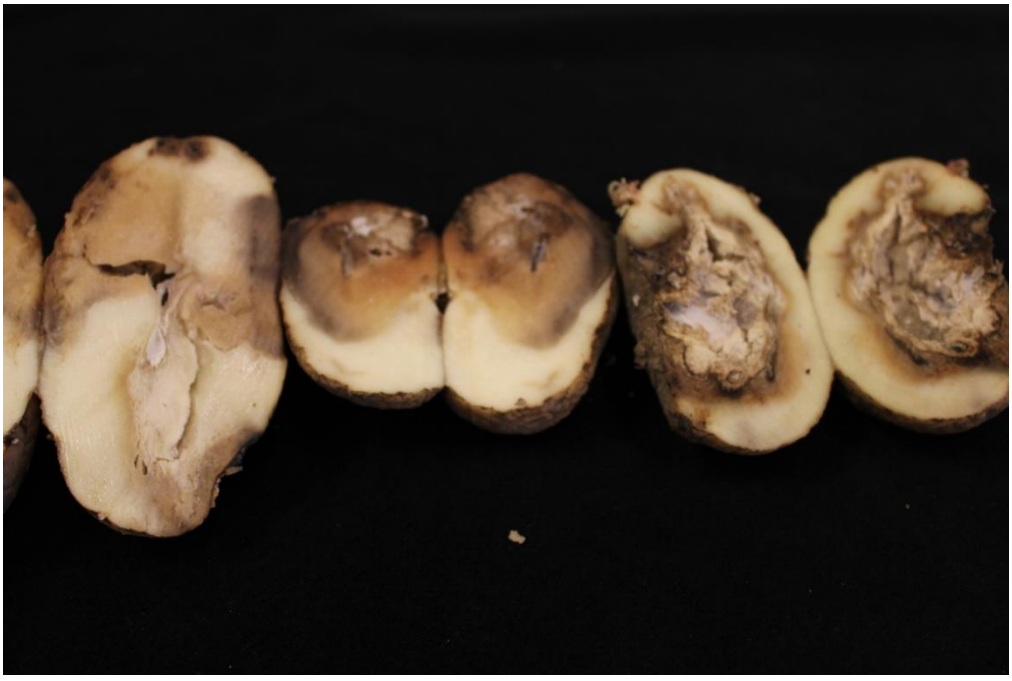
Government of Alberta

Fusarium Disease Management in Potato: Identification and Integration of Best Management Practices

Project 2011F103R



Prepared for the

Alberta Crop Industry Development Fund

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by

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Executive Summary

This project was undertaken to

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Introduction

Fusarium species are important pathogens of potatoes in Alberta and other production areas in Canada. They cause destructive diseases, such as seed-piece decay, wilt and dry rot. Management of fusarium diseases can be achieved, in part, by following best management practices (BMPS) such as cultivar selection, seed piece treatments, crop rotation, bruise avoidance on tubers, fungicidal treatments on tubers going into storage and controlling storage environments. However, some BMPS are not well-defined for Alberta potato growers, i.e. very few of the currently used potato varieties have been tested for their tolerance to strains of *Fusarium spp.* occurring in Alberta and the degree of resistance registered seed/piece and/or storage treatment fungicides and amongst Fusarium isolates has not been well characterized. The purpose of this project is to generate new information and create a comprehensive set of BMPs for fusarium diseases in fields and storages, with emphasis on processing varieties in southern Alberta. These BMPs will help Alberta potato producers to minimize risks and reduce future losses due to *Fusarium spp*.

Background

Fusarium species are important pathogens of potatoes in Alberta that can affect seed tubers after planting (seed piece decay), reduce plant vigor in season (fusarium wilt) and cause tuber decay (dry rot in storages). Fusarium is a competent saprophyte and occurs in almost all fields where potatoes are grown. Some species that attack potato are also pathogenic on other field crops. Infection occurs mainly at wound sites on tubers, which are caused through cutting and handling of seed at planting and on tubers prior to and during harvest, as well as when the potatoes are in storage. Fusarium diseases cause significant losses to the potato industry each year. Seed piece decay leads to ”misses” in stands, which then reduces crop yield and tuber size/quantity in adjacent plants. Fusarium wilt can reduce plant health and tuber yield either directly or by compounding other vascular diseases, such as early dying. Finally, fusarium dry rot (FDR) can cause major losses in storage, e.g. thousands of tonnes of potatoes were severely affected by dry rot in 2009-10, which caused major economic losses to the processing potato industry in Alberta. These losses take the form of heavy grade-outs from storage, down-graded finished product quality and the considerable effort needed to resolve customer complaints related to product defects. Processors have commented that the dry rot problem has been getting worse over the span of 2006-11 (B. Lewis, personal communication).

Management of fusarium diseases can be achieved, in part, by following best management practices (BMPS) such as cultivar selection, seed piece treatments, crop rotation, bruise avoidance on tubers, fungicidal treatments on tubers going into storage and carefully controlling storage environments. However, some BMPS are not well-defined for Alberta potato growers. For example, not all potato varieties have been tested for their fusarium tolerance in storage and relative sensitivity or resistance of Alberta Fusarium isolates to registered seed-piece and/or storage treatment fungicides is not well known. Fusarium species fungicidal resistance in potatoes is now commonplace in Alberta and elsewhere in Canada. Developing strategies for overcoming this problem as well as promoting fungicide resistance stewardship is a high priority in the potato industry. Furthermore, detailed analyses of effects of crop rotation and storage environments are not available to Alberta potato producers and processors. The purpose of this project is to fill these information gaps and to create a comprehensive set of BMPs for fusarium diseases in both fields and storages, with emphasis on processing potatoes in southern Alberta. These BMPs will help Alberta producers minimize risks and reduce future losses due to *Fusarium spp.*

Project Objectives

The project objectives are:

1. **Fusarium disease surveillance**: Survey Alberta-grown seed, processing and fresh market potatoes for seed-piece decay, wilt and dry rot over three growing seasons. Then collect, isolate,

purify and identify *Fusarium spp*. from infected plants and tubers. Also, collect data from potato producers on crop rotations, irrigation regimes, other cultural practices and estimates of the disease economic impact on them.

2. **Fungicide sensitivity:** Assess the *F. spp.* isolates sensitivity to registered post-harvest and seed-treatment fungicides.
3. **Disease management and cultural practices:** This includes resistance screening to FDR in both new and established potato varieties. This will also include analyzing cropping records from the producers for their cultural practices that may be predisposing plants to fusarium diseases, such as irrigation regimes. Seed sources may also be tracked.
4. **Fungicide and disinfectant usage in disease management**: Evaluate at least five or more experimental fungicides (chemical and biological products) and compare with registered industry standards for efficacy and adverse effects when applied to seed-pieces and post-harvest tubers. Also, evaluate five commercial cleaners for their ability to eradicate fusarium contamination from types of hard surfaces typically found in potato storages and on potato handling equipment.
5. **Technology transfer and demonstrations**: Prepare reports and presentations for dissemination at producer and scientific meetings. Demonstrate storage and equipment sanitation protocols on a few potato farms and processing plants using ARD's Mobile Sanitation Unit.

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SECTION 1: FUSARIUM DISEASE SURVEILLANCE AND FUSARIUM SPP. ISOLATION STUDY

1-1 YEAR 1: 2011-12

PROJECT OBJECTIVES

1. Survey Alberta-grown seed, processing and fresh market potatoes as well as wilted potato plants for fusarium disease
2. Collect, isolate, purify and identify *Fusarium* species from infected tubers and plants.
3. Screen these isolates for sensitivity or resistance to two commercial standard fungicides: fludioxinol (Maxim) and thiabendazole (Mertect).

RESEARCH PROTOCOL

MATERIALS: Fusarium *spp. isolation study*

Table 1: Crop and disease species used in this study

Crop species	**Common name**	**Cultivar**
Solanum tuberosum	Potato	Various
Disease species	**Common name**	**Source**
Fusarium sambucinum	Fusarium dry rot (FDR)	Potato

METHODS

Project staff collected 20 varieties of seed potatoes from retail outlets and commercial storage facilities. These tubers were then assessed for FDR symptoms and the dry rot positive tubers were consequently rinsed free of excess soil and aseptically sliced through the infected portion of the tuber. Small cubes (3-5mm) of symptomatic tissue were aseptically removed from the slices and placed on acidified potato dextrose agar (PDA-A) and incubated at room temperature until spore forming bodies were present.

The technical staff then performed single-spore isolations by immersing *fusarium spp*. spores in sterile water, serial diluting them and plating the resulting suspensions onto PDA-A agar. The following day, plates were examined for individual, germinating spores. These spores were excised from the agar with a sterile needle and transferred to fresh PDA-A, where they were allowed to grow until spore production was achieved. These spores were collected and placed in cryogenic storage, and shipped to Dr. L.K. Kawchuk for species identification and fungicide resistance evaluation. Results are shown in **Table 2.**

RESULTS AND DISCUSSION

On a number of tubers, >1 *Fusarium* species were identified; however, when multiple isolates of the same *Fusarium* species were isolated from the same tuber, differences in fludioxonil resistance could often be identified between the isolates.

Table 2. Source, identity and *in vitro* sensitivity to two post-harvest fungicides of *Fusarium* isolates obtained from seed and processing potato tubers infected with fusarium dry rot.

Fungicide	Sensitivity rating	Fusarium species identification				Total number of isolates	Percent of total isolates tested (%)
		Fusarium avenaceum	*Fusarium coereuleum*	*Fusarium culmorum*	*Fusarium sambucinum*		
	Isolates from tubers from commercial seed growers and retail outlets						
Fludioxonil	Resistant				4	47	8.5
	Intermediate	2	1		6	47	19.1
	Sensitive				4	47	8.5
	Controlled				30	47	63.8
Thiabendazole	Resistant				6	47	17.0
	Intermediate				0	47	0.0
	Sensitive				0	47	0.0
	Controlled	2	1		38	47	87.2
	Isolates from tubers from a commercial potato processing plant						
Fludioxonil	Resistant				8	45	17.8
	Intermediate	7	10	2	3	45	48.9
	Sensitive			1	1	45	4.4
	Controlled	11			2	45	28.9
Thiabendazole	Resistant	2			10	45	26.7
	Intermediate		6	1		45	15.6
	Sensitive					45	0.0
	Controlled	13	4	2	4	45	51.1

CONCLUSION

Comments on results by Dr. Larry Kawchuk:

"As in the past, *F. sambucinum* is the dominant species followed by *Fusarium avenaceum*. It is remarkable that there are so few other *Fusarium* species and these were *F. coeruleum* and a few *F. culmorum*. Perhaps the continued production of potatoes on specific land is selecting for the *Fusarium* species that prefer potato as a host.

Resistance to the thiabendazole Mertect appears to be similar to earlier surveys, with resistance only observed in *F. sambucinum* but the majority of isolates of *F. sambucinum* are still sensitive. Some *F. avenaceum* are now showing an intermediate response to the thiabendazole, Mertect. This would probably be sufficient to minimize the effectiveness of Mertect to prevent dry rot caused by *F. avenaceum*. Application of Mertect should probably be considered only in those situations where the potatoes will be stored for several months and are badly bruised or wounded and there is no reason to suspect that the pathogens are resistant or intermediate in their response to the thiabendazole.

There is some resistance to the fludioxonil and all resistant isolates were F*. sambucinum*. Isolates of the other *Fusarium* species have in some cases developed an intermediate reaction to the fludioxonil. The prevalence of resistance or intermediate response to the fludioxonil will limit the effectiveness of this fungicide to prevent dry rot."

1-2 YEAR 2: 2012-13

PROJECT OBJECTIVES

The 2012-13 project objectives were the same as in 2011.

RESEARCH PROTOCOL

MATERIALS: Fusarium *spp. isolation and chemical resistance/susceptibility study*

Table 1: Crop and disease species used in this study

Crop species	**Common name**	**Cultivar**
Solanum tuberosum	Potato	Various
Disease species	**Common name**	**Source**
Fusarium sambucinum	Fusarium dry rot (FDR)	Potato

METHODS

A total of 94 Fusarium species were collected and isolated from Alberta potatoes in 2012/2013 by Innovotech Inc. CDC South staff and examined to determine the species and reaction towards two commonly used fungicides, including a contact and a systemic. Isolates were single-spored and plated on water agar and subsequently Potato Dextrose Agar to facilitate microscopic examination and measurement of the phialides, microconidia and macroconidia.

RESULTS, DISCUSSION AND CONCLUSION

Dr. Larry Kawchuk found that, interestingly, the majority of the isolates were taxonomically identified to be *Fusarium sambucinum*. This Fusarium species has been the dominant species infecting potato but the prevalence has never been observed at these levels on Alberta potatoes. This may indicate an increase in the dominance of *F. sambucinum* due to the management strategies being implemented, environmental conditions during the growing season, or a sampling bias. Further analysis will show if this is an anomaly or a more permanent shift in the potato Fusarium population. There were also 5 isolates *of Fusarium avenaceum*, 1 unidentified isolate of a *Fusarium spp*., and 2 isolates contaminated with bacteria.

A slight increase compared to previous years was observed in the number of *F. sambucinum* isolates resistant to the systemic thiabendazole storage treatment Mertect. Previous levels of resistance in *F. sambucinum* were close to 50% of the isolates. Remarkably, there was only 1 isolate of *F. sambucinum* with an intermediate response, indicating that resistance to this benzimidazole was either non-existent or complete in this pathogen. This may indicate a point mutation, possibly at the beta-tubulin gene as in many other fungi, although previous studies showed a lack of linkage. Thiabendazole resistance was not observed in *Fusarium avenaceum*, although an isolate did show an intermediate response.

Unlike the systemic thiabendazole, the fludioxynil produced a range of reactions with a similar number of isolates showing sensitive, intermediate, and resistant reactions. These reactions appear to be *Fusarium spp.* independent, unlike the thiabendazole resistance which is restricted to isolates of *Fusarium sambucinum*. There appears to be no linkage between the resistances to the fungicides with various combinations of reactions segregating independently of each other. For example*, F. sambucinum* isolates resistant to the thiabendazole were found to be resistant, intermediate, or sensitive to the fludioxynil.

1-3 YEAR 3: 2013-14

PROJECT OBJECTIVES

The 2013-14 project objectives were the same as in 2011.

RESEARCH PROTOCOL

MATERIALS: Fusarium *spp. isolation study*

Table 1: Crop and disease species used in this study

Crop species	**Common name**	**Cultivar**
Solanum tuberosum	Potato	Various
Disease species	**Common name**	**Source**
Fusarium sambucinum	Fusarium dry rot (FDR)	Potato

METHODS

A total of 105 *Fusarium spp.* subcultures were collected and isolated by the CDC South Plant Pathology Program staff, from Alberta potato storage tubers in June 2013, December 2013 and February 2014. They were subcultured onto Potato Dextrose Agar (PDA) with 80 plates chosen and submitted to Dr. Larry Kawchuk for identification, including testing for Mertect (thiabendazole) and Maxim (fludioxinol) susceptibility. He also had another 12 *Fusarium spp*. isolates that AAFC staff, Lethbridge, AB staff had collected for the same testing. Additionally, 56 duplicate subcultures of the December and February plates were submitted to Dr. Rick Peters, AAFC, Charlottetown, PEI for identification and difenoconazole sensitivity testing.

RESULTS, DISCUSSION AND CONCLUSION

Comments by Dr. Larry Kawchuk that was included on a project report on December 3, 2014:

Alberta Fusarium Identification and Fungicide Reactions 2013/2014 (Table 2)

A total of 92 *Fusarium* species were collected and isolated from Alberta potatoes in 2013/2014 and examined to determine the species and reaction towards three commonly used fungicides, including a contact and a systemic. **Table 2** shows the results for 84 of the isolates that were single-spored and plated on water agar and subsequently potato dextrose agar (PDA) to facilitate microscopic examination and measurement for taxonomic identifications. Samples in 2013/2014 included a larger number of isolates from the Edmonton area and seed farms as compared to previous years.

Once again *F. sambucinum* dominated the population of pathogen inciting disease with *F. avenaeceum. F. coereuleum, F. solani* and *F.culmorum* also represented in the isolates. However, there were some remarkable changes in the sensitivity of the isolates to the fungicides. Although more isolates that were not *F. sambucinum* exhibited a higher level of insensitivity to the thiabendazole, the overall number of isolates showing insensitivity was lower. More remarkably was the lower insensitivity to the thiabendazole displayed by the *F. sambucinum* isolates. This has not been observed previously and represents the first example of the thiabendazole resistance reverting to a sensitive or intermediate insensitivity to the systemic fungicide. It may provide evidence that reduced usage and more careful application can increase the effectiveness of the systemic thiabendazole. This would provide growers with an excellent postharvest management option where required. Sequencing of the beta-tubulin gene from the *F. sambucinum* isolates did not detect any

sequence substitutions linked to this improved thiabendazole sensitivity and further investigation is required to confirm this improvement of the systemic fungicide in preventing disease (**Figure 1**).

Table 2. Source, identity and *in vitro* sensitivity to two post-harvest fungicides of 84 *Fusarium* isolates obtained from seed and processing potato tubers infected with fusarium dry rot.

Fungicide	Sensitivity rating	Fusarium species identification					Total isolates tested	Percent of total isolates tested (%)
		Fusarium avenaceum	*Fusarium coereuleum*	*Fusarium culmorum*	*Fusarium sambucinum*	*Fusarium solani*		
		Isolates from tuber isolations done in June 2013 from Crop Diversification Centre South						
Fludioxonil	Resistant	0	0	0	1	0	19	5.3
	Intermediate	2	2	2	6	0	19	63.2
	Sensitive	1	2	1	2	0	19	31.6
Thiabendazole	Resistant	0	0	0	0	0	19	0.0
	Intermediate	1	0	0	3	0	19	21.1
	Sensitive	2	4	3	6	0	19	78.9
		Isolates from tuber isolations done in December 2013 and February 2014 (Crop Diversification Centre South) and in 2013 (AAFC, Lethbridge)						
Fludioxonil	Resistant	2	7	1	1	0	65	16.9
	Intermediate	7	10	11	15	2	65	69.2
	Sensitive	0	0	2	6	1	65	13.8
Thiabendazole	Resistant	1	0	0	1	2	65	6.2
	Intermediate	3	8	1	14	1	65	41.5
	Sensitive	5	9	13	7	0	65	56.9

Conclusions for Dr. Larry Kawchuk's testing **(Table 2 and Figure 1)**

A majority of *Fusarium* species again displayed insensitivity to fludioxonil rendering this fungicide of limited effectiveness. Unlike the thiabendazole, there was no strong fludioxonil specificity as to *Fusarium* species and all were able to develop some level of insensitivity. Similar results were observed with the difenoconazole and all *Fusarium* species produced a number of isolates that exhibited an unexpected level of insensitivity. As with the fludioxonil, there was no apparent *Fusarium* species specificity and the majority of isolates were insensitive. Difenoconazole (not shown) results indicate this would have limited capability in preventing dry rot of potato in Alberta. There may be some value of using difenoconazole in those storages with *Fusarium* species exhibiting thiabendazole resistance, as many were not resistant to both fungicides.

Figure 1. Nucleotide sequence derived from the beta-tubulin gene from *Fusarium sambucinum* isolates. No mutations were observed that corresponded with the different sensitivities to the thiabendazole. This testing was performed by Dr. Larry Kawchuk and his technologists at AAFC, Lethbridge, Alberta in 2014.

1 atgcgtgaga ttgtaagtgc tttccattga actctaactt caagctgctg cacgcgttga
61 gcttgtcttc tgtgctcctg gttctactgt accccgccgg ccggcggcag ctcaacaaca
121 atgcatgata gctcgcagct tgatcaatct tcttccccag aaacaagaga agagaagaga
181 agctaacctt atctttttct ttgcgatagg ttcaccttca gaccggtcag tgcgtaagta
241 tttatctgct cttccatctc acccgaggga gatgctaaca tgtttattag ggtaaccaaa
301 tcggtgctgc tttctggcag actatctctg gcgagcacgg tctcgacagc aatggtgttt
361 acagcggtac ctccgagctc cagctcgagc gcatgagcgt ttacttcaac gaggtttgtt
421 tcatcactcc tgccacgaaa aacacaagct cacgtgtgta ggcctccggt aacaaatatg
481 ttccccgtgc cgtcctcgtc gatctcgagc ccggtaccat ggacgccgtc cgtgccggtc
541 ccttcggaca gcttttccga cccgacaact tcgttttcgg tcaatccggt gccggaaaca
601 actgggccaa gggtcattac actgagggag ctgaacttgt cgaccaagtt ctcgatgtcg
661 tccgccgtga ggccgagggc tgtgactgcc tccagggctt ccaaatcacc cactctcttg
721 gtggtggtac cggcgccggt atgggtaccc tgttgatctc caagatccgt gaggaatttc
781 ccgaccgtat gatggcaaca ttctccgtcg ttccttcccc taaggtctcc gacaccgtcg
841 tcgagcctta taacgccacc ctctccgtcc atcaactggt tgagaactcc gacgagacct
901 tctgtatcga taacgaggct ctttacgaca tttgtatgcg caccctcaag ctgtccaacc
961 cctcttacgg cgacttgaac taccttgtct ccgccgtcat gtccggcgtc accacctgtc
1021 tccgtttccc cggtcagctg aactctgacc tccgaaagct cgccgtcaac atggtgccct
1081 tccctcgtct gcacttcttt atggtcggat tcgctccctt gaccagccgt ggtgctcact
1141 ctttccgtgc tgtcagcgtt cctgagctga cccagcagat gttcgacccc aagaacatga
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1261 gtgtcgccat gaaggaggtt gaggaccaga tgcgcaatgt ccagagcaag aactcatcat
1321 acttcgtcga gtggattcct aacaacatcc agaccgctct ctgcgctatc ccacctcgtg
1381 gacttacaat gtcttccact tttattggaa attccacctc tatccaggag cttttcaagc
1441 gtgttggcga gcagttcact gctatgttcc gacgcaaggc tttcttgcat tggtacactg
1501 gtgagggtat ggatgagatg gagttcactg aggctgagtc taacatgaac gatcttgtct
1561 ctgaatacca gcagtaccag gatgctggta ttgacgagga agaagaggag tacgaggagg
1621 agctgcctga gggcgaggag taa

Comments by Dr. Rick Peters, PEI in May 2014

Alberta Fusarium Identification and Fungicide Reactions 2013/2014

Dr. Rick Peters reported that all 56 isolates that he received were sensitive to difenconazole, as shown on a MS Excel spreadsheet that he sent to the Plant CDCS Pathology Program and that all isolates were tested against 0, 1, 10, and 100 ppm difenoconazole, with readings taken at 7 and 14 days. In summary, there was no evidence for resistance to difenoconazole in this sample set. However, he cautioned that unfortunately, there were several isolates in this collection that were not *Fusarium* spp. at all, but other fungal genera. This would be confirmed in Larry Kawchuk's culture identifications.

1-4 YEAR 1: 2013 EARLY DYING in POTATO PLANTS SURVEY

PROJECT OBJECTIVES

This was the only year that an early dying potato plant survey was completed and the purpose of it was to find out what were the major causative pathogens of potato plants dying during the growing season in southern Alberta

RESEARCH PROTOCOL

MATERIALS: Fusarium early dying potato stem survey

Table 1: Crop used in this study

Crop species	Common name	Cultivar
Solanum tuberosum	Potato	Various

METHODS

A total of nine potato plant samples were collected from 6 southern Alberta fields in September 2013 and were processed by the CDC South Plant Pathology Program staff. On September 20, a technologist cut three infected lower stems /field sample each into a 0.3 m section. This was further excised into 3 (5.1 cm) subsections (roots, just above soil level and top of the lower stem). These were gently washed under running tap water and then surface sterilized in 1% sodium hypochlorite for 3 minutes before thoroughly rinsing in sterile RO water. After sterilization by using aseptic technique and sterilized tools, the ends were cut off of each section and disposed of. Each sterile piece was cut into at least 5 small pieces, so that there were at least 45 sections/field of stem pieces. These were placed on up to nine acidified potato dextrose agar (PDA-A) plates (4 – 5 pieces/plate) per field, depending upon how many of the stems/field that were actually infected with early dying symptoms.

These plates were incubated at room temperature (RT) for six days until Dr. Ron Howard evaluated them on September 26 for pathogen growth. Subcultures of the identified pathogens were set up the following day by a technologist on Potato Dextrose Agar (PDA) until they were examined on October 1 and resubbed if contaminated. All plates were stored in a refrigerated storage at 5°C until they could have the culture identifications finalized. This data were then summarized onto an MS Excel spreadsheet, with a results summary shown on **Table 2.**

RESULTS, DISCUSSION AND CONCLUSION

Fusarium spp. followed by *Colletotrichum coccodes* were the major pathogens isolated from the 2013 survey. *Verticillium spp*. was only found in Field 6 **(Table 2).**

Table 2: Average disease incidence percentage levels *Fusarium spp., Verticillium spp.* and *Colletotrichum coccodes* isolated onto the PDA-A primary culture plates. This was for the Early Dying in Potato Field Survey completed in September 2013 by the Crop Diversification Centre South, Brooks, Alberta.

Field number	*Fusarium spp*. (DI%)	*Verticillium spp.* (DI%)	*Colletotrichum coccodes* (DI%)
1	42.0	0.0	18.0
2	92.5	0.0	22.5
3	88.9	0.0	82.2
4	88.0	0.0	24.0
5	86.7	0.0	68.9
6	97.8	6.7	84.4
7	100.0	0.0	82.2
8	91.1	0.0	66.7
9	73.3	0.0	33.3

SECTION 2: DISEASE MANAGEMENT AND CULTURAL PRACTICES

POTATO VARIETAL RESISTANCE

2-1 YEAR 1: 2011-12

PROJECT OBJECTIVES

The 2011 project objective was to screen stored potato cultivars for fusarium dry rot (FDR) resistance and compare with the industry standard variety, Russet Burbank.

RESEARCH PROTOCOL

MATERIALS

Crop species	**Common name**	**Cultivar**
Solanum tuberosum	Potato	Various: See Table
Disease species	**Common name**	**Source**
F. sambucinum	Fusarium dry rot (FDR)	CDC South Pathology Program: Potato isolates 12-1 and 12-2

METHODS

In December 2011, 11 tubers varieties were collected into ca. 4.7 kg lots, with additional batches of Niska collected for destructive sampling (to determine an optimum evaluation date). *F. sambucinum* (CDC South isolates 12-1: thiabendazole–sensitive & 12-2: thiabendazole-resistant) spore suspensions were prepared by adding 10 mL of sterile water to each of 5 agar plates/isolate and then sterile smear tool was used to loosen and detach the spores from the colonies. These two spore suspensions were poured into two sterile tubes, spore counts were enumerated by using a hemocytometer and then they were mixed together in a 50:50 ratio to give a final concentration of $1.2x10^6$ spores/ml in a large enough volume to cover all tuber lots.

Each tuber lot was placed in a cement mixer to allow cutting/bruising of the potatoes and ca. 10 mL of spore suspension was applied to them while tumbling. The tubers were then allowed to dry and were consequently placed into cold storage at 10°C and 80% RH on December 23, 2011. The extra Niska tubers were also inoculated and checked periodically to determine the timing for disease symptom evaluations.

On April 13, 2012, all tubers were cut in half and rated for disease incidence (DI) and disease severity (DS) levels. DI was determined as the percentage of infected tubers in each bag, while DS was rated by estimating the % area of the internal tuber flesh with visible dry rot symptoms according to the following 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.

Data were then entered onto an MS Excel spreadsheet, where the average DS/subplot was calculated by using the following formula:

$$DS_{average} = [(N_0 \times 0) + (N_1 \times 1) + (N_2 \times 2) + (N_3 \times 3) + (N_4 \times 4) + (N_5 \times 5)]/N_t$$

where N_0 = the number of tubers with DS = 0, N_1 = no. with DS = 1, N_2 = no. with DS = 2, N_3 = no. with DS = 3, N_4 = no. with DS = 4, N_5 = no. with DS = 5, and N_t = total number of tubers examined /subplot.

Additionally, an overall disease score was determined by multiplying DSxDI.

Data for all ratings were summarized and analyzed using the ARM 8 for statistical software program by Gylling Data Management. Duncan's Multiple Range Test (DMRT) was utilized for means comparisons, where F-tests were statistically significant ($P \leq 0.05$). Bartlett's Test for Homogeneity of Variance was also used for all ANOVA calculations

RESULTS AND DISCUSSION

Table 1. An analysis of variance was performed on the DI, DS and Index Score (ID = DSxDI) values for a potato varietal resistance screening trial that was performed at the Crop Diversification Centre South, Brooks, AB from December 2011 until April 2012.

Treatment number	Potato variety	DI (%)[1,2,5]	DS (0-5)[1,3,5]	ID Score (0-5) [1,4,5]
1	Russet Burbank	79.8 b	2.784 abc	2.223 cde
2	Lady Blanca	100.0 a	3.417 ab	3.417 ab
3	Blazer Russet	100.0 a	3.596 ab	3.596 ab
4	Monticello	97.0 a	2.059 cd	2.012 de
5	Lady Valora	78.8 b	1.500 d	1.1775 e
6	ERG 01 4022	100.0 a	3.917 a	3.916 a
7	Starburst	100.0 a	2.643 bcd	2.643 bcd
8	Lady Joe	94.0 a	3.188 abc	3.008 a-d
9	Sentinel	96.5 a	3.572 ab	3.464 ab
10	CV97065-1	100.0 a	3.773 ab	3.773 ab
11	Niska	100.0 a	3.313 ab	3.313 abc
ANOVA (P≤0.05)		0.0001	0.001	0.0006
Treatment F		7.436	3.607	4.366
Cooefficient of variation (%)		6.24	25.86	27.62

[1]Results are the means of five replications.
[2]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms.
[3]Disease severity (DS) means are 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.
[4]Disease index score (ID) means are a calculation where DI * DS= ID score (0-5).
[5]Data were significantly different according to Duncan's Multiple Range test at P ≤ 0.05 (by least significant differences or LSD).

Result: Overall, only Lady Valora was equivalent to Russet Burbank in DI, while this variety also had significantly lower DS than the commercial standard.

Figure 1. All varieties were ranked in order of Disease Index Score. These were graphed in order of increasing Disease Index. Overall, Lady Valora performed the best in the trial, while ERG 01-4022 performed the poorest.

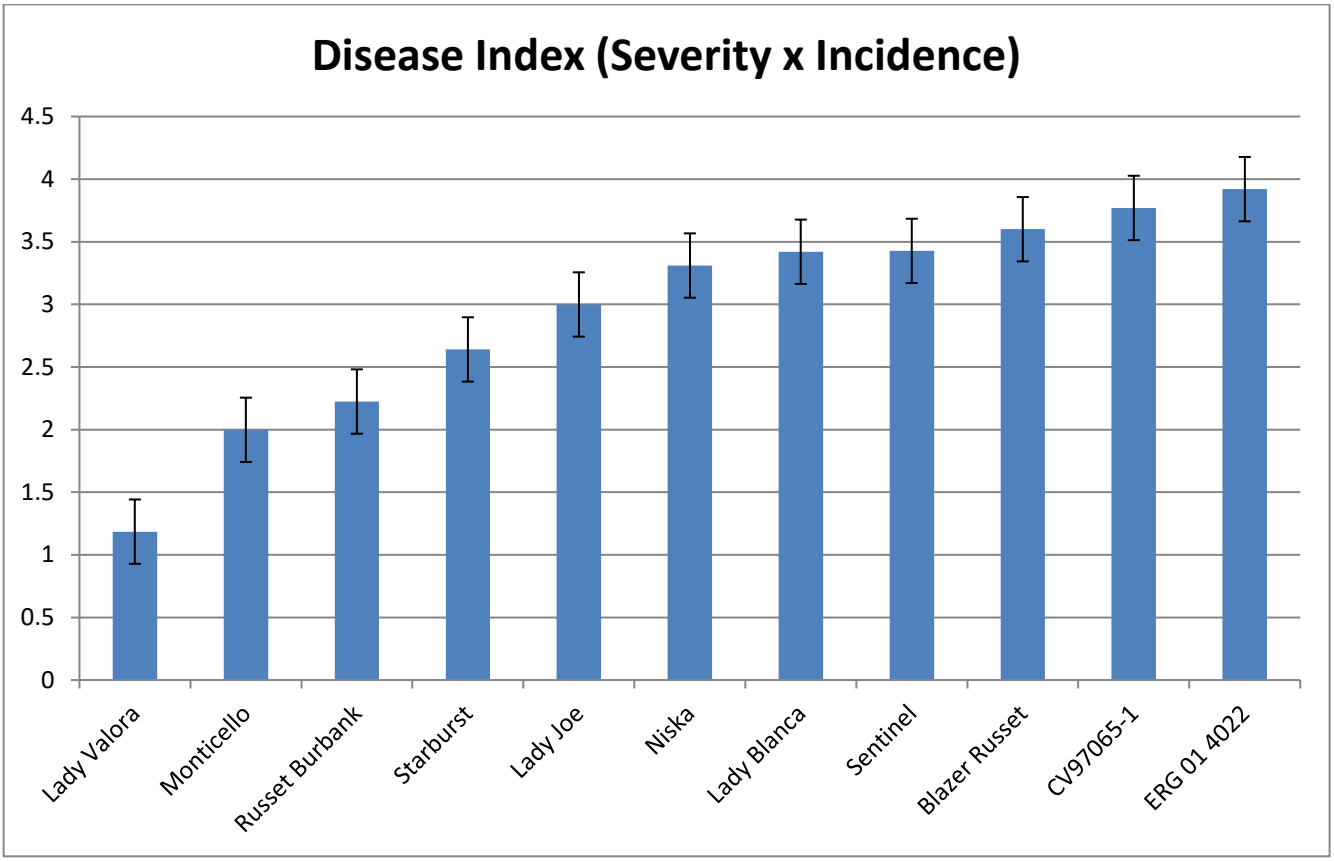


Figure 1.

CONCLUSIONS

Overall, only Lady Valora was equivalent to Russet Burbank in DI%, while this variety also had significantly lower DS than Russet Burbank. Overall, it performed the best in all ratings parameters in this trial and appears to be a very promising potato cultivar for dry rot resistance

2-2 YEAR 2: 2012-13

PROJECT OBJECTIVES

The major emphasis of this Year 2 postharvest varietal screening storage trial was to determine the relative resistance of 17 registered and experimental potato varieties to FDR.

RESEARCH PROTOCOL

MATERIALS

17 potato cultivars (13 varieties and 4 breeding lines) were selected for this trial **(Table 1)** and were placed into a controlled environment storage room (CES) at 5°C and 90% RH until ready for use.

METHODS

In November 2012, Innovotech Inc. Brooks, AB staff revived two isolates of *Fusarium sambucinum*: one thiabendazole-resistant (isolate 12-2) and one thiabendazole-susceptible (isolate 12-1), from mini-vials held in an ultra-low temperature refrigerator (-80°C) at CDCS. These originated off of diseased tubers collected from a commercial potato storage near Fincastle, AB in 2010. These isolates were then subcultured onto ca. 15 petri plates, containing potato dextrose agar culture medium acidified with sterile lactic acid (PDA-A) and then were grown in natural light on a lab bench for ca. 7 days to induce sporulation. These were later used during this trial for *F. sambucinum* inoculum preparation that would be applied to the tubers.

A randomized complete block (RCB) plot design was prepared for this five-replication trial, using the Agricultural Research Manager Version 7 computer software program (ARM 7) by Gylling Data Management, Inc., Brookings, SD, USA. Therefore, each replication consisted of 17 potato varieties with 20 tubers/subplot.

On December 17, 100 tubers per variety that were reasonably free of soil and with no dry rot symptoms, were counted into labeled 50 lb. (22.3 kg) mesh bags and were set aside until the following day. Then, all of the tubers were wounded by hand-cutting three uniform slashes into each of them, by using the mixer fins of a small cement mixer. The potatoes were placed back into the labeled bags overnight.

On December 19, *F. sambucinum* tuber inoculum was prepared by emulsifying one plate each of the two subculture types, with 10 mL of sterile RO water and then scraping these contents into two small sterile beakers. The conidia were then enumerated under a compound microscope. From this count, each isolate was diluted to prepare an equivalency of $1x10^4$ conidia/mL in ample tap water. These volumes were combined 1:1 so that each tuber would receive 2 mL of fusarium inoculum.

For each variety, 10 tubers at a time were placed and then shaken in a 15 lb. (6.8 kg) poly bag containing 20 mL of inoculum. Then, 20 tubers each were dispensed into five pre-labeled small mesh bags (one bag/replication) and then into a plastic tote in a CES room, set at10°C and 95% RH. Also, 100 additional Niska (Treatment 8) tubers were placed into four additional mesh bags for monthly destructive sampling during the trial to determine a final evaluation date. Thus, at four week-intervals, interim FDR internal disease evaluations were performed on them, by slicing each tuber in half through one of the wounds and scoring them from 0-5 points, based on the same scale used for the final disease severity (DS) ratings (shown below).

Final FDR disease severity (DS) evaluations were performed from February 26 – 28, 2013. Again, the tubers were sliced in half and were visually examined for disease symptoms, receiving a DS rating based upon the following 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.

Data were then entered onto an MS Excel spreadsheet, where the average DS/subplot was calculated by using the following formula:

$DS_{average} = [(N_0 \times 0) + (N_1 \times 1) + (N_2 \times 2) + (N_3 \times 3) + (N_4 \times 4) + (N_5 \times 5)]/N_t$

where N_0 = the number of tubers with DS = 0, N_1 = no. with DS = 1, N_2 = no. with DS = 2, N_3 = no. with DS = 3, N_4 = no. with DS = 4, N_5 = no. with DS = 5, and N_t = total number of tubers examined /subplot.

Disease incidence (DI), the percentage of tubers with dry rot and the Disease index score (ID) were also calculated/subplot. This last calculation used the following formula:

Disease index (ID) score = DS*DI/500*100 and was calculated as a %. This provided an accurate evaluation parameter based upon both the DS and DI levels.

Data for all ratings were summarized and analyzed using the ARM 7 and 8 statistical software programs. Duncan's Multiple Range Test (DMRT) was utilized for means comparisons, where F-tests were statistically significant ($P \leq 0.05$). Bartlett's Test for Homogeneity of Variance was also used for all ANOVA calculations, as well as data transformations (arcsine or square root). Detransformed means, when needed, are presented in **Table 2**.

RESULTS AND CONCLUSIONS

Table 1: Potato cultivar listing
Table 2 and **Figures 1, 2, and 3**: Disease ratings for DS, DI and ID

Based upon Duncan's Multiple Range Testing (MRT), only the DS (0 - 5 scale) and ID% results were statistically significant ($p \leq 0.05$); however, the latter data failed the Bartlett's Test of Homogeneity, so the letter gradings couldn't be reported. The DI% results all had the same Duncan's MRT grouping, so the varieties were statistically similar.

Overall, the two best-performing varieties were from AAFC: WV4479-1 (Treatment 16) and AC Vigor (Treatment 1), with DS values of 2.36 and 2.53 respectively. Shepody, V1115-3, Satina, Dakota Pearl and Bintje, with results extending up to 2.95 DS, were statistically similar to these varieties. In contrast though, Russet Burbank, an industry-standard French fry and table cv. (Treatment 12), was mid-range at 3.49 DS.

CONCLUSIONS

Two very promising AAFC varieties for FDR disease resistance emerged from this trial: WV4479-1 and AC Vigor. Four other varieties also demonstrated similar potential: Shepody, 1115-3, Satina, Dakota Pearl and Bintje. However, this was only the second year of this project.

Table 1. Potato varieties used for a fusarium dry rot cultivar resistance trial at the Crop Diversification Centre South, Brooks, Alberta that was evaluated in February, 2013.

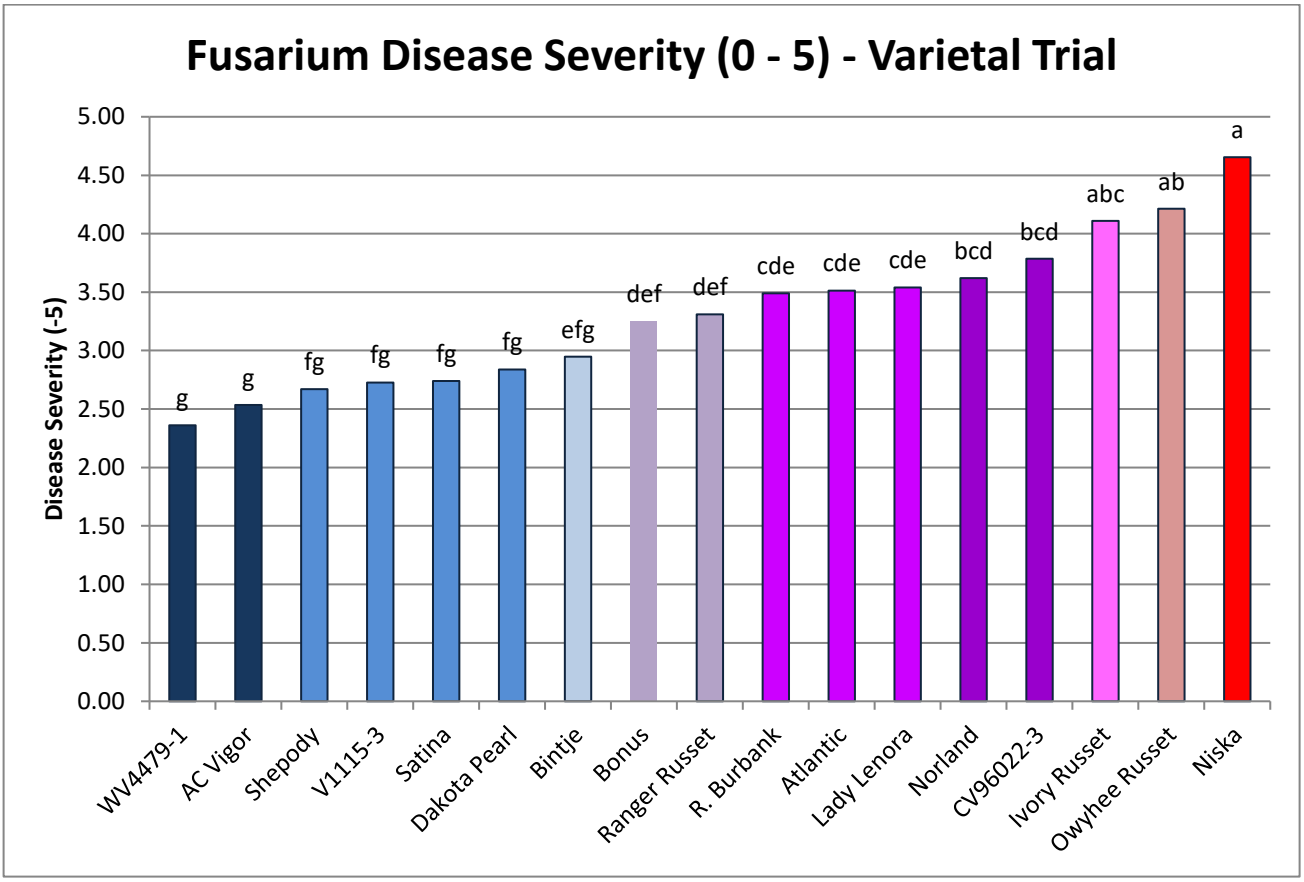
Treatment Number	Cultivar	Type	Source
1	AC Vigor	Chipper	AAFC
2	Atlantic	Chipper	CDCS
3	Bintje	Multi-purpose	PGA
4	CV96022-3	Chipper	AAFC
5	Dakota Pearl	Chipper	PGA
6	Ivory Russet	French fry	ConAgra
7	Lady Lenora	Chipper	CDCS
8	Niska	Chipper	CDCS
9	Norland	Table	CDCS
10	Owyhee Russet	French fry	CDCS
11	Russet Burbank	French fry	CDCS
12	Ranger Russet	French fry	CDCS
13	Satina	Table	PGA
14	Shepody	French fry	PGA
15	V1115-3	Table	AAFC
16	WV4479-1	Chipper	AAFC
17	Bonus	Chipper	Old Dutch Foods

Table 2. Fusarium dry rot disease severity (DS), incidence (DI) and index of disease (ID) levels for a varietal resistance screening trial that was evaluated at the Crop Diversification Centre South, Brooks, AB in February, 2013.

Treatment number	Treatment name (*see Table 1 also*)	Dry rot DS (0-5)[1,2,6]	Dry rot DI (%)[1,3,7]	Dry rot ID score %[1,4,8]
1	AC Vigor	2.53 g	92.28	46.70
2	Atlantic	3.51 cde	93.78	64.39
3	Bintje	2.95 efg	96.90	55.99
4	CV96022-3	3.79 bcd	100.00	75.71
5	Dakota Pearl	2.84 fg	95.09	52.72
6	Ivory Russet	4.11 abc	100.00	82.19
7	Lady Lenora	3.54 cde	97.57	67.22
8	Niska	4.65 a	98.73	89.00
9	Norland	3.62 bcd	97.71	68.61
10	Owyhee Russet	4.21 ab	100.00	84.27
11	Russet Burbank	3.49 cde	98.81	67.93
12	Ranger Russet	3.31 def	97.01	62.90
13	Satina	2.74 fg	96.47	52.00
14	Shepody	2.67 fg	99.80	52.82
15	V1115-3	2.73 fg	97.96	52.82
16	WV4479-1	2.36 g	93.68	43.54
17	Bonus	3.25 def	93.06	59.31
ANOVA (P≤0.05)		0.0001	0.0746	0.0001
LSD (P=0.05)[5]		0.572	---	---
Coefficient of variation		13.65	11.44	11.84

[1]Results are the means of five replications.
[2]Disease severity (DS) means are on a 1-5 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.
[3]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms.
[4]Index of disease score (ID) means are a calculation where DI * DS/500*100 = ID score (%).
[5]Least significant differences were not calculated for transformed data.
[6]Raw data were used for analysis and were significantly different according to Duncan's Multiple Range test at P ≤ 0.05.
[7]Arcsine-transformed data were used for analysis
[8]Raw data were used for analysis but it failed the Bartlett's test for homogeneity of variance, as did the data transformations.

Figure 1. Fusarium dry rot disease severity (DS) rating levels, performed on 17 cultivars of potato tubers at the Crop Diversification Centre South, Brooks, Alberta in February, 2013.



The navy blue and deep red colors were statistically unique letter grades based on Duncan's Multiple Range Test. Shades of the same color are statistically equivalent (i.e. pink or blue and light blue. Purple columns are not statistically equivalent to either red or blue.

Figure 2. Fusarium dry rot disease incidence (DI%) rating levels, performed on 17 cultivars of potato tubers at the Crop Diversification Centre South, Brooks, Alberta in February, 2013.

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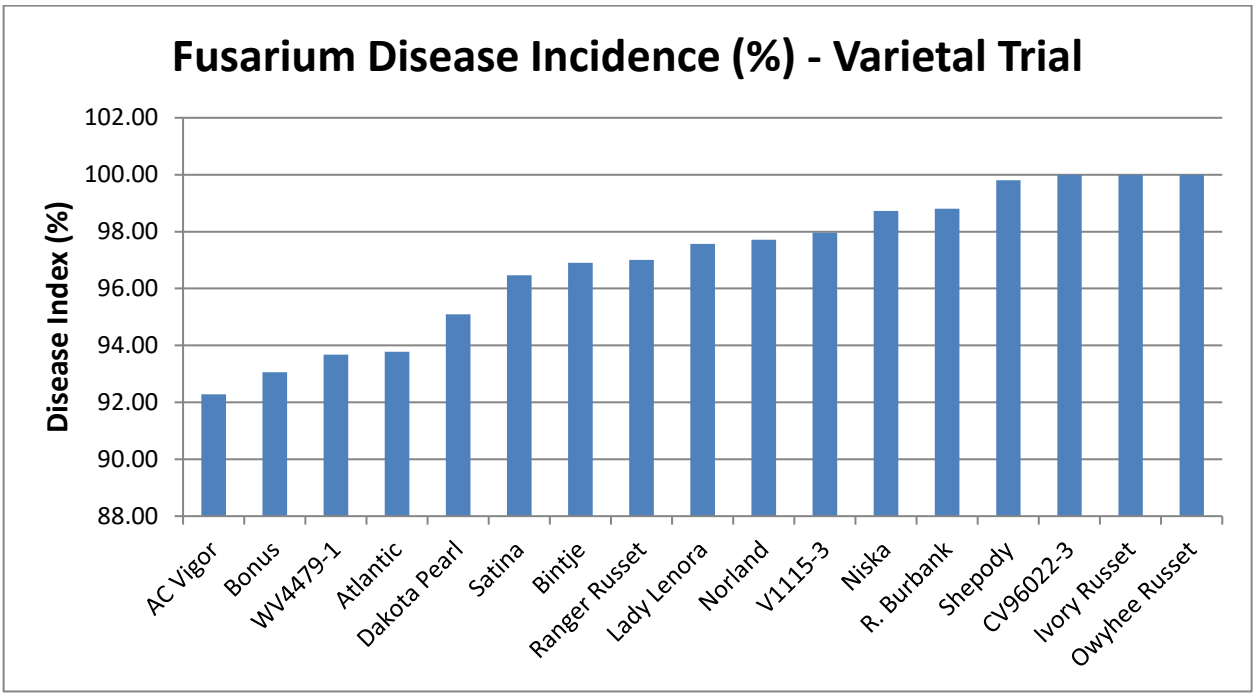
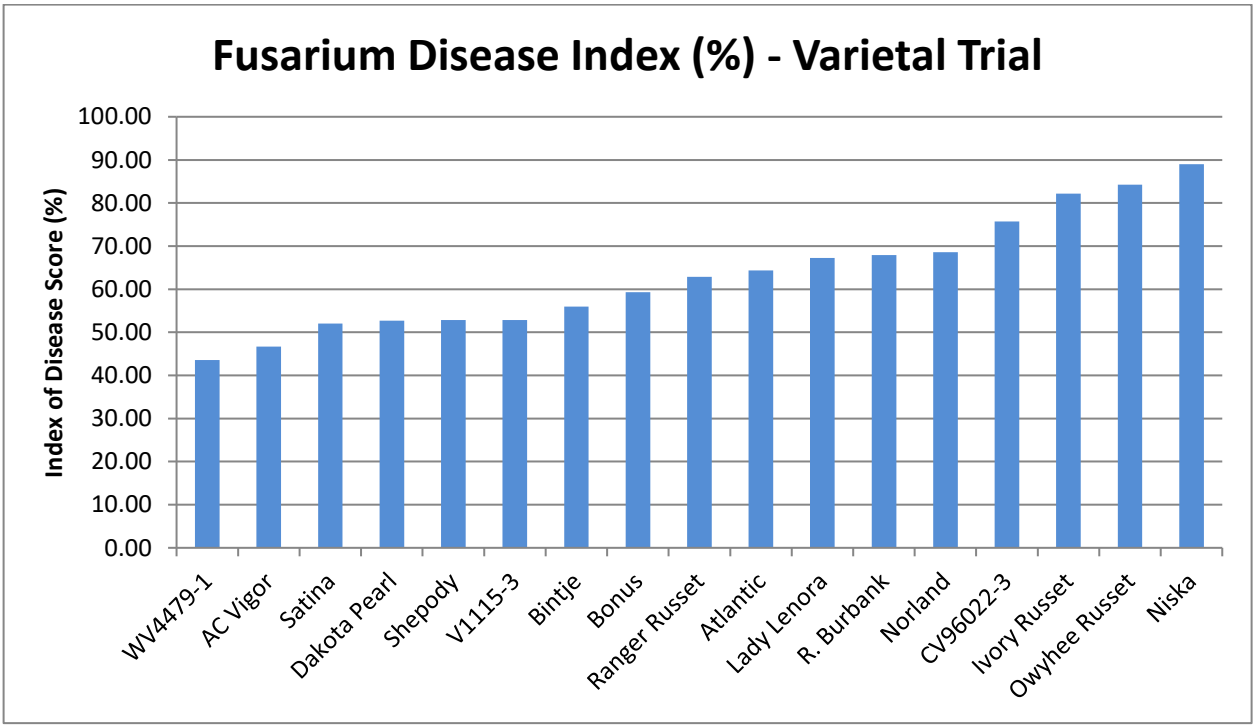


[1]All results were statistically similar based on Duncan's Multiple Range Test, so this arcsine-transformed data are shown in a deep blue color.

Figure 3. Fusarium dry rot disease (ID) rating levels, performed on 17 cultivars of potato tubers at the Crop Diversification Centre South, Brooks, Alberta in February, 2013.



[1]All results were statistically similar based on Duncan's Multiple Range Test, so this raw data are shown in a deep blue color.
[2]These results failed the Bartlett's test of Homogeneity so they could not be shown as statistically different based on Duncan's Multiple Range Test.

2-3 YEAR 3: 2013-14

PROJECT OBJECTIVES

The project object 2013-14 was again, to screen stored potato cultivars for fusarium dry rot (FDR) resistance and compare with the industry standard variety, Russet Burbank.

RESEARCH PROTOCOL

MATERIALS

18 potato cultivars (11 varieties and 7 breeding lines) were selected for this trial **(Table 1)** and were placed into a controlled environment storage room (CES) at 5°C and 90% RH until ready for use.

METHODS

In November 2013, Plant Pathology Program staff at the Crop Diversification Centre South (CDC South), Brooks, AB staff four isolates of *Fusarium sambucinum*, two thiabendazole-resistant (isolates 12-2 and 12-21) and two thiabendazole-susceptible (isolates 12-1 and 12-22), from mini-vials held in an ultra-low temperature refrigerator (-80°C) at CDCS. These originated off of diseased tubers collected from a commercial potato storage near Fincastle, AB in 2010. These isolates were each then subcultured onto five petri plates, containing potato dextrose agar culture medium acidified with sterile lactic acid (PDA-A) and then were grown in natural light on a lab bench for ca. 7 days to induce sporulation. Isolates 12-21 and 12-22 were later used during this trial for *F. sambucinum* inoculum preparation applied to the tubers, as the other two isolates didn't sporulate well.

A randomized complete block (RCB) plot design was prepared for this five-replication trial, using the Agricultural Research Manager Version 8 computer software program (ARM 8) by Gylling Data Management, Inc., Brookings, SD, USA. Therefore, each replication consisted of 18 potato varieties with 20 tubers/subplot.

On November 20, 100 tubers per variety that were reasonably free of soil and with no dry rot symptoms, were counted into labeled tote bins and were set aside until the following day. Then, all of the tubers were wounded by hand-cutting three uniform slashes into each of them, by using a cleaver. The potatoes were placed back into the labeled totes overnight but meanwhile, 49 ventilated plastic totes were prelabeled also, as per the experimental plot plan, for two subplot bags/tote.

On November 21, *F. sambucinum* tuber inoculum was prepared by emulsifying one plate from each of the two subculture types, with 10 mL of sterile RO water and then scraping these contents into two small sterile beakers. The conidia from each were then enumerated under a compound microscope. From this count, each isolate was diluted to prepare an equivalency of 10,000 conidia/mL in ample tap water, so that when these two equal volumes were combined, each tuber would receive 2 mL of fusarium inoculum.

Following this for each variety, 10 tubers at a time were placed and then shaken in a 15 lb. (6.8 kg) poly bag containing 20 mL of inoculum, giving uniform application. Then, 20 each were dispensed into five pre-labeled small mesh bags (one bag/replication). Two subplot bags were placed in order into each pre-labeled tote and were stacked, according to replication, in a CES room, set at10°C and 95% RH. Also, 100 additional Niska (Treatment 12) tubers were placed into four additional mesh bags for monthly destructive sampling during the trial. The purpose of this step was to determine a final evaluation date. Thus, at four week-intervals, interim FDR internal disease progression evaluations were performed on them, by slicing each in half through one of the wounds and scoring them from 0-5 points, based on the same scale used for the final disease severity ratings (shown below). This was so that the final disease evaluations could be completed optimally when moderate FDR levels were present.

Final FDR disease severity (DS) evaluations; therefore were performed from March 19-21, 2014. Again, the tubers were sliced in half and were visually examined for disease symptoms, receiving a DS rating based upon the following 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.

Data were then entered onto an MS Excel spreadsheet, where the average DS/subplot was calculated by using the following formula:

$DS_{average} = [(N_0 \times 0) + (N_1 \times 1) + (N_2 \times 2) + (N_3 \times 3) + (N_4 \times 4) + (N_5 \times 5)]/N_t$

where N_0 = the number of tubers with DS = 0, N_1 = no. with DS = 1, N_2 = no. with DS = 2, N_3 = no. with DS = 3, N_4 = no. with DS = 4, N_5 = no. with DS = 5, and N_t = total number of tubers examined /subplot.

Disease incidence (DI), the percentage of tubers with dry rot and the Disease index score (ID) were also calculated/subplot. This last calculation used the following formula:

Disease index (ID) score = DS*DI/500*100 and was calculated as a %. This provided an accurate evaluation parameter based upon both the DS and DI levels.

Data for all ratings were summarized and analyzed using the ARM 8 statistical software program. Duncan's Multiple Range Test (DMRT) was utilized for means comparisons, where F-tests were statistically significant ($P \leq 0.05$). Bartlett's Test for Homogeneity of Variance was also used for all ANOVA calculations, as well as data transformations (arcsine or square root). Detransformed means, when needed, are presented in Table 2.

RESULTS AND DISCUSSION

Table 1: Potato cultivar listing
Table 2 and **Figures 1, 2, and 3**: Disease ratings for DS, DI and ID

Based upon Duncan's Multiple Range Testing (MRT), all 2013-14 data from the three rating parameters were statistically significant ($p \leq 0.05$) as opposed to the 2012-13 FDR variety screening trial results.

Overall, the best-performing variety was again from AAFC: CV97050-3 (Treatment 5) with a DS of 0.35 (0-5 scale), DI of 12.56% and an ID of just 0.94%. For DS only, two other AAFC numbered varieties, CV02321-1 and CV99222-2, were statistically identical to this treatment, with results at 0.37 and 0.50 respectively. However, for the ID (%) ratings, these two cultivars were only statistically similar to CV97050-3, as well as V1588-1, CV96044-3, AC Vigor, Shepody, WV7868-1, Glacier and Norland, with results ranging 2.04% for CV97050-3 up to 9.61% for Norland. The same pattern was shown with the DI (%) results (ranging from 27% to 39%), except this time, Glacier wasn't in the same Duncan's grouping. The remaining cultivars weren't as promising, with the most FDR found in Montecello, Atlantic, Niska and Dakota Diamond. The industry standard, Russet Burbank was statistically similar to these varieties.

CONCLUSIONS

Three very promising AAFC varieties for FDR disease resistance emerged from this trial: CV97050-3, CV02321-1 AND CV99222-2. The remaining AAFC cultivars also demonstrated great potential. Shepody and Norland actually performed very well in this trial too. Excellent statistically significant data was obtained from all rating parameters, so overall; this was a very successful final year for this trial.

Table 1. Potato varieties used for a fusarium dry rot cultivar resistance trial at the Crop Diversification Centre South, Brooks, Alberta that was evaluated in March 2014.

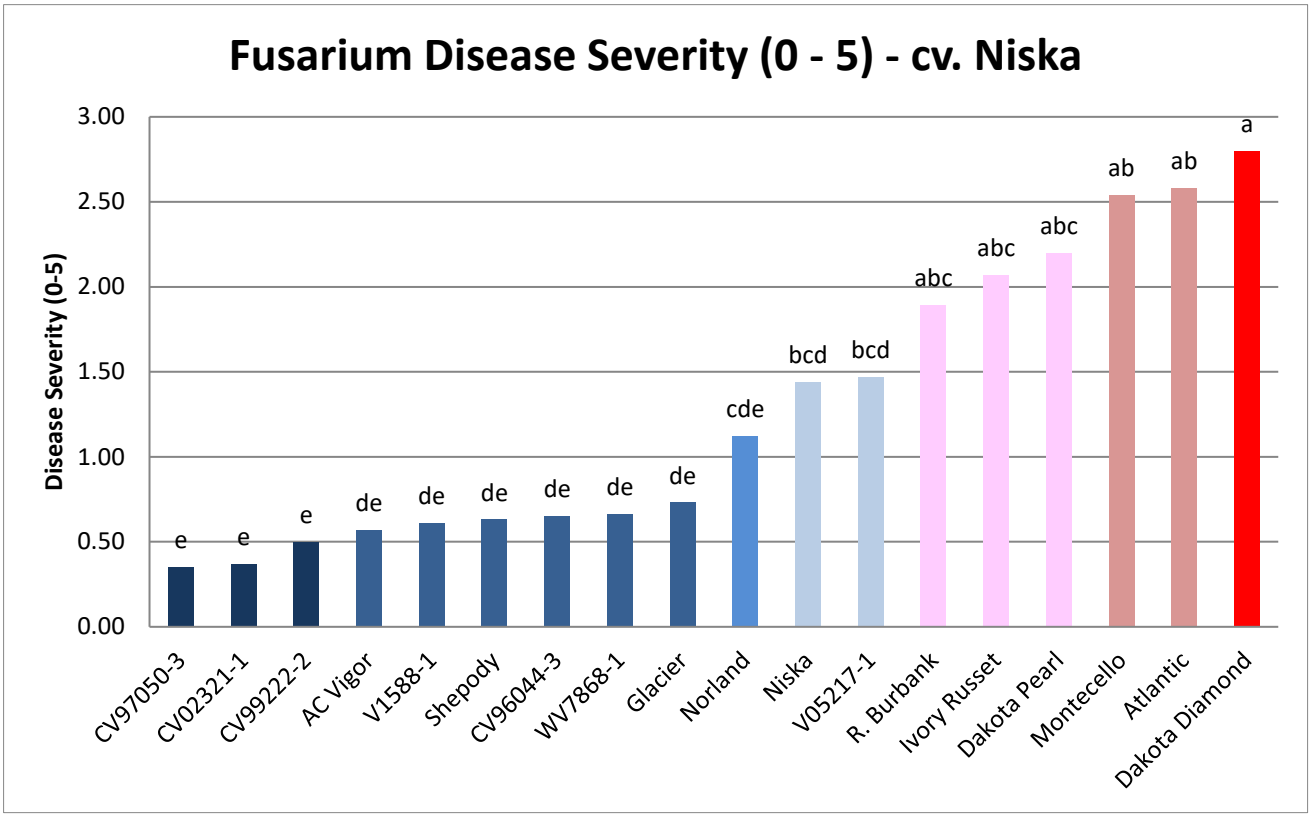
Treatment Number	Cultivar	Type	Source
1	AC Vigor	Chipper	AAFC
2	Atlantic	Chipper	CDCS
3	CV02321-1	Chipper	AAFC
4	CV96044-3	Chipper/Creamer	AAFC
5	CV97050-3	Table	AAFC
6	CV99222-2	French fry	AAFC
7	Dakota Diamond	Chipper	ODF
8	Dakota Pearl	Chipper	CDCS
9	Glacier	Chipper	PGA
10	Ivory Russet	French fry	ConAgra
11	Montecello	Chipper	ODF
12	Niska	Chipper	PGA
13	Norland	Table	CDCS
14	Russet Burbank	French fry	CDCS
15	Shepody	French fry	CDCS
16	V05217-1	Chipper	AAFC
17	V1588-1	Chipper	AAFC
18	WV7868-1	Table	AAFC

Table 2. Fusarium dry rot disease severity (DS), incidence (DI) and index of disease (ID) levels for a varietal resistance screening trial that was evaluated at the Crop Diversification Centre South, Brooks, AB in March 2014.

Treatment number	Treatment name (*see Table 1 also*)	Dry rot DS (0-5)[1,2,6,7]	Dry rot DI (%)[1,3,7,8]	Dry rot ID score %[1,4,7,9]
1	AC Vigor	0.57 de	34.00 de	4.10 ef
2	Atlantic	2.58 ab	73.58 ab	39.04 a
3	CV02321-1	0.37 e	27.00 de	2.04 ef
4	CV96044-3	0.65 de	33.18 de	4.06 ef
5	CV97050-3	0.35 e	12.56 e	0.94 f
6	CV99222-2	0.50 e	36.00 de	4.25 ef
7	Dakota Diamond	2.80 a	81.00 a	46.18 a
8	Dakota Pearl	2.20 abc	71.00 abc	35.74 ab
9	Glacier	0.73 de	55.00 a-d	8.84 def
10	Ivory Russet	2.07 abc	68.48 abc	28.93 abc
11	Montecello	2.54 ab	83.04 a	45.16 a
12	Niska	1.44 bcd	77.00 ab	25.37 a-d
13	Norland	1.12 cde	38.68 cde	9.61 c-f
14	Russet Burbank	1.89 abc	59.00 a-d	26.27 a-d
15	Shepody	0.63 de	32.00 de	4.14 ef
16	V05217-1	1.47 bcd	47.00 bcd	14.86 b-e
17	V1588-1	0.61 de	28.00 de	3.65 ef
18	WV7868-1	0.66 de	39.00 cde	5.83 ef
ANOVA (P≤0.05)		0.0001	0.0001	0.0001
LSD (P=0.05)[5]		---	28.34	---
Coefficient of variation		20.13	45.04	46.7

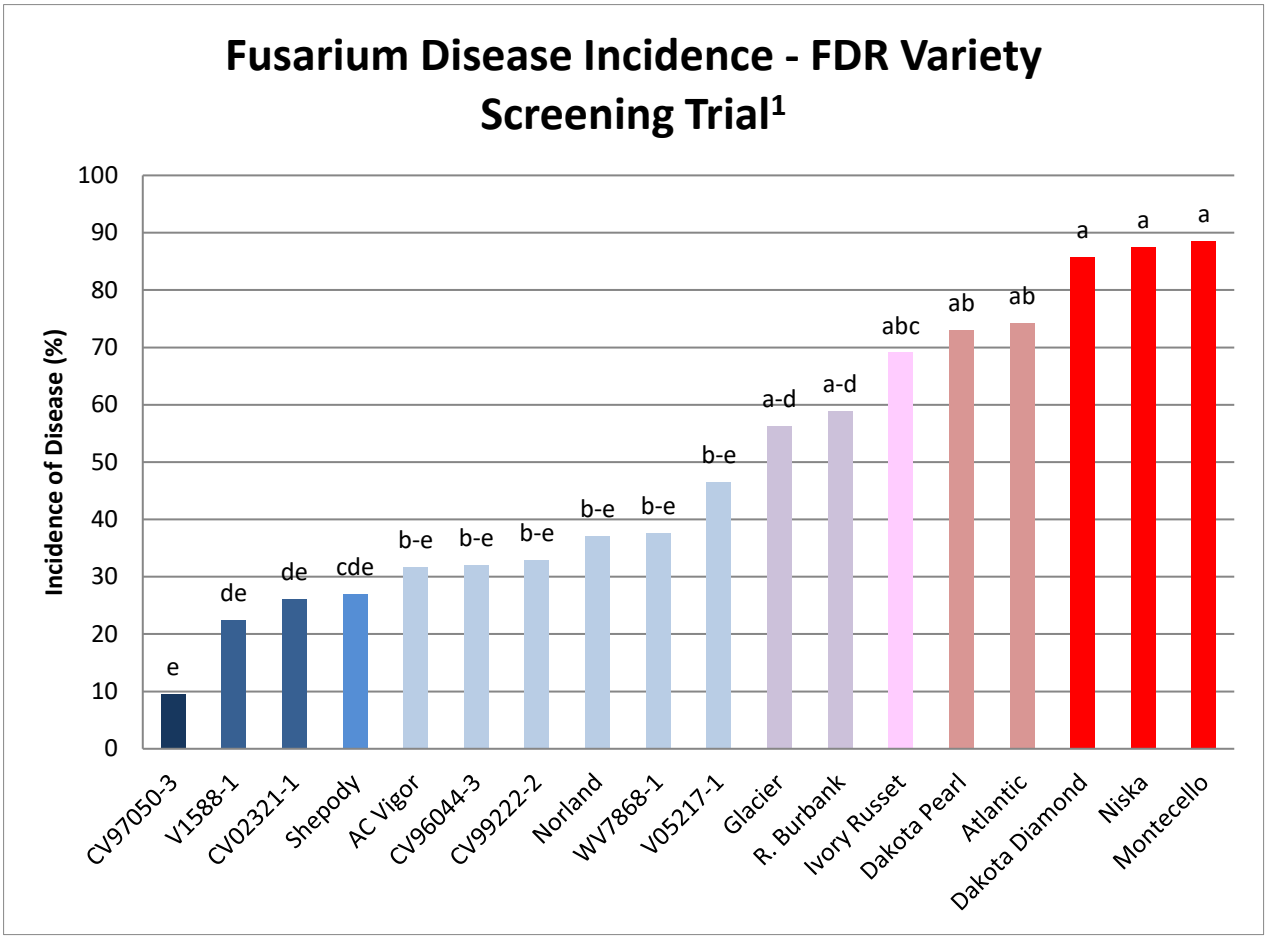
[1]Results are the means of five replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms.
[4]Index of disease score (ID) means are a calculation where DI * DS/500*100 = ID score (%).
[5]Least significant differences were not calculated for transformed data.
[6]Square root-transformed data were used for analysis
[7]Data were significantly different according to Duncan's Multiple Range test at P ≤ 0.05.
[8]Raw data were used for analysis.
[9]Arcsine-transformed data were used for analysis

Figure 1. Fusarium dry rot disease severity (DS) rating levels, performed on 18 cultivars of potato tubers at the Crop Diversification Centre South, Brooks, Alberta in March 2014.



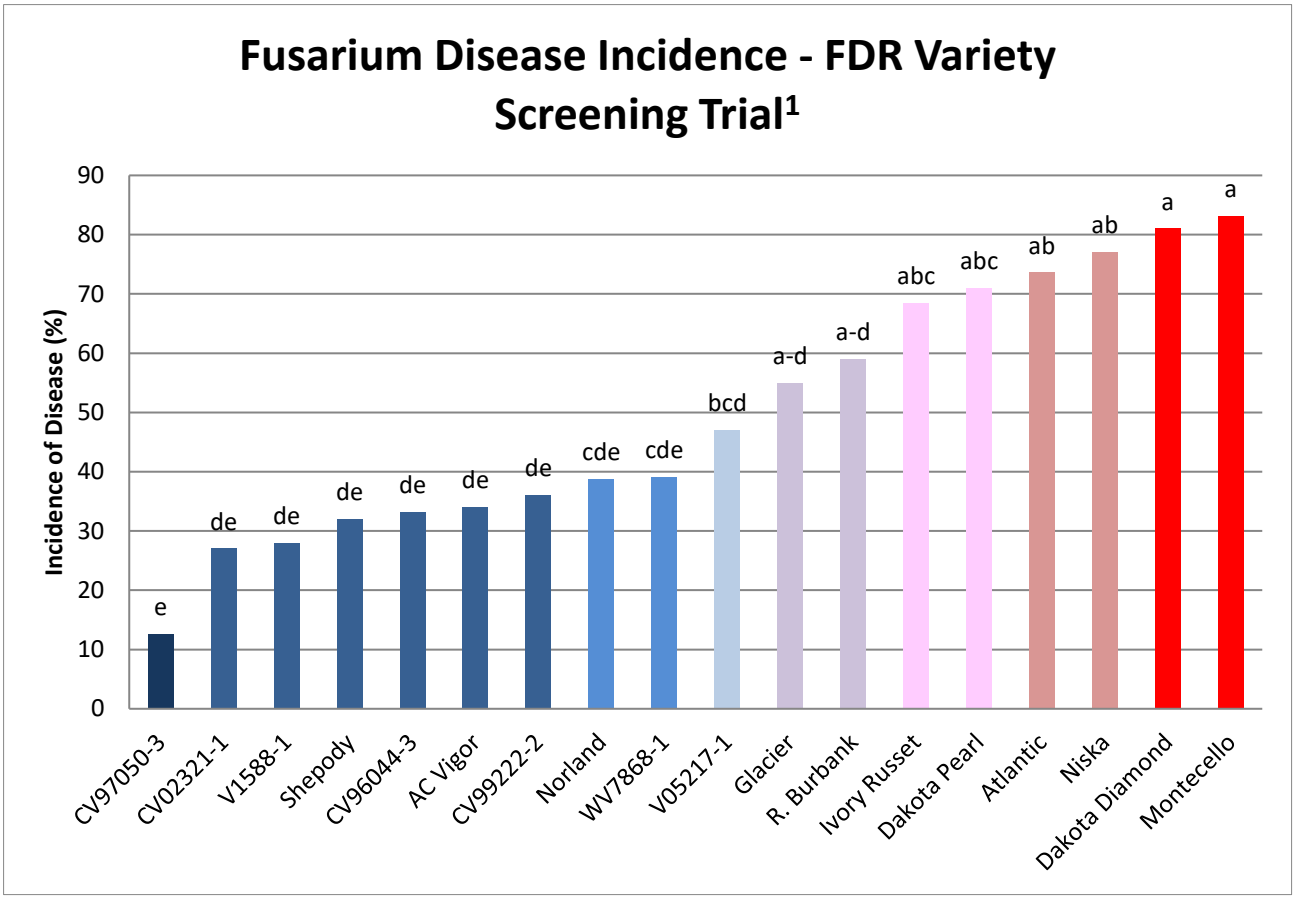
The navy blue and red columns were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. medium blue, pink and dark pink) to the navy blue and red columns.

Figure 2. Fusarium dry rot disease incidence (DI%) rating levels, performed on 18 cultivars of potato tubers at the Crop Diversification Centre South, Brooks, Alberta in March 2014.



[1]Results are based upon raw data. The navy and red colors were statistically unique letter grades based on Duncan Multiple Range Test. The shades of blue, light purple and pink columns are statistically similar to the red and blue column

Figure 3. Fusarium dry rot disease (ID) rating levels, performed on 18 cultivars of potato tubers at the Crop Diversification Centre South, Brooks, Alberta in March 2014.



The deep red, mahogany and navy blue colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. blue and pink).

SECTION 3: FUNGICIDE AND DISINFECTANT SEED PIECE TREATMENT USAGE IN FUSARIUM DISEASE MANAGEMENT

SEED PIECE TREATMENT FIELD TRIALS

3-1 YEAR 1: 2011 Field Trial

PROJECT OBJECTIVES

1. To evaluate the relative efficacy of registered and experiment fungicides for fusarium dry rot control in field potatoes.
2. The tubers used for Objectives 1 will be bruised and inoculated with *F. sambucinum* prior to treatment, to ensure significant disease pressure.

RESEARCH PROTOCOL

MATERIALS

Crop species	**Common name**	**Cultivar**
Solanum tuberosum	Potato	Niska
Disease species	**Common name**	**Source**
F. sambucinum	Fusarium dry rot (FDR)	CDC South Pathology Program: Potato isolates 12-1 and 12-2

Seed Treatments used:
AGRESS® (oxysilver nitrate), SODIUM DIPERIODATEARGENTATE (III)®[1] (Sodium D in this report) [1] MAXIM ® PSP fungicide (0.5% fludioxinol), MAXIM ® MZ PSP fungicide (0.5% fludioxinol + 5.7% mancozeb), SENATOR ® WSB (70% thiophate methyl), SOLAN™ MZ (16% mancozeb), (0.5% fludioxinol), EMESTO™ SILVER (9.35% penflufen + 1.68% prothioconazole), HeadsUp® Plant Protectant (49.65% saponin) and finally PHOSTROL® (phosphorous acid).

METHODS

Seed of Niska, a chipping potato cultivar, was provided by Old Dutch Foods and seed treatment products were provided by each sponsor. Seed was cut (70 to 85 g) and suberized prior to application of inoculum or treatments. As in the varietal testing, plates of (isolates 12-1 and 12-2R) were harvested by adding 10ml of sterile water and using a sterile smear tool to loosen and detach the spores from the colonies. The same protocol was used to enumerate the spores but this time, the inoculant contained $4x10^5$ spores/mL. Ca.10 mL of the *F. sambucinum*. suspension was applied per 20 Niska seed pieces by using a calibrated hand sprayer while tumbling in the cement mixer, which slashed and bruised the tubers for 1 minute. Seed was air-dried for 1-2 hours at room temperature, rotating every 30-min.

80 pieces of cut inoculated seed/treatment then received either a liquid solution or a powdered fungicide **(Table 1).** The solutions were mixed for 5 minutes with a magnetic stir bar on a stir plate before applying evenly to seed piece surfaces with a 1L spray bottle. The tubers were rotated during this process to ensure that the treatment was dispersed evenly over their surfaces. They were then left to dry in a dark area at RT. Fungicidal powders were applied by placing tubers into a clean plastic bag, adding the powders and then shaking them until even application was achieved. Treatment rates were as per label, or manufacturers', recommendations Table 1. Similarly, 80 pieces of non-

[1] Sodium D was a manufacturer reformulation of Silver periodate used in studies from previous years.

inoculated, cut seed were used for the non-inoculated check treatment. Treated seed was air-dried overnight at room temperature in the dark and placed into labeled paper bags and stored at 8 to 10°C until planting in small plots at the Crop Diversification Centre South in Brooks, AB.

The purpose of this field trial was to evaluate seed treatments, including Class M products, registered industry standards, and other experimental fungicides to determine efficacy and non-safety adverse effects on a susceptible chipping variety, Niska. Efficacy was evaluated by measuring plant emergence, stand, total and marketable yield, specific gravity and defects.

Soil fertility was achieved through a combination of soil fertility (105 lbs/ac N; 214 lbs/ac P, 720 lbs/ac K), and broadcast fertilizer (350 lbs/ac of 34-17-0) incorporated at hilling. Potatoes were planted in four replicate rows in a randomized complete block design. Each block was planted adjacent to guard rows of the same variety to reduce any edge effects (see plot plan, Appendix A).

Eptam 8E (2.2 L/ac) and Sencor 75DF (150 g/ac) were applied pre-plant (May 13) to control weeds. Potatoes were planted May 20, 2011 approximately 5 to 5½"deep using a two-row tuber unit planter. Seed was planted at 30cm spacing in 6m rows spaced 90cm apart.

The potatoes were hilled June 8 with a power hiller. The plots were irrigated throughout the season to maintain soil moisture close to 70%. Foliar fungicides were applied several times during the growing season to prevent early and late blight from developing **(Table 2).** Insecticide was applied on July 17 (Decis 5 EC, 50 mL/ac) to control Colorado potato beetle. **Figure 1** is a photo of this field trial on August 18.

Table 1. Chemical treatments and checks used for a CDCS potato seed treatment trial that was planted in a field plot at the Crop Diversification Centre South, Brooks, Alberta in 2011.

Treatment number	Treatment name	Chemical application rates[1]	Treatment application methods to seed pieces
1	Agress	0.1 g/kg	Spray application in 150 ml of distilled water
2	Emesto Silver	0.2 ml/kg	Spray application in 150 ml of distilled water
3	Heads-Up	1g/l	Spray application until germinating eyes coated
4	Heads-Up + Phostrol (F)	1g/l	Spray application of HeadsUp until germinating eyes coated.
5	Maxim D	1.3 ml/kg	Spray application in 150 ml of distilled water
6	Maxim MZ PSP	5 g/kg	Dry shaking with tubers
7	Maxim Liquid PSP	0.052 mL/kg	Wet shaking with 10mL mixture /kg seed
8	Senator WSB	0.7 g/kg in 150ml of sterile water	Spray application in 150 ml of distilled water
9	Sodium D	0.1 g/kg	Spray application in 150 ml of distilled water
10	Solan MZ	5 g/kg	Dry shaking with tubers
11	Inoculated-Water check	300mL sterile water	Spray application
12	Non- Inoculated- Water check	300mL sterile water	Spray application

[1]Manufacturers label application rates for postharvest disease control in potato st

Table 2: Foliar fungicides applied to the potato crop to prevent early and late blight development.

Date of Application	***Fungicide***	***Rate***
July 18	Bravo 500	0.64 L/ac
Aug 2	Bravo 500	0.64 L/ac
Aug 23	Dithane DG Rainshield	0.91 kg/ac

Figure 1: Fusarium seed piece treatment trial with Niska at CDCS in Brooks, AB August 18, 2011.

Reglone (1.4 L/ac) was applied September 6 and re-applied (1.0 L/ac) September 12 to facilitate mechanical harvest. Tubers were harvested September 27 – 28 with a one-row Grimme harvester for yield and grade data.

Tubers were stored at 10˚C until graded. Tubers were graded into size categories (less than 48 mm, 48 – 88 mm, over 88 mm and deformed). A sample of twenty-five tubers (over 48 mm) from each replicate was used to determine specific gravity using the weight in air over weight in water method. These tubers were cut longitudinally to assess internal defects.

Data in **Tables 3 - 6** were summarized and analyzed using the ARM 7 statistical software program by Gylling Data Management. Duncan's Multiple Range Test (DMRT) was utilized for means comparisons, where F-tests were statistically significant ($P \leq 0.05$). Bartlett's Test for Homogeneity of Variance was also used for all ANOVA calculations

RESULTS AND DISCUSSION

Tables 3, 4, 5 and 6 and Figures 2 and 3

Emergence and final stand counts are presented in **Table 3 and Figures 2 and 3**. Emergence data were recorded weekly between 39 and 56 days after planting (DAP). Emergence and stand counts for the inoculated check (water) was very high in replicate #4 with 38 out of a possible 40 plants emerged in the subplot (**Figures 2 and 3**). The average stand for replicates 1, 2 and 3 combined was 24 out of 40 plants. It is unknown why the inoculated check had unusually high emergence in replicate #4. Additionally, it is not known why the emergence and stand for some treatments such as Agress and Heads-Up SPT (alone) was less than the inoculated check. No treatment gave significantly higher emergence than this check either. It was possible that the inoculation was ineffective and a variable amount of naturally occurring *F. sambucinum* on some seed tubers may have led to the unpredicted and variable results.

Table 3: Emergence dates and final stand count of Niska potatoes treated with various seed piece treatments. Emerging plants in both rows/subplot were used in summarizing this data.

Treatment number	Treatment name	Average emergence count at 39 DAP[1,2,3]	Stand count (out of 40) at 56 DAP[1,2,3]
1	Agress	13.25 cd	14.50 d
2	Emesto Silver	18.25 a-d	24.25 abc
3	Heads-Up	10.75 d	15.25 cd
4	Heads-Up + Phostrol	13.75 cd	18.50 bcd
5	Maxim D	23.75 ab	25.00 ab
6	Maxim MZ PSP	23.00 ab	28.50 a
7	Maxim Liquid PSP	20.25 abc	23.00 a-d
8	Senator WSB	17.50 a-d	20.75 a-d
9	Sodium D	17.00 bcd	20.00 a-d
10	Solan MZ	25.00 a	23.25 a-d
11	Inoculated-Water check	22.50 ab	27.50 ab
12	Non- Inoculated- Water check	20.00 abc	23.00 a-d
ANOVA P value		0.0022	0.0234
LSD (P = 0.05)		6.91	8.07
Coefficient of Variation (%)		25.50	25.45

[1]Results are the means of four replications after 20 treated potato seeds were planted per replicate and raw data were used for the statistical analysis.
[2]Data were significantly different according to Duncan's Multiple Range test at P ≤ 0.05 (by least significant differences or LSD).
[3]Data followed by the same letter in each column of the table are not significantly different at the p < 0.05 level.

Figure 2: Average stand counts for each replicate out of 40 planted seed pieces at 39 DAP.

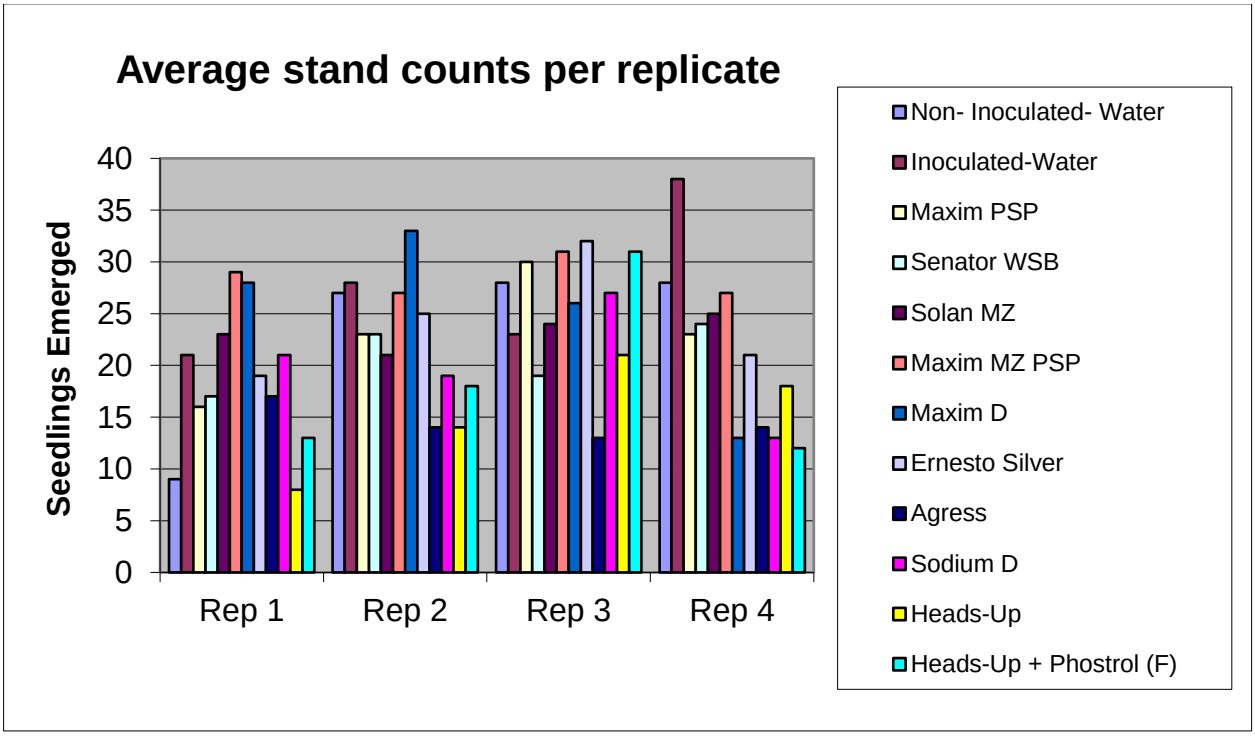


Figure 3: Average stand counts for each treatment out of 40 planted seed pieces at 39 DAP

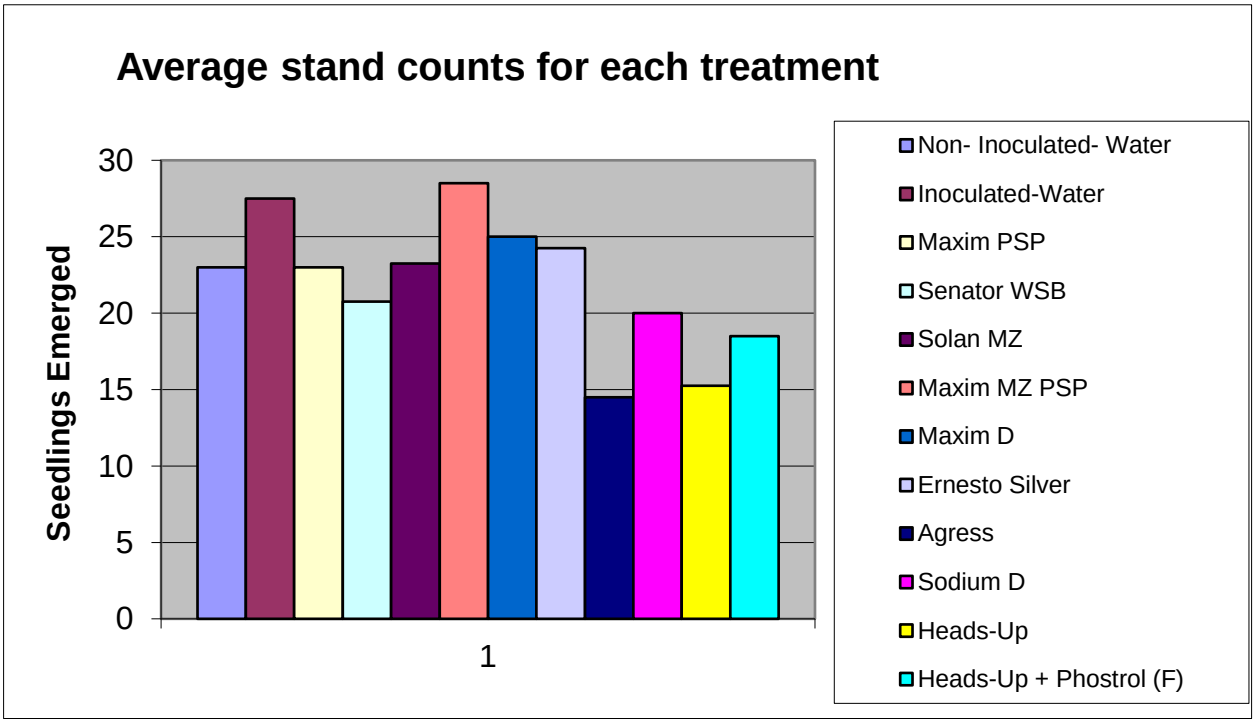


Table 4 shows the yield data (total yield; ton/ac) and specific gravities of tubers from each treatment. Although the total yield data failed the Bartlett's test of homogeneity (=0.03), trends show that the highest yield was observed when Maxim D was used as a seed treatment followed by Maxim MZ, Solan MZ, Emesto Silver, Senator and Maxim PSP. Unfortunately, the inoculated and the uninoculated check yields had similar results, indicating that the inoculation protocol may not have allowed for sufficient differentiation between treatments. A high level of inoculum present in the seed lot may have affected the uninoculated check. Water was applied to seed as they were tumbled to simulate the inoculation process in the absence of additional inoculum.

The specific gravity (SG) of tubers from Maxim MZ followed by Maxim D, Senator and the two checks rows were significantly higher than the remaining treatments. Heads Up + Phostrol had the lowest SG result.

Table 4: Estimated total yield (ton/acre) and specific gravity of tubers from each seed piece treatment. Data shown is the mean of four replicates. Data followed by the same letter in each column of the table are not significantly different at the $p < 0.05$ level.

Treatment number	Treatment name	Yield (ton/ac)[1,2]	SG[1,3,4]
1	Agress	11.0	1.074 bcd
2	Emesto Silver	19.2	1.074 bcd
3	Heads-Up	6.1	1.072 cd
4	Heads-Up + Phostrol (F)	11.6	1.070 d
5	Maxim D	24.3	1.078 ab
6	Maxim MZ PSP	23.0	1.080 a
7	Maxim Liquid PSP	18.4	1.075 bc
8	Senator WSB	19.6	1.076 abc
9	Sodium D	16.8	1.075 bc
10	Solan MZ	22.4	1.075 bc
11	Inoculated-Water check	21.0	1.078 ab
12	Non- Inoculated- Water check	18.0	1.076 abc
ANOVA P value		0.0001	0.023
LSD (P = 0.05)		5.33	0.0043
Coefficient of Variation (%)		25.19	0.33

[1]Results are the means of four replications with raw data shown.
[2]Data failed the Bartlett's test of homogeneity, so the Duncan Multiple Range test letter gradings couldn't be used.
[3]Data were significantly different according to Duncan's Multiple Range test at $P \leq 0.05$ (by least significant differences or LSD).
[4]Data followed by the same letter in each column of the table are not significantly different at the $p < 0.05$ level.

The mean percentage of total tuber number in each weight category is shown in **Table 5**. It is important to note that harvesting with small plot equipment and manual labour recovers all potatoes over 19mm in diameter. This tended to increase the yield of small potatoes relative to a commercial situation where more of these tubers may be left behind in the field. There were no statistical differences between treatments in the percentage yield of tubers under <48 mm or >88 mm. Statistically, the greatest percentage of marketable tubers (48 – 88 mm) was observed when Maxim D, Maxim MZ and Solan MZ were used as seed treatments; however the two checks were statistically similar unfortunately. The only treatments that weren't comparable to these were Agress and the Heads Up seed treatment + Phostrol foliar spray.

Statistical significance for the deformed tubers % data was proven where the rows treated with Aggress, followed by the Heads-Up/Phostrol treatment as well as three other treatments and the inoculated check had the most deformity. Emesto Silver, Maxim D and Solan MZ had the lowest results. However, the two checks were statistically similar to them.

Table 5: Percentage of total tuber number in each weight category (< 48 mm, 48 to 88 mm, > 88 mm, and deformed) for each treatment.

.

Treatment number	Treatment name	< 48 mm[1,2,5]	48 – 88 mm[1,3,4,5]	> 88 mm[1,2,6]	Deformed mm[1,3,4,5,6]
1	Agress	18.36	44.65 bc	20.39	14.3 a
2	Emesto Silver	18.06	63.79 a	14.30	2.30 c
3	Heads-Up	24.39	51.40 abc	13.28	5.34 abc
4	Heads-Up + Phostrol (F)	23.25	40.78 c	23.40	10.09 ab
5	Maxim D	15.90	69.87 a	11.91	1.98 c
6	Maxim MZ PSP	16.30	69.95 a	9.94	2.96 bc
7	Maxim Liquid PSP	23.59	55.31 abc	13.98	5.79 abc
8	Senator WSB	20.72	54.29 abc	19.13	4.35 bc
9	Sodium D	16.94	59.69 ab	16.40	6.27 abc
10	Solan MZ	19.10	66.77 a	11.96	1.31 c
11	Inoculated-Water check	17.81	61.82 ab	14.12	5.22 abc
12	Non- Inoculated- Water check	15.02	62.36 ab	16.87	3.46 bc
ANOVA P value		0.8652	0.0118	0.2137	0.0245
LSD (P = 0.05)[6]		---	16.304	---	---
Coefficient of Variation (%)		21.86	19.34	20.39	39.75

[1]Results are the means of four replications.
[2]There were no significant differences between treatments ($p < 0.05$ level).
[3]Data were significantly different according to Duncan's Multiple Range test at $P \leq 0.05$ (by least significant differences or LSD).
[4]Data followed by the same letter in each column of the table are not significantly different at the $p < 0.05$ level.
[5]Raw data were used for analysis.
[6]Square root-transformed data were used for analysis.

Table 6 shows the tuber yield (estimated ton/ac) harvested from each treatment by size category. There were no significant differences in the yields of oversized potatoes or deformed potatoes from different seed treatments. The marketable yields data failed the Bartlett's test of homogeneity but trends suggested that Maxim D and Maxim MZ PSP may have the highest yields. Some significant differences were noted in the small size category though, as the Maxim Liquid PSP seed treatment followed by Maxim MZ, Solan MZ, Emesto Silver, Senator Maxim D and the inoculated water check had the highest yields and were not significantly different. Tuber yields from the two check treatments were quite high also unfortunately, so this experiment will need to be repeated with some inoculation protocol modifications, allowing for better separation between checks.

Table 6: Estimated yield (ton/ac) in each weight category (< 48 mm, 48 – 88 mm, > 88 mm and deformed) for each treatment.

Treatment number	Treatment name	< 48 mm [1,2,3]	48 – 88 mm[1,4]	> 88 mm[1,5]	Deformed[1,5]
1	Agress	0.40 c	4.29	4.57	1.80
2	Emesto Silver	0.88 abc	11.09	6.28	0.93
3	Heads-Up	0.45 c	2.81	1.87	0.97
4	Heads-Up + Phostrol (F)	0.46 c	4.47	4.56	2.11
5	Maxim D	0.88 abc	16.02	6.72	0.71
6	Maxim MZ PSP	1.09 ab	15.58	5.01	1.31
7	Maxim Liquid PSP	1.19 a	9.67	5.84	1.76
8	Senator WSB	0.91 abc	9.79	7.37	1.55
9	Sodium D	0.63 bc	8.76	6.00	1.36
10	Solan MZ	1.09 ab	14.34	6.31	0.70
11	Inoculated-Water check	0.90 abc	11.84	6.33	1.90
12	Non- Inoculated- Water check	0.44 c	10.23	6.10	1.22
ANOVA P value		0.0222	0.0001	0.18	0.5988
LSD (P = 0.05)		0.44	4.00	2.83	1.23
Coefficient of Variation (%)		47.32	33.65	42.17	75.44

[1]Results are the means of four replications and are expressed in ton/ac.
[2]Data were significantly different according to Duncan's Multiple Range test at P ≤ 0.05 (by least significant differences or LSD).
[3]Data followed by the same letter in each column of the table are not significantly different at the p < 0.05 level.
[4]Data failed the Bartlett's test of homogeneity, so the Duncan Multiple Range test letter gradings couldn't be used.
[5]There were no significant differences between treatments (p < 0.05 level).

Additionally, tuber samples that were used to measure specific gravity were evaluated for hollow heart, brown centre, stem-end discoloration, other types of internal necrosis and scab. There were very few internal defects observed in the tubers examined. Hollow heart was noted in a few tubers of the Niska from several treatments but there was no treatment effect.

CONCLUSIONS

The Fusarium Best Management trial included an evaluation of potato seed treatments to protect against fusarium seed piece decay, fusarium wilt and potentially fusarium dry rot. In 2011, the variety Niska was used in southern Alberta to evaluate ten products or combinations against an inoculated check and an uninoculated (water inoculated) check. Unfortunately, the yield from the inoculated check and the uninoculated check were not statistically different from one another, indicating that the inoculation protocol may not have allowed for sufficient differentiation between treatments. Water was applied to seed as they were tumbled to simulate the inoculation process in the absence of additional inoculum. A high level of inoculum present in the seed lot may have affected the uninoculated check. The experiment will need to be repeated with some modifications to the inoculation protocol in the next years to allow for better separation between the inoculated and the uninoculated checks.

Recommendations from the 2011 field trial

- Modification of the inoculation protocol may be required to ensure greater separation between the two check treatments and more meaningful data from the seed treatments.
- The trial should be conducted in southern Alberta for at least 3 years to evaluate treatments across different environmental conditions.

3-2 YEAR 2: 2012 Field Trial

PROJECT OBJECTIVES

1. To evaluate the relative efficacy of registered and experiment fungicides for fusarium dry rot control in field potatoes.
2. The tubers used for Objectives 1 will be bruised and inoculated with *F. sambucinum* prior to treatment, to ensure significant disease pressure.

MATERIALS

Crop species	Common name	Cultivar
Solanum tuberosum	Potato	Niska
Disease species	**Common name**	**Source**
F. sambucinum	Fusarium dry rot (FDR)	CDC South Pathology Program: Potato isolates 12-1 and 12-2

Seed Treatments used:
AGRESS® (oxysilver nitrate), Syngenta Canada Inc. experiment product No. A18232, EMESTO™ SILVER (9.35% penflufen + 1.68% prothioconazole), HeadsUp® Plant Protectant (49.65% saponin), PHOSTROL® (phosphorous acid), MAXIM ® D liquid suspension fungicide (difenconazole + fludioxinol), MAXIM ® MZ PSP fungicide (0.5% fludioxinol + 5.7% mancozeb), MAXIM ® PSP fungicide (0.5% fludioxinol), SENATOR ® WSB (70% thiophate methyl) and finally SOLAN™ MZ (16% mancozeb), (0.5% fludioxinol).

METHODS

The seed treatment evaluation was conducted in small plots at the Crop Diversification Centre South in Brooks, AB. Fertility was achieved through a combination of soil fertility (74 lbs/ac N; 254 lbs/ac P, 850 lbs/ac K), and broadcast fertilizer (176 lbs/ac of 34-0-0 and 100 lbs/ac of 11-52-0) incorporated prior to planting. Eptam 8E (2.2 L/ac) and Sencor 75DF (150 g/ac) were applied pre-plant (May 10) to control weeds.

Seed of Niska, a chipping potato cultivar, was provided by Old Dutch Foods and seed treatment products were provided by each sponsor. Seed was cut (70 to 85 g) and suberized prior to application of inoculum or treatments. As in 2011 (Year 1), on May 2, 2012 plates *of F. sambucinum* (isolates 12-1 and 12-2R) were harvested by adding 10ml of sterile water and using a sterile smear tool to loosen and detach the spores from the colonies. The same protocol was used to enumerate the spores, so that the inoculant contained $4x10^5$ spores/mL. This was prepared in a sufficient quantity to cover all seed pieces receiving inoculum (2 mL of inoculum/seed piece). This *F. sambucinum* suspension was thus applied to10 tubers at a time, by shaking them in a 15 lb. (6.8 kg) poly bag containing 20 mL of inoculum.

Potatoes were planted on May 11, 2012, ca. 5 to 5½"deep using a two-row tuber unit planter. Seed was planted at 30cm spacing in four replicate 6m rows spaced 90cm apart in a randomized complete block design. Each block was planted adjacent to guard rows of the same variety to reduce any edge effects.

The potatoes were hilled June 4 with a power hiller. The plots were irrigated throughout the season to maintain soil moisture close to 70%. Foliar fungicides were applied several times during the growing

season to prevent early and late blight from developing (Table 1). Insecticide was applied July 17 (Matador 120 EC, 40 mL/ac) and August 15 (Decis 5 EC, 50 mL/ac) to control Colorado potato beetle.

Table 1: Foliar fungicides applied to the potato crop to prevent early and late blight development.

Date of Application	***Fungicide***	***Rate***
June 29	Bravo 500	0.64 L/ac
July 27	Ridomil Gold/Bravo	883 mL/ac
Aug 15	Bravo 500	0.64 L/ac

Table 2. Chemical treatments and checks used for a CDCS potato seed treatment trial that was planted in a field plot at the Crop Diversification Centre South, Brooks, Alberta in 2012.

Treatment number	Treatment name	Chemical application rates[1]	Treatment application methods to seed pieces
1	Agress	0.1 g/kg	Spray application in 150 ml of distilled water
2	A18232A	Do not have this rate	Spray application in 150 ml of distilled water
3	Emesto Silver	0.2 ml/kg	Spray application in 150 ml of distilled water
4	Heads-Up	1g/l	Spray application until germinating eyes coated
5	Heads-Up + Phostrol	1g/l	Spray application of HeadsUp in Phostrol until germinating eyes coated.
6	Maxim D	1.3 ml/kg	Spray application in 150 ml of distilled water
7	Maxim MZ	5 g/kg	Dry shaking with tubers
8	Maxim PSP	5 g/kg	Dry shaking with tubers
9	Senator ® WSB	0.7 g/kg in 150ml of sterile water	Spray application in 150 ml of distilled water
10	Solan MZ	5 g/kg	Dry shaking with tubers
11	Inoculated Check	300mL sterile water	Spray application
12	Uninoculated Check	300mL sterile water	Spray application

[1]Manufacturers label application rates for postharvest disease control in potato storages.

Figure 1: Fusarium seed piece treatment trial with Niska at CDCS in Brooks, AB June 28, 2012.

Reglone (1.4 L/ac) was applied August 28 to facilitate mechanical harvest. Tubers were harvested September 10 with a one-row Grimme harvester for yield and grade data.

Tubers were stored at 10˚C until graded. Tubers were graded into size categories (less than 48 mm, 48 – 88 mm, over 88 mm and deformed). A sample of twenty-five tubers (48-88 mm) from each replicate was used to determine specific gravity using the weight in air over weight in water method. These tubers were cut longitudinally to assess internal defects.

All data were summarized and analyzed using the ARM 7 statistical software program by Gylling Data Management. Duncan's Multiple Range Test (DMRT) was utilized for means comparisons, where F-tests were statistically significant ($P \leq 0.05$). Bartlett's Test for Homogeneity of Variance was also used for all ANOVA calculations

RESULTS AND DISCUSSION

Emergence data, recorded as days to 50% emergence, full emergence and final stand counts are presented in **Table 3**. There were no statistical differences observed between treatments with respect to emergence or stand.

Table 3: Emergence dates and final stand count of Niska potatoes treated with various seed piece treatments. Data shown is the mean of four replicates. Data followed by the same letter in each column of the table were not significantly different at the $p < 0.05$ level.

Treatment number	Treatment name	Days to 50% Emergence[1,2]	Days to Full Emergence[1,2]	Stand Count (out of 20)[1,2]
1	Agress	29.4	44.3	20.0
2	A18232A	29.4	42.0	20.0
3	Emesto Silver	27.8	45.6	20.0
4	Heads-Up	29.9	49.5	19.9
5	Heads-Up + Phostrol	30.0	49.3	20.0
6	Maxim D	28.6	46.4	20.0
7	Maxim MZ	28.8	41.9	20.0
8	Maxim PSP	29.0	41.5	20.0
9	Senator ® WSB	29.1	42.0	20.0
10	Solan MZ	29.1	47.3	20.0
11	Inoculated Check	29.0	44.3	20.0
12	Uninoculated Check	29.8	47.6	19.9
	ANOVA P value	0.1822	0.2141	0.4671
	LSD (P = 0.05)	1.45	7.09	0.14
	Coefficient of Variation (%)	3.45	10.88	0.49

[1]Results are the means of four replications with raw data shown.
[2]Data were not significantly different according to Duncan's Multiple Range test at $P \leq 0.05$ (by least significant differences or LSD).

Yield data (total yield; ton/ac) and specific gravities of tubers from each treatment are shown in **Table 4** but no significant differences appeared ($p<0.05$). However, trends suggested that all treatments, except for the two checks, had yields of >23.5 ton/acre. Unfortunately, the yields from the two checks were not much lower so again, inoculation protocol may not have allowed for sufficient differentiation between treatments. A high level of inoculum present in the seed lot may have affected the uninoculated check. Water was applied to seed as they were tumbled to simulate the inoculation process in the absence of additional inoculum.

Table 4: Estimated total yield (ton/acre) and specific gravity of tubers from each seed piece treatment. Data shown is the mean of four replicates. Data followed by the same letter in each column of the table are not significantly different at the $p < 0.05$ level.

Treatment number	Treatment name	Yield (ton/ac)[1,2]	SG[1,2]
1	Agress	24.3	1.088
2	A18232A	26.5	1.087
3	Emesto Silver	25.8	1.088
4	Heads-Up	24.7	1.086
5	Heads-Up + Phostrol	24.2	1.085
6	Maxim D	25.9	1.086
7	Maxim MZ	26.4	1.089
8	Maxim PSP	23.9	1.086
9	Senator ® WSB	25.1	1.087
10	Solan MZ	24.0	1.085
11	Inoculated Check	22.9	1.087
12	Uninoculated Check	20.9	1.090
	ANOVA P value	0.2294	0.437
	LSD (P = 0.05)	3.92	0.004
	Coefficient of Variation (%)	11.07	0.27

[1]Results are the means of four replications with raw data shown.
[2]Data were not significantly different according to Duncan's Multiple Range test at $P \leq 0.05$ (by least significant differences or LSD).

The yield of tubers (estimated ton/ac) harvested from each treatment are shown by size category in **Table 5**. The uninoculated check, Heads Up (alone), Heads Up + Phostrol and Senator treatments resulted in significantly lower yields of small tubers than many of the other treatments. The marketable (48 – 88 mm), large (>88 mm) and deformed size categories data weren't statistically significant. The greatest marketable yield was observed when A18232A was used as a seed treatment, but this was only a trend. In 2012, some modifications were made to the 2011 inoculation protocol to allow for better separation between the inoculated and the uninoculated checks. However, the yields of marketable tubers from the inoculated check and the uninoculated check were very similar and were just slightly lower than the other treatments. No deformed tubers from the Maxim D seed treatment were found.

Table 5: Estimated yield (ton/ac) in each weight category (< 48 mm, 48 – 88 mm, > 88 mm and deformed) for each treatment.

Treatment number	Treatment name	< 48 mm[1,2,3]	48 – 88 mm[1,4]	> 88 mm[1,4]	Deformed[1,4]
1	Agress	2.6 bc	20.7	0.6	0.5
2	A18232A	2.7 abc	22.2	1.0	0.4
3	Emesto Silver	2.9 abc	20.8	1.4	0.6
4	Heads-Up	2.2 cd	21.2	0.9	0.1
5	Heads-Up + Phostrol	1.4 d	21.8	0.7	0.2
6	Maxim D	2.8 abc	21.3	1.6	0.0
7	Maxim MZ	3.7 a	21.5	0.6	0.3
8	Maxim PSP	3.5 ab	19.4	0.6	0.1
9	Senator ® WSB	2.0 cd	21.8	1.2	0.1
10	Solan MZ	2.7 bc	20.3	0.5	0.4
11	Inoculated Check	2.4 c	18.3	1.6	0.4
12	Uninoculated Check	1.5 d	18.1	1.0	0.2
ANOVA P value		0.0001	0.4628	0.6045	0.1395
LSD (P = 0.05)		0.83	3.91	1.23	0.46
Coefficient of Variation (%)		22.8	13.12	86.71	111.47

[1]Results are the means of four replications.
[2]Data were significantly different according to Duncan's Multiple Range test at P ≤ 0.05 (by least significant differences or LSD).
[3]Data followed by the same letter in each column of the table are not significantly different at the p < 0.05 level.
[4]Data were not significantly different according to Duncan's Multiple Range test at P ≤ 0.05 (by least significant differences or LSD).

The mean percentage of total tuber number in each weight category is shown in **Table 6** (on the following page)**.** Noteworthy is that harvesting with small plot equipment and manual labor recovers all potatoes over 19mm in diameter. This tended to increase the yield of small potatoes, relative to a commercial situation where more of these tubers may be left behind in the field.

There were statistical differences between treatments in all size categories, except for tubers >88 mm. The highest percentage of small tubers (< 48 mm) was observed when Maxim PSP was used as a seed treatment; however, this data were not significantly different from the inoculated check or from rows where A18232A, Emesto Silver, Maxim D, Maxim MZ, or Solan MZ were used as seed treatments. The greatest percentages of marketable tubers (48 – 88 mm) was observed when Agress, Heads Up + Phostrol, Heads Up (alone), Maxim D and Senator were used as seed treatments but were not significantly different from the uninoculated check.

The highest percentage of deformed tubers was observed from the inoculated check and rows that were treated with Agress, A18232A, Emesto Silver, Maxim MZ or Solan MZ. Conversely, the lowest percentages were with Maxim D (0%) followed by Maxim PSP, and Senator but the uninoculated check was also in this same category.

Table 6: Percentage of total tuber number in each weight category (< 48 mm, 48 to 88 mm, > 88 mm, and deformed) for each treatment.

Treatment number	Treatment name	< 48 mm[1,2,3,4]	48 – 88 mm[1,2,3,4]	> 88 mm[1,4,5]	Deformed mm[1,2,3,4]
1	Agress	27.21 bcd	70.76 a-d	0.72	0.89 ab
2	A18232A	29.81 abc	68.43 bcd	0.87	0.60 abc
3	Emesto Silver	30.60 abc	66.73 bcd	1.47	0.74 ab
4	Heads-Up	26.85 bcd	71.54 abc	1.17	0.36 bc
5	Heads-Up + Phostrol	20.16 d	78.07 a	0.92	0.28 bc
6	Maxim D	28.59 abc	69.25 a-d	1.65	0.00 c
7	Maxim MZ	33.90 ab	64.45 cd	0.58	0.71 abc
8	Maxim PSP	36.70 a	61.79 d	0.67	0.11 bc
9	Senator ® WSB	23.59 cd	74.55 ab	1.22	0.13 bc
10	Solan MZ	30.70 abc	67.55 bcd	0.53	0.68 abc
11	Inoculated Check	30.28 abc	66.22 bcd	1.53	1.47 a
12	Uninoculated Check	22.86 cd	75.40 ab	1.31	0.18 bc
ANOVA P value		0.0053	0.0097	0.7739	0.0079
LSD (P = 0.05)[6]		---	---	---	---
Coefficient of Variation (%)		9.25	4.00	31.71	23.88

[1]Results are the means of four replications.
[2]Data were significantly different according to Duncan's Multiple Range test at P ≤ 0.05 (by least significant differences or LSD).
[3]Data followed by the same letter in each column of the table are not significantly different at the p < 0.05 level.
[4]Square root-transformed data were used.
[5]Data were not significantly different according to Duncan's Multiple Range test at P ≤ 0.05 (by least significant differences or LSD).
[6]Least significant differences were not calculated for transformed data.

CONCLUSIONS

The Fusarium Best Management trial included an evaluation of potato seed treatments to protect against fusarium seed piece decay, fusarium wilt and potentially fusarium dry rot. In 2012, the variety Niska was used in southern Alberta to evaluate ten products or combinations against an inoculated check and an uninoculated (water inoculated) check. Although total yield from the inoculated check and the uninoculated check were not statistically different from one another, marketable yields (Table 6) were statistically different. This time, the inoculation protocol appeared to have been successful, as there were statistical differences between the two checks, as the uninoculated check had a slightly higher percentage of marketable potatoes than the inoculated check.

Recommendations

- Modification of the inoculation protocol may be required to ensure greater separation between the two check treatments and more meaningful data from the seed treatments.
- This trial should be conducted in southern Alberta for at least 3 years to evaluate treatments across different environmental conditions.

3-3 YEAR 3: 2013 Field Trial

PROJECT OBJECTIVES

1. To evaluate the relative efficacy of registered and experiment fungicides for fusarium dry rot control in field potatoes.
2. The tubers used for Objectives 1 will be bruised and inoculated with *F. sambucinum* prior to treatment, to ensure significant disease pressure.

RESEARCH PROTOCOL

MATERIALS

Crop species	**Common name**	**Cultivar**
Solanum tuberosum	Potato	Dakota Pearl
Disease species	**Common name**	**Source**
F. sambucinum	Fusarium dry rot (FDR)	CDC South Pathology Program: Potato isolates 12-1 and 12-2

Seed Treatments used:
MAXIM ® PSP fungicide (0.5% fludioxinol), SOLAN™ MZ (16% mancozeb), SENATOR ® PSP (10% thiophate-methyl), MAXIM ® Liquid PSP fungicide (40.3% fludioxinol), MAXIM ® MZ PSP fungicide (0.5% fludioxinol + 5.7% mancozeb), CRUISER MAXX POTATO EXTREME liquid fungicide/insecticide (difenconazole + fludioxinol + thiamethoxam), MAXIM ® D liquid suspension fungicide (difenconazole + fludioxinol), HeadsUp® Plant Protectant (49.65% saponin), PHOSTROL® (phosphorous acid), and finally EMESTO™ SILVER (9.35% penflufen + 1.68% prothioconazole).

METHODS

2013 was the third where the potato seed piece treatment evaluation was conducted in small plots at the Crop Diversification Centre South in Brooks, AB, concurrently with a PSPT storage trial. Plot fertility was achieved through a combination of soil fertility (124 lbs/ac N; 361 lbs/ac P, 1930 lbs/ac K), and broadcast fertilizer (165 lbs/ac of 34-0-0 and 96 lbs/ac of 11-52-0) incorporated prior to planting. Eptam 8E (2.2 L/ac) and Sencor 75DF (150 g/ac) were applied pre-plant (May 6) to control weeds.

Seed of Dakota Pearl, a chipping potato cultivar, was provided by Old Dutch Foods and seed treatment products were provided by each sponsor. Seed was cut (70 to 85 g) and suberized prior to application of inoculum or treatments. As in the field trials done previously, on May 21, 2013, plates *of F. sambucinum* (isolates 12-1 and 12-2R) were harvested by adding 30ml of sterile water and using a sterile smear tool to loosen and detach the spores from the colonies. The same protocol was used to enumerate the spores, so that the inoculant contained $1x10^4$ spores/mL this time. This was prepared in a sufficient quantity to cover all seed pieces receiving inoculum (2 mL of inoculum/seed piece). This *F. sambucinum* suspension was thus applied to10 tubers at a time, by shaking them in a 15 lb. (6.8 kg) poly bag containing 20 mL of inoculum except for except for Treatment 1 (untreated/uninoculated check). After inoculating the tubers, they were placed back into the plastic crates and these were set inside a 10°C 95% RH CES room until they were planted on May 22, ca. 4 to 6” deep using a two-row tuber unit planter. Seed was planted at 30cm spacing in four replicate 6m

rows spaced 90cm apart in a randomized complete block design. Each block was planted adjacent to guard rows of the same variety to reduce any edge effects.

The potatoes were hilled June 17 with a power hiller. The plots were irrigated throughout the season to maintain soil moisture close to 70%. Foliar fungicides were applied several times during the growing season to prevent early and late blight from developing (Table 1). Insecticide was applied July 10 (Matador 120 EC, 40 mL/ac).

Table 1: Foliar fungicides applied to the potato crop to prevent early and late blight development.

Date of Application	***Fungicide***	***Rate***
July 10	Quadris	202mL/ac
July 19	Gavel	
June 20	Bravo 500	0.64 L/ac
August 15	Ridomil Gold/Bravo	883 mL/ac
August 19	Gavel	July 19

Reglone (1.4 L/ac) was applied August 27 to facilitate mechanical harvest. Tubers were harvested September 5 with a one-row Grimme harvester for yield and grade data.

Tubers were stored at 10˚C until graded. Tubers were graded into size categories (less than 48 mm, 48 – 88 mm, over 88 mm and deformed). A sample of twenty-five tubers (48-88 mm) from each replicate was used to determine specific gravity using the weight in air over weight in water method. These tubers were cut longitudinally to assess internal defects.

All data were summarized and analyzed using the ARM 7 statistical software program by Gylling Data Management. Duncan's Multiple Range Test (DMRT) was utilized for means comparisons, where F-tests were statistically significant ($P \leq 0.05$). Bartlett's Test for Homogeneity of Variance was also used for all ANOVA calculations

Table 2. Chemical treatments and checks used for a CDCS potato seed treatment trial that was planted in a field plot at the Crop Diversification Centre South, Brooks, Alberta in 2013.

Treatment number	Treatment name	Chemical application rates to seed pieces[1]	Treatment application methods to seed pieces
1	Uninoculated Check (water)	10 mL/kg	Wet shaking with 10mL tapwater /kg seed
2	Inoculated check (water)	10 mL/kg	Wet shaking with 10mL tapwater /kg seed
3	Maxim Powder PSP	5 g/kg	Dry shaking with 5 g of powder/kg seed
4	Solan MZ PSPT	5 g/kg	Dry shaking with 5 g of powder/kg seed
5	Senator PSPT	5 g/kg	Dry shaking with 5 g of powder/kg seed
6	Maxim Liquid PSP	0.052 mL/kg	Wet shaking with 10mL mixture /kg seed
7	Maxim MZ	5 g/kg	Dry shaking with 5 g of powder/kg seed
8	Cruiser Maxx Potato Extreme	0.2 mL/kg	Wet shaking with 10mL mixture /kg seed
9	Maxim D	0.75 mL/kg	Wet shaking with 10mL mixture /kg seed
10	Heads-Up (seed treatment) + Phostrol (foliar spray)	1g/L	Mix Heads-Up in 1L of water and apply by wet shaking, using 10 mL of mixture/kg of seed so that the germinating eyes are coated.
11	Heads-Up	1g/L	As above
12	Emesto Silver	0.2 ml/kg	Wet shaking with 10mL mixture /kg seed

[1]Manufacturers label application rates for postharvest disease control in potato storages.

RESULTS AND DISCUSSION

Emergence data was recorded between mid-June and July 1, 2013 for dates of 50% emergence, full emergence and final stand counts are presented in **Table 3**. There were no significant differences in the number of days for the plants to reach 50% emergence. However, the 100% emergence data were very highly significant; this was achieved in just 26 days after planting (DAP) with HEADS-UP(seed treatment) + PHOSTROL (foliar spray). This was followed by HEADS-UP (seed treatment only) at 30 days DAP, although these results were significantly different. These two treatments also demonstrated the greatest stand/20 plants.

Table 3: Emergence dates and final stand count of Niska potatoes treated with various seed piece treatments for a CDC South field trial in 2013.

Treatment number	Treatment name	Days to 50% Emergence[1,2]	Days to Full Emergence[1,3,4]	Stand Count (out of 20)[1,3,4]
1	Uninoculated Check (water)	26	42.00 a	16.00 cde
2	Inoculated check (water)	26	42.00 a	15.75 cd
3	Maxim Powder PSP	26	42.00 a	17.63 cd
4	Solan MZ PSPT	26	40.88 a	17.25 cd
5	Senator PSPT	26	41.13 a	17.88 cd
6	Maxim Liquid PSP	26	42.00 a	14.38 e
7	Maxim MZ	26	42.00 a	16.5 cde
8	Cruiser Maxx Potato Extreme	26	40.88 a	17.00 cd
9	Maxim D	26	42.00 a	16.75 cde
10	Heads-Up (seed treatment) + Phostrol (foliar spray)	26	26.00 c	22.63 a
11	Heads-Up	26	30.00 b	20.38 ab
12	Emesto Silver	26	39.38 a	18.5 bc
	ANOVA P value	1.000	0.0001	0.0001
	LSD (P = 0.05)	0	2.638	2.331
	Coefficient of Variation (%)	0	4.66	9.20

[1]Results are the means of four replications with raw data used.
[2]Data were not significantly different according to Duncan's Multiple Range test at P ≤ 0.05 (by least significant differences or LSD).
[3]Data were significantly different according to Duncan's Multiple Range test at P ≤ 0.05 (by least significant differences or LSD).
[4]Data followed by the same letter in each column of the table are not significantly different at the p < 0.05 level.

Yield data (total yield; ton/ac) and specific gravities of tubers from each treatment are shown in **Table 4**. There were no significant differences in the yields (ton/acre). Unfortunately, the yield from the inoculated check and the uninoculated check were not statistically different from one another, indicating that the inoculation protocol may not have allowed for sufficient differentiation between treatments. A high level of inoculum present in the seed lot may have affected the uninoculated check.

There were no statistical differences in specific gravity of tubers between treatments included in the study.

Table 4: Estimated total yield (ton/acre) and specific gravity of tubers from each seed piece treatment for a CDC South field trial in 2013. Data shown is the mean of four replicates. Data followed by the same letter in each column of the table are not significantly different at the $p < 0.05$ level.

Treatment number	Treatment name	Yield (ton/ac)[1,2]	SG[1,2]
1	Uninoculated Check (water)	18.06	1.084
2	Inoculated check (water)	17.09	1.081
3	Maxim Powder PSP	18.80	1.085
4	Solan MZ PSPT	19.67	1.086
5	Senator PSPT	20.12	1.084
6	Maxim Liquid PSP	18.45	1.082
7	Maxim MZ	17.99	1.085
8	Cruiser Maxx Potato Extreme	21.54	1.078
9	Maxim D	19.46	1.085
10	Heads-Up (seed treatment) + Phostrol (foliar spray)	23.73	1.081
11	Heads-Up	20.57	1.081
12	Emesto Silver	22.59	1.082
	ANOVA P value	0.0852	0.3646
	LSD (P = 0.05)	4.226	0.0059
	Coefficient of Variation (%)	14.75	0.37

[1]Results are the means of four replications and raw data were used.
[2]Data were not significantly different according to Duncan's Multiple Range test at $P \leq 0.05$ (by least significant differences or LSD).

The yield of tubers (estimated ton/ac) harvested from each treatment are shown by size category in **Table 5**. The greatest marketable yield was observed when Emesto silver was used as a seed treatment but again, this was only a trend. The data for the >88 mm category failed the Bartlett's test of homogeneity so significant differences could not be reported. The Maxim D seed treatment had the lowest weight of deformed tubers but not significantly so.

Table 5: Estimated yield (ton/ac) in each weight category (< 48 mm, 48 – 88 mm, > 88 mm and deformed) for each treatment.

Treatment number	Treatment name	< 48 mm[1,2,]	48 – 88 mm[1,2]	> 88 mm[1,3]	Deformed[1,2]
1	Uninoculated Check (water)	1.95	14.01	1.24	0.28
2	Inoculated check (water)	1.80	13.12	1.02	0.22
3	Maxim Powder PSP	1.98	15.76	0.42	0.27
4	Solan MZ PSPT	2.1	16.14	0.61	0.21
5	Senator PSPT	2.38	16.53	0.51	0.20
6	Maxim Liquid PSP	2.52	14.22	0.68	0.11
7	Maxim MZ	2.57	14.77	0.32	0.48
8	Cruiser Maxx Potato Extreme	2.81	16.04	1.39	0.29
9	Maxim D	2.47	15.89	0.45	0.06
10	Heads-Up (seed treatment) + Phostrol (foliar spray)	2.60	18.41	1.81	0.63
11	Heads-Up	1.75	16.34	2.07	0.16
12	Emesto Silver	2.35	17.56	1.00	0.36
ANOVA P value		0.0762	0.3547	0.0423	0.6015
LSD (P = 0.05)		0.729	4.036	1.117	0.498
Coefficient of Variation (%)		22.2	17.77	80.63	127.31

[1]Results are the means of four replications and raw data were used.
[2]Data were not significantly different according to Duncan's Multiple Range test at P ≤ 0.05 (by least significant differences or LSD).
[3]Data failed the Bartlett's test of homogeneity, so the Duncan Multiple Range test letter gradings couldn't be used.

The mean percentage of total tuber number in each weight category is shown in **Table 6** (on the following page)**.** Noteworthy is that harvesting with small plot equipment and manual labor recovers all potatoes over 19mm in diameter. This tended to increase the yield of small potatoes, relative to a commercial situation where more of these tubers may be left behind in the field.

The small, marketable and deformed tuber data were not statistically significant and the marketable tuber category had a very tight range of value from 62.33% for Cruiser Maxx Potato Extreme up to 70.31% for Maxim Powder PSP but the two checks were very similar. However, statistical differences ($p<0.05$) between treatments existed for tubers >88 mm, where Maxim MZ had the lowest percentage of over-sized tubers at just 0.47%. However, it also had the greatest amount of deformed tubers at 1.39% but this was only a trend. Conversely, the Heads-Up seed piece treatment had the highest percentage of tubers in the >88 mm category at 3.71% and even exceeded the uninoculated check at 2.59%. The lowest percentage of deformed tubers was observed from the Heads-Up treatment but could only be reported as a trend.

Table 6: Percentage of total tuber number in each weight category (< 48 mm, 48 to 88 mm, > 88 mm, and deformed) for each treatment.

Treatment number	Treatment name	< 48 mm[1,2,3,]	48 – 88 mm[1,2,3,]	> 88 mm[1,4,5]	Deformed mm[1,2,3]
1	Uninoculated Check (water)	30.86	65.33	2.59 ab	0.86
2	Inoculated check (water)	30.46	66.19	1.98 abc	0.91
3	Maxim Powder PSP	27.92	70.31	0.72 bc	0.63
4	Solan MZ PSPT	28.37	69.74	0.89 bc	0.55
5	Senator PSPT	29.37	68.94	0.86 bc	0.38
6	Maxim Liquid PSP	35.08	62.64	0.84 bc	0.63
7	Maxim MZ	33.21	64.37	0.47 c	1.39
8	Cruiser Maxx Potato Extreme	34.28	62.33	2.19 abc	0.92
9	Maxim D	30.46	68.31	0.71 bc	0.27
10	Heads-Up (seed treatment) + Phostrol (foliar spray)	29.64	67.02	1.76 abc	1.22
11	Heads-Up	25.50	69.70	3.71 a	0.41
12	Emesto Silver	29.77	67.51	1.56 abc	0.80
ANOVA P value		0.3884	0.3132	0.0213	0.8212
LSD (P = 0.05)[6]		---	---	---	---
Coefficient of Variation (%)		8.37	3.70	29.68	35.07

[1]Results are the means of four replications.
[2]Data were not significantly different according to Duncan's Multiple Range test at P ≤ 0.05 (by least significant differences or LSD).
[3]Square root-transformed data were used.
[4]Data were significantly different according to Duncan's Multiple Range test at P ≤ 0.05 (by least significant differences or LSD).
[5]Data followed by the same letter in each column of the table are not significantly different at the p < 0.05 level.
[6]Least significant differences were not calculated for transformed data.

CONCLUSION

Based upon the field trial results, HEADS-UP(seed treatment) + PHOSTROL (foliar spray) and the HEADS-UP(seed treatment only) gave the best overall results as seed piece treatments with PHOSTROL applied as a foliar spray during the growing season for emergence and stand counts. The market yield data were not consistent so that a best treatment wasn't apparent. HEADS-UP (seed treatment) + PHOSTROL (foliar spray) showed the highest total yield but this was only a trend as the data weren't statistically significant. It is also noteworthy that the seed piece inoculation protocol may not have been highly effective in 2013 either. This was the final year for this field trial so it was not repeated in 2014.

SEED PIECE TREATMENT STORAGE TRIALS

3-4 YEAR 1: 2013 SEED PIECE TREATMENT STORAGE TRIAL

PROJECT OBJECTIVES

1. To evaluate the relative efficacy of registered and experiment fungicides for fusarium dry rot control on potato seed pieces that were put in placed in storage for 1.5 months
2. The tubers used for Objectives 1 will be bruised and inoculated with *F. sambucinum* prior to treatment, to ensure significant disease pressure.

RESEARCH PROTOCOL

MATERIALS

Crop species	**Common name**	**Cultivar**
Solanum tuberosum	Potato	Niska
Disease species	**Common name**	**Source**
F. sambucinum	Fusarium dry rot (FDR)	CDC South Pathology Program: Potato isolates 12-1 and 12-2

Seed Treatments used:
MAXIM ® PSP fungicide (0.5% fludioxinol), SOLAN™ MZ (16% mancozeb), SENATOR ® PSP (10% thiophate-methyl), MAXIM ® Liquid PSP fungicide (40.3% fludioxinol), MAXIM ® MZ PSP fungicide (0.5% fludioxinol + 5.7% mancozeb), CRUISER MAXX POTATO EXTREME liquid fungicide/insecticide (difenconazole + fludioxinol + thiamethoxam), MAXIM ® D liquid suspension fungicide (difenconazole + fludioxinol), HeadsUp® Plant Protectant (49.65% saponin), PHOSTROL® (phosphorous acid), and finally EMESTO™ SILVER (9.35% penflufen + 1.68% prothioconazole).

METHODS

2013 was the first and only year where the potato piece seed treatments were evaluated in a short storage trial at the Crop Diversification Centre South in Brooks, AB and was conducted concurrently with the field trial. Seed of Dakota Pearl, a chipping potato cultivar, was provided by Old Dutch Foods and seed treatment products were provided by each sponsor. Seed was cut (70 to 85 g) and suberized prior to application of inoculum or treatments. As in the field trials done previously, on May 21, 2013, plates *of F. sambucinum* (isolates 12-1 and 12-2R) were harvested by adding 30ml of sterile water and using a sterile smear tool to loosen and detach the spores from the colonies. The same protocol was used to enumerate the spores, so that the inoculant contained $1x10^4$ spores/mL this time. This was prepared in a sufficient quantity to cover all seed pieces receiving inoculum (2 mL of inoculum/seed piece). This suspension was thus applied to10 tubers at a time, by shaking them in a 15 lb. (6.8 kg) poly bag containing 20 mL of inoculum except for except for Treatment 1 (untreated/uninoculated check). After inoculating the tubers, they were placed back into the plastic crates and these were set inside a 10°C 95% RH CES room until May 24.

They were removed from cold storage then and the fungicidal seed treatments were applied by, again shaking the tubers in each of them inside 15 lb. (6.8 kg) poly bags **(Table 1).** The seed pieces were placed into individually labeled plastic crates (1 crate/subplot with 25 tubers each) and were placed back into the 10°C CES room. Each month, interim fusarium dry rot evaluations were performed, by slicing each tuber in half with a sharp knife through one of the wounds; thus monitoring for internal disease progression only, so that the final disease evaluations could be completed at an optimum time when there were moderate dry rot levels present.

Disease Evaluations

Final fusarium dry rot disease severity (DS) evaluations took place ca. 49 days later from July 11-12, as moderate dry rot symptoms had developed by then. Again, the tubers were sliced in half and were visually examined for disease symptoms, receiving a DS rating based upon the following 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.

Data were then entered onto an MS Excel spreadsheet, where the average DS/subplot was calculated by using the following formula:

$DS_{average} = [(N_0 \times 0) + (N_1 \times 1) + (N_2 \times 2) + (N_3 \times 3) + (N_4 \times 4) + (N_5 \times 5)]/N_t$

where N_0 = the number of tubers with DS = 0, N_1 = no. with DS = 1, N_2 = no. with DS = 2, N_3 = no. with DS = 3, N_4 = no. with DS = 4, N_5 = no. with DS = 5, and N_t = total number of tubers examined /subplot.

Disease incidence (DI), the percentage of tubers with dry rot and the Index of Disease (ID) were also calculated/subplot. This last calculation used the following formula:

The Index of Disease score (ID) formula = DS*DI/500*100 and is reported as a percentage. This provided an accurate evaluation parameter based upon both the DS and DI levels.

Data for all ratings were summarized and analyzed using the ARM 8 update for this statistical software program by Gylling Data Management. Duncan's Multiple Range Test (DMRT) was utilized for means comparisons, where F-tests were statistically significant ($P \leq 0.05$). Bartlett's Test for Homogeneity of Variance was also used for all ANOVA calculations as well as data transformations (arcsine or square root). Detransformed means when needed are presented in Tables 2.

Table 1. Chemical treatments and checks used for a CDCS potato seed treatment trial that was planted in a field plot at the Crop Diversification Centre South, Brooks, Alberta in 2012.

Treatment number	Treatment name	Chemical application rates to seed pieces[1]	Treatment application methods to seed pieces
1	Uninoculated Check (water)	10 mL/kg	Wet shaking with 10mL tap water /kg seed
2	Inoculated check (water)	10 mL/kg	Wet shaking with 10mL tap water /kg seed
3	Maxim Powder PSP	5 g/kg	Dry shaking with 5 g of powder/kg seed
4	Solan MZ PSPT	5 g/kg	Dry shaking with 5 g of powder/kg seed
5	Senator PSPT	5 g/kg	Dry shaking with 5 g of powder/kg seed
6	Maxim Liquid PSP	0.052 mL/kg	Wet shaking with 10mL mixture /kg seed
7	Maxim MZ	5 g/kg	Dry shaking with 5 g of powder/kg seed
8	Cruiser Maxx Potato Extreme	0.2 mL/kg	Wet shaking with 10mL mixture /kg seed
9	Maxim D	0.75 mL/kg	Wet shaking with 10mL mixture /kg seed
10	Heads-Up (seed treatment) + Phostrol (foliar spray)	1g/L	Mix Heads-Up in 1L of water and apply by wet shaking, using 10 mL of mixture/kg of seed so that the germinating eyes are coated.
11	Heads-Up	1g/L	As above
12	Emesto Silver	0.2 ml/kg	Wet shaking with 10mL mixture /kg seed

[1]Manufacturers label application rates for postharvest disease control in potato storages.

RESULTS AND DISCUSSION

Table 2 and Figures 1-3: All data were very highly significant where P = 0.0001. The uninoculated and inoculated check both had extremely high FDR DS/DI levels at 3.9 / 99.47% (Treatment 1) and 3.87/ 98.99% (Treatment 2) but there must have been naturally occurring fusarium on the potatoes for both levels to be that high. However, SENATOR PSPT significantly lowered the amount of amount of dry rot on seed pieces treated with it, as the DS value was only 1.56 with 44.98% DI and just 14.2% ID. This was followed by EMESTO SILVER in a separate Duncan's grouping at 2.20 DS, 64.40% DI and 28.6% ID. The remaining treatments showed similar amounts of FDR as the checks did; in fact, both Heads-Up treatments had the highest amounts of dry rot on the seed pieces than any of the rest of them.

CONCLUSION

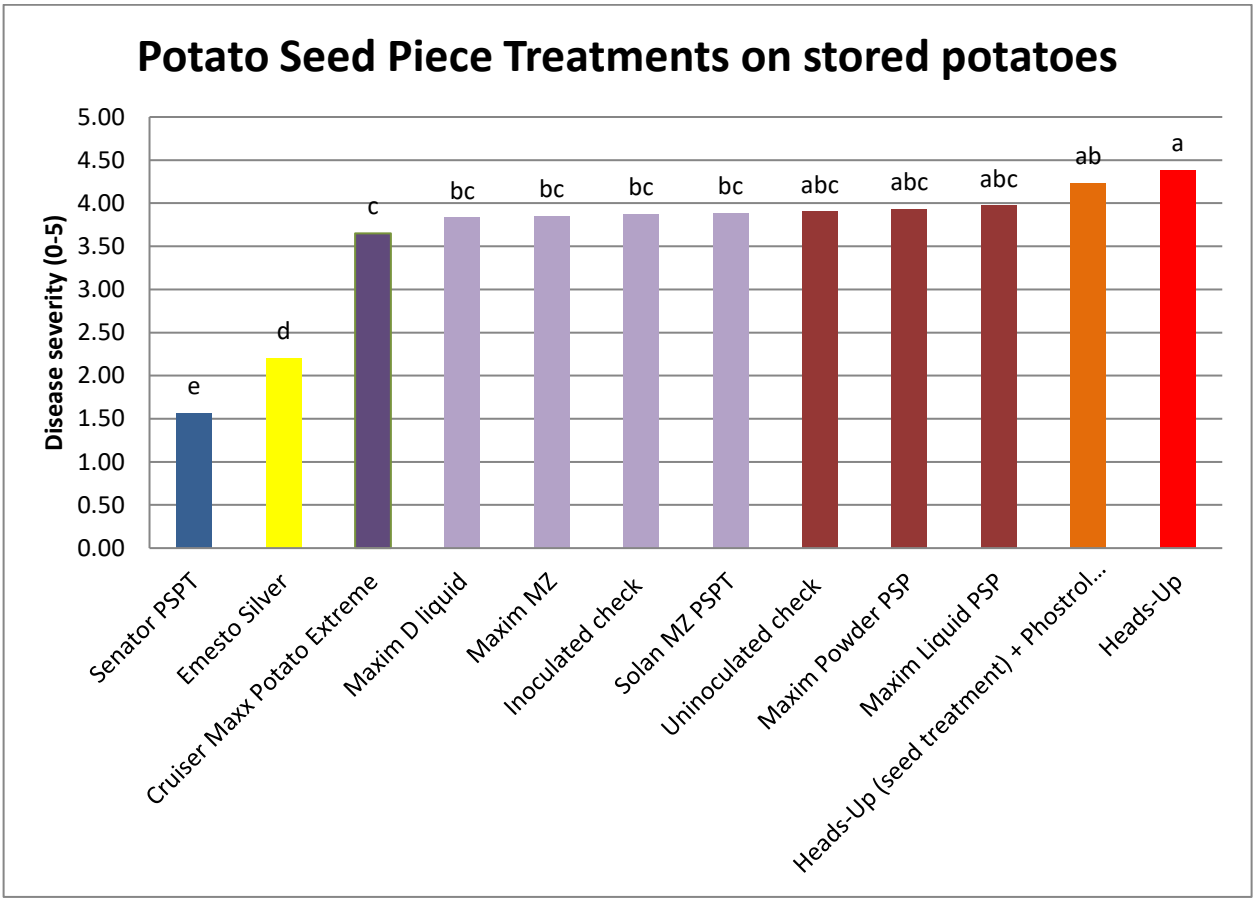
SENATOR PSPT and EMESTO SILVER both very significantly lowered dry rot on potato seed pieces that were stored at 10°C and 95% RH in a controlled environmental storage room for 49 days. This data may be helpful in situations where field planting has to be delayed.

Table 2. Potato seed piece treatment storage trial dry rot disease severity (DS), incidence (DI) and index of disease (ID) levels for Dakota Pearl (cv.) tuber ratings performed at the Crop Diversification Centre South at Brooks, Alberta in July, 2013.

Treatment number	Treatment name (*see Table 1 also*)	Dry rot DS (0-5)[1,2,5]	Dry rot DI (%)[1,3,6,7]	Dry rot ID score (%)[1,4,5]
1	Uninoculated check	3.90 abc	99.47 abc	76.5 bc
2	Inoculated check	3.87 bc	98.99 abc	75.9 bc
3	Maxim Powder PSP	3.93 abc	99.49 abc	77.2 bc
4	Solan MZ PSPT	3.88 bc	97.74 abc	75.3 bc
5	Senator PSPT	1.56 e	44.98 e	14.2 e
6	Maxim Liquid PSP	3.97 abc	99.49 abc	77.9 abc
7	Maxim MZ	3.85 bc	96.29 bc	73.2 c
8	Cruiser Maxx Potato Extreme	3.65 c	94.65 c	69.0 c
9	Maxim D liquid	3.83 bc	99.75 ab	75.9 bc
10	Heads-Up (seed treatment) + Phostrol (foliar spray)	4.23 ab	100.0 a	84.6 ab
11	Heads-Up	4.38 a	99.75 ab	86.7 a
12	Emesto Silver	2.20 d	64.40 d	28.6 d
ANOVA (P≤0.05)		0.0001	0.0001	0.0001
LSD (P=0.05)[5]		0.439	---	8.53
Coefficient of variation		8.44	7.75	10.47

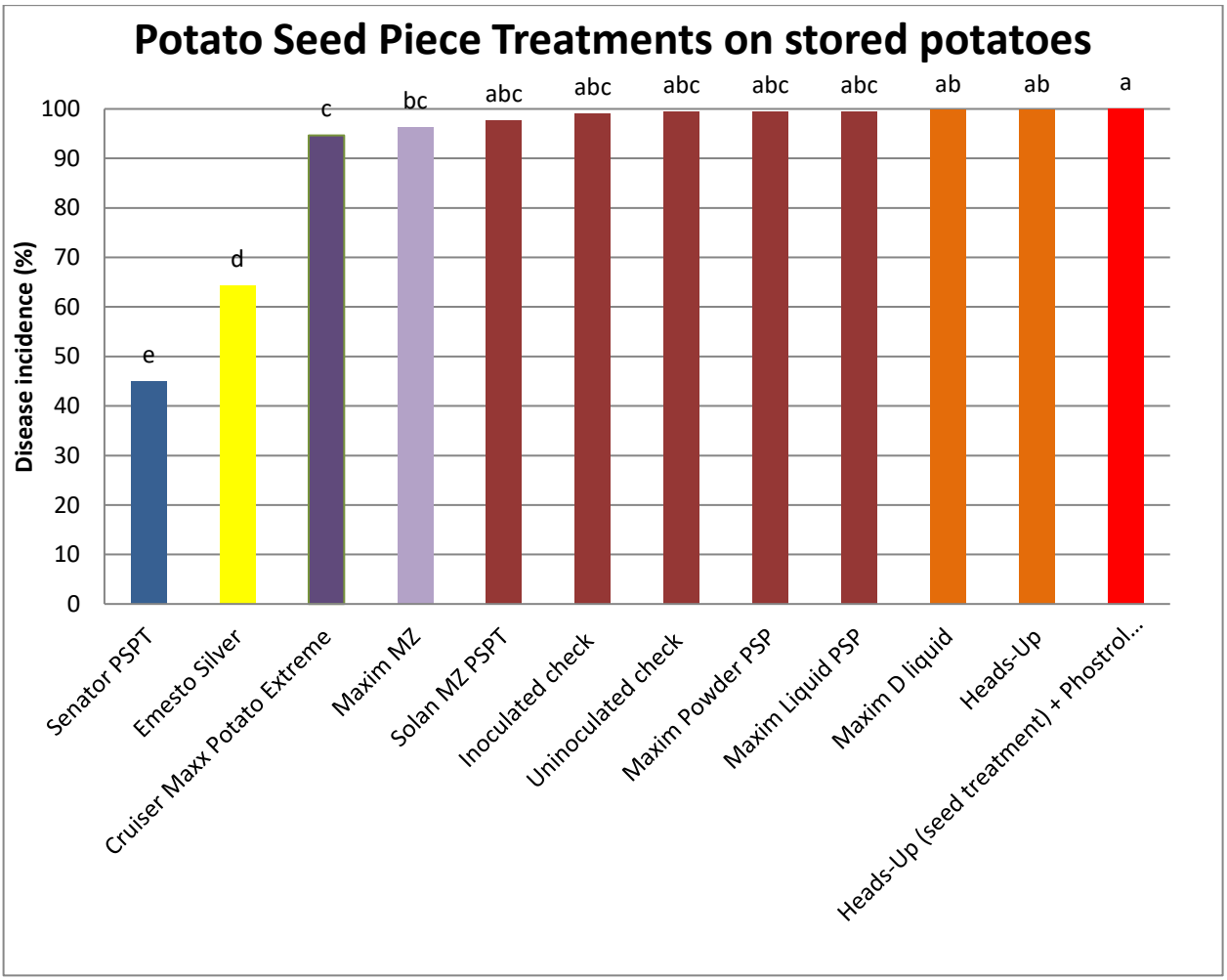
[1]Results are the means of four replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms.
[4]Index of disease score (ID) means are a calculation where DI * DS/500*100 = ID score (%).
[5]Raw data were used for analysis and were significantly different according to Duncan's Multiple Range test at P ≤ 0.05.
[6]Arcsine-transformed data were used for analysis and were significantly different according to Duncan's Multiple Range test at P ≤ 0.05.
[7]Least significant differences were not calculated for transformed data.

Figure 1. Dry rot disease severity (DS) rating levels, performed on stored seed pieces of Dakota Pearl (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in July 2013.



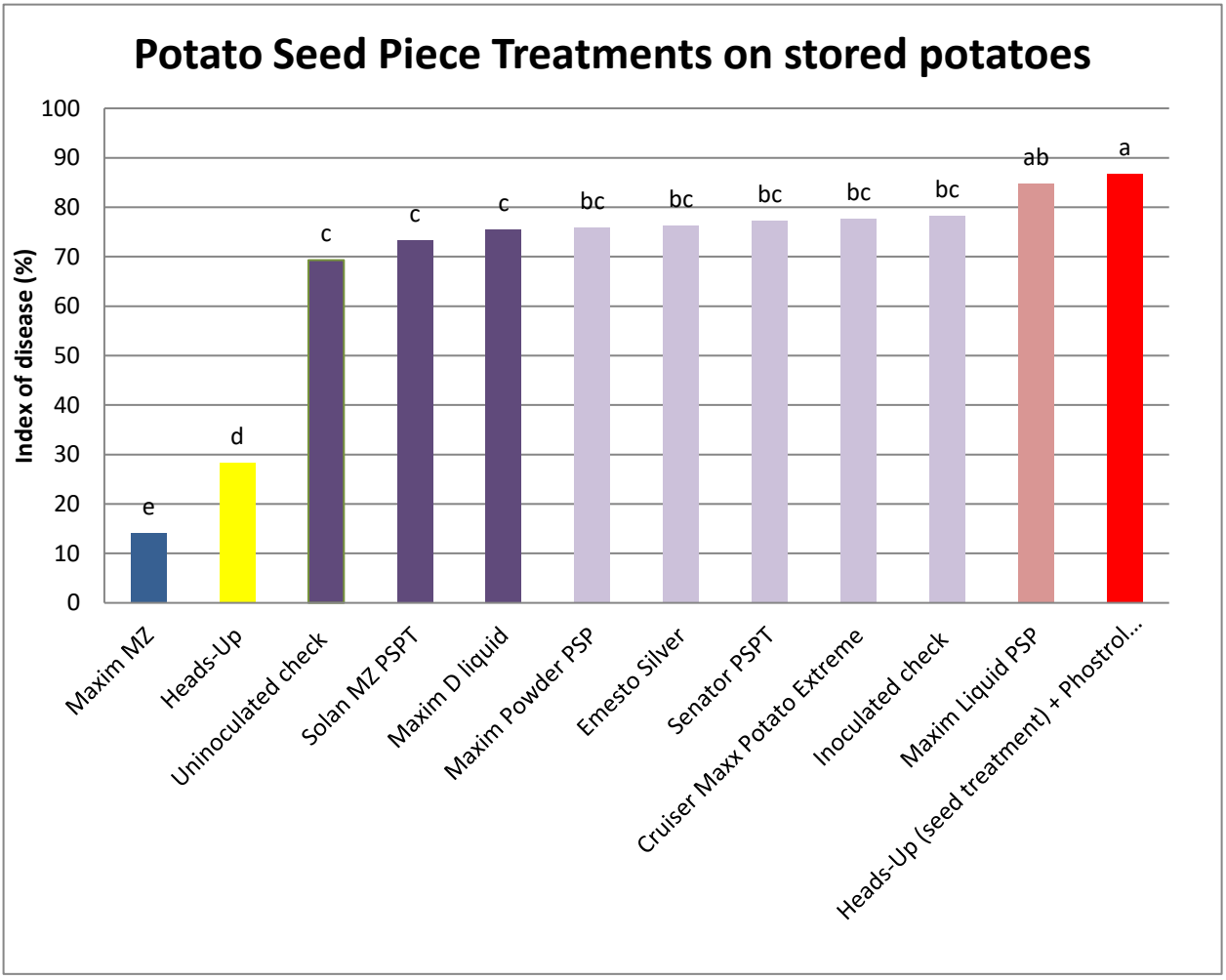
The navy blue, yellow, dark purple and red columns were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. purple and mahogany red). These columns are not statistically equivalent to navy blue, yellow, dark purple and red columns.

Figure 2. Dry rot disease incidence (DI) rating levels, performed on stored seed pieces of Dakota Pearl (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in July 2013.



The navy blue, yellow, dark purple and red columns were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. light purple, orange and mahogany red). These columns are not statistically equivalent to navy blue, yellow, dark purple and red columns.

Figure 3. Dry rot Index of Disease score (ID) rating levels, performed on stored seed pieces of Dakota Pearl (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in July 2013.



The navy blue, yellow, dark purple and red columns were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. light purple and dark pink) to the statistically unique letter grades(purple and red).

SECTION 4: POSTHARVEST FUNGICIDE EFFICACY TRIALS ON STORED POTATO

4-1 YEAR 1: 2011-12

PROJECT OBJECTIVES

1. To evaluate the relative efficacy of 11 registered and experiment fungicides, either alone or in combination, for fusarium dry rot control in stored potatoes.
2. The tubers will be bruised and inoculated with *F. sambucinum* prior to treatment, to ensure significant disease pressure.
3. Data generated by this trial will be used to refine current postharvest fungicide use patterns.
4. To supply data to fungicide companies and the PMRA to support new product registrations.

RESEARCH PROTOCOL

MATERIALS

MERTECT SC Fungicide (thiabendazole 500g/L), STOROX bactericide/fungicide (hydrogen peroxide), CONFINE (phosphorous acid), AGRESS® (oxysilver nitrate), SILVER PERIODATE®, BIO-SAVE® 10LP (*Pseudomonas syringae* Strain ESC-10), INSPRIRE® 250SC (difenconazole), SCHOLAR® 230SC fungicide (fludioxinol), QUADRIS® 250SC (azoxystrobin), STADIUM (Syngenta Canada Inc. experiment product No. A19432: difenconazole + fludioxinol + azoxystrobin combination) and finally, PHOSTROL® (phosphorous acid).

METHODS

In late April 2012 at CDC South, two *F. sambucinum* subcultures, one that was thiabendazole-resistant and the other thiabendazole–sensitive were further subcultured onto 15 potato dextrose agar (PDA) plates each. These cultures were grown under natural lighting at RT for ca. 7 days, until they sporulated. These were used for inoculating the tubers in May.

Also, tubers from two potato cultivars, Niska (Trial 1) and Russet Burbank (Trial 2) were placed into a CES unit set at 5°C and 93% RH. Each trial had 11 chemical treatments plus two checks (Table 1) with four replications. On May 1, 110 tubers/trial treatment were enumerated into groups of 25 tubers/subplot. This also included ten additional tubers as extras. An identical randomized complete block (RCB) plot design was prepared per trial, using the Agricultural Research Manager Version 7 computer software program (ARM 7) by Gylling Data Management, Inc., Brookings, SD, USA.

All of the tubers were bruised and cut by a small electric cement mixer, useful for simulating harvesting conditions. They were then were placed back into the same refrigerated storage overnight. On May 2, the *F. sambucinum* tuber inoculum was prepared by emulsifying one plate from each of the two subculture types, with 10 mL of sterile RO water and then scraping these contents into two small sterile beakers. The conidia from each were then enumerated under a compound microscope. From this count, a dilution of each isolate was prepared in reverse osmosis (RO) water to equal $1x10^4$ conidia/mL so that when these two equal volumes were combined, each tuber would receive 2 mL of fusarium inoculum. All treatments, except for Treatment 13 (untreated/uninoculated check), were placed 10 at a time into a 15 lb. (6.8 kg) poly bag that contained 20 mL of inoculum. After inoculating the tubers, they were placed back into the plastic crates and these were set inside a 10°C 95% RH CES room until the following day.

On May 3, the tubers from each trial treatment were placed onto a moving conveyor belt system, with a two-nozzle, CO_2-propelled spray boom, positioned over a chute at the end of it. As the tubers

reached the end of this, they were therefore tumbled through the spray stream of their respective treatments at the predefined experimental rates (**Table 1**), thoroughly coating the potatoes on all sides. Equipment was scrupulously cleaned with tap water prior to the next treatment application. After treating them, the tubers were placed into individually labeled plastic crates (1 crate/subplot with 25 tubers each) and were placed back into the 10°C CES room. Each month, interim fusarium dry rot (FDR) evaluations were performed, by slicing each tuber in half with a sharp knife through one of the wounds; thus monitoring for internal disease progression only, so that the final disease evaluations could be completed at an optimum time when there were moderate dry rot levels present.

Trial 1 – Niska Disease Evaluations

Final FDR disease severity (DS) evaluations took place from July 26-31, 2012, as moderate dry rot symptoms had developed by then. Again, the tubers were sliced in half and were visually examined for disease symptoms, receiving a DS rating based upon the following 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.

Data were then entered onto an MS Excel spreadsheet, where the average DS/subplot was calculated by using the following formula:

$$DS_{average} = [(N_0 \times 0) + (N_1 \times 1) + (N_2 \times 2) + (N_3 \times 3) + (N_4 \times 4) + (N_5 \times 5)]/N_t$$

where N_0 = the number of tubers with DS = 0, N_1 = no. with DS = 1, N_2 = no. with DS = 2, N_3 = no. with DS = 3, N_4 = no. with DS = 4, N_5 = no. with DS = 5, and N_t = total number of tubers examined /subplot.

Disease incidence (DI), the percentage of tubers with dry rot and the Index of Disease (ID) were also calculated/subplot. This last calculation used the following formula:

The Index of Disease score (ID) formula = DS*DI/500*100 and is reported as a percentage. This provided an accurate evaluation parameter based upon both the DS and DI levels.

Data for all ratings were summarized and analyzed using the ARM 7, and later the ARM 8 update for this statistical software program by Gylling Data Management. Duncan's Multiple Range Test (DMRT) was utilized for means comparisons, where F-tests were statistically significant ($P \leq 0.05$). Bartlett's Test for Homogeneity of Variance was also used for all ANOVA calculations as well as data transformations (arcsine or square root). Detransformed means when needed are presented in Tables 2.

Trial 2 – Russet Burbank Disease Evaluations

The final fusarium dry rot disease ratings for the Russet Burbank potatoes were performed from July 31 to August 3, using the same ratings protocol as for Trial 1 above and the data are presented in Table 3.RESULTS AND DISCUSSION

Trial 1- Niska cv. Results (Table 2 and Figures 1 – 3)

DS, DI and ID data were all very highly statistically significant ($p \leq 0.05$). Overall, the best-performing fungicide was the Treatment 8 tank mixture composed of INSPIRE, SCHOLAR and QUADRIS, which only had a DS of 1.19, DI of 44.93% and ID of 11.26%. This was significantly more effective than MERTECT SC (Treatment 1) for disease severity with a DS of 2.07 but the latter treatment had a DI of 50.34% and ID of 21.45% so was in the same Duncan's grouping for those two parameters only. MERTECT SC has been the industry standard for potato postharvest storages for many years but *F. sambucinum* especially has become increasingly resistant to this fungicide; therefore dry rot disease levels become higher over time.

However, for the DS results (**Table 1 and Figure 1**), five other treatments were in a similar ANOVA grouping as the tank mixture, so ranging from lowest to highest disease levels, they were: STOROX, STADIUM (60% application rate), STADIUM (full application rate), PHOSTROL and AGRESS. MERTECT SC and the untreated, uninoculated check (Treatment 13) were in the same ANOVA grouping as the untreated, inoculated check. After reviewing the DI results (**Table 2** and **Figure 2**), again the very lowest dry rot levels, 44.93%, were found with the Treatment 8 tank mixture; however, all of the treatments, except for CONFINE (64.93% DI) and BIO-SAVE® 10LP (83.81% DI), were statistically similar to it. These last two treatments had even more FDR than the untreated, inoculated check meaning that naturally-occurring dry rot was in in the stored potatoes. Using the dry rot ID ratings parameter (**Table 3 and Figure 3**), the Treatment 8 tank mixture had the lowest FDR at 11.26%; however, STADIUM – 60% rate, STOROX, AGRESS, PHOSTROL, STADIUM – full rate, SILVER PERIODATE and MERTECT were in a similar Duncan's grouping.

Trial 2- Russet Burbank cv. Results (Table 3 and Figures 4 – 6)

After similarly rating the R. Burbank stored tubers for FDR DS, DI and ID, again all data were very highly significant ($p \leq 0.05$). With this cultivar though for the DS levels, the two STADIUM application rates (Treatments 9 and 10) were the best-performing postharvest fungicides and were significantly lower than the remaining treatments. This chemical, applied at the full rate to the potatoes (Treatment 9) showed a DS level of just 0.75 (0-5 points) closely followed by the 60% rate (Treatment 10) at 1.20. STADIUM – full rate also proved to have nearly 60% less dry rot than MERTECT SC and nearly 80% less than the untreated inoculated check. INSPIRE also performed well as it was in the same statistical grouping as STADIUM – 60% rate. The DI% data were also very promising, as the STADIUM-treated tubers (full rate: Treatment 9) had nearly half the dry rot (28%), as MERTECT SC (53%) and ca. two-thirds less than the untreated inoculated check, Treatment 12 (77.83%). Only STADIUM at the 60% application rate (44% DI) and INSPIRE (40% DI) were in the same lowest ANOVA grouping as this treatment.

A similar pattern was expressed ID scores, with STADIUM - full rate (Treatment 9) having just 4.22%, demonstrating ca. 90% less dry rot than the two checks having the most FDR (53.16% and 47.42% ID). This was the only treatment that showed statistically less FDR than MERTECT SC (21.83%). However, STADIUM - 60% application rate (Treatment 10) with an ID of 10.56%, was the only fungicide in the same Duncan's grouping as STADIUM – full rate.

CONCLUSIONS

Trial 1 – Niska (cv.):

After evaluating this trial, the tank mixture of INSPIRE, SCHOLAR and QUADRIS (Treatment 8) proved to be the most effective treatment and a possible alternative to using MERTECT in postharvest potato storages. Other possibilities may be STADIUM premixed (both at the label rate and 60%), STOROX, PHOSTROL and AGRESS.

Trial 2 - Russet Burbank (cv.):

Overall, this trial suggested that STADIUM (premixed combination of INSPIRE, SCHOLAR and QUADRIS; applied at the either the full rate or at 60%), may be very beneficial as a potential MERTECT SC replacement, as it demonstrated significantly < FDR than this industry standard.

Table 1. Chemical treatments and checks used for both Trials 1 and 2 for a CDCS postharvest potato storage experiment that was performed at Brooks, Alberta in 2012.

Treatment number	Treatment name	Chemical application rates[1]
1	Mertect SC Fungicide	7.5 L Mertect per 170 L of water
2	Storox	100 mL StorOx per 10 L of water (1:100)
3	Confine	100 mL Confine per 0.43 L of water (1:4.3)
4	Agress	N/A (experimental product)
5	Silver Periodate	N/A (experimental product)
6	Bio-Save(R) 10LP	500 g of Bio-Save per 100 L of water
7	Inspire	44 mL Inspire 250SC in 210 mL water
8	Tank mix #1: Inspire + Scholar + Quadris	1.44 mL Inspire 250SC + 2 mL Scholar 230SC + 2 mL Quadris 250SC in 210 mL water
9	Premix #1: Stadium A19432A (full rate)	3.3 mL A19432A in 210 mL water
10	Premix #2: Stadium A19432A (60% rate)	2.0 mL A19432A in 210 mL water
11	Phostrol	0.42 L in 2L water
12	Untreated check (inoculated)	N/A
13	Untreated check (non-inoculated)	N/A

[1]Manufacturers label application rates for postharvest disease control in potato storages.

Table 2. Trial 1 fusarium dry rot disease severity (DS), incidence (DI) and index of disease (ID) levels for postharvest Niska (cv.) tuber ratings performed at the Crop Diversification Centre South at Brooks, Alberta in July, 2012.

Treatment number	Treatment name (*see Table 1 also*)	Dry rot DS (0-5)[1,2,6]	Dry rot DI (%)[1,3,6]	Dry rot ID score (%)[1,4,7]
1	Mertect SC	2.07 b-e	50.34 bc	21.45 bcd
2	Storox	1.65 ef	50.22 bc	17.82 cd
3	Confine	2.61 bcd	64.93 ab	34.02 bc
4	Agress	1.90 def	46.76 bc	17.89 cd
5	Silver Periodate	1.96 cde	54.36 bc	21.36 bcd
6	Bio-Save(R) 10LP	3.99 a	83.81 a	69.42 a
7	Inspire	2.80 bc	63.76 abc	38.36 b
8	Tank mix #1: Inspire + Scholar + Quadris	1.19 f	44.93 c	11.26 d
9	Premix #1: Stadium A19432A (full rate)	1.83 def	50.99 bc	18.64 cd
10	Premix #2: Stadium A19432A (60% rate)	1.73 ef	45.82 bc	15.94 cd
11	Phostrol	1.83 def	49.14 bc	18.57 cd
12	Untreated check (inoculated)	2.91 b	63.23 abc	38.56 b
13	Untreated check (uninoculated)	2.40 b-e	61.83 bc	30.29 bc
ANOVA (P≤0.05)		0.0001	0.0030	0.0001
LSD (P=0.05)[5]		---	---	---
Coefficient of variation		9.69	10.35	25.02

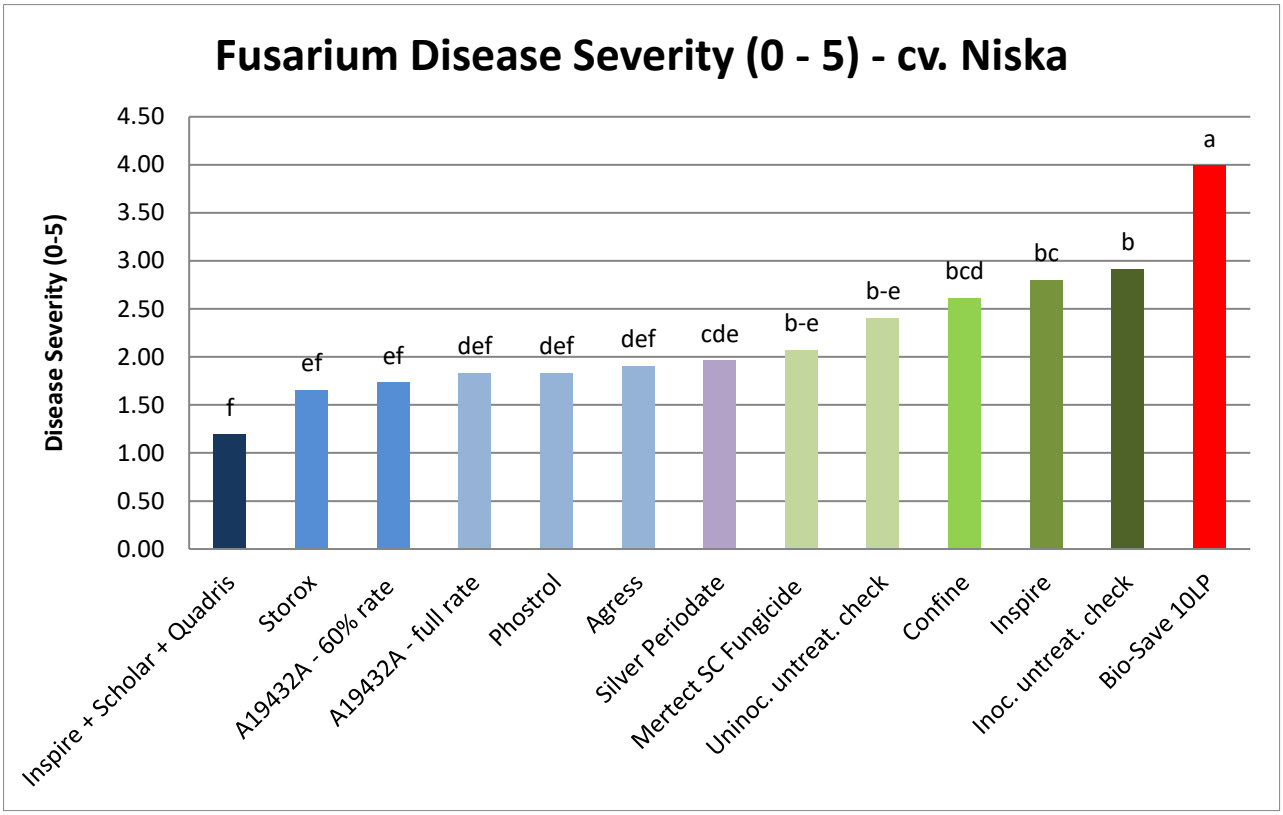
[1]Results are the means of four replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms.
[4]Index of disease score (ID) means are a calculation where DI * DS/500*100 = ID score (%).
[5]Least significant differences were not calculated for transformed data.
[6]Square root-transformed data were used for analysis and were significantly different according to Duncan's Multiple Range test at P ≤ 0.05.
[7]Arcsine-transformed data were used for analysis and were significantly different according to Duncan's Multiple Range test at P ≤ 0.05.

Table 3. Fusarium dry rot disease severity (DS, incidence (DI) and index of disease (ID) levels for postharvest R. Burbank (cv.) tuber ratings performed at the Crop Diversification Centre South at Brooks, Alberta in August, 2012.

Treatment number	Treatment name (*see Table 1 also*)	Dry rot DS (0-5)[1,2,6]	Dry rot DI (%)[1,3,7]	Dry rot ID score (%)[1,4,6]
1	Mertect SC	2.07 cd	53.00 bc	21.83 bcd
2	Storox	2.59 abc	60.00 ab	31.07 ab
3	Confine	2.35 bcd	55.00 bc	25.85 bc
4	Agress	2.64 abc	61.00 ab	32.17 ab
5	Silver Periodate	2.75 abc	62.00 ab	34.10 ab
6	Bio-Save(R) 10LP	2.86 abc	62.00 ab	35.49 ab
7	Inspire	1.75 de	40.00 cd	13.99 cd
8	Tank mix #1: Inspire + Scholar + Quadris	2.72 abc	62.00 ab	33.69 ab
9	Premix #1: Stadium A19432A (full rate)	0.75 f	28.00 d	4.22 e
10	Premix #2: Stadium A19432A (60% rate)	1.20 ef	44.00 bcd	10.56 de
11	Phostrol	2.04 cd	48.00 bc	19.56 bcd
12	Untreated check (inoculated)	3.42 a	77.83 a	53.16 a
13	Untreated check (uninoculated)	3.12 ab	76.23 a	47.42 a
ANOVA (P≤0.05)		0.0001	0.0001	0.0001
LSD (P=0.05)[5]		22.45	16.31	---
Coefficient of variation		9.01	20.35	20.29

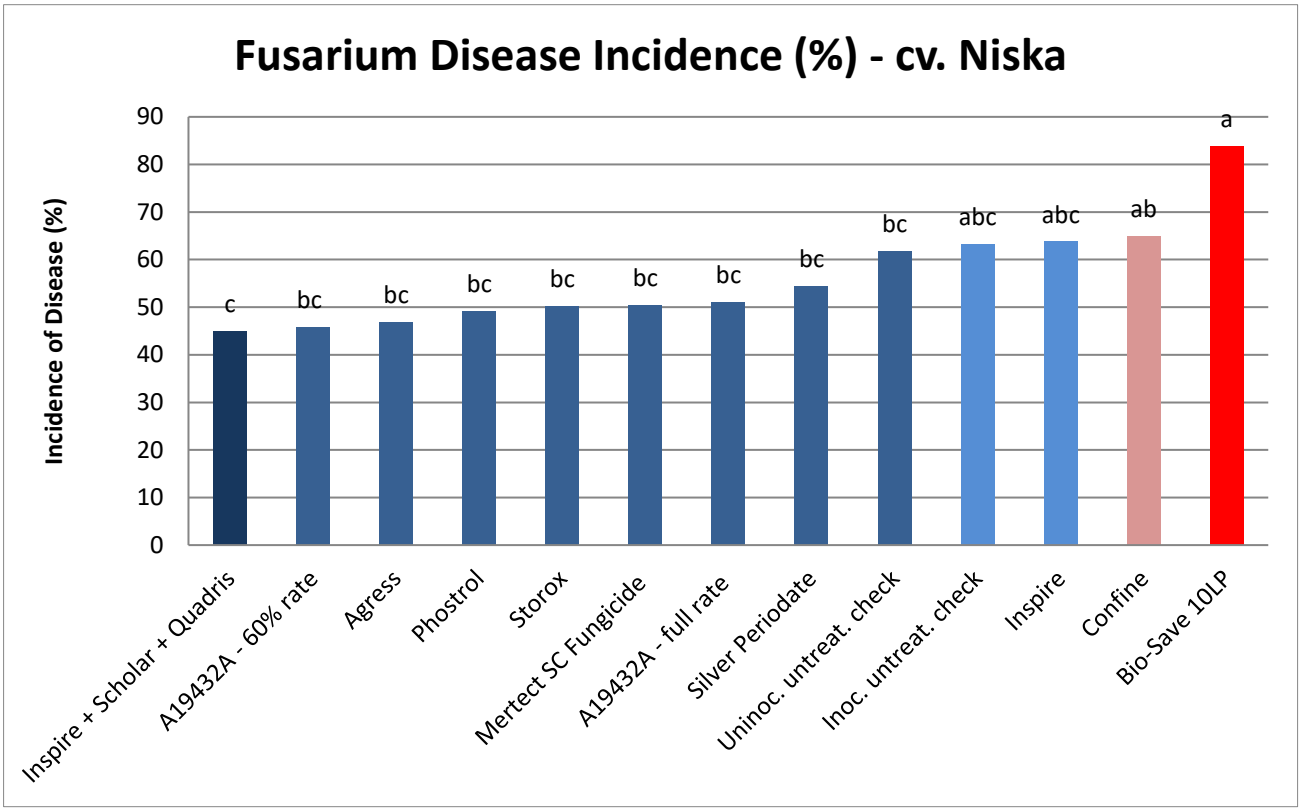
[1]Results are the means of four replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms.
[4]Index of disease score (ID) means are a calculation where DI * DS/500*100 = ID score (%).
[5]Least significant differences were not calculated for transformed data.
[7]Raw data were used for analysis were used for analysis and were significantly different according to Duncan's Multiple Range test at P ≤ 0.05.
[6]Square root-transformed data were used for analysis and were significantly different according to Duncan's Multiple Range test at P ≤ 0.05.

Figure 1. Trial 1 dry rot disease severity (DS) rating levels, performed on postharvest Niska (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in August, 2012.



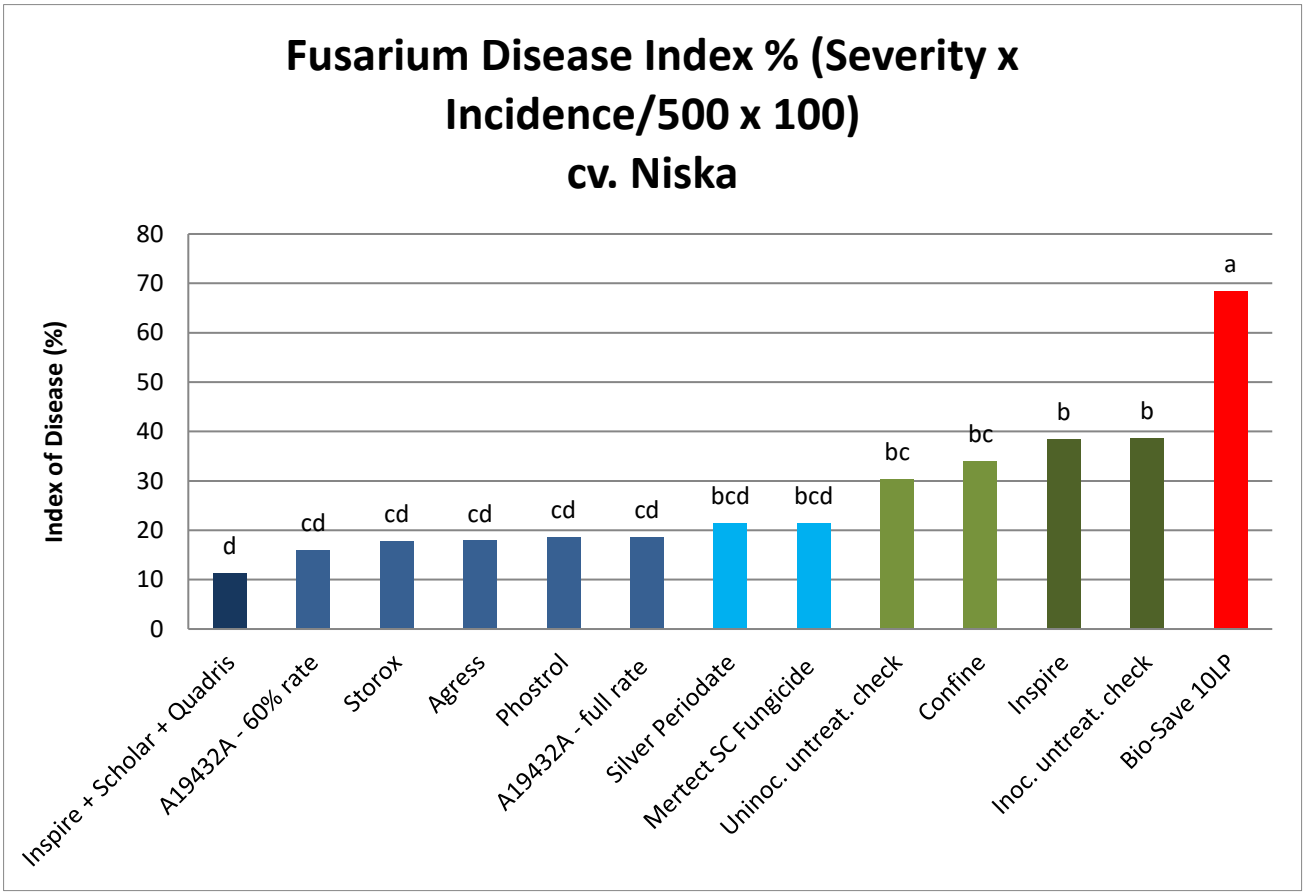
The navy blue, dark green and red colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. medium blue, light blue, olive green, bright green and light green). The purple column was not statistically equivalent to the red, green and blue columns.

Figure 2. Trial 1 dry rot disease incidence (DI) rating levels, performed on postharvest Niska (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in August, 2012



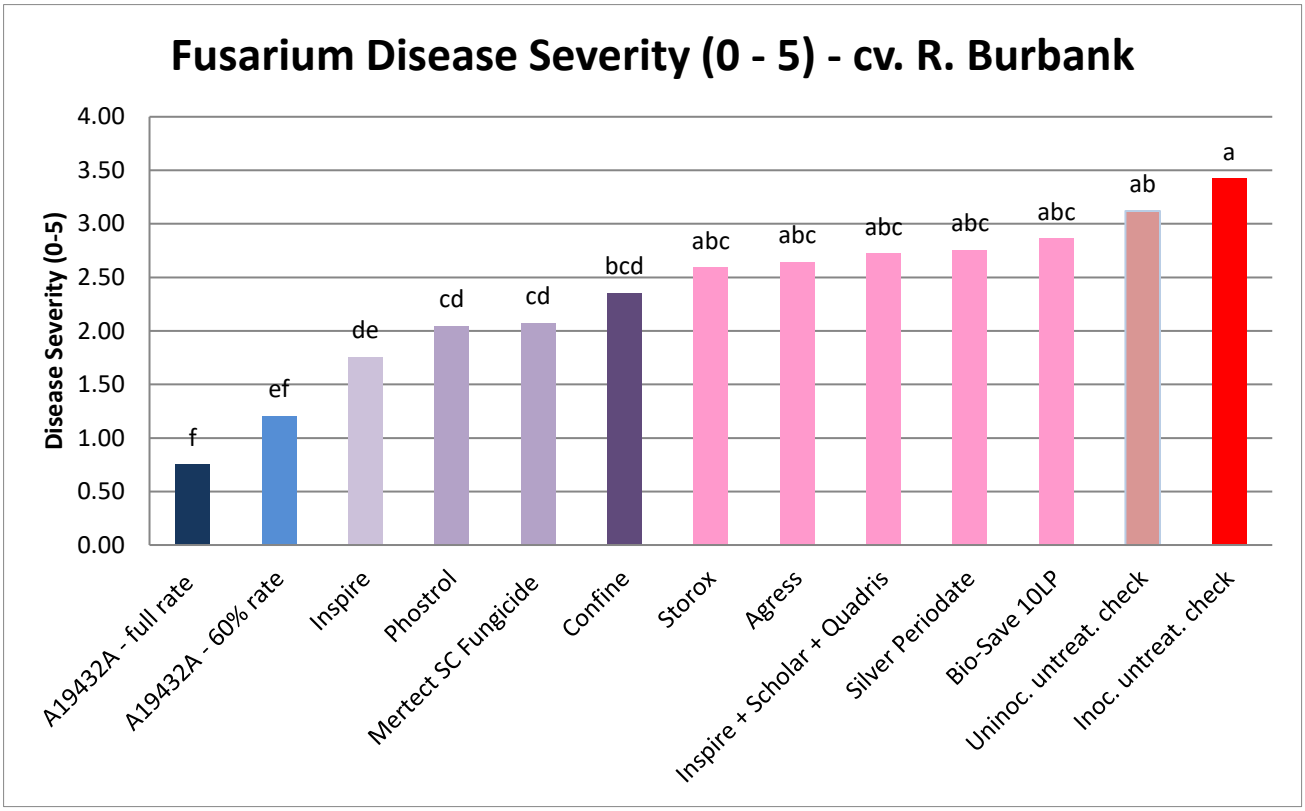
The navy blue and red colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. pink or blue and light blue).

Figure 3. Trial 1 Index of Disease (ID) rating levels, performed on postharvest Niska (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in August, 2012



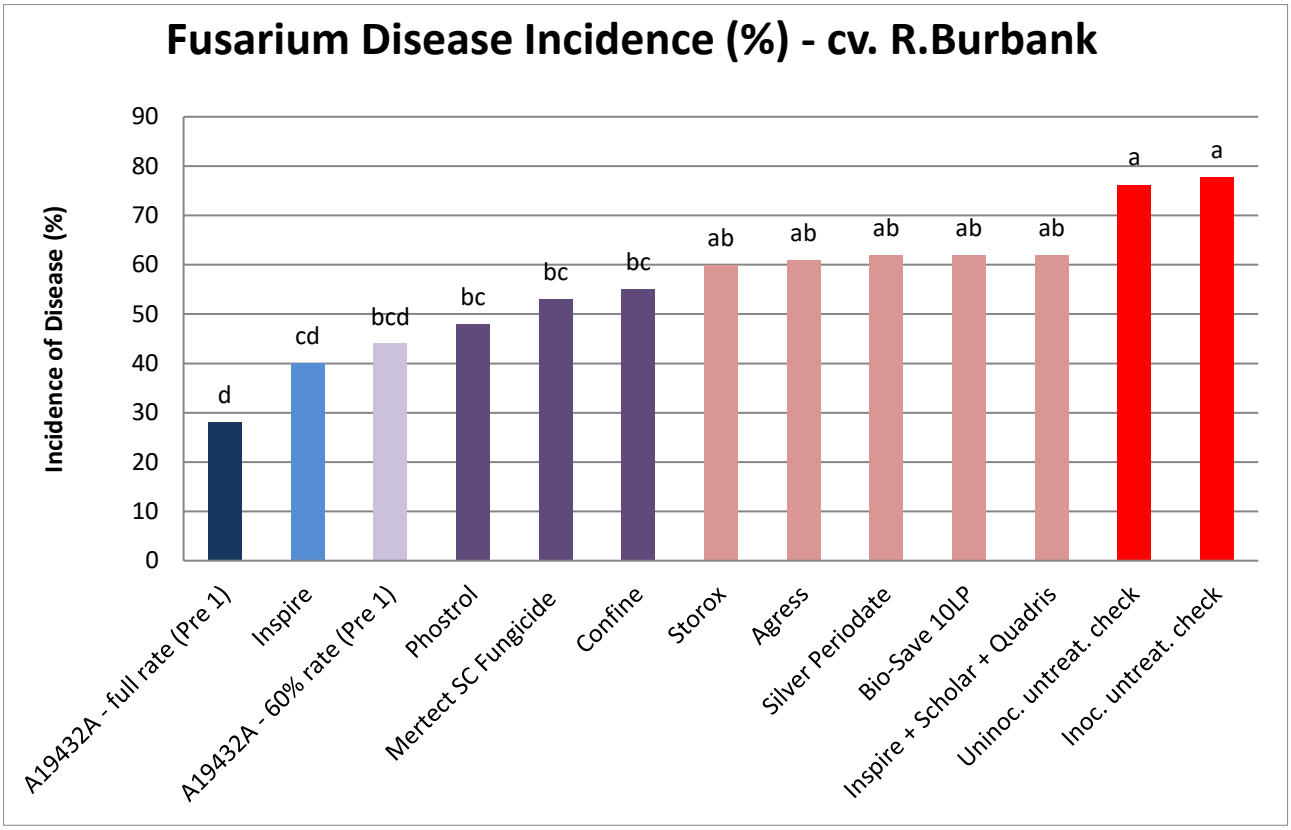
The navy blue, dark green and red colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. dark blue, turquoise and medium green).

Figure 4. Trial 2 dry rot disease severity (DS) rating levels performed on postharvest R. Burbank (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in August, 2012.



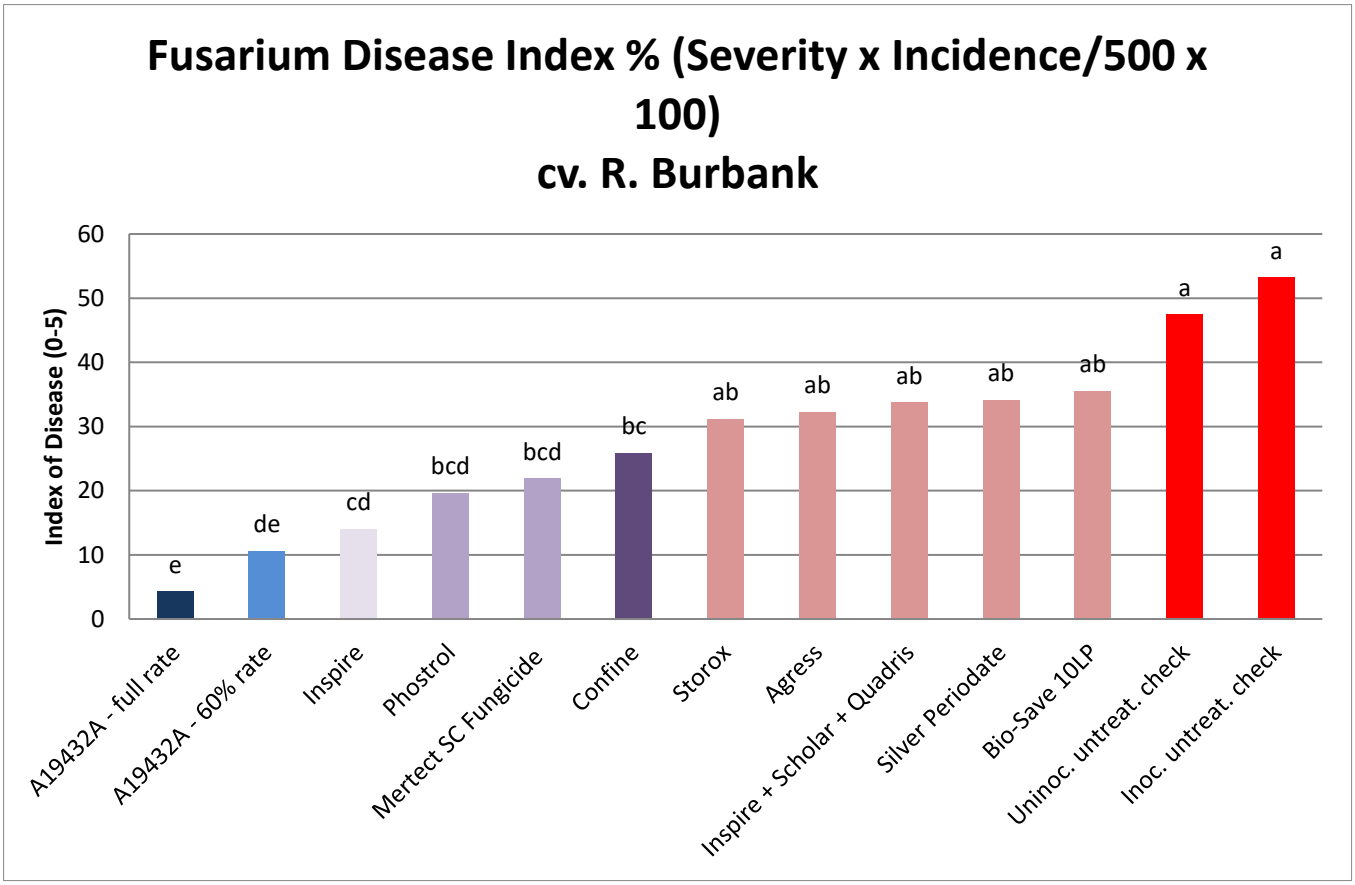
The navy blue and red colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. dark pink or bright pink or medium blue). Purple columns are not statistically equivalent to either red or blue.

Figure 5. Trial 2 dry rot disease incidence (DI) rating levels, performed on postharvest R. Burbank (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in August, 2012.



The navy blue and red colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. dark pink or medium blue). Purple columns are not statistically equivalent to either red or blue.

Figure 6. Trial 2 Index of Disease (ID) rating levels, performed on postharvest R. Burbank (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in August, 2012.



The navy blue and red colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. pink or medium blue). Purple columns are not statistically equivalent to either red or blue.

4-2 YEAR 1: 2011 – Prince Edward Island

PROJECT OBJECTIVES

The same objectives as in Alberta were reached in this trial to evaluate the relative efficacy of 10 registered and experiment fungicides, either alone or in combination, for fusarium dry rot (FDR) control in stored potatoes.

RESEARCH PROTOCOL

MATERIALS

MERTECT SC Fungicide (thiabendazole 500g/L), STOROX bactericide/fungicide (hydrogen peroxide), CONFINE (phosphorous acid), AGRESS® (oxysilver nitrate), SILVER PERIODATE®, BIO-SAVE® 10LP (*Pseudomonas syringae* Strain ESC-10), INSPRIRE® 250SC (difenconazole), SCHOLAR® 230SC fungicide (fludioxinol), QUADRIS® 250SC (azoxystrobin) and finally, STADIUM (Syngenta Canada Inc. experiment product No. A19432: difenconazole + fludioxinol + azoxystrobin combination)

METHODS

In 2011, at the Harrington Research Farm of Agriculture and Agri-Food Canada, Charlottetown, PEI, Yukon Gold and Russet Burbank tubers that were grown there, were used for two trials. Each trial was designed as a randomized complete block with four replications and each experimental unit (subplot) consisted of plastic, ventilated crates each containing 25 tubers that were clean, air-dried and visibly free of disease or blemishes.

Tubers were inoculated with a local, fungicide-resistant (resistant to fludioxonil and thiabendazole/thiophanate-methyl) isolate of *Fusarium sambucinum*, as a spore suspension ($1x10^4$ conidia/mL). The tubers were wounded with a scoring tool to simulate post-harvest handling wounds prior to inoculation with a very similar inoculation methodology as used in Alberta. After inoculation, the tubers were incubated overnight at room temperature.

The chemicals applications were sprayed on the tubers the following day (volume of 210 mL/100 kg per treatment) by arranging the tubers on a flat surface and half of each fungicide solution was applied to one side of them and they were allowed to dry. They were then turned over, with the remainder chemical sprayed on them. After treatment, tubers were stored for 2-3 months (depending on disease progression in the controls) at 5°C and 95% RH (Yukon Gold) or at 10°C and 95% RH (Russet Burbank). Temperatures differed due to the storage requirements of tablestock (Yukon Gold) and processing (Russet Burbank) potatoes. Each trial was completed in a separate storage facility.

Trial 1 – Yukon Gold Disease Evaluations

After 2-3 months of storage, individual tubers were assessed for percent of tuber surface covered with fusarium dry rot lesions (disease severity – DS%), as well as the incidence of disease (percent infected tubers – DI%). Also, tubers were cut longitudinally from the point of wounding and pathogen penetration into internal tuber tissues causing visible necrosis was measured using Vernier callipers (in mm).

Data was analyzed by analysis of variance (ANOVA) and when a significant treatment effect is found, means were compared with a protected test of least significant difference ($P<0.05$). Where necessary for normalization, data were transformed (log[x+1]) prior to analysis of variance.

At the Crop Diversification Centre South on October 20, 2015, the MS Excel data from this trial were analyzed again by using the ARM 7 statistical software programs. Duncan's Multiple Range Test (DMRT) was utilized for means comparisons, where F-tests were statistically significant ($P \leq 0.05$).

Bartlett's Test for Homogeneity of Variance was also used for all ANOVA calculations, as well as data transformations (arcsine or square root). Detransformed means as needed are presented in Table 2.

Trial 2 – Russet Burbank Disease Evaluations

Similarly, the Russet Burbank potatoes were rated by using the same evaluation protocol as per Trial 1, with the data is presented in Table 3.

RESULTS AND CONCLUSIONS

Trial 1- Yukon Gold cv. Results (Table 2)

All tubers developed FDR, so the DI% then was 100% for all treatments; therefore this statistical analysis was not performed. Both the DS% and the depth of FDR tuber penetration (mm) results failed the Bartlett's Test of Homogeneity, so even though the data were statistically significant, the Duncan's grouping could not be reported. However trends from both of these rating parameters suggested that INSPIRE, INSPIRE + SCHOLAR + QUADRIS, STADIUM (full rate) and STADIUM (60% rate) may be beneficial for dry rot prevention in stored potatoes if fusarium infested them. The untreated, uninoculated check had very low results too, meaning that there was very little naturally-occurring fusarium on them prior to the experiment. Conversely, the inoculated, untreated check had results that were ca. 4x as high, which meant that the inoculum worked very well.

Trial 2- Russet Burbank cv. Results (Table 3)

After rating the R. Burbank stored tubers for fusarium dry rot DS%, this data were very highly significant ($p \leq 0.05$). This proved that the INSPIRE + SCHOLAR + QUADRIS, STADIUM (full rate) and STADIUM (60% rate) treatments had significantly lower FDR than the untreated, inoculated check, so these are very promising fungicides, even when fusarium is present on the tuber skins. Again, the untreated, uninoculated check was in the same Duncan's grouping as them and the untreated, inoculated check had ca. twice as much disease as the best treatments. FDR infested 100% of the potatoes so data analyses for DI% weren't done. The depth of FDR tuber penetration (mm) results failed the Bartlett's Test of Homogeneity, so even though the data were statistically significant, the Duncan's grouping could not be reported. However, trends suggested that the four best-performing treatments (in DS%) also may prevent FDR from penetrating into the potatoes.

CONCLUSIONS

Trial 1 – Yukon Gold (cv.):

Unfortunately, statistical significance couldn't be reported and as stated in the *Results* section, trends only suggested that INSPIRE, INSPIRE + SCHOLAR + QUADRIS, STADIUM (full rate) and STADIUM (60% rate) may be beneficial for dry rot prevention in stored potatoes - if fusarium infested them. This experiment, however, will be repeated in 2012 and 2013 to verify this finding. Incidentally, the fusarium inoculum also appeared to work very well in Year 1.

Trial 2- Russet Burbank (cv.)

Overall, this trial showed that INSPIRE + SCHOLAR + QUADRIS, STADIUM (full rate) and STADIUM (60% rate) treatments were very promising for reducing FDR, when compared with the wounded, untreated, inoculated check, the industry standard, Mertect SC and the other six fungicides under test. However, two additional years of research are definitely needed to finalize the most effective treatments against fusarium dry rot

Table 1. Chemical treatments and checks used for both Trials 1 and 2 for an AAFC potato storage experiment that was performed at Charlottetown, PEI in 2011.

Treatment number	Treatment name	Chemical application rates[1]
1	Mertect SC Fungicide	7.5 L Mertect per 170 L of water
2	Storox	100 mL StorOx per 10 L of water (1:100)
3	Confine	100 mL Confine per 0.43 L of water (1:4.3)
4	Agress	N/A (experimental product)
5	Silver Periodate	N/A (experimental product)
6	Bio-Save(R) 10LP	500 g of Bio-Save per 100 L of water
7	Inspire	44 mL Inspire 250SC in 210 mL water
8	Tank Mix 1: Inspire + Scholar + Quadris	1.44 mL Inspire 250SC + 2 mL Scholar 230SC + 2 mL Quadris 250SC in 210 mL water
9	Tank Mix 2: Stadium A19432A (full rate)	3.3 mL A19432A in 210 mL water
10	Tank Mix 3: Stadium A19432A (60% rate)	2.0 mL A19432A in 210 mL water
11	Untreated check (inoculated)	N/A
12	Untreated check (non-inoculated)	N/A

[1]Manufacturers label application rates for postharvest disease control in potato storages.

Table 2. Trial 1 fusarium dry rot disease severity (DS) and incidence (DI) and index of disease (ID) levels for postharvest Yukon Gold (cv.) tuber ratings performed at AAFC, Charlottetown, PEI Brooks, Alberta in 2011.

Treatment number	Treatment name (*see Table 1 also*)	Dry rot DS (%)[1,2,6,7]	Dry rot DI (%)[1,3]	Depth of FDR penetration in tuber (mm)[1,4,6,7]
1	Mertect SC Fungicide	17.48	100	13.34
2	Storox	19.26	100	16.20
3	Confine	26.55	100	18.00
4	Agress	12.97	100	9.53
5	Silver Periodate	16.29	100	12.03
6	Bio-Save(R) 10LP	13.26	100	9.99
7	Inspire	6.90	100	2.68
8	Tank Mix 1: Inspire + Scholar + Quadris	5.49	100	0.79
9	Tank Mix 2: Stadium A19432A (full rate)	6.33	100	2.84
10	Tank Mix 3: Stadium A19432A (60% rate)	5.57	100	1.12
11	Untreated check (inoculated)	18.00	100	15.23
12	Untreated check (non-inoculated)	4.16	100	0.20
ANOVA (P≤0.05)		0.0001	--	0.0001
LSD (P=0.05)[5]		---	--	---
Coefficient of variation		8.45	--	21.57

[1]Results are the means of four replications.
[2]Disease severity (DS) means are the percent (%) of the tuber surface showing dry rot lesions.
[3]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms but statistical analysis was not done as all treatments were 100% DI.
[4]Depth of FDR penetration was calculated as the extent of internal necrosis by dry rot and was measured with Vernier callipers (in mm).
[5]Least significant differences were not calculated for transformed data.
[6]Square root-transformed data were used for analysis.
[7]Data failed the Bartlett's test of homogeneity, so the Duncan Multiple Range test letter gradings couldn't be used.

Table 3. Trial 2 fusarium dry rot disease severity (DS), incidence (DI) and index of disease (ID) levels for postharvest Russet Burbank (cv.) tuber ratings performed at AAFC, Charlottetown, PEI Brooks, Alberta in 2011.

Treatment number	Treatment name (*see Table 1 also*)	Dry rot DS (%)[1,2,6]	Dry rot DI (%)[1,3,6]	Depth of FDR penetration in tuber (%)[1,4,6,7]
1	Mertect SC Fungicide	17.87 a	100	14.44
2	Storox	17.88 a	100	15.67
3	Confine	19.21 a	100	14.13
4	Agress	16.58 ab	100	15.81
5	Silver Periodate	11.52 bc	100	10.25
6	Bio-Save(R) 10LP	15.18 ab	100	14.77
7	Inspire	14.88 ab	100	11.27
8	Tank Mix 1: Inspire + Scholar + Quadris	7.45 cd	100	3.86
9	Tank Mix 2: Stadium A19432A (full rate)	8.00 cd	100	4.00
10	Tank Mix 3: Stadium A19432A (60% rate)	7.17 d	100	2.90
11	Untreated check (inoculated)	16.17 ab	100	14.60
12	Untreated check (non-inoculated)	4.56 d	100	0.05
ANOVA (P≤0.05)		0.0001	--	0.0001
LSD (P=0.05)[5]		---	--	---
Coefficient of variation		11.95	--	37.27

[1]Results are the means of four replications.
[2]Disease severity (DS) means are the percent (%) of the tuber surface showing dry rot lesions.
[3]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms but statistical analysis was not done as all treatments were 100% DI.
[4]Depth of FDR penetration was calculated as the extent of internal necrosis by dry rot and was measured with Vernier callipers (in mm).
[5]Least significant differences were not calculated for transformed data.
[6]Square root-transformed data were used for analysis.
[7]Data failed the Bartlett's test of homogeneity, so the Duncan Multiple Range test letter gradings couldn't be used.

4-3 YEAR 2: 2012-13- Alberta

PROJECT OBJECTIVES

The same objectives as in the first year were reached in this trial to evaluate the relative efficacy of 11 registered and experiment fungicides, either alone or in combination, for fusarium dry rot control in stored potatoes.

RESEARCH PROTOCOL

MATERIALS

MERTECT SC Fungicide (thiabendazole 500g/L), STOROX bactericide/fungicide (hydrogen peroxide), CONFINE (phosphorous acid), AGRESS® (oxysilver nitrate), SILVER PERIODATE®, BIO-SAVE® 10LP (*Pseudomonas syringae* Strain ESC-10), INSPRIRE® 250SC (difenconazole), SCHOLAR® 230SC fungicide (fludioxinol), QUADRIS® 250SC (azoxystrobin), STADIUM (Syngenta Canada Inc. experiment product No. A19432: difenconazole + fludioxinol + azoxystrobin combination) and finally, PHOSTROL® (phosphorous acid).

METHODS

In December 2012, two *F. sambucinum* subcultures, one that was thiabendazole-resistant and the other thiabendazole–sensitive were further subcultured onto 15 potato dextrose agar (PDA) plates each. These cultures were grown under natural lighting at RT for ca. 7 days, until they sporulated. These were used for inoculating the tubers for both trials in January 2013.

As per the April 2012 experiments, Niska and Russet Burbank tubers were used for Trials 1 and 2 and were placed into a controlled environmental storage unit (CES), set at 5°C and 93% RH, until the experiment commenced. Each trial had 11 chemical treatments plus three checks this time however (**Table 1**), with five replications.

From Jan 7-8, 2013, 135 tubers/trial treatments were counted out and placed in groups of 25 each into labeled plastic totes, one/subplot and again included ten extra tubers that were set aside as extras. An identical randomized complete block (RCB) plot design was prepared per trial, using the Agricultural Research Manager Version 7 computer software program (ARM 7) by Gylling Data Management, Inc., Brookings, SD, USA.

The following day, all tubers except for those for Treatment 14 (unwounded check) were bruised and cut by a small electric cement mixer for 3 min. (Niska) and 4 min. (R. Burbank) in 60-70 tuber lots. Those with < 3 slashes on them were hand-wounded by using the dull edge of a cleaver and this simulated harvesting condition. The potatoes were then were placed back into the same refrigerated storage overnight. On January 10, the *F. sambucinum* tuber inoculum was prepared exactly the same as the previous year and was used to inoculate the potatoes in Treatments 1-12, as before. Again, they were placed back into the original plastic crates that were set inside a 10°C 95% RH CES room until the following day.

On January 11, the same moving conveyor belt system, with a two-nozzle, CO_2-propelled spray boom positioned over a chute at the end of it, was used to treat the potatoes with either the fungicidal treatments or water (see *Year 1*). After treatment, the tubers were placed into individually labeled plastic crates (1 crate/subplot with 25 tubers each), which then went into a 10°C CES room. As in 2012, interim fusarium dry rot evaluations were performed until the final ratings could be completed when there were moderate dry rot levels present.

Trial 1 – Niska Disease Evaluations

Final fusarium dry rot disease severity (DS) evaluations took place from February 20-21; so again, the tubers were sliced in half and were visually examined for disease symptoms, receiving a DS rating

based upon the same 0-5 point scale as in 2012. The disease incidence (DI) and Index of Disease score (ID) score calculations were also identical to the previous year.

Data for all ratings were summarized and analyzed using the ARM 7 and ARM 8 statistical software programs. Duncan's Multiple Range Test (DMRT) was utilized for means comparisons, where F-tests were statistically significant ($P \leq 0.05$). Bartlett's Test for Homogeneity of Variance was also used for all ANOVA calculations, as well as data transformations (arcsine or square root). Detransformed means as needed are presented in Table 2.

Trial 2 – Russet Burbank Disease Evaluations

Similarly, the Russet Burbank potatoes were rated from March 19 – April 2, using the same evaluation protocol as per Trial 1, with the data is presented in Table 3.

RESULTS AND CONCLUSIONS

Trial 1- Niska cv. Results (Table 2 and Figures 1 – 3)

The DI and ID data were all very highly statistically significant ($p \leq 0.05$). The unwounded, untreated and non-inoculated check (Treatment 14) had the least FDR at 18.4% DI and 1.56% ID, meaning that if the potatoes weren't bruised or cut, there was very little natural inoculum present to infect them. For both rating parameters, STADIUM applied at the full label rate (Treatment 9) was the best-performing fungicide, with a DI/ ID values of 62.2% and 20.81% respectively. SILVER PERIODATE (Treatment 5) at 62.94% was statistically identical for DI% only; however, the ID score was slightly higher at 23.23%, so was only statistically similar to Treatment 9. However, both of these treatments reduced dry rot more effectively than the wounded, inoculated untreated check, Treatment 12 but not significantly so.

MERTECT SC (Treatment 1) has been the industry standard for potato postharvest storages for many years but *F. sambucinum* especially has become increasingly resistant to this fungicide; therefore dry rot disease levels become higher over time. This was again proven with this trial, as it was a fungicide with moderately high results (71.20 % DI and 34.53% ID). The DS results, however failed the Bartlett's Test of Homogeneity, so even though the data were statistically significant, the Duncan's grouping could not be reported, unfortunately. However, there were similar trends shown as with the DI and ID data.

Trial 2- Russet Burbank cv. Results (Table 3 and Figures 4 – 6)

After rating the R. Burbank stored tubers for fusarium dry rot DI and ID, again all data were very highly significant ($p \leq 0.05$) but unfortunately, no chemical treatment was effective in reducing dry rot when compared to the wounded, untreated, inoculated check (Treatment 12). In fact, they were all statistically similar, except for Treatment 5 (SILVER PERIODATE) which had the most diseased tubers. CONFINE, at 48% DI and11.25% numerically had the lowest FDR but not statistically so. Again, the DS results failed the Bartlett's Test of Homogeneity, so even though the data were statistically significant, the Duncan's grouping could not be reported, unfortunately. However these trends suggested that CONFINE and INSPIRE followed by INSPIRE + SCHOLAR + QUADRIS in combination, BIO-SAVE 10LP, PHOSTROL and finally, STOROX, may be slightly more effective in reducing dry rot disease than Treatment 12 mentioned above. With the R. Burbank tubers this time, SILVER PERIODATE was not effective at all in reducing FDR. Overall, these results were quite low as compared with the Niska tubers, as was expected to be the case.

CONCLUSIONS

Trial 1 – Niska (cv.):

After evaluating this trial, STADIUM applied at the label rate, followed by SILVER PERIODATE proved to be the most effective treatments and both may be alternatives to using MERTECT in postharvest potato storages. However, as seen in trial 2 with R. Burbank, SILVER PERIODATE was the least effective treatment, so it shouldn't necessarily be recommended for eradicating FDR in all potato cultivars, without further testing performed.

Trial 2- Russet Burbank (cv.)

Overall, this trial showed that no chemical treatment was significantly effective at reducing FDR when compared with the wounded, untreated, inoculated check. A third year of research was definitely needed to finalize treatments against FDR that may be more effective than the industry standard, MERTECT.

Table 1. Chemical treatments and checks used for both Trials 1 and 2 for a CDCS postharvest potato storage experiment that was performed at Brooks, Alberta in 2012.

Treatment number	Treatment name	Chemical application rates[1]
1	Mertect SC Fungicide	7.5 L Mertect per 170 L of water
2	Storox	100 mL StorOx per 10 L of water (1:100)
3	Confine	100 mL Confine per 0.43 L of water (1:4.3)
4	Agress	N/A (experimental product)
5	Silver Periodate	N/A (experimental product)
6	Bio-Save ® 10LP	500 g of Bio-Save per 100 L of water
7	Inspire	44 mL Inspire 250SC in 210 mL water
8	Tank mix #1: Inspire + Scholar + Quadris	1.44 mL Inspire 250SC + 2 mL Scholar 230SC + 2 mL Quadris 250SC in 210 mL water
9	Premix #1: Stadium A19432A (full rate)	3.3 mL A19432A in 210 mL water
10	Premix #2: Stadium A19432A (60% rate)	2.0 mL A19432A in 210 mL water
11	Phostrol	0.42 L in 2L water
12	Wounded, untreated check (inoculated)	N/A
13	Wounded, untreated check (non-inoculated)	N/A
14	Unwounded, untreated check (non-inoculated)	

[1]Manufacturers label application rates for postharvest disease control in potato storages.

Table 2. Trial 1 fusarium dry rot disease severity (DS), incidence (DI) and index of disease (ID) levels for postharvest Niska (cv.) tuber ratings performed at the Crop Diversification Centre South at Brooks, Alberta in February 2013.

Treatment number	Treatment name (*see Table 1 also*)	Dry rot DS (0-5)[1,2,5]	Dry rot DI (%)[1,3,5,6]	Dry rot ID score (%)[1,4,6,7,8]
1	Mertect SC fungicide	2.41	71.20 ab	34.53 abc
2	Storox	2.43	73.60 ab	36.48 ab
3	Confine	2.24	71.20 ab	32.03 abc
4	Agress	2.44	78.40 a	38.64 a
5	Silver periodate	1.83	62.94 b	23.23 bc
6	Bio-Save®10LP	1.98	67.20 ab	26.95 abc
7	Inspire	2.20	80.00 a	35.28 ab
8	Tank mix #1: Inspire + Scholar + Quadris	1.96	74.54 ab	29.62 abc
9	Premix #1: Stadium A19432 (full rate)	1.68	62.20 b	20.81 c
10	Premix #2: Stadium A19432 (60% rate)	1.95	69.94 ab	27.21 abc
11	Phostrol	2.27	82.58 a	37.61 ab
12	Wounded, untreated inoculated check	2.12	67.20 ab	28.45 abc
13	Wounded, untreated, non-inoculated check	2.28	69.60 ab	32.18 abc
14	Unwounded, untreated, non-inoculated check	0.42	18.4 c	1.56 d
ANOVA (P≤0.05)		0.0001	0.001	0.0001
LSD (P=0.05)[5]		0.54	12.99	---
Coefficient of variation		21.05	15.13	19.21

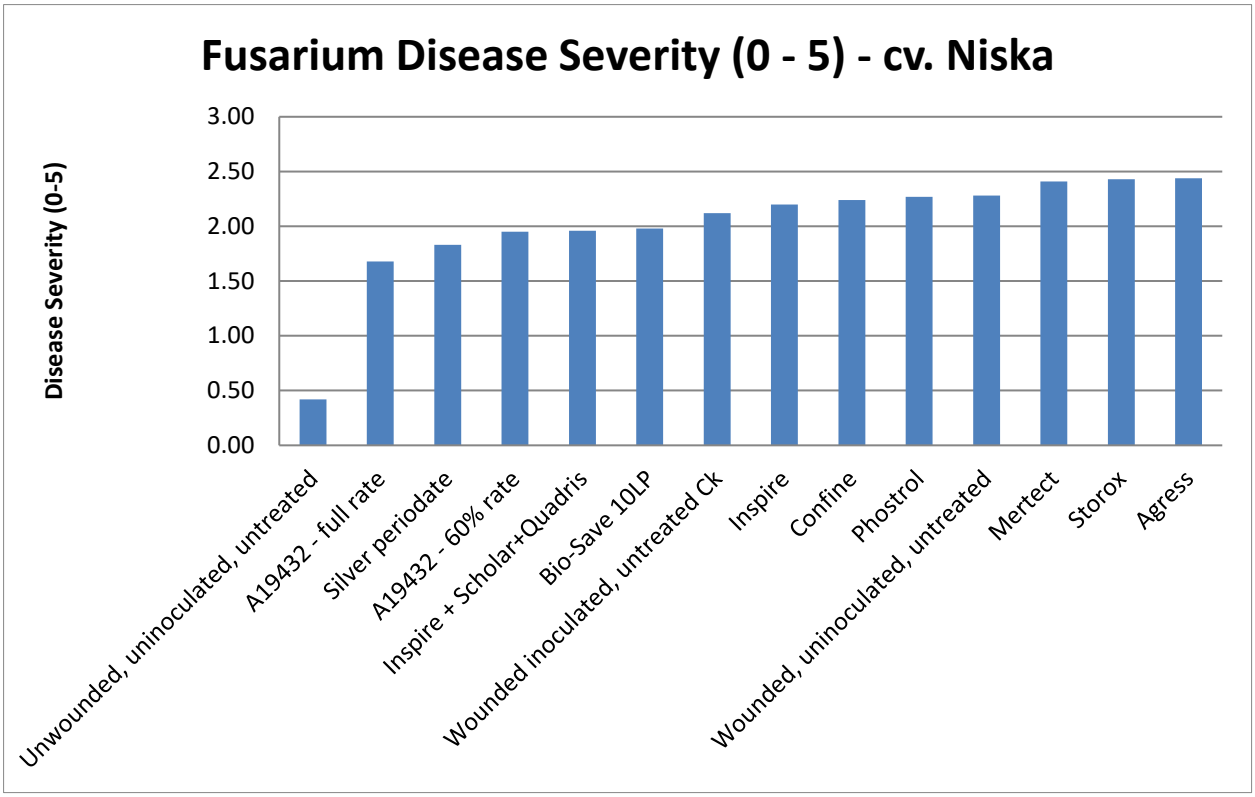
[1]Results are the means of five replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms.
[4]Index of disease score (ID) means are a calculation where DI * DS/500*100 = ID score (%).
[5]Raw data were used for analysis.
[6] Data were significantly different according to Duncan's Multiple Range test at P ≤ 0.05.
[7]Arcsine-transformed data were used for analysis.
[8]Least significant differences were not calculated for transformed data.

Table 3. Fusarium dry rot disease severity (DS, incidence (DI) and index of disease (ID) levels for postharvest R. Burbank (cv.) tuber ratings performed at the Crop Diversification Centre South at Brooks, Alberta in April 2013.

Treatment number	Treatment name (*see Table 1 also*)	Dry rot DS (0-5)[1,2,5,6]	Dry rot DI (%)[1,3,7,8]	Dry rot ID score (0-5)[1,4,8,9,10]
1	Mertect SC fungicide	1.72	56.44 bc	19.31 b
2	Storox	1.47	55.20 bc	16.34 b
3	Confine	1.16	48.00 bc	11.25 b
4	Agress	2.35	61.76 bc	17.45 b
5	Silver periodate	2.25	84.80 a	38.40 a
6	Bio-Save®10LP	1.43	63.20 bc	18.71 b
7	Inspire	1.35	49.60 bc	13.45 b
8	Tank mix #1: Inspire + Scholar + Quadris	1.39	52.80 bc	14.65 b
9	Premix #1: Stadium A19432 (full rate)	1.63	52.00 bc	17.23 b
10	Premix #2: Stadium A19432 (60% rate)	1.64	56.00 bc	18.90 b
11	Phostrol	1.44	56.80 bc	16.50 b
12	Wounded, untreated inoculated check	1.75	50.40 bc	17.80 b
13	Wounded, untreated, non-inoculated check	1.10	45.60 c	10.32 b
14	Unwounded, untreated, non-inoculated check	0.21	20.80 d	0.87 c
ANOVA (P≤0.05)		0.0001	0.0001	0.0001
LSD (P=0.05)[10]		---	13.81	---
Coefficient of variation		13.81	20.29	22.45

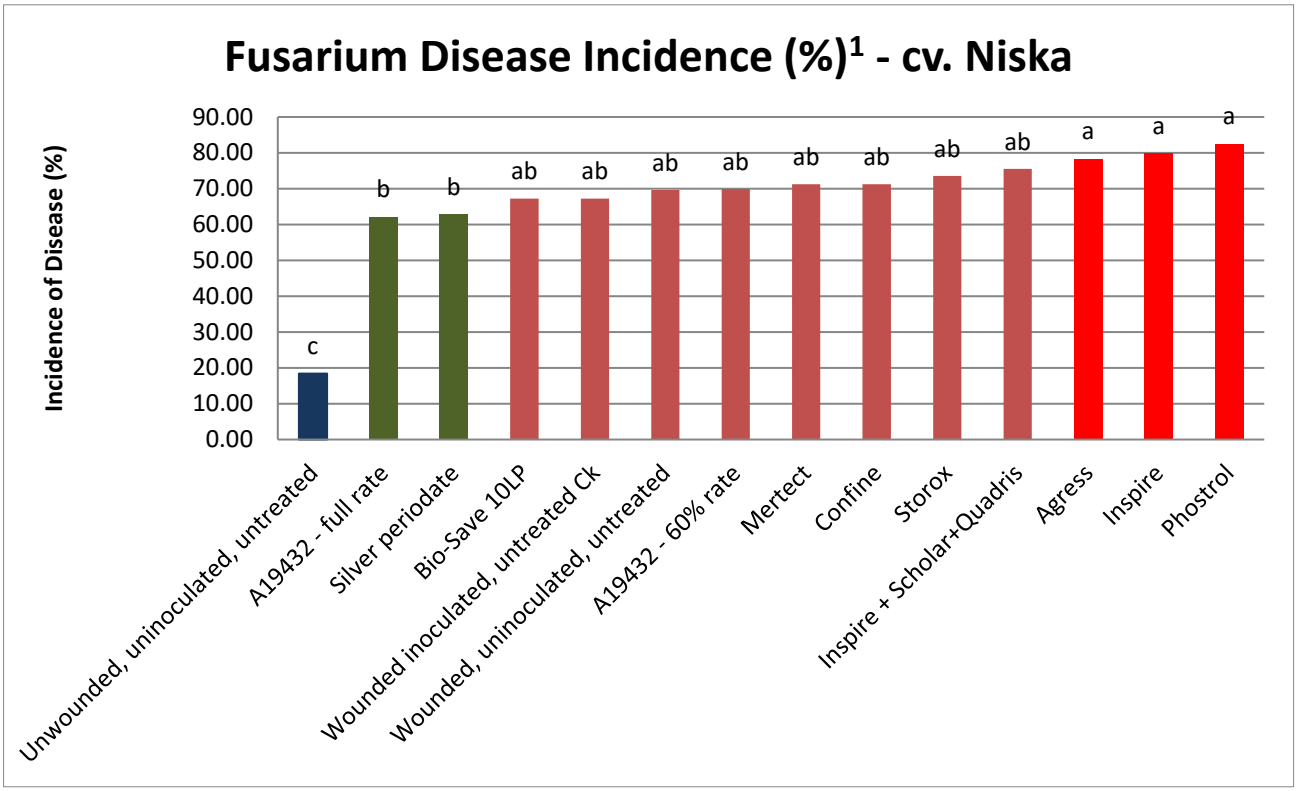
[1]Results are the means of five replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms.
[4]Index of disease score (ID) means are a calculation where DI * DS/500*100 = ID score (%).
[5]Square root-transformed data were used for analysis.
[6]Data failed the Bartlett's test of homogeneity, so the Duncan Multiple Range test letter gradings couldn't be used.
[7]Raw data were used for analysis.
[8]Data were significantly different according to Duncan's Multiple Range test at P ≤ 0.05.
[9]Arcsine-transformed data were used for analysis.
[10]Least significant differences were not calculated for transformed data.

Figure 1. Trial 1 dry rot disease severity (DS) rating levels, performed on postharvest Niska (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in February, 2013.



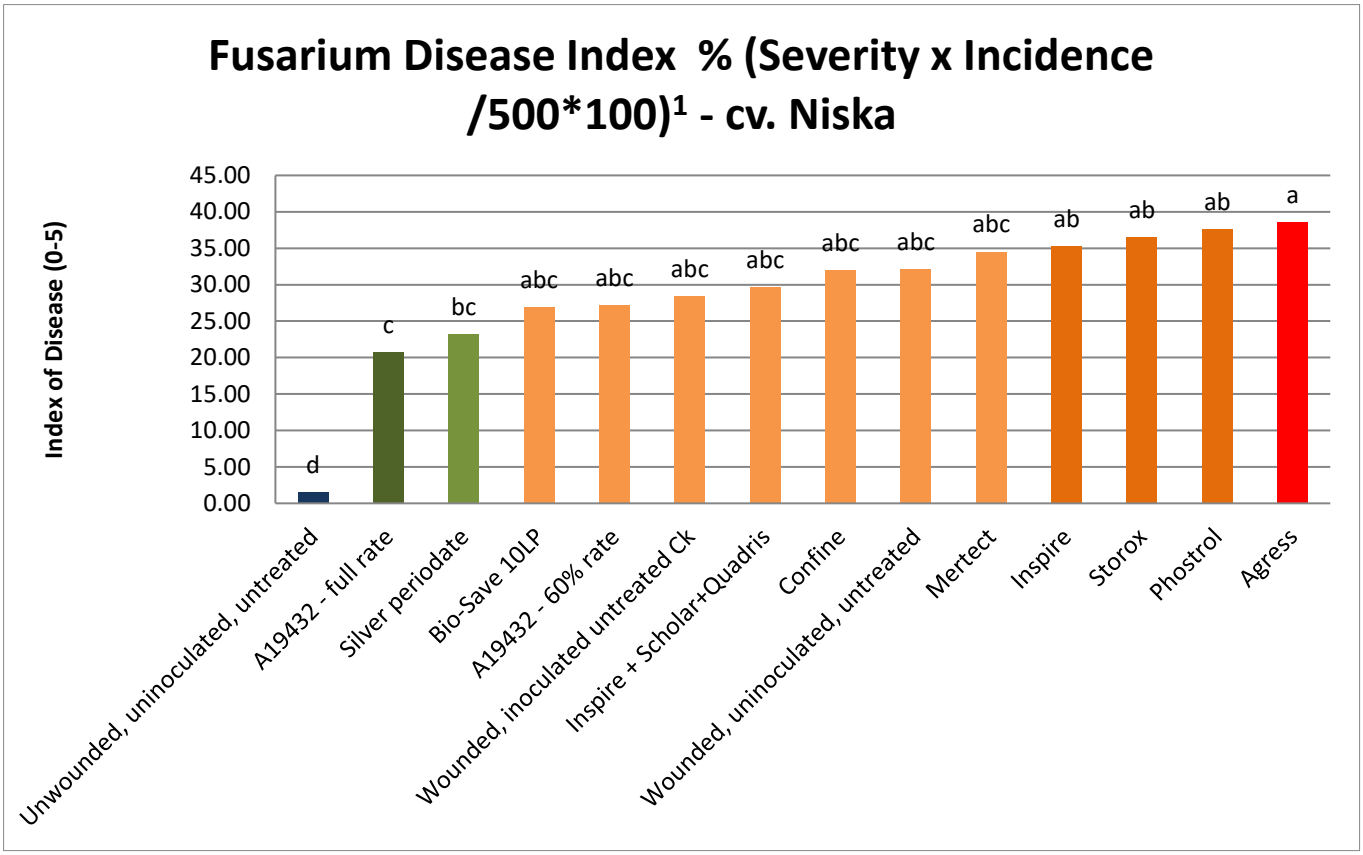
[1]Raw data failed the Bartlett's test of homogeneity, as did the transformed, so all data are shown as statistically equivalent.

Figure 2. Trial 1 dry rot disease incidence (DI) rating levels, performed on postharvest Niska (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in February, 2013



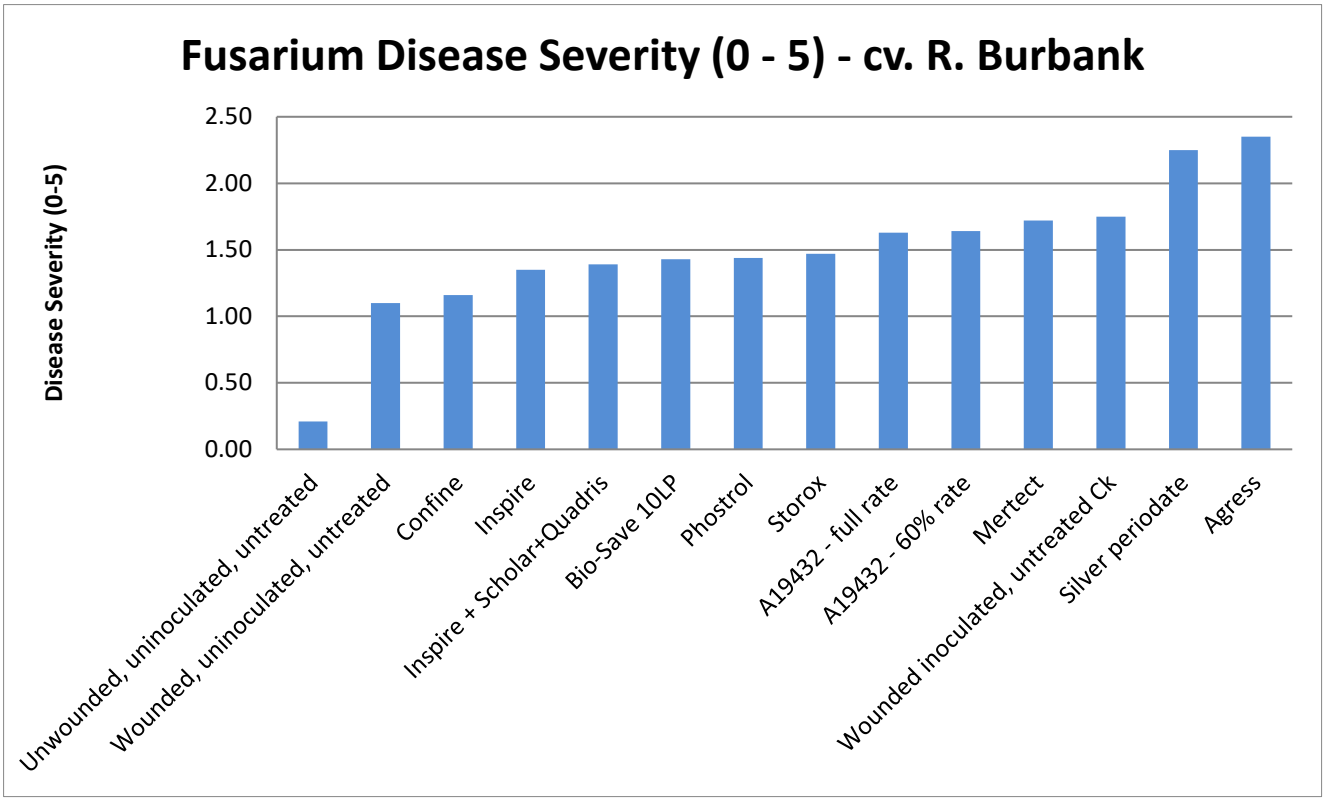
[1]Raw data were used for analysis, where the green, navy blue and red colors were statistically unique letter grades based on Duncan's Multiple Range Tests. The mahogany colors were statistically similar to the red and blue columns.

Figure 3. Trial 1 Index of Disease (ID) rating levels, performed on postharvest Niska (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in February 2013.



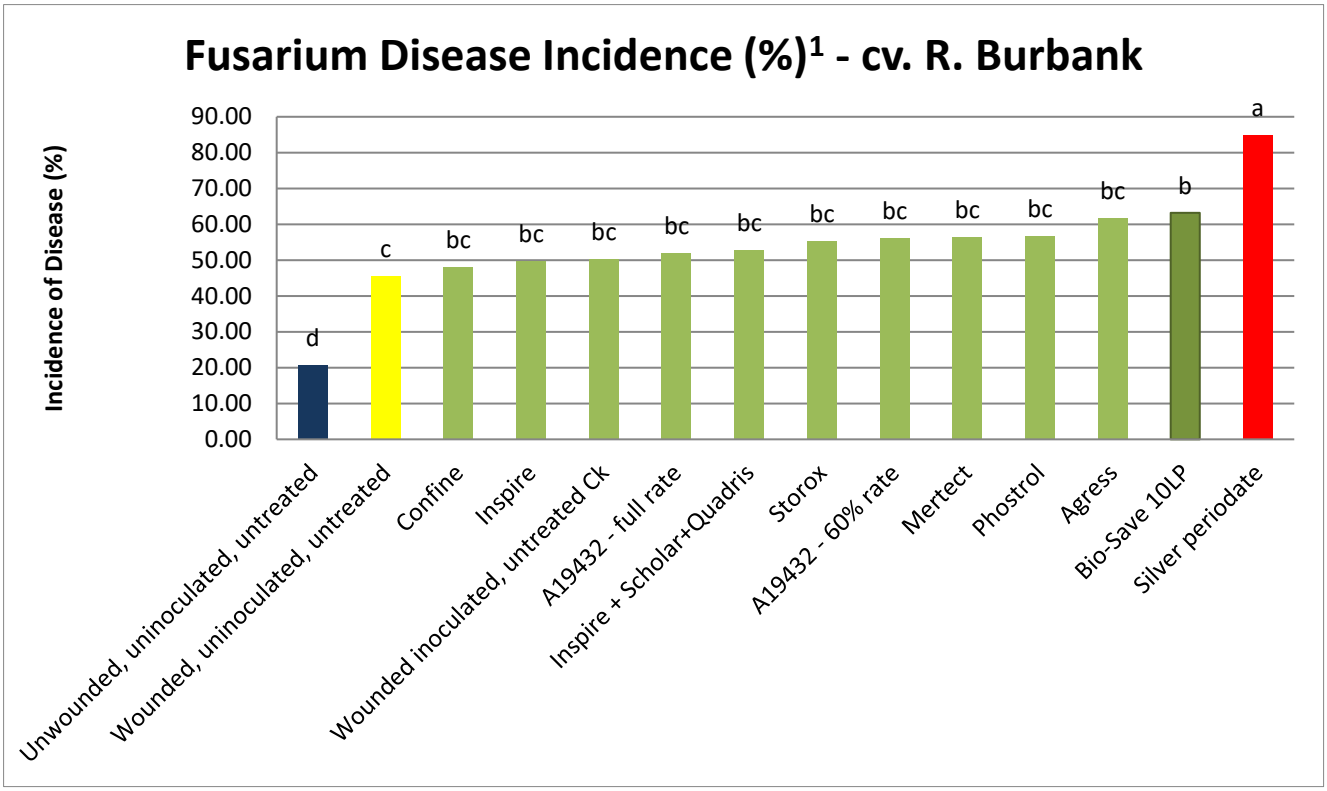
[1]Arcsine-transformed data were used for analysis, where the navy blue, green and red colors were statistically unique letter grades based upon Duncan's Multiple Range Tests. The medium green and orange shades colors were statistically similar to the green and red columns.

Figure 4. Trial 2 dry rot disease severity (DS) rating levels performed on postharvest R. Burbank (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in April, 2013.



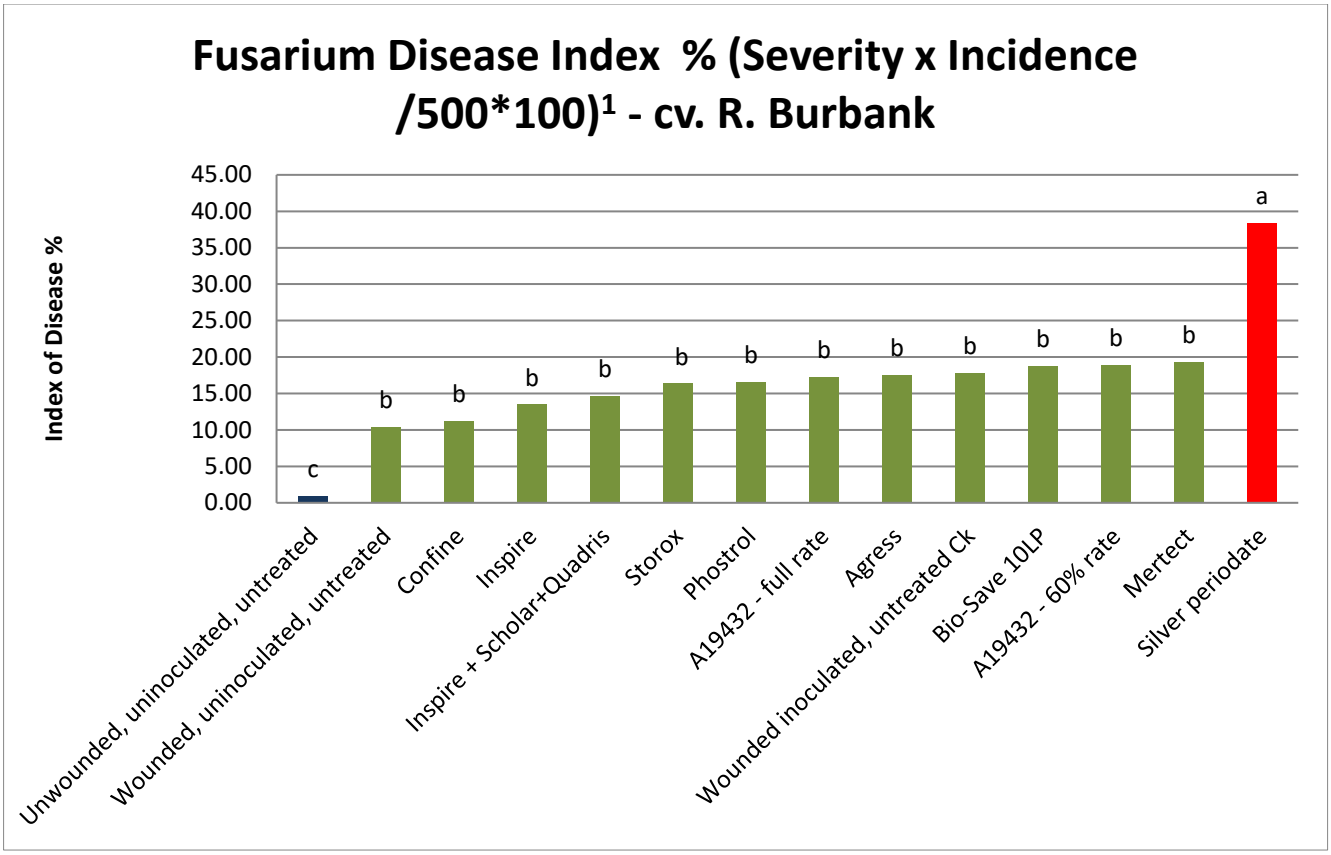
[1]Square-root transformed failed the Bartlett's test of homogeneity, as did the raw data and two other transformations, so all data are shown as statistically equivalent.

Figure 5. Trial 2 dry rot disease incidence (DI) rating levels, performed on postharvest R. Burbank (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in April 2013.



[1]Raw data were used for analysis, where the navy blue, yellow, dark green and red colors were statistically unique letter grades based on Duncan's Multiple Range Tests. The medium-green colored-columns were statistically similar to the yellow and dark green columns.

Figure 6. Trial 2 Index of Disease (ID) rating levels, performed on postharvest R. Burbank (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in April 2013.



[1]Raw data were used for analysis, where the navy blue, dark green and red colors were statistically unique letter grades based on Duncan's Multiple Range Tests.

4-4 YEAR 2: 2012 – Prince Edward Island

PROJECT OBJECTIVES

The same objectives as in Alberta were reached in this trial to evaluate the relative efficacy of 10 registered and experiment fungicides, either alone or in combination, for fusarium dry rot control in stored potatoes.

RESEARCH PROTOCOL

MATERIALS

MERTECT SC Fungicide (thiabendazole 500g/L), STOROX bactericide/fungicide (hydrogen peroxide), CONFINE (phosphorous acid), AGRESS® (oxysilver nitrate), SILVER PERIODATE®, BIO-SAVE® 10LP (*Pseudomonas syringae* Strain ESC-10), INSPRIRE® 250SC (difenconazole), SCHOLAR® 230SC fungicide (fludioxinol), QUADRIS® 250SC (azoxystrobin) and finally, STADIUM (Syngenta Canada Inc. experiment product No. A19432: difenconazole + fludioxinol + azoxystrobin combination)

METHODS

In 2012, at the Harrington Research Farm of Agriculture and Agri-Food Canada, Charlottetown, PEI, Yukon Gold and Russet Burbank tubers that were grown there, were used for two trials. Each trial was designed as a randomized complete block with four replications and each experimental unit (subplot) consisted of plastic, ventilated crates each containing 25 tubers that were clean, air-dried and visibly free of disease or blemishes.

The remaining methodology was the same as used in 2011 so please refer to *Section 4-2.*

Trial 1 – Yukon Gold Disease Evaluations

After 2-3 months of storage, individual tubers were assessed for percent of tuber surface covered with fusarium dry rot lesions (disease severity – DS %), as well as the incidence of disease (percent infected tubers – DI %). As well, tubers were cut longitudinally from the point of wounding and pathogen penetration into internal tuber tissues causing visible necrosis was measured with Vernier callipers (in mm).

However, the MS Excel spreadsheet showed that there was a lot of missing data for this trial, so statistical analysis was not performed.

Trial 2 – Russet Burbank Disease Evaluations

Similarly, the Russet Burbank potatoes were rated by using the same evaluation protocol as per Trial 1, with the data is presented in Table 2. At the Crop Diversification Centre South on October 22, 2015, the MS Excel data from this trial were analyzed by using the ARM 7 statistical software program. Duncan's Multiple Range Test (DMRT) was utilized for means comparisons, where F-tests were statistically significant ($P \leq 0.05$). Bartlett's Test for Homogeneity of Variance was also used for all ANOVA calculations, as well as data transformations (arcsine or square root). Detransformed means as needed are presented in Table 2.

RESULTS AND CONCLUSIONS

Trial 1- Yukon Gold cv. Results

There were insufficient data to perform the statistical analysis in 2012 for Yukon Gold so there isn't a results table set up for this cultivar.

Trial 2- Russet Burbank cv. Results (Table 2)

Unfortunately, all data failed the Bartlett's test for homogeneity of variance, so that the ANOVA Duncan's groupings could not be reported. However, there are noteworthy trends, showing that INSPIRE and STADIUM applied at the label rate had absolutely no FDR present at all after storing the potatoes but the untreated, uninoculated check had 0.10% DS, 1.50% DI and finally, 0.05 mm of disease penetration into the tubers on average. Therefore the two fungicides may be effective in dry rot control but another year of research is definitely needed. Incidentally, the industry standard, Mertect had levels of 8.23% DS, 18.16% DI and 6.90 mm for dry rot tuber penetration.

CONCLUSIONS

As there were no usable data for Yukon Gold, it will be set up again anyway in 2013.

Trial 2- Russet Burbank (cv.)

Although trends were shown, suggesting that INSPIRE and STADIUM applied at the label rate may be very promising fungicides to replace the industry standard, Mertect, repeating this trial during the 2013-14 potato storage season would be very beneficial. Also the inoculation protocol appeared to work very well, as the untreated, inoculated check had much higher values than the uninoculated check.

Table 1. Chemical treatments and checks used for both Trials 1 and 2 for an AAFC potato storage experiment that was performed at Charlottetown, PEI in 2012.

Treatment number	Treatment name	Chemical application rates[1]
1	Mertect SC Fungicide	7.5 L Mertect per 170 L of water
2	Storox	100 mL StorOx per 10 L of water (1:100)
3	Confine	100 mL Confine per 0.43 L of water (1:4.3)
4	Agress	N/A (experimental product)
5	Silver Periodate	N/A (experimental product)
6	Bio-Save(R) 10LP	500 g of Bio-Save per 100 L of water
7	Inspire	44 mL Inspire 250SC in 210 mL water
8	Tank Mix 1: Inspire + Scholar + Quadris	1.44 mL Inspire 250SC + 2 mL Scholar 230SC + 2 mL Quadris 250SC in 210 mL water
9	Tank Mix 2: Stadium A19432A (full rate)	3.3 mL A19432A in 210 mL water
10	Tank Mix 3: Stadium A19432A (60% rate)	2.0 mL A19432A in 210 mL water
11	Untreated check (inoculated)	N/A
12	Untreated check (non-inoculated)	N/A

[1]Manufacturers label application rates for postharvest disease control in potato storages.

Table 2. Trial 2 fusarium dry rot disease severity (DS), incidence (DI) and index of disease (ID) levels for postharvest Russet Burbank (cv.) tuber ratings performed at AAFC, Charlottetown, PEI in 2012.

Treatment number	Treatment name (*see Table 1 also*)	Dry rot DS (%)[1,2,3,4,7]	Dry rot DI (%)[1,3,4,5,7]	Depth of FDR penetration in tuber (%)[1,4,6]
1	Mertect SC Fungicide	8.23	18.16	6.90
2	Storox	14.45	29.95	7.72
3	Confine	13.87	30.31	9.14
4	Agress	6.14	21.12	4.92
5	Silver Periodate	7.36	19.36	4.79
6	Bio-Save(R) 10LP	8.84	27.01	6.00
7	Inspire	0.00	0.00	0.00
8	Tank Mix 1: Inspire + Scholar + Quadris	1.81	8.09	2.12
9	Tank Mix 2: Stadium A19432A (full rate)	0.00	0.00	0.00
10	Tank Mix 3: Stadium A19432A (60% rate)	1.03	5.63	0.93
11	Untreated check (inoculated)	5.02	25.84	4.50
12	Untreated check (non-inoculated)	0.10	1.50	0.05
ANOVA (P≤0.05)		0.0001	0.0001	0.0001
LSD (P=0.05)[5]		---	---	3.70
Coefficient of variation		31.86	28.57	65.41

[1]Results are the means of four replications.
[2]Disease severity (DS) means are the percent (%) of the tuber surface showing dry rot lesions.
[3]Square root-transformed data were used for analysis.
[4]Data failed the Bartlett's test of homogeneity, so the Duncan Multiple Range test letter gradings couldn't be used.
[5]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms.
[6]Depth of FDR penetration was calculated as the extent of internal necrosis by dry rot and was measured with Vernier callipers (in mm) and raw data were used for analysis.
[7]Least significant differences were not calculated for transformed data.

4-5 YEAR 3: 2013-14 Alberta

PROJECT OBJECTIVES

The project objectives for this 2013-14 trial (Year 3) were the same as in Years 1 and 2 but this time, the relative efficacy of just 10 registered and experiment fungicides, either alone or in combination, were evaluated for FDR control in stored potatoes.

RESEARCH PROTOCOL

MATERIALS

MERTECT SC Fungicide (thiabendazole 500g/L), STOROX bactericide/fungicide (hydrogen peroxide), CONFINE (phosphorous acid), BIO-SAVE® 10LP (*Pseudomonas syringae* Strain ESC-10), INSPRIRE® 250SC (difenconazole), SCHOLAR® 230SC fungicide (fludioxinol), QUADRIS® 250SC (azoxystrobin), STADIUM (Syngenta Canada Inc. experiment product No. A19432: difenconazole + fludioxinol + azoxystrobin combination), PHOSTROL® (phosphorous acid) and SERENADE® CPB biofungicide *(Bacillus subtilis*, strain QST 713)

METHODS

In November 2013, two *F. sambucinum* subcultures, one that was thiabendazole-resistant and the other thiabendazole–sensitive were revived off freezer stocks and a week later, they were subcultured onto 5 acidified potato dextrose agar (PDA-A) plates each. These cultures were grown under natural lighting at RT for ca. 7 days, until they sporulated and then were refrigerated. These were used for inoculating the tubers from both trials in December.

Also, tubers from two potato cultivars, Niska (Trial 1) and Russet Burbank (Trial 2) used for these two separate CDCS trials in this experiment, were placed into a controlled environmental storage unit (CES), set at 5°C and 93% RH, until the experiment commenced. Each trial had 10 chemical treatments plus three checks (Table 1) with five replications.

From November 30 – December 3, 135 tubers/trial treatments were counted out and placed in groups of 25 each into labeled plastic totes: one/subplot, including ten extra tubers set aside as extras as in Years 1 and 2. An identical randomized complete block (RCB) plot design was prepared per trial, using the Agricultural Research Manager Version 8 computer software program (ARM 8) by Gylling Data Management, Inc., Brookings, SD, USA.

On December 4, all tubers except for those for Treatment 13 (unwounded check) were bruised and hand-wounded by using a dull edge of a cleaver so that they had three slashes each: thus simulating harvesting conditions. The potatoes were then were placed back into 60-70 tuber-lots in tote bins into the same refrigerated storage overnight. The next day, the F*. sambucinum* tuber inoculum was prepared and the same inoculation /cold storage methodology as in the previous two years was used on the potatoes.

On December 6, the tubers from each treatment received the fungicides and water treatments, using the same process as last year. Each month, interim fusarium dry rot evaluations were performed as before, by slicing each tuber in half with a sharp knife through one of the wounds until moderate FDR levels were apparent.

Trial 1 – Niska Disease Evaluations

Final FDR disease severity (DS) evaluations took place from March 26-27, 2014; so again, the tubers were sliced in half and were visually examined for disease symptoms, receiving a DS rating based upon the same 0-5 point scale as used in Years 1 and 2.

Similarly, the Disease incidence (DI), the percentage of tubers with dry rot and the Index of Disease (ID) were also calculated/subplot.

Data for all ratings were summarized and analyzed using the ARM 8 statistical software programs. Duncan's Multiple Range Test (DMRT) was utilized for means comparisons, where F-tests were statistically significant ($P \leq 0.05$). Bartlett's Test for Homogeneity of Variance was also used for all ANOVA calculations, as well as data transformations (arcsine or square root). Detransformed means as needed are presented in **Table 2.**

Trial 2 – Russet Burbank Disease Evaluations

Similarly, the Russet Burbank potatoes were rated from March 27 – 31, using the same evaluation protocol as per Trial 1, with the data is presented in **Table 3**.

RESULTS AND DISCUSSION

Trial 1- Niska cv. Results (Table 2 and Figures 1 – 3)

The DS, DI and ID data were all highly statistically significant ($p \leq 0.05$); however, the ID data failed the Bartlett's Test of Homogeneity, so the Duncan's grouping could not be reported, unfortunately. The unwounded, untreated and non-inoculated check (Treatment 13) had the least dry rot at 0.29 DS, 14.21% DI and 0.81% ID, meaning that if the potatoes weren't bruised or cut, there was very little natural inoculum present to infect them.

For the DS rating, STOROX (Treatment 2) at 1.60 and STADIUM (Treatment 8: 60% of the label rate) at 1.63 were the best-performing fungicides but were in the same grouping as Treatment 11 (wounded, uninoculated, untreated check). However, for DI, STADIUM (60% rate) was the most effective fungicide in FDR control, as just 91.26%. STOROX was statistically similar but showed that 97.19% of the tubers had dry rot. Treatments 11 and 12 (wounded check treatments) were statistically identical to STOROX though. MERTECT SC (Treatment 1), the industry standard did not suppress FDR development well at all, as its ratings were 2.52 and was even higher than the Treatment 11 check, so it appeared ineffective with FDR control.

Trial 2- Russet Burbank cv. Results (Table 3 and Figures 4 – 6)

R. Burbank generally has greater dry rot disease resistance than Niska, so the FDR results were expectedly, much lower for this trial. The DS, DI and ID data again, were very highly significant ($p \leq 0.05$). Treatment 13 (unwounded, untreated, non-inoculated check) demonstrated the very lowest FDR levels at 0.22 DS, 12,8% DI and just 0.57% ID, meaning that there was very little natural disease presence in the field tubers; however, STADIUM applied at the label rate (Treatment 7) apparently was very effective at dry rot control, even after the tubers were wounded and inoculated, as the FDR levels were in the same Duncan's grouping as the aforementioned check. Great potential was demonstrated for this fungicide, as it had just 0.40 DS, 31.2% DI and 2.52 % ID values in the disease ratings. Other overall promising fungicides with similar Duncan's grouping were BIO-SAVE® 10L, CONFINE and STOROX, closely followed by INSPIRE (DS and ID only). The remaining treatments were only marginally effective in FDR control, including MERTECT and this time, STADIUM (60% rate).

CONCLUSIONS

Trial 1 – Niska (cv.): STADIUM applied at 60% of the label rate, followed by STOROX proved to be the most effective treatments and possible alternatives to using MERTECT

Trial 2 - Russet Burbank (cv.): To control FDR in R. Burbank stored tubers, data from this trial suggested that STADIUM applied at the label rate showed great potential, even though the potatoes were wounded and inoculated with fusarium. Other promising fungicides were BIO-SAVE® 10L, CONFINE and STOROX.

Table 1. Chemical treatments and checks used for both Trials 1 and 2 for a CDCS postharvest potato storage experiment that was performed at Brooks, Alberta in March 2014.

Treatment number	Treatment name	Chemical application rates[1]
1	Mertect SC Fungicide	7.5 L Mertect per 170 L of water
2	Storox	100 mL StorOx per 10 L of water (1:100)
3	Confine	100 mL Confine per 0.43 L of water (1:4.3)
4	Bio-Save ® 10LP	500 g of Bio-Save per 100 L of water
5	Inspire	44 mL Inspire 250SC in 210 mL water
6	Tank mix #1: Inspire + Scholar + Quadris	1.44 mL Inspire 250SC + 2 mL Scholar 230SC + 2 mL Quadris 250SC in 210 mL water
7	Premix #1: Stadium A19432A (full rate)	3.3 mL A19432A in 210 mL water
8	Premix #2: Stadium A19432A (60% rate)	2.0 mL A19432A in 210 mL water
9	Phostrol	0.42 L in 2L water
10	Serenade CPB biofungicide	175 mL per 1000 kg. of potatoes
11	Wounded, untreated check (inoculated)	N/A
12	Wounded, untreated check (non-inoculated)	N/A
13	Unwounded, untreated check (non-inoculated)	

[1]Manufacturers label application rates for postharvest disease control in potato storages.

Table 2. Trial 1 fusarium dry rot disease severity (DS), incidence (DI) and index of disease (ID) levels for postharvest Niska (cv.) tuber ratings performed at the Crop Diversification Centre South at Brooks, Alberta in March 2014.

Treatment number	Treatment name (*see Table 1 also*)	Dry rot DS (0-5)[1,2,5,6]	Dry rot DI (%)[1,3,6,8]	Dry rot ID score (%)[1,4,8,9]
1	Mertect SC Fungicide	2.52 a	99.84 a	50.34
2	Storox	1.60 cd	97.19 ab	30.44
3	Confine	2.72 a	100.00 a	54.74
4	Bio-Save ® 10LP	2.61 a	100.00 a	52.16
5	Inspire	1.93 bc	99.35 a	38.09
6	Tank mix #1: Inspire + Scholar + Quadris	2.68 a	99.50 a	53.38
7	Premix #1: Stadium A19432A (full rate)	1.99 bc	98.37 ab	38.14
8	Premix #2: Stadium A19432A (60% rate)	1.63 cd	91.26 b	29.04
9	Phostrol	2.32 ab	99.84 a	46.31
10	Serenade CPB biofungicide	2.66 a	99.07 a	52.02
11	Wounded, untreated check (inoculated)	2.24 ab	98.11 ab	43.60
12	Wounded, untreated check (non-inoculated)	1.22 d	96.71 ab	22.88
13	Unwounded, untreated check (non-inoculated)	0.29 e	14.21 c	0.81
ANOVA (P≤0.05)		0.0001	0.0001	0.0001
LSD (P=0.05)[7]		---	---	---
Coefficient of variation		7.38	9.60	12.92

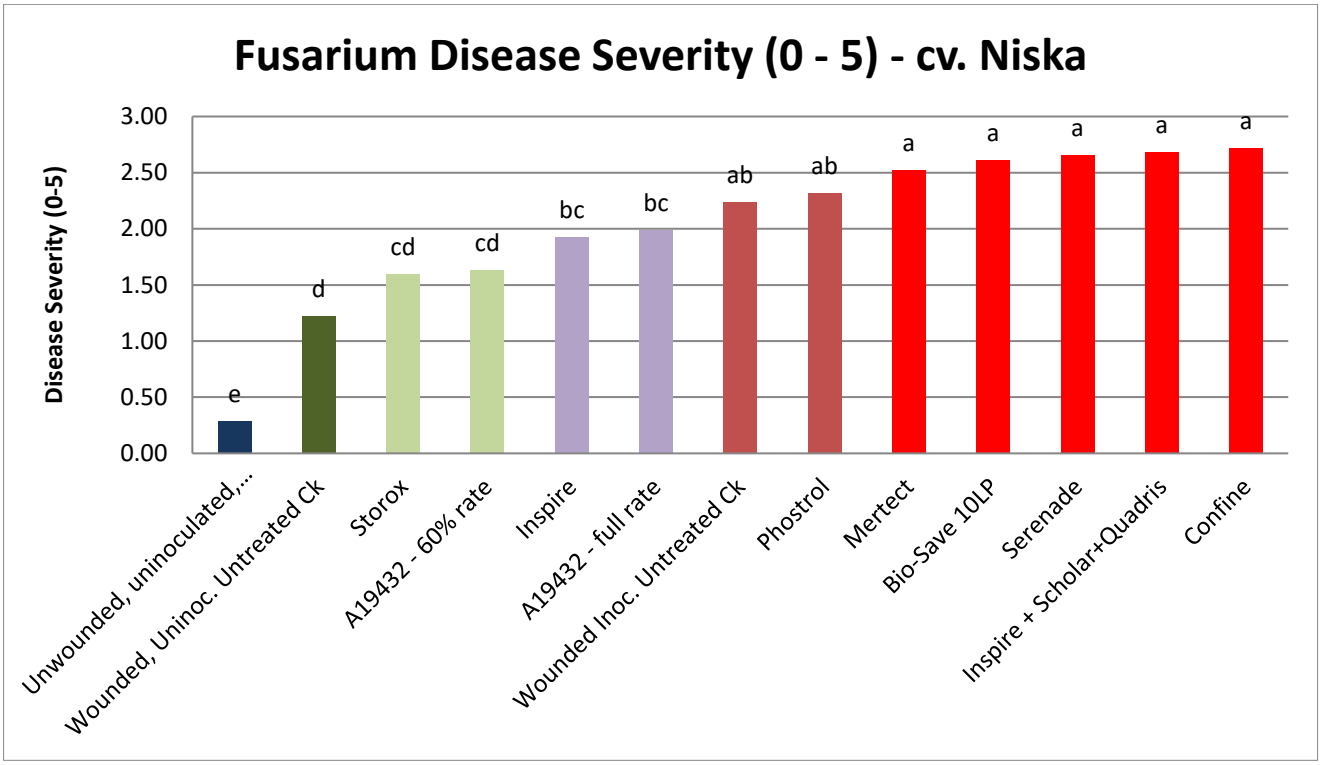
[1]Results are the means of five replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms.
[4]Index of disease score (ID) means are a calculation where DI * DS/500*100 = ID score (%).
[5]Square root-transformed data were used for analysis.
[6]Data were significantly different according to Duncan's Multiple Range test at P ≤ 0.05.
[7]Least significant differences were not calculated for transformed data.
[8]Arcsine-transformed data were used for analysis.
[9]Data failed the Bartlett's test of homogeneity, so the Duncan Multiple Range test letter gradings couldn't be used.

Table 3. Fusarium dry rot disease severity (DS, incidence (DI) and index of disease (ID) levels for postharvest R. Burbank (cv.) tuber ratings performed at the Crop Diversification Centre South at Brooks, Alberta in April 2014.

Treatment number	Treatment name (*see Table 1 also*)	Dry rot DS (0-5)[1,2,5,6]	Dry rot DI (%)[1,3,6,8]	Dry rot ID score (0-5)[1,4,6,9]
1	Mertect SC Fungicide	1.03 abc	60.6 ab	13.20 abc
2	Storox	0.61 cde	47.2 abc	6.18 cde
3	Confine	0.58 de	44.8 abc	5.20 cde
4	Bio-Save ® 10LP	0.56 de	40.8 bc	4.72 de
5	Inspire	0.86 bcd	54.4 abc	9.79 bcd
6	Tank mix #1: Inspire + Scholar + Quadris	0.95 bcd	63.2 ab	12.07 a-d
7	Premix #1: Stadium A19432A (full rate)	0.40 ef	31.2 cd	2.52 ef
8	Premix #2: Stadium A19432A (60% rate)	1.18 ab	59.2 ab	13.48 abc
9	Phostrol	0.94 bcd	68.8 a	12.98 abc
10	Serenade CPB biofungicide	1.46 a	63.2 ab	18.46 ab
11	Wounded, untreated check (inoculated)	1.45 a	68.0 a	20.44 a
12	Wounded, untreated check (non-inoculated)	0.78 bcd	65.6 ab	10.42 a-d
13	Unwounded, untreated check (non-inoculated)	0.22 f	12.8 d	0.57 f
ANOVA (P≤0.05)		0.0001	0.0001	0.0001
LSD (P=0.05)[7]		---	22.21	---
Coefficient of variation		11.31	33.17	33.42

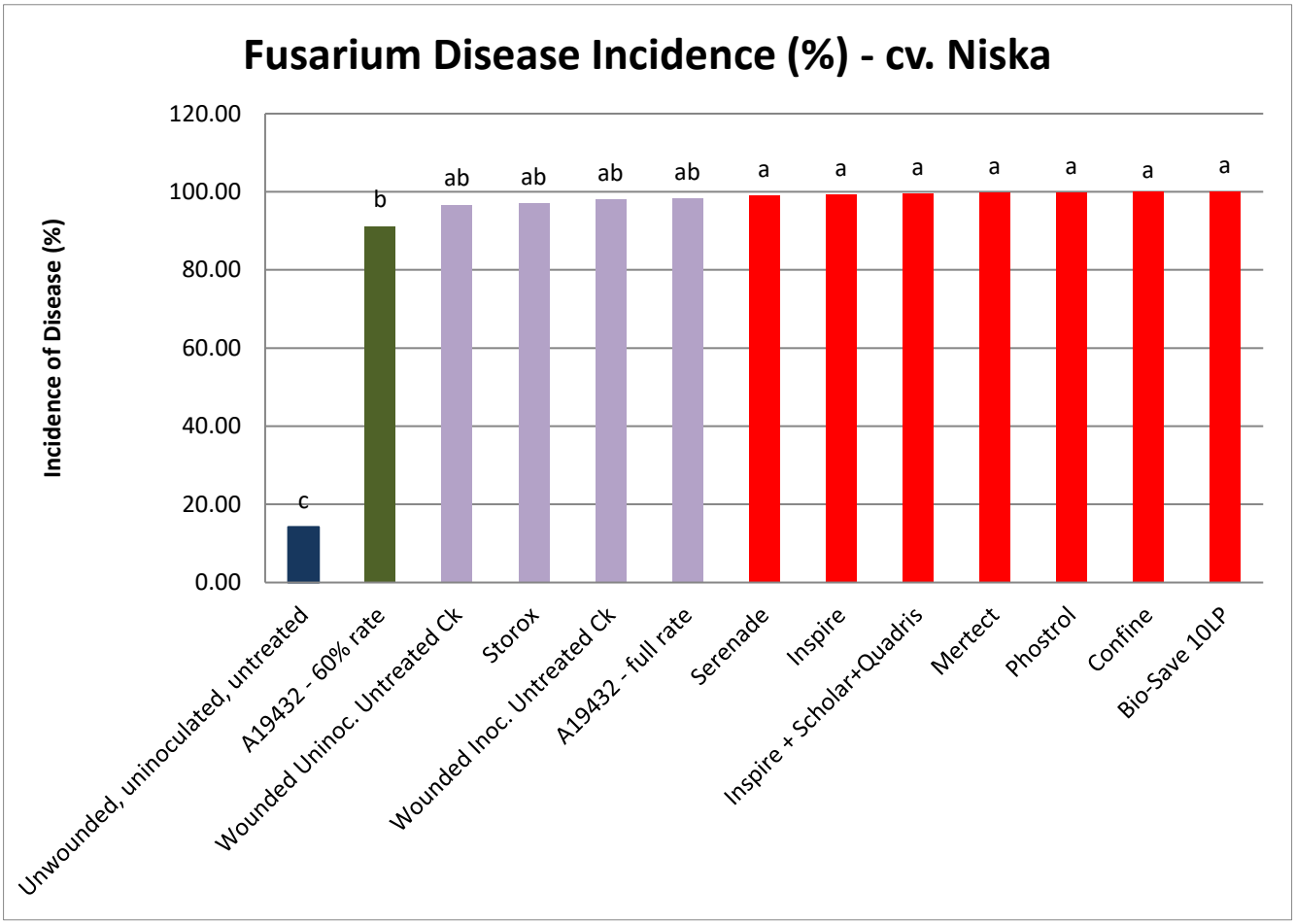
[1]Results are the means of five replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms.
[4]Index of disease score (ID) means are a calculation where DI * DS/500*100 = ID score (%).
[5]Square root-transformed data were used for analysis.
[6]Data were significantly different according to Duncan's Multiple Range test at P ≤ 0.05.
[7]Least significant differences were not calculated for transformed data.
[8]Raw data were used for analysis.
[9]Arcsine-transformed data were used for analysis.

Figure 1. Trial 1 dry rot disease severity (DS) rating levels, performed on postharvest Niska (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in March 2014.



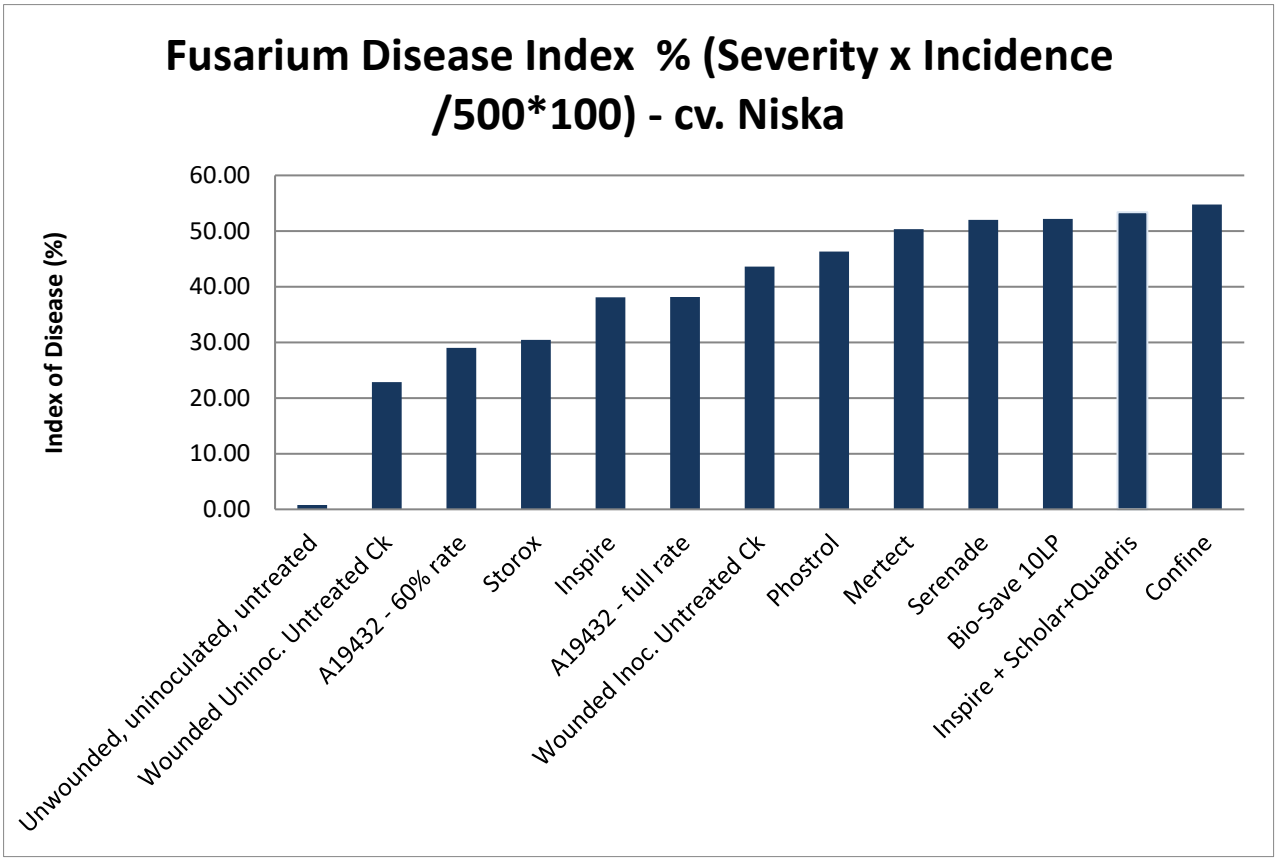
The dark green, navy blue and red columns were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. medium green and mahogany red). Purple columns are not statistically equivalent to red, navy blue and dark green columns.

Figure 2. Trial 1 dry rot disease incidence (DI) rating levels, performed on postharvest Niska (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in March 2014



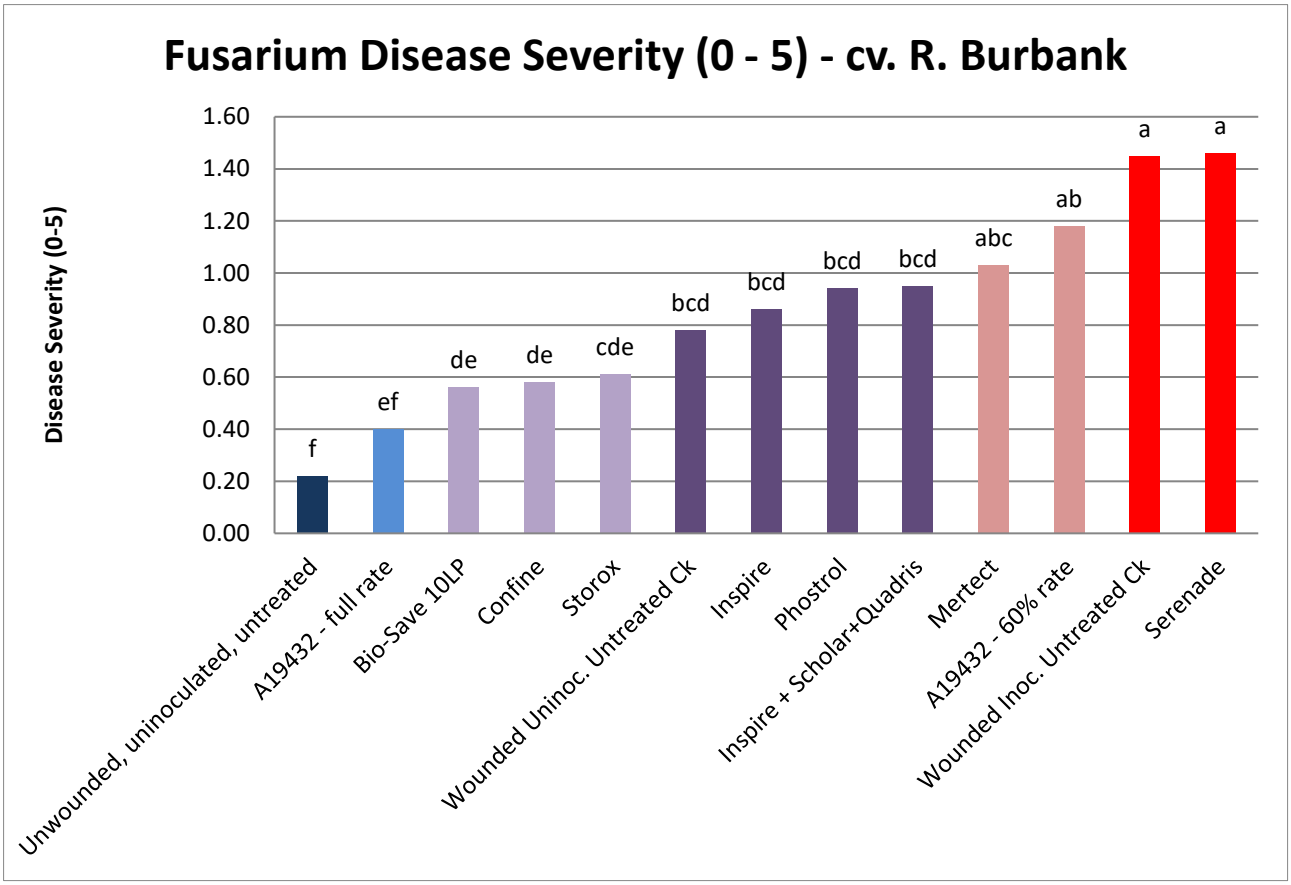
The dark green, navy blue and red colors were statistically unique letter grades based on Duncan Multiple Range Test. The purple columns are statistically similar to the red and dark green columns.

Figure 3. Trial 1 Index of Disease (ID) rating levels, performed on postharvest Niska (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in March 2014.



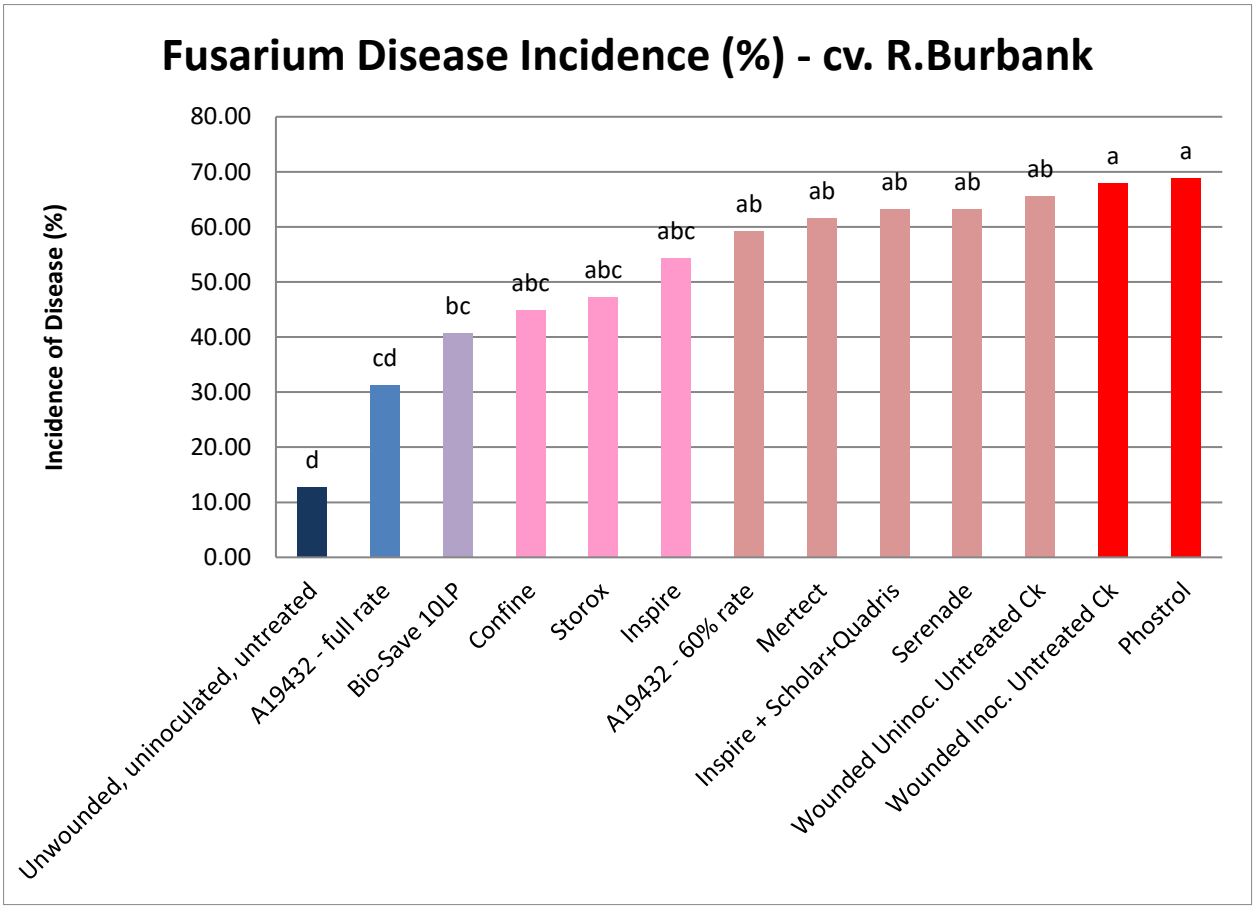
All color columns are navy blue, as this data failed the Bartlett's test of homogeneity so that statistical differences could not be reported. Arcsine-transformed data was used for this analysis.

Figure 4. Trial 2 dry rot disease severity (DS) rating levels performed on postharvest R. Burbank (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in April, 2014.



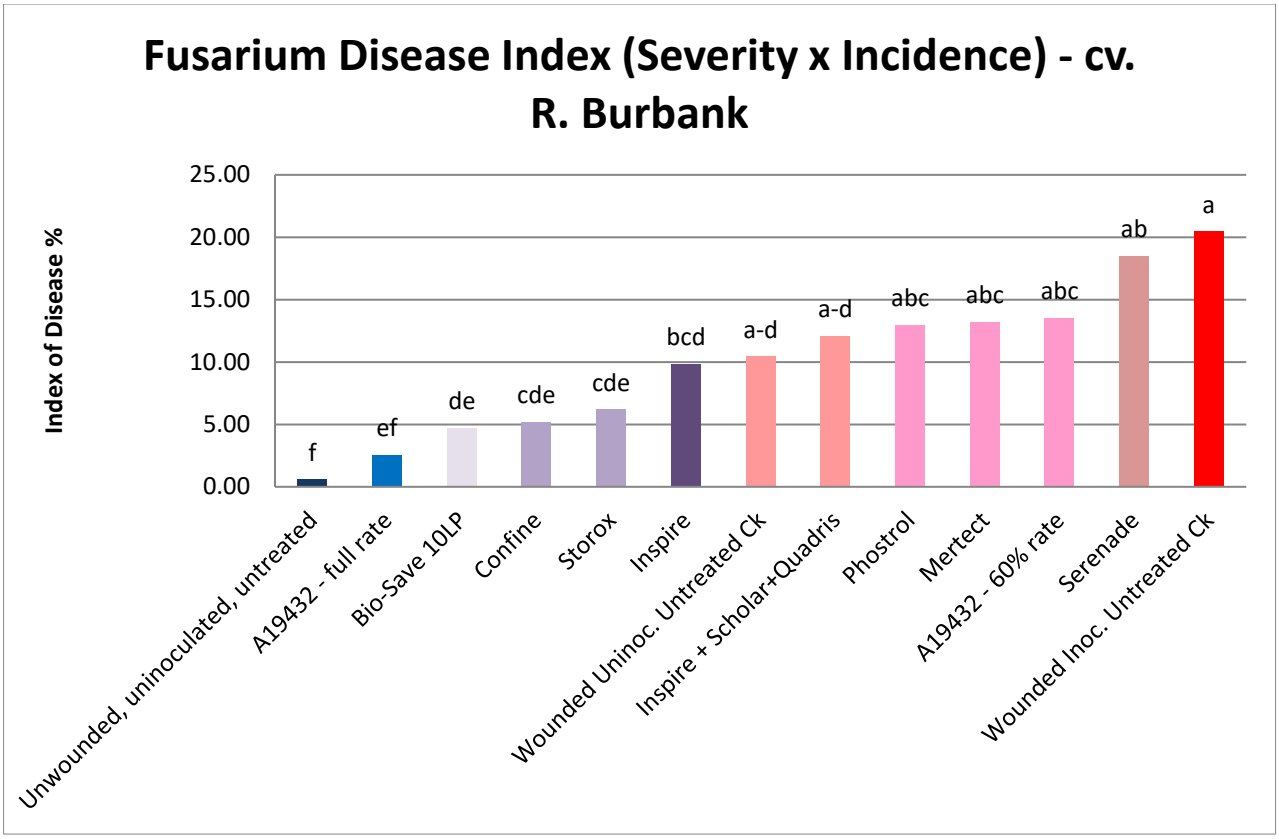
The deep red and blue colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. pink and medium blue). Purple columns are not statistically equivalent to red and blue columns.

Figure 5. Trial 2 dry rot disease incidence (DI) rating levels, performed on postharvest R. Burbank (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in April 2014.



The navy blue and red colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. pink and blue). Purple columns are not statistically equivalent to either red or blue columns.

Figure 6. Trial 2 Index of Disease (ID) rating levels, performed on postharvest R. Burbank (cv.) tubers at the Crop Diversification Centre South, Brooks, Alberta in April 2014.



The navy blue and red colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. Pink, bright pink or light pink). Purple columns are not statistically equivalent to either red or blue columns.

4-6 YEAR 3: 2013 – Prince Edward Island

PROJECT OBJECTIVES

The project objectives for this 2013-14 trial (Year 3) were the same as in Years 1 and 2 but this time, the relative efficacy of just 10 registered and experiment fungicides, either alone or in combination, were evaluated for FDR control in stored potatoes.

RESEARCH PROTOCOL

MATERIALS

MERTECT SC Fungicide (thiabendazole 500g/L), STOROX bactericide/fungicide (hydrogen peroxide), CONFINE (phosphorous acid), BIO-SAVE® 10LP (*Pseudomonas syringae* Strain ESC-10), INSPRIRE® 250SC (difenconazole), SCHOLAR® 230SC fungicide (fludioxinol), QUADRIS® 250SC (azoxystrobin), STADIUM (Syngenta Canada Inc. experiment product No. A19432: difenconazole + fludioxinol + azoxystrobin combination), PHOSTROL® (phosphorous acid) and SERENADE® CPB biofungicide *(Bacillus subtilis*, strain QST 713)

METHODS

In 2013, at the Harrington Research Farm of Agriculture and Agri-Food Canada, Charlottetown, PEI, Yukon Gold and Russet Burbank tubers that were grown there, were used for two trials. Each trial was designed as a randomized complete block with four replications and each experimental unit (subplot) consisted of plastic, ventilated crates each containing 25 tubers that were clean, air-dried and visibly free of disease or blemishes. Please refer to Section 4-4 for the 2011 methodology, as it was very similar in 2013.

Trial 1 – Yukon Gold Disease Evaluations

After 2-3 months of storage, individual tubers were assessed for percent of tuber surface covered with fusarium dry rot (FDR) lesions (disease severity – DS %), as well as the incidence of disease (percent infected tubers – DI %). As well, tubers were cut longitudinally from the point of wounding and pathogen penetration into internal tuber tissues causing visible necrosis was measured with Vernier callipers (in mm).

At the Crop Diversification Centre South on October 20, 2015, the MS Excel data from this trial were analyzed by using the ARM 7 statistical software programs. Duncan's Multiple Range Test (DMRT) was utilized for means comparisons, where F-tests were statistically significant ($P \leq 0.05$). Bartlett's Test for Homogeneity of Variance was also used for all ANOVA calculations, as well as data transformations (arcsine or square root). Detransformed means as needed are presented in Table 2.

Trial 2 – Russet Burbank Disease Evaluations

Similarly, the Russet Burbank potatoes were rated by using the same evaluation protocol as per Trial 1, with the data is presented in Table 3.

RESULTS AND CONCLUSIONS

Trial 1- Yukon Gold cv. Results (Table 2)

The DS%, DI% and the FDR penetration depth (mm) data were all highly statistically significant ($p \leq 0.05$); however, the depth of penetration, unfortunately failed the Bartlett's test of homogeneity, so the Duncan Multiple Range test letter gradings couldn't be used. Both the wounded and unwounded, untreated and non-inoculated checks (Treatments 12 and 13) had no dry rot at all, meaning that there wasn't any natural inoculum present to infect them.

For the DS% and DI% ratings, STADIUM (60% rate) appeared to be the most effective fungicide in FDR control, at 5.15% and 61% respectively. INSPIRE + SCHOLAR +QUADRIS tank mix and STADIUM (Treatment 7: label rate) were also statistically similar, so they are also very promising fungicides. However, these three fungicides were in the same grouping as Treatment 11 (wounded, inoculated, untreated check), so further testing may be required as to why this occurred. MERTECT SC (Treatment 1), the industry standard, did not suppress FDR development well at all, as its DS rating was 11.09%, whereas the wounded, inoculated, untreated check was only 6.48%. The FDR penetration depth ratings only showed similar trends as the DS% and DI% ratings.

Trial 2- Russet Burbank cv. Results (Table 3)

R. Burbank generally had lesser dry rot disease resistance than Yukon Gold in this trial. The DS% data failed the Bartlett's Test of Homogeneity, so the Duncan's grouping could not be reported. Trends only suggest that the INSPIRE, STADIUM (60% and label rates) *may* be effective in preventing FDR in stored potatoes. However, the DI% results were very highly significant ($p \leq 0.05$) and proved that the two STADIUM treatments worked the best in dry rot control. In fact, they were had much lower results than Mertect and this time, the wounded, inoculated, untreated check, unlike the Yukon Gold cv. Again, both the wounded and unwounded, untreated and non-inoculated checks (Treatments 12 and 13) had absolutely no FDR present. The same pattern was demonstrated with the depth of FDR tuber penetration results.

CONCLUSIONS

Trial 1 – Yukon Gold (cv.):

STADIUM applied at 60% of the label rate, INSPIRE + SCHOLAR +QUADRIS tank mix and STADIUM (Treatment 7: label rate) may be possible alternatives to using MERTECT but weren't statistically different from the wounded, inoculated, untreated check.

Trial 2- Russet Burbank (cv.)

To control FDR in R. Burbank stored tubers, data from this trial suggested that STADIUM applied, at either 60 % or 100% of the label rate, showed great potential for dry rot control in stored potatoes.

Table 1. Chemical treatments and checks used for both Trials 1 and 2 for an AAFC potato storage experiment that was performed at Charlottetown, PEI in 2013.

Treatment number	Treatment name	Chemical application rates[1]
1	Mertect SC Fungicide	7.5 L Mertect per 170 L of water
2	Storox	100 mL StorOx per 10 L of water (1:100)
3	Confine	100 mL Confine per 0.43 L of water (1:4.3)
4	Bio-Save ® 10LP	500 g of Bio-Save per 100 L of water
5	Inspire	44 mL Inspire 250SC in 210 mL water
6	Tank mix #1: Inspire + Scholar + Quadris	1.44 mL Inspire 250SC + 2 mL Scholar 230SC + 2 mL Quadris 250SC in 210 mL water
7	Premix #1: Stadium A19432A (full rate)	3.3 mL A19432A in 210 mL water
8	Premix #2: Stadium A19432A (60% rate)	2.0 mL A19432A in 210 mL water
9	Phostrol	0.42 L in 2L water
10	Serenade CPB biofungicide	175 mL per 1000 kg. of potatoes
11	Wounded, untreated check (inoculated)	N/A
12	Wounded, untreated check (non-inoculated)	N/A
13	Unwounded, untreated check (non-inoculated)	

[1]Manufacturers label application rates for postharvest disease control in potato storages.

Table 2. Trial 1 fusarium dry rot disease severity (DS) and incidence (DI) and index of disease (ID) levels for postharvest Yukon Gold (cv.) tuber ratings performed at AAFC, Charlottetown, PEI in 2013.

Treatment number	Treatment name (*see Table 1 also*)	Dry rot DS (%)[1,2,3,6,7]	Dry rot DI (%)[1,3,4]	Depth of FDR penetration in tuber (mm)[1,5,7,8]
1	Mertect SC Fungicide	11.09 ab	82.00 a	16.00
2	Storox	8.65 bcd	75.58 ab	16.25
3	Confine	11.00 ab	85.83 a	19.37
4	Bio-Save ® 10LP	10.33 abc	83.00 a	11.88
5	Inspire	8.25 bcd	73.00 ab	13.30
6	Tank mix #1: Inspire + Scholar + Quadris	5.87de	61.00 b	9.56
7	Premix #1: Stadium A19432A (full rate)	7.10 cde	60.00 b	10.94
8	Premix #2: Stadium A19432A (60% rate)	5.15 e	61.00 b	9.82
9	Phostrol	11.45 ab	85.00 a	18.78
10	Serenade CPB biofungicide	13.34 a	84.00 a	20.37
11	Wounded, untreated check (inoculated)	6.48 de	63.00 b	11.40
12	Wounded, untreated check (non-inoculated)	0.00 f	0.00 c	0.00
13	Unwounded, untreated check (non-inoculated)	0.00 f	0.00 c	0.00
ANOVA (P≤0.05)		0.0001	0.0001	0.0001
LSD (P=0.05)[6]		---	17.15	5.11
Coefficient of variation		13.54	19.18	29.47

[1]Results are the means of four replications.
[2]Disease severity (DS) means are the percent (%) of the tuber surface showing dry rot lesions
[3]Data were significantly different according to Duncan's Multiple Range test at P ≤ 0.05.
[4]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms and raw data were used
[5]Depth of FDR penetration was calculated as the extent of internal necrosis by dry rot and was measured with Vernier callipers (in mm) and raw data were used.
[6]Least significant differences were not calculated for transformed data.
[7]Square root-transformed data were used for analysis.
[8]Data failed the Bartlett's test of homogeneity, so the Duncan Multiple Range test letter gradings couldn't be used.

Table 3. Trial 2 fusarium dry rot disease severity (DS), incidence (DI) and index of disease (ID) levels for postharvest Russet Burbank (cv.) tuber ratings performed at AAFC, Charlottetown, PEI in 2013.

Treatment number	Treatment name (*see Table 1 also*)	Dry rot DS (%)[1,2,3,4]	Dry rot DI (%)[1,5,6]	Depth of FDR penetration in tuber (%)[1,4,6,7]
1	Mertect SC Fungicide	27.44	84.43 a	22.20 ab
2	Storox	34.86	97.22 a	28.08 a
3	Confine	25.37	91.92 a	23.04 ab
4	Bio-Save ® 10LP	31.18	94.00 a	22.38 ab
5	Inspire	17.08	81.73 ab	17.95 bc
6	Tank mix #1: Inspire + Scholar + Quadris	26.45	66.21 bc	18.18 bc
7	Premix #1: Stadium A19432A (full rate)	14.44	60.25 c	15.47 c
8	Premix #2: Stadium A19432A (60% rate)	16.16	58.36 c	15.61 c
9	Phostrol	22.50	84.69 a	26.41 a
10	Serenade CPB biofungicide	32.01	97.77 a	26.04 a
11	Wounded, untreated check (inoculated)	21.49	93.17 a	26.33 a
12	Wounded, untreated check (non-inoculated)	0.00	0.00 d	0.00 d
13	Unwounded, untreated check (non-inoculated)	0.00	0.00 d	0.00 d
ANOVA (P≤0.05)		0.0001	0.0001	0.0001
LSD (P=0.05)[8]		---	16.03	5.54
Coefficient of variation		20.88	16.03	20.85

[1]Results are the means of four replications.
[2]Disease severity (DS) means are the percent (%) of the tuber surface showing dry rot lesions.
[3]Data failed the Bartlett's test of homogeneity, so the Duncan Multiple Range test letter gradings couldn't be used.
[4]Square root-transformed data were used for analysis.
[5]Disease incidence (DI) means are based on the percentage of tubers evaluated per treatment that had dry rot symptoms and raw data were used for this statistical analysis.
[6]Data were significantly different according to Duncan's Multiple Range test at P ≤ 0.05.
[7]Depth of FDR penetration was calculated as the extent of internal necrosis by dry rot and was measured with Vernier callipers (in mm).
[8]Least significant differences were not calculated for transformed data.

SECTION 5: COMMERCIAL DISINFECTANT USAGE IN POTATO STORAGES

5-1 YEAR 1: 2012

PROJECT OBJECTIVES

The main objective of this trial was to evaluate five commercial detergent cleaners for their ability to eradicate Fusarium contamination from the types of hard surfaces that are typically found in potato storages and on potato-handling equipment.

RESEARCH PROTOCOL

MATERIALS

The detergent cleaners that were used in the storage in this report were Carbon-Ate, Ripper 1, Ripper-2, wet steam and a water control.

METHODS

Storage 1- Duchess, Alberta- area potato storage Bin 2 – Detergent Trial – Tables 1 and 2

At this storage unit **(Table 1)** on May 24, 2012 (prewash interval), five equal-sized strips were marked between the main doors for the treatments and the water check**.** Sterile sponges (Qualicum Scientific) in pre-labeled bags, containing 2 mL of phosphate buffer, were each used on a 225 cm^2 area for this and by using the supplied sterile gloves for each sponge, each strip was swabbed for all five treatments, with each used sponges sealed back into its bag. One swab per disinfectant or check were taken from the following surface sub-areas: galvanized steel wall, spray-on foam insulation, wood leaner, cement floor and wood trench cover **(Table 2).**

The bags were put into a portable cooler with an ice pack and were transported back to the Crop Diversification Centre South, Brooks, Alberta for processing. These coolers were placed into refrigerated Controlled Environment Storage rooms (5°C) until they were processed on May 30. On that day, acidified potato dextrose agar plates (PDA-A), 3M Total Plate Count (TPC) Petrifilm and 3M Yeast Molds (YM) Petrifilm were prelabeled for each sample as well as sterile 10 mL phosphate buffer test tubes.

A technologist added the one tuber of the buffer to a sample bag, it was then resealed and a Seward Stomacher blended the contents for 1 minute. The bag was aseptically opened and the contents were squeezed back into the 10^0 dilution tube so that there was 12 mL of liquid in it. This was serially diluted into four other tubes by using a 1 mL sterile pipet tip, so that the final dilution level was 1/10,000. 100 µL of each dilution was then pipetted with a sterile pipet tip again, onto PDA-A plates, using sterile pipet tips, with dilution plates then up to 1/1000. A disposable sterile L-spreader was then used to evenly coat the plate's surface. The plates were allowed to dry in the laminar flow hood for 1 hr. and then the groups of plates were placed into labelled poly bags that were left at RT until growth occurred ca. 5 days later and the colony forming units (CFUs) could be numerated. Concurrently, 1 mL of each dilution was pipetted onto the two labelled Petrifilm plates with the two provided spreading tools, as per the manufacturer's instructions. This was repeated with the remaining dilutions up to a 1/10,000 dilution. These were placed into a 35°C incubator and the PCA plates were enumerated at 2 days and the YM plates 5 days later. If the PCA plates couldn't be counted at the specified time, they were placed into a freezer until they could be viewed. This process was then repeated on May 30 after the storage was pressure-washed and then had the actual cleaners applied.

The PDA-A plates were evaluated by choosing plates for each treatment that had a range of 20-200 colonies. A technologist counted the colonies by using a Quebec Colony Counter and reflected light on a dissecting microscope. *Fusarium spp.* colonies were separately counted and recorded for the purpose of this project. For calculating the results, the results were multiplied by the various dilution factors on an

MS Excel spreadsheet. The plate values per treatment were averaged to arrive at the arithmetic mean value and expressed as colony forming units (cfu) /mL. and then were converted to log means, where the log of each value + 1 was calculated. The Log reduction from the pre-cleaning to the post-cleaning intervals was consequently calculated. Although the PCA and YM plates were also enumerated, as *Fusarium spp*. couldn't be counted on them, these readings are not included on this report.

RESULTS

Storage 1- Duchess, Alberta- area potato storage Bin 2 (Table 2)

Table 2 shows log reductions for both the total growth on the PDA-A culture plates as well as for *Fusarium spp*. only. Log reduction values between 2.0 (99% removal) and 3.0 (99.9% removal) would generally be acceptable for storages. Results of samples taken from five surfaces of potato storage Bin 2 treated with four storage cleaners and a check showed that 76% of the samples had a log reduction of 2.00 or greater, so the cleaners appeared to be very effective overall. This data suggested that Carbon-Ate performed the best, except when applied to the wood plenum. This was followed by wet steam, where all of the results had a log reduction of >2.00. Ripper 1 didn't fare quite as well in this trial, as the wood leaner had a log reduction of 1.93 and actually, the water control appeared to work more effectively than the lowest treatment, Ripper 2. Fusarium only grew on the cement floor in the pre-clean interval for Carbon-Ate; however, after this cleaner was applied, this pathogen was eradicated.

Table 1: Layout of Storage 1: Duchess, Alberta- area potato storage Bin 2

Information Criteria	**Details**
Bin number	2
Storage end use	Chipping potatoes
Capacity (tons)	500 tons
Dimensions (length, width, height)	94 × 19.5 × 15 ft deep
Number of bins and sizes	11 bins
Building frame (wood, steel, etc.)	Wood frame, galvanized steel walls
Interior wall finishes (wood, metal, etc.)	Galvanized
Type(s) of insulation on walls and foundation	Spray-on foam at base of wall
Type of floor (wood, concrete, etc.)	Concrete with centre plenum
Type(s) of plenums (galvanized steel, etc.)	Wood with two leaners on side and centre
Type of humidification system	Jaybird foggers
Method(s) used to clean storage	Sweep into Bobcat and pump of plenum
On-farm food safety program (yes/no)	In the process of implementing

Table 2. Storage 1 cleaners, sampled surfaces with PDA-A total plate and fusarium only count log means for pre- and post-cleaners used at Bin 2, near Duchess Alberta. This also shows the log reductions per treatment.

Treatment	Surface	Log means pre-clean (cfu/mL)	Log means post-clean (cfu/mL)	Log reduction means (cfu/mL)	Fusarium log means pre-clean (cfu/mL)	Fusarium Log means post-clean (cfu/mL)	Fusarium Log reduction means (cfu/mL)
Wet Steam	Steel Wall	3.20	0.64	2.57	0.00	0.00	0.00
Wet Steam	Foam border	4.11	1.59	2.52	0.00	0.00	0.00
Wet Steam	Wood Leaner	4.07	1.16	2.91	0.00	0.00	0.00
Wet Steam	Cement Floor	4.13	1.44	2.69	0.00	0.00	0.00
Wet Steam	Wood Plenum	4.44	2.20	2.24	0.00	0.00	0.00
Carbon-Ate	Steel Wall	2.61	0.00	2.61	0.00	0.00	0.00
Carbon-Ate	Foam border	3.94	1.29	2.66	0.00	0.00	0.00
Carbon-Ate	Wood Leaner	4.44	1.10	3.34	0.00	0.00	0.00
Carbon-Ate	Cement Floor	4.10	0.97	3.13	2.70	0.00	2.70
Carbon-Ate	Wood Plenum	4.22	2.34	1.87	0.00	0.00	0.00
Ripper-1	Steel Wall	2.89	0.64	2.25	0.00	0.00	0.00
Ripper-1	Foam border	4.22	1.16	3.06	0.00	0.00	0.00
Ripper-1	Wood Leaner	4.29	2.36	1.93	0.00	0.00	0.00
Ripper-1	Cement Floor	4.18	1.44	2.73	0.00	0.00	0.00
Ripper-1	Wood Plenum	3.95	1.39	2.56	0.00	0.00	0.00
Ripper-2	Steel Wall	3.40	0.43	2.98	0.00	0.00	0.00
Ripper-2	Foam border	4.00	2.35	1.65	0.00	0.00	0.00
Ripper-2	Wood Leaner	3.90	0.43	3.48	0.00	0.00	0.00
Ripper-2	Cement Floor	3.29	1.96	1.34	0.00	0.00	0.00
Ripper-2	Wood Plenum	3.50	2.14	1.35	0.00	0.00	0.00
Water (control)	Steel Wall	2.63	0.43	2.21	0.00	0.00	0.00
Water (control)	Foam border	4.31	1.44	2.87	0.00	0.00	0.00
Water (control)	Wood Leaner	3.15	0.88	2.27	0.00	0.00	0.00
Water (control)	Cement Floor	3.79	2.30	1.48	0.00	0.00	0.00
Water (control)	Wood Plenum	3.79	1.29	2.51	0.00	0.00	0.00

SECTION 6: TECHNOLOGY TRANSFER AND DEMONSTRATIONS

6-1 YEAR 1: 2011-12

6-2 YEAR 2: 2012-13

6-3 YEAR 3: 2013

Best-Management Practices for the Control of Fusarium Dry Rot on Potatoes in Storage

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Causal agent: *Fusarium sambucinum* (teleomorph = *Gibberella pulicaris*) and other *Fusarium* species
Symptoms: Early symptoms include darkened depression on tuber surfaces. The skin becomes wrinkled in concentric rings as tissues become desiccated due to the dry rot. Internal tissues are darkened by necrosis shaded from light to dark chocolate brown and even black (Figure 1). The disease is common at points of injury on the tubers such as cuts in the skin or weakened skin found at bruises. Late infections will have fungal signs such as yellow to white to pink fungal mycelia and spores. Seed-piece decay will appear as blanks or misses in the potato stand (Figure 1). During the growing season, some *Fusarium* species will invade and block the vascular system of the stems, leading to yellowing and wilting. This disease is called Fusarium wilt and may be part of the Early Dying Complex on potatoes in Alberta.

Figure 1. Fusarium disease symptoms on potato including dry rot on stored potato tubers (upper left and lower right) and reduced potato stand due to seed piece decay (upper right and lower left)

Best Management Practices

1. **Cultural Control**

The dry rot pathogen cannot invade intact, healthy tubers. Therefore, the primary method for management of dry rot in storages is to avoid cuts, bruises, or other mechanical injuries to tubers during harvesting and going into storage. Dry rot can be significantly reduced and even halted by use of the following cultural methods:

a. Employ good crop rotation practices to avoid the build-up of *F. sambucinum* in the soil. Potatoes should be planted only once every four years in the same field. Suitable rotational crops include cereal, oilseed, pulse and forage crops.
b. Unfortunately, *Fusarium*-resistant potato cultivars are not available; however, some are more tolerant to dry rot than others. See Figures1 and 2 under “Varietal Resistance” below for a summary of dry rot sensitivities for a limited selection of potato cultivars based on screening trials carried out at CDC South in 2011 and 2012.
c. Control seed piece decay by using certified seed, free of *F. sambucinum*, and treated with a registered seed treatment that includes *Fusarium* on the label to establish healthy potato crops and control seed-piece decay. Seed piece decay can be an important source of dry rot pathogens in the subsequent storage of harvested tubers.
d. Where possible, avoid irrigating prior to emergence to avoid creating a soil environment that may encourage *F. sambucinum* infection of the seed tuber.
e. Harvest tubers after vines are dead and the skin is mature. Tubers with well-developed skins are more tolerant of bruising during harvesting and post-harvest handing.
f. When possible, harvest tubers when their core temperatures are less than 10°C, but avoid harvesting cold tubers, which may be prone to shatter cracking and bruising.
g. Adjust harvesting and handling equipment carefully to avoid unnecessary tuber injury
    i. Avoid dropping tubers from heights over 6 inches wherever possible
    ii. Make the avoidance of bruising and injury a priority at harvest time
    iii. When making modifications to harvesters or other equipment, consider potential effect(s) on tuber injury
    iv. Adjust harvest speed to match soil conditions
    v. Minimize or avoid tangling and plugging problems caused by wet, tough vines
    vi. Avoid having tubers bumping one another at the harvester blade and/or on chains
    vii. Avoid pinching tubers by replacing old chains prone to excessive flex
    viii. Keep chains tight to avoid bouncing
    ix. Run chains slower than the forward speed of the harvester
    x. Do not use severe shaking to remove or to break up dirt clods
    xi. Install guides or belting to divert tubers away from link hooks and bare ends
    xii. Adjust harvesting/chain speeds to give a uniform distribution of tubers over the width of chains
    xiii. Carefully regulate boom height to minimize drops onto hard surfaces below
    xiv. Tarp loaded trucks to avoid sun and wind damage that can prevent suberization
h. Minimize dry rot potential at the storage site by:
    i. Cleaning and disinfecting equipment and bins prior to handling and receiving tubers to minimize the carryover of *Fusarium* spores to new tubers going into storage
    ii. Train storage personnel on proper procedures to avoid tuber damage during bin filling
    iii. Ensure that potato handling surfaces are rubberized or padded on every surface used for handling tubers
    iv. If tubers are harvested in wet conditions, allow them to dry before bringing them into storage
    v. See that bin filling equipment has adequate capacity to allow removal of dirt, debris and under-grade material without excessive speeds

vi. Use step-piling when placing the tubers into storage
vii. If necessary, apply a registered post-harvest chemical fungicide on tubers going into storage (see more information below under 'Chemical Control')

i. Store tubers in conditions that promote rapid wound healing for 10 to 14 days. Cold storages are ineffective if proper conditioning is not performed. Conditions for good skin set and wound healing include:
   i. Plenty of air circulation
   ii. Plenty of humidity (90% to 95%); however, avoid free moisture on tuber surface
   iii. Warm temperatures (13°C to 18°C)
j. After wound healing, decrease storage temperatures by 0.5°C per day to reach the desired long-term storage temperature
k. Ideally, store tubers long-term at temperatures lower than 4°C and do not allow free moisture to accumulate on tuber surfaces. Use to 2ºC – 5ºC for fresh-market/table potatoes or 10ºC for processing potatoes
l. Prevent conditions that block airflow through the pile and around individual tubers (dirt, debris, etc).

2. Chemical Control of Dry Rot in Stored Potatoes

a. A number of tuber-applied chemical and biological post-harvest fungicides are registered for the control of dry rot in stored potatoes. In addition, several storage disinfectants are available for sanitizing wall, floors, plenums, handling equipment, etc. between crops.

   Fungicides
   - Thiabendazole (Mertect)
   - Hydrogen peroxide (Storox)
   - Bio-Save (*Pseudomonas syringae*)

   Check the most recent Alberta *Crop Protection* Guide for registered fungicides.

   Disinfectants
   - Chlorine-based compounds (Bleach)
   - Peroxide-based compounds (SaniDate)
   - Quaternary ammonium-based compounds (General Storage Disinfectant)

b. Fungicide resistance, and cross-resistance, has been a major problem with the use of thiabendazole (Mertect) in Alberta and some other Canadian provinces. Thiabendazole will only be effective in storages that do not have resistant populations of *F. sambucinum*.
c. Ensure that fungicide application equipment provides adequate coverage to all tuber surfaces.
d. Follow label directions and avoid unnecessary, or unsafe worker exposures to chemicals.

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