Farm Innovation Program (FIP)

Final Reporting Templates

The FIP Agreement, Schedule "C" Reporting and Claim Requirements, outlines the specific submission dates for your project reports.

Please note that the Knowledge Transfer Plan and Translation section may require input from both the commodity association and the researcher, if both parties are undertaking knowledge transfer activities.

(Add additional rows if needed)

Farm Innovation Program - Final Report

Please note that the final payment for projects will not be released until a final report has been submitted and accepted by the AAC. Final Reports must be a minimum of two pages and should answer all of the questions outlined below and be **submitted by the completion date of the project and/or no later than December 1st, 2012.**

Applicant Name:	Fresh Vegetable Growers of Ontario
Project Title:	Cooperative Plant Pathology across the Vegetable Spectrum
FIP Project Number:	1086
Reporting Period:	October 1, 2009 – October 1, 2012
Date of Submission:	October 1, 2012
AAC Program Coordinator:	

Executive Summary

This project was a collaborative effort between the Fresh Vegetable Growers of Ontario, University of Guelph & Michigan State University to provide growers in Ontario with effective disease management tools and strategies and to increase the knowledge base for diseases caused by water molds (oomycetes) including *Phytophthora capsici* (cucurbits, peppers, and tomatoes), *Phytophthora asparagi* (asparagus), and *Pseudoperonospora cubensis* (cucurbits); these pathogens are common to both growing regions.

The University of Guelph through this project has evaluated new technologies that are coming available to growers in order to predict disease outbreaks and identify the most effective (and environmentally friendly) management methods. Some of these methods include resistant or tolerant varieties, reduced risk fungicides, biofungicides and cultural control methods. The registration of these new materials will also be essential to maintain the competitiveness of the sector, because competitors in the United States will have access to these new products. Demonstrating the effectiveness of the new technologies will accelerate the pace of uptake and adoption. The trials will be conducted in the growing area where they will be utilized so the research will be the most relevant to the industry.

Field trials to evaluate new fungicides for the control of onion smut were established in order to determine their effectiveness at controlling onion smut. Through this project RANCONA (ipconazole) at rates of 100, 150 and 250 mg a.i./100g seed was identified as a potentially effective seed treatment. PRO-GRO at 2000 mg a.i./100g seed was not as effective as RANCONA but still had significantly less smut losses than the untreated check. Effective biofungicides were studied and examined to determine their control of onion white rot, and the sclerotia of the fungi that cause botrytis leaf blight and sclerotinia rot of carrot. This was completed first in laboratory screenings and then tested in field trials for 2011 and 2012. Through this project CONTANS has been identified as a potential biofungicides as well as *Trichoderma atroviride* A, *Trichoderma atroviride* B, and *Microspaeropsis ochracea.* In order to determine the carrot cultivars that are most resistant to cavity spot, and to evaluate reduced risk fungicides for control of cavity spot field trials were established in 2010-2012. An effective fungicide to control cavity spot was not identified in 2010 or 2011, but results in 2012 may identify an effective option. Cavity spot tolerant cultivars were identified through this project and may lead to many resistant breeding lines. Field trials to evaluate reduced risk fungicides for the control of sclerotinia rot of carrot in comparison to trimming of the carrot foliage were carried out over the 3 years of the project. Trials at the Muck Station as well as large-scale replicated trials were carried out in 2010 and 2011 at the Muck Crops Research Station and three grower field sites. Trimming in combination with reduces risk fungicides and ELEXA-4 was found to be an effective way to control sclerotinia infection in the field. This technology is currently available to Holland Marsh carrot growers who can immediately utilize this management practice. Club root of Brassicae vegetables field trials were carried out in 2010, 2011 and 2012. Separate trials were established to identify the most resistant and best quality cultivars of cabbage and napa cabbage. Trials were also conducted to identify the most effective biofungicides and reduced risk fungicides for clubroot control. MYCOSTOP, SERENADE, PRESTOP and RANMAN reduced clubroot incidence while PRESTOP and RANMAN reduced clubroot severity. Varieties Kilatron, Tekila, Kilaherb, and Kilaxy were also evaluated on muck soils and found to be resistant to clubroot infection. The target audience of this project was the growers of onions (200 growers), carrots (250 growers), and Brassica vegetables (200 growers) in Ontario. This group was reached though the 14 reports, 10 presentations, poster, and two scientific abstracts associated with this project.

Effective disease management is one of the biggest challenges for vegetable growers. Good disease management is essential for high yields, top quality and consistent product. This research has provided information and tools to improve disease management on root, bulb and Brassica vegetables in Ontario in order to preserve Ontario's competitive and innovative agricultural sector

Michigan State University goals of this project were to identify the similarities or differences of isolates of each pathogen between the two growing regions, genetically type the isolates, indentify possible chemical resistance to fungicides, and to build an efficacy data base for registered and newly discovered fungicides. Isolates of each pathogen were collected by researchers at Michigan State University and tested for virulence, genetic diversity, population dynamics and resistance to mefenoxam. Twenty different active ingredients of oomycete fungicides were tested on all three diseases in replicated studies over two different growing seasons. New application methods for the fungicides were tested to determine if soil-directed applications via drip irrigation, crown soaks, or transplant drenches would be more effective than fungicides applied to the foliage. Data were also collected regarding cultural disease management strategies and included determining the susceptibility of squash to fruit rot at varying stages of maturity.

A vast collection of isolates representing each pathogen was created and can be used as a baseline for future comparative studies to determine if there is a genetic shift in local populations within the sampled regions. Several effective active ingredients were discovered for each disease and vegetable production system. The research clearly determined that soil-directed applications of fungicides were more effective in limiting disease caused by the soilborne pathogen *Phytophthora capsici*.

Research findings were published in scientific journals and proceedings. Dozens of oral presentations were made to growers and peers within the agricultural community. The research was the basis for the recommendations regarding disease control that were communicated at meetings, grower visits, twitter and facebook updates, and by postings on the University website.

Additional collaboration between the two growing regions will assist in increasing the access to important data regarding pathogen virulence, fungicide sensitivity, unregistered fungicides, and new application technology and therefore decrease the risk to growers and processors when growing susceptible vegetables.

Detailed Description of the Project

1. Identify overall project objectives reached:
The use of innovative new technologies for improving management of diseases of root and bulb vegetables and Brassica vegetables was accomplished by:

1. Effective biofungicides were studied and examined to determine their control of onion white rot, and the sclerotia of the fungi that cause botrytis leaf blight and sclerotinia rot of carrot. Through this project CONTANS has been identified as a potential biofungicides as well as *Trichoderma atroviride* A, *Trichoderma atroviride* B, The biofungicide *Microspaeropsis ochracea* was not as effective as the others.

2. New reduced risk fungicides were examined to determine their effectiveness at controlling onion smut. Through this project RANCONA (ipconazole) at rates of 100, 150 and 250 mg a.i./100g seed was identified as an effective seed treatment. PRO-GRO at 2000 mg a.i./100g seed was not as effective as RANCONA but still had significantly less smut losses than the untreated check.

3. The control of cavity spot of carrots was improved through identifying carrots with reduced susceptibility to cavity spot and determining the most effective reduced risk fungicides for control of cavity spot. An effective fungicide to control cavity spot was not identified in 2010 or 2011, but results in 2012 may identify an effective option. Cavity spot tolerant cultivars were identified through this project and may lead to may resistant breeding lines.

4. The control of sclerotinia rot of carrot with reduced risk fungicides, biofungicides and timed trimming of the carrot canopy. Trimming in combination with reduced risk fungicides and ELEXA-4 was found to be an effective way to control sclerotinia infection in the field. The trimming technology is currently available to Holland Marsh carrot growers who can immediately utilize this management practice.

5. Reduced risk fungicides and resistant varieties for management of clubroot of Brassica vegetables were identified through this project. MYCOSTOP, SERENADE, PRESTOP and RANMAN reduced clubroot incidence while PRESTOP and RANMAN reduced clubroot severity. However, none of the biofugicides reduced clubroot enough to be economically viable. Varieties Kilaton, Tekila, Kilaherb, and Kilaxy were also evaluated on muck soils and found to be resistant to clubroot infection. Resistant cultivars were much more effective than fungicides and biofungicides

The increased knowledge base for diseases caused by water molds on cucurbits, peppers, tomatoes and asparagus was accomplished by:

6. Isolates were collected and research regarding the phenotypic characteristics were determined

7. Genetic diversity and population structure of *Phytophthora capsici* and *pseudoperonospora cubensis* were determined.

8. Efficacy trials were conducted to evaluate existing and newly discovered fungicides for the control of *P. capsici, Phytophthora asparagi,* and *Ps. cubensis*

2. Identify <u>all activities</u> undertaken to reach the project objectives (link these activities to the Milestone Performance as per Schedule "B" Part III of the Agreement):

1. Field trials to evaluate new fungicides for the control of onion smut were completed in 2010, 2011, and 2012. Insecticides to control onion maggot were included in this trial because the fungicides must be compatible with insecticides on the seed and there must be no phytotoxicity. These replicated trials were repeated for 3 years.

2. Field trials were established in 2010-2012 to determine the carrot cultivars that are most resistant to cavity spot. Separate field trials to evaluate reduced risk fungicides for control of cavity spot were also completed. These replicated trials were repeated for 3 years.

3. Field trials to evaluate reduced risk fungicides for the control of sclerotinia rot of carrot in comparison to trimming of the carrot foliage were carried out over the 3 years of the project. New fungicides and biofungicides for control of sclerotinia rot were evaluated at a more intensely managed replicated trial at the Muck Station. Large-scale replicated

trials were carried out in 2010 and 2011 at the Muck Crops Research Station as well as at three grower field sites. These demonstration trials on growers' fields were carried out through matching funds from the AAFC Risk Reduction program.

4. Club root of Brassicae vegetables field trials were carried out in 2010, 2011, and 2012. Separate trials were established to identify the most resistant and best quality cultivars of cabbage and napa cabbage. Separate trials were also conducted to identify the most effective biofungicides and reduced risk fungicides for clubroot control. This was conducted in 2011 and 2012, since funds for 2010 had been approved through a previous FIP application.

5. Field trials to further test the most effective biocontrols for the pathogens that cause onion white rot and botrytis leaf blight were conducted in 2011 and 2012.

Laboratory Trials.

1. Laboratory assays were conducted to screen for biocontrols that attack the sclerotia (overwintering form) of the pathogens that cause onion white rot, botrytis leaf blight and sclerotinia rot of carrot. The products CONTANS, *Trichoderma atroviride* A, *Trichoderma atroviride* B, were found to be most effective and were then tested in the field. The biocontrol *Microspaeropsis ochracea,* was not as effective as the others.

6. Study the virulence, phenotypic characteristics, genetic diversity and population structure of isolates of (a) *Phytophthora capsici* and (b) *Phytophthora asparagi* collected from Canada and compare with the current collection maintained at Michigan State University**.** Researchers determined the virulence and phenotypic diversity of 124 *P. capsici* isolates from 12 countries (Australia, Brazil, Cameroon, India, Italy, Japan, Korea, Mexico, Norway, Peru, Spain, Taiwan, Thailand, Uruguay, and United States). To assess isolate virulence, pickling cucumber, zucchini, tomato, and pepper fruits were inoculated using 6-mm-diameter agar plugs of *P. capsici*, incubated in clear plastic boxes at room temperature (~26ºC and 100% relative humidity). Virulence was estimated by measuring the lesion diameter three (cucumber, zucchini) or four (tomato, pepper) days later. To determine phenotypic variation within *Phytophthora capsici*, isolates were characterized for sporangial length and width, pedicle length, oospore diameter, sporangia and chlamydospore production, and growth at 32, 35, and 38°C. Sporangia, pedicle, and oospore size was measured using a compound microscope and optical micrometer. Chlamydospore production was assessed after 3 weeks incubation in liquid medium. Sporangial production was assessed by measuring the number of sporangia that formed on a 7-day-old agar culture of each isolate. Genetic diversity and population structure were determined from 255 *P. capsici* isolates from six continents and 21 countries worldwide (Australia, Brazil, Cameroon, Chile, China, France, Guatemala, India, Indonesia, Italy, Japan, Korea, Mexico, Norway, Peru, Spain, Taiwan, Thailand, Uruguay, United States, the former Yugoslavia) representing 26 host species. Isolates were genotyped for four mitochondrial and six nuclear loci and Bayesian clustering, split networks, and statistical parsimony genealogies were used to discover population structure. Genetic differentiation and diversity estimates were calculated for isolates grouped by geography, host of origin, mating type, and mefenoxam sensitivity. Population structure was also determined for isolates grouped by these factors. Unfortunately, we were not able to establish collaboration with colleagues in Canada to receive Canadian isolates of *Phytophthora capsici* so no Canadian isolates were included in these studies.

To determine virulence of *Phytophthora asparagi* in the region, 6 isolates were tested over time on D-Anjou pears and Braeburn apples that were wounded and inoculated with 8-mm V8 agar plugs. An uninoculated control group was also wounded and covered with sterile V8 agar plugs. The fruits were incubated in aluminum trays covered in clear plastic wrap at room temperature (about 25°C) with moist paper towels to maintain high relative humidity. Lesion area was measured 3, 5, 7, and 9 days after inoculation.

The research findings collected in this section of the activities were linked to Milestones (5, 10, and 13) that included technology transfer at the 2010 and 2011 Great Lakes Expo held in Grand Rapids, MI, USA via poster presentations. This Expo is well attended by growers from Canada. The data from this work was also presented at the *Phytophthora* and Downy Mildew Workshop held on 1 February, 2012 at the Southwest Research and Extension Center in Benton Harbor, MI. Three publications were also generated from research findings from this objective.

7. Study the genetic diversity and population structure of *Pseudoperonospora cubensis* isolates collected from diseased cucurbit hosts in Canada and compare with the current DNA collection maintained at Michigan State University. *Pseudoperonospora cubensis* (*Ps. cubensis*) sporangia were collected from single lesions on diseased cucurbit leaves in both Canada and Michigan cucurbit growing regions. In 2011, twenty-five leaves were collected from each Michigan cucumber field (in Allegan, Berrien counties, Frankenmuth, and the Plant Pathology Research Farm and the MSU Muck Soils Research Center) and sporangia from two lesions per leaf for each leaf were collected to represent the genotypic diversity of the field. Samples were collected at early, mid and late season stages of the disease incidence. In Canada, 614 samples were collected representing 307 single leaf collections from a range of cucurbit hosts were collected from 11 locations (Simcoe Research Station, Ridgetown, Knelson, Lowen, Aylmer, Vittoria-Haskett, Vittoria-Harzok, Port Dover, St. Williams, Port Rowan, Muck Crops Station) in late summer 2011. Canadian samples were sent as dehydrated sporangia to reduce losses from poor samples. Collections for 2012 are in progress for both Michigan and Canada; late onset of downy mildew for 2012 has limited our ability to collect samples over time during this year. As a result, we are limiting ourselves to single time samplings for 2012. The research findings collected in this section of the activities were linked to Milestones (5, 10, and 13) that included technology transfer at the 2010 and 2011 Great Lakes Expo held in Grand Rapids, MI via poster presentations and strong grower attendance representing Michigan and Canada. The data from this work was also presented at the *Phytophthora* and Downy Mildew Workshop held on 1 February, 2012 at the Southwest Research and Extension Center in Benton Harbor, MI.

8. Fungicide efficacy and resistance against downy mildew, *Phytophthora capsici*, and *Phytophthora asparagi*. In 2011 a total of 20 different fungicides were tested for efficacy either on *P. capsici*, *P. asparagi*, or downy mildew. Crops tested included asparagus (crown soaks, spears), pickling cucumber (foliar, drip), yellow squash (foliar, drip, drench), and pepper (foliar, drip, drench). During 2012, a total of 16 different fungicides were tested on asparagus (crown soak), pickling cucumber (foliar), pepper (drip, drench, foliar), and yellow squash (drip, drench, foliar). Additional studies were conducted on two processing squash types ('Dickenson,' 'Golden Delicious') for fruit age susceptibility to *P. capsici* in both 2011 and 2012. In another study, 103 eggplant cultivars were screened for *P. capsici* susceptibility during 2012. The establishment and collection of replicated data of field research trials on fungicide screenings, application methods, and cultivar screenings met the Milestones of plot establishment, disease assessment, and statistical analysis (1, 2, 4, 7, 8, 11, and 12). Research findings from the fungicide trials were used in the technology Milestone via presentations at the 2010 and 2011 Great Lakes Expo held in Grand Rapids, MI via poster presentations. The data from this work was also presented at the *Phytophthora* and Downy Mildew Workshop held on 1 February, 2012 at the Southwest Research and Extension Center in Benton Harbor, MI (Milestones 5, 10, 13).

3. Identify the outputs created as a result of the activities undertaken (if materials are produced, a sample should be included in the report):

The University of Guelph reported Technical reports in the Muck Vegetable Cultivar Trial and Research Reports in 2010, 2011 and 2012. These reports are readily available to growers in the Holland Marsh and are distributed at the annual Muck Vegetable Growers Conference held yearly in March.

In 2010 the University of Guelph reported on the following:
Evaluations of fungicides and canopy trimming to manage Sclerotinia rot of carrot 2010. MR McDonald, M Parker
Demonstration of carrot foliage trimming technology for the control and management of *Sclerotinia sclerotiorum* and Sclerotinia rot of carrots in Ontario 2010. MR McDonald, D Van Dyk
Evaluation of RANMAN for control of cavity spot on carrots 2010. MR McDonald, L. Riches
Evaluation of various colored carrots for susceptibility to cavity spot 2010. MR McDonald, L. Riches
Comparison of various broccoli, green and napa cabbage cultivars for resistance and susceptibility to clubroot 2010. MR McDonald, L. Riches
Efficacy of biofungicides and fungicides for the reduction of clubroot incidence and severity in napa cabbage 2010. MR McDonald, L. Riches
Evaluation of biofungicides and fungicides for clubroot control on Shanghai pak choi 2010. MR McDonald, L. Riches
Evaluation of various seed treatments for control of onion smut in yellow cooking onions 2010. MR. McDonald, A Taylor, L. Riches

In 2011 the University of Guelph reported on the following:
Evaluation of coloured carrots for susceptibility to cavity spot 2011. MR McDonald, L. Riches
Evaluation of RANMAN for control of cavity spot on carrots 2011. MR McDonald, L. Riches
Effect of biocontrol products on germination and survival of sclerotia of *Sclerotinia cepivorum* on onions 2011. MR McDonald, M. Tesfiandrias.
Effect of biocontrol products on germination and survival of sclerotia of *Sclerotinia sclerotiorum* in carrot 2011. MR McDonald, M. Tesfiandrias.
Evaluation of canopy trimming and fungicides to manage Sclerotinia rot of carrot 2011. MR McDonald, M Parker
Evaluation of RANCONA seed treatments for control of onion smut in yellow cooking onions 2011. MR McDonald, A Taylor, L. Riches.

The University of Guelph made presentations at the Muck Vegetable Growers conferences in 2011, 2012 and the 2012 results will be presented in March 2013.
2011

-Muck Vegetable Growers Conference –

- Research update for carrots and leafy vegetables. Mary Ruth McDonald, L. Riches, and M. Tesfaendrias
- Onion research update. Mary Ruth McDonald, L. Riches and M. Tesfaendrias

2012

-2012 Canadian Phtopathological Society Annual meeting

- Biological products on germination and survival of Sclerotia of *Sclerotium cepivorum* and *S. Sclerotiorum*. M. Tesfaendrias

-Muck Vegetable Growers Conference

- Research update for carrots and leafy vegetables. Mary Ruth McDonald, L. Riches, D. Van Dyk and M. Tesfaendrias
- Onion research update. Mary Ruth McDonald, L. Riches, and M. Tesfaendrias
- Biological controls for onion white rot, sclerotinia rot of carrot and botrytis leaf blight. Killing three pathogens at once? Laura Barbison, M. R. McDonald and G. J. Boland

A poster presentation on the Sclerotia biocontrol work *Sclerotium cepivorum* and *S. sclerotiorum* was presented at the 2012 Canadian Phytopathological Society meeting

Abstracts published:

- Canadian Journal of Plant Pathology 2012
- Effect of host resistance on infection by *Plasmodiophora brassicae* in canola. A. Deora, B. D. Gossen and M.R. McDonald
- Effect of soil type on assessment of biofungicides efficacy against clubroot under controlled conditions. B.D. Gossen, H. Kasinathan, G. Peng and M. R. McDonald
- A comparison of clubroot resistance in Brassica vegetable crops. Phytopathology 102 (Supplement 4): S4.78 M.R. McDonald, K. Sharma, A.V. Nieuwelaar and B.D. Gossen

Michigan State University as a result of the activities created the following:

Study the virulence, phenotypic characteristics, genetic diversity and population structure of isolates of (a) *Phytophthora capsici* and (b) *Phytophthora asparagi* collected from Canada and compare with the current collection maintained at Michigan State University. When *P. capsici* isolates were grouped by genetic cluster, significant differences in virulence were observed on cucumber and zucchini, with isolates belonging to genetic cluster five causing larger lesions than isolates from genetic cluster six. On tomato, no significant differences were observed for *P. capsici* isolates grouped by genetic cluster, but isolates from vegetable crops were generally more virulent than isolates from tropical hosts. Isolates from fabaceous (bean) hosts sporulated better on cucumber fruits than isolates from solanaceous hosts. Isolates from vegetable hosts sporulated better on zucchini than isolates from tropical hosts. No significant differences in lesion diameter were noted on pepper when isolates were grouped by host family of origin or genetic cluster, but differences in pathogen sporulation were apparent by host family. Our findings suggest that isolate characteristics such as host family of origin and genetic cluster membership may be used to guide initial isolate selection for cucurbit fruit resistance screening. Final isolate selection should incorporate the phenotypic and genetic diversity of *P. capsici,* including isolates with differing virulence to the host organ of interest.

Sporangia were 23 to 35 µm wide and 38 to 60 µm long; differences in width and length were noted when isolates were grouped by genetic cluster and continent of origin. Length:breadth ratio (1.34 to 2.07) and pedicle length (20 to 260 µm long) varied widely among isolates; differences were apparent by continent and host family of origin. Oospore diameters varied among isolates (22 to 37 µm), but no differences were noted by isolate genetic cluster, host family of origin, continent of origin, mating type, or sensitivity to mefenoxam. Differences in sporangia production were observed among isolates grouped by continent, and isolates from nonvegetable hosts produced fewer sporangia than isolates from vegetable hosts. When cultures were incubated in liquid medium, 35 *P. capsici* isolates formed chlamydospores. Most (122 of 124) of the isolates were able to grow at 35°C, but all of the isolates grew poorly at 38°C. The results of this study indicate substantial variation in morphological and physiological characteristics among *P. capsici* isolates.

Bayesian clustering revealed some population structure by host, geographic origin and mefenoxam sensitivity with some clusters occurring more or less frequently in particular categories. Bayesian clustering, split networks, and statistical parsimony genealogies also detected the presence of non-*P. capsici* individuals in our sample corresponding to *P. tropicalis* and isolates of a distinct cluster closely related to *P. capsici* and *P. tropicalis*. Our findings of genetic structuring in *P. capsici* populations highlight the importance of including isolates from all detected clusters that represent the genetic variation in *P. capsici* for development of diagnostic tools, fungicides, and host resistance. The population structure detected will also impact the design and interpretation of association studies in *P. capsici*. This study provides an initial map of global population structure of *P. capsici* but continued genotyping of isolates will be necessary to expand our knowledge of genetic variation in this important plant pathogen.

Four of the 6 isolates of *P. asparagi* began forming lesions on the pears by day 3, and on apples by days 5 and 7. Lesion size increased at a greater rate on the pears than on the apples. Additionally, it was noted that the lesion margin was much more distinct on the light-skinned pears than the red apples. When all isolates were replated onto V8 agar from both pears and apples, more aerial mycelial growth was noted than for the same isolates prior to inoculation. This preliminary work suggests that apples and pears increase vigor of *P. asparagi*. Further research should be done to see if this “activation” from fruit hosts can increase virulence on asparagus (*Asparagus officialis*). This technique may be useful to compare virulence among *P. asparagi* isolates.

We contributed to the species description for *Phytophthora asparagi* in the Phytophthora database and provided pictures of pathogen structures and diseased plants. The full description may be found at: http://www.phytophthoradb.org/species.php?a=dv&id=290294.

Study the genetic diversity and population structure of *Pseudoperonospora cubensis* isolates collected from diseased cucurbit hosts in Canada and compare with the current DNA collection maintained at Michigan State University. Population structure is being analyzed within and between Michigan and Canada sites to look for differences in genetic diversity and populations. Within Michigan, population structure is being evaluated within and between sites to look for changes in distribution and frequency of genotypes over the growing season. DNA from *Ps. cubensis* sporangia are being amplified directly using 30 markers from both published primers and developed from single copy genes spanning the downy mildew genome. Amplified genes are being analyzed using an enzyme that detects and cleaves single nucleotide polymorphism differences between the unknown samples and the sequenced isolate MSU-1. Amplified and digested fragments are visualized using an agarose gel. Preliminary results show differences within Michigan and Canada populations using this method.

Fungicide efficacy and resistance against downy mildew, *Phytophthora capsici*, and *Phytophthora asparagi*. Efficacy data were generated each year of the grant for fungicides (both registered and unregistered) from various chemical companies. Presidio (fluopicolide) fungicide was proven to be effective on *P. capsici* (squash, peppers, cucumbers) and *Ps. cubensis* (cucumbers, melons) when applied as a foliar spray. Presidio is also effective in controlling these pathogens when applied via drip irrigation. Presidio was also effective in controlling *P. asparagi* when applied as a crown soak. Two experimental products (V-10208, QGU42) were tested for efficacy on *P. capsici*, *Ps. cubensis*, and *P. asparagi* as foliar sprays, plant drenches, and drip irrigation applications. Both experimental products were very effective on the oomycete pathogens that were studied. The efficacy data generated for these two products will be used for registration on asparagus, cucurbit and solanaceous crops grown in both Canada and the USA. Efficacy data were also generated for Zampro (ametoctradin/dimethomorph), Revus (mandipropamid), Ranman (cyazofamid), Gavel (zoxamide/mancozeb), Tanos (famoxadone/cymoxanil), Previcur Flex (propamocarb), Forum (dimethomorph), Bravo (chlorothalonil), and Reason (fenamidone). Registrants in Canada require efficacy data in order to register fungicide for use in that country. Through this project, significant data have been generated which can be utilized to speed fungicide registrations in Canada.

4. Explain changes or issues affecting completion of activities:

Currently some trials involving biofungicides for control of onion white rot, and the sclerotia of the fungi that cuse botrytis leaf blight and sclerotinia rot of carrot are still underway due to the length of time required to carry out such projects. These trials will be coming to completion shortly and results made available to the growers in time for the Muck Vegetable Cultivar Trial and Research Report 2012 and Muck Vegetable Growers Conference.

Establishing collaborators to collect *Phytopthora* spp. isolates in Canada was more difficult than first anticipated. This fact limited our analysis of isolates for genetic diversity and population structure of current isolates from Canada. We will be receiving *P. asparagi* isolates from Canada later this calendar year and will assist in molecular characterization of this newly-discovered pathogen. We did receive a large number of downy mildew isolates from different sources in Canada to meet the goals of those activities.

5. Identify the project inputs used to complete the activities and during the course of the project (include: farmer(s) involved, funding level, financial contributions, staff resources, other resources, etc.). If you did not access all of the FIP funding, or If your actual budget is different from the approved budget, please explain why and outline the reason(s) for those variances. All categories that are over/under budget should be discussed:

The project inputs needed to complete all the activities included field trial plot rental at the Muck Crops Research Station, greenhouse and growth room rental at both the Muck crops Research Station and at the University of Guelph Technical staff was required at these locations to operate and maintain the facilities and to maintain the vegetable field plots.

Dr. Hausbeck and her laboratory personnel were involved in the project which was established on research farms and in research plots in grower-cooperators' fields in Michigan.

It took a long time for the contract to be set up between the Fresh Vegetable Growers of Ontario and Michigan State University. Dr. Hausbeck even requested an advance account; however, funds were not available for her use until 10 months after the effective date of this project (17 January 2011 instead of 16 March 2010). Because of the extremely late start, Dr. Hausbeck deviated from the approved budget to best implement the research project. This resulted in a substantial increase in the personnel involved while the supplies charged to this project were decreased. This did not mean that very few supplies were used in this project, as Dr. Hausbeck supplemented the budget for supplies by charging them to her general research account. Travel was decreased due to the shortened length of time of the actual project activities and use of university-owned trucks (maintenance and gasoline was charged to Dr. Hausbeck's general research account).

Benefits & Impact

6. Compare final project results with the expected short term results and explain any differences:

The final project results fulfilled the expected short term results that were expected from this project.

Disease management methods for the Muck Crops Research Station IPM program have improved due to the ability to recommend new and reduced risk fungicides as well as effective cultural methods. Resistance and quality information for onions, carrots, cabbage, napa cabbage, cauliflower has been generated. The proven effectiveness of fungicides and biocontrols for the various vegetable crops will also benefit Ontario vegetable growers.

The isolate collection will help determine the level of pathogen resistance to mefenoxam and establish a baseline to be used in future studies. The collection will also help determine if resistance in one part of North America will be common to other nearby areas of the region. Several registered products were identified as being effective against *P. capsici*, *P. asparagi*, and downy mildew and will assist in the recommendations for rotating fungicide products to delay development of fungicide resistance. The two new active ingredients that are not yet registered but have been recently released from laboratory discovery will provide needed tools for growers to delay fungicide resistance. The information from the fruit-age susceptibility studies will help growers better time fungicide applications to developing cucurbit fruit.

7. Explain if the final project results are satisfactory:

The final results of this project are satisfactory as it has generated usable data for Ontario agriculture in order to maintain an innovative and competitive agricultural sector. The fungicides, resistant cultivars, and cultural practice will soon be available to growers if not already available.

Knowledge was increased in the area of fungicide efficacy on all pathogens included in the project. Two new products are in the process of being registered; their labels will include vegetable crops that are infected by *P. capsici*, *P. asparagi*, and *Ps. cubensis*. Researchers also determined the most effective application methods for the products tested. As a result, the application of the active ingredients via drip irrigation and soil drenches at transplanting should be included on new fungicide labels.

8. Identify the public good/benefit of the project to date:

Not only do growers benefit from these results but the public in turn benefits as well. Confidence in Ontario-based agriculture grows as a result of increased food safety and an innovative agricultural sector. Public health risk is decreased with a reduction in the amount of pesticides applied as a result of this project.

Research from this project has increased knowledge on each pathogen, improved disease identification, and identified the most effective fungicide products. Growers in both Canada and USA will now have the data needed to determine the most effective products and whether preferred chemicals have pathogen resistance concerns.

9. Explain how many on farm technologies the project has assessed:

This project has assessed four on-farm technologies including resistant or tolerant varieties, reduced risk fungicides, biofungicides and cultural control methods, especially trimming of carrot foliage.

Research conducted on both research farms and in research plots established with grower cooperators examined different methods of fungicide delivery systems. Crown soaks are a newly-identified means for growers to treat dormant asparagus crowns for protection against *P. asparagi*. The use of oomycete fungicides through drip irritation lines or as a transplant drench was shown to be more effective than foliar applications for the control of *P. capsici*. Two different studies looked at the amount of water or drip tape emitter configuration that would give the best control with various fungicides for control of *P. capsici*. The fungicide Presidio was also effective on downy mildew when applied through drip irritation. This use will make treatment of crops grown in low tunnels feasible for early season control of downy mildew.

10. Explain how the project success will be measured in the long-term (include the indicators outlined in Schedule "B" of the Agreement):

The long term success of this project will ultimately be measured by reducing losses of onions, carrots, and Brassica vegetables to disease as a result of improved disease management practices and disease forecasting. Furthermore the data generated should assist in label expansion and registration for biofungicides and reduced risk fungicides for diseases of vegetable crops. Commercially available resistant cultivars of onions, carrots and Brassica vegetables as a result of this project will also be a measurable success. In general the further development of consistent quality and yields of onions, carrots and cole crops is the overall goal to further Ontario's agricultural industry.

As well, the addition of new labels for vegetable use on effective products will be one indicator of long-term success of this project. The successful registration of V-10208 and QGU42 will be another indicator of success. The ability to rotate among several effective fungicide treatments should delay the development of a pathogen strain that is resistant to the newly identified active ingredients.

11. If applicable, indicate how this initiative will be economically viable and self-sustaining from this point forward. Explain what the next steps are for this initiative:

The economical viability of this initiative will be evident in the fact that private enterprises such as seed and chemical companies can use the information provided by this project to commercially supply the resistant cultivars and the effective new fungicides. Fungicide registrants are expanding their efforst to identify the range of effectiveness and the most efficient means of fungicide application. With these data, IR-4 residue studies on these currently unregistered fungicides have been initiated jointly with Canada. Label expansion of new and reduced risk fungicides will be determined by the Pest Management Regulatory Agency (PRMA). The next steps of this initiative would be to continue to pursue resistant cultivars and new low-risk fungicides and improved application techniques for an ever changing agricultural industry.

12. Indicate the current actual financial impact to farmers who may adopt the technology versus the estimated impact (see question '6.e.' in the application):

The actual financial impact can be difficult to determine. Resistant cultivars reduce the cost per acre to the grower since no fungicides will have to be applied. Cultural practices such as trimming the carrot foliage can reduce fungicide sprays by up to 3 sprays per year compared to a calendar based spray. This means significant financial savings for the grower over a growing season. When new and effective fungicides are needed and used the grower will have higher income, since there will be less crop loss to disease and fewer grading costs or rejected fields.

The identification of effective fungicides will lower the grower's reliance of costly soil-applied fumigation. In addition to cost, Canada growers do not currently have access to certain fumigants as in the past. In particular, chloropicrin is no longer allowed in Canada due to several instances of reported gas exposure of growers and workers. The alternative fumigants can cost $600-$2,500 per treated acre which is a much higher cost than a season of fungicide applications. Drip application and transplant drench applications have the potential to reduce the total amount of fungicide active ingredient applied per acre and will help to lower the control cost. Reduction of plant and yield loss and increase in vegetable quality through the reduction in disease will also be a direct economic advantage to growers.

13. Indicate the target audience and the total number of people reached by this project:

Ontario growers of onion (200 growers), carrots (250 growers), Brassica Vegetables (200 growers)
Oral Presentations at Muck Vegetable Growers Conference and the FVGO annual meeting reach about 100 people at each presentation.
Poster at the Ontario Fruit and Vegetable Conference up to 800 people over two days
All reports in the Muck Vegetable Cultivar Trial and Research Report are available on line as well as the website of the FVGO. The Canadian Journal of Plant Pathology with an impact factor of 0.884 and is available online worldwide
2010 GL Expo: up to 3,500 growers, processors, and agricultural companies.
2011 GL Expo: up to 3,200 growers, processors, and agricultural companies.
2012 Phytophthora and Downy Workshop: 50 growers and extension personnel.
2012 GL Expo up to 3,200-3,500 growers, processors, and agricultural companies.

Knowledge Transfer Plan & Translation

14. Indicate how information has been communicated with industry for the duration of the project (refer to the plan developed as part of question 7 in the final funding application):

Information Requested	Commodity Association Activities	Researcher Activities

Indicate the type and number of communication materials that were developed (i.e. brochure, display, CD/DVD, poster, website, handbook, etc.) and how they were distributed:	Reports will be available on the FVGO website as well as provided as part of the AGM packages	Technical reports – 14 – published in the Muck Vegetable cultivar Trial and Research Reports in 2010, 2011, and 2012 In addition another 5 reports are pending publication in the 2012 Muck Vegetable Cultivar Trial and Research Greenbook. Distributed annually at the Muck Vegetable Growers Conference and are available online on the website of the Fresh Vegetable Growers of Ontario and the Muck Crops Research Station. FVGO Annual meeting; Annual Muck Vegetable Growers Conference of the material on the website. Poster presentation at 2012 Canadian Phytopatholgical Society meeting on Sclerotia biocontrol work. Six presentations have been made with another four presentations planned for the 2013 Muck Vegetable Growers Conference. 2011 -Research update for carrots and leafy vegetables, Mary Ruth McDonald, L. Riches andM. Tesfaendrias -Onion research update. Mary Ruth McDonald, L. Riches and M. Tesfaendrias 2012 -Research update for carrots and leafy vegetables. Mary Ruth McDonald, L. Riches, D. Van Dyk and M. Tesfaendrias -onion research update. Mary Ruth McDonald, L. Riches and M. Tesfaendrias -Biological controls for onion white rot, sclerotinia rot of carrot and botrytis leaf blight. Killing three pathogens at once? Laura Barbison, M.R. McDonald and G. J. Boland 2012 Canadian Phytopathological Society annual meeting -Biological products on germination and survival of Sclerotia of Sclerotium cepivorum and S. Sclerotiorum. M. Tsfaendrias 2012 Ontario Fruit and Vegetable Growers Conference -Resistance and other management practices for clubroot of Brassica vegetables. M.R. McDonald - the audience reached for oral presentation was around 100 MSU website: 1 2011 Twitter updates : 1 2011 Facebook updates: 1 Posters: 7 Workshop handouts: 50 GL expo proceedings: 7 using 150-200 hard copies per session. Also posted on GL Expo website.

Indicate the number of presentations that were made and the total audience reached:		Two scientific abstracts published in the Canadian Journal of Plant Pathology -effect of host resistance on infection by *Plasmodiophora brassicae* in canola. A. Deora, B. D. Gossen, and M.R. McDonald -Effect of soil type on assessment of biofungicides efficacy against clubroot under controlled conditions. B.D. Gossen, H. Kasinathan, G. Peng and M. R. McDonald -The Can J. Plant Pathol is a highly respected scientific journal, widely available in both English and French. 23 Presentations at: APS North Central Meeting (100-200) 3rd International *Phytophthora capsici* Meeting (50-75) Annual Meeting of APS, 2010 Cucurbitacea Meeting (100) Fruit and Vegetable Association of Delaware (250) Midwest Pickle Assocation Meeting (75) 2010, 2011, and 2012 Great Lakes Expo (3,200-3,500) 2012 *Phytophthora* and Downy Mildew Workshop (50)
Indicate the number of scientific and popular press articles that were developed and how they were distributed:		14 scientific publications: Plant Disease Phytopathology Plant Disease Management Reports MSU Extension News for Agriculture, Vegetables
Identify any other communication activities, including but not limited to internet publications, advertising, billboards, radio and television broadcasts:		
Indicate if any project materials have been made available for use in the French language:		The Canadian Journal of Plant Pathology publishes all abstracts in both English and French

15. Indicate when AAFC/OMAFRA/AAC were identified as a supporter throughout the period of the project:

AAFC/OMAFRA/AAC was identified as a supporter throughout the duration of the project on all the outputs that the project produced.

Conclusion & Final Comments

16. Provide a discussion of lessons learned, recommendations and overall perception of project success:

This project covered a large scope of the most important (and most difficult to control) vegetable diseases of root, bulb and vegetable crops. This research was vital in order for the growers in these vegetable industries to stay competitive. With the move to increase consumption of local food, growers have a greater opportunity to provide produce to chain stores as well as smaller retailers. Another growing trend is the focus on food safety which is why focusing research on reduced risk fungicides and resistant cultivars is an approach to keep the Ontario agricultural industry credible and profitable. It is important that the industry and industry groups have access to these materials and varieties as soon as possible, and that there is unbiased information available so growers can make informed decisions when they choose disease management practices. Over the duration of the project grower interest was high, and the presentations were well attended at all the venues that the project was presented. This positive response should lead to early adoption of the new technologies resulting from the research. As an example, already the cultural practice of carrot trimming has been adopted by some in the Holland Marsh. Growers were keenly interested in this new management method and there were multiple volunteers for grower field sites. The lessons learned from this project opens doors to continue to grow our knowledge and research to further benefit the industry.

Creating an isolate collection for each pathogen from several regions will allow for study of the different populations of the pathogens and their possible genetic differences. Understanding these differences will provide insight on how a disease organism changes over the course of the growing season and will allow us to better target control measures for each disease and cropping system. Knowing if a region has a population of isolates resistant to mefenoxam (or other fungicides) will better aid consultants and growers to select an effective chemical control program. By screening all available oomycete fungicides researchers were able to determine the most effective products for each disease. Chemical control options can now be posted for growers to give the best disease control while limiting the possibility of fungicide resistance from developing in the pathogens. The new information of soil-applied applications of fungicides will allow chemical companies to amend their labels to allow for the use of their products through drip irrigation and transplant drenches. The overall outcome of this project is that these once troublesome diseases can now be controlled with proper planning of cultural practices and timely application of crop protectants.

Media Coverage – *If possible please provide a copy of the media coverage for our files*

Date	Source	Title	Reach	FIP Recognition (Yes/No)

(Add additional rows if needed)