Evaluation and comparison of biocontrol and conventional fungicides for control of postharvest potato tuber diseases

Esther Gachango\textsuperscript{a}, William Kirk\textsuperscript{a,\ast}, Robert Schafer\textsuperscript{a}, Phillip Wharton\textsuperscript{b}

\textsuperscript{a}Department of Plant, Soil and Microbial Sciences, Michigan State University, East Lansing, MI 48824, USA
\textsuperscript{b}Department of Plant Pathology, University of Idaho, Aberdeen Research & Extension Center, Aberdeen, ID 83210, USA

HIGHLIGHTS

- There is a shortage of postharvest fungicides to control potato diseases in storage.
- In these studies, the biocontrol fungicides were to some extent as effective as the conventional fungicides.
- Both offered limited broad-spectrum control of potato storage diseases.
- Use of these products should be integrated with other management strategies.

ABSTRACT

Two biocontrol fungicides (\textit{Bacillus subtilis} and \textit{Bacillus pumilus}) and three conventional fungicides (phosphorous acid, azoxystrobin and hydrogen peroxide) were evaluated in two storage trials over 2 years for efficacy in suppressing tuber infection caused by \textit{Phytophthora infestans}, \textit{Phytophthora erythroseptica}, \textit{Pythium ultimum} and \textit{Fusarium sambucinum}. A chip-processing cultivar, FL 1879, stored at 10 $^\circ$C was used for the two trials. Tubers were inoculated followed by treatment with the fungicides prior to storage. Disease incidence was assessed after 120 d in storage. The biocontrol fungicides had limited control of the storage pathogens compared to the conventional fungicides. Phosphorous acid, hydrogen peroxide and azoxystrobin were moderately effective in controlling diseases caused by the oomycete pathogens. Although none of the products evaluated completely controlled the storage diseases, the conventional fungicides showed a higher potential for suppressing tuber infection in storage than the biocontrol fungicides. Use of these biocontrol fungicides could be integrated with other management strategies.

1. Introduction

Potato growers aim to produce and harvest a healthy and high quality crop. However, there are several diseases that infect potatoes in storage thus compromising their quality and creating a potential economic loss (Secor and Gudmestad, 1999). The major storage diseases include late blight caused by \textit{Phytophthora infestans} (Mont.) de Bary, dry rot caused by \textit{Fusarium sambucinum} Fuc.-kell. and \textit{Fusarium} spp., Pythium leak caused by \textit{Pythium ultimum} Trow. and pink rot caused by \textit{Phytophthora erythroseptica} Pethbr. (Secor and Gudmestad, 1999). These pathogens are soilborne and seedborne, and have both field and storage stages with losses in storage tending to be more economically overwhelming for the grower (Powelson and Rowe, 2008). Infection of tubers in the field by all these pathogens takes place through underground stems, stolons, or roots as tubers develop although the exact mechanisms vary among pathogens. Indirect infection may also occur during harvesting in storage loading when tubers are damaged through the lenticels, eyes and wounds inflicted to the periderm (Powelson and Rowe, 2008). The likelihood of infection by these pathogens is highly affected by the health of the seed tubers, management
practices during the growing period, harvesting and handling practices and the environmental conditions maintained throughout storage (Shetty, 1996). In the field, tubers may be wounded during harvest, transport to storage and during storage activities. The duration of this process depending on the distance of the field to the storage (up to 150 km in MI, USA) and the handling capacity of the system can take up to 24 h during Sep to Oct in temperatures ranging from 15 to 25 °C (Dr. Karl Ritchie, Agronomist, Walther Potato Farms, Three Rivers, Michigan, USA, Pers. Comm.) especially when equipment breaks down. In these experiments, the inoculated tubers were stored for 24 h at 20 °C before treatment with fungicides or biofungicides as an approximate extended period simulating worse case scenario situations.

Currently, the primary control for these diseases in storage facilities includes elimination of infected tubers prior to storage and storage management using forced air ventilation, and controlled temperature and humidity feedback systems (Knowles and Plissey, 2008). There is a shortage of postharvest fungicides or effective disinfectant products to completely control these pathogens (Olsen et al., 2003). The few compounds available for potato tuber treatment in storage include chlorine-based disinfectants such as, sodium hypochlorite, calcium hypochlorite and chlorine dioxide and mixtures of hydrogen peroxide and peroxycetic acid (Afek et al., 2001; Norikane et al., 2001; Wharton et al., 2007). Hydrogen peroxide (H\textsubscript{2}O\textsubscript{2}; Oxidate™, hydrogen dioxide acid (Afek et al., 2001; Norikane et al., 2001; Miller, 2005). Hydrogen peroxide is environmentally friendly with its activities based on oxidation of fungi and bacteria, and has successfully been reported to control silver scurf (Afek et al., 2001) and pink rot (Al-Mughrabi, 2006). However, use of disinfectants does not completely control storage pathogens (Olsen et al., 2003; Miller et al., 2006), hence other postharvest products in combination with proper storage management are recommended (Powelson and Rowe, 2008).

In recent years, several new biocontrol fungicides based on bacteria, Bacillus subtilis (QST 713; Serenade; AgraQuest, Inc. CA) and Bacillus pumilus (QST 2808; Sonata; AgraQuest, Inc. CA) have been registered for control of potato pathogens. These products are used for organic potato production to complement copper products and have successfully shown a reduction of foliar late blight disease development (Stephan et al., 2005). B. subtilis produces three groups of lipopeptides that work together to stop spores of plant pathogens from germinating, disrupt germ tube and mycelial growth and inhibit attachment of the plant pathogen to the leaf surface (Marrone, 2002). Another product registered for postharvest use is Bio-Save 10LP (Pseudomonas syringae: ESC-10), which has been reported to reduce Fusarium dry rot and silver scurf when applied to tubers prior to storage (Olsen and Miller, 2005; Hopkins and Hirnycz, 2008). A positive effect of B. subtilis in combination with field-applied biofungicides and fungicides for the control of postharvest diseases of potatoes in Michigan was reported by Gachango et al. (in press).

Phosphorous acid (Phostrol, mono and di-basic sodium, potassium and ammonium salts of phosphorous acid; Nufarm Americas, Inc., AGT-Division, Burr Ridge, IL) was recently registered for postharvest use in potato production (Powelson and Rowe, 2008). The United States Environmental Protection Agency (US-EPA) considers it as a systemic fungicide but not a biochemical (http://tinyurl.com/659xty3). Phosphorous acid has both a direct and an indirect mode of action (Brunings et al., 2005). Direct effects include inhibition of mycelial growth and inhibition of particular metabolic processes, and indirect effects include stimulation of the natural defense responses of the plant (Guest and Bompeix, 1990). Phosphorous acid has been reported to effectively control tuber late blight and pink rot in storage (Olsen and Miller, 2005; Miller et al., 2006; Johnson, 2008, 2010).

Control of dry rot in storage has primarily been achieved through reducing tuber bruising, providing conditions for rapid wound healing (Secor and Johnson, 2008) and applying thiabendazole (TBZ; Mertect 340-F, Syngenta, Greensboro, NC), a benzimidazole fungicide as tubers are loaded into storage (Hide et al., 1992). However, F. sambucinum resistant to TBZ and other benzimidazole fungicides were discovered in Europe in 1973 (Hide et al., 1992) and in the US in 1992 (Desjardins, 1995), leading to reduced effectiveness in controlling dry rot (Staub, 1991). To counteract this loss, registration of other chemistries is imperative. Although azoxystrobin is registered for foliar application in potato fields, it has been proposed for registration as a postharvest fungicide to control tuber decay caused by Fusarium spp. (Adaskaveg and Förster, 2010). Thus, studies were initiated and carried out from 2006 to 2007 to evaluate the efficacy of B. subtilis and B. pumilus for the control of potato storage pathogens under post-harvest conditions. These products were compared with several conventional fungicides including phosphorous acid, hydrogen dioxide and azoxystrobin under storage conditions.

2. Materials and methods

2.1. Tuber preparation

Potato cultivar, cv. FL 1879, used for chip processing was used in 2006 and 2007 trials. The tests were carried out at 10 °C, the temperature used in the potato industry for chip processing (Knowles and Plissey, 2008). Potatoes free from visible symptoms were selected and prepared for inoculation by grazing with a single light stroke with a wire brush sufficient to abrade the skin of the tubers to a depth of 0.01 mm.

2.2. Inoculum

Isolates of P. erythroseptica, P. ultimum and F. sambucinum previously isolated from potato tubers in Michigan were grown on potato dextrose agar (PDA; Difco, Detroit, Michigan), while P. infestans (US-8; A2 mating type, mfenoxam resistant) was grown on rye media prepared by steaming rye seed (100 g L\textsuperscript{-1} of distilled water) for 1 h, with addition of 7.5 g sucrose, 0.05 g ß-sitosterol and 1.5% agar to the resulting broth filtrate. The cultures were grown 10 d prior to preparation of inoculum solutions. Solutions containing sporangia of P. infestans, oospores/sporangia of P. erythroseptica, oospores of P. ultimum and macroconidia of F. sambucinum were prepared and spore concentration adjusted to 10,000 mL\textsuperscript{-1} using a hemacytometer. Damaged tubers, (25/replicate/treatment; total 100 tubers/treatment) were sprayed with 10 mL of pathogen suspension, for a final dosage of about 0.1 mL/tuber. The inoculated tubers were stored at 20 °C for 24 h before treatment with the biocontrols or conventional fungicides (Table 1).

2.3. Treatments

Treatments applied to the potato tubers were B. pumilus (20.9 mL/100 kg potato tubers); B. subtilis [(20.9 mL (high rate) or 10.4 mL (low rate)/100 kg potato tubers]; phosphorous acid (83.5 mL/100 kg potato tubers); hydrogen peroxide (8.15 mL/100 kg potato tubers); and azoxystrobin (1.96 mL/100 kg potato tubers)]. All the treatments were applied in a liquid in water suspension with a single R&D XR11003VS spray nozzle at a rate of 1L/ton at 344.7 KPa onto the tuber surfaces, with the entire seed surface being coated. Two untreated controls, either inoculated with one of the pathogens or non-inoculated were included in
the trial. Tubers were incubated in the dark in plastic boxes for 120 d at 10 °C.

2.4. Disease assessment

After incubation, all the tubers were cut in half longitudinally and disease incidence assessed visibly for each one as presence of signs or symptoms with late blight, Pythium leak, pink rot or Fusarium dry rot. Disease incidence was computed as percentage of tubers infected per replicate.

2.5. Data analysis

Data were tested for assumptions of normality and analyzed by analysis of variance platform in JMP (JMP © 2008, SAS Institute Inc., Cary, NC). Mean separation was performed using Tukey’s honestly significant difference test when the F test was significant (p < 0.05) for a test factor. Data for the repeated experiments were first tested for homogeneity of variances using Bartlett’s test of homogeneity. The data were also tested for significance of the main effects and interactions. If variances were homogeneous for each experiment, and no significant differences were measured between the repeats of any of the experiments, the data were combined and analyzed statistically using analysis of variance (ANOVA). In both years, analysis of variance showed that there were significant differences between results from each year for dry rot and tuber late blight, so data from each year were analyzed separately. In both years, analysis of variance showed that there were no significant differences between results from each year for pythium and pink rot, so data from each year were combined for analysis of each disease.

3. Results

No significant differences in disease incidence were measured between the two executions of the experiments for pythium and pink rot (Table 2) so data were combined for subsequent analyses. Significant differences in disease incidence were measured between the two executions of the experiments for Fusarium dry rot and tuber late blight (Table 2) so data were analyzed separately. The main effects analyses for biofungicide and fungicide efficacy against the diseases tested indicated that there were significant effects among treatments (Table 2).

3.1. Fusarium dry rot

There were differences (p = 0.0003) among treatments for dry rot incidence in 2006 and 2007 (Table 2). Higher disease levels were observed in 2007 than in 2006. However, a similar trend was observed in some of the treatments (Table 3). For instance, inoculated tubers treated with either B. subtilis at high rate or B. pumilus did not differ (p < 0.05) from the untreated inoculated checks in both years with respect to dry rot incidence. Dry rot incidence was also observed on the non-inoculated tubers but at a very low percentage (Table 3). Tubers treated with the biocontrols had a higher dry rot incidence (p < 0.05) than those treated with the conventional fungicides (Table 3). In 2007, B. subtilis applied at the lower rate was the only treatment that differed (p < 0.05) from the inoculated untreated check. However, the effect was not significantly different (p < 0.05) from that of B. subtilis (high rate), B. pumilus, phosphorous acid or hydrogen peroxide (Table 3).

3.2. Tuber blight

There were differences (p < 0.0001) among treatments for tuber blight incidence in 2006 and 2007 (Table 2). No tuber blight incidence was observed on non-inoculated tubers in 2006 and in 2007. Tuber blight incidence was lower in 2006 than in 2007 and all treatments differed (p < 0.05) from the untreated check but did not differ (p < 0.05) from each other with respect to tuber blight incidence (Table 4). In 2007, there were differences (p < 0.05) among treatments; the untreated check and the axoxystrobin treatment had significantly higher (p < 0.05) tuber blight incidence in 2007 than in 2006.

### Table 1

Products evaluated in the study including company code, FRAC group, active ingredient, formulation and manufacturer.

<table>
<thead>
<tr>
<th>Product name/code FRAC Group</th>
<th>Active ingredient</th>
<th>Formulation</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxidate</td>
<td>Hydrogen dioxide</td>
<td>27 SC</td>
<td>BioSafe Systems, LLC, East Hartford, CT</td>
</tr>
<tr>
<td>Quadris (11)</td>
<td>Azoxystrobin</td>
<td>250 SC</td>
<td>Syngenta Crop Protection Inc., Greensboro, NC, USA</td>
</tr>
<tr>
<td>Serenade QST 713 (44)</td>
<td>B. subtilis</td>
<td>1.34 SC</td>
<td>AgraQuest Inc. Davis, CA</td>
</tr>
<tr>
<td>Sonata QST 2808 (44)</td>
<td>B. pumilus</td>
<td>1.38 SC</td>
<td>AgraQuest Inc. Davis, CA</td>
</tr>
<tr>
<td>Phostrol (34)</td>
<td>Phosphorous acid</td>
<td>53.6 SC</td>
<td>Nufarm Americas Inc., AGT Division, Burr Ridge, IL, USA</td>
</tr>
</tbody>
</table>

* FRAC = Fungicide Resistance Action Committee; FRAC code-number and letters used to distinguish fungicide groups according to their cross resistance behavior (file://localhost/[http://www.frac.info:frac:publication:anhang:FRAC Code List 2011-final.pdf]).
* Formulation = products added to the active ingredient to change its physical characteristic and allow compatibility with the machinery; SC = suspension concentrates.

### Table 2

Main effects analyses of the biofungicide and fungicide treatments on incidence of dry rot, late blight, pythium leak and pink rot on potato tubers stored at 10 °C (cv. FL1879) as impacted by (a) the year in which the experiments were carried out, 2006 and 2007 and (b) by the treatment.

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Disease Incidence</th>
<th>F ratio</th>
<th>Prob &lt; F</th>
<th>Year of Trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Effect of year</td>
<td></td>
<td></td>
<td></td>
<td>2006</td>
</tr>
<tr>
<td>Dry rot</td>
<td>13.8091</td>
<td>0.0003</td>
<td>19.2</td>
<td>42.1</td>
</tr>
<tr>
<td>Late blight</td>
<td>20.9004</td>
<td>&lt;0.0001</td>
<td>3.4</td>
<td>24.5</td>
</tr>
<tr>
<td>Pythium</td>
<td>3.9200</td>
<td>0.0502</td>
<td>12.9</td>
<td>6.1</td>
</tr>
<tr>
<td>Pink rot</td>
<td>1.6373</td>
<td>0.2034</td>
<td>5.0</td>
<td>3.3</td>
</tr>
<tr>
<td>(b) Effect of treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry rot</td>
<td>9.828</td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pythium</td>
<td>40.503</td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pink rot</td>
<td>6.683</td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Incidence was calculated as the percentage of tubers relative to the total number of tubers in each replicate showing dry rot, tuber late blight, Pythium leak or pink rot symptoms sampled 120 d after treatments were applied (n = 25 tubers/replicate, total 100 tubers). Tubers were stored in the dark at 10 °C on for 120 d after treatment.
* HSD = Tukey’s Honestly significant difference of the comparison between a) the years and b) the treatment for each measured variable.
* Data from 2006 and 2007 were combined because there were no significant differences between years of the analysis.

E. Gachango et al. / Biological Control 63 (2012) 115–120
Table 3
Incidence of Fusarium dry rot on potato tubers, cv. FL1879, stored at 10°C for 120 d after treatment with biocontrols and conventional fungicides.

<table>
<thead>
<tr>
<th>Treatment and rates (mL/100 kg tubers)</th>
<th>Inoculation</th>
<th>Mean disease incidence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2006</td>
</tr>
<tr>
<td>Untreated</td>
<td></td>
<td>56.3</td>
</tr>
<tr>
<td>Phosphorous acid (83.5)</td>
<td>+</td>
<td>10.0</td>
</tr>
<tr>
<td>Hydrogen peroxide (8.5)</td>
<td>+</td>
<td>12.5</td>
</tr>
<tr>
<td>B. subtilis (10.4)</td>
<td>+</td>
<td>31.3</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>5.0</td>
</tr>
<tr>
<td>B. subtilis (20.9)</td>
<td>+</td>
<td>32.5</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>20.0</td>
</tr>
<tr>
<td>B. pumilus (20.9)</td>
<td>+</td>
<td>35.0</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>18.8</td>
</tr>
<tr>
<td>Azoxystrobin (1.96)</td>
<td>+</td>
<td>21.3</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>2.5</td>
</tr>
</tbody>
</table>

a Tubers were treated with the fungicides/biofungicides 24 h after inoculation. The rates were in mL of the product per 100 kg of potato tubers applied at a rate of 1 L/ton. Tubers were stored in the dark at 10°C on for 120 d after treatment.

b Incidence expressed as a percentage was calculated as mean number of tubers showing dry rot symptoms relative to number of tubers per replicate (n = 25 tubers, total 100 tubers) X 100 sampled 120 d after treatments were applied.

c Numbers followed by the same letter within a column followed by the same letter are not significantly different at p = 0.05 (Tukey test).

d Numbers followed by the same letter within a column followed by the same letter are not significantly different at p = 0.05 (Tukey test).

Table 4
Incidence of tuber late blight on cv. FL1879 stored at 10°C on for 120 d after treatment with biocontrols and conventional fungicides.

<table>
<thead>
<tr>
<th>Treatment and rates (mL/100 kg tubers)</th>
<th>Mean Incidence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2006</td>
</tr>
<tr>
<td>Untreated</td>
<td>22.5</td>
</tr>
<tr>
<td>Phosphorous acid (83.5)</td>
<td>3.8</td>
</tr>
<tr>
<td>Hydrogen peroxide (8.5)</td>
<td>0.0</td>
</tr>
<tr>
<td>B. subtilis (10.4)</td>
<td>5.0</td>
</tr>
<tr>
<td>B. pumilus (20.9)</td>
<td>6.3</td>
</tr>
<tr>
<td>Azoxystrobin (1.96)</td>
<td>0.0</td>
</tr>
</tbody>
</table>

a tubers not included in analysis due to extensive soft rotting.

b Incidence expressed as a percentage was calculated as mean number of tubers showing late blight symptoms relative to number of tubers per replicate (n = 25 tubers, total 100 tubers) X 100 sampled 120 d after treatments were applied.

c Numbers followed by the same letter within a column followed by the same letter are not significantly different at p = 0.05 (Tukey test).

d Numbers followed by the same letter within a column followed by the same letter are not significantly different at p = 0.05 (Tukey test).

4. Discussion

Due to limited availability of postharvest products for control of potato storage pathogens, strategies to ensure tubers are free from risk of pathogen infection should be integrated. The rationale behind postharvest application of fungicides is the assumption that healthy tubers are exposed to pathogens during harvesting operations and also in storage from soil adhering to the tubers or from infected tubers (Gudmestad et al., 2007). Tubers become wounded during harvesting, transportation and storage loading operations thus increasing their susceptibility to pathogen infection (Knowles and Plissey, 2008). The current study was set up to mimic tuber bin loading in a situation where pathogens are present. The wounding of the tubers was more severe than what could occur in a normal situation in the field and the storage conditions provided were conducive for disease development. Therefore, postharvest application of fungicides to effectively control storage disease development under these conditions was important. The variation in disease development between the two years could be attributed to the viability of the pathogens, since all other conditions remained the same during the experiments.

Application of B. subtilis and B. pumilus products had variable effects on control of the storage disease development depending on year and respective pathogen. For instance, treatment with B. subtilis at the high rate of application had very little effect on reduction of Fusarium dry rot and Pythium leak compared to application of B. subtilis at the low rate of application in 2006. This suggested that increasing the rate of application of B. subtilis did not improve the efficacy of controlling storage tuber storage diseases and hence growers could use the lower rate in combination with other management strategies. B. subtilis and B. pumilus are currently used in organic farming to supplement the copper compounds whose continued use has resulted in toxic build-up in the soil (Hopkins and Hirnyck, 2008). Indeed, B. subtilis was reported to
reduce the development of foliar late blight while applied up to 3 d before or just after inoculation, but was not as effective as the copper compounds (Stephan et al., 2005). This finding partly agrees with our findings where B. subtilis at the lower rate of application reduced the development of tuber blight. Other products could be used in addition to B. subtilis and B. pumilus for postharvest management to improve control of storage pathogens.

Application of phosphorous acid after tubers are harvested and at bin loading has been reported to effectively reduce the development of tuber late blight and pink rot once the tubers are exposed to the pathogens (Miller et al., 2006). In our study, phosphorous acid effectively reduced tuber blight incidence with limited effect on pink rot and Pythium leak incidence. These results indicate that phosphorous acid can be used to control tuber diseases caused by the oomycete pathogens, and are in agreement with other researchers (Cooke and Little, 2002; Johnson et al., 2004).

Hydrogen peroxide, a disinfectant, has been shown to effectively suppress storage pathogens (Afek et al., 2001; Al-Mughrabi, 2005, 2006). Despite the different application methods used, emitting hydrogen peroxide through a fogging system (Al-Mughrabi, 2005) or adding it into humidification water (Norikane et al., 2005, 2006). Despite the different application methods used, emitting hydrogen peroxide through a fogging system (Al-Mughrabi, 2005) or adding it into humidification water (Norikane et al., 2005, 2006), hydrogen peroxide has had promising results in controlling storage pathogens. Our results indicated that hydrogen peroxide reduced the development of tuber late blight, pink rot, Pythium leak, but had limited control of Fusarium dry rot under high disease pressure. According to Miller et al. (2006), hydrogen peroxide moderately controlled pink rot and late blight but the degree of control was subject to the duration between inoculation and time of application. Although the disinfectant was not applied immediately after inoculation as suggested by Miller et al. (2006), a significant reduction of disease incidence caused by the oomycete pathogens was attained using the method in this study.

Azoxystrobin is registered for foliar application in potato fields. However, it has been proposed for registration as a postharvest product for managing tuber decays caused by Fusarium species (Adaskaveg and Förster, 2010) since thiabendazole is the only registered postharvest fungicide for controlling Fusarium dry rot and is no longer effective in controlling dry rot caused by F. sambucinum (Ocamb et al., 2007). Olsen and Miller (2005) reported that azoxystrobin could be used to reduce silver scurf in storage. Azoxystrobin provided limited control of Fusarium dry rot even under low disease pressure, but it effectively controlled Pythium leak and pink rot. The study showed that none of the products evaluated provided complete control of the storage pathogens; however, they still have a high potential when used in an integrated management strategy for postharvest disease control in potatoes. These strategies include careful handling of tubers during harvesting, transportation, and storage loading, removal of all infected tubers prior to storage and maintenance of proper storage conditions (Knowles and Plissey, 2008).

In these studies, the biocontrol fungicides were to some extent as effective as the conventional fungicides but at best both only offered limited broad-spectrum control of potato storage diseases.

Acknowledgments

This research was funded, in part, by the Michigan State University AgBioResearch GREEEN (Generating Research and Extension to Meet Economic and Environmental Needs) Initiative and CSREES Hatch Project Number MICL01966 and the Michigan Potato Industry Commission.

References


