Date Received
For Administrative Use Only

PROJECT FINAL REPORT

Instructions:

- **Please note that making changes to the project without prior written consent from the funder(s) could constitute sufficient grounds for termination of funding.**
- This report must be a stand-alone report, *i.e.,* must be complete in and of itself. Scientific articles or other publications cannot be substituted for the report.
- A signed electronic copy of this report must be forwarded to the funders' representative on or before the due date, as per the investment agreement.
- A detailed, signed statement of revenues received and expenses incurred during the entire funding period of the project must be submitted along with this report, as per the investment agreement.
- For any questions regarding the preparation and submission of this report, please contact the funders' representative.

Section A: Project overview

1. Project number: 2016F018R
2. Project title: Harvest Weed seed control in early- versus late-maturing crops
3. Abbreviations: AAFC= Agriculture and Agri-Food Canada, HWSC= Harvest weed seed control
4. Project start date: 2016/04/01
5. Project completion date: 2019/03/31

6. Final report submission date: (2019/04/15)	
7. Research and development team data	
a) Principal Investigator: (Requires personal data sheet (refer to Section 14) only if Principal Investigator has changed since last report.)	
Name	**Institution**
Breanne Tidemann	AAFC Lacombe
b) Research team members (List all team members. For each new team member, *i.e.*, joined since the last report, include a personal data sheet. Additional rows may be added if necessary.)	
Name	**Institution**
Greg Semach	AAFC Beaverlodge
Cindy Gampe	AAFC Scott
Rob Gulden	U of M, Winnipeg

Section B: Non-technical summary (max 1 page)

Harvest weed seed control (HWSC) is a new theory of weed management developed in Australia that focusses on managing weed seeds retained in the field at crop harvest that would otherwise be spread by the combine. There is interest in using HWSC methods in western Canada such as the integrated Harrington Seed Destructor, the Seed Terminator, or other HWSC methods like chaff lining. Previous research has indicated a number of good target weeds, however, our primary herbicide resistant weed in the Prairies, wild oat, has been identified as a poor target because of early seed shed. This project looked to determine if you could target a higher proportion of wild oat seed by growing early maturing crops in your rotation, compared to a normal canola-wheat rotation, or to later maturing crops. Preliminary analysis indicates that wild oat density and biomass is lowest after two years of early maturing crops with HWSC implemented. This indicates that by combining HWSC with early maturing crops, wild oat may be targetable, and therefore manageable with these techniques. This increases the suitability of HWSC for western Canada and the likelihood of adoption by Prairie producers.

Section C: Project details

1. Background (max 1 page)

Harvest weed seed control (HWSC) is a new paradigm of weed management developed in Australia (Walsh et al. 2013). It aims to manage weed seeds that are retained on the plant at the time of harvest that would otherwise be returned to the seedbank by the combine chaff spreaders (Walsh et al. 2013). There are numerous methods of HWSC including chaff carts, narrow windrow burning, chaff lining, bale direct systems, and physical impact implements including the integrated Harrington Seed Destructor and the Seed Terminator (Walsh et al. 2013, AHRI 2018). All of these methods are dependent on weed seed retention until crop harvest.

Key Canadian weeds have been measured and reviewed for their seed retention to identify good targets for harvest weed seed control methods (Beckie et al. 2018, Burton et al. 2016, 2017, Tidemann et al. 2017). Of particular interest has been wild oat due to the extensive herbicide resistance profile of the weed (Heap 2018), and the continued development of herbicide resistance through the Prairies. Seed retention measurements for wild oat have been quite low in our typical crops including wheat and fababean (Tidemann et al. 2017). This raises concern about producer interest in adopting HWSC when it will not target one of our major weeds. However, seed retention has been previously linked to Growing Degree Day (GDD) accumulation (Shirtliffe and Entz 2000, Tidemann et al. 2017). This suggests that if a crop matures and is harvested in fewer GDD, it is possible that an increased proportion of wild oat seed will be retained at the harvest timing and therefore available for management with HWSC methods.

2. Objectives and deliverables (max 1 page)

The original objective of the project was to determine the effect of early- compared to late-maturing crops on our ability to collect and remove weed seeds using harvest weed seed control methods. The objective did not change throughout the project. Anticipated deliverables were identification of rotations that allowed for increased seed collection of wild oat, and determination of swathing and straight cutting efficacy to collect weed seeds. Additional deliverables include a scientific manuscript on the results.

3. Research design and methodology (max 4 pages)

The trial was conducted at 4 locations: Lacombe, AB, Beaverlodge, AB, Carman, MB, and Scott, SK. The treatments included an early maturing crop rotation (field peas followed by winter wheat), a “normal” crop rotation (spring wheat followed by canola), and a late maturing crop rotation (fababeans followed by flax). Each treatment had the first crop grown in 2016, the second crop grown in 2017 (2016-2017 for winter wheat) and all treatments were followed by barley in 2018. For each cropping rotation there were two harvest ‘types’: swathed and straight cut. The trial was arranged as a factorial RCBD with 3 crop maturity rotations x 2 harvest ‘types’ resulting in a total of 6 treatments. Each treatment was replicated 4 times.

The trial was direct seeded with fertility applied as recommended by soil tests at each location. Herbicide applications were limited to management of broadleaf weeds; no herbicides with efficacy on wild oats were applied aside from the pre-seed burn-offs. Desiccation was allowed in the straight cut treatments ONLY if necessary, and a minimum of one week was left between swathing and applying the desiccation treatments on the straight cut treatments to ensure there was differentials in the timing of weed kill.

Important data collection parameters included wild oat population density, wild oat biomass, wild oat density in the collected chaff, and wild oat density in the soil seedbank. Additional data included crop density, crop yield and barley quality.

Data was analyzed using Proc Mixed in SAS. Data was analyzed across sites with rotation and harvest type as fixed effects and replicate nested in location as a random effect. A pdiff statement was used to retrieve least square means as well as comparisons between appropriate treatments. These statistics and the results reported below are preliminary. The

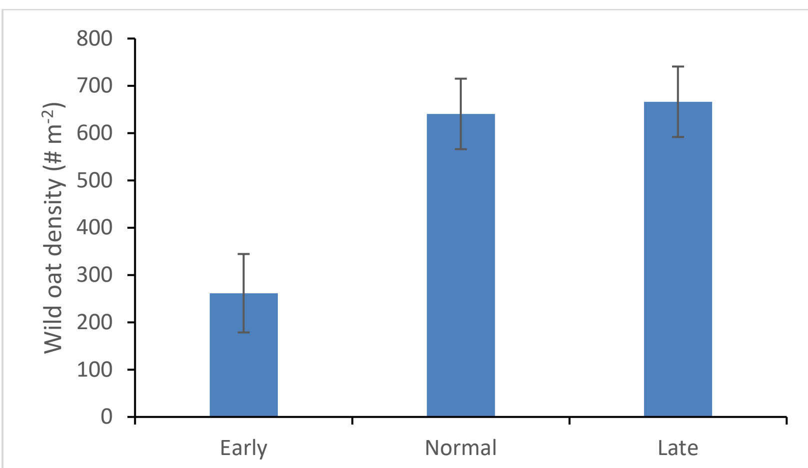
Primary Investigator is on parental leave until May at which time the data and results will be investigated and interpreted more thoroughly.

CHANGES TO THE PLANNED METHODOLOGY. Changes to the planned methodology were required at the Scott, SK location in 2017. Severe winter kill was observed on both winter wheat treatments in all replicates at that location. As a result the early maturing crop rotation was lost at that location. The trial was continued as data could still be collected on the effects of earlier maturation in comparisons of the "normal" crop maturity and the late crop maturity treatments.

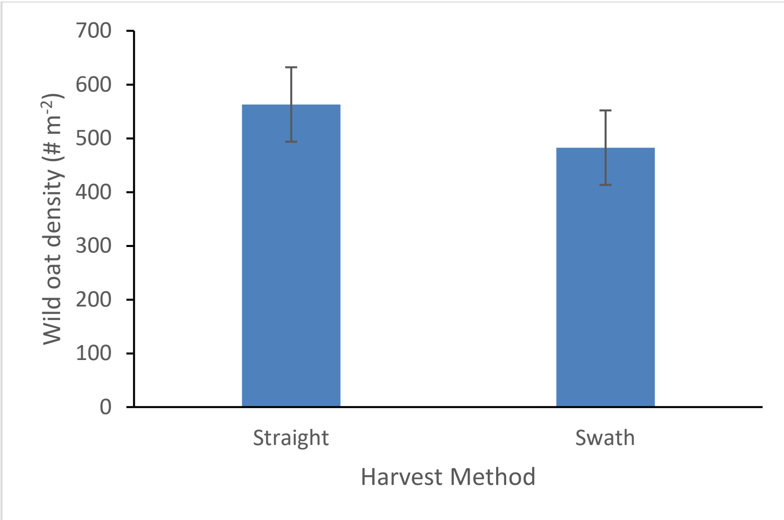
4. Results, discussion and conclusions (max 8 pages)

Only preliminary results are being presented at this point. Final statistical analysis will be conducted upon the return of the PI from parental leave.

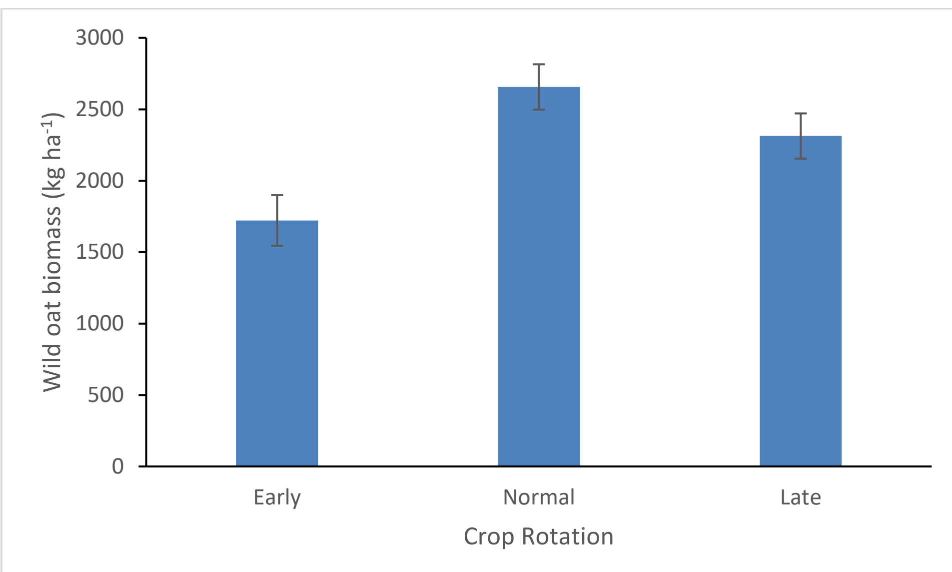
Wild oat densities were significantly affected by cropping rotation only after 3 years; harvest type did not have a significant impact. This is a change from the interim analysis where harvest type appeared to be having a bigger effect. Wild oat numbers in the barley crop grown in 2018, when analyzed across locations, were lowest in the early maturing crop rotation treatments, followed by the "normal" cropping rotation treatments and the late cropping rotation treatments having the highest wild oat density. This is in line with the initial hypothesis that early maturing crops would allow increased collection of wild oats in the chaff due to limited seed shatter at the time of harvest.



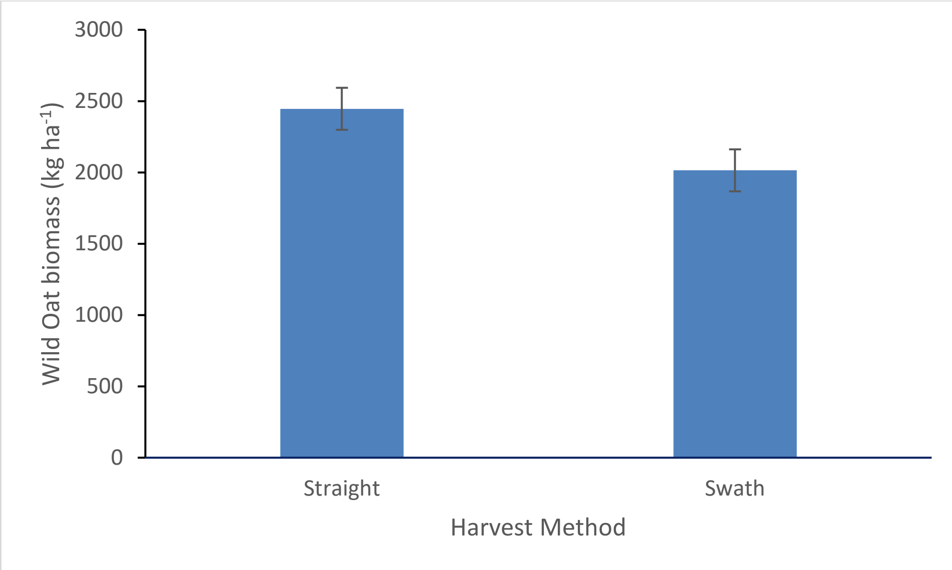
Wild oat numbers were not significantly affected by harvest method. This is interesting as in previous years the harvest method seemed to be having a larger effect than crop type. However, while not significant, across locations there were fewer wild oats counted on average in the swathed treatments. So while the difference may not be significant the absolute averages support our hypothesis that swathing would increase the number of wild oats collected, limiting populations in future years.



Wild oat dry weight biomass does not align as nicely with our initial populations as the density does. Both crop rotation and harvest method significantly affected the wild oat biomass when analyzed across locations. Wild oat biomass was lowest in the early maturing crop rotation, but highest in the "normal" crop rotation treatments. The reasoning for this is currently not clear. Further analysis and investigation into the data may reveal some logic behind these measurements.



Lower wild oat biomass was observed in the swathed treatments compared to those that had been straightcut. This agrees with the initial observation and with the wild oat numbers, although those were not significant. This indicates that wild oat biomass can be decreased through use of swathing to maintain wild oat seed retention prior to harvest.



Other data such as wild oat numbers in the chaff and wild oat seedbank have not yet been analyzed. We are in the process of confirming materials and methods with our other locations to ensure that all conversion factors used to calculate final data numbers are correct (i.e. to convert the volume of the soil corers to a wild oat density per square meter).

Preliminary analysis indicates that our initial hypotheses were correct; wild oat can become a better target for harvest weed seed control methods through the use of early maturing crop rotations and incorporation of swathing. However, these two techniques did not interact on wild oat numbers or biomass. It is likely that combining the techniques, however, would provide the best opportunity to target wild oat seeds. There are some additional data parameters that we still need to analyze, including the wild oat seed bank which may alter overall conclusions. If the seedbank is higher in the early maturing crop rotation it may indicate that management options were not as effective as the density and biomass numbers are currently indicating. This is an important final piece to the information. I apologize that we don't have the information ready for the report, however I want to ensure the data that I report is correct which is why we are taking the additional time to confirm the materials and methods and data prior to analysis. Overall, producers with a significant wild oat problem could potentially manipulate their cropping rotation and harvest methods to increase their ability to manage wild oat with harvest weed seed control. These results are still preliminary pending further statistical analysis and preparation of a scientific manuscript.

5. Literature cited

AHRI (2018) Spoiled rotten – the sequel. Published June 29, 2018. Available at https://ahri.uwa.edu.au/spoiled-rotten-the-sequel

Beckie HJ, Blackshaw RE, Harker KN, Tidemann BD (2018) Weed seed shatter in spring wheat in Alberta. Can J Plant Sci 98:107-114.

Burton NR, Beckie HJ, Willenborg CJ, Shirtliffe SJ, Schoenau JJ, Johnson EN (2016) Evaluating seed shatter of economically important weed species. Weed Sci 64: 673-682.

Burton NR, Beckie HJ, Willenborg CJ, Shirtliffe SJ, Schoenau JJ, Johnson EN (2017) Seed shatter of six economically important weed species in producer fields in Saskatchewan. Can J Plant Sci 97: 266-276.
Heap I (2018) The International Survey of Herbicide Resistant Weeds. Available at www.weedscience.com
Shirtliffe SJ, Entz MH (2000) *Avena fatua* development and seed shatter as related to thermal time. Weed Sci 48: 555-560.
Tidemann BD, Hall LM, Harker KN, Beckie HJ, Johnson EN, Stevenson FC (2017) Suitability of wild oat (*Avena fatua*), false cleavers (*Galium spurium*), and volunteer canola (*Brassica napus*) for harvest weed seed control in Western Canada. Weed Sci 65: 769-777.
Walsh M, Newman P, Powles S (2013) Targeting weed weeds in-crop: A new weed control paradigm for global agriculture. Weed Tech 27: 431-436.

6. Project team (max ½ page)

The project was led by Breanne Tidemann after the retirement of Dr. Neil Harker. Breanne led the Lacombe site which was managed by the technical staff: Larry Michielsen, Patty Reid, Elizabeth Sroka and Jennifer Zuidhof. The Beaverlodge location was led by Greg Semach. The Scott location was led by Cindy Gampe/Alick Mulenga (Alick was hired after the project was initiated). The Carman location was led by Dr. Rob Gulden and managed by his technician Rebecca Dueck.

7. Benefits to the industry (max 1 page; respond to sections *a)* and *b)* separately)

a) Describe the impact of the project results on the Alberta or western Canadian agriculture and food industry (results achieved and potential short-term, medium-term and long-term outcomes).

The results of the project indicate that it may be possible to increase the proportion of wild oat available for management by harvest weed seed control methods. This increases the viability of harvest weed seed control as a new weed management method for Canadian producers. This may increase interest in incorporating HWSC methods into production systems. In the long run, incorporation of HWSC methods could increase the usable effective lifetime of our herbicides, and reduce selection for new herbicide resistant biotypes. It may also limit the spread of current resistant biotypes that are geographically limited. The indication that swathing will increase wild oat management over straight cutting is against the current trend where producers are shifting to a higher proportion of straight cutting in their harvest methods. This indicates that producers will have to consider where weed control ranks on their priority list when making decisions about how they will proceed with harvest decisions in the future.

b) Quantify the potential economic impact of the project results (*e.g.,* cost-benefit analysis, potential size of market, improvement in efficiency, etc.).

It’s estimated that management of wild oat costs about $500 million per annum. This estimate can only have increased with increased herbicide resistance requiring more herbicides, more expensive herbicides, or additional management tactics to exert control over this weed. Being able to increase the proportion of wild oats retained at crop harvest means that a larger proportion of wild oats can be targeted with HWSC. This can help manage wild oat populations, potentially without needing to increase spending on herbicide options. Being able to manage wild oat may increase the adoption of HWSC by producers, meaning the impact will extend to numerous other weed species as well – HWSC targets any weed seeds retained in the crop at the time of harvest, not just wild oat.

8. Contribution to training of highly qualified personnel (max ½ page)

7 technical staff, and at least 12 summer students and up to 24 summer students were trained on this project.

9. Knowledge transfer/technology transfer/commercialisation (max 1 page)

Describe how the project results were communicated to the scientific community, to industry stakeholders, and to the general public. Please ensure that you include descriptive information, such as the date, location, etc. Organise according to the following categories as applicable:

a) Scientific publications (*e.g.*, scientific journals); attach copies of any publications as an appendix to this final report
The manuscript will be prepared upon the PI's return to work.

b) Industry-oriented publications (*e.g.*, agribusiness trade press, popular press, etc.); attach copies of any publications as an appendix to this final report
None

c) Scientific presentations (*e.g.*, posters, talks, seminars, workshops, etc.); attach copies of any presentations as an appendix to this final report
Scientific presentations of this project have not yet been completed as the most important data was only collected in 2018 (wild oat densities and biomass after two years of crop rotation and harvest type treatments). However, it has been referenced in numerous scientific presentations on seed retention and harvest weed seed control. As wild oat seed retention is a significant barrier to harvest weed seed control adoption in the Prairies, this project has been introduced and referenced in each of those presentations to indicate that we are aware of the concern and investigating ways to work around this barrier. The results of this project will be presented at the Canadian Weed Science Society 2019 Meeting and the Weed Science Society of America/Western Society of Weed Science 2020 Meeting, pending travel approval for the PI.

d) Industry-oriented presentations (*e.g.*, posters, talks, seminars, workshops, etc.); attach copies of any presentations as an appendix to this final report
As with the scientific presentations, industry-oriented presentations on the data collected in this project have been delayed until after the 2018 field season. The project has been referenced as mentioned above and it is expected that significant extension activities will occur in 2019 and 2020.

e) Media activities (*e.g.*, radio, television, internet, etc.)
As with the presentations mentioned above, direct extension of this project's results have been limited due to critical data being collected in 2018. It has been referenced as described above and extension efforts will be significant in 2019 and 2020.

f) Any commercialisation activities or patents
None

N.B.: Any publications and/or presentations should acknowledge the contribution of each of the funders of the project, as per the investment agreement.

Section D: Project resources

1. **Provide a detailed listing of all cash revenues to the project and expenditures of project cash funds in a separate document certified by the organisation's accountant or other senior executive officer, as per the investment agreement.**
The below spreadsheet is for the final fiscal year of 2018-2019. Expenditures for previous fiscal years has been reported in the interim reports with justification for variance in those reports. The below spreadsheet was generated by our financial officer at Lacombe.

Type	Personnel	Travel	Capital Assets	Supplies	CDL*	Other	Total:
Budgeted	$23,522.00	$3,000.00	$0.00	$17,565.00	$2,000.00	$6,913.00	$53,000.00
Spent	$11,105.49	$1,546.46	$0.00	$33,435.05	$0.00	$6,913.00	$53,000.00

2. **Provide a justification of project expenditures and discuss any major variance (*i.e.*, ± 10%) from the budget approved by the funder(s).**
Personnel costs were lower than budgeted as some student salaries were covered through other project funding. Travel and CDL costs were lower due to the PI being on maternity leave. Supply costs were higher than anticipated – this may be due to planning discrepancies between the former and current PI. This may also be associated to the inexperience of the current PI. It is expected that expenditures will be closer to budgeted in future projects. Additionally, we do not know how budget was spent for the Manitoba location, so all of their expenditures are accounted for under 'Supplies'.

3. **Resources:**
Provide a list of all external cash and in-kind resources which were contributed to the project.

Total resources contributed to the project		
Source	**Amount**	**Percentage of total project cost**

Agriculture Funding Consortium	$117,000	36.45%
Other government sources: Cash		%
Other government sources: In-kind	$204,000	63.55%
Industry: Cash		%
Industry: In-kind		%
Total Project Cost	**$321,000**	**100%**

External resources (additional rows may be added if necessary)		
Government sources		
Name (no abbreviations unless stated in Section A3)	Amount cash	Amount in-kind
AAFC Lacombe		57,000
AAFC Beaverlodge		49,000
AAFC Scott		45,000
University of Manitoba		53,000
Industry sources		
Name (no abbreviations unless stated in Section A3)	Amount cash	Amount in-kind

Section E: Research Team Signatures and Authorised Representative's Approval

The Principal Investigator and an authorised representative from the Principal Investigator's organisation of employment MUST sign this form.

Research team members and an authorised representative from their organisation(s) of employment MUST also sign this form.

By signing as an authorised representative of the Principal Investigator's employing organisation and/or the research team member's(s') employing organisation(s), the undersigned hereby acknowledge submission of the information contained in this final report to the funder(s).

Principal Investigator

Principal Investigator	
Name:	**Title/Organisation:**
Signature:	**Date:**
Principal Investigator's Authorised Representative's Approval	
Name:	**Title/Organisation:**
Signature:	**Date:**

Research Team Members (add more tables as needed)

1. Team Member	
Name:	**Title/Organisation:**
Signature:	**Date:**
Team Member's Authorised Representative's Approval	
Name:	**Title/Organisation:**
Signature:	**Date:**

2. Team Member	
Name:	**Title/Organisation:**
Signature:	**Date:**
Team Member's Authorised Representative's Approval	
Name:	**Title/Organisation:**
Signature:	**Date:**

Section F: Suggested reviewers for the final report

Provide the names and contact information of four potential reviewers for this final report. The suggested reviewers should not be current collaborators. The Agriculture Funding Consortium reserves the right to choose other reviewers. Under *Section 34* of the *Freedom of Information and Protection Act (FOIP)* reviewers must be aware that their information is being collected and used for the purpose of the external review.

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