Control of seed-borne tuber diseases with Biofungicides and Commercial Storage Products.

P. S. Wharton, D. Berry, R. L. Schafer, W. W. Kirk and P. Tumbalam. Department of Plant Pathology, Michigan State University, East Lansing, MI 48824.

Introduction

Potatoes are susceptible to a variety of storage pathogens, including late blight (*Phytophthora infestans*), Fusarium dry rot (*Fusarium sambucinum*), Pythium leak (*Pythium ultimum*), pink rot (*Phytophthora erythroseptica*) and tuber soft rot (*Erwinia* spp). These pathogens are of major concern to potato producers due to the great losses they cause in stored potatoes. Current recommendations for potato storage diseases include sanitation and exclusion as the primary controls for these pathogens. No fungicides are registered for direct application to tubers for control of these pathogens and few compounds are available for potato tuber treatment in storage. In recent years, several new biofungicides based on the biocontrol bacteria *Bacillus subtilis* (Serenade) and *B. pumilis* (Sonata) have been registered or are awaiting EPA approval for use on potato. These have shown promise in the control of seed and soil borne diseases such as late blight and pink rot. Neither of these products has been evaluated for the control of potato storage pathogens under post-harvest conditions. Thus, studies were initiated to evaluate the efficacy of these biofungicides under post-harvest storage conditions. For a comparison, a commercial storage product Oxidate (hydrogen dioxide) and experimental treatments [Amistar (azoxystrobin) and Zoxium (zoxamide)] were evaluated for their effectiveness under storage conditions.

Materials and Methods

- Experiments were carried out in November 2005 with potato cultivar "FL1879".
- Potatoes free from visible diseases were selected for the trials from tubers harvested in October 2005.
- Tubers were 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.
- Solutions (1 x 10^3/ml) of sporangia/zoosporangia of *P. infestans* (late blight), oospores/sporangia of *P. erythroseptica* (pink rot), oospores of *P. ultimum* (Pythium leak), macroconidia of *F. sambucinum* (dry rot) and bacterial cells of *E. carotovora* (soft rot) were prepared from cultures of the pathogens previously isolated from potato tubers in Michigan. All pathogens were grown on PDA for 10 days prior to preparation of inoculum solutions. Two non-treated controls, either inoculated with one of the pathogens or non-inoculated were included in the trial.
- Damaged tubers, (10/replicate/treatment; total 40 tubers/treatment) were sprayed with 10 ml of pathogen suspension, for a final dosage of about 0.25 ml per tuber.
- Tubers were stored for 24 h after inoculation at 20ºC before treatment.
- Fungicides were applied as liquid treatments in a water suspension with a single R&D XR11003VS spray nozzle at a rate of 1L/ton at 50 psi onto the tuber surfaces, with an entire seed surface being coated in the seed treater.
- After inoculation, tubers were incubated in the dark in plastic boxes at 12ºC for 60 days.
- Tubers were cut open and the number of tubers with symptoms or signs of the individual pathogens were counted to determine incidence of disease. Disease severity was assessed using a disease severity index (see Footnote).

Conclusions

In the late blight studies (Table 1) none of the treatments were significantly different from the inoculated check. However, the Amistar and Sonata treatments had the lowest mean severity and disease incidence indices. In the Pythium leak experiment (Table 2), Amistar, followed by Oxidate provided the best disease control and were not significantly different from the non-inoculated check. The biofungicides Serenade and Sonata provided limited disease control. There were no significant differences among treatments in the Fusarium dry rot (Table 3) or Erwinia soft rot (Table 4) experiments. In the dry rot experiments, none of the products tested provided effective disease control. In the Erwinia experiments, disease incidence in the inoculated check was low indicating a poor rate of infection of tubers. In the Pink rot experiments (Table 5), only Amistar provided effective disease control, with disease incidence in the other treatments being higher than in the inoculated check. Overall, the biofungicides provided limited control of potato storage diseases.

Results

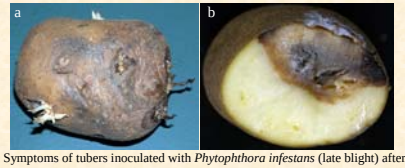

Figure 1. Symptoms of tubers inoculated with *Phytophthora infestans* (late blight) after 120 days in storage. Late blight is characterized by irregularly shaped, slightly depressed brown to purplish areas on the skin (a). A tan to reddish brown, granular rot is found under the skin in the discolored area (b).

	Treatment (rate/ton)[z]	Percentage of tubers in each disease severity class[y]						Mean Severity Index[x]		Mean disease incidence	
		Class 0	Class 1	Class 2	Class 3	Class 4	Class 5				
1	Inoculated check	87.5	3.8	0.0	1.3	7.5	0.0	7.5	a[w]	12.5	a
2	Amistar 80WG (70g)	96.3	0.0	0.0	0.0	1.3	2.5	3.5	a	3.8	a
3	Oxidate 27SC (76 ml)	86.3	3.8	0.0	1.3	0.0	8.8	10.3	a	13.8	a
4	Serenade ASO (190 ml)	85.0	1.3	0.0	0.0	7.5	6.3	12.5	a	15.0	a
5	Serenade ASO (95 ml)	88.8	3.8	0.0	0.0	3.8	3.8	7.5	a	11.3	a
6	Sonata AS (190 ml)	95.0	2.5	0.0	0.0	1.3	1.3	2.8	a	5.0	a
7	Zoxium 80WG (0.45 kg)	82.5	5.0	0.0	0.0	3.8	8.8	12.8	a	17.5	a
8	Untreated check (non-inoculated)	100.0	0.0	0.0	0.0	0.0	0.0	0.0	b	0.0	b
	$LSD_{0.05}$	19.6	10.4	2.4	6.9	10.7	12.5	14.8		19.6	

Table 1. Percentage of tubers in each disease severity class, the mean potato late blight severity indices and disease incidences 120 days after treatment with fungicides/biofungicides.

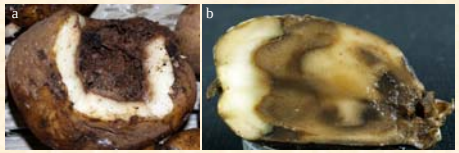

Figure 2. Symptoms of tubers inoculated with *Pythium ultimum* (Pythium leak) after 120 days in storage. In a storage pile, under dry conditions, tubers may be hollowed out leaving thin shell (a). Under moist conditions, infected tuber tissue turns from gray to brown and finally black (b). A dark line separates diseased tissue from healthy tissue.

	Treatment (rate/ton)[z]	Percentage of tubers in each disease severity class[y]						Mean Severity Index[x]		Mean disease incidence	
		Class 0	Class 1	Class 2	Class 3	Class 4	Class 5				
1	Inoculated check	73.8	0.0	0.0	0.0	6.3	20.0	25.0	bcd[w]	26.3	bcde
2	Amistar 80WG (70g)	95.0	0.0	0.0	0.0	0.0	5.0	5.0	d	5.0	de
3	Oxidate 27SC (76 ml)	87.5	0.0	0.0	1.3	0.0	11.3	12.0	cd	12.5	cde
4	Serenade ASO (190 ml)	70.0	2.5	0.0	0.0	5.0	22.5	27.0	bcd	30.0	bcde
5	Serenade ASO (95 ml)	55.0	0.0	0.0	0.0	7.5	37.5	43.5	bc	45.0	bc
6	Sonata AS (190 ml)	66.3	0.0	0.0	0.0	3.8	30.0	33.0	bcd	33.8	bcd
7	Zoxium 80WG (0.45 kg)	46.3	0.0	0.0	0.0	12.5	41.3	51.3	ab	53.8	ab
8	Untreated check (non-inoculated)	100.0	0.0	0.0	0.0	0.0	0.0	0.0	d	0.0	e
	$LSD_{0.05}$	35.2	2.4		2.1	16.6	34.0	33.1		35.2	

Table 2. Percentage of tubers in each disease severity class, the mean Pythium leak severity indices and disease incidences 120 days after treatment with fungicides/biofungicides.

Footnote for Tables 1-4.

[z] The rate of product per ton (metric) seed tubers applied in mixture with water at 2 L/ton.

[y] Severity classes were determined as class 0 = 0%; 1 = 1 - 10%; 2 = 11 - 20%; 3 = 21 - 50; 4 > 51 – 100% internal area of tuber tissue with disease.

[x] The severity index is the number in each class multiplied by the class number and summed. The sum is then multiplied by a constant to express severity on a 0 – 100 scale.

[w] Mean values of diseased tubers followed by the same letter are not significantly different at $p = 0.05$ (Tukey test).

	Treatment (rate/ton)[z]	Mean disease incidence	
1	Inoculated check	23.3	ab[y]
2	Amistar 80WG (70g)	10.0	ab
3	Oxidate 27SC (76 ml)	38.8	ab
4	Serenade ASO (190 ml)	33.8	b
5	Serenade ASO (95 ml)	53.8	ab
6	Sonata AS (190 ml)	75.0	ab
7	Zoxium 80WG (0.45 kg)	42.5	ab
8	Untreated check	0.0	b
	$LSD_{0.05}$	69.8	

Table 5. Percentage mean pink rot disease incidence 120 days after treatment with fungicides/biofungicides.

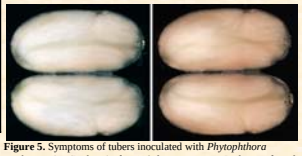

Figure 5. Symptoms of tubers inoculated with *Phytophthora erythroseptica* (Pink rot) after 120 days in storage. Pink rot infected tubers turn pink after exposure to air for 15 to 30 minutes.

Results

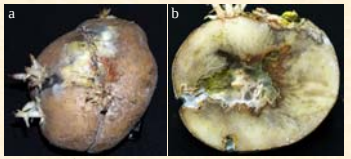

Figure 3. Symptoms of tubers inoculated with *Fusarium sambucinum* (dry rot) after 120 days in storage. Dark depressions may form on the tuber surface along with white to pink to yellow spore masses (a). Mycelia penetrate the tuber surface forming an internal dry necrotic cavity hollowed out from rotted tissue (b).

	Treatment (rate/ton)[z]	Percentage of tubers in each disease severity class[y]						Mean Severity Index[x]		Mean disease incidence	
		Class 0	Class 1	Class 2	Class 3	Class 4	Class 5				
1	Inoculated check	31.3	31.3	26.3	8.8	2.5	0.0	24.0	a[w]	68.8	a
2	Amistar 80WG (70g)	51.3	25.0	20.0	2.5	1.3	0.0	15.5	abc	48.8	ab
3	Oxidate 27SC (76 ml)	47.5	23.8	21.3	7.5	0.0	0.0	17.8	ab	52.5	ab
4	Serenade ASO (190 ml)	56.3	21.3	16.3	1.3	2.5	2.5	16.0	abc	43.8	ab
5	Serenade ASO (95 ml)	51.3	36.3	12.5	0.0	0.0	0.0	12.3	bc	48.8	ab
6	Sonata AS (190 ml)	55.0	25.0	17.5	1.3	1.3	0.0	13.8	abc	45.0	ab
7	Zoxium 80WG (0.45 kg)	56.3	28.8	13.8	1.3	0.0	0.0	12.0	bc	43.8	ab
8	Untreated check (non-inoculated)	73.8	0.0	0.0	0.0	6.3	20.0	7.0	c	26.3	b
	$LSD_{0.05}$	35.3	34.7	19.3	8.2	6.1	3.4	14.8		35.3	

Table 3. Percentage of tubers in each disease severity class, the mean Fusarium dry rot severity indices and disease incidences 120 days after treatment with fungicides/biofungicides.

Figure 4. Symptoms of tubers inoculated with *Erwinia* spp. (soft rot) after 120 days in storage. Lesions develop in lenticles or wounds (a) and affected tissue becomes cream to tan and is often soft and granular (b).

	Treatment (rate/ton)[z]	Percentage of tubers in each disease severity class[y]						Mean Severity Index[x]		Mean disease incidence	
		Class 0	Class 1	Class 2	Class 3	Class 4	Class 5				
1	Inoculated check	92.5	2.5	0.0	0.0	1.3	3.8	8.8	a[w]	7.5	a
2	Amistar 80WG (70g)	100.0	0.0	0.0	0.0	0.0	0.0	0.0	a	0.0	a
3	Oxidate 27SC (76 ml)	97.5	0.0	1.3	0.0	0.0	1.3	2.8	a	2.5	a
4	Serenade ASO (190 ml)	96.3	1.3	0.0	0.0	0.0	0.0	0.0	a	3.7	a
5	Serenade ASO (95 ml)	100.0	0.0	0.0	0.0	0.0	2.5	3.5	a	0	a
6	Sonata AS (190 ml)	95.0	1.3	0.0	0.0	2.5	1.3	4.4	a	5	a
7	Zoxium 80WG (0.45 kg)	98.8	0.0	0.0	0.0	0.0	1.3	1.6	a	1.2	a
8	Untreated check (non-inoculated)	100.0	0.0	0.0	0.0	0.0	0.0	0.0	a	0	a
	$LSD_{0.05}$	15.5	5.5	2.1		3.2	8.6	10.9		15.5	

Table 4. Percentage of tubers in each disease severity class, the mean Erwinia soft rot severity indices and disease incidences 120 days after treatment with fungicides/biofungicides.

Figure 5. (a) In storage tubers may be infected by multiple fungal pathogens, followed by soft rot. The action of these pathogens eventually turns tuber tissue mushy and slimy leaving little more than a pile of collapsed potato skins (b).

Acknowledgements

This work was funded in part by a grant from the USDA-ARS IR-4 program and with support from the Michigan Potato Industry Commission.

MICHIGAN STATE UNIVERSITY