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Management of silver scurf and Fusarium dry rot of potatoes in storage using Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*)

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EXECUTIVE SUMMARY

Silver scurf of potatoes, caused by the fungus *Helminthosporium solani* is an important disease in Canada and worldwide. Although primary infection occurs in the field, it is considered a problem of storage potatoes, often adversely affecting the appearance and skin color of potato tubers and ultimately resulting in reduced consumer acceptance. Fusarium dry rot caused by *Fusarium sambucinum* is another important post harvest disease of potato which develops as a result of injury such as bruises or cuts of the tuber. Extensive rotting, tissue shrinkage and collapse may result. Very few fungicides are effective against the silver scurf and dry rot pathogens and pathogen resistance has developed for at least one of these (thiabendazole). Bio-Save 10LP and 11LP are microbial pest control products based upon the organism *Pseudomonas syringae* and are registered for control of silver scurf and dry rot in the United States. This project was initiated to assess the efficacy of these biopesticides against silver scurf and dry rot and to provide the data generated in support of registration of these biopesticides in Canada. Potato samples infected with silver scurf and Fusarium dry rot were collected from NB, PEI and AB. These samples were used to isolate silver scurf and dry rot fungal cultures. The isolates were purified, subcultured and then stored in the refrigerator for further use. Subcultures were identified based on morphological characteristics and also using molecular techniques, and were deposited at the National Fungal Identification Service of Agriculture and Agri-Food Canada, Ottawa. *Fusarium sambucinum* was the most frequently isolated strain from dry rot samples. However, other strains including *F. tumidum*, *F. coeruleum*, *F. culmorum*, *F. avenaceum* were also isolated. *Helminthosporium solani* isolated from samples collected from AB and PEI was found to belong to 2 different groups (only one group in case of NB) based on internal transcribed spacer (ITS) analysis.

The efficacy of Bio-Save 10LP and Bio-Save 11LP against *F. sambucinum* and *H. solani* isolates representing NB, PEI and AB were tested *in vitro*. The products were tested separately and in combination with Mertect (thiabendazole). Bio-Save 11LP was very effective against *F. sambucinum* and *H. solani* while Bio-Save 10LP was effective against *H. solani* only. Application of Mertect alone or in combination with either Bio-Save 10LP or Bio-Save 11LP significantly reduced the growth of *F. sambucinum* and *H. solani* compared to the control. The Fusarium dry rot isolate from NB was more sensitive to Mertect than those from AB and PEI. The silver scurf isolates from AB were more sensitive to Mertect than those from NB and PEI.

Storage trials were conducted in NB, PEI and AB to assess the efficacy of Bio-Save applied after harvest against dry rot and silver scurf. The application of Bio-Save or Mertect SC alone or in combination with each other was very effective in significantly reducing the incidence and severity of dry rot and silver scurf in both NB and PEI. However, the data obtained from AB with regard to these treatments were inconclusive. The results of the storage trials are in accordance with the observations recorded in the *in vitro* studies. The results of the present trial indicate that the use of Bio-Save (10LP or 11LP) or Mertect alone or the combination of both appears to be a potentially sound strategy that can be used in the management of both *H. solani* and *F. sambucinum* and the resistance management of both products.

DEMONSTRATION OF ACHIEVEMENT OF PROJECT OBJECTIVES AND COMPLETION OF DELIVERABLES

1. Sixteen (16) isolates of Fusarium dry rot and 14 isolates of silver scurf have been collected, identified and their culture collections were deposited at the National Fungal Identification Services, AAFC, Ottawa; and at the Potato Pathology unit at the Potato Development Centre, Department of Agriculture and Aquaculture in Wicklow, NB.
2. *In vitro* studies to assess the efficacy of Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*) and their combinations with Mertect (thiabendazole) against different isolates of silver scurf and dry rot pathogens were completed. The data have been analyzed and results are included in this report.
3. Storage trials were conducted in AB, PEI and NB to assess efficacy of Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*) and their combinations with Mertect (thiabendazole) applied post harvest for the control of silver scurf and dry rot. The data were analyzed and results are included in this report.
4. The project findings were presented at the Northeast Potato Technology Forum held in Fredericton (12-13 March 2008) and at Canadian Phytopathological Society Annual meeting held in Charlottetown (15-19 June 2008).

MATERIALS AND METHODS

Sample collection and pathogen isolation, purification and identification.

Potato tubers infected by silver scurf or *Fusarium* dry rot pathogens were collected from NB, PEI, NS, and AB, and were used for isolating the pathogens. Tubers infected with silver scurf pathogen were collected, washed thoroughly and examined for disease symptoms. The procedure reported by Holley and Kawchuck (1996) was followed for isolation of both silver scurf and dry rot pathogens.

A fine needle was used to remove *Helminthosporium solani* spores from skin surfaces of infected tubers. It was then transferred to acidified potato dextrose agar plates or potato dextrose agar plates amended with penicillin and streptomycin. The plates were incubated for 5-8 weeks at 20° C. Colonies containing *H. solani* spores were subcultured on malt agar and incubated for 5-8 weeks at 20° C.

For dry rot, tubers with cuts or pressure bruises were sliced open and wefts of mycelia inside dry rot cavities were removed and placed on potato dextrose agar plates amended with penicillin and streptomycin. In cases where mycelia were not present, the infected tuber tissue was removed from the edges of dry rot lesions and surface sterilized with alcohol. These were then placed on acidified potato dextrose agar plates or potato dextrose agar plates amended with penicillin and streptomycin and incubated for 7-14 days at 20° C. Colonies with macroconidia were transferred to fresh PDA plates and allowed to grow for 7-14 days at 20° C.

A set of isolated pathogens were sent to the National Fungal Identification Service in Ottawa (Dr. Tharcisse Barasubiye) for identification using molecular techniques and another set was used for identification in the lab by standard micromorphological techniques.

Analysis of antagonist population level. After receiving the Bio-Save products, the antagonistic population level in 1 gm of the product was determined using the pour plate technique. The population of *Pseudomonas syringae* in Bio-Save 10 LP was 88×10^9 CFU/ gm of the formulated product while the population of *P. syringae* in Bio-Save 11 LP was 86×10^9 CFU/ gm of the formulated product.

***In vitro* efficacy of Bio-Save 10LP and 11LP against *Fusarium sambucinum* and *Helminthosporium solani*.** The efficacies of Bio-Save 10LP and Bio-Save 11LP against different isolates of *F. sambucinum* and *H. solani* were tested *in vitro*. One isolate of *F. sambucinum* from each province was selected in case of dry rot. In case of silver scurf, one isolate of *H. solani* was selected from NB and two isolates were selected from both AB and PEI (each represents a different group). One mL of Bio-Save (*Pseudomonas syringae*) solution (4.412 g in 1L of water; label rate is 500 g in 30 gallons of water) was amended to plates

containing half strength of potato dextrose agar (PDA). In addition, series of concentrations (0, 0.1, 1, 10, 100, and 1000 ppm) were also tested. Plates were incubated overnight in order for the biopesticides to be absorbed in the media. Plates receiving 1 mL of sterile distilled water served as controls. Agar plugs (5 mm in diameter) were taken from actively growing cultures of *F. sambucinum* or *H. solani* and placed in the centre of PDA plates amended with the respective treatments (Table 1). The plates were then incubated at room temperature (approximately 7 weeks of incubation for *H. solani* and 1 week for *F. sambucinum*). Radial growth of the fungus was recorded every two days until the untreated control overgrows the plates. Two perpendicular measurements were recorded and the mean values were calculated. Percent radial growth was then calculated relative to the untreated control.

Post Harvest Storage Trials. Replicated storage trials using randomized complete block design were setup in NB, PEI, and AB. Eight treatments (Table 2) with 4 replicates each were used to better handle natural variation in the trial. Separate experiments will be conducted for silver scurf (SS) and Fusarium dry rot (FDR). Treatments were assigned as per a single factor experiment, *i.e.* various types, combinations and rates of products would be integrated as outlined in the proposal.

Analysis of antagonist population level. During the trial conducted in NB, some samples were marked and treated with Bio-Save. After two days in storage, the samples were sent to JET Harvest Solutions in Florida for analysis of Bio-Save (*Pseudomonas syringae*) population levels in the treated samples. Bio-Save solution (500 g of Bio-Save in 30 gallons of water) was applied to naturally infected tubers of silver scurf. For dry rot, tubers were artificially wounded (1x3 mm wound), inoculated with a spore suspension of *F. sambucinum* and then treated with Bio-Save solution. The wounds were excised 48 hr after treatment and tested for the level of *P. syringae* population on KBBC agar plates. The population of *P. syringae* was approximately 1×10^5 cfu mL⁻¹.

Dry rot: Tubers were dry-brushed to remove any adhering soil, and then wounded in a bruise box. Tubers requiring pathogen inoculation received 2 mL spray of a suspension of 10,000 conidia/mL of *Fusarium sambucinum* prepared by scraping the surface of 14 day old cultures growing on PDA (Figure 1). The inoculum was applied the day before treatments were applied. After inoculation, tubers were placed in plastic crates and allowed to incubate in the storage chamber until treatments were applied the next day. The steps involved in treatment application are shown in Figure 2. Each set of 25 tubers were then placed on a conveyor belt and sprayed with the respective treatments at label rates using a CO₂ sprayer mounted at the end of the conveyor. Equipment was thoroughly cleaned prior to next treatment application. For each treatment, tubers were placed in individual plastic crates and stored in a defined storage facility set at 10°C and 95% RH for a period of 16 weeks. Following storage, dry rot incidence (number of diseased tubers) and severity (depth of internal necrosis)

were assessed. Data were analyzed statistically using standard statistical techniques.

Silver scurf: Seed tubers naturally infected with silver scurf were used. Tubers were dry-brushed to remove any adhering soil. Each set of 25 tubers were then placed on a conveyor belt and sprayed with the respective treatments (Table 2) at label rates using a CO₂ sprayer mounted at the end of the conveyor to simulate application of postharvest spray to tubers entering storage. Equipment was thoroughly cleaned prior to the next treatment application. For each treatment, tubers were placed in individual plastic crates and stored in a defined storage facility set at 10°C and 95% RH for a period of 6 months. After storage, silver scurf disease incidence (number of diseased tubers) and severity (% tuber surface diseased) were assessed. Data were analyzed statistically using standard statistical techniques.

The addition of thiabendazole (Mertect) to Bio-Save as a combined product is part of a resistance management strategy for Bio-Save. Both products are compatible according to the US label of Bio-Save.

RESULTS

Sample collection and pathogen isolation, purification and identification. Isolates obtained from the infected tuber samples were identified and culture collections were deposited at the National Fungal Identification Service (NFIS) in Ottawa. Identification was done at the NFIS using morphological observations and molecular techniques (DNA sequences and internal transcribed spacer analysis). Approximately 30 isolates belonging to *Fusarium* or *Helminthosporium* genera were identified. The *Fusarium* isolates were identified as *Fusarium sambucinum*, *F. tumidum*, *F. coeruleum*, *F. culmorum*, *F. avenaceum*. The *Helminthosporium* isolates were identified as *H. solani* (Table 3). The *Helminthosporium* isolates from PEI and AB belonged to 2 groups and the isolates from NB belonged to one group only. Of the 30 isolates collected, 13 were from NB, 12 from PEI, 3 from AB, and 2 from NS. Subcultures of the isolates were also deposited at the Potato Pathology unit, Potato Development Centre, Department of Agriculture and Aquaculture, NB.

Analysis of antagonist population level. The population of *Pseudomonas syringae* in Bio-Save 10 LP was 88 x 10⁹ CFU/ gm of the formulated product while the population of *P. syringae* in Bio-Save 11 LP was 86 x 10⁹ CFU/ gm of the formulated product.

***In vitro* efficacy of Bio-Save 10LP and 11LP against *Fusarium sambucinum* and *Helminthosporium solani*.** The growth of all the isolates of *H. solani* were significantly inhibited by both Bio-Save 10LP and Bio-Save 11LP (Table 4). The use of Mertect alone or in combination with either Bio-Save 10LP or Bio-Save 11LP significantly reduced the growth of all isolates of *H. solani* compared to the

untreated, inoculated control. The *H. solani* isolates from AB were more sensitive to Mertect than those from PEI and NB. Bio-Save 11LP significantly inhibited the growth of *F. sambucinum*. However, Bio-Save 10LP was unable to inhibit the growth of *F. sambucinum* (Table 5). Similarly, the use of Mertect alone or in combination with either Bio-Save 10LP or Bio-Save 11LP significantly reduced the growth of all isolates of *F. sambucinum* compared to the untreated, inoculated control. The *F. sambucinum* isolate from NB was more sensitive to Mertect than those from AB and PEI.

Post Harvest Storage Trials

Storage trial conducted at the Crop Diversification Centre South, Brooks, Alberta.

Fusarium Dry Rot trial. Among all the treatments tested, the least amount of external and internal disease incidence of dry rot was recorded from Bio-Save 10LP + Mertect SC which differed significantly when compared to Bio-Save 11LP + Mertect SC (Table 6). Although all other treatments had higher incidence values than Bio-Save 10LP + Mertect SC, they did not differ significantly from it.

Although differences were noted among all the treatments with regard to external and internal disease severity values of dry rot, none of them differed significantly. The lowest amount of external and internal disease severity was recorded for Bio-Save 10LP + Mertect SC treatment (Table 6).

Silver Scurf trial. The lowest incidence of silver scurf was recorded for the Bio-Save 11LP + Mertect SC treatment which differed significantly from Bio-Save 10LP and Bio-Save 11LP (Table 7). All other treatments did not differ significantly from Bio-Save 11LP + Mertect SC with regard to incidence of silver scurf. The lowest severity of silver scurf was found in the treatment receiving Mertect SC but it did not differ significantly from the remaining treatments (Table 7).

Storage trial conducted at Agriculture and Agri-Food Canada, Charlottetown, Prince Edward Island.

Fusarium Dry Rot trial. The lowest amount of external and internal disease incidence was recorded from the treatment Bio-Save 10LP followed by Mertect SC, Bio-Save 11LP + Mertect SC, Bio-Save 11LP and Bio-Save 10LP + Mertect SC (Table 8). The external and internal disease incidence values recorded by all these treatments differed significantly compared to the inoculated, untreated control (Table 8).

The lowest external severity of dry rot was recorded for Bio-Save 10LP (0.42%) followed by Bio-Save 11LP + Mertect SC (0.48%), Bio-Save 11LP (0.92%), Mertect SC (0.99%) and Bio-Save 10LP + Mertect SC (1.21%) (Table 9). All

these treatments differed significantly compared to the untreated control inoculated with *Fusarium sambucinum*. All the treatments including Bio-Save 10LP (0.52 mm), Bio-Save 11LP (0.61 mm), Bio-Save 10LP + Mertect SC (0.81 mm), Bio-Save 11LP + Mertect SC (0.41 mm) and Mertect SC (1.0 mm) significantly reduced the internal disease severity of dry rot compared to the inoculated, untreated control (7.05 mm) (Table 9).

Silver Scurf trial. The incidence of silver scurf was 100% for all the treatments tested in this trial and there was no significant difference among the treatments with regard to the incidence levels of silver scurf. Among all the treatments tested, the severity of silver scurf was the lowest in tubers treated with Bio-Save 11LP (7.02%) and it differed significantly from the inoculated, untreated control (19%) and Bio-Save 10LP + Mertect SC (9.09%)(Table 10). The disease severity values recorded for Bio-Save 10LP, Bio-Save 10LP + Mertect SC and Mertect SC differed significantly compared to the inoculated, untreated control (Table 10).

Storage trial conducted at Potato Development Centre, Department of Agriculture and Aquaculture, New Brunswick.

Fusarium Dry Rot trial. The lowest external incidence of dry rot was recorded for the Bio-Save 11LP + Mertect SC treatment (24%). All treatments tested significantly reduced the external incidence of dry rot compared to the inoculated, untreated control (93%) (Table 11). External disease incidence values recorded for Bio-Save 11LP + Mertect SC (24%) differed significantly from Bio-Save 11LP (60%) and Mertect SC (42%) (Table 11). Similarly, the highest internal incidence of dry rot was recorded for inoculated, untreated control treatment (81%) which differed significantly from the Bio-Save 11LP (19%), Bio-Save 10LP (22%), Bio-Save 10LP + Mertect SC (24%), Mertect SC (28%) and Bio-Save 11LP + Mertect SC (30%) treatments (Table 11).

The external disease severity was lowest in treatments receiving Bio-Save 11LP + Mertect SC (1.4%) followed by Bio-Save 10LP (1.8%), Bio-Save 10LP + Mertect SC (1.9%), Mertect SC (2.6%) and Bio-Save 11LP (3.1%) (Table 12). All of these treatments differed significantly from the inoculated, untreated control treatment (8.2%). The external disease severity values recorded for Bio-Save 11LP + Mertect SC (1.4%) differed significantly from the Bio-Save 11LP (3.1%) and Mertect SC treatment (2.6%) (Table 12). Similarly, the lowest internal disease severity values were recorded for Bio-Save 11LP (1.3 mm) and Bio-Save 11LP + Mertect SC (1.3 mm) followed by Bio-Save 10LP (1.5 mm), Bio-Save 10LP + Mertect SC (1.8 mm) and Mertect SC (1.9 mm) treatments (Table 12). All these five treatments differed significantly from the inoculated, untreated control treatment (6.4 mm) with regard to internal disease severity.

Silver Scurf trial. The incidence of silver scurf was lowest for the Bio-Save 10LP + Mertect SC treatment (10%) followed by Bio-Save 10LP (11%), Bio-Save 11LP

+ Mertect SC (19%), Bio-Save 11LP (21%) and Mertect SC (22%) treatments (Table 13). The treatments Bio-Save 10LP + Mertect SC, Bio-Save 10LP, Bio-Save 11LP + Mertect SC, Bio-Save 11LP and Mertect SC differed significantly from the inoculated, untreated control treatment (79%) (Table 13). Disease incidence values recorded for Bio-Save 10LP + Mertect SC treatment (10%) were significantly different from the Mertect SC (22%) and Bio-Save 11LP (21%) treatments. Similarly, the lowest severity of silver scurf was recorded for Bio-Save 10 LP + Mertect SC treatment (0.7%), followed by Bio-Save 10 LP (0.9%), Bio-Save 11LP (1.4%), Bio-Save 10LP + Mertect SC (1.5%) and Mertect SC (1.8%) (Table 13). All these treatments significantly reduced the severity of silver scurf compared to the inoculated, untreated control.

DISCUSSION

Sample collection and pathogen isolation, purification and identification.

Sixteen (16) isolates of *Fusarium* extracted from tubers infected with dry rot, and 14 isolates of *Helminthosporium* extracted from tubers infected with silver scurf were collected from NB, PEI, NS, and AB. The isolates were purified and sent to the National Fungal Identification Service (NFIS) in Ottawa to confirm the identity of the isolates. Dr. Tharcisse Barasubiye and a team of mycologists at the NFIS identified the isolates based on morphological characteristics and molecular based techniques. The isolates were then deposited in the national culture collection at the NFIS, AAFC, Ottawa.

Fusarium dry rot. A new strain (*F. tumidum*) was isolated from 2 samples collected from NB. The majority of the isolates that were collected from NB, PEI, NS, and AB were identified as *F. sambucinum*. Therefore, *F. sambucinum* was used in the *in vitro* and storage trials.

Silver scurf. The *H. solani* isolates from PEI and AB were found to belong to 2 groups (groups I and II) based on internal transcribed spacer (ITS) analysis. NB isolates were found to belong to group II only. Therefore, 2 isolates from both PEI and AB, each representing one group, and one isolate from NB were used in the *in vitro* studies.

In vitro Studies

Efficacy of Bio-Save 10LP and 11LP (*Pseudomonas syringae*) against *Fusarium sambucinum*. Bio-Save 10LP was ineffective in inhibiting or suppressing the growth of *F. sambucinum* when it was used at different concentrations (0.1, 1.0, 10,100, and 1000 ppm) as well as at the label rate. Mertect (thiabendazole) used alone at the label rate was very effective against the fungus. The combination of Mertect and Bio-Save 10LP was effective, most likely due to the efficacy of Mertect. On the other hand, Bio-Save 11LP was

effective in suppressing *F. sambucinum*. An increased efficacy was observed when it was combined with Mertect (Figure 3). The *Fusarium* dry rot isolate from NB was more sensitive to Mertect than from AB and PEI.

Efficacy of Bio-Save 10LP and 11LP (*Pseudomonas syringae*) against *Helminthosporium solani*. Both Bio-Save 10LP and Bio-Save 11LP used at the label rates were effective in suppressing the growth of *H. solani* (groups I & II). Bio-Save 11LP (Figure 5) was slightly more efficacious than Bio-Save 10LP (Figure 4). The combination of either product with Mertect yielded higher efficacy than using each product alone. The silver scurf isolates from AB were more sensitive to Mertect than those from NB and PEI.

The *in vitro* studies suggest that Bio-Save 11LP is effective in suppressing the growth of both *F. sambucinum* and *H. solani*. This product is more economical to use than 10LP which is effective against one pathogen only (*H. solani*). Mertect was found to be effective against both fungi. The combination of Mertect and Bio-Save can be used as a strategy in the management of resistance to both products.

Post Harvest Storage Trials

In AB, none of the products tested provided adequate control of fusarium dry rot. Bio-Save 11LP failed to control dry rot when compared to inoculated, untreated control, even when combined with Mertect SC. However, Bio-Save 10LP combined with Mertect SC showed better dry rot control than Bio-Save 11LP.

Bio-Save 11LP + Mertect SC offered better protection against *Helminthosporium solani* than the other treatments. Bio-Save 10LP and Bio-Save 11LP were not as effective when used alone; however, after combining Bio-Save 10LP with Mertect SC, the efficacy of this product slightly improved, but not in a significant manner. The final DI ratings in this trial were very high (91-100%), suggesting that none of the products tested was highly effective against silver scurf.

In PEI, Bio-Save 10LP, Bio-Save 11LP and Mertect SC were effective in reducing the severity of dry rot and silver scurf. Bio-Save 10LP and Bio-Save 11LP also performed better when they were applied in combination with Mertect SC. The results suggest that Bio-Save 10LP, Bio-Save 11LP and Mertect SC can be used alone or in combination with each other for the control of dry rot and silver scurf in storage.

In NB, Bio-Save (10LP and 11LP) or Mertect SC applied alone was very effective in reducing the severity of both fusarium dry rot and silver scurf. In addition, Bio-Save 10LP and Bio-Save 11LP also performed better when they were applied in combination with Mertect SC. These results suggest that Bio-Save 10LP, Bio-Save 11 LP and Mertect SC can be used alone or in combination with each other for the control of dry rot and silver scurf in storage.

KEY MESSAGES PERTAINING TO THE PROJECT

Why the project was undertaken, what issue(s) it addressed? Dry rot and silver scurf are two important post harvest diseases of potato for which effective control is lacking in Canada. These diseases are found in every potato storage across the country. Incidence and severity levels of these diseases are on the rise and annual economic losses caused can reach 25%. The management of dry rot and silver scurf has been traditionally done with the use of thiabendazole. Over the years, resistance to thiabendazole in isolates of *Fusarium sambucinum* and *Helminthosporium solani* has been reported in Europe and North America. The options that are available for post-harvest disease management of Fusarium dry rot and silver scurf have proven to be not efficient. This limited availability of efficacious post-harvest fungicides prompted the search for new and efficient methods to control silver scurf and dry rot in potato. The use of biopesticides is a promising perspective for safe and sustainable disease management. The identification and registration of effective biopesticides is urgently needed to control silver scurf and dry rot pathogens and to avoid growers' reliance on chemicals. In the U.S.A., Bio-Save 10LP and 11LP (*Pseudomonas syringae*) are registered for control of silver scurf and dry rot. The registrant, JET Harvest Solutions is also pursuing registration of the product in Canada. Therefore, the present study was undertaken to assess the efficacy of Bio-Save 10LP and Bio-Save 11LP against silver scurf and dry rot of potatoes. To avoid or manage potential resistance to this product, treatments combining both Bio-Save and Mertect we added and found to be very effective. This project will aid in managing an already nationally identified priority crop and disease of potatoes by the PMRA.

Who will benefit from the project? The potato growers in Eastern and Western Canada will benefit significantly from this new tool for post-harvest disease management of silver scurf and dry rot. The use of the Bio-Save pesticide to control dry rot and silver scurf will aid in the reduced use of harmful and ineffective pesticides. Reducing environmental pollution by limiting the amount of chemicals released in the air, soil or water will in turn benefit the general public and wildlife. The results obtained from this trial will provide Canadian data to support the registration of Bio-Save 10LP and 11LP for potato silver scurf and Fusarium dry rot control in Canada.

The general approach taken and key collaborators involved? Expert scientists from NB, PEI and AB met and agreed to conduct a national project in three provinces that represent both Eastern and Western Canada. These scientists are members of the national committee on dry rot and silver scurf. One of the biopesticides that has been used in controlling storage potato diseases in the USA was identified as Bio-Save (*Pseudomonas syringae*). The project leader approached the manufacturer of Bio-Save and inquired if they would be interested in registering it in Canada. The manufacturer was very interested and had submitted an application to the PMRA to consider its registration. Potato

growers associations in NB, PEI, and AB were approached and provided letters of support and interest in pursuing this project. No Canadian data on the efficacy of this product existed at that time. An application for funding was submitted to the Pest Management Centre of Agriculture and Agri-Food Canada in Ottawa. Funding was provided for one year.

Tuber samples infected with either silver scurf or dry rot were collected from NB, PEI, NS and AB. These samples were used for isolation of silver scurf and dry rot pathogens which were later identified by morphological and molecular techniques. The efficacy of biopesticides, Bio-Save 10LP and Bio-Save 11LP to control silver scurf and dry rot was tested under *in vitro* conditions. Storage trials were initiated in PEI, NB and AB to assess the ability of these biopesticides to control dry rot and silver scurf.

Collaborators:

Dr. Rick Peters, Ph.D., Agriculture and Agri-Food Canada, Charlottetown, PEI.

Role: Supervise and conduct research trials in PEI.

Dr. Ron Howard, Ph.D., Alberta Agriculture and Food, Brooks, AB.

Role: Supervise and conduct research trials in AB.

Lucie Grant, JET Harvest Solutions, Longwood, FL 32791, USA.

Role: Registrant of Bio-Save 10LP and Bio-Save11LP (*Pseudomonas syringae*); provide products and trial validation.

Grower Groups: Potatoes NB, PEI Potato Board, and Potato Growers of Alberta

Role: Project support.

Kelvin Lynch, NB Department of Agriculture and Aquaculture, Fredericton, NB.

Role: Facilitate communication among project partners to optimize studies for product registration in Canada.

Key findings and outcomes of the project

Note: Key outcomes on the efficacy of biopesticides are based on *in vitro* trials only. Final key outcomes will be formulated upon completion of the post harvest storage trials.

1. *Fusarium* species isolated from dry rot infected potatoes include *F. sambucinum*, *F. tumidum*, *F. coeruleum*, *F. culmorum*, *F. avenaceum*.
2. *Fusarium sambucinum* is the most frequently isolated species from dry rot infected potatoes in NB, PEI, NS, and AB.
3. Two groups of *Helminthosporium solani* exists in PEI and AB. Only one group (group II) exists in NB.
4. Bio-Save 11LP significantly inhibited the growth of both *F. sambucinum* and *H. solani* compared to the untreated, inoculated control.
5. Bio-Save 10 LP significantly inhibited the growth of *H. solani* while it failed to inhibit the growth of *F. sambucinum*.
6. Mertect significantly inhibited the growth of both *F. sambucinum* and *H. solani* compared to the untreated, inoculated control.
7. The combinations of Mertect + Bio-Save 10 LP and Mertect + 11LP significantly reduced the growth of *F. sambucinum* and *H. solani*.
8. The *F. sambucinum* isolate from NB was more sensitive to Mertect than those from AB and PEI.
9. The silver scurf fungal isolates from AB were more sensitive to Mertect than those from NB and PEI.
10. Bio-Save 10LP and Bio-Save 11LP significantly reduced the incidence and severity of both *F. sambucinum* and *H. solani* in NB and PEI storage trials.
11. Mertect significantly reduced the incidence and severity of both *F. sambucinum* and *H. solani* in NB and PEI storage trials.
12. The combinations of Mertect + Bio-Save 10LP and Mertect + 11LP significantly reduced the incidence and severity of *F. sambucinum* and *H. solani* in NB and PEI storage trials.
13. The use of Bio-Save alone or in combination with Mertect appears to be a potentially sound strategy that can be used in the management of both silver scurf and dry rot and for managing the resistance for both products.

Pesticide risk reduction results (as measured or anticipated). The use of Bio-Save for controlling dry rot and silver scurf pathogens will prevent the need to use harmful and ineffective pesticides. Since the combination of Bio-Save and Mertect have given better results of dry rot and silver scurf control, Mertect use can be alternated with Bio-Save, thus reducing its risk and negative impact on the environment. This can extend the life of these products and help prevent or manage potential resistance of the pathogens to either product.

Table 1: Treatment details of *in vitro* study

1. Sterile distilled water (Control)
2. Bio-Save 10LP (Label rate = 500g/30 gal or 4.4 g/L of water)
3. Bio-Save 10LP (0.1 ppm)
4. Bio-Save 10LP (1.0 ppm)
5. Bio-Save 10LP (10.0 ppm)
6. Bio-Save 10LP (100.0 ppm)
7. Bio-Save 10LP (1000.0 ppm)
8. Bio-Save 11LP (Label rate = 500g/30 gal or 4.4 g/L of water)
9. Bio-Save 11LP (0.1 ppm)
10. Bio-Save 11LP (1.0 ppm)
11. Bio-Save 11LP (10.0 ppm)
12. Bio-Save 11LP (100.0 ppm)
13. Bio-Save 11LP (1000.0 ppm)
14. Mertect (Label rate = 7.5 L/170 L or 44 ml/L of water)
15. Mertect (treatment 14) + Bio-Save 10LP (treatment 2)
16. Mertect (treatment 14) + Bio-Save 11LP (treatment 8)

Table 2: Treatment details of storage trial

1. Untreated un-inoculated
2. Untreated tubers naturally infected with <i>Helminthosporium solani</i>
3. Untreated inoculated with <i>Fusarium sambucinum</i>
4. Bio-Save 10LP (500 g in 30 gallons or 4.4 g in 1L of water to treat 3000 cwt of potatoes)
5. Bio-Save 11LP (500 g in 30 gallons or 4.4 g in 1L of water to treat 3000 cwt of potatoes)
6. Mertect (7.5 L in 170 L or 44 ml in 1L of water; 2 L of suspension/1000 kg of potato)
7. Mertect + Bio-Save 10LP (treatments 4 + 6)
8. Mertect + Bio-Save 11LP (treatments 5 + 6)

Table 3: List of silver scurf and dry rot pathogens isolated from tubers collected from NB, AB, PEI and NS.

Strain Number	Genus	Species	Habitat	Location	Province
2007-029 (2007M-73)	<i>Helminthosporium</i>	<i>solani</i> (Group II)	Potato storage	Gillispie	NB
2007-037 (2007M-74)	<i>Helminthosporium</i>	<i>solani</i> (Group II)	Potato storage	Holmesville	NB
2007-067 (2007M-75)	<i>Helminthosporium</i>	<i>solani</i> (Group II)	Potato storage	Jacksonville	NB
2007-042 (2007M-85)	<i>Fusarium</i>	<i>tumidum</i>	Potato storage	Glassville	NB
2007-054 (2007M-86)	<i>Fusarium</i>	<i>sambucinum</i>	Potato storage	Woodstock	NB
2007-060 (2007M-87)	<i>Fusarium</i>	<i>coeruleum</i>	Potato storage	Woodstock	NB
2007-063 (2007M-88)	<i>Fusarium</i>	<i>tumidum</i>	Potato storage		NB
2007-112 (2007M-89)	<i>Fusarium</i>	<i>culmorum</i>	Potato storage		NB
2007-124 (2007M-90)	<i>Fusarium</i>	<i>culmorum</i>	Potato storage		NB
2007-131 (2007M-101)	<i>Fusarium</i>	<i>culmorum</i>	Potato storage		NB
2007-132 (2007M-102)	<i>Fusarium</i>	<i>sambucinum</i>	Potato storage		NB
2007-133 (2007M-103)	<i>Fusarium</i>	<i>culmorum</i>	Potato storage		NB
2007-134 (2007M-104)	<i>Fusarium</i>	<i>coeruleum</i>	Potato storage		NB
2007-103 (2007M-76)	<i>Helminthosporium</i>	<i>solani</i> (Group II)	Potato storage	Pisquid	PEI
2007-104 (2007M-77)	<i>Helminthosporium</i>	<i>solani</i> (Group I)	Potato storage	Pisquid	PEI
2007-105 (2007M-78)	<i>Helminthosporium</i>	<i>solani</i> (Group II)	Potato storage	Pisquid	PEI
2007-106 (2007M-79)	<i>Helminthosporium</i>	<i>solani</i> (Group II)	Potato storage	Pisquid	PEI
2007-107 (2007M-80)	<i>Helminthosporium</i>	<i>solani</i> (Group II)	Potato storage	Pisquid	PEI
2007-108 (2007M-81)	<i>Helminthosporium</i>	<i>solani</i> (Group I)	Potato storage	Pisquid	PEI
2007-109 (2007M-82)	<i>Helminthosporium</i>	<i>solani</i> (Group II)	Potato storage	Pisquid	PEI
2007-110 (2007M-83)	<i>Helminthosporium</i>	<i>solani</i> (Group I)	Potato storage	Pisquid	PEI
2007-111 (2007M-84)	<i>Helminthosporium</i>	<i>solani</i> (Group I)	Potato storage	Pisquid	PEI
PL1Col1 (2007M-100)	<i>Helminthosporium</i>	<i>solani</i> (Group I)	Potato field	Spruce Grove	AB
PL2Col3 (2007M-99)	<i>Helminthosporium</i>	<i>solani</i> (Group II)	Potato field	Spruce Grove	AB
FS001-A1b (2007M-97)	<i>Fusarium</i>	<i>sambucinum</i>	Potato storage	Taber	AB
PEF378 (2007M-92)	<i>Fusarium</i>	<i>sambucinum</i>			PEI
PEF918 (2007M-96)	<i>Fusarium</i>	<i>sambucinum</i>			NS
PEF400 (2007M-93)	<i>Fusarium</i>	<i>coeruleum</i>			PEI
PEF888 (2007M-95)	<i>Fusarium</i>	<i>coeruleum</i>			NS
PEF423 (2007M-94)	<i>Fusarium</i>	<i>avenaceum</i>			PEI

Table 4: *In vitro* efficacy of Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*) against *Helminthosporium solani*.

Treatments	% Fungal Growth Inhibition*				
	AB I	AB II	PEI I	PEI II	NB
Sterile Distilled Water (Control)	0 ^f	0 ^f	0 ^f	0 ^h	0 ^f
Bio-Save 10 LP (label rate = 4.4 g/L of water)	40 ^c	42 ^c	50 ^{cd}	44 ^d	68 ^a
Bio-Save 10 LP (0.1 ppm)	5 ^{ef}	19 ^{de}	43 ^{de}	20 ^f	39 ^b
Bio-Save 10 LP (1 ppm)	11 ^{def}	3 ^{ef}	9 ^{ghi}	5 ^{gh}	29 ^{bc}
Bio-Save 10 LP (10 ppm)	0 ^f	5 ^{def}	17 ^{gh}	4 ^h	16 ^{cde}
Bio-Save 10 LP (100 ppm)	65 ^b	8 ^{def}	32 ^{ef}	3 ^h	6 ^{ef}
Bio-Save 10 LP (1000 ppm)	9 ^{def}	60 ^b	22 ^{igh}	40 ^{de}	40 ^b
Bio-Save 11 LP (label rate = 4.4 g/L of water)	66 ^b	45 ^{bc}	73 ^a	67 ^{bc}	72 ^a
Bio-Save 11 LP (0.1 ppm)	19 ^{de}	13 ^{def}	0 ^f	14 ^{fg}	14 ^{def}
Bio-Save 11 LP (1 ppm)	18 ^{def}	21 ^d	8 ^{hi}	8 ^{gh}	6 ^{ef}
Bio-Save 11 LP (10 ppm)	0 ^f	0 ^f	8 ^{hi}	2 ^h	5 ^{ef}
Bio-Save 11 LP (100 ppm)	1 ^{ef}	8 ^{def}	9 ^{ghi}	9 ^{gh}	10 ^{def}
Bio-Save 11 LP (1000 ppm)	24 ^{cd}	15 ^{def}	23 ^{fg}	31 ^e	22 ^{cd}
Mertect (label rate = 44 ml/L of water)	100 ^a	100 ^a	65 ^{ab}	77 ^a	79 ^a
Mertect (label rate) + Bio-Save 10 LP (label rate)	100 ^a	100 ^a	53 ^{bcd}	64 ^c	70 ^a
Mertect (label rate) + Bio-Save 11 LP (label rate)	100 ^a	100 ^a	63 ^{abc}	74 ^{ab}	74 ^a

* Average values of 3 replicates. Mean followed by the same letter within each column are not significantly different from each other at $P=0.1$.

Table 5: *In vitro* efficacy of Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*) against *Fusarium sambucinum*.

Treatments	% Fungal Growth Inhibition*		
	AB	PEI	NB
Sterile Distilled Water (Control)	0 ^h	0 ^f	0 ^g
Bio-Save 10 LP (label rate = 4.4 g/L of water)	0 ^h	0 ^f	0 ^g
Bio-Save 10 LP (0.1 ppm)	2 ^{gh}	2 ^{ef}	5 ^{ef}
Bio-Save 10 LP (1 ppm)	5 ^{igh}	0 ^f	7 ^{de}
Bio-Save 10 LP (10 ppm)	5 ^{igh}	1 ^{ef}	5 ^{ef}
Bio-Save 10 LP (100 ppm)	3 ^{gh}	0 ^f	3 ^{fg}
Bio-Save 10 LP (1000 ppm)	2 ^{gh}	0 ^f	0 ^g
Bio-Save 11 LP (label rate = 4.4 g/L of water)	43 ^c	28 ^d	54 ^b
Bio-Save 11 LP (0.1 ppm)	1 ^h	0 ^f	3 ^{fg}
Bio-Save 11 LP (1 ppm)	8 ^{fg}	1 ^{ef}	5 ^{ef}
Bio-Save 11 LP (10 ppm)	10 ^{ef}	0 ^f	2 ^{fg}
Bio-Save 11 LP (100 ppm)	15 ^e	3 ^e	10 ^d
Bio-Save 11 LP (1000 ppm)	26 ^d	1 ^{ef}	29 ^c
Mertect (label rate = 44 ml/L of water)	86 ^a	88 ^b	100 ^a
Mertect (label rate) + Bio-Save 10 LP (label rate)	74 ^b	77 ^c	100 ^a
Mertect (label rate) + Bio-Save 11 LP (label rate)	83 ^a	100 ^a	100 ^a

* Average values of 3 replicates. Mean followed by the same letter within each column are not significantly different from each other at $P=0.1$.

Table 6. External and internal dry rot disease severity and incidence levels on tubers treated with Bio-Save (*Pseudomonas syringae*), Mertect or the combination of both in a storage trial conducted in Alberta.

Treatments	External Disease Incidence (%) ¹	Internal Disease Incidence (%) ¹	External Disease Severity (%) ²	Internal Disease Severity (%) ²
Inoculated, untreated control	81.2 ^{ab*}	80.2 ^{abc*}	1.59 ^{a*}	1.75 ^{a*}
Bio-Save 10 LP	81 ^{ab}	84 ^{abc}	1.66 ^a	1.87 ^a
Bio-Save 11 LP	86.2 ^{ab}	89.8 ^{ab}	1.84 ^a	2.06 ^a
Mertect SC	85.1 ^{ab}	78.7 ^{bc}	1.82 ^a	1.88 ^a
Bio-Save 10 LP + Mertect SC	77.5 ^b	73.5 ^c	1.52 ^a	1.63 ^a
Bio-Save 11 LP + Mertect SC	91 ^a	95 ^a	1.84 ^a	1.77 ^a
LSD @ 0.05%	10.5	15.9	0.46	0.6

* Average values of 4 replicates. Each replicate contained a set of 25 tubers. Means followed by the same letter within each column are not significantly different from each other at $P=0.05$.

¹External and internal disease incidence means were based on the percentage of tubers evaluated per treatment that displayed symptoms of infection.

²External and internal disease severity means are expressed on a 0-5 point scale, where 0 = no dry rot present, 1 = <1% dry rot, 2 = 1-10% dry rot, 3 = 11-25% dry rot, 4 = 26-50% dry rot and 5 = >50% dry rot.

Table 7. Silver scurf disease severity and disease incidence levels on tubers treated with Bio-Save (*Pseudomonas syringae*), Mertect or the combination of both in a storage trial conducted in Alberta.

Treatments	Disease Incidence (%) ¹	Disease Severity (%) ²
Inoculated, untreated control	99 ^{ab*}	1.92 ^{a*}
Bio-Save 10 LP	100 ^a	1.89 ^a
Bio-Save 11 LP	100 ^a	1.76 ^a
Mertect SC	94.9 ^{bc}	1.65 ^a
Bio-Save 10 LP + Mertect SC	96.8 ^{ab}	1.82 ^a
Bio-Save 11 LP + Mertect SC	90.8 ^c	1.75 ^a
LSD @ 0.05%	4.5	0.35

* Average values of 4 replicates. Each replicate contained a set of 25 tubers. Means followed by the same letter within each column are not significantly different from each other at $P=0.05$.

¹Disease incidence means were based on the percentage of tubers evaluated per treatment that displayed symptoms of infection.

²Disease severity means are expressed on a 0-5 point scale, where 0 = no dry rot present, 1 = <1% dry rot, 2 = 1-10% dry rot, 3 = 11-25% dry rot, 4 = 26-50% dry rot and 5 = >50% dry rot.

Table 8. The disease incidence of dry rot on tubers treated with Bio-Save (*Pseudomonas syringae*), Mertect or the combination of both in a storage trial conducted in Prince Edward Island.

Treatments	External Disease Incidence (%) ¹	Internal Disease Incidence (%) ¹
Inoculated, untreated control	64 ^a	64 ^a
Bio-Save 10 LP	8 ^d	8 ^d
Bio-Save 11 LP	21 ^{bc}	21 ^{bc}
Mertect SC	10 ^d	10 ^d
Bio-Save 10 LP + Mertect SC	24 ^b	24 ^b
Bio-Save 11 LP + Mertect SC	11 ^{cd}	11 ^{cd}
LSD @ 0.05%	10	10

* Average values of 4 replicates. Each replicate contained a set of 25 tubers. Means followed by the same letter within each column are not significantly different from each other at $P=0.05$.

¹External and internal disease incidence means were based on the percentage of tubers evaluated per treatment that displayed symptoms of infection.

Table 9. The disease severity of dry rot on tubers treated with Bio-Save (*Pseudomonas syringae*), Mertect or the combination of both in a storage trial conducted in Prince Edward Island.

Treatments	External Disease Severity (%) ¹	Internal Disease Severity (mm) ²
Inoculated, untreated control	6.28 ^{a*}	7.05 ^{a*}
Bio-Save 10 LP	0.42 ^b	0.52 ^b
Bio-Save 11 LP	0.92 ^b	0.61 ^b
Mertect SC	0.99 ^b	1.00 ^b
Bio-Save 10 LP + Mertect SC	1.21 ^b	0.81 ^b
Bio-Save 11 LP + Mertect SC	0.48 ^b	0.41 ^b
LSD @ 0.05%	1.24	1.36

* Average values of 4 replicates. Each replicate contained a set of 25 tubers. Means followed by the same letter within each column are not significantly different from each other at $P=0.05$.

¹External disease severity was measured on a scale of 0-100% (Cruickshank *et al.*, 1982; Dorrance and Inglis, 1997).

²Internal disease severity (depth of rubber decay) was measured using a digital caliper (VWR Scientific Products, Mississauga, Ontario, Canada).

Table 10. The disease severity of silver scurf on tubers treated with Bio-Save (*Pseudomonas syringae*), Mertect or the combination of both in a storage trial conducted in Prince Edward Island.

Treatments	Disease Severity (%)
Inoculated, untreated control	19 ^{a*}
Bio-Save 10 LP	7.41 ^{bc}
Bio-Save 11 LP	7.02 ^c
Mertect SC	7.91 ^{bc}
Bio-Save 10 LP + Mertect SC	9.09 ^b
Bio-Save 11 LP + Mertect SC	8.78 ^{bc}
LSD @ 0.05%	1.98

* Average values of 4 replicates and each replicate contained a set of 25 tubers. Mean followed by the same letter within each column are not significantly different from each other at $P=0.05$.

¹Disease severity was measured on a scale of 0-100% (Cruickshank *et al.*, 1982; Dorrance and Inglis, 1997).

Table 11. The disease incidence of dry rot on tubers treated with Bio-Save (*Pseudomonas syringae*), Mertect or the combination of both in a storage trial conducted in New Brunswick.

Treatments	External Disease Incidence (%) ¹	Internal Disease Incidence (%) ²
Inoculated, untreated control	93 ^a	81 ^a
Bio-Save 10 LP	34 ^{cd}	22 ^b
Bio-Save 11 LP	60 ^b	19 ^b
Mertect SC	42 ^c	28 ^b
Bio-Save 10 LP + Mertect SC	34 ^{cd}	24 ^b
Bio-Save 11 LP + Mertect SC	24 ^d	30 ^b
LSD @ 0.05%	12	12

* Average values of 4 replicates. Each replicate contained a set of 25 tubers. Means followed by the same letter within each column are not significantly different from each other at $P=0.05$.

¹External and internal disease incidence means were based on the percentage of tubers evaluated per treatment that displayed symptoms of infection.

Table 12. The disease severity of dry rot on tubers treated with Bio-Save (*Pseudomonas syringae*), Mertect or the combination of both in a storage trial conducted in New Brunswick.

Treatments	External Disease Severity (%) ¹	Internal Disease Severity (mm) ²
Inoculated, untreated control	8.2 ^a	6.4 ^a
Bio-Save 10 LP	1.8 ^{cd}	1.5 ^b
Bio-Save 11 LP	3.1 ^b	1.3 ^b
Mertect SC	2.6 ^{bc}	1.9 ^b
Bio-Save 10 LP + Mertect SC	1.9 ^{cd}	1.3 ^b
Bio-Save 11 LP + Mertect SC	1.4 ^d	1.8 ^b
LSD @ 0.05%	0.94	1.5

* Average values of 4 replicates. Each replicate contained a set of 25 tubers. Means followed by the same letter within each column are not significantly different from each other at $P=0.05$.

¹External disease severity was measured on a scale of 0-100% (Cruickshank *et al.*, 1982; Dorrance and Inglis, 1997).

²Internal disease severity (depth of rubber decay) was measured using a digital caliper (VWR Scientific Products, Mississauga, Ontario, Canada).

Table 13. The disease incidence and severity of silver scurf on tubers treated with Bio-Save (*Pseudomonas syringae*), Mertect or the combination of both in a storage trial conducted in New Brunswick

Treatments	Disease Incidence (%) ¹	Disease Severity (%) ²
Inoculated, untreated control	79 ^a	12.8 ^a
Bio-Save 10 LP	11 ^{cd}	0.9 ^b
Bio-Save 11 LP	21 ^{bc}	1.4 ^b
Mertect SC	22 ^b	1.8 ^b
Bio-Save 10 LP + Mertect SC	10 ^d	0.7 ^b
Bio-Save 11 LP + Mertect SC	19 ^{bcd}	1.5 ^b
LSD @ 0.05%	11	1.5

* Average values of 4 replicates. Each replicate contained a set of 25 tubers. Means followed by the same letter within each column are not significantly different from each other at $P=0.05$.

¹External and internal disease incidence means were based on the percentage of tubers evaluated per treatment that displayed symptoms of infection.

²Disease severity was measured on a scale of 0-100% (Cruickshank *et al.*, 1982; Dorrance and Inglis, 1997).



Figure 1. Steps in the inoculation of tubers with *Fusarium sambucinum*.



Figure 2. Steps involved in treatment application in the dry rot and silver scurf storage trials.



Figure 3. *In vitro* efficacy of Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*), Mertect (thiabendazole), and a combination of both against *Fusarium sambucinum*. Control refers to the untreated, inoculated control. *F. sambucinum* isolates tested were collected from Prince Edward Island (PEI), New Brunswick (NB), and Alberta (AB), Canada.

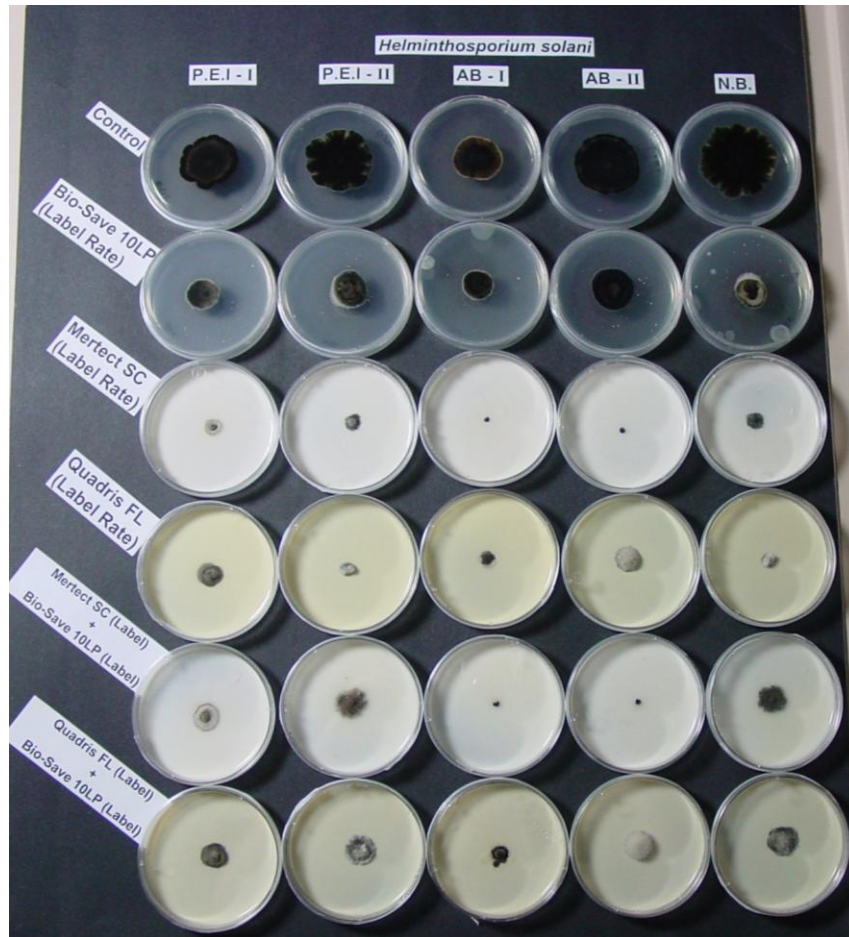


Figure 4. *In vitro* efficacy of Bio-Save 10LP (*Pseudomonas syringae*), Mertect (thiabendazole), and a combination of both against *Helminthosporium solani*. Control refers to the untreated, inoculated control. *H. solani* isolates tested were collected from Prince Edward Island (PEI), New Brunswick (NB), and Alberta (AB), Canada.

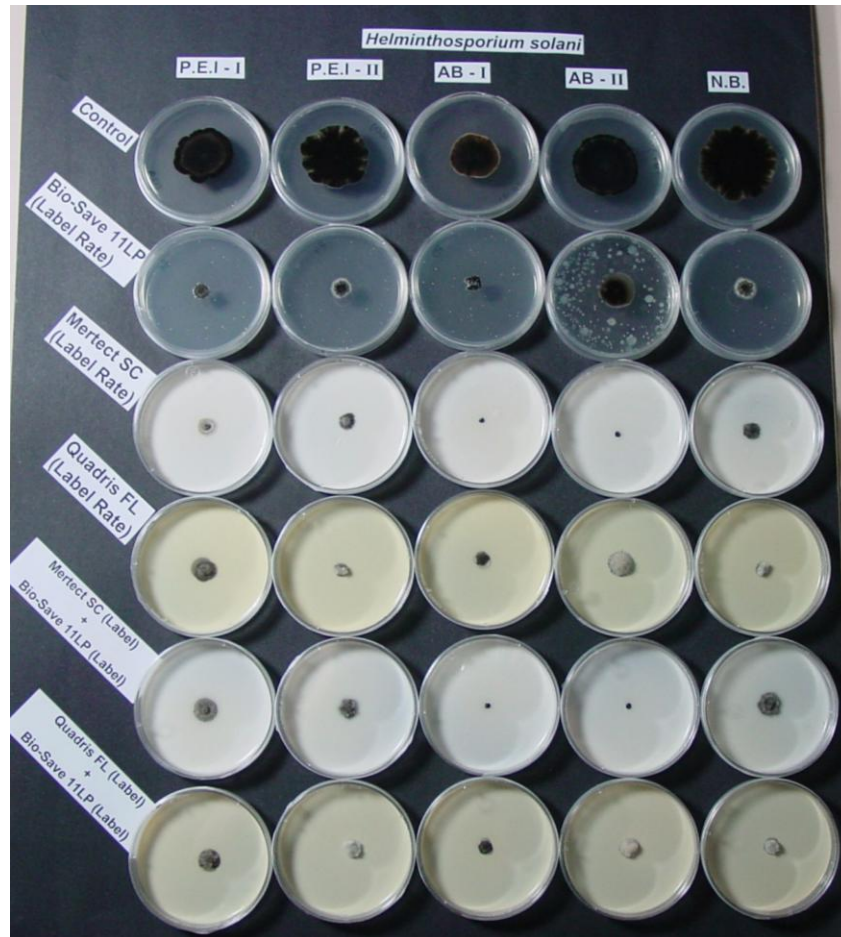


Figure 5. *In vitro* efficacy of Bio-Save 11LP (*Pseudomonas syringae*), Mertect (thiabendazole), and a combination of both against *Helminthosporium solani*. Control refers to the untreated, inoculated control. *H. solani* isolates tested were collected from Prince Edward Island (PEI), New Brunswick (NB), and Alberta (AB), Canada.