Date Received
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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: 2017F002R
2. Project title: Long-Term Sustainable Canola Production – All Phases Rotations
3. Abbreviations: AAFC = Agriculture & Agri-Food Canada
4. Project start date: (2017/04/01)
5. Project completion date: (2020/05/31)
6. Final report submission date: (2020/05/31)

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**
Kelly Turkington	AAFC, Lacombe
Charles Geddes	AAFC, Lethbridge
Newton Lupwayi	AAFC, Lethbridge
Alick Mulenga	AAFC, Scott
Yantai Gan	AAFC, Swift Current (Now retired)
Gary Peng	AAFC, Saskatoon (Melfort)
Patrick Mooleki	AAFC, Saskatoon (Melfort) *NEW*
K. Neil Harker	Retired

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

Canola is a popular and profitable crop for Canadian farmers. The ability to profit means some farmers have increased the proportion of canola in their rotation leading to canola being grown continuously or every second year. This study was the final three years of a 12 year long study comparing yield as well as pest risks from growing canola continuously compared to every second year or every third year. The results from these three years are consistent with the results throughout the study in that canola yield increases when not grown continuously. Previously, statistics suggested that for each year out of canola there was an equal increase in yield (i.e. 5 bu/acre yield increase for each year out of canola). These final three years suggest that the yield benefit is highest moving from continuous canola to every second year (~7 bu/acre) and is less moving from every second year to every third year (~2 bu/acre). Additional exploration into the data is needed to explain why this is the case.

Weed pressures were highest in continuous canola prior to spraying, but in the canola every second year rotation post-herbicide application. Root maggot damage decreased with each year out of canola but the overall range of damage was quite low. Frequency of canola in a rotation did not impact days to crop maturity, although the Liberty Link variety matured about 1 day earlier than the RoundUp Ready variety.

Additional analyses still need to be conducted including on blackleg incidence, and quality, which was interrupted by the Covid pandemic. In addition correlation analyses will be used to determine if there is a relationship between some of the data such as weed density and yield (i.e. perhaps weed density is impacting the canola yield). Economic analysis looking at profitability of the rotations is just getting underway and analysis of microbial biomass samples is also ongoing. We will also be conducting analyses across the entire twelve year study, as well

as the final six years to look at trends and changes over the entire course of the study. There is a lot more information to be gained from this study with additional in depth statistics to be run.

The information from this study will help to identify the most sustainable ways to grow canola in terms of agronomic aspects like yield and weed pressures, but will also look at the economics involved. Key messages for producers right now is to extend the number of years between canola crops to reduce risks associated with weeds (and possible selection for herbicide resistance), insects and decreases in yield.

Section C: Project details

1. Background (max 1 page)

Canola is the largest cash crop in the Prairies with 18.6 million tonnes produced in 2019, a decrease from other recent years due in large part to poor harvest conditions (Statistics Canada 2019). With such a high value crop, many producers have tried to shorten the recommended 1 in 4 year canola rotation to 1 in 2 or, occasionally, 1 in 1. In a 2012-2014 survey of AB and SK 46% of producers were growing canola 1 in 2 years (Beckie 2016). While this may provide opportunity to maximise profit in the short term, the long term risks warranted investigation.

Short term studies have consistently shown negative yield impacts of shortening the canola rotation (Cathcart et al. 2006; Christen and Sieling 1995; Harker et al. 2012; Johnston et al. 2005; Kutcher and Brandt 2008; Sieling et al. 1997). More recently, Harker et al. (2015) in a six year study showed decreases in blackleg and root maggot incidence and consistent negative yield impacts as the number of years between canola crops decreased from 2 to 0. However, shorter term studies have not been able to consistently show yield impacts (Cathcart et al. 2006, Kutcher et al. 2013); longer term studies are needed to clearly demonstrate the impact of short-rotation canola. The Harker et al. (2015) study was continued through 2016. Preliminary analysis at that time indicated an average yield increase of 5 bushels per acre for each year of a non-canola crop in rotation (up to two years between canola crops). Since not all treatments were fully completed at that time, this project aimed to run the study for an additional three years. The study ran for a complete 12 years, the longest term continuous canola study that the study participants are aware of. This allows us to look at long term risks of continuous or short rotation canola in terms of yield, but also additional impacts such as insect and disease issues, as well as an economic analysis.

2. Objectives and deliverables (max 1 page)

Short term objectives:

- Identify the impact of continuous or short rotation canola on yield and pest pressures
- Identify the impact of continuous or short rotation canola on soil health

Long term objectives:

- Identify the economic impact of growing canola continuously or in short rotations, and the sustainability of such rotations
- Educate producers on the most sustainable rotations in which to grow canola

3. Research design and methodology (max 4 pages)

This project was a continuation of a long term rotational trial that was initiated in 2008. Rotations include canola 1-in-1, -2, and -3 years of the rotation and consider all sequences of the multi-year rotations. One rotation is a diversified 3 year rotation, so the true rotation only repeats after a 6-year cycle (see treatment 13). Direct seeded no-till experiments were conducted at the original five sites (Lacombe, and Lethbridge, AB< and Scott, Swift Current and Melfort, SK). The treatment list is below – this particular project provided funding for the 2017-2019 field seasons.

Trt #	YBC	2008	2009	2010	2011	2012	2013	2014	2015	2016	*2017*	*2018*	*2019*
1	**0**	LL	LL	LL	LL	LL	LL	LL	LL	LL	***LL***	***LL***	***LL***
2	**0**	RR	RR	RR	RR	RR	RR	RR	RR	RR	***RR***	***RR***	***RR***
3	**1**	LL	W	LL	W	LL	W	LL	W	LL	***W***	***LL***	***W***
4	**1**	W	LL	W	LL	W	LL	W	LL	W	***LL***	***W***	***LL***
5	**1**	RR	W	RR	W	RR	W	RR	W	RR	***W***	***RR***	***W***
6	**1**	W	RR	W	RR	W	RR	W	RR	W	***RR***	***W***	***RR***
7	**2**	LL	P	B	LL	P	B	LL	P	B	***LL***	***P***	***B***
8	**2**	P	B	LL	P	B	LL	P	B	LL	***P***	***B***	***LL***
9	**2**	B	LL	P	B	LL	P	B	LL	P	***B***	***LL***	***P***
10	**2**	RR	P	B	RR	P	B	RR	P	B	***RR***	***P***	***B***
11	**2**	P	B	RR	P	B	RR	P	B	RR	***P***	***B***	***RR***
12	**2**	B	RR	P	B	RR	P	B	RR	P	***B***	***RR***	***P***
13	**2***	Len	W	LL	P	B	RR	Len	W	LL	***P***	***B***	***RR***

YBC = Years Between Canola (Trt. #13 is a more diverse 2 YBC rotation)
LL = Liberty Link Canola
RR = Roundup Ready Canola
W = Spring Wheat
P = Field Peas
B = Spring Barley
Len = Lentils

The Liberty Link (LL) canola variety used from 2017-2019 was L241C, and the Round-up Ready (RR) variety was 75-42(CR). These varieties were seeded at 150 seeds m^{-2} each spring while peas were seeded at 100 seeds m^{-2}, cereals at 300 seeds m^{-2}, and lentils at 140 seeds m^{-2}. Fertilizer rates were determined by soil sample analysis for each rotational phase. Pre-seed burn-off each spring was a tank mix of glyphosate at 900 g a.e. ha^{-1} and bromoxynil at 330 g ai ha^{-1}. In Lacombe, Authority (sulfentrazone) was applied prior to pea treatments to allow for

management of group 2 resistant cleavers. LL canola treatments were treated with recommended rates of liberty and Select for in-crop weed control, while RR canola treatments received a recommended rate of RoundUp. Peas and lentils received Solo, Assure and Merge, while in Lacombe Viper ADV +UAN was used to manage group 2 resistant cleavers in peas. Cereal herbicides were dependent on weeds present. For example Lacombe used Pixxaro A+B with Axial and Adigor to manage broadleaves (cleavers in particular) and grass weeds.

Data collection included crop emergence counts 2-3 weeks after emergence with 2 rows x 1m in 2 spots counted per plot. Weed density counts prior to in-crop herbicide were conducted in a staked 0.5 m^2 area. In non-canola treatments weed densities included broadleaves, grasses and volunteer canola. Volunteer canola were not separated out in canola treatments due to difficulty differentiating weeds and crop. Weed densities were repeated in the same marked area 3-4 weeks after the final in-crop herbicide application herbicides. Soil microbial diversity was sampled in treatments 1, 2, 4, 6, 8, 11 and 13 when the canola was at 50% bloom. Insect assessments were done on canola phase treatments for flea beetles, sweep net captured insects, root maggots, and cabbage seedpod weevil at Lethbridge and Swift Current (if insecticide was applied for them). Weed biomass was measured at maturity. Days to maturity was determined at 60% colour change. Crop yield was collected and measured using a plot combine. Surveys were conducted at all sites to determine if assessments were necessary for black spot and sclerotinia. Roots sent for root maggot damage were also assessed for blackleg incidence and severity as well as for clubroot. After harvest cleaned grain samples were evaluated for % oil and protein.

In addition to sampling conducted for this original project, additional microbial sampling was conducted for an add-on project for Dr. Chantal Hamel (AAFC) and PRS probe sampling for Dr. Bobbi Helgason for an add-on CARP project. Results of those projects are not reported here, but will also be completed soon and add to the full story behind the project. Economic analyses will also be done for this project and are being worked on by Dr. Emma Stephens (replaced Dr. Elwin Smith upon his retirement from AAFC).

Preliminary data analysis was conducted in SAS 9.4. using Proc Mixed. A mixed models ANOVA was run both across and by locations for yield, weed densities (pre- and post- in-crop spray), maturity and cabbage root maggot damage by treatment. In addition, mixed models ANOVA was conducted across and by location for the same data, but only for those treatments in canola and based on the variety and the number of years out of canola. Linear and quadratic regression contrasts were used to determine if linear or quadratic regressions were appropriate to describe the response of the data variable with increasing years in the rotation out of canola. Additional analyses will be conducted prior to the writing of the final paper but this allowed examination of the most important data of the study. Additional analyses may include incorporation of data collected across all 12 years of the study, correlation analyses to tease out possible explanatory relationships, as well as analyses of quality data not presented here (oil and protein).

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

YIELD: When averaged across site-years yield had a quadratic relationship with years between canola. This matches the original hypothesized relationship where the biggest yield increase is moving from continuous canola to canola every second year, and a small increase moving from canola 1 in 2 to canola 1 in 3. Yield increased from 2007 kg/ha in continuous canola to 2385 kg/ha with canola 1 in 2 and 2500 kg/ha with canola 1/3 (see Figure 1A in the appendix). In bushels per acre yield increased by about 7 bu/acre from continuous canola to canola 1 in 2, and an additional 2 bu/acre from canola 1 in 2 to 1 in 3 (Figure 1B). When investigating site-years individually there were equal numbers of quadratic and linear responses with increasing years between canola crops, however, one linear relationship was a linear decrease in yield with increasing years out of canola (data not shown). There were 5 site-years with no relationship between yield and years out of canola: Lethbridge 2018, Melfort 2017 and 2018, Scott 2019 and Swift Current 2018. In site-years with a relationship between yield and years out of canola, yield increased from continuous to 1 year out of canola (canola 1 in 2). The yield difference between canola 1 in 2 and canola 1 in 3 either increased, plateaued or, in some cases, decreased. Overall, continuous canola, with one exception, consistently showed the lowest yield out of the rotations. Variety was not a significant factor on the yield trend across site-years. Where individual site-years had a significant variety effect the main effects was overall yield amount, while the trend with years out of canola was typically quite similar. Interestingly, compared to Harker et al. (2015) yields in the last 3 years for the continuous canola rotation seem to have declined – further analyses need to be conducted to look at the overall trend of yield across the entire twelve year study period.

WEED DENSITIES: Across site-years there is a significant decrease in weed density prior to in-crop spraying as there are increased years between canola crops. Each year out of canola results in ~17 fewer weeds per square meter (Figure 2). This differs from Harker et al. (2015) where the highest weed densities were found in the 1 year out of canola rotations. This may be linked to the long-term impacts of the rotation and will warrant additional investigation and thought during preparation of the manuscript. Dominant weed species varied by site-year and will also be subjected to additional in-depth analyses prior to the preparation of the manuscript. Post-spraying weed densities peaked with 1 year between canola crops (canola 1 in 2) (Figure 3). This is likely related to the ability to identify volunteer canola plants as volunteers in a subsequent non-canola crop compared to continuous canola. Because of the relatively short seed-bank of canola, there would be fewer volunteers after two years between canola than with one year between canola. Post-spray weed densities were not reported in Harker et al. 2015 and so further investigation into changes over time within the study must be carried out during manuscript preparation. Variety was not a significant effect on weed densities pre or post spray. Effects of rotation and variety at individual site-years was highly variable, as were the weed densities associated with each site-year.

MATURITY: Crop maturity was not related to years between canola crops when averaged across site-years. Variety was a significant factor with the Liberty Link variety requiring ~1 extra day to mature compared to the Roundup Ready variety. The effects of rotation frequency appear to have very limited if any impact on days to maturity (data not shown).

CABBAGE ROOT MAGGOTS: Cabbage root maggot damage was significantly affected by both variety and years between canola crops. The LL variety showed slightly less damage than the RR variety (Figure 4). Both showed decreasing damage with increasing years between canola crops, however the differences were biologically very small and likely insignificant in terms of contributing impact on plant health or yield. Overall the impact of room maggots was quite low (damage rating of 1.6-1.8 on a 0-5 scale). Across all site-years damage never rated higher than a 2.5 out of 5 on the assessment scale. This is in contrast to assessments done in earlier years of the study where a bigger range of damage was observed (Harker et al. 2015, Dodsdall et al. 2012). Damage has not continued to increase as first observed by Dodsdall et al. 2012, and has in fact decreased slightly since that paper. The reason for this is unclear and may warrant further investigation and collaboration with entomologists.

There is still significant analysis to be done on this study including multi-variate analyses, and analyses incorporating the first 9 years of the study. Additional correlation analyses will be conducted to determine the strength of correlations between collected data such as weed densities and yield. It will be interesting to hear the results of two add-on projects from soil scientist colleagues as well as these may help provide explanations for some of the yield results we are observing. The economic analysis can only be conducted now that the field seasons are completed. The intention was to initiate the economic analysis this spring however it has been delayed due to working through the Covid-19 crisis. There is a lot of intriguing information from this study and it will take time to sift through all of it for the most important outcomes. Once a manuscript has been prepared it will also be shared with Alberta Canola and Western Grains Research Foundation.

5. Literature cited

Beckie, H.J. 2016. State of weed resistance in western Canada and future outlook. Herbicide Resistance Summit Presentation, March 2, 2016. Saskatoon, SK.

Cathcart, R. J. et al. 2006. Rotation length, canola variety and herbicide resistance system affect weed populations and yield. Weed Sci. 54: 726-734.

Christen, O. and Sieling, K. 1995. Effect of different preceding crops and crop rotations on yield of winter oil-seed rape (*Brassica napus* L.). J. Agron. Crop Sci. 174: 265-271.

Dodsdall, L.M. et al. 2012. Crop sequence effects on root maggo (Diptera: Anthomyiidae: *Delia* spp.) infestations in canola. J Econ Ent 105: 1261-1267.

Harker, K. N., et al. 2012. High-yield no-till canola production on the Canadian Prairies. Can. J. Plant Sci. 92:221-233.

Harker, K. N., et al. 2015. Canola rotation frequency impacts canola yield and associated pest species. Can J. Plant Sci. 95: 9-20.

Johnston, A. M. et al. 2005. Impact of crop sequence decisions in the Saskatchewan Parkland. Can. J. Plant Sci. 85: 95-102.

Kutcher, H. R., and Brandt, S. A. 2008. Optimizing Canola Production: Pest Implications of Intensive Canola Rotations. Final Canola Agronomic Research Program Report to the Canola Council of Canada. 39 pp

Sieling, K., et al. 1997. Effects of previous cropping on seed yield and yield components of oil-seed rape (*Brassica napus* L.). Eur. J Agron. 6: 215-223

Statistics Canada 2020. Production of principal field crops, November 2019. Accessed May 19, 2020. Available online: https://www150.statcan.gc.ca/n1/dailyquotidien/191206/dq191206b-eng.htm

6. Project team (max ½ page)

K. Neil Harker – Dr. Harker was the project lead until his retirement in December of 2017. Dr. Harker will be involved in manuscript preparation.

Breanne Tidemann: Dr. Tidemann took over as project lead upon Dr. Harker's retirement and was also the Lacombe site lead. She is responsible for data analysis and leading the manuscript preparation.

All below team members will also participate in manuscript preparation and submission.
Charles Geddes: Dr. Charles Geddes is the Lethbridge site lead.
Alick Mulenga: Mr. Mulenga is the Scott site lead.
Yantai Gan: Yantai Gan was the Swift Current site lead until his retirement in 2019.
Gary Peng: Dr. Peng was the Melfort site lead until 2019 when he passed responsibility for the site to Dr. Mooleki.
Patrick Mooleki: Dr. Mooleki became the Melfort site lead in 2019.
Kelly Turkington: Dr. Turkington is responsible for disease assessments on the project.
Newton Lupwayi: Dr. Lupwayi led sampling for microbial data which he will be analyzing and writing a manuscript on or contributing a section to the main manuscript.

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

a) These results, and the results to come from additional analyses help to identify the highest yielding and most sustainable way of growing canola, which is in rotation. Ideally this will lead to more farmers extending the time between canola within their rotations. This would be beneficial for the impacts on yield, insects and weeds described above, but would also be beneficial for industry concerns such as clubroot. Future analyses may also highlight important information (i.e. if there is in fact a trend to declining yields in the continuous canola rotation). There is so much data available that the biggest benefits may not have yet been identified due to not being complete all analyses. The results of the economic analysis will be critical to determining level of adoption of longer term rotations as a results of data from this study (whether it's

economically beneficial) or whether other pressures force producers to longer rotations (e.g. clubroot).

b) The economic impact is difficult to quantify as it will be more of a long term impact in sustainability than any short term economic gains for the industry. This project can aid in encouraging producers to grow canola in the most sustainable way possible resulting in a healthy and vibrant canola industry for many years, as well as potentially increasing acres of rotational crops in the future.

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

Each location would have had a number of personnel working on this project. In Lacombe there are 4 technicians, and 3-4 summer students each year. We also hired casual or term employees in the fall that would assisted with harvest sample processing and quality analyses. Similar numbers would have been involved at each of the locations. There were no PDF's or graduate students involved with 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
Publications are now in preparation. Copies of publications will be forwarded to Alberta Canola and Western Grains Research Foundation once they are completed.

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
Now that final data is available scientific presentations will start. With the COVID-19 pandemic travel plans and conferences are very uncertain, but tech transfer will be a goal of this fall. An invitation to present at the Agronomy Research Update in Saskatoon has recently been received. The presentation is currently tentative pending what happens with COVID and when travel approvals resume.

d) Industry-oriented presentations (*e.g.*, posters, talks, seminars, workshops, etc.); attach copies of any presentations as an appendix to this final report
This trial was presented at the Western Applied Research Corporation Field Day in Scott Saskatchewan by Dr. Tidemann in July of 2019. Additional industry-oriented presentations will be conducted as analyses are completed and as travel and interaction are permitted after the Covid-19 pandemic.

e) Media activities (*e.g.*, radio, television, internet, etc.)

Media activities will be ongoing as data analyses are complete and as publications are completed. We expect to engage with ag media forums such as Top Crop Manager, Real Agriculture, Canadian Agronomist and Canola Watch as final results and analyses are available.

f) Any commercialisation activities or patents

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.** Revenues should be identified by funder, if applicable. Expenditures should be classified into the following categories: personnel; travel; capital assets; supplies; communication, dissemination and linkage (CDL); and overhead (if applicable).
2. **Provide a justification of project expenditures and discuss any major variance (*i.e.*, ± 10%) from the budget approved by the funder(s).**
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	$240,000	%52.37
Other government sources: Cash		%
Other government sources: In-kind	$218,250	%47.63
Industry: Cash		%
Industry: In-kind		%
Total Project Cost	**$458,250**	**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
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).
Attached as a separate document.

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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