Date Received
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Full Research Project Final Report

- 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.
- One electronic copy and one signed original copy are to be forwarded to the lead funding agency on or before the due date as per the investment agreement.
- A detailed, signed income and expenditure statement incurred during the entire funding period of the project must be submitted along with this report. 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; and overhead (if applicable).
- For any questions regarding the preparation and submission of this report, please contact ACIDF

Section A: Project overview

1. Project number: 2013F109R
2. Project title: Improving Sclerotinia disease control in edible beans and canola
3. Research team leader: Michael Harding
4. Research team leader's organisation: Alberta Agriculture and Forestry
5. Project start date (yyyy/mm/dd): 2013/04/01
6. Project completion date (yyyy/mm/dd): 2017/03/31
7. Project final report date (yyyy/mm/dd): 2017/08/18

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

Diseases caused by *Sclerotinia sclerotiorum* are an important production constraint to many crops in Alberta. Fungicides are important management tools for control of *S. sclerotiorum*. This project evaluated the potential for improvement in Sclerotinia disease control in two ways; 1) improvement of fungicide efficacy using trace element tank mix partners, and 2) activation or enhancement of host resistance. These methods have been reported to be effective in some situations (Kataria and Sunder, 1985; Kurt *et al.*, 2003; Campagna and Brignoli, 2005; Worrall *et al.*, 2012).

Phase 1 involved screening for synergies between combinations of foliar-applied trace elements (Ag, Bo, Ca, Cu, Mn, Zn) and currently registered fungicides (boscalid, fluazinam, penthiopyrad, picoxystrobin, ciprodnyl, fludioxinil). This screening took a biofilm approach (Harding *et al.*, 2011) and used a novel, high throughput biofilm reactor and standard method (ASTM E2799-11) to test 324 treatment combinations and identify the top ten candidates for field testing. Phase 2 involved field testing of the top 10 most effective combinations. Two of the fungicides (fluazinam and cyprodinil) were very responsive to the addition of at least one of the trace elements tested. The results demonstrated that trace elements such as $CuSO_4$, $AgNO_3$ and $ZnSO_4$ can improve the efficacy of some fungicides versus *S. sclerotiorum* biofilms. While the mechanism is not characterized, the effect is similar to that seen with metallic complexes of antibiotic drugs (Uivarosi, 2013).

Evaluations of activators of plant resistance applied to seed have also been previously reported (Worrall *et al.*, 2012). This experiment evaluated four compounds that had been reported to activate or enhance resistance when applied to seed to see if there was any improvement in control of Sclerotinia diseases. One of the resistance activators (Heads Up®) reduced white mold on dry bean in three of eight site years, and had the highest yield in 5 of 8 site years. This product has been rapidly and universally adopted by the industry and is already a standard treatment on all dry bean seed used in Alberta. Unfortunately the effect was only observed on dry bean, but not on canola.

Section C: Project details

1. Project team (max ½ page)

Describe the contribution of each member of the R&D team to the functioning of the project. Also describe any changes to the team which occurred over the course of the project.

Dr. Amin Omar was responsible for the biofilm cultivation and high throughput testing of the 324 fungicide/trace element combinations. His work was critical to the early success of the project. The biofilm testing identified the most promising combinations that were then used in field trials done with fungicides + trace elements.

Dr. Syama Chatterton was a key team member for the entire project. She was instrumental in developing the proposal, she coordinated the dry bean field trials at Lethbridge and was an advocate and spokesperson for the project and results.

While not strictly team members on the proposal, it is necessary to acknowledge Drs. Sheau-Fang Hwang, Kan-Fa Chang and Jie Feng at the Crop Diversification Centre North. Drs. Hwang and Chang helped with coordination of the canola field plots in Edmonton, and Dr. Feng presented the project results at the Canadian Phytopathology Meetings in 2017 on my behalf.

Finally, technical advice and seed from Viterra's Alberta Bean Division, Bayer CropScience and Pioneer HiBred is gratefully acknowledged.

Background (max 1 page)

Describe the project background and include the related scientific and development work that has been completed to date by your team and/or others.

This project was designed to evaluate non-traditional methods for improving control of Sclerotinia diseases. The objectives of this proposal were: 1) high throughput screening of synergistic interactions between existing fungicides (boscalid, fluazinam, penthiopyrad, picoxystrobin, ciprodnyl, fludioxinil) and plant micronutrient ions (Ag, Bo, Ca, Cu, Mn, Zn) for efficacy against *S. sclerotiorum* biofilms; 2) field evaluations of most promising fungicide/micronutrient combinations against white mold in dry bean, and stem rot in canola, and 3) field evaluations of activators of plant resistance Heads Up®, jasmonic acid (JA), ß-aminobutryric acid (BABA), and acibenzolar-S-methyl (ASM) for control of white mold and stem rot. Deliverables included: 1) Ranking of fungicide efficacies against biofilms of *S. sclerotiorum* and white mold (dry bean) and stem rot (canola), 2) rankings of plant resistance activators for controlling white mold (dry bean) and stem rot (canola), 3) information on any synergistic interactions between registered fungicides and micronutrient fertilizers.

The first approach was combining foliar-applied micronutrients, containing the trace elements Ag, Bo, Ca, Cu, Mn, Zn, with currently registered fungicides (boscalid, fluazinam, penthiopyrad, picoxystrobin, ciprodnyl, fludioxinil). Some preliminary results had suggested that some micronutrient solutions added to fungicides may improve efficacy (M. Harding, unpublished). Due to the high number of treatment combinations, an *in vitro* laboratory component preceded the fungicide field trials. A biofilm approach to perform *in vitro* screening was used that allowed for rapid, high throughput screening. Additionally, this approach was more likely to predict performance in the field because biofilms are the predominant form of microbial growth in natural and agricultural environments, and they are known to have increased tolerance to treatments when compared to the planktonic forms normally grown in laboratory cultures (Harding *et al.*, 2009; Harding *et al.*, 2017b).

The second method was to evaluate the ability of seed-applied plant resistance activators in small-plot, replicated field trials to control sclerotinia diseases. Field evaluations of the plant activators were done in years 1-4. There were a few known activators of plant resistance that were reported to be effective when applied to seed, namely; Heads Up®, jasmonic acid (JA), ß-aminobutryric acid (BABA), and acibenzolar-S-methyl (ASM). The field evaluations assessed the feasibility of fungicide/micronutrient mixtures, and resistance activators, for control of Sclerotinia diseases on bean and canola. All small-plot, replicated trials were arranged in a randomized, complete block design with four replicate blocks. Field evaluations were done at two locations for white mold on dry bean (Brooks, AB and Lethbrdge, AB), and two locations for stem rot on canola (Brooks, AB and Edmonton, AB). Analyses of variance and statistical separations of means were performed for all field trials.

Objectives and deliverables (max 1 page)

State what the original objective(s) and expected deliverable(s) of the project were. Also describe any modifications to the objective(s) and deliverable(s) which occurred over the course of the project.

The objectives of this proposal were: 1) high throughput screening of synergistic interactions between existing fungicides (boscalid, fluazinam, penthiopyrad, picoxystrobin, ciprodnyl, fludioxinil) and plant micronutrient ions (Ag, Bo, Ca, Cu, Mn, Zn) for efficacy against *S. sclerotiorum* biofilms; 2) field evaluations of most promising fungicide/micronutrient combinations against white mold in dry bean, and stem rot in canola, and 3) field evaluations of activators of plant resistance Heads Up® (chenopodium extracts/saponins), jasmonic acid (JA), ß-aminobutryric acid (BABA), acibenzolar-S-methyl (ASM) for control of white mold and stem rot.

Deliverables included: 1) Ranking of fungicide efficacies against biofilms of *S. sclerotiorum* and white mold (dry bean) and stem rot (canola), 2) rankings of plant resistance activator for controlling white mold (dry bean) and stem rot (canola), 3) information on any synergistic interactions between registered fungicides and micronutrients.

2. Research design and methodology (max 4 pages)

Describe and summarise the project design, methodology and methods of laboratory and statistical analysis that were actually used to carry out the project. Please provide sufficient detail to determine the experimental and statistical validity of the work and give reference to relevant literature where appropriate. For ease of evaluation, please structure this section according to the objectives cited above.

High throughput laboratory screening of fungicide efficacies vs. *S. sclerotiorum* biofilms was done using a multi-well plate assay system known as the MBEC® Assay. This powerful assessment technique was developed by Innovotech, an Alberta-based company. Dr. Amin Omar at Innovotech coordinated the work with the MBEC® Assay. The assay is an ASTM standard method (E2799-11) for evaluation of anti-biofilm potential. This method had been used successfully to culture and evaluate microbial biofilms formed by other plant pathogenic microbes (Harding et al, 2010; 2011; 2015; 2017a). Briefly, *S. sclerotiorum* biofilms were grown in YMB pH=7.4 using the MBEC® Assay as described by Harding et al (2011). The fungicides were prepared at three concentrations (0.5 x, 1x and 2x the manufacturers' recommended rates) and mixed separately with each micronutrient at one of three concentrations for a total of 324 treatment combinations. After biofilms were mature, they were challenged with each of the 324 treatment combinations (in triplicate). Survival of fungal cells within the biofilm was quantified by detection of live cells using a Resazurin cell viability assay. A standard curve was created using a serial dilution of a concentrated culture that had been quantified using a haemocytometer. To each dilution, 100µL of resazurin solution was added and read at A_{595} (λ_{max} for Resazurin). From this, the linear equation of absorbance vs. CFU was calculated. The extinction for resazurin coefficient was calculated from the data in the linear region of the graph. Biofilms were exposed to the fungicide for 24 hours in 300uM resazurin. After the fungicide treatment, quantification was done using a microplate reader at 595 nm. The log recovery was calculated as:

$$\textit{Log Recovery} = \ln\left(\frac{A595}{0.0018}\right)/1.190$$

The Log reduction of cells within the biofilm was calculated as:

Log_{10} recovery (growth control) – Log_{10} recovery (test).

Field evaluations of the plant resistance activators were performed in years 1-4 at two locations for beans and two locations for canola. White mold on dry bean and stem rot on canola were evaluated as disease incidence and severity where incidence was measured as the percent plants with symptoms in each subplot and severity was estimated using a 0-5 scale (Johnston *et al.*, 2005) in each subplot. The evaluations were done in small-plot, replicated trials arranged in a randomized, complete block design with four replicate blocks. ANOVA and appropriate statistical separations of means was performed.

Field evaluations of fungicides/ micronutrient combinations was done in years 2-4 at the same locations as the plant resistance activators. The top ten combinations (based on the MBEC® Assay results from year one) were used to determine which of the 324 combinations to include in the field trials. White mold on dry bean and stem rot on canola were measured using the same protocol as described for the plant resistance activators (above).

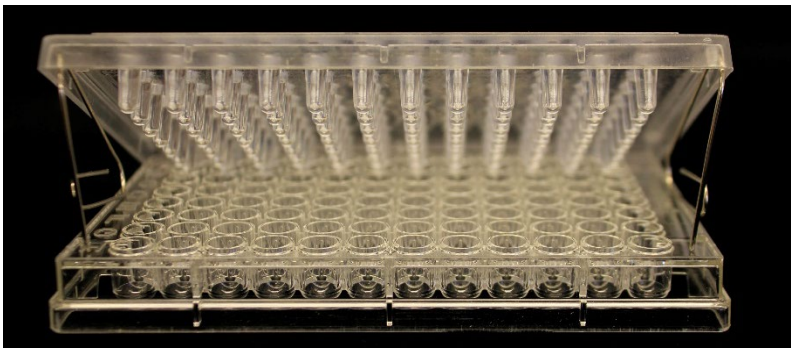


Figure 1. The MBEC Assay plate.

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

Present the project results and discuss their implications. Discuss any variance between expected targets and those achieved. Highlight the innovative, unique nature of the new knowledge generated. Describe implications of this knowledge for the advancement of agricultural science. For ease of evaluation, please structure this section according to the objectives cited above.

NB: Tables, graphs, manuscripts, etc., may be included as appendices to this report.

Objective 1: High throughput screening of synergistic interactions between existing fungicides (boscalid, fluazinam, penthiopyrad, picoxystrobin, ciprodnyl, fludioxinil) and plant micronutrient ions (Ag, Bo, Ca, Cu, Mn, Zn) for efficacy against *S. sclerotiorum* biofilms.

Results: top-ten combinations of fungicides + micronutrients

Fungicide (concentration) + micro	=	log reduction
Fluazinam (1.67mg/mL) + CuSO4	=	3.64
Cyprodinil (1.0 mg/mL) + CuSO4	=	1.87
Fludioxonil (1.83 mg/mL) + AgNO3	=	1.87
Boscalid (2.7 mg/mL) + AgNo3	=	1.86
Cyprodinil (1.0 mg/mL) + MnSO4	=	1.54
Fludioxonil (1.83 mg/mL) + CuSO4	=	1.54
Fluazinam (1.67mg/mL) +AgNO3	=	1.43
Boscalid (2.7 mg/mL) + CuSO4	=	1.24
Picoxystrobin (1.1 mg/mL) + AgNO3	=	1.23
Penthiopyrad (1.49mg/mL) + CuSO4	=	1.18

Objective 2: Field evaluations of most promising fungicide/micronutrient combinations against white mold in dry bean, and stem rot in canola.

Results:	Beans	Canola
2016	Boscalid+$AgNO_3$ and Cyprodinil+$CuSO_4$ [1]	Cyprodinil+$CuSO_4$ [2]
2015	Ciprodinil+$MnSO_4$ [1]	no data[3]
2014	Boscalid+$MnSO_4$ and Cyprodinil+$AgNO_3$ [1]	Boscalid+$MnSO_4$ [1]

[1] no statistically significant differences between treatments
[2] insufficient disease pressure at site #2
[3] insufficient disease pressure at both sites

Objective 3: field evaluations of activators of plant resistance [chenopodium extracts (saponins), jasmonic acid (JA) and/or ß-aminobutryric acid (BABA), acibenzolar-S-methyl (ASM)] for control of white mold and stem rot.

Results:	Beans	Canola
2016	Heads Up® and Methyl Jasmonate [1]	Acobezolar-S-Methyl[2]
2015	Heads Up® [1,2]	no data[3]
2014	Acibenzolar-S-Methyl and Methyl Jasmonate [1]	ß -Aminobutanoic acid [1,2]
2013	ß -Aminobutanoic acid [1,2]	no data[3]

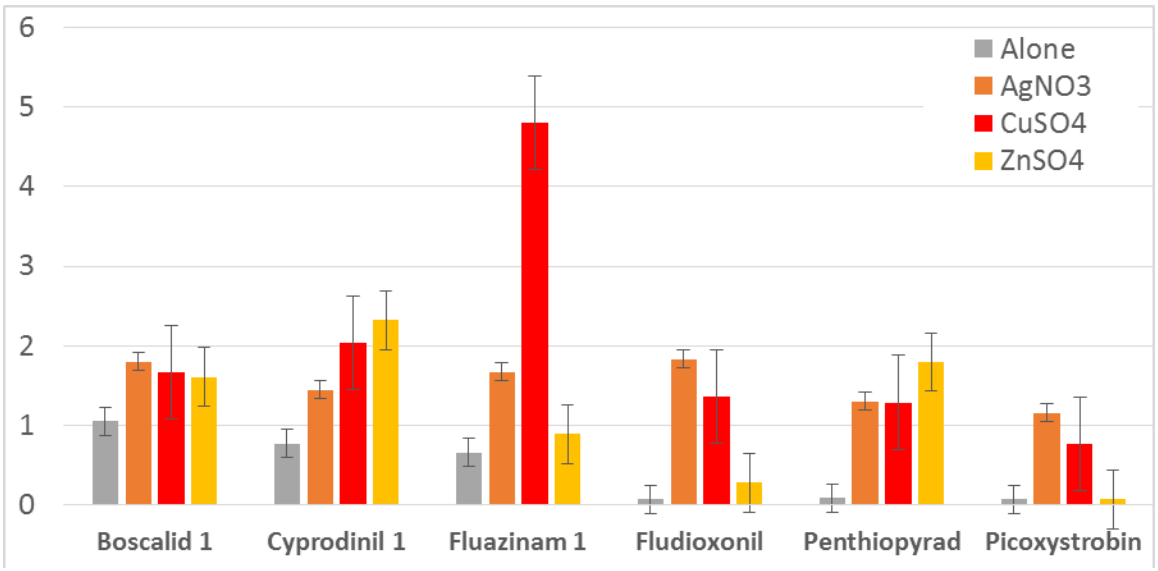
[1] no statistically significant differences between treatments
[2] insufficient disease pressure at site #2
[3] insufficient disease pressure at both sites

Deliverables:

1) Ranking of fungicide efficacies against biofilms of *S. sclerotiorum* and white mold (dry bean) and stem rot (canola).
    - See results for Objective 1 above

2) rankings of plant resistance activator for controlling white mold (dry bean) and stem rot (canola)
    - Heads Up® was the best at reducing white mould in dry bean for 3 out of 8 site years, and methyl jasmonate was best for 2 out of 8 dry bean site years. Heads Up® had the highest seed yield for dry bean in 5 of 8 site years.
    - Acibenzolar-S-methyl and ß -Aminobutanoic acid were best at reducing stem rot on canola and 3-Aminobutanoic acid had the highest yields in 4 out of 8 site years.

3) Information on any synergistic interactions between registered fungicides and micronutrient fertilizers.
    - Fluazinam activity was the most responsive to the addition of micronutrient, and was greatly enhanced in its ability to reduce *S. sclerotiorum* biofilms. For example, efficacy went from 1-log (90% reduction) when used alone, to more than 4-logs (99.99% reduction) when $CuSO_4$ was added. It was also responsive to $AgNO_3$.
    - Cyprodinil was the next most responsive, and its activity was increased with $AgNO_3$, $CuSO_4$ and $ZnSO_4$.



Log reduction values of *Sclerotinia sclerotiorum* biofilms treated with fungicides alone, or in combination with three trace elements. Error bars represent the standard error of the mean.

Additional Findings:

1. Sclerotinia incidence and severity was consistently reduced in a cultivar with a Sclerotinia-tolerance trait. In fact, Sclerotinia tolerance was the most predictable and consistent tool for reducing stem rot on canola (more consistent than resistance activators and foliar fungicides). However, the reductions in Sclerotinia did not always have highest yields.

Year	Cultivar	DI (%)	DS (0-5)	Yield (kg/ha)
2016	46M34[1]	31	1.44	5089.5
2016	45CS40[2]	12	0.57	4952.3
2015	no data			
2014	45H29[1]	16	0.7	4924.2
2014	45S52[2]	7	0.26	4167.2

[1] No Sclerotinia tolerance
[2] Sclerotinia tolerance trait

2. Water quality (pH) did not significantly affect the efficacies of foliar fungicides for control of white mold on dry bean (not shown).

3. There were no statistically significant differences in efficacies of seven foliar fungicides registered for control of white mold on dry bean (not shown).

4. Year (weather) had the most significant effect on *S. sclerotiorum* disease.

4. Literature cited

Provide complete reference information for all literature cited throughout the report.

Harding, M.W., Olson, M.E., Marques, L.L.R., and Howard, R.J. 2011. Biology and management of microbial biofilms on plant surfaces. In: *ISHS Acta Horticulturae 905: International Symposium on Biological Control of Postharvest Diseases: Challenges and Opportunities.* M. Wisniewski, S. Droby (eds). ISHS, Leuven, Belgium. ISBN: 978 90 6605 357 1

Uivarosi, V., 2013. Metal complexes of quinolone antibiotics and their applications: an update. *Molecules*, *18*(9), pp.11153-11197.

Kataria, H. R. and Sunder, S. (1985), Effect of micronutrients on the efficacy of fungicides against Rhizoctonia solani on cowpea seedlings. Pestic. Sci., 16: 453–456.

Kurt, S., Dervis, S., and Sahinler, S. (2003), Sensitivity of Verticillium dahlia to prochloraz and prochloraz-managanese complex and control of Verticillium wilt of cotton in the field. Crop Protection, 22(1):51-55.

Campagna, G. and P. Brignoli. (2005). The use of coadjuvants in tank mix with fungicides in order to improve their effectiveness even at low dosages. Central European Agriculture, 6(4): 603-610

Worrall, D., Holroyd, G. H., Moore, J. P., Glowacz, M., Croft, P., Taylor, J. E., Paul, N. D. and Roberts, M. R. (2012), Treating seeds with activators of plant defence generates long-lasting priming of resistance to pests and pathogens. New Phytologist, 193: 770–778.

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

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

Two of the fungicides (fluazinam and cyprodinil) were very responsive to the addition of at least one of the trace elements tested. The results demonstrated that trace elements such as CuSO4, AgNO3 and ZnSO4 can improve efficacy. Additionally, activators of plant resistance applied to seed for control of Sclerotinia diseases were also able to improve control of Sclerotinia diseases. While the mechanism is not characterized, the effect is similar to that seen with metallic complexes of antibiotic drugs (Uivarosi, 2013). Additionally, one of the resistance activators reduced white mold in three of eight site years, and had the highest yield in 5 of 8 site years. This product has been universally adopted by the industry and is now a standard treatment on all dry bean seed used in Alberta and providing disease prevention and improved yields for the dry bean industry in Alberta.

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

Dry edible beans in Alberta are grown on approximately 50,000 acres each year. Yields frequently reach 2500 to 3000 lbs/acre and can be valued at $0.35/lb. This means there is currently a potential farm gate value of $52,000,000/year for dry beans. Heads Up® provided a 10% yield increase in some years which means that there is a potential $5 million per year economic benefit from this product.

The tank mixing of trace elements had a smaller incremental benefit, but a 1% improvement in white mold control would provide over $2 million in canola yield savings annually. (a conservative provincial average of 35 bu/ac was assumed, and 10% of the yield potential was lost to stem rot, the resulting loss is approximately 17.5 million bu/yr which currently represents more than $227 million lost to stem rot each year).

Taken together, these values indicate that the results from this research project are already producing up to $5 million dollars per year for dry bean growers, and the potential to protect an additional $2 million per year if the fungicide/micronutrient tank mix synergies can be exploited.

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

Specify the number of highly qualified personnel (e.g., students, post-doctoral fellows, technicians, research associates, etc.) who were involved in the project.

Technicians and summer students at AF
Ms. Sharon Lisowski
Mr. Greg Daniels
Mr. Dustin Burke
Ms. Carol Pugh
Mr. Arvind Gill
Ms. Vivian Gietz
Mr. Blake Hill

7. 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. 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

One in preparation.

b) Industry-oriented publications (*e.g.*, agribusiness trade press, popular press, etc.) attach copies of any publications as an appendix to this final report

https://pulse.ab.ca/research/evaluating-foliar-fungicides-controlling-sclerotinia-white-mould-dry-bean-crops/

c) Scientific presentations (*e.g.*, posters, talks, seminars, workshops, etc.)

M.W. HARDING, R.J. HOWARD, D.A. BURKE, S.L.I. LISOWSKI, G.C. DANIELS, C.A. PUGH. 2015. Survey of Dry Bean Field Demonstrations for Sclerotinia White Mold. Plant Pathology Society of Alberta Annual General Meeting, Lethbridge Research Centre, Lethbridge, Alberta, Canada, November 16-18, 2015

Harding, M.W., D.A. Burke, S.L.I. Lisowski, C.A. Pugh. 2013. Field evaluations of `resistance priming`as a strategy for controlling sclerotinia. Proceedings of the 34th Plant Pathology Society of Alberta Annual Meeting, Brooks, AB. November 4-6, 2013.

Harding, M.W., G.C. Daniels, M.J. Unruh, A. ElHadrami. (2012). Alternative strategies for controlling Sclerotinia white mold in dry edible bean. Proceedings of the 33rd Annual Meeting of the Plant Pathology Society of Alberta. Lloydminster, AB. November 5-7, 2012 (Oral Presentation).

D.A. BURKE, M.W. HARDING G.C. DANIELS, C.A. PUGH and T.B. HILL. (2017). Efficacy of chemical fungicides against white mold of dry edible bean in southern Alberta. Meeting of the Plant Pathology Society of Alberta. Drumheller, AB. November 6-9, 2017 (Oral Presentation).

d) Industry-oriented presentations (*e.g.*, posters, talks, seminars, workshops, etc.)

Harding, M.W., S. Chatterton, S.F. Hwang, C.F. Chang. 2017. Sclerotinia survey and improving sclerotinia disease control. 2017 Canola Science-O-Rama. Lacombe, AB, April 5, 2017

Harding, M.W., R.J. Howard, S.L.I. Lisowski, S. Chatterton, S.F. Hwang and K.F. Chang. 2014. Research Update: Fungicides for the control of white mould. Viterra's Alberta Bean Division Growers Meetings. Burdett, AB. February 4, 2014 and Taber, AB. February 5, 2014.

Harding, M.W. and R.J. Howard. 2013. Important diseases of canola and pulses. MNP`s Farm Management Club, Lethbridge, AB. January 9th, 2013.

Orchard, D. and M.W. Harding. Canola diseases: blackleg, sclerotinia and clubroot. Lacombe County Diseases of Canola Information Meeting, Gilby, AB. February 11, 2013.

Harding, M.W.. 2013. Using fungicides to manage dry bean diseases. Viterra – Alberta Bean Division Production Meeting, Taber, AB February 25, 2013.

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

Clark Stork. 2013. Sclerotinia poses problems for producers. Discover Humboldt, March 26, 2013.

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.

Section D: Project resources

1. ***Statement of revenues and expenditures:***
   a) ***In a separate document certified by the organisation's accountant or other senior executive officer, provide a detailed listing of all cash revenues to the project and expenditures of project cash funds.*** *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; and overhead (if applicable).*

Please see attached financial report

   b) ***Provide a justification of project expenditures and discuss any major variance (i.e., ± 10%) from the budget approved by the funder(s).***

A much higher amount of government in-kind support was brought to support this project than was originally estimated. This meant that only $297,566.46 of the $372,247.00 estimated budget was needed.

2. 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**
Funders	297,566.46	65.8%
Other government sources: Cash		%
Other government sources: In-kind	114,553.05	25.4%
Industry: Cash		%
Industry: In-kind	40,000	8.8%
Total Project Cost	**452,119.51**	**100%**

External resources (additional rows may be added if necessary)		
Government sources		
Name (only approved abbreviations please)	Amount cash	Amount in-kind
Industry sources		
Name (only approved abbreviations please)	Amount cash	Amount in-kind

Section E: The next steps (max 2 pages)

Describe what further work if any needs to be done.

a) *Is new research required to deal with issues and opportunities that the project raised or discovered but were not dealt with within the current project?*

There have been a few compounds identified over the past 5 years that disrupt biofilms or biofilm formation. These compounds have not been tested as tank mix partners with fungicides and may have potential to improve efficacy.

Most of the canola work was done using seed already treated. It is possible that the commercial treatments on seed were inhibitory to resistance activators. The canola work should be repeated using untreated seed.

b) *Is there related work that needs to be undertaken to continue advancement of the project technology or practice?*

No

c) *Did the project identify any new technology or practice that needs to be developed?*

Yes…Heads Up® treatment, and it is already registered and adopted by the dry bean industry.

d) *What suggestions do you have that increase commercial use of results by farmers and/or companies. These may be:*

1. commercial uptake:
   Heads Up® is already used on 100% of the dry bean seed coming into Alberta.
   further research toward commercial use:
   Heads Up® is already used commercially on beans. The product was not effective on canola, but perhaps testing on other pulse crops (peas, lentils, soybeans) may be useful.
2. extension and information disbursement.
   Dry bean seed is already treated when bean producers acquire it, so there is no additional extension needed.

Section F: Research Team Signatures and Employers' Approval

The team leader and an authorised representative from his/her 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 representatives of the research team leader'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).

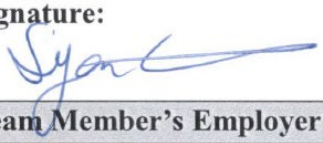
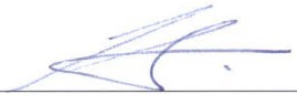
Team Leader's Organisation

Team Leader	
Name: Michael Harding	**Title/Organisation:** Research Scientist/Alberta Agriculture and Forestry
Signature:	**Date:** 24-Nov-2017
Team Leader's Employer's Approval	
Name: David Feindel	**Title/Organisation:** Director, Pest Surveillance Section/Alberta Agriculture and Forestry
Signature: David Feindel	**Date:** Nov. 27/17

Research Team Members (add more lines as needed)

1. Team Member	
Name: AMIN OMAR	**Title/Organisation:** Chief Operating Officer
Signature:	**Date:** 24 - NOV. 2017
Team Member's Employer's Approval	
Name: AMIN OMAR	**Title/Organisation:** Chief Operating Officer.
Signature:	**Date:** 24 - NOV. 2017

Research Team Members (add more lines as needed)

1. Team Member	
Name: **Syama Chatterton**	**Title/Organisation:** **Research Scientist/AAFC**
Signature: 	**Date:** **November 27, 2017**
Team Member's Employer's Approval	
Name: **Francois Eudes**	**Title/Organisation:** **Director Research Development Technology/AAFC**
Signature: 	**Date:** NOV 2 7 2017

APPENDICES

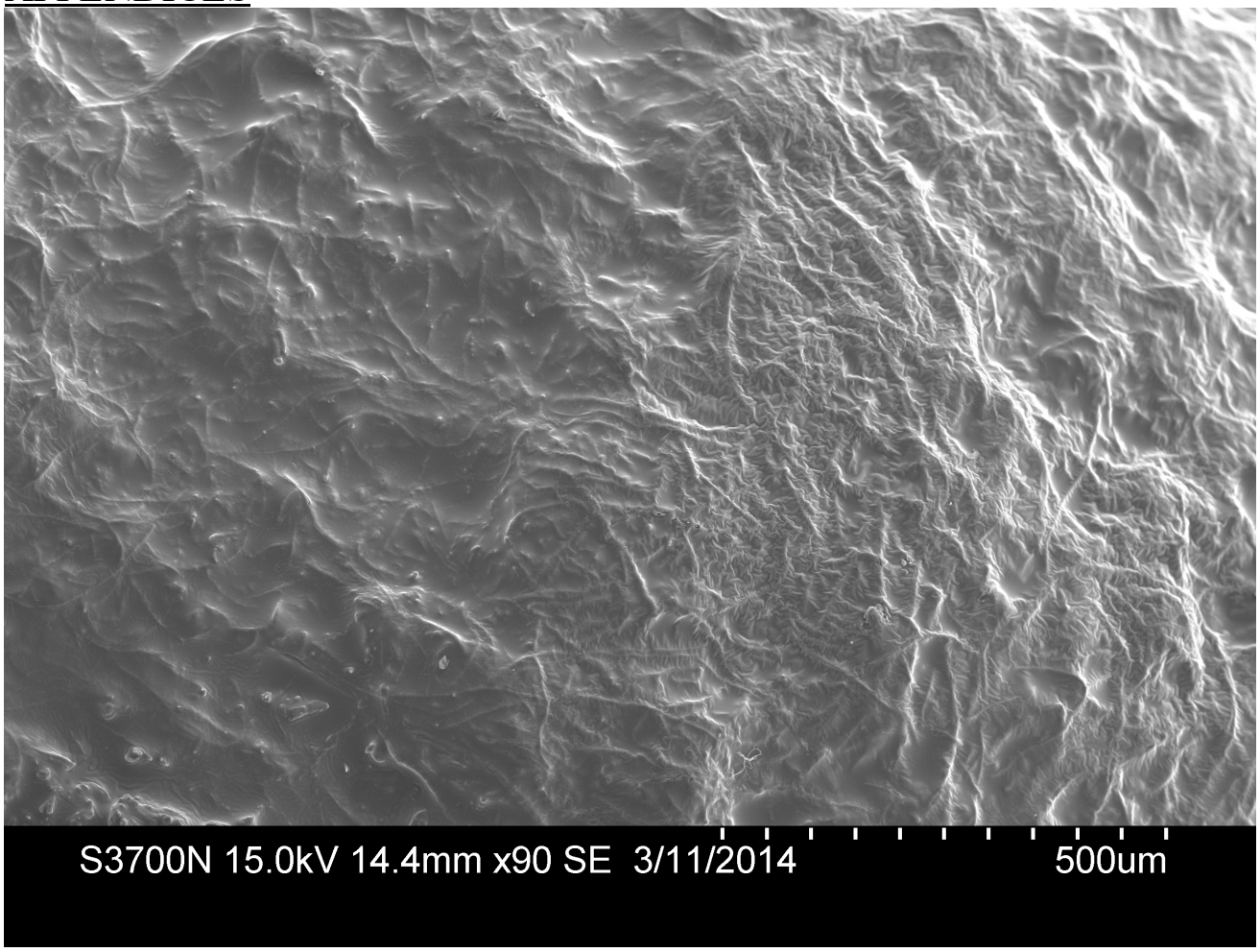


Figure 1. Sclerotinia biofilm on MBEC® plate

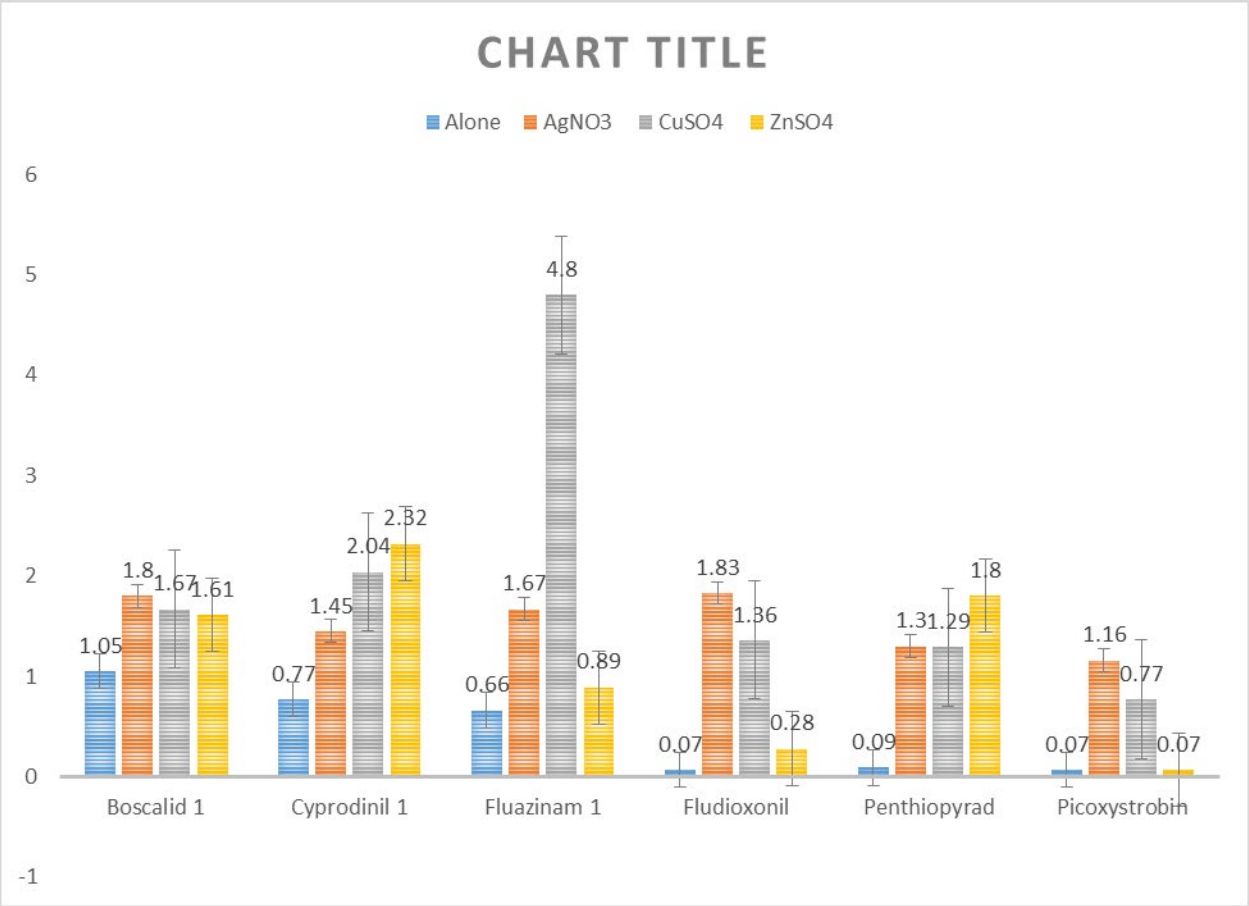


Figure 2. Efficacy (log reduction) of six fungicides, alone or tank mixed with one of three micronutrients, versus *Sclerotinia sclerotiorum* biofilms.

Figure 3. Irrigated bean plots in 2015.

Figure 4. Irrigated bean plots under new linear irrigation system in 2016.