draw more reliable conclusions, we proposed to redo Exp. 1, instead of starting the previously planned Experiment 2, at these locations in 2022, which was supported by CFCRA.
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 found that ESN (Environmentally Smart Nitrogen) at MERN (136 kg ha^{-1}) was the best for all cultivars at the Ottawa site. Urea at MERN was equally good for Camden at Ottawa, for all cultivars at New Liskeard, and for Souris and Summit (MERN of 148 kg ha^{-1}) at Melfort. The highest yielding cultivar was Akina at Ottawa, Nicolas at New Liskeard, and Souris at Melfort. No significant benefit was found for split N applications, likely due to the dry conditions. This experiment will be repeated in 2022.
4. Experiment 3 aimed at determining the optimum seeding rate was conducted at all sites (Ottawa, New Liskeard, Normandin, Melfert, Yorkton, Lacombe, and Beaverlodge). Cultivar-specific responses to seeding rates were obvious at all sites. For example, at Ottawa, the best seeding rate was 300 seeds m^{-2} for Akina but 500 seeds m^{-2} for Nicolas. In contrast, at Beaverlodge and other western sites, the best seeding rate was 100 seeds m^{-2}, probably due to the severe drought. For locations where a quadratic response to seeding rates can be fitted, the estimated best seeding rate was 372 seeds m^{-2}. In general, the best rate was

between 300 and 400 seeds m^{-2} for the eastern sites and 200-300 seeds m^{-2} for the western sites. Exp. 3 will be repeated at all sites in 2022.

5. In the two N experiments (Exps. 1 & 2), grain yield was consistently and significantly correlated with the number of seeds per panicle. Similar correlations were also found in the density study, but the relationship was more influenced by drought. For example, a negative correlation between yield and final panicle count was observed at some western sites.
6. Quality of the samples are being determined by the quality lab.
7. More detailed analysis and writing up are under way.

Objective #3: Genomic selection (**Tinker, Bekele**)

- The Rapture-based oat genotyping assay continues to perform well. A total of 3500 training and breeding lines were genotyped in 2021.
- For the ORDC program, 3040 single seed-derived lines of selected 17S and 18S crosses were grown in the greenhouse, genotyped, and selected based GS models. 120 GS lines, 40 GC lines, and 120 VS lines were sent to New Zealand for seed increase. These lines will be tested in the 2022 Home Test.
- For the RBDC program, 80 GS lines were sent to NZ for seed increase.
- The performance of GS lines from previous cohorts has been described above under "cultivar development."

Objective #4: crown rust study (**Yan**)

- This objective was removed from the original proposal due to reduced budget. Nevertheless, a population of c. 400 individuals from the cross AAC Reid (*Pc58*?)/AAC Stature (*Pc94*) has been advanced to F6, which will be grown in the Hill nursery for selection in 2022.

Objective #5: Crown rust test and survey **(Menzies, Xue, Yan)**

- 378 new oat lines tested in HT, Preliminary, and Registration trials were screened for crown rust resistance at Ottawa ON and crown rust and smut resistance at Morden MB. There was little crown rust pressure at Morden but good disease rating was obtained at Ottawa.
- 159 fields of common and wild oats were assessed for crown rust infection in Manitoba, with 75 of these fields having crown rust infected plants. Samples were collected from crown rust infected plant in the 75 fields. Thirty samples of crown rust infected plants from 20 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.

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 4 locations and shared with all breeding programs and the genomic selection group (except the University of Saskatchewan lines).

Objective #7: Oat Data and Knowledge Management **(Wight, Tinker)**

- Participation in weekly conference calls with the T3/Oat and GrainGenes teams (USDA-ARS) continues.
- The issues with transferring pedigree data from POOL to the T3/Oat database (https://oat.triticeaetoolbox.org/) were resolved. Breeders have been asked to send their more recent pedigree data. Data from a large QTL study (Tinker et al., 2022) of five mapping populations have been added to T3/Oat (phenotypic data) and GrainGenes (genotypic data; https://wheat.pw.usda.gov/GG3/).
- Molecular genetic maps continue to be uploaded to GrainGenes as they are produced by the oat research community.
- The MS Access database created to hold all of the information regarding mapped oat genes, QTL (Quantitative Trait Loci), and RGAs (Resistance Gene Analogues) is being used to produce the final versions of the inventory, which will be presented in two different forms. A method was found not just to locate the QTL/genes on the consensus oat map of Bekele, et al. (2018), but also to align these with the most recent release of the OT3098 v2 genome sequence. This involved first finding a way to align the genetic map (2018 consensus) with the physical one (OT3098 v2).

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?

1. Some trials were not possible due to reduced work or delayed planting in 2020 in response to the COVID-19 pandemic. No Observation nursery was grown in 2021, no GS lines in the 2021 Home Test, and there were not many promising lines identified in the 2021 Home Test. These effects will be carried over to future years until next breeding cycle takes over. Nevertheless, cultivar release will not be affected as we maintain a healthy breeding pipeline. To compensate for the loss of GS work in 2020, the GS work was doubled to cover both the 2017 and the 2018 crosses.
2. Due to severe drought, Exp 1 in the Agronomic study at Normandin, Yorkton, Lacombe, and Beaverlodge varied greatly from the year-1 results. We decided to redo this experiments at these sites, in place of Exp 2, in 2022.

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. **OA1644-13** was supported for registration by OCCC. It displayed good levels of yield, groat, beta-glucan, test weight, maturity, and crown rust resistance and is most adapted to ME1. This line was also tested in the Quaker Oat Area Test and proved as a preferred milling oat. It was tendered by SeCan

2. **OA1623-5** was supported for registration by OCCC. It showed high yield and β-glucan content and good levels of other breeding objectives and is most adapted to ME2. It was tendered by SeCan.
3. **OA1627-1** has completed two years of test in WCORT. It yielded among the best and showed exceptionally large and plump kernels and was supported for registration by PGDC. This is the first ORDC line that was supported by PGDC. It was also tendered by SeCan.
4. AAC Excellence released in 2019 showed promise to become a popular milling oat in Quebec, Maritimes, and northern Ontario (ME2).
5. AAC Reid released in 2019 showed promise to become a popular milling oat in Areas 2 and 3 of Ontario (ME1).

Annex A

Performance Measures Table	
Performance Measures	**Description**
1. Number of highly qualified personnel (HQP) working on funded activities	This includes only 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.