PGA RESEARCH ARCHIVE

DIESEASES

POTATO GROWERS OF ALBERTA

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POTATO DEVELOPMENT INC.

FUNDING APPLICATION

Early blight disease of Potatoes (*Alternaria solani*): characterization of pathogen population and host-pathogen interaction.

Submitted by

P.S. Bains, J.D. Holley and J. Calpas

January 26, 2000

POTATO DEVELOPMENT INC.
FUNDING APPLICATION - SUMMARY

PROJECT TITLE: Early blight disease of Potatoes (*Alternaria solani*): characterization of pathogen population and host-pathogen interaction.

REASON FOR PROJECT: Early blight disease of potatoes *(Alternaria solani* Sorauer) causes significant risk to potato productivity in the field and tuber quality in the storage. The disease has always been present in Alberta but it seems that in recent years the disease has become prevalent even when the growers have started spraying fungicides in recent years to control the late blight disease of potatoes. Majority of the fungicides used to control late blight, also provide protection from early blight. The question, therefore is why early blight has started causing significant economic losses to Alberta potato growers? Increased disease severity may be due to the development of more aggressive isolates of the pathogen, development of insensitivity in the pathogen population to registered fungicide(s), the planting of potato cultivars more susceptible to the pathogen, and/or the existing potato production methods which are more conducive for the disease development. Higher aggressiveness of the isolates might be due to the adaptation of pathogen population to warm drier weather, higher growth rate, higher levels of spore production and spore germination, and/or other physiological changes. Knowledge of comparative aggressiveness of the pathogen population, which might be correlated to the geographical region and/or to potato cultivars, will help to manage the disease effectively. No such study on early blight of potato pathogen population in Alberta has been conducted in the last ,at least, 25 years. Present production methods might also be encouraging the development of early blight. Continuous Pivot Irrigation creates cycles of wet and dry environment and causes leaching of nitrogen, both these conditions are very suitable for early blight development. Furthermore, with the announcements of two new processing plants, Alberta potato acerage is going to go up considerably in the coming 2-3 years. Increased acerage will reduce the physical separation of potato fields and in some cases may also reduce the rotation time, and inturn create an environment conducive for spread of many diseases including early blight.

PROJECT PLAN: The research plan includes collection of isolates of *A. solani* from infected potato plants collected from all potato growing areas of Alberta, and collection of information on the cultural practices (irrigation method, fertilization, variety, rotation, soil type etc.). The isolates will be evaluated for variations in pathogenicity, mycelial growth, spore production, and spore germination and for the development of resistance in the pathogen population to the fungicide(s) registered to control this disease. It will include the evaluation of efficacy of any other fungicide which might be available from a company for potential registration for this disease. Genetic analyses of the isolates showing differential pathogenicity and fungicide sensitivity will be conducted by random polymorphic DNA (RAPD) which will help in the development of probe(s), a valuable tool for diseases management. Field susceptibility of potato cultivars grown in Alberta to natural early blight infection and to inoculation with *A. solani.* isolates will be determined by conducting small plot experiments at four locations. Knowledge of cultivar susceptibility is a major factor in devising early blight management schedule.

BENEFITS TO ALBERTA'S POTATO INDUSTRY: The results of this project will help to understand the presence and distribution of differential levels of pathogenicity and sensitivity to fungicide(s) in pathogen population. It will also determine the levels of susceptibility of various cultivars to the existing pathogen population. Knowledge of susceptibilities of the cultivars, relative pathogenicities and fungicide sensitivities of Alberta isolates of the pathogen is very crucial for making the disease management decisions. Probe(s) which might be developed from genetic analyses of pathogen isolates depicting differential pathogenicity and fungicide sensitivity will be an extremely useful tool for early blight management.As a package, the information generated will be very helpful to reduce the losses caused by this disease and inturn increase profitability of the industry.

DURATION OF PROJECT: July 1999 to November 2001.

FINANCIAL INFORMATION:

	This year only	Total all years
Project cost	$25,198	$59,270
Amount requested from PDI	$12,599	$27,635
Amount from other sources	$12,599	$31,635

PRINCIPAL APPLICATION INFORMATION:

Dr. Piara Bains 403 415 2302

Principal applicant's name Phone

Alberta Agriculture Food & Rural Development

Research agency or company

Crop Diversification Centre North, R.R. #6, Edmonton AB T5B 4K3
Crop Diversification Centre South, SS #4, Brooks AB T1R 1E6

Location of research project Postal code

Progress To Date (Renewals only)

In August 1999, 104 potato fields from the northern, central and southern potato growing regions of Alberta were examined for evidence of brown lesions with concentric rings characteristic of early blight, caused by *Alternaria solani*, Sorauer. Isolates of *A. solani* recovered from diseased leaves from each site confirmed visual observations. Fields with a few small lesions on isolated plants were categorized as having low, fields with large numbers of lesions on many plants as having moderate, and fields where whole leaves and stems were completely necrotic as having high levels of the disease. Observations from the survey are summarized in table 1.

Pure cultures of *A. solani* have been isolated and worked out conditions for production of large number of spores for *in vitro* and greenhouse experiments. Determinations of differentiations in cultural characteristics and sensitivities of the isolates to various fungicides are in progress.

RESULTS AND COMMENTS: The disease was found on all potato cultivars and was present at different severities (Table 1). The disease severity observations suggested that majority (61%) of the fields planted with cultivar Russet Burbank developed low levels of the disease. Differences in disease severity in different fields planted with the same cultivar may have been caused by variations in levels of inoculum, plant maturity, nutritional status, local environmental conditions, and production methods including application of fungicides and irrigation. More than 90% of the fields surveyed in this study received at least one fungicide application, majority of the fields though received more than one.

Table 1. Severity of early blight on different potato cultivars in Alberta.

	Number of fields in various severity categories		
Cultivar*	Low	Moderate	High
Norland	1	2	1
Russet Burbank	32	12	8
Russet Norkotah	2	5	4
Shepody	0	3	2
Snowdon	2	4	1
Bintje	2	0	3
Niska	0	2	2

* Cultivars with minimum of four fields surveyed are included in this table.

ALBERTA AGRICULTURAL RESEARCH INSTITUTE (AARI)
MATCHING GRANTS PROGRAM APPLICATION - 2000/2001

Office Use Only: Date Received _____ Application Number _____

1. ***Project Title (maximum 15 words)*** Early blight disease of Potatoes (*Alternaria solani*): characterization of pathogen population and host-pathogen interaction.

2. ***Commencement and Duration of Project***

Expected commencement date for this request for funding April 2000

Anticipated duration of project is 2.5 year(s) Is this a renewal application? Yes

If yes, state the first year the project was funded 199 and the current project # 99M524

3. ***Choice of Research Committee***

Beef & Dairy		Pork, Poultry, Sheep & Other Livestock	
Cereals & Oilseeds		Forage, Pulse, Vegetable & Other Crops	X
Resource Conservation		Policy, Economics & Marketing	

4. ***Principal Researcher***

Name	Dr. P. S. Bains	Mailing Address	RR #6, 17507 Fort Road
Title	Research Scientist		Edmonton AB T5B 4K3
Organization	Crop Diversification Centre N.		
Department	Alberta Agriculture Food &	Telephone #	403 415 2302
	Rural Development	Fax #	403 427 6096

5. ***Co-applicants***

Name	Dr. J.D. Holley	Mailing Address	SS #4, Brooks AB T1R 1E6
Title	Post-harvest Scientist		
Organization	Crop Diversification Centre S.		
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	Rural Development	Fax #	403 362 2554
Name	Mr. J. Calpas	Mailing Address	SS #4, Brooks AB T1R 1E6
Title	Greenhouse Specialist		
Organization	Crop Diversification Centre S.		
Department	Alberta Agriculture Food &	Telephone #	403 362 1312
	Rural Development	Fax #	403 362 2554

6. *Approval of Employer(s)*

This application is submitted, and will be evaluated, under the authority of the Alberta Agricultural Research Institute Act and the Farming for the Future Matching Grants Program Guidelines. As representatives of the applicants' employing organization, the undersigned hereby verify acceptance of the terms and conditions specified in the guidelines. They further agree to allow the applicant to devote time to the project and use the facilities of the organization to conduct the proposed research. **Please print or type name on the first line and sign in blue ink (see block 6 instructions for required signatures).** This personal information is being collected to confirm your approval for a research application being submitted to AARI. It is subject to the provisions of the Freedom of Information and Protection of Privacy Act. If you have any questions about the collection, contact Dr. Yilma Teklemariam, Research Manager, AARI, #202, 7000 - 113 Street, Edmonton, AB, T6H 5T6.

Principal Researcher's Organization

A. Name Dr. R.J. Howard Title Leader Horticulture Unit & Director, CDC South, Brooks

Signature R.J. Howard Date Jan. 24'00

B. Name Title

Signature Date

C. Name Title

Signature Date

Co-applicant's Organization

Co-applicant's Name Dr. J.D. Holley

A. Name Dr. S. Blade Title Director, CDC North, Edmonton

Signature Date Jan. 25/2000

B. Name Title

Signature Date

C. Name Title

Signature Date

Co-applicant's Organization

Co-applicant's Name Mr. J. Calpas

A. Name Dr. R.J. Howard Title Leader Horticulture Unit & Director, CDC South, Brooks

Signature R.J. Howard Date Jan. 24'00

B. Name Title

Signature Date

C. Name Title

8. *Outline of Research Proposal (one page may be added to this block if required)*

A. Background and Key Results Expected

i. Background

Early blight disease of potatoes *(Alternaria solani* Sorauer) causes significant risk to potato productivity in the field and tuber quality in the storage. The pathogen causes dark brown to black circular lesions on leaves and stems. The lesions are usually concentric (bulls eye) and may become angular if these are retarded by a large leaf vein. The disease has always been present in Alberta but in recent years it has been observed to cause significant economic losses in some fields. The irony is that the disease seems to has become prevalent even when the growers have started spraying fungicides in recent years to control the late blight disease of potatoes. Majority of the fungicides used to control late blight, also provide protection from early blight. The question, therefore is why early blight has started causing significant economic losses to Alberta potato growers?

Increased disease severity may be due to the development of more aggressive isolates of the pathogen, development of insensitivity in the pathogen population to registered fungicide(s), the planting of potato cultivars more susceptible to the pathogen, and/or the existing potato production methods which are more conducive for the disease development. Higher aggressiveness of the isolates might be due to the adaptation of pathogen population to warm drier weather, higher growth rate, higher levels of spore production and spore germination, and/or other physiological changes. Knowledge of comparative aggressiveness of the pathogen population, which might be correlated to the geographical region and/or to potato cultivars, will help to manage the disease effectively. Development of higher aggressiveness in a pathogen population is well documented for late blight of potato pathogen, *Phytophthora infestans*. Present production methods might also be encouraging the development of early blight. Continuous Pivot Irrigation creates cycles of wet and dry environment and causes leaching of nitrogen, both these conditions are very suitable for early blight development. Sub-optimal level of nitrogen fertilizer has been indicated to be a factor for the development of this disease (Mackenzie, 1988). Furthermore, with the announcements of two new processing plants, Alberta potato acerage is going to go up considerably in the coming 2-3 years. Increased acerage will reduce the physical separation of potato fields and in some cases may also reduce the rotation time, and inturn create an environment conducive for spread of many diseases including early blight.

Isolates of some plant pathogens have been reported to develop resistance to fungicides eg. Late blight of potato pathogen to metalaxyl (Goodwin et al., 1996), fusarium dry rot pathogen, *Fusarium sambucinum*, to thiabendazole (Mertect) (Hide *et al.*, 1992; Kawchuk *et al.* 1994), and silver scurf of potato pathogen, *Helminthosporium solani*, to Mertect (Bains et al. 1996). It is likely that isolates of *A. solani* may have developed some resistance to the registered fungicide(s). Knowledge of resistance development in a pathogen population to a fungicide(s) is very crucial for effective fungicidal control of the disease caused by that pathogen. Genetic analyses of the isolates showing differential pathogenicity and fungicide sensitivity will be conducted by random polymorphic DNA (RAPD) for development of probe(s), a valuable tool for diseases management. Determination of genetic differences between Fungicide sensitivity and insensitivity and variations in pathogenicity will be useful for mass characterization of the pathogen population and disease management decisions. No such study on early blight of potato pathogen population in Alberta has been conducted in the last ,at least, 25 years.

Control of early blight is very much dependent on the identification of the 'critical period', which is defined by the concurrence presence of sufficient amounts of inoculum of the pathogen, favourable environment, and susceptible host, it pinpoints the initiation of the spray schedule of protectant fungicides (Pscheidt & Stevenson, 1988; Zadoks & Shein, 1979). Knowledge of the susceptibility of the cultivars, therefore is important to determine the timing of the first fungicide spray. All early blight forecasting systems require similar information for fungicide spray schedule determination. Reaction of potato cultivars to *A. solani*, however is not sufficiently well characterized (Pelletier & Fry, 1990). Generally, early-maturing cultivars are more susceptible to early blight pathogen than the late-maturing cultivars (Douglas & Pavek, 1972; Harrison *et al.* 1965; Johanson & Thurston, 1990), and older leaves are more susceptible than the younger leaves (Sinden *et al.* 1973). All potato cultivars do not conform to this generalization, Buckskin, a very late-maturing cultivar was not the most resistant cultivar, and Hampton, a late-maturing cultivar was susceptible and was ranked with early- and medium-maturing cultivars (Christ, 1991). Other factors such as incubation period, lesion expansion rate, and spore production

ability may explain the differences in cultivar resistances observed in the field (Holley *et al.* 1983; Pelletier & Fry, 1989). Susceptibility differences as observed by disease progress are observed within each maturity group and it is possible to select least susceptible cultivars or breeding lines in each maturity group (Stevenson, 1994). Knowledge of reactions of potato cultivars to the local pathogen population, therefore is very critical for fungicide spray schedule.

ii. Key Results Expected (for renewal projects, include all changes or modifications to original expectations, citing reasons)

Overall objective of the project is to manage the disease to the level that it is not of any economic importance to potato growers of Alberta. Increases in the incidence and severity of the disease in recent years may be due to any or combination of the following reasons: a shift in the virulence of the pathogen population, planting of potato cultivars susceptible to the existing pathogen population, development of insensitivity in the pathogen population to the presently registered fungicides for control of this disease. It is expected that the results of studies of biology of the pathogen, genetic differences in pathogen population for pathogenicity and sensitivity to the fungicide(s), and susceptibility of potato cultivars will provide a clearer picture of early blight development in Alberta and inturn help for effective management of the disease. This will be accomplished by the following objectives.

Objectives:

1. To collect isolates of *A. solani* from infected potato plants collected from all potato growing areas of Alberta, and to collect information on the cultural practices (irrigation method, fertilization, variety, rotation, soil type etc.)
2. To test the isolates for variations in pathogenicity, mycelial growth, spore production, and spore germination.
3. To determine the development of resistance in the pathogen population to the fungicide(s) registered to control this disease: test the sensitivity of the isolates to the registered fungicides (contact, systemic) and any other fungicide available from companies for potential registration for this disease.
4. Genetic analyses of *A. solani* isolates sensitive and insensitive to fungicide(s) and showing variations in pathogenicity.
5. To determine the susceptibility of potato cultivars grown in Alberta to *A. solani*.

B. Biotechnology Related Proposals

i. Does this proposal involve biotechnology research? Yes _____ No __X__

If yes, state any potential adverse impact the project results may have on:

- food safety and human health:

- environmental sustainability:

ii. Does the research involve transfer of DNA between unrelated organisms? Yes _____ No _____

If yes, state:

- the common name of the source of the genetic material:

- the Latin name:

C. Expected Industry Impact/Benefits of the Project

With the announcements of two new processing plants, Alberta potato industry is going to double in value, an increase of millions of dollars. It is expected that the acerage of potatoes will increase from 26,000 to about 50, 000. This is going to reduce the physical separation of potato fields and in some cases may also reduce the rotation time, and inturn creating an environment conducive for spread of many diseases eg. early blight. The disease has always been present in Alberta but in recent years there has been an increase in its severity which is also roughly coinciding with increased use of fungicides that control this disease. The fungicides were sprayed for late blight but are also effective against this disease. The results of this project will help to understand the presence and distribution of differential levels of pathogenicity and sensitivity to fungicide(s) in pathogen population. Genetic analyses of *A. solani* isolates sensitive and insensitive to fungicide(s) and those showing variations in pathogenicity will help to develop probe(s) for analyses of these characteristics in pathogen population for effective management of the disease. It will also determine the levels of susceptibility of various cultivars to the existing pathogen population. The information generated will help to manage the disease effectively and increase profits for the industry.

E. Technology Transfer Plan

The results obtained from the project will be presented to the industry at the annual, area, and breakfast meetings. The results will be published in the industry newsletter (The Common Tater) and in a refereed journal. Presentations will also be made at scientific meetings.

E. Research Plan

Alberta isolates of Alternaria solani. Large number of isolates of the pathogen will be isolated from naturally infected potato plants collected from all potato growing areas of Alberta (Edmonton, Lacombe, and Taber Vauxhall areas). Infected tissues will be surface sterilized and incubated in a moist chamber for 4 days. Single spore isolations will be made onto V8 juice medium, grown at 21 C for 7 days for maintenance, and at 4 C for long-term storage.

Growth characteristics of *A. solani* isolates.
Radial growth: A 4 mm plug from a 7-day-old colony of an isolate will be placed in the centre of a petrie plate containing V8 juice agar medium. The radial growth measurement (average of two diameters measured at 90^0 to each other minus 4 and divided by 2) will be taken after 7 days of incubation at 21 C with 12 hour photoperiod. The experiment will be conducted with six replications of one plate each and will be repeated at least once. The data will be statistically analysed for differences in rate of growth.

Production and germination of spores of A. solani isolates: The isolates of *A. solani* will be compared for their spore production and spore germination capabilities using the following procedure. For spore production, the isolates will be grown on V8 juice agar medium containing 0.004% Rose Bengal (Bains and Tewari, 1987), on water agar at 21 C with 12 hour photoperiod, or on potato dextrose agar medium until it reaches the edge of the plate and then exposed to ultra-violet radiation to induce sporulation. Five 4 mm plugs from a 7-day-old colony will be transferred into 2 ml of sterile distilled water containing five drops of Tween 20 per 100 ml of water, vortexed for 15 seconds, passed through a double layer of cheesecloth, and counted number of spores per ml using a hemacytometer. A 100 µl aliquot of the spore suspension will be spread on V8 juice agar medium in a petrie dish and incubated as described previously. Percent germination of spores will be determined after 24 hours of incubation. The experiments will be conducted with six replications of one plate each and will be repeated at least once. The data will be statistically analysed for differences in production and germination of spores.

Evaluation of fungicides in controlling radial growth and spore germination of A. solani isolates. A 4 mm plug from the edge of an actively growing colony of an isolate will be placed in the centre of a petrie plate containing V8 juice agar medium modified with one of the test fungicides. The fungicides to be tested include chlorothalonil (Bravo), chlorothalonil + metalaxyl (Bravo/Ridomil), metalaxyl + mancozeb (Ridomil MZ 72WP), dimathomorph + mancozeb (Acrobat MZ), mancozeb (Dithane DG), mancozeb (Manzate 200), metiram (Polyram 16D, Polyram DF), menab (Dithane M-22), propamocarb hydrochloride + chlorothalonil (Tattoo C), and any other fungicide which may be available from a chemical company. The incubation and radial growth determination will be done as described previously. The data will be used to determine the development of insensitivity (LD_{50}) in the pathogen population, and to compare the efficacies of various fungicides in controlling the pathogen.

Comparative pathogenicity of isolates: Twenty isolates selected on the basis of their differences in growth characteristics and sensitivity to fungicide(s) will be tested for their comparative pathogenicity using greenhouse-grown Russet Burbank and Warba plants. The plants will be inoculated after they have flowered. Each isolate will be grown on potato dextrose agar medium until it reaches the edge of the plate. Cultures will then be exposed to ultra-violet radiation to induce sporulation, the spores will be washed off of the agar surface with sterile de-ionized water and concentration of spore suspension adjusted to 10^6 spores / ml. The spore suspension of each test isolate will be sprayed individually onto four test plants to leaf wetness. Control test plants will be sprayed with a solution of de-ionized water. Each sprayed plant will be enclosed in its own transparent poly-ethylene bag and allowed to incubate for 7 to 14 days in growth chambers at 20^0C . Each poly-ethylene bag will be opened once each day for 3 to 5 days and the plants sprayed gently with de-ionized water to leaf wetness. The plants will be examined for level of early blight infection at the end of the incubation period. In addition, four mature leaves from each plant will be examined for number and area of lesions on each leaf. Data will be statistically analyzed for comparative pathogenicity of the isolates.

Genetic analyses of isolates: Twenty five to 50 *A. solani* isolates selected on the basis of their differential pathogenicity and sensitivity to fungicide(s) will be analyzed for genetic relatedness by random polymorphic DNA (RAPD) method

(Welsh & McClelland, 1990). The isolates will be grown in pure culture and DNA will be extracted. The RAPD method will be used to generate genetic fingerprints for each isolate and the isolates will be grouped according to their genetic similarity. Any groupings will be examined and correlated to the differential pathogenicity and fungicide sensitivity exhibited by the same isolates. The investigation will determine whether highly pathogenic or fungicide insensitive isolates can be distinguished by DNA fingerprinting.

Comparative field susceptibility of potato cultivars: Comparative field susceptibility of Russet Burbank, Amisk, Shepody, Russet Norkotah, Atlantic, Alpha, Norland, and Snowden plants to early blight pathogen will be determined by planting the cultivars in small test plots in four randomized complete blocks at four locations. Each small plot will have three fifteen meter rows and will be separated from the adjacent plots by a guard row of Warba. Of four locations, two will be artificially inoculated after the trial has been planted. Inoculations will be done by using *A. solani*-infected potato plants. Greenhouse-grown Norland plants will be sprayed either with spores from a normal or an aggressive isolate of *A. solani*. Plants infected with one of the two strains will be transplanted one each in the middle of the centre row of each small plot at the first field location, whereas those infected with the second isolate at the second field location. The third trial location will be on a farm which has not had difficulties with abnormally high levels of early blight and the fourth on a farm that has had serious problems with early blight in the past.

Each row of the plots will be examined for evidence of early blight infection at regular intervals during the growing season and an estimate of the percentage of the canopy showing early blight lesions will be recorded. At the end of the season, readings from each observation time will be summarized for each row for each small plot. Percentages will be transformed into proportions for each row (50% transformed to 0.5) and the proportions (X) used to establish logit , i.e. ln {X/1-X} values. The logit values will be regressed against time elapsed in days from planting to establish apparent infection rates (r) for each row in each small plot. The r values from each experiment will be used to characterize the aggressiveness of the pathogen at each location. The field experiments will be repeated the following season.

F. Action Plan

i. 1999-2000

Determine cultural characteristics and fungicide sensitivities of the isolates (in progress)	January - February

ii. 2000-2001

Determine genotypic differences in isolates for differential pathogenicity and fungicide sensitivity using molecular techniques.	April - June
Determine comparative virulence of selected isolates.	April - August
Compare field susceptibilities of potato cultivars commonly grown in Alberta to the natural inoculum and to selected isolates of *A. solani*.	May - September
Analyse data	October

iii. 2001-2002

Comparative field susceptibility of potato cultivars commonly grown in Alberta.	May - September
Analyse data and prepare the final report.	October - November

G. Related Research Performed in Your Organization

At Crop Diversification Centre North, Plant Pathology laboratory is very much involved in research on potato diseases. The diseases of potatoes on which research is being conducted or was conducted in the near past include early blight (*Alternaria solani*) stem canker and black scurf (*Rhizoctonia solani*), silver scurf (*Helminthosporium solani*), fusarium dry rot (*Fusarium sambucinum*), and black leg (*Erwinia carotovora* subsp. *atroseptica*). The project on early blight included the development of rapid techniques for disease resistance screening. Apart from this a major project was conducted by PSB on a disease caused by *Alternaria brassicae* on canola, and by JDH on early blight of potato and is involved with determining reaction of advanced breeding lines of potato to early blight pathogen.

H. Related Research Performed in Other Agencies

Early blight is an economically important disease of potatoes. Many groups have worked on fungicidal control of the disease and reported significant improvements in total yield: 18-39% in Colorado (Harrison and Venette, 1970), 19-21% in Wisconsin (Stevenson *et al.*, 1990), and 56 - 92% in Minnesota (Teng & Bissonnette, 1985). Tebuconazole was reported to reduce lesion expansion rate compared to that of chlorothalonil (Shtienberg et al.,1996). Systemic fungicides (tebuconazole, difenoconazole) provided better control of the disease compared to that of protectant fungicides (chlorothalonil, mancozeb) only in some of the experiments conducted in Israel. Integrated use of systemic and protectant fungicides is important for resistance management. Protectant fungicides could be used at the beginning of the fungicide program and towards the end of the season a more effective control of the disease could be achieved by systemic fungicides ((Shtienberg *et al.*,1995;1996).

All most all early blight forecasting systems include susceptibility of potato cultivars to predict the timing of the first spray

to control the disease. Generally, early-maturing cultivars are more susceptible to early blight pathogen than the late-maturing cultivars (Douglas *et al*, 1972; Harrison *et al.* 1965; Johanson & Thurston, 1990). All potato cultivars, however do not conform to this generalization. Buckskin, a very late-maturing cultivar was not the most resistant cultivar, and Hampton, a late-maturing cultivar was susceptible and was ranked with early- and medium-maturing cultivars (Christ, 1991). Other factors such as incubation period, lesion expansion rate, and spore production ability may explain the differences in cultivar resistance observed in the field (Holley *et al.* 1983; Pelletier & Fry, 1989). Results of this study, differentiating *A. solani* isolates for various biological characteristics including pathogenicity and sensitivity to various fungicides and reactions of potato cultivars to the present population of the pathogen will help to understand and effectively control early blight of potato in Alberta.

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Teng, P.S. and H.L. Bissonnette. 1985. Estimating potato yield responses from chemical control of early blight in Minnesota. Am. Potato J. 62:595-606.

Welsh, J. and M. McClelland. 1990. Fingerprinting genomes using PCR with arbitrary primers. Nucl. Acids Res. 18: 7213-7218.

Zadoks, J.C. and R.D. Shein. 1979. Epidemiology and Plant Disease Management. Oxford University Press, Inc. New York. 427 pp.

9. *Budget and Manpower Needs for 1999-2000*

State the amount being requested in each category. One page may be added to this block to describe budget requests or any unusual items.

A. Manpower

	Name	Title	Person Years Required for 2000-2001	Amount Requested for 2000-2001
Principal Researcher	Dr. P. S. Bains	Research Scientist	0.15 PY	nil
Co-applicant (1)	Dr. J.D. Holley	Post-harvest Scientist	0.10 PY	nil
Co-applicant (2)	Mr. J. Calpas	Greenhouse Specialist	0.05 PY	nil
Professional				
Technical	Ms. May Yu	Research Technician	0.2 PY	nil
	Mr. H. Bennypaul	Research Technician	0.28 PY	$8,770
	To be hired	Research Technician	0.40 PY	$12,528
Graduate Students				
Other (specify)				
		TOTAL A		$21,298

Justification must be outlined below if more than a total of one person year is hired for the project or the amounts requested for technicians and graduate students exceed $32,000 and $15,000, respectively, per person per year:

Note: Principal researchers and co-applicants who are employees of public institutions are not eligible for wages, honoraria, or other compensation from project funds. However, they must note the amount of time they expect to devote to the project during the fiscal year. Applicants should carefully read the instructions before completing block 9.

B. Capital Assets (specify)

TOTAL B	

Justification for capital assets:

C. Supplies and Services

i. Travel (includes travel and accommodation costs)

a. **Project Travel**

Traveller's Name: P. Bains and/or Res. Tech, J. Holley and/or Res. Tech

Destination(s): Edmonton & Brooks areas

Number of Trips: 5 +5 = 10

Mode of Travel: Govt. Vehicle

Purpose: To collect early blight-infected samples

Cost: $600

b. **Conference Travel**

Traveller's Name: P. Bains

Destination(s): Plant pathology meeting

Number of Trips: 1

Mode of Travel: car/air

Purpose: To discuss and present the results of the project

Cost: $500

Justification is required for requests over $1,000:

ii. Materials/Supplies (if you have more than six items, please attach a list)

List Item	Quantity	$ Per Unit	Cost
Petrie plates, media, chemicals for molecular analyses of isolates, greenhouse supplies: pots, fertilizer, poly-ethylene bags, potting soil, and supplies for field experiments including potato seed, brown bags, and gunny sacks.			
		Total:	$2,800

iii. Computer Cost

Justification is required for requests over $300:

iv. Publication Cost (specifically for this project's results)

Justification is required if request is over $500:

v. Rentals and Leases

vi. Contract Personnel

TOTAL C

TOTAL A + B + C $25,198

D. Overhead Cost

Indicate how overhead costs were calculated (refer to instructions on page 7):

TOTAL AMOUNT REQUESTED FOR 2000-2001 (A + B + C + D) $25,198

10. Summary of Budgets for Anticipated Duration of Project

	RENEWALS A. Amount Approved in 1999-00	B. Amount Proposed for 2000-2001	C. Amount Proposed for 2001-2002	D. Amount Proposed for 2002-2003
Manpower	$25,608	$21,298	$3668	
Capital Assets				
Travel	$1500	$1,100	$500	
Materials/Supplies	$1,896	$2,800	$300	
Computer Cost				
Publication Cost			$500	
Rentals & Leases				
Contract Personnel				
Overhead Cost				
TOTAL	$29,004	$25,198	$5068	

E. Total amount for this request and future requests anticipated for this project $15,133

F. Total amount approved in previous years for this project $14,502

G. Approval in any year does not guarantee funding for subsequent years. Provide substantive reasons to justify proposals requesting multiple year funding.

The disease appears late in the season. First part of the project including collection of diseased samples and isolation of *A. solani* isolates will be done in fall of 1999. In winter of 1999/2000 growth characteristics and sensitivity experiments will be done followed by greenhouse testing of pathogenicity in the spring of 2000. Based on these results isolates of *A. solani* will be selected for genetic analyses to be conducted in the beginning of 2000/2001 project year and it will be followed by the field experiment. For confidence in field experiment data it is very important to have 2 year data. The experiment will be repeated in 2001/2002 project year.

11. *Funding Support Applied for, Granted, or Promised for This Project From Sources Other Than Alberta Government Departments, Agencies or Programs*

	Funding Agency	Amount of Grant in Cash	Amount of Grant In-kind	Total Amount Applied for, Granted or Promised	Date Grant Received or Expected
A.	Potato Development Inc. (Growers of Alberta)	$12,599		$12,599	March 1999
B.					
C.					
D.					
TOTAL AMOUNT REQUESTED FROM OTHER AGENCIES (A + B + C +D)				$12,599	

12. *Amount Requested From AARI*

Total amount requested from AARI for the 2000-2001 fiscal year is $_12,599_____. This amount should not exceed one half of the total amount requested for 2000-2001 or the difference between the total shown in block 9 for 2000/2001 and the contributions from other sources, whichever is less.

13. *Other Researchers.* This personal information is being collected for the purpose of assessing the researchers' qualifications under the authority of the AARI Act. It is subject to the provisions of the Freedom of Information and Protection of Privacy Act.

Name _____ Title _____

Function in Project _____ Organization _____

Signature _____ Telephone # _____

Name _____ Title _____

Function in Project _____ Organization _____

Signature _____ Telephone # _____

Name _____ Title _____

Function in Project _____ Organization _____

Signature _____ Telephone # _____

12. *Terms and Conditions*

A. This application is submitted, and will be evaluated, under the authority of the Alberta Agricultural Research Institute Act and the Farming for the Future Matching Grants Program Guidelines. The applicant accepts the conditions specified in the guidelines.

B. All completed applications submitted to AARI become the property of AARI and will not be returned to the applicant. While every effort will be made to keep the information contained in the application form confidential, the application review procedures require that copies of the application be distributed to a number of reviewers. The contents of this application may also be subject to access under the Freedom of Information and Protection of Privacy Act.

C. The decision of AARI's Board of Directors regarding this application is final.

Baird — Principal Researcher's Signature

Jan 25, 2000 — Date

T.D. Holley — Co-applicant's Signature

Jan. 24/2000 — Date

James Calpas — Co-applicant's Signature

Jan. 24/2000 — Date

PRINCIPAL RESEARCHER - BIOGRAPHICAL DATA

Name (surname first): Bains, Piara

Post-Secondary Education and Training Relevant to Proposal:

Institution	Field Specialization	Degree/Diploma	Year Completed
University of Alberta	Plant Pathology	Ph. D.	1989
University of Alberta	Plant Pathology	M. Sc.	1980
Punjab Agric. University	Horticulture	M. Sc.	1974
Punjab Agric. University	Plant Pathology	B. Sc.	1972

Relevant Professional Experience (begin with present position):

Dates	Position or Function	Employer	Location
1996-Present	Senior Research Scientist	AAFRD	Edmonton, AB
1992-1996	Research Scientist	AAFRD	Edmonton, AB
1988- 1992	Laboratory Scientist	AAFRD	Edmonton, AB

Research Activities Related to Research Proposal (list up to 4 projects):

Title	Date
Project Manager, Alberta Agricultural Research Institute Project (99M516)	1999-Present
Project Manager, Alberta Agricultural Research Institute Project (98M204)	1998-Present
Project Manager, Alberta Agricultural Research Institute Project (97M077)	1997-99
Project Manager, Alberta Agricultural Research Institute Project (97M078)	1997-98
Project Manager, Alberta Agricultural Research Institute Project (95 E111)	1995- 97
Project Manager, Alberta Agricultural Research Institute Project (94M604)	1994-96

Relevant Articles Published in Refereed Journals and Other Relevant Works in the Last Three Years

Bains, P.S., V.S. Bisht, D.R. Lynch, L.M. Kawchuk and J.P. Helgeson. 1999. Identification of stem rot (*Erwinia carotovora* subspecies *atroseptica*) resistance in potato. American Journal of Potato Research 76:137-141.

Bains, P.S. 1999. Soil survival, host range, cultivar reactions and fungicidal control of silver scurf pathogen of potato. Alberta Agricultural Research Institute, Edmonton, Alberta. Project no. 94M604. 46p.

Bains, P.S., H.S. Bennypaul, S.F. Blade and C. Weeks. 2000. First report of hemp canker caused by *Sclerotinia sclerotiorum* in Alberta, Canada. Plant Disease 84..... (in press)

Bains, P.S., H. Bennypaul and M. Mirza. 1999. First report of powdery mildew of green-house grown tomatoes in Alberta, Canada. Plant Disease 83:488.

Bains, P.S. 1999. Integrated management of entomosporium leaf and berry spot disease of saskatoon. Alberta Agricultural Research Institute, Edmonton, Alberta. Project no. 95E111. 58p.

Lange, R.M., P.S. Bains and R.J. Howard. 1998. Efficacy of fungicides for control of Entomosporium leaf and berry spot of saskatoon. Plant Disease 82:1137-1141.

Bains, P.S., R.M. Lange and R.J. Howard. 1996. Development of a fungicidal control program for entomosporium leaf and berry spot of saskatoon. Alberta Agricultural Research Institute, Edmonton, Alberta. Project no. 93-0290. 43 pp.

Lynch, D.R., L.M. Kawchuk, J. Hachey, P.S. Bains and R.J. Howard. 1997. Identification of a gene conferring high levels of resistance to Verticillium wilt in *Solanum chacoense*. Plant Disease 81:1011-1014.

Bains, P.S., V.S. Bisht and D.A. Benard. 1996. Soil survival and thiabendazole sensitivity of *Helminthosporium solani* isolates from Alberta. Potato Research 39:23-29.

Total Number of Articles Published in Refereed Journals in the Last Three years 9

CO-APPLICANT (1) - BIOGRAPHICAL DATA

Name (Surname first): Holley, James, D.

Post-Secondary Education and Training Relevant to Proposal:

Institution	Field Specialization	Degree/Diploma	Year Completed
Univ. of Guelph	Plant Physiology / Plant Pathology	PhD	1984

Relevant Professional Experience (Begin with present position):

Dates	Position or Function	Employer	Location
July '93- Oct. '96	Post-Harvest Research Scientist	AB Agriculture, Food & Rural Development	CDC-South Brooks, AB.
Sept. '91- July '93	Extension Plant Pathologist / Diagnostician	AB Agriculture, Food & Rural Development	CDC-South Brooks, AB.
June '88- Sept. '91	Post-Harvest Research Scientist	AB Agriculture, Food & Rural Development	CDC-South Brooks, AB.

Research Activities Related to Research Proposal (List research project titles and dates):

Identification of cross-resistance to thiabendazole and thiophanate-methyl in the potato silver scurf pathogen, *Helminthosporium solani* and survey to determine how common cross resistance is in fusarium dry rot pathogen(s) in Alberta's potato storages.

Identification of effective methods used to measure levels of thiabendazole on the skins of stored potatoes.

Relevant Articles in Refereed Journal and Other Relevant Works Published in the Last Three Years:

1. Kawchuk, L.M., Holley, J.D., Lynch, D.M., and Clear, R.M. 1994. Resistance to thiabendazole and thiophanate-methyl in isolates of *Fusarium sambucinum* and *Helminthosporium solani*. Am. Potato J. 71: 185-192.

2. Holley, J.D., and Kawchuk, L.M. 1996. Distribution of thiabendazole and thiophanate-methyl resistant strains of *Helminthosporium solani* and *Fusarium sambucinum* in Alberta potato storages. Canadian Plant Disease Survey 76: 21-27.

3. Szeto, S.Y., Joshi, V., Price, P.M., and Holley, J.D. 1993. Persistence and efficacy of thiabendazole on potatoes for control of silver scurf. J. Agric. Food Chem. 41: 2156-2159.

CO-APPLICANT (2) - BIOGRAPHICAL DATA

This personal information is being collected for the purpose of assessing the researchers' qualifications under the authority of the AARI Act. It is subject to the provisions of the Freedom of Information and Protection of Privacy Act.

Name (Surname First):

CALPAS, James T.

Post-Secondary Education and Training Relevant to Proposal:

Institution	Field Specialization	Degree/Diploma	Year Completed
University of Alberta	Plant Pathology/Greenhouse Production	Ph.D.	In progress
Simon Fraser University	Plant Pathology	M. Sc.	1991
University of Alberta	Crop Protection	B.Sc. Ag.	1985

Relevant Professional Experience (begin with present position):

Dates	Position or Function	Employer	Location
1994-present	Greenhouse Research & Extension Specialist	Alberta Agriculture	CDCS, Brooks, AB
1991-1994	Plant Pathologist, Quality Control Manager	Brooks Diagnostics Ltd.	Brooks, AB
1997 (July-Sept)	Diagnostician	Alberta Agriculture	Brooks, AB
1991 (Jan-July)	Research Scientist	Bion Research Inc.	Kelowna, BC

Research Activities Related to Research Proposal (list up to 4 projects):

Title	Date
Development of a Biological Control for the Gray Mold Pathogen, *Botrytis cinerea* in Greenhouse Vegetable Crops	1998

Relevant Articles Published in Refereed Journals and Other Relevant Works in the Last Three Years

Calpas, J.T. and J.E. Rahe. 1995. Distribution of Verticillium albo-atrum in the root systems of resistant and susceptible alfalfa plants. Can. J. Plant. Pathol. 17:240-246.

Calpas, J.T., A. Tellier, and P. Cote. 1995. Greenhouse Crops Program CDCS, Annual Report *in* Alberta Agriculture, Food and Rural Development, Horticulture/Apiculture Unit Annual Report.

Calpas, J.T., A. Tellier, and P. Cote. 1996. Greenhouse Crops Program CDCS, Annual Report *in* Alberta Agriculture, Food and Rural Development, Horticulture/Apiculture Unit Annual Report.

Calpas, J.T. contributing editor to *Greenhouse Coverings* a monthly newsletter published by the Greenhouse Program Staff of the Horticulture/Apiculture Unit. Alberta Agriculture, Food and Rural Development.

ACKNOWLEDGEMENT OF RECEIPT

Please fill out the name, address and title information and submit this form with your original application (14 copies of this sheet are not required). The form will be returned to you to acknowledge receipt of your Matching Grants Program application by the Alberta Agricultural Research Institute.

Principal Researcher Dr. P. S. Bains

Mailing Address Crop Diversification Centre North
17507 Fort Road, R.R. #6
Edmonton AB T5B 4K3

This is to acknowledge receipt of your proposal entitled:

Early blight disease of Potatoes (*Alternaria solani*): characterization of pathogen population and host-pathogen interaction.

For Office Use Only

Your proposal has been assigned project number _____. Please quote this number on future correspondence.

Your application is:

_____ **complete as received**

_____ **incomplete. Please forward immediately:**

_____ **14 photocopies of your application**

_____ **original signatures in Blocks 6, 13 & 14 for:**

_____

_____

_____ **animal care certificate**

_____ **completed biographical data for:**

_____

_____ _____

You will be provided with a written response regarding the status of your application when the evaluation process is completed. We expect the evaluation process to be completed by March, 1999.

Date Received: _____

Alberta
AGRICULTURE, FOOD AND
RURAL DEVELOPMENT

Crop Diversification Centre North

RR6, 17507 Fort Road
Edmonton, Alberta
Canada T5B 4K3

Telephone 780/422-1789
Fax 780/422-6096

January 30, 2001

Mr. Stan Mills, Chair
Potato Development Inc.
Potato Growers of Alberta
6008 - 46th Ave.
Taber AB T1G 2B1

Dear Mr. Mills:

Ref: An Application for Funding by Potato Development Inc.

Enclosed renewal application "**Early blight disease of Potatoes (*Alternaria solani*): characterization of pathogen population and host-pathogen interaction.**" is respectfully submitted for funding by Potato Development Inc., Potato Growers of Alberta. Twenty copies of the application are enclosed for the approval process. Thanks for considering this request.

Yours sincerely,

Bains

Piara Bains
Research Scientist/Plant Pathologist

Approved

POTATO DEVELOPMENT INC.

FUNDING APPLICATION

Early blight disease of Potatoes (*Alternaria solani*): characterization of pathogen population and host-pathogen interaction.

Submitted by

P.S. Bains, J.D. Holley and J. Calpas

February 1, 2001

POTATO DEVELOPMENT INC.
FUNDING APPLICATION - SUMMARY

PROJECT TITLE: Early blight disease of Potatoes (*Alternaria solani*): characterization of pathogen population and host-pathogen interaction.

REASON FOR PROJECT: Early blight disease of potatoes *(Alternaria solani* Sorauer) causes significant risk to potato productivity in the field and tuber quality in the storage. The disease has always been present in Alberta but it seems that in recent years the disease has become prevalent even when the growers have started spraying fungicides in recent years to control the late blight disease of potatoes. Majority of the fungicides used to control late blight, also provide protection from early blight. The question, therefore is why early blight has started causing significant economic losses to Alberta potato growers? Increased disease severity may be due to the development of more aggressive isolates of the pathogen, development of insensitivity in the pathogen population to registered fungicide(s), the planting of potato cultivars more susceptible to the pathogen, and/or the existing potato production methods which are more conducive for the disease development. Higher aggressiveness of the isolates might be due to the adaptation of pathogen population to warm drier weather, higher growth rate, higher levels of spore production and spore germination, and/or other physiological changes. Knowledge of comparative aggressiveness of the pathogen population, which might be correlated to the geographical region and/or to potato cultivars, will help to manage the disease effectively. No such study on early blight of potato pathogen population in Alberta has been conducted in the last ,at least, 25 years. Present production methods might also be encouraging the development of early blight. Continuous Pivot Irrigation creates cycles of wet and dry environment and causes leaching of nitrogen, both these conditions are very suitable for early blight development. Furthermore, with the announcements of two new processing plants, Alberta potato acerage is going to go up considerably in the coming 2-3 years. Increased acerage will reduce the physical separation of potato fields and in some cases may also reduce the rotation time, and inturn create an environment conducive for spread of many diseases including early blight.

PROJECT PLAN: The research plan includes collection of isolates of *A. solani* from infected potato plants collected from all potato growing areas of Alberta, and collection of information on the cultural practices (irrigation method, fertilization, variety, rotation, soil type etc.). The isolates will be evaluated for variations in pathogenicity, mycelial growth, spore production, and spore germination and for the development of resistance in the pathogen population to the fungicide(s) registered to control this disease. It will include the evaluation of efficacy of any other fungicide which might be available from a company for potential registration for this disease. Genetic analyses of the isolates showing differential pathogenicity and fungicide sensitivity will be conducted by random polymorphic DNA (RAPD) which will help in the development of probe(s), a valuable tool for diseases management. Field susceptibility of potato cultivars grown in Alberta to natural early blight infection and to inoculation with *A. solani*. isolates will be determined by conducting small plot experiments at four locations. Knowledge of cultivar susceptibility is a major factor in devising early blight management schedule.

BENEFITS TO ALBERTA'S POTATO INDUSTRY: The results of this project will help to understand the presence and distribution of differential levels of pathogenicity and sensitivity to fungicide(s) in pathogen population. It will also determine the levels of susceptibility of various cultivars to the existing pathogen population. Knowledge of susceptibilities of the cultivars, relative pathogenicities and fungicide sensitivities of Alberta isolates of the pathogen is very crucial for making the disease management decisions. Probe(s) which might be developed from genetic analyses of pathogen isolates depicting differential pathogenicity and fungicide sensitivity will be an extremely useful tool for early blight management.As a package, the information generated

will be very helpful to reduce the losses caused by this disease and inturn increase profitability of the industry.

DURATION OF PROJECT: July 1999 to January 2001.

FINANCIAL INFORMATION:

	This year only	Total all years
Project cost	$4,968	$59,170
Amount requested from PDI	$2,484	$27,585
Amount from other sources	$2,484	$31,585

PRINCIPAL APPLICATION INFORMATION:

Dr. Piara Bains 403 415 2302

Principal applicant's name Phone

Alberta Agriculture Food & Rural Development

Research agency or company

Crop Diversification Centre North, R.R. #6, Edmonton AB T5B 4K3
Crop Diversification Centre South, SS #4, Brooks AB T1R 1E6

Location of research project Postal code

ALBERTA AGRICULTURAL RESEARCH INSTITUTE (AARI)
MATCHING GRANTS PROGRAM APPLICATION - 2000/2001

Office Use Only: Date Received Application Number

1. ***Project Title (maximum 15 words)*** Early blight disease of Potatoes (*Alternaria solani*): characterization of pathogen population and host-pathogen interaction.

2. ***Commencement and Duration of Project***

Expected commencement date for this request for funding July 2001

Anticipated duration of project is 2.5 year(s) Is this a renewal application? Yes

If yes, state the first year the project was funded 99 and the current project # 99M524

3. ***Choice of Research Committee***

Beef & Dairy		Pork, Poultry, Sheep & Other Livestock	
Cereals & Oilseeds		Forage, Pulse, Vegetable & Other Crops	X
Resource Conservation		Policy, Economics & Marketing	

4. ***Principal Researcher***

Name	Dr. P. S. Bains	Mailing Address	RR #6, 17507 Fort Road
Title	Research Scientist		Edmonton AB T5B 4K3
Organization	Crop Diversification Centre N.		
Department	Alberta Agriculture Food & Rural Development	Telephone #	403 415 2302
		Fax #	403 427 6096

5. ***Co-applicants***

Name	Dr. J.D. Holley	Mailing Address	SS #4, Brooks AB T1R 1E6
Title	Post-harvest Scientist		
Organization	Crop Diversification Centre S.		
Department	Alberta Agriculture Food & Rural Development	Telephone #	403 362 1336
		Fax #	403 362 2554
Name	Mr. J. Calpas	Mailing Address	SS #4, Brooks AB T1R 1E6
Title	Greenhouse Specialist		
Organization	Crop Diversification Centre S.		
Department	Alberta Agriculture Food & Rural Development	Telephone #	403 362 1312
		Fax #	403 362 2554

6. ***Approval of Employer(s)***

6. *Approval of Employer(s)*

This application is submitted, and will be evaluated, under the authority of the Alberta Agricultural Research Institute Act and the Farming for the Future Matching Grants Program Guidelines. As representatives of the applicants' employing organization, the undersigned hereby verify acceptance of the terms and conditions specified in the guidelines. They further agree to allow the applicant to devote time to the project and use the facilities of the organization to conduct the proposed research. **Please print or type name on the first line and sign in blue ink (see block 6 instructions for required signatures).** This personal information is being collected to confirm your approval for a research application being submitted to AARI. It is subject to the provisions of the Freedom of Information and Protection of Privacy Act. If you have any questions about the collection, contact Dr. Yilma Teklemariam, Research Manager, AARI, #202, 7000 - 113 Street, Edmonton, AB, T6H 5T6.

Principal Researcher's Organization

A. Name	Dr. R.J. Howard	Title	Leader Horticulture Unit & Director, CDC South, Brooks
Signature	R.J. Howard	Date	2001
B. Name		Title	
Signature		Date	
C. Name		Title	
Signature		Date	

Co-applicant's Organization

Co-applicant's Name Dr. J.D. Holley

A. Name	Dr. S. Blade	Title	Director, CDC North, Edmonton
Signature	for	Date	Jan. 31, 01
B. Name		Title	
Signature		Date	
C. Name		Title	
Signature		Date	

Co-applicant's Organization

Co-applicant's Name Mr. J. Calpas

A. Name	Dr. R.J. Howard	Title	Leader Horticulture Unit & Director, CDC South, Brooks
Signature	R.J. Howard	Date	January 26, 2001
B. Name		Title	
Signature		Date	
C. Name		Title	
Signature		Date	

7. *Progress to Date (renewal applications)*

Provide a concise report of the results achieved. The report should state whether the results expected under the action plan for the year have been achieved. If appropriate, present a summary of the data collected and any preliminary conclusions. One page may be added to this section if required.

plan for the year have been achieved. If appropriate, present a summary of the data collected and any preliminary conclusions. One page may be added to this section if required.

In August 1999, 104 potato fields from the northern, central and southern potato growing regions of Alberta were examined for evidence of brown lesions with concentric rings characteristic of early blight. Early blight disease was present in all three potato growing areas of Alberta and it was observed in every field and was present at different severities on all the cultivars surveyed. The disease severity observations suggested that majority (61%) of the fields planted with cultivar Russet Burbank developed low levels of the disease.

Fungicide tests for inhibition of growth of early blight pathogen *Alternaria solani*.
Of ten fungicides/fungicide combinations tested at 250 ppm, none was able to cause complete inhibition of *in vitro* radial growth of *A. solani* (Fig. 1). Only azoxystrobin (Quadris) at 1000 ppm was able to cause a complete inhibition of the growth. Germination of spores, however was completely inhibited by Chlorothalonil (Bravo) and fungicides containing chlothalonil [chlorothalonil + metalaxyl (Bravo/Ridomil), propamocarb +chlothalonil (Tattoo C)] at 1 ppm (Figs. 2-3). Quadris was not effective in inhibiting the spore germination.

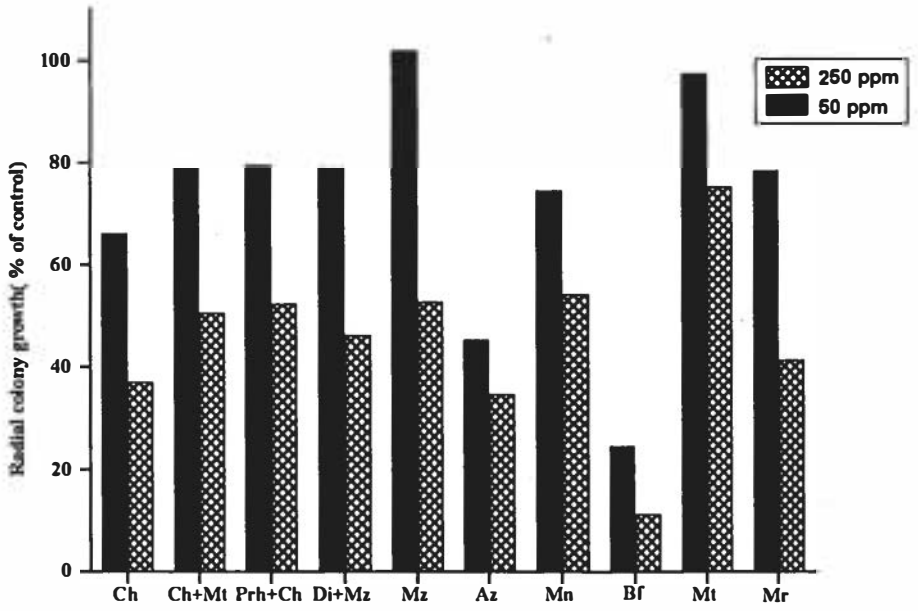

Fig. 1. Effect of fungicides on *in vitro* radial growth of NM99-1-2 isolate of *Alternaria solani*. Colony growth measurements were taken after 7 days of growth on fungicide-amended V8 Agar medium in dark at 22°C. Ch=cholorothlonil, Mt=metalaxyl, Prh=propamocarb hydrochloride,Di=dimethomorph, Mz=mancozeb, Az=azoxystrobin, Mn=maneb, Bf=bas50000f, Mr=metiram.

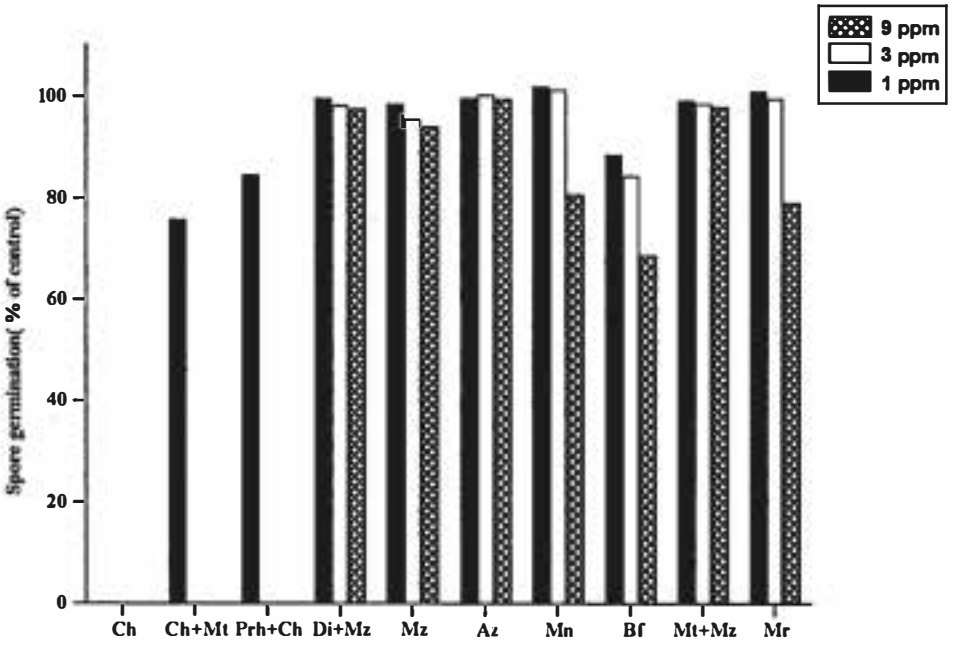

Fig. 2. Effect of different fungicides on *in vitro* spore germination of NM99-1-2 isolate of *Alternaria solani*. Spore germination observations were taken after 24 hrs. of incubation on fungicide-amended PDA at 20°C in dark. Ch=cholorothlonil, Mt=metalaxyl, Prh=propamocarb Mr=metiram.)

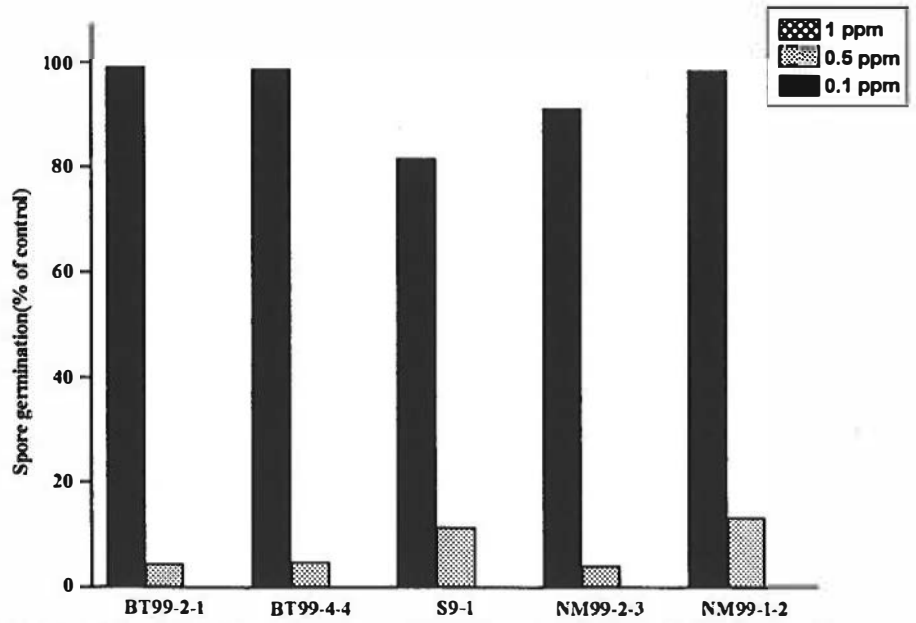

Fig. 3. Effect of Chlorothalonil on *in vitro* spore germination of five Alberta isolates of *Alternaria solani*. Spore germination observations were taken after 24 hrs. of incubation on PDA at 20° in dark.

Comparative susceptibility of potato cultivars to *Alternaria solani*.
Results of cultivar susceptibility of 1999 and 2000 taken together indicated that potato cultivars differ in their susceptibilities to *A. solani* (Table). Both years Norland, Rode Earstling, Russet Norkotah were comparatively more susceptible than Rode Star, Russet Burbank, Chipeta, and Alpha. In general, the cultivars showed similar comparative reactions. Cultivar susceptibility experiment results from three sites in southern Alberta also showed Norland to be significantly more susceptible than Russet Burbank and Shepody.

Comparative virulences of Alberta isolates of *Alternaria solani*.
Table 5 shows the results of comparative virulence determination of various isolates of *A. solani*. There was a large variation in the virulences of isolates. It was observed that percent germination of spores of some isolates was lower than others, a repeat experiment is planned to minimize the effect of variation in percent spore germination on comparative virulence.

Genetic characterization of Alberta isolates of *Alternaria solani*.
Thirty one isolates, based on their sensitivity reaction to Bravo were selected for genetic characterization. Three isolates representing three sensitivity groups were selected to screen 80 RAPD primers on the basis of their suitability to produce genetic fingerprints that demonstrated differences among the isolates representing the three groups. Ten primers were selected to study the 31 isolates. The genetic fingerprinting work of all 31 isolates is near completion, the work remaining include statistical analysis and generation of a phenograph (family tree) showing the genetic grouping of the isolates resulting from the RAPD analysis.

Table 1. Comparative susceptibility of potato cultivars/ breeding lines to natural inoculum of *Alternaria solani*.

1999			2000		
Cultivar	Incidence (%)[1]	Severity (%)[2]	Cultivar	Incidence (%)[1]	Severity (%)[2]
Norland	100.0 a[3]	100.0 a	Norland	96.75a	6.45a
Rode Earstling	98.2 ab	84.6 ab	U0024-6	92.00ab	4.22cd
Warba	97.2 ab	82.7 ab	U0123-25	92.00ab	5.51ab
Russet Norkotah	98.3 ab	75.9 abc	U0056-1	90.00ab	4.60bc
Sangre	96.6 ab	76.8 abc	Rode Earstling	89.00ab	4.56bc
Yukon Gold	92.2 abcd	69.3 bc	Atlantic	87.50abc	4.54bc
Carlton	94.3 abc	54.7 cd	Russet Norkotah	86.00abcd	4.15cd
Shepody	94.2 abc	53.6 cd	Bintje	82.75abcde	4.69bc
Red LaSoda	88.2 abcde	39.7 de	Eramosa	78.25abcdef	3.73cde
Banana	86.5 abcde	26.8 ef	Umatilla	73.75bcdef	3.21def
Bintje	89.8 abcde	23.2 ef	Yukon Gold	73.50bcdef	3.16def
Alpha	83.0 abcde	18.7 ef	Shepody	73.00bcdef	3.58cdef
White Rose	81.2 bcdef	16.3 ef	Sangre	72.25bcdef	4.52bc
Ranger Russet	86.2 abcde	14.8 ef	Wis75-30	67.00cdefg	2.73ef
Chipeta	72.7 ef	13.3 ef	Banana	66.00defg	2.79ef
Desiree	75.3 def	10.7 f	Cu87101-1	66.00defg	2.55ef
Russet Burbank	76.5 cdef	10.5 f	Penta	62.75efg	3.20def
Nordonna	81.3 bcdef	7.4 f	Ranger Russet	62.75efg	2.74ef
Russet Nugget	65.2 f	6.7 f	Red Lasoda	58.75gf	3.15def
Rode Star	38.3 g	2.8 f	White Rose	50.50g	2.62ef
			Chipeta	48.75g	2.32f
			R. Brubank	48.75g	2.62ef
			Rode Star	27.75h	2.45ef
			Alpha	25.25h	2.54ef

[1] Percent number of leaves showing early blight symptoms. Twenty leaves each from five alternate plants in a row were used for incidence determination.

[2] Twenty leaves each from five alternate plants in a row were rated for severity of early blight symptoms based on Horsfall and Barret scale. The values were back-transferred to percentages using the midpoint rule.

[3] Means in a column followed by the same letter are not significantly different by Duncan's Multiple Range Test.

Table 2. Comparative virulence of various *Alternaria solani* isolates[1].

Isolate	Leaf area colonized (square mm)	Isolate	Leaf area colonized (square mm)
BT2-1	712.8 a[2]	S10-1	168.8 fghi
NM1-2	604.8 a	S6-5	113.8 ghij
J3-4	451.3 b	S34-5	102.8 ghij
MW3-2	428.6 bc	S22-5	99.6 ghij
BT4-4	398.3 bcd	S38-5	68.3 hij
GV2-3	331.3 bcde	S29-1	49.7 ij
J2-2	322.5 cde	S17-5	44.8 ij
S40-5	290.5 def	S11-3	28.0 j
S26-4	280.9 def	S7-4	21.2 j
NB4-2	261.8 ef	S21-5	19.9 j
S42-6	222.3 efg	S9-1	4.6 j
VL2-2	193.3 fgh	S3-4	0.0 j
AM2-3	183.2 fgh	Check	0.0 j

Dctached leaf method was used to determine the comparative virulences of isolates. Freshly harvested spores were placed on three freshly scratched areas (~ 3 mm^2) on one side of thc mid rib of a potato cv. Warba leaf. Distilled water was used on the other side of thc mid rib for control (water) treatment. The leaf was incubated on a moist papers in a pctric dish. Mcasurements of colonized leaf area were taken after 3 days of incubation.

[2] Means in a column followed by the same letter are not significantly different by Duncan's Multiple Rangc Test at p=0.01.

8. Outline of Research Proposal (one page may be added to this block if required)

A. Background and Key Results Expected

i. Background

Early blight disease of potatoes *(Alternaria solani* Sorauer) causes significant risk to potato productivity in the field and tuber quality in the storage. The pathogen causes dark brown to black circular lesions on leaves and stems. The lesions are usually concentric (bulls eye) and may become angular if these are retarded by a large leaf vein. The disease has always been present in Alberta but in recent years it has been observed to cause significant economic losses in some fields. The irony is that the disease seems to has become prevalent even when the growers have started spraying fungicides in recent years to control the late blight disease of potatoes. Majority of the fungicides used to control late blight, also provide protection from early blight. The question, therefore is why early blight has started causing significant economic losses to Alberta potato growers?

Increased disease severity may be due to the development of more aggressive isolates of the pathogen, development of insensitivity in the pathogen population to registered fungicide(s), the planting of potato cultivars more susceptible to the pathogen, and/or the existing potato production methods which are more conducive for the disease development. Higher aggressiveness of the isolates might be due to the adaptation of pathogen population to warm drier weather, higher growth rate, higher levels of spore production and spore germination, and/or other physiological changes. Knowledge of comparative aggressiveness of the pathogen population, which might be correlated to the geographical region and/or to potato cultivars, will help to manage the disease effectively. Development of higher aggressiveness in a pathogen population is well documented for late blight of potato pathogen, *Phytophthora infestans*. Present production methods might also be encouraging the development of early blight. Continuous Pivot Irrigation creates cycles of wet and dry environment and causes leaching of nitrogen, both these conditions are very suitable for early blight development. Sub-optimal level of nitrogen fertilizer has been indicated to be a factor for the development of this disease (Mackenzie, 1988). Furthermore, with the announcements of two new processing plants, Alberta potato acerage is going to go up considerably in the coming 2-3 years. Increased acerage will reduce the physical separation of potato fields and in some cases may also reduce the rotation time, and inturn create an environment conducive for spread of many diseases including early blight.

Isolates of some plant pathogens have been reported to develop resistance to fungicides eg. Late blight of potato pathogen to metalaxyl (Goodwin et al., 1996), fusarium dry rot pathogen, *Fusarium sambucinum*, to thiabendazole (Mertect) (Hide *et al.*, 1992; Kawchuk *et al.* 1994), and silver scurf of potato pathogen, *Helminthosporium solani*, to Mertect (Bains et al. 1996). It is likely that isolates of *A. solani* may have developed some resistance to the registered fungicide(s). Knowledge of resistance development in a pathogen population to a fungicide(s) is very crucial for effective fungicidal control of the disease caused by that pathogen. Genetic analyses of the isolates showing differential pathogenicity and fungicide sensitivity will be conducted by random polymorphic DNA (RAPD) for development of probe(s), a valuable tool for diseases management. Determination of genetic differences between Fungicide sensitivity and insensitivity and variations in pathogenicity will be useful for mass characterization of the pathogen population and disease management decisions. No such study on early blight of potato pathogen population in Alberta has been conducted in the last ,at least, 25 years.

Control of early blight is very much dependent on the identification of the 'critical period', which is defined by the concurrence presence of sufficient amounts of inoculum of the pathogen, favourable environment, and susceptible host, it pinpoints the initiation of the spray schedule of protectant fungicides (Pscheidt & Stevenson, 1988; Zadoks & Shein, 1979). Knowledge of the susceptibility of the cultivars, therefore is important to determine the timing of the first fungicide spray. All early blight forecasting systems require similar information for fungicide spray schedule determination. Reaction of potato cultivars to *A. solani*, however is not sufficiently well characterized (Pelletier & Fry, 1990). Generally, early-maturing cultivars are more susceptible to early blight pathogen than the late-maturing cultivars (Douglas & Pavek, 1972; Harrison *et al.* 1965; Johanson & Thurston, 1990), and older leaves are more susceptible than the younger leaves (Sinden *et al.* 1973). All potato cultivars do not conform to this generalization, Buckskin, a very late-maturing cultivar was not the most resistant cultivar, and Hampton, a late-maturing cultivar was susceptible and was ranked with early- and medium-maturing cultivars (Christ, 1991). Other factors such as incubation period, lesion

expansion rate, and spore production ability may explain the differences in cultivar resistances observed in the field (Holley *et al.* 1983; Pelletier & Fry, 1989). Susceptibility differences as observed by disease progress are observed within each maturity group and it is possible to select least susceptible cultivars or breeding lines in each maturity group (Stevenson, 1994). Knowledge of reactions of potato cultivars to the local pathogen population, therefore is very critical for fungicide spray schedule.

ii. Key Results Expected (for renewal projects, include all changes or modifications to original expectations, citing reasons)

Overall objective of the project is to manage the disease to the level that it is not of any economic importance to potato growers of Alberta. Increases in the incidence and severity of the disease in recent years may be due to any or combination of the following reasons: a shift in the virulence of the pathogen population, planting of potato cultivars susceptible to the existing pathogen population, development of insensitivity in the pathogen population to the presently registered fungicides for control of this disease. It is expected that the results of studies of biology of the pathogen, genetic differences in pathogen population for pathogenicity and sensitivity to the fungicide(s), and susceptibility of potato cultivars will provide a clearer picture of early blight development in Alberta and inturn help for effective management of the disease. This will be accomplished by the following objectives.

Objectives:

1. To collect isolates of *A. solani* from infected potato plants collected from all potato growing areas of Alberta, and to collect information on the cultural practices (irrigation method, fertilization, variety, rotation, soil type etc.)
2. To test the isolates for variations in pathogenicity, mycelial growth, spore production, and spore germination.
3. To determine the development of resistance in the pathogen population to the fungicide(s) registered to control this disease: test the sensitivity of the isolates to the registered fungicides (contact, systemic) and any other fungicide available from companies for potential registration for this disease.
4. Genetic analyses of *A. solani* isolates sensitive and insensitive to fungicide(s) and showing variations in pathogenicity.
5. To determine the susceptibility of potato cultivars grown in Alberta to *A. solani*.

B. Biotechnology Related Proposals

i. Does this proposal involve biotechnology research? Yes ____ No __X__

If yes, state any potential adverse impact the project results may have on:

- food safety and human health:

- environmental sustainability:

ii. Does the research involve transfer of DNA between unrelated organisms? Yes ____ No ____

If yes, state:

- the common name of the source of the genetic material:

- the Latin name:

C. Expected Industry Impact/Benefits of the Project

With the announcements of two new processing plants, Alberta potato industry is going to double in value, an increase of millions of dollars. It is expected that the acerage of potatoes will increase from 26,000 to about 50, 000. This is going to reduce the physical separation of potato fields and in some cases may also reduce the rotation time, and inturn creating an environment conducive for spread of many diseases eg. early blight. The disease has always been present in Alberta but in recent years there has been an increase in its severity which is also roughly coinciding with increased use of fungicides that control this disease. The fungicides were sprayed for late blight but are also effective against this disease. The results of this project will help to understand the presence and distribution of differential levels of pathogenicity and sensitivity to fungicide(s) in pathogen population. Genetic analyses of *A. solani* isolates sensitive and insensitive to fungicide(s) and those showing variations in pathogenicity will help to develop probe(s) for analyses of these characteristics in pathogen population for effective management of the disease. It will also determine the levels of susceptibility of various cultivars to the existing pathogen population. The information generated will help to manage the disease effectively and increase profits for the industry.

E. Technology Transfer Plan

The results obtained from the project will be presented to the industry at the annual, area, and breakfast meetings. The results will be published in the industry newsletter (The Common Tater) and in a refereed journal. Presentations will also be made at scientific meetings.

E. Research Plan

Alberta isolates of Alternaria solani. Large number of isolates of the pathogen will be isolated from naturally infected potato plants collected from all potato growing areas of Alberta (Edmonton, Lacombe, and Taber Vauxhall areas). Infected tissues will be surface sterilized and incubated in a moist chamber for 4 days. Single spore isolations will be made onto V8 juice medium, grown at 21 C for 7 days for maintenance, and at 4 C for long-term storage.

Growth characteristics of *A. solani* isolates.
Radial growth: A 4 mm plug from a 7-day-old colony of an isolate will be placed in the centre of a petrie plate containing V8 juice agar medium. The radial growth measurement (average of two diameters measured at 90^0 to each other minus 4 and divided by 2) will be taken after 7 days of incubation at 21 C with 12 hour photoperiod. The experiment will be conducted with six replications of one plate each and will be repeated at least once. The data will be statistically analysed for differences in rate of growth.

Production and germination of spores of A. solani isolates: The isolates of *A. solani* will be compared for their spore production and spore germination capabilities using the following procedure. For spore production, the isolates will be grown on V8 juice agar medium containing 0.004% Rose Bengal (Bains and Tewari, 1987), on water agar at 21 C with 12 hour photoperiod, or on potato dextrose agar medium until it reaches the edge of the plate and then exposed to ultra-violet radiation to induce sporulation. Five 4 mm plugs from a 7-day-old colony will be transferred into 2 ml of sterile distilled water containing five drops of Tween 20 per 100 ml of water, vortexed for 15 seconds, passed through a double layer of cheesecloth, and counted number of spores per ml using a hemacytometer. A 100 µl aliquot of the spore suspension will be spread on V8 juice agar medium in a petrie dish and incubated as described previously. Percent germination of spores will be determined after 24 hours of incubation. The experiments will be conducted with six replications of one plate each and will be repeated at least once. The data will be statistically analysed for differences in production and germination of spores.

Evaluation of fungicides in controlling radial growth and spore germination of A. solani isolates. A 4 mm plug from the edge of an actively growing colony of an isolate will be placed in the centre of a petrie plate containing V8 juice agar medium modified with one of the test fungicides. The fungicides to be tested include chlorothalonil (Bravo), chlorothalonil + metalaxyl (Bravo/Ridomil), metalaxyl + mancozeb (Ridomil MZ 72WP), dimathomorph + mancozeb (Acrobat MZ), mancozeb (Dithane DG), mancozeb (Manzate 200), metiram (Polyram 16D, Polyram DF), menab (Dithane M-22), propamocarb hydrochloride + chlorothalonil (Tattoo C), and any other fungicide which may be available from a chemical company. The incubation and radial growth determination will be done as described previously. The data will be used to determine the development of insensitivity (LD_{50}) in the pathogen population, and to compare the efficacies of various fungicides in controlling the pathogen.

Comparative pathogenicity of isolates: Twenty isolates selected on the basis of their differences in growth characteristics and sensitivity to fungicide(s) will be tested for their comparative pathogenicity using greenhouse-grown Russet Burbank and Warba plants. The plants will be inoculated after they have flowered. Each isolate will be grown on potato dextrose agar medium until it reaches the edge of the plate. Cultures will then be exposed to ultra-violet radiation to induce sporulation, the spores will be washed off of the agar surface with sterile de-ionized water and concentration of spore suspension adjusted to 10^6 spores / ml. The spore suspension of each test isolate will be sprayed individually onto four test plants to leaf wetness. Control test plants will be sprayed with a solution of de-ionized water. Each sprayed plant will be enclosed in its own transparent poly-ethylene bag and allowed to incubate for 7 to 14 days in growth chambers at 20^0C . Each poly-ethylene bag will be opened once each day for 3 to 5 days and the plants sprayed gently with de-ionized water to leaf wetness. The plants will be examined for level of early blight infection at the end of the incubation period. In addition, four mature leaves from each plant will be examined for number and area of lesions on each leaf. Data will be statistically analyzed for comparative pathogenicity of the isolates.

Genetic analyses of isolates: Twenty five to 50 *A. solani* isolates selected on the basis of their differential pathogenicity and sensitivity to fungicide(s) will be analyzed for genetic relatedness by random polymorphic DNA (RAPD) method (Welsh & McClelland, 1990). The isolates will be grown in pure culture and DNA will be extracted. The RAPD method

will be used to generate genetic fingerprints for each isolate and the isolates will be grouped according to their genetic similarity. Any groupings will be examined and correlated to the differential pathogenicity and fungicide sensitivity exhibited by the same isolates. The investigation will determine whether highly pathogenic or fungicide insensitive isolates can be distinguished by DNA fingerprinting.

Comparative field susceptibility of potato cultivars: Comparative field susceptibility of Russet Burbank, Amisk, Shepody, Russet Norkotah, Atlantic, Alpha, Norland, and Snowden plants to early blight pathogen will be determined by planting the cultivars in small test plots in four randomized complete blocks at four locations. Each small plot will have three fifteen meter rows and will be separated from the adjacent plots by a guard row of Warba. Of four locations, two will be artificially inoculated after the trial has been planted. Inoculations will be done by using *A. solani*-infected potato plants. Greenhouse-grown Norland plants will be sprayed either with spores from a normal or an aggressive isolate of *A. solani*. Plants infected with one of the two strains will be transplanted one each in the middle of the centre row of each small plot at the first field location, whereas those infected with the second isolate at the second field location. The third trial location will be on a farm which has not had difficulties with abnormally high levels of early blight and the fourth on a farm that has had serious problems with early blight in the past.

Each row of the plots will be examined for evidence of early blight infection at regular intervals during the growing season and an estimate of the percentage of the canopy showing early blight lesions will be recorded. At the end of the season, readings from each observation time will be summarized for each row for each small plot. Percentages will be transformed into proportions for each row (50% transformed to 0.5) and the proportions (X) used to establish logit , i.e. ln {X/1-X} values. The logit values will be regressed against time elapsed in days from planting to establish apparent infection rates (r) for each row in each small plot. The r values from each experiment will be used to characterize the aggressiveness of the pathogen at each location. The field experiments will be repeated the following season.

F. Action Plan

ii. 2000-2001

Determine cultural characteristics and fungicide sensitivities of the isolates (in progress)	June - July
Determine comparative virulence of selected isolates (in progress)	April - August
Determine genotypic differences in isolates for differential pathogenicity and fungicide sensitivity using molecular techniques.	August -November
Compare field susceptibilities of potato cultivars commonly grown in Alberta to the natural inoculum and to selected isolates of *A. solani*.	May - September
Analyse data	December

iii. 2001-2002

Comparative field susceptibility of potato cultivars commonly grown in Alberta.	May - October
Analyse data and prepare the final report.	November - January

G. Related Research Performed in Your Organization

At Crop Diversification Centre North, Plant Pathology laboratory is very much involved in research on potato diseases. The diseases of potatoes on which research is being conducted or was conducted in the near past include early blight (*Alternaria solani*) stem canker and black scurf (*Rhizoctonia solani*), silver scurf (*Helminthosporium solani*), fusarium dry rot (*Fusarium sambucinum*), and black leg (*Erwinia carotovora* subsp. *atroseptica*). The project on early blight included the development of rapid techniques for disease resistance screening. Apart from this a major project was conducted by PSB on a disease caused by *Alternaria brassicae* on canola, and by JDH on early blight of potato and is involved with determining reaction of advanced breeding lines of potato to early blight pathogen.

H. Related Research Performed in Other Agencies

Early blight is an economically important disease of potatoes. Many groups have worked on fungicidal control of the disease and reported significant improvements in total yield: 18-39% in Colorado (Harrison and Venette, 1970), 19-21% in Wisconsin (Stevenson *et al.*, 1990), and 56 - 92% in Minnesota (Teng & Bissonnette, 1985). Tebuconazole was reported to reduce lesion expansion rate compared to that of chlorothalonil (Shtienberg et al.,1996). Systemic fungicides (tebuconazole, difenoconazole) provided better control of the disease compared to that of protectant fungicides (chlorothalonil, mancozeb) only in some of the experiments conducted in Israel. Integrated use of systemic and protectant fungicides is important for resistance management. Protectant fungicides could be used at the beginning of the fungicide program and towards the end of the season a more effective control of the disease could be achieved by systemic fungicides ((Shtienberg *et al.*,1995;1996).

All most all early blight forecasting systems include susceptibility of potato cultivars to predict the timing of the first spray to control the disease. Generally, early-maturing cultivars are more susceptible to early blight pathogen than the late-maturing cultivars (Douglas *et al*, 1972; Harrison *et al.* 1965; Johanson & Thurston, 1990). All potato cultivars, however do not conform to this generalization. Buckskin, a very late-maturing cultivar was not the most resistant cultivar, and Hampton, a late-maturing cultivar was susceptible and was ranked with early- and medium-maturing cultivars (Christ, 1991). Other factors such as incubation period, lesion expansion rate, and spore production ability may explain

the differences in cultivar resistance observed in the field (Holley *et al.* 1983; Pelletier & Fry, 1989). Results of this study, differentiating *A. solani* isolates for various biological characteristics including pathogenicity and sensitivity to various fungicides and reactions of potato cultivars to the present population of the pathogen will help to understand and effectively control early blight of potato in Alberta.

I. List of References

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9. *Budget and Manpower Needs for 1999-2000*

State the amount being requested in each category. One page may be added to this block to describe budget requests or any unusual items.

A. Manpower

	Name	Title	Person Years Required for 2000-2001	Amount Requested for 2000-2001
Principal Researcher	Dr. P. S. Bains	Research Scientist	0.15 PY	nil
Co-applicant (1)	Dr. J.D. Holley	Post-harvest Scientist	0.10 PY	nil
Co-applicant (2)	Mr. J. Calpas	Greenhouse Specialist	0.05 PY	nil
Professional				
Technical	Ms. May Yu	Research Technician	0.2 PY	nil
	Ms. S. Lisowski	Research Technician	0.1 PY	$3,668
Graduate Students				
Other (specify)				
		TOTAL A	0.6 PY	$3,668

Justification must be outlined below if more than a total of one person year is hired for the project or the amounts requested for technicians and graduate students exceed $32,000 and $15,000, respectively, per person per year:

Note: Principal researchers and co-applicants who are employees of public institutions are not eligible for wages, honoraria, or other compensation from project funds. However, they must note the amount of time they expect to devote to the project during the fiscal year. Applicants should carefully read the instructions before completing block 9.

B. Capital Assets (specify)

TOTAL B	

Justification for capital assets:

C. Supplies and Services

i. Travel (includes travel and accommodation costs)

a. **Project Travel**

Traveller's Name _____

Destination(s) _____

Number of Trips _____

Mode of Travel _____

Purpose _____

_____

_____ Cost _____

b. **Conference Travel**

Traveller's Name P. Bains

Destination(s) To be determined

Number of Trips 1

Mode of Travel car/air

Purpose To discuss and present the results of the project

_____

_____ Cost $500

Justification is required for requests over $1,000:

ii. Materials/Supplies (if you have more than six items, please attach a list)

List Item	Quantity	$ Per Unit	Cost
Greenhouse supplies: fertilizer, potting soil, and few			
supplies for field experiments.			
		Total:	$300

iii. **Computer Cost**

Justification is required for requests over $300:

iv. **Publication Cost (specifically for this project's results)**

Publication cost for project results	$500

Justification is required if request is over $500:

v. **Rentals and Leases**

vi. **Contract Personnel**

TOTAL C	
TOTAL A + B + C	$4,968

D. Overhead Cost

Indicate how overhead costs were calculated (refer to instructions on page 7):

TOTAL AMOUNT REQUESTED FOR 2000-2001 (A + B + C + D)	$4,968

10. Summary of Budgets for Anticipated Duration of Project

	RENEWALS A. Amount Approved in 2000-2001	B. Amount Proposed for 2001-2002	C. Amount Proposed for 2002-2003	D. Amount Proposed for 2003-2004
	$21,298	$3668		
Manpower				
Capital Assets				
Travel	$1,100	$500		
Materials/Supplies	$2,800	$300		
Computer Cost				
Publication Cost		$500		
Rentals & Leases				
Contract Personnel				
Overhead Cost				
TOTAL	$25,198	$4,968		

E. Total amount for this request and future requests anticipated for this project $2,484

F. Total amount approved in previous years for this project $27,101

G. Approval in any year does not guarantee funding for subsequent years. Provide substantive reasons to justify proposals requesting multiple year funding.

The disease appears late in the season. First part of the project including collection of diseased samples and isolation of *A. solani* isolates will be done in fall of 1999. In winter of 1999/2000 growth characteristics and sensitivity experiments will be done followed by greenhouse testing of pathogenicity in the spring of 2000. Based on these results isolates of *A. solani* will be selected for genetic analyses to be conducted in the of 2000/2001 project year and it will be followed by the field experiment. For confidence in field experiment data it is very important to have 2 year data. The experiment will be repeated in 2001/2002 project year.

*11. **Funding Support Applied for, Granted, or Promised for This Project From Sources Other Than Alberta Government Departments, Agencies or Programs***

	Funding Agency	Amount of Grant in Cash	Amount of Grant In-kind	Total Amount Applied for, Granted or Promised	Date Grant Received or Expected
A.	Potato Development Inc. (Growers of Alberta)	$2,484		$2,484	March 2001
B.					
C.					
D.					
TOTAL AMOUNT REQUESTED FROM OTHER AGENCIES (A + B + C +D)				$2,484	

*12. **Amount Requested From AARI***

Total amount requested from AARI for the 2000-2001 fiscal year is $_2,484__. This amount should not exceed one half of the total amount requested for 2000-2001 or the difference between the total shown in block 9 for 2000/2001 and the contributions from other sources, whichever is less.

*13. **Other Researchers.*** This personal information is being collected for the purpose of assessing the researchers' qualifications under the authority of the AARI Act. It is subject to the provisions of the Freedom of Information and Protection of Privacy Act.

Name _____ Title _____

Function in Project _____ Organization _____

Signature _____ Telephone # _____

Name _____ Title _____

Function in Project _____ Organization _____

Signature _____ Telephone # _____

Name _____ Title _____

Function in Project _____ Organization _____

Signature _____ Telephone # _____

conditions specified in the guidelines.

B. All completed applications submitted to AARI become the property of AARI and will not be returned to the applicant. While every effort will be made to keep the information contained in the application form confidential, the application review procedures require that copies of the application be distributed to a number of reviewers. The contents of this application may also be subject to access under the Freedom of Information and Protection of Privacy Act.

C. The decision of AARI's Board of Directors regarding this application is final.

Principal Researcher's Signature — Date: Jan. 30, 2001

Co-applicant's Signature — Date: Jan. 26/2001

Co-applicant's Signature — Date: Jan 25/2001

PRINCIPAL RESEARCHER - BIOGRAPHICAL DATA

Name (surname first): Bains, Piara

Post-Secondary Education and Training Relevant to Proposal:

Institution	Field Specialization	Degree/Diploma	Year Completed
University of Alberta	Plant Pathology	Ph. D.	1989
University of Alberta	Plant Pathology	M. Sc.	1980
Punjab Agric. University	Horticulture	M. Sc.	1974
Punjab Agric. University	Plant Pathology	B. Sc.	1972

Relevant Professional Experience (begin with present position):

Dates	Position or Function	Employer	Location
1996-Present	Senior Research Scientist	AAFRD	Edmonton, AB
1992-1996	Research Scientist	AAFRD	Edmonton, AB
1988- 1992	Laboratory Scientist	AAFRD	Edmonton, AB

Research Activities Related to Research Proposal (list up to 4 projects):

Title	Date
Project Manager, Alberta Agricultural Research Institute Project (99M516)	1999-Present
Project Manager, Alberta Agricultural Research Institute Project (98M204)	1998-Present
Project Manager, Alberta Agricultural Research Institute Project (97M077)	1997-99
Project Manager, Alberta Agricultural Research Institute Project (97M078)	1997-98
Project Manager, Alberta Agricultural Research Institute Project (95 E111)	1995- 97
Project Manager, Alberta Agricultural Research Institute Project (94M604)	1994-96

Relevant Articles Published in Refereed Journals and Other Relevant Works in the Last Three Years

Bains, P.S., V.S. Bisht, D.R. Lynch, L.M. Kawchuk and J.P. Helgeson. 1999. Identification of stem rot (*Erwinia carotovora* subspecies *atroseptica*) resistance in potato. American Journal of Potato Research 76:137-141.

Bains, P.S. 1999. Soil survival, host range, cultivar reactions and fungicidal control of silver scurf pathogen of potato. Alberta Agricultural Research Institute, Edmonton, Alberta. Project no. 94M604. 46p.

Bains, P.S., H.S. Bennypaul, S.F. Bladc and C. Wecks. 2000. First report of hemp canker caused by *Sclerotinia sclerotiorum* in Alberta, Canada. Plant Disease 84:372.

Bains, P.S., H. Bennypaul and M. Mirza. 1999. First report of powdery mildew of green-house grown tomatoes in Alberta, Canada. Plant Disease 83:488.

Bains, P.S. 1999. Integrated management of entomosporium leaf and berry spot disease of saskatoon. Alberta Agricultural Research Institute, Edmonton, Alberta. Project no. 95E111. 58p.

Lange, R.M., P.S. Bains and R.J. Howard. 1998. Efficacy of fungicides for control of Entomosporium leaf and berry spot of saskatoon. Plant Disease 82:1137-1141.

Bains, P.S., R.M. Lange and R.J. Howard. 1996. Development of a fungicidal control program for entomosporium leaf and berry spot of saskatoon. Alberta Agricultural Research Institute, Edmonton, Alberta. Project no. 93-0290. 43 pp.

Lynch, D.R., L.M. Kawchuk, J. Hachey, P.S. Bains and R.J. Howard. 1997. Identification of a gene conferring high levels of resistance to Verticillium wilt in *Solanum chacoense*. Plant Disease 81:1011-1014.

Total Number of Articles Published in Refereed Journals in the Last Three years 9

CO-APPLICANT (1) - BIOGRAPHICAL DATA

Name (Surname first): Holley, James, D.

Post-Secondary Education and Training Relevant to Proposal:

Institution	Field Specialization	Degree/Diploma	Year Completed
Univ. of Guelph	Plant Physiology / Plant Pathology	PhD	1984

Relevant Professional Experience (Begin with present position):

Dates	Position or Function	Employer	Location
July '93- Oct. '96	Post-Harvest Research Scientist	AB Agriculture, Food & Rural Development	CDC-South Brooks, AB.
Sept. '91- July '93	Extension Plant Pathologist / Diagnostician	AB Agriculture, Food & Rural Development	CDC-South Brooks, AB.
June '88- Sept. '91	Post-Harvest Research Scientist	AB Agriculture, Food & Rural Development	CDC-South Brooks, AB.

Research Activities Related to Research Proposal (List research project titles and dates):

Identification of cross-resistance to thiabendazole and thiophanate-methyl in the potato silver scurf pathogen, *Helminthosporium solani* and survey to determine how common cross resistance is in fusarium dry rot pathogen(s) in Alberta's potato storages.

Identification of effective methods used to measure levels of thiabendazole on the skins of stored potatoes.

Relevant Articles in Refereed Journal and Other Relevant Works Published in the Last Three Years:

1. Kawchuk, L.M., Holley, J.D., Lynch, D.M., and Clear, R.M. 1994. Resistance to thiabendazole and thiophanate-methyl in isolates of *Fusarium sambucinum* and *Helminthosporium solani*. Am. Potato J. 71: 185-192.

2. Holley, J.D., and Kawchuk, L.M. 1996. Distribution of thiabendazole and thiophanate-methyl resistant strains of *Helminthosporium solani* and *Fusarium sambucinum* in Alberta potato storages. Canadian Plant Disease Survey 76: 21-27.

3. Szeto, S.Y., Joshi, V., Price, P.M., and Holley, J.D. 1993. Persistence and efficacy of thiabendazole on potatoes for control of silver scurf. J. Agric. Food Chem. 41: 2156-2159.

CO-APPLICANT (2) - BIOGRAPHICAL DATA

This personal information is being collected for the purpose of assessing the researchers' qualifications under the authority of the AARI Act. It is subject to the provisions of the Freedom of Information and Protection of Privacy Act.

Name (Surname First):
CALPAS, James T.

Post-Secondary Education and Training Relevant to Proposal:

Institution	Field Specialization	Degree/Diploma	Year Completed
University of Alberta	Plant Pathology/Greenhouse Production	Ph.D.	In progress
Simon Fraser University	Plant Pathology	M. Sc.	1991
University of Alberta	Crop Protection	B.Sc. Ag.	1985

Relevant Professional Experience (begin with present position):

Dates	Position or Function	Employer	Location
1994-present	Greenhouse Research & Extension Specialist	Alberta Agriculture	CDCS, Brooks, AB
1991-1994	Plant Pathologist, Quality Control Manager	Brooks Diagnostics Ltd.	Brooks, AB
1997 (July-Sept)	Diagnostician	Alberta Agriculture	Brooks, AB
1991 (Jan-July)	Research Scientist	Bion Research Inc.	Kelowna, BC

Research Activities Related to Research Proposal (list up to 4 projects):

Title	Date
Development of a Biological Control for the Gray Mold Pathogen, *Botrytis cinerea* in Greenhouse Vegetable Crops	1998

Relevant Articles Published in Refereed Journals and Other Relevant Works in the Last Three Years

Calpas, J.T. and J.E. Rahe. 1995. Distribution of Verticillium albo-atrum in the root systems of resistant and susceptible alfalfa plants. Can. J. Plant. Pathol. 17:240-246.

Calpas, J.T., A. Tellier, and P. Cote. 1995. Greenhouse Crops Program CDCS, Annual Report *in* Alberta Agriculture, Food and Rural Development, Horticulture/Apiculture Unit Annual Report.

Calpas, J.T., A. Tellier, and P. Cote. 1996. Greenhouse Crops Program CDCS, Annual Report *in* Alberta Agriculture, Food and Rural Development, Horticulture/Apiculture Unit Annual Report.

Calpas, J.T. contributing editor to *Greenhouse Coverings* a monthly newsletter published by the Greenhouse Program Staff of the Horticulture/Apiculture Unit. Alberta Agriculture, Food and Rural Development.

ACKNOWLEDGEMENT OF RECEIPT

Please fill out the name, address and title information and submit this form with your original application (14 copies of this sheet are not required). The form will be returned to you to acknowledge receipt of your Matching Grants Program application by the Alberta Agricultural Research Institute.

Principal Researcher Dr. P. S. Bains

Mailing Address Crop Diversification Centre North

17507 Fort Road, R.R. #6

Edmonton AB T5B 4K3

This is to acknowledge receipt of your proposal entitled:

Early blight disease of Potatoes (*Alternaria solani*): characterization of pathogen population and host-pathogen interaction.

For Office Use Only

Your proposal has been assigned project number _____. Please quote this number on future correspondence.

Your application is:

_____ **complete as received**

_____ **incomplete. Please forward immediately:**

_____ **14 photocopies of your application**

_____ **original signatures in Blocks 6, 13 & 14 for:**

_____

_____

_____ **animal care certificate**

_____ **completed biographical data for:**

_____

_____ _____

You will be provided with a written response regarding the status of your application when the evaluation process is completed. We expect the evaluation process to be completed by March, 1999.

Date Received: _____

ALBERTA RESEARCH COUNCIL

Vegreville
Mailing
PO Bag 4000
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File No.: 2000M-P01/00

January 31,2001

Potato Grower Association
6008 – 46 Avenue
TABER, AB T1G 2B1

Dear Sir or Madam:

Please find enclosed a Potato Development, Inc. Funding Application titled: "Potato Purple Top and Witches'-Broom Phytoplasma Diseases: Tuber and Insect Transmission, Inoculum Sources, Quality Aspect and Control Strategies" for your review and consideration. Fifteen copies have also been enclosed.

Thank you.

Abdul-Hameed Khadhair, Ph.D.
Research Scientist
Molecular Biology and Plant Pathology

Enclosure

/pc/CPA2001M.219.LTR

Approved
$13,000

POTATO DEVELOPMENT, INC.
FUNDING APPLICATION

PROJECT TITLE:
POTATO PURPLE TOP AND WITCHES'-BROOM PHYTOPLASMA DISEASES: TUBER AND INSECT TRANSMISSION, INOCULUM SOURCES, QUALITY ASPECT AND CONTROL STRATEGIES

Project team: Khadhair, Abdul-Hameed, Piara Bains, Patricia DuPlessis and Kwesi Ampong-Nyarko

Submitted by
Dr. A.-H. Khadhair
Research Scientist
Alberta Research Council
Bag 4000, Vegreville, AB T9C 1T4
Phone (780) 632-8225, Fax: (780) 632-8612

Date of Submission: January 31, 2001

Note to applicants:
Applicants who receive funding from PDI must get approval from PDI chairman before reporting any finding

POTATO DEVELOPMENT, INC.
FUNDING APPLICATION-SUMMARY PAGE

PROJECT TITLE: Potato Purple Top and Witches'-broom Phytoplasma Diseases: Tuber and Insect Transmission, Inoculum Sources, Quality Aspect and Control Strategies

REASON FOR PROJECT (Objectives for projects):
The seed potato industry is being challenged by potato purple top (PT) and witches'-broom (WB) diseases caused by phytoplasmas. In the last three years, PT and WB phytoplasma diseases were found in all three potato growing areas of Alberta (Edmonton, Lacombe and Taber), and incidence of these diseases is creating considerable concern for a number of potato growers. WB can cause leaf narrowing, formation of aerial tubers, plant stunting and reduction in number and size of tubers. PT is generally associated with a narrow leaf system and purplish leaves and internal necrosis of tubers. A report from Minnesota indicated that PT could cause brown discoloration for potato chips obtained from tubers collected from PT-infected potatoes. Recent increases in acreage have reduced physical separation of potato fields and enhanced the capabilities of PT and WB diseases to spread by insect leafhoppers.
This study will determine 1) species identity and population dynamics of leafhoppers associated with spread of PT and WB diseases in potatoes fields, 2) whether the tubers produced by infected plants will produce infected plants in the following season, 3) sources of initial inoculum of the phytoplasma diseases 4) Chipping quality in tubers of infected potato plants (e.g. Atlantic cultivar).

PROJECT PLAN (What is going to be done):
At least nine potato fields (more will be considered) in southern and central potato-growing areas of Alberta will be included in this study. Yellow sticky traps will be posted weekly in four corners in small fields otherwise more will be posted at proper distances in large fields. Leafhopper numbers will be scored every week before replacing the traps in each field. Samples of phytoplasma-infected plants and leafhoppers will be collected for identification and characterization studies. Tubers will be collected from infected potato plants to determine any transmission of WB and/or PT phytoplasma. Phytoplasma-infected samples will be collected from fields near potato fields to determine whether the initial disease inoculum comes from other potato fields or is transmitted from other plant species to potatoes. Chips will be made from tubers collected from phytoplasma-infected potato plants considering cv. Atlantic to determine quality aspects.

BENEFITS TO ALBERTA'S POTATO INDUSTRY:
The overall objectives of this project are to develop strategies for effective management of the PT and WB phytoplasma diseases. This will be achieved by generating information about the epidemiology of these diseases. It is expected that the results of this study will help to combat these diseases and to help to maintain a healthy potato industry.

DURATION OF THE PROJECT: It will start **April, 2001** and run until **March, 2003**

FINANCIAL INFORMATION:

	This year only	Total all years
Project cost	$71,330.00	$142,660.00
Amount requested from PDI	$13,000.00	$26,000.00
Amount from other sources	$56,330.00	$112,660.00

PRINCIPAL APPLICANT INFORMATION

Name	Dr. A.H. Khadhair	Mailing Address	P.O. Bag 4000, ARC, Vegreville,
Title	Research Scientist		AB T9C 1T4
Organization	Alberta Research Council	Telephone #	(780) 632-8225
Department	Crop and Plant Management	Fax #	(780) 632-8612
		E-mail	hameed@arc.ab.ca

Location of Research Project:
Potato fields in central and southern Alberta and ARC laboratories

PROJECT CONTINGENCIES

a) If you do not get grant monies from sources can this project be conducted as submitted?

Yes ___ No __X__ Yes, with changes ___

b) Modifications necessary:

BACKGROUND, OBJECTIVES, AND PLAN

A) Background to the Proposed Project:

Purple top (PT) and witches' broom (WB) diseases of potatoes are caused by phytoplasmas, which are implicated in causing more than 300 plant diseases to a variety of agriculture crops worldwide. The pathogen is an obligate parasite and is transmitted from infected to healthy plants by leafhoppers. These insect vectors are naturally capable of feeding on a wide range of plants and are highly mobile in the field. Phytoplasmas have been present for over three decades in Alberta and their host ranges are expanding. They are producing yellows-type symptoms in various herbaceous plant species including some perennials, which may become sources for transmitting phytoplasma to other economical plant species. In the last three years, PT and WB phytoplasma diseases were found in all three potato growing areas of Alberta (Edmonton, Lacombe and Taber), and incidence of the disease was high enough to cause considerable concern to a number of potato seed growers. WB can cause leaf narrowing, plant stunting and reduction in number and size of tubers while PT is generally associated with a narrow leaf system, purple discoloration of leaves and tubers containing internal necrosis. A report from Minnesota indicated that PT could cause brown discoloration in chips obtained from tubers collected from PT-infected potatoes (cvs. Monona and Norchip). Increased potato acreage has reduced physical separation of potato fields and enhanced the capabilities of purple top disease transmission by the insects.

Our preliminary study showed that progeny tubers collected from infected plants will produce infected plants in following season. There is no information on percentage of WB and/or PT phytoplasma transmission through tubers. This has serious implications. Not only there will be a reduction in the yield due to loss of production from infected plants, but the plants will serve as reservoir of inoculum for infection to healthy potato plants by leafhoppers. Very little is known about the initial sources of phytoplasma. Do phytoplasmas from canola, alfalfa and other annual and/or perennial crops cause the disease in potatoes and if so, is there any leafhopper species specificity in transmission of phytoplasma from these crop species? The information generated PT and WB diseases will be used to develop the control strategies based on market demand.

B) Objectives

The overall objectives of this project is to develop strategies for effective management of the phytoplasma diseases. This will be achieved by generating information about the epidemiology of these diseases. It is expected that the results of this study will assist to combat these diseases and in the long term, will to maintain a healthy potato industry.The specific objectives are:

1. To determine the percentage and ability of tubers from infected plants to produce PT and WB-infected plants in the following season.
2. To evaluate the effect phytoplasma infection on chipping quality of tubers produced from infected potato plants.
3. To determine whether the initial disease inoculum comes from potato or transmitted from other plant species to potatoes.
4. To determine population dynamics of leafhoppers associated with transmission of PT and WB phytoplasmas in potato fields.
5. To develop control strategies and recommendations.

C) Research Plan

Collection, maintenance and identification of phytoplasmas infecting potato cultivars: Nine or more potato fields in different locations of Alberta will be included for sampling in this study. During each visit, PT and WB phytoplasma-infected plant samples will be flagged and monitored for symptom development and to collect their tubers at the end of the season. Infected potato plants showing PT and/or WB symptoms will be collected before flowering for maintenance under greenhouse conditions. They will be used as sources of phytoplasma isolates for identification and tuber production. Phytoplasma-infected samples will be also collected from crops and weeds near potato fields to determine other phytoplasma sources and phylogenetic relationship between common isolates within the same area.

Evaluation of effect of PT and WB on chipping quality: Tubers harvested prior to top kill from flagged infected potato plants (cv. Atlantic) will be collected from designated potato fields. The tubers also will be collected at a later stage from infected potato plants grown under green house conditions. Potato chips will be prepared from infected and healthy potato tubers for evaluation based on a color scale. A specific protocol will be followed to ensure any distinction between chips quality at Food Chemistry Laboratory, AAFRD, Brooks.

Determination of phytoplasma transmission by tubers: Potato tubers will be collected from healthy and phytoplasma-infected potato plants to determine the efficiency of these tubers to transmit the phytoplasma. These tubers will be kept under cold conditions (3-5° C) until January to break the dormancy. Hormonal treatment may be used to enhance this process for some cultivars. Subsequently, the tubers will be grown under greenhouse conditions to monitor symptom development and to detect the presence of phytoplasmas using molecular methods. Eyes will be removed from dormant tubers and be germinated under tissue culture conditions. The progeny tubers from these plants will be tested for the presence of phytoplasmas.

Determination of population dynamics of leafhopper: Sticky traps will be used to determine population of leafhopper insects in nine potato fields in Alberta. The traps will be posted in the corners of each potato field and replaced every week. In larger and round or irregular shaped fields, more traps will be posted at proper distances depend on the size of the field. The number of leafhoppers will be scored on weekly basis to monitor leafhoppers population. More fields will be included for this purpose if more potato growers are willing to assist with posting, replacing and sending us sticky traps to reduce traveling costs.

Leafhopper identification and transmission: In addition to the testing of seed tubers as a source of PT or WB phytoplasma inoculum, leafhoppers present on other crop species and weeds will be collected for species identification. Leafhoppers will be collected by sweeping net for identification and transmission studies. The most common leafhopper species found in potato fields will be used to transmit phytoplasma to healthy potato plants under growth cabinet conditions. The insects will also be monitored to study crop history and identify the most common species in potato and neighboring crops and weeds.

Identification and characterization of phytoplasma isolates: Molecular and/or traditional methods will be used to identify PT and WB phytoplasma isolates in infected potato samples. These isolates also will be subjected to molecular analyses to determine any phylogenetic relationship with phytoplasmas from other sources in fields neighbouring potato fields.

Control Strategies and recommendations: The expected results of this study will include evaluating the ability of tubers from phytoplasma-infected plants to produce infected plants in the following season and identification of leafhopper species involved in transmission of PT and/or WB phytoplasmas to potatoes. Other results will include identification of inoculum sources and common phytoplasma isolates in potato and other hosts. All these taken together will assist to develop control strategies based on market demand and effective management for PT and WB.

D) Action Plan and Work Schedules

i. 2001-2002

April – May: Preparation of cages for insect transmission, chemical, buffers and other reagents as well as setting program for molecular analysis. Selecting nine potato fields for leafhopper population dynamics and sample identification studies.

June - August: Collection, maintenance and identification of phytoplasmas infecting potato. Determination of population dynamics of leafhopper by scoring numbers of leafhoppers number attracted to sticky traps on a weekly basis. Also, to collect plant samples from other plant species (cultivated and weeds) growing near potato fields to study the source of phytoplasma inoculum. Leafhoppers collected from potato fields will be used to determine phytoplasma transmission on healthy potatoes.

October - December: Evaluation of potato chipping quality of potato tubers collected from phytoplasma-infected and healthy plants. Extractions of the total genomic DNA from plant samples to determine the percentage of phytoplasma infection using the PCR assay with universal and specific primers. Healthy plants will be used as control in all testing procedures.

January-March: Grow potato tubers collected from infected plants to determine the phytoplasma transmission through tubers and to observe symptom development. Some pieces containing eyes from potato tubers will be grown under tissue culture conditions to detect phytoplasma and to compare with samples from their counterparts grown in the soil. DNA will be extracted during plant growth development to determine the concentration of phytoplasmas present in the progeny.

November - March: Conduct molecular analysis on the DNA of different phytoplasma isolates from plant and insect samples to determine the molecular relatedness among the phytoplasma collection from plant and insect sources.

ii. 2002-2003

April-Feberuary: The above action plan will be followed in the second year.

March: Final report preparation

RELATED RESEARCH

a) At your institution:

The genetic relatedness among four isolates of potato witches'-broom phytoplasma in four potato cultivars (see attached abstract) were studied previously by the principal applicant at Alberta Research Council, Vegreville site (5). Also, other studies on phytoplasma identification in herbaceous plant species such as parsnip (1), alfalfa (6), purple coneflower and monarda (7), parsley (4), willow (8) and scentless chamomile (3) have been published in international journals. In these studies, the identification was based on field surveys, symptoms observation, electron microscopy, insect and seed transmission and molecular characterization. Recently, the principle applicant has completed a publication on potato witches'-broom phytoplasma to be published in the Crop Protection Compendium in U.K. (in press, 2).

b) At other institutions:

Studies on purple top and/or witches'-broom phytoplasmas in leafhopper insects associated with potato plants and epidemiological and control strategy on phytoplasma infecting potato have not been reported from any part of Canada. Molecular studies on other phytoplasma isolates were conducted at the University of Alberta (9, 10) and the principal applicant was associated with some of these studies (5, 6, 8).

c) References. (List references cited in the above literature review.)

1. Khadhair, A. H and I.R. Evans. 2000. Molecular and microscopical detection of aster yellows phytoplasma associated with infected parsnip. Microbiological Research 155:53-57.
2. Khadhair, A. H. 2000. Potato witches'-broom phytoplasma. Crop Protection Compendium (accepted).
3. Khadhair, A. H. and A. McClay 1999. Aster yellows phytoplasma identified in scentless chamomile by microscopical examination and molecular characterization. J. Phytopathol. 147:149-154.
4. Khadhair. A. H., L. Kawchuk, R. C. Taillon, G. Botar (1998): Detection and molecular characterization of aster yellows phytoplasma in parsley. Can. J. Plant Pathol. 20:55-61.
5. Khadhair, A. H., Hiruki, C. and S. F. Hwang. 1997. Molecular identification of four potato witches'-broom isolates on four potato cultivars in central Alberta. Microbiological Research 152:281-286.
6. Khadhair, A. H., Hwang, S. F. and C. Hiruki. 1997. Molecular identification of alfalfa witches'-broom phytoplasma in four species of leafhoppers associated with infected alfalfa. Microbiological Research 152:269-275.
7. Khadhair, A. H., Hwang, S-F., Chang, K. and R. Howard. 1997. Molecular identification of aster yellows phytoplasma associated with purple cone flower and monarda based on PCR amplication and RFLP analysis of 16S rDNA sequences. Plant Disease and Protection 104: 403-410.
8. Khadhair, A. H. and C. Hiruki. 1995. The molecular genetic relatedness of willow witches'-broom phytoplasma to the clover proliferation group. Proc. Japan Acad. 71B: 145-147.
9. Wang, K. and C. Hiruki. 2000. Genetic characterization and classification of phytoplasmas associated with canola yellows and a new phytoplasma strain associated with dandelion in Canada. Plant Dis. (in press).
10. Wang, K. and C. Hiruki. 2000. Heteroduplex mobility assay (HMA) detects DNA mutations for differentiation of closely related phytoplasma strains. J. Microbiol. Methods 41:59-68.

BENEFITS OF PROJECT

a) To Alberta's potato producers.

This project will provide information on transmision of purple top and witches'-broom phytoplasmas. The study will also provide evaluation of the effect of PT and WB phytoplasmas on potato chipping quality. It will determine population dynamics and identify the common species of leafhopper insects associated with transmition of PT and WB phytoplasmas from infected to healthy potato plants. Determination of the history of associated crops will identify sources of inoculum when potato cultivars are grown near other plant species. This will serve in developing control strategies. The types and molecular relatedness of phytoplasma isolates associated with leafhoppers and potato cultivars will be determined to assist in establishing the epidemiology of the pathogen. The findings of this study will help to manage potato purple top and witches'-broom phytoplasmas effectively, and reduce losses caused by these diseases. Developing control strategies against PT and WB diseases will be of great benefit to Alberta potato growers in minimizing potential income reduction due to PT and WB diseases.

b) To Alberta's potato industry.

The potato industry of Alberta is rapidly expanding due to the opening of two new potato-processing plants in southern Alberta. High quality disease-free seed potato is critical to the success of our industry. Purple top can cause necrosis inside the tubers and potato witches'-broom can cause considerable reduction in potato tuber yields. Conducting this research on PT and WB phytoplasmas will generate information to clarify current confusion concerning the impact of these diseases and proper management practices to control them. This study will develop control strategies to overcome the impact of phytoplasma diseases on the yield and quality aspects in this crop and will help to maintain a healthy potato industry.

BUDGET AND MANPOWER NEEDS FOR 1 YEAR

A) MANPOWER TO BE HIRED WITH PDI/OTHER FUNDS

NAME (If known)	POSITION	TIME REQUIRED	RATE OF PAY	AMOUNT REQUIRED
To be hired	Technician	0.35		$10,000.0
Casual manpower				
		TOTAL LABOUR COSTS		**$10,000.0 A**

B) TRAVEL EXPENSES TO BE PAID WITH PDI/OTHER FUNDS FOR 1 YEAR

DESTINATION	PERSON	PURPOSE	NUMBER OF TRIPS	TRAVEL COSTS	MEALS AND ACCOM.	TOTAL COST
Taber, Edmonton, westlock	1	Field sampling, leafhopper population & lab	12	$2400.0 for fuel	$600.0	$3,000.0
			TOTAL TRAVEL COSTS			**B= $3,000.0**

C) MATERIALS, SUPPLIES AND SERVICES TO BE PAID WITH PDI/OTHER FUNDS

DESCRIPTION	COST
TOTAL COST OF MATERIALS, SUPPLIES AND SERVICES FOR 1 YEAR	C= Nil

D) OTHER EXPENSES TO BE PAID WITH PDI/OTHER FUNDS FOR 1 YEAR

DESCRIPTION	AMOUNT
AARI overhead -- 5 percent. Applies to grants for which AARI matching funds will not be received.	
Other	
TOTAL OTHER EXPENSES	D= Nil

E) SUMMARY OF FUNDS REQUIRED FROM PDI AND OTHER SOURCES FOR 1 YEAR

DESCRIPTION	COST
Professional, technical, and casual labour	A= $10K
Travel and accommodation	B= $3K
Materials, supplies and services	C
Other expenses	D
TOTAL COSTS FOR WHICH FUNDING IS REQUESTED FROM ALL FUNDING SOURCES (A+B+C+D)	E= $13K

F) FUNDING SOURCE SUMMARY FOR 1 YEAR

FUNDING SOURCE	AMOUNT
Amount requested from PDI in this application	$13,000.0
Other	
Other	
TOTAL FUNDS APPLIED FOR (EQUAL TO E, ABOVE)	**E= $13K**

G) VALUE OF "IN KIND" CONTRIBUTIONS BY RESEARCH AGENCY FOR 1 YEAR

Include estimated value of research staff time and operating budgets contributed by principal researcher's agency, or other cooperator's agency, towards this project in the period covered by this application. (Funding is not requested for these items.)

DESCRIPTION	PERSON YEARS	APPROX. VALUE
Professional, technical, and other staff	0.2+0.1+0.1=0.4	$24K
Materials and supplies (greenhouse, chemical reagents, cages, aspirators, etc)		$5K
Travel for professional		$2K
Overhead (estimate for ARC 60%) and benefits		$18K
	TOTAL VALUE "IN-KIND" COSTS	**F= $49K**

ESTIMATED TOTAL PROJECT COST FOR 1 YEAR

ESTIMATED TOTAL COST OF PROJECT (1 YEAR) E & F	**$62,000.0**

APPROVAL BY PRINCIPAL APPLICANT'S EMPLOYER

The undersigned declare the approval and support of their organization for the research project as describe in this application. Signatures confirm that space and basic facilities for carrying out the proposed research are available for use and that the applicant is authorized to participate in this research project.

Name	Signature	Position	Date
Dr. Paul Sharma	MPSharma	Manager of Crop and Plant Business Unit	Jan. 30/2001

TERMS AND CONDITIONS

The applicant(s) agree that, upon acceptance of funding, a commitment is made to:

a) Conduct the research as laid out in the proposal, excepting changes mutually agreed upon by the applicant(s) and the Executive of the Alberta Potato Research Association.

b) Allow the Alberta Potato Research Association to use all information, data and results generated as a result of the research for extension purposes.

c) Not publish or present any data from this study without the written permission of the Chairman of the PDI.

Principal Applicant: Dr. A. H. Khadhair Signature [signature] Date Jan. 26, 2001
Organization: Alberta Research Council

Co-applicant (1): Dr. Piara Bains Signature [signature] Date Jan 26, 2001
Organization: AAFRD- CDC North

Co-applicant (2): Ms. Patricia DuPlessis Signature [signature] Date Jan 26/01
Organization: AAFRD- CDC North

Co-applicant (2): Dr. Kwesi Ampong-Nyarko Signature [signature] Date Jan 26, 2001
Organization: AAFRD- CDC North

PDI Executive Committee Signature

Date

Microbiol. Res. (1997) **152**, 281–286

Microbiological Research

Molecular identification and relatedness of potato witches'-broom phytoplasma isolates from four potato cultivars

Abdul-Hameed Khadhair[1,2], Chuji Hiruki[2], Shue Fang Hwang[1], Keri Wang[2]

[1] Alberta Research Council, Bag 4000, Vegreville, AB T9C 1T4, Canada
[2] Department of Agriculture, Food and Nutritional Science, University of Alberta, Edmonton, AB T6G 2P5, Canada

Accepted: June 22, 1997

Abstract

Four isolates of potato witches'-broom phytoplasma, designated as PW1, PW2, PW3 and PW4, were established on four potato cultivars. The identity of each isolate was confirmed by PCR using two universal primer pairs and one specific primer set derived from phytoplasma of 16S rDNA sequences. The four isolate samples formed similar RFLP patterns after digestion of 1.2 kb PCR products with restriction endonucleases AluI, HhaI, RsaI and Sau3A. The direct DNA sequencing with the specific primer pair showed that there are no differences in the base sequences among PW1, PW2, and PW3 phytoplasma isolates and that PW4 is closely related to them. Thus, the four isolates were identified as members of the clover proliferation group.

Key words: DNA sequencing – phytoplasma – PCR – potato

Introduction

Phytoplasmas (formerly called mycoplasmalike organisms) are unique plant pathogenic wall-less prokaryotes having ultrastructural characteristics of mollicutes. In the last thirty years, all attempts to isolate these microorganisms in pure culture have failed, so until recently, their evolutionary origin and genetic diversity have remained uncertain (Lim and Sears 1992). Traditional methods based on electron microscopy, vector specificity and symptoms development in the plant host, have been inadequate to precisely characterize these prokaryotes. Application of molecular techniques using DNA sequence homologies and DNA polymorphisms has become a reliable approach toward identification, establishing genetic relatedness and classification of several phytoplasmas (Ahrens and Seemüller 1992; Lee *et al.* 1993; Deng and Hiruki 1991a; Gundersen *et al.* 1994b; Khadhair and Hiruki 1995; Schneider *et al.* 1993).

In Alberta, Canada, potato is a very important commercial crop grown for local consumption, industry, seed production and export. In 1995, the total acreage of potato in Alberta was 30,000 acres which was worth approximately 200 million dollars annually. However, in Canada, various potato cultivars were found susceptible to several plant diseases which had a serious impact on both plants and tubers (Hodgson *et al.* 1981).

Yellows-type diseases associated with phytoplasmas on a variety of plant species were reported in Alberta as early as the 1960s. Among the first reported diseases was clover proliferation (CP) phytoplasma which was found on alsike clover (Chiykowski 1965). Although potato witches'-broom (PWB) phytoplasma was described as a member of the CP group (Deng and Hiruki 1991a), little is known about this phytoplasma in potato cultivars grown in the local fields. In the last three years, several potato fields in Alberta have been surveyed and PWB phytoplasma was commonly found on some of these cultivars. Therefore, this molecular study was conducted to determine the genetic relationship between PWB phytoplasma isolates associated with four potato cultivars grown in Alberta fields.

Materials and methods

Plants and phytoplasma isolates. In summer of 1994, potato plants showing witches'-broom symptoms from four potato cultivars (Norchip, Range Rosset, Shepody and Chieftain) were collected from four fields in central

Corresponding author: A-H. Khadhair

POTATO DEVELOPMENT, INC.
FUNDING APPLICATION

Renewal (second year)

$13,000- Approved
Mar 12/02 Paid.

PROJECT TITLE:
POTATO PURPLE TOP AND WITCHES'-BROOM PHYTOPLASMA DISEASES: TUBER AND INSECT TRANSMISSION, INOCULUM SOURCES, QUALITY ASPECT AND CONTROL STRATEGIES

Project team: Khadhair, Abdul-Hameed, Patricia Duplessis-McAllister, Piara Bains, and Kwesi Ampong-Nyarko

Submitted by
Dr. A.-H. Khadhair
Research Scientist
Alberta Research Council
Bag 4000, Vegreville, AB T9C 1T4
Phone (780) 632-8225, Fax: (780) 632-8612

Date of Submission: January 31, 2002
Second year renewal

Note to applicants:
Applicants who receive funding from PDI must get approval from PDI chairman before reporting any finding

POTATO DEVELOPMENT, INC.
FUNDING RE-NEWAL APPLICATION-SUMMARY PAGE

PROJECT TITLE: Potato Purple Top and Witches'-broom Phytoplasma Diseases: Tuber and Insect Transmission, Inoculum Sources, Quality Aspect and Control Strategies

REASON FOR PROJECT (Objectives for projects):
The seed potato industry is being challenged by potato purple top (PT) and witches'-broom (WB) diseases caused by phytoplasmas. In the last three years, PT and WB phytoplasma diseases were found in the three main potato growing areas of Alberta (Edmonton, Lacombe and Taber), and incidence of these diseases is creating considerable concern for a number of Alberta potato growers. WB can cause leaf narrowing, formation of aerial tubers, plant stunting and reduction in number and size of tubers. PT is generally associated with a narrow leaf system and purplish leaves and internal necrosis of tubers. A report from Minnesota indicated that PT could cause brown discoloration in potato chips made from tubers from PT infected plants. Recent increases in acreage have reduced physical separation of potato fields and thereby have enhanced the potential for PT and WB diseases to be spread by leafhoppers. This study will determine: 1) species identity and population dynamics of leafhoppers associated with the spread of PT and WB diseases in potato fields; 2) whether the tubers produced by infected plants will produce infected plants in the following season; 3) sources of initial inoculum of the phytoplasma diseases; and 4) chipping quality in tubers from infected potato plants (e.g. Atlantic).

PROJECT PLAN (What is going to be done):
A minimum of nine potato fields (more will be considered) in the three main potato growing areas of the province will be included in this study. Yellow sticky traps will be posted weekly in accessible locations in the potato fields included in the study. Leafhopper numbers will be scored from the collected cards. Samples of phytoplasma-infected plants and leafhoppers will be collected for identification and characterization studies. Tubers will be collected from infected potato plants to determine transmission of WB and/or PT phytoplasma. Phytoplasma-infected samples will be collected from fields near potato fields to determine whether the initial disease inoculum comes from other potato fields or is transmitted from other plant species to potatoes. Chips will be made from tubers collected from phytoplasma-infected potato plants of chipping cultivars to determine quality aspects.

BENEFITS TO ALBERTA'S POTATO INDUSTRY:
The overall objectives of this project are to develop strategies for effective and economical management of the PT and WB phytoplasma diseases. This will be achieved by generating information about the epidemiology of these diseases. It is expected that the results of this study will help to combat these diseases and to help to maintain a healthy potato industry. The first year of the project was completed in 2001 and preliminary results presented in poster form at the PGA Annual Meeting in Banff.

DURATION OF THE PROJECT: Initiated **April, 2001** and run until **March, 2003**

FINANCIAL INFORMATION:

	This year only	Total all years
Project cost	$71,330.00	$142,660.00
Amount requested from PDI	$13,000.00	$26,000.00
Amount from other sources	$56,330.00	$112,660.00

PRINCIPAL APPLICANT INFORMATION

Name	Dr. A.H. Khadhair	Mailing Address	P.O. Bag 4000, ARC, Vegreville,
Title	Research Scientist		AB T9C 1T4
Organization	Alberta Research Council	Telephone #	(780) 632-8225
Department	Crop and Plant Management	Fax #	(780) 632-8612
		E-mail	hameed@arc.ab.ca

Location of Research Project:
Potato fields in the three major potato production areas in Alberta, CDC North, and ARC laboratories.

Progress report (2001): A population study was conducted on leafhopper insects associated with the transmission of phytoplsma diseases. The survey was conducted on a total of 10 potato fields throughout Alberta, focusing on Edmonton, Innisfail and Brooks/Taber areas. Our data of summer 2001 indicates a variation in leafhopper population directly proportional to environmental conditions and plant development. A total of 63 potato plants, representing 10 different cultivars, and showing typical phytoplasma symptoms, were collected during initial rouging. A representative sample of each cultivar was tested using molecular assays to detect and identify the infecting phytoplasma. In 82% of the samples tested, potato witches'-broom (PWB) and purple top (PT) phytoplasmas were positively identified by specific DNA testing. These two phytoplasmas were identified by DNA amplification with one universal primer pair (P1/P6) and two specific primer pairs (R16F1/R1 and 1A/1B). Based on RFLP analyses, PWB and PT phytoplasmas were found to belong to the clover proliferation and aster yellows phytoplasma groups, respectively. These two groups are commonly found associated with various field, vegetable and special crops in Alberta. Ongoing studies include: 1)molecular analyses for grouping and genetic relatedness; 2)studying phytoplasma transmission through tubers; and 3)the impact of phytoplasma infection on quality aspects of processed potato products.

Observations from summer 2001 indicated that:

- typical witches'-broom symptoms were found associated with early infection due to transmission through potato tubers in 10 potato cultivars.
- Purple top symptoms observed as late infection in some cultivars were probably due to insect transmission.
- Weather variation seems to have a major role in the population dynamics of the potential leafhoppers involved in the transmission of phytoplasma diseases.
- Infected potato plants produced very small tubers in the case of early infection.
- Sources of infection may include perennial hosts infected with witches'-broom and/or purple top that harboring leafhoppers use as primary or secondary hosts to complete their life cycles.

PROJECT CONTINGENCIES

a) If you do not get grant monies from sources can this project be conducted as submitted?

Yes ____ No __X__ Yes, with changes ____

b) Modifications necessary:

BACKGROUND, OBJECTIVES, AND PLAN

A) Background to the Proposed Project:

Purple top (PT) and witches' broom (WB) diseases of potatoes are caused by phytoplasmas, which are implicated in causing more than 300 plant diseases to a variety of agriculture crops worldwide. The pathogen is an obligate parasite and is transmitted from infected to healthy plants by leafhoppers. These insect vectors are naturally capable of feeding on a wide range of plants and are highly mobile in the field. Phytoplasmas have been present for over three decades in Alberta and their host ranges are expanding. They are producing yellows-type symptoms in various herbaceous plant species including some perennials, which may become sources for transmitting phytoplasma to other economical plant species. In the last three years, PT and WB phytoplasma diseases were found in all three major potato growing areas in Alberta (Edmonton, Lacombe and Taber), and incidence of the disease was high enough to cause considerable concern to a number of seed potato growers. WB can cause leaf narrowing, plant stunting and reduction in the number and size of tubers while PT is generally associated with a narrow leaf system, purple discoloration of leaves and tubers containing internal necrosis. A report from Minnesota indicated that PT could cause brown discoloration in chips obtained from tubers

collected from PT-infected plants (cvs. Monona and Norchip). Increased potato acreage has reduced physical separation of potato fields and has enhanced the potential for purple top disease transmission by leafhoppers.

Our preliminary study showed that progeny tubers collected from infected plants will produce infected plants in following season. There is no information on percentage of WB and/or PT phytoplasma transmission through tubers. This has serious implications. Not only will there be a reduction in the yield due to loss of production from infected plants, but the plants will serve as a source of inoculum for infection of healthy potato plants by leafhoppers. Very little is known about the initial sources of phytoplasma. Do phytoplasmas from canola, alfalfa and other annual and/or perennial crops cause the disease in potatoes and if so, is there any leafhopper species specificity in transmission of phytoplasma from these crop species? The information generated on PT and WB diseases will be used to develop control strategies based on market demand.

B) Objectives

The overall objective of this project is to develop strategies for effective management of the phytoplasma diseases. This will be achieved by generating information about the epidemiology of these diseases. It is expected that the results of this study will assist in combating these diseases and in the long term, will help to maintain a healthy potato industry. The specific objectives are:

1. To determine the percentage and ability of tubers from infected plants to produce PT and WB-infected plants in the following season.
2. To evaluate the effect of phytoplasma infection on chipping quality of tubers produced from infected potato plants.
3. To determine whether the initial disease inoculum comes from potato or is transmitted from other plant species to potatoes.
4. To determine the population dynamics of leafhoppers associated with transmission of PT and WB phytoplasmas in potato fields.
5. To develop control strategies and recommendations for PT and WB.

C) Research Plan

Collection, maintenance and identification of phytoplasmas infecting potato cultivars: Nine or more potato fields in different locations of Alberta will be included for sampling in this study. During each visit, PT and WB phytoplasma-infected plant samples will be flagged and monitored for symptom development and tubers will be collected prior to top kill. Infected potato plants showing PT and/or WB symptoms will be collected before flowering for maintenance under greenhouse conditions. They will be used as sources of phytoplasma isolates for identification and tuber production. Phytoplasma-infected samples will be also collected from crops and weeds near potato fields to determine other phytoplasma sources and phylogenetic relationship between common isolates within the same area.

Evaluation of effect of PT and WB on chipping quality: Tubers harvested prior to top kill from flagged infected potato plants of chipping varieties and tubers collected at a later stage from infected potato plants grown under green house conditions will be used to determine phytoplasma effect on processed potato products. Potato chips will be prepared from infected and healthy potato tubers for evaluation based on a color scale. A specific protocol will be followed to ensure any distinction in chip quality is identified at the Food Chemistry Laboratory, AAFRD, Brooks.

Determination of phytoplasma transmission by tubers: Potato tubers will be collected from healthy and phytoplasma-infected potato plants to determine the efficiency of these tubers to

transmit the phytoplasma. These tubers will be kept under cold conditions (3-5° C) until January to break the dormancy. Hormonal treatment may be used to enhance this process for some cultivars. Subsequently, the tubers will be grown under greenhouse conditions to monitor symptom development and to detect the presence of phytoplasmas using molecular methods. If tubers are available tissue culture may be used to determine transmission potential from mother tuber to daughter plant. The progeny tubers from these plants will be tested for the presence of phytoplasmas.

Determination of population dynamics of leafhopper: Sticky traps will be used to determine population dynamics of leafhoppers in nine potato fields in Alberta. The traps will be posted in accessible locations in the fields. The number of leafhoppers will be scored on weekly basis to monitor leafhoppers population. More fields will be included for this purpose if potato growers are willing to assist with posting, replacing and sending us sticky traps to reduce costs.

Leafhopper identification and transmission: In addition to the testing of seed tubers as a source of PT or WB phytoplasma inoculum, leafhoppers present on other crop species and weeds will be collected for species identification. Leafhoppers will be collected using a sweep net for identification and transmission studies. The most common leafhopper species found in potato fields will be used to transmit phytoplasma to healthy potato plants under growth cabinet conditions. The insects will also be monitored to study crop history and identify the most common species in potato and neighboring crops and weeds.

Identification and characterization of phytoplasma isolates: Molecular and/or traditional methods will be used to identify PT and WB phytoplasma isolates in infected potato samples. These isolates also will be subjected to molecular analyses to determine any phylogenetic relationship with phytoplasmas from other sources in fields neighbouring potato fields.

Control Strategies and recommendations: The expected results of this study will include evaluating the ability of tubers from phytoplasma-infected plants to produce infected plants in the following season and identification of leafhopper species involved in transmission of PT and/or WB phytoplasmas to potatoes. Other results will include identification of inoculum sources and common phytoplasma isolates in potato and other hosts. These results will assist in developing control strategies based on market demand and effective management for PT and WB.

D) Action Plan and Work Schedules

2002-2003 (second year)

April – May: Preparation of chemical, buffers and other reagents as well as setting program for molecular analysis. Selecting potato fields for leafhopper population dynamics and sample identification studies.

June - August: Collection, maintenance and identification of phytoplasmas infecting potato. Determination of population dynamics of leafhopper by scoring numbers of leafhoppers attracted to sticky traps on a weekly basis. Also, to collect plant samples from other plant species (cultivated and weeds) growing near potato fields to study the source of phytoplasma inoculum. Leafhoppers collected from potato fields will be used to determine phytoplasma transmission on healthy potatoes.

October - December: Evaluation of potato chipping quality of potato tubers collected from phytoplasma-infected and healthy plants. Extractions of the total genomic DNA from plant samples to determine the percentage of phytoplasma infection using the PCR assay with universal and specific primers. Healthy plants will be used as control in all testing procedures.

January-March: Grow potato tubers collected from infected plants to determine the phytoplasma transmission through tubers and to observe symptom development. . If tubers are available tissue culture may be used to determine transmission potential from mother tuber to daughter plant . Eyes from the same tubers would be planted in the soil for comparison. DNA will be extracted during plant growth development to determine the concentration of phytoplasmas present in the progeny.

November - March: Conduct molecular analysis on the DNA of different phytoplasma isolates from plant and insect samples to determine the molecular relatedness among the phytoplasma collection from plant and insect sources.

March: Final report preparation

RELATED RESEARCH

a) At your institution:

The genetic relatedness among four isolates of potato witches'-broom phytoplasma in four potato cultivars (see attached abstract) were studied previously by the principal applicant at Alberta Research Council, Vegreville site (5). Also, other studies on phytoplasma identification in herbaceous plant species such as parsnip (1), alfalfa (6), purple coneflower and monarda (7), parsley (4), willow (8) and scentless chamomile (3) have been published in international journals. In these studies, the identification was based on field surveys, symptoms observation, electron microscopy, insect and seed transmission and molecular characterization. Recently, the principle applicant has completed a publication on potato witches'-broom phytoplasma and it was published in the Crop Protection Compendium in U.K (2).

b) At other institutions:

Studies on purple top and/or witches'-broom phytoplasmas in leafhopper insects associated with potato plants and epidemiological and control strategy on phytoplasma infecting potato have not been reported from any part of Canada. Molecular studies on other phytoplasma isolates were conducted at the University of Alberta (9, 10) and the principal applicant was associated with some of these studies (5, 6, 8).

c) References. (List references cited in the above literature review.)

1. Khadhair, A. H and I.R. Evans. 2000. Molecular and microscopical detection of aster yellows phytoplasma associated with infected parsnip. Microbiological Research 155:53-57.
2. Khadhair, A. H. 2001. Potato witches'-broom phytoplasma. Crop Protection Compendium, Vol 2001.
3. Khadhair, A. H. and A. McClay 1999. Aster yellows phytoplasma identified in scentless chamomile by microscopical examination and molecular characterization. J. Phytopathol. 147:149-154.
4. Khadhair. A. H., L. Kawchuk, R. C. Taillon, G. Botar (1998): Detection and molecular characterization of aster yellows phytoplasma in parsley. Can. J. Plant Pathol. 20:55-61.
5. Khadhair, A. H., Hiruki, C. and S. F. Hwang. 1997. Molecular identification of four potato witches'-broom isolates on four potato cultivars in central Alberta. Microbiological Research 152:281-286.
6. Khadhair, A. H., Hwang, S. F. and C. Hiruki. 1997. Molecular identification of alfalfa witches'-broom phytoplasma in four species of leafhoppers associated with infected alfalfa. Microbiological Research 152:269-275.
7. Khadhair, A. H., Hwang, S-F., Chang, K. and R. Howard. 1997. Molecular identification of aster yellows phytoplasma associated with purple cone flower and monarda based on PCR amplication and RFLP analysis of 16S rDNA sequences. Plant Disease and Protection 104: 403-410.
8. Khadhair, A. H. and C. Hiruki. 1995. The molecular genetic relatedness of willow witches'-broom phytoplasma to the clover proliferation group. Proc. Japan Acad. 71B: 145-147.
9. Wang, K. and C. Hiruki. 2000. Genetic characterization and classification of phytoplasmas associated with canola yellows and a new phytoplasma strain associated with dandelion in Canada. Plant Dis. (in press).
10. Wang, K. and C. Hiruki. 2000. Heteroduplex mobility assay (HMA) detects DNA mutations for differentiation of closely related phytoplasma strains. J. Microbiol. Methods 41:59-68.

BENEFITS OF PROJECT

a) To Alberta's potato producers.

This project will provide information on transmision of purple top and witches'-broom phytoplasmas. The study will also provide evaluation of the effect of PT and WB phytoplasmas on potato chipping quality. It will determine population dynamics and identify the common species of leafhopper insects associated with transmition of PT and WB phytoplasmas from infected to healthy potato plants. Determination of the history of associated crops will identify sources of inoculum when potato cultivars are grown near other plant species. This will serve in developing control strategies. The types and molecular relatedness of phytoplasma isolates associated with leafhoppers and potato cultivars will be determined to assist in establishing the epidemiology of the pathogen. The findings of this study will help to manage potato purple top and witches'-broom phytoplasmas effectively, and reduce losses caused by these diseases. Developing control strategies against PT and WB diseases will be of great benefit to Alberta potato growers in minimizing potential income reduction due to PT and WB diseases.

b) To Alberta's potato industry.

The potato industry in Alberta is rapidly expanding due to the opening of two new potato-processing plants in southern Alberta. High quality disease-free seed is critical to the success of our industry. Purple top can cause necrosis inside the tubers and potato witches'-broom can cause considerable reduction in potato tuber yields. Conducting this research on PT and WB phytoplasmas will generate information to clarify current confusion concerning the impact of these diseases and proper management practices to control them. This study will develop control strategies to overcome the impact of phytoplasma diseases on the yield and quality aspects in this crop and will help to maintain a healthy potato industry.

BUDGET AND MANPOWER NEEDS FOR 1 YEAR

A) MANPOWER TO BE HIRED WITH PDI/OTHER FUNDS

NAME (If known)	POSITION	TIME REQUIRED	RATE OF PAY	AMOUNT REQUIRED
To be hired	Technician	0.35		$10,000.0
Casual manpower				
		TOTAL LABOUR COSTS		**$10,000.0 A**

B) TRAVEL EXPENSES TO BE PAID WITH PDI/OTHER FUNDS FOR 1 YEAR

DESTINATION	PERSON	PURPOSE	NUMBER OF TRIPS	TRAVEL COSTS	MEALS AND ACCOM.	TOTAL COST
Taber, Edmonton, Westlock	1	Field sampling, leafhopper population & lab	12	$2400.0 for fuel	$600.0	$3,000.0
			TOTAL TRAVEL COSTS			**B= $3,000.0**

C) MATERIALS, SUPPLIES AND SERVICES TO BE PAID WITH PDI/OTHER FUNDS

DESCRIPTION	COST
TOTAL COST OF MATERIALS, SUPPLIES AND SERVICES FOR 1 YEAR	C= Nil

D) OTHER EXPENSES TO BE PAID WITH PDI/OTHER FUNDS FOR 1 YEAR

DESCRIPTION	AMOUNT
AARI overhead -- 5 percent. Applies to grants for which AARI matching funds will not be received.	
Other	
TOTAL OTHER EXPENSES	D= Nil

E) SUMMARY OF FUNDS REQUIRED FROM PDI AND OTHER SOURCES FOR 1 YEAR

DESCRIPTION	COST
Professional, technical, and casual labour	A= $10K
Travel and accommodation	B= $3K
Materials, supplies and services	C
Other expenses	D
TOTAL COSTS FOR WHICH FUNDING IS REQUESTED FROM ALL FUNDING SOURCES (A+B+C+D)	E= $13K

F) FUNDING SOURCE SUMMARY FOR 1 YEAR

FUNDING SOURCE	AMOUNT
Amount requested from PDI in this application	$13,000.0
Other	
Other	
TOTAL FUNDS APPLIED FOR (EQUAL TO E, ABOVE)	**E= $13K**

G) VALUE OF "IN KIND" CONTRIBUTIONS BY RESEARCH AGENCY FOR 1 YEAR

Include estimated value of research staff time and operating budgets contributed by principal researcher's agency, or other cooperator's agency, towards this project in the period covered by this application. (Funding is not requested for these items.)

DESCRIPTION	PERSON YEARS	APPROX. VALUE
Professional, technical, and other staff	0.2+0.1+0.1=0.4	$24K
Materials and supplies (greenhouse, chemical reagents, cages, aspirators, etc)		$5K
Travel for professional		$2K
Overhead (estimate for ARC 60%) and benefits		$18K
	TOTAL VALUE "IN-KIND" COSTS	**F= $49K**

ESTIMATED TOTAL PROJECT COST FOR 1 YEAR

ESTIMATED TOTAL COST OF PROJECT (1 YEAR) E & F	**$62,000.0**

APPROVAL BY PRINCIPAL APPLICANT'S EMPLOYER

The undersigned declare the approval and support of their organization for the research project as describe in this application. Signatures confirm that space and basic facilities for carrying out the proposed research are available for use and that the applicant is authorized to participate in this research project.

Name	Signature	Position	Date
Dr. Paul Sharma	M P Sharma	Manager of Crop and Plant Business Unit/ARC	02/01/30

TERMS AND CONDITIONS

The applicant(s) agree that, upon acceptance of funding, a commitment is made to:

a) Conduct the research as laid out in the proposal, excepting changes mutually agreed upon by the applicant(s) and the Executive of the Alberta Potato Research Association.

b) Allow the Alberta Potato Research Association to use all information, data and results generated as a result of the research for extension purposes.

c) Not publish or present any data from this study without the written permission of the Chairman of the PDI.

Principal Applicant: Dr. A. H. Khadhair Signature A H Khadhair Date Jan. 30, 02
Speciality: Phytoplasma specialist Organization: Alberta Research Council

Co-applicant (1): Dr. Piara Bains Signature Bains Date Feb. 1, 2002
Speciality: Potato Pathologist Organization: AAFRD- CDC North

Co-applicant (2): Ms. Patricia DuPlessis Signature P DuPlessis Date Feb 1/02
Speciality: Potato Specialist Organization: AAFRD- CDC North

Co-applicant (3): Dr. Kwesi Ampong-Nyarko Signature _____ Date Jan 30, 2002
Speciality: Entomologist Organization: AAFRD- CDC North

PDI Executive Committee Signature

_____
Date

_____

Powdery Scab Discussion

Potato Growers of Alberta Annual Meeting
Capri Centre, Red Deer, AB, San Remo room
November 18, 2004
4:45 PM to 5:45 PM

Attendees:
Dr. R. Howard, Plant Pathologist, AAFRD
Lori Delanoy, Extension Agronomist, AAFRD
Tricia McAllister, Potato Seed Specialist, AAFRD
Dr. Jill Thompson, Research Associate, U of Saskatchewan
Dr. Piara Bains,
Alfonso Parra, Technical Director, PGA
Harold Perry, Chair, Research Priorities Committee, PGA and Grower
Terry Morishita, Old Dutch chip growers
Hal Reed, Taber Home and Farm
Sherry Lisowski, Pathology Technologist, AAFRD
J Douglas Cuss, Leo-Chem Enterprises Inc.
Dr. Michele Konschuh, Potato Research Scientist, AAFRD

Lori Delanoy facilitated the meeting. Michele Konschuh recorded notes.

To our knowledge, this is the first open discussion about powdery scab in southern Alberta.

The reason for calling people together was an increase in the incidence of powdery scab in 2004. Terry Morishita and Hal Reed identified a significant problem with powdery scab in southern Alberta in 2004. Lesions in 2004 appeared larger than normal and get larger in storage. Some lesions on AC Glacier Chip tubers were quarter-sized. Some bins are "going down" due to soft rot and other secondary pathogens.

Ron clarified that, depending on weather conditions, it is possible to see a series of infections during the growing season. Lesions of different sizes in storage are likely the result of infections at different stages.

Varieties observed to be susceptible to powdery scab include Shepody, AC Glacier Chip, Goldrush, FL1879, FL1533, Kennebec, Niska, and Ivory Crisp. Dakota Pearl has fewer symptoms.

There is a region in southern Alberta that has periodically had powdery scab outbreaks. The region begins north of Brooks and extends south of Grassy Lake. Area around Nobleford and Lethbridge also have a history of powdery scab. The same "strip of land" was a problem in other years when environmental conditions favored powdery scab. Soil in these fields tends to be sandy. Root galls were present in 2003. Tuber lesions were observed in 2004. So far, no Potato Mop-Top Virus (PMTV) has been found in Alberta,

but powdery scab is the vector for this disease. Canada and the US are working on a joint strategy for PMTV eradication.

Factors contributing to an increase in the incidence of powdery scab include short rotations (potato on potato or potato-snow-potato), environmental conditions (rainfall and temperature), irrigation, and inoculum. Powdery scab is often found in "low spots" in fields, where drainage may be a problem. Cool conditions at tuber set along with high moisture favor powdery scab development. Powdery scab is aggravated by soil temperatures of 12 to 15C.

Early planting may be beneficial. Seed piece treatments may have an impact. There are reports that mancozeb may reduce powdery scab. Some growers may be using less mancozeb in favor of products such as Maxim PSP.

A 6 to 10 year crop rotation may be necessary to reduce inoculum of powdery scab in an infested field.

Powdery scab was also observed on "virgin" potato land in 2004. The field could have been cross-contaminated by moving equipment and field soil from field to field. Powdery scab spores could also come in from the water supply. Water for some of the infested fields comes from processing plant lagoons and spores could have been introduced from soil and potato peels. Soil erosion may also spread spores from one field to another. Powdery scab spores can survive the bovine digestive tract, so composted manure from cattle fed cull potatoes and peels may contribute to the problem. Compost increases organic matter in soil and may improve moisture retention, or it may actually contain spores. Also, symptom-less seed can have spore balls on tubers. There are PCR tests for spore balls (no commercial tests available in Alberta).

To reduce incidence of powdery scab:

- Use clean seed
- Select fields with no history of the disease
- Use mancozeb as a seed treatment or foliar fungicide
- Use judicious irrigation management
- Allegro (fluazinam) as a foliar treatment reduced powdery scab incidence in research trials
- Use a long rotation between potato crops (6 to 10 years)
- Some studies have shown that Bo and Zn reduced powdery scab infection, but can be phytotoxic
- Clean equipment between potato fields
- Irrigation 10 days prior to tuber set until 10 days after tuber set is critical, need to balance plants need for water with increased risk for powdery scab infections

Doug Cuss of Leo-Chem Enterprises addressed the group. They market a number of products including biosurfactant-type products (rhamnolipids). Bosurfactants are very effective ways of treating zoospores. Their product "Zonix" physically penetrates the zoospores by lysing cell membranes. It is effective at a rate of 100ppm/acre. The all-

natural biosurfactant product biodegrades within 28 days. It costs approximately $15 – 18 CAD/acre (8.5% Zonix). There is no chemical tolerance build up due to the physical nature of the control. The product can be applied via pivot, directly to sol or to foliage. It works best in a pH environment of 5 to 8. It works well in high mineral salt environments. Trials so far have focused on foliar protection and systems which give access to roots. Dr Awata (Idaho) has done a number of trials with Zonix.

Once the situation had been described, the group discussed opportunities for research and strategies to prevent problems in the future.

- Future research is needed on products like Allegro (fluazinam) and Zonix (biosurfactant)
- Irrigation work could be done. It is not know whether irrigating frequently with low volumes is better than irrigating less frequently with larger volumes when it comes to prevention of powdery scab.
- Soil from prospective fields could be tested using a bioassay approach in conhunction with a research facility. Tricia can provide disease-free nuclear potato tubers, growth chambers at CDCS or other facilities could be used to provide controlled conditions. Jill Thompson cautioned people about the danger of cross-contamination if watering or sampling is sloppy. Sample the control first, then others. Isolate treatments if possible.
- Commercial tests may need to be developed. AAFRD could play a role in method development and tech transfer to the private sector.

None of the proposed research can be accomplished without some source of funding. Research proposals will need to be drafted before any of this work will move forward.

Notes will be circulated to participants.

Project #
New: **X** Renewal:

MEMORANDUM OF UNDERSTANDING

Between: The Potato Growers of Alberta
(hereafter referred to as "PGA")

and

Alberta Agriculture, Food & Rural Development
(hereafter referred to as "AAFRD")

PROJECT TITLE

A Survey to Assess the Distribution, Incidence and Severity of *Alternaria* species Causing Leaf Blight on Potatoes in Southern Alberta

OBJECTIVES

1) To assess the distribution, incidence (% affected plants) and severity (proportion of leaf area affected) of brown spot (*Alternaria alternata*) and early blight (*Alternaria solani*) in commercial fields of processing potatoes grown under irrigation in southern Alberta.
2) To determine the relative frequency of brown spot and early blight in individual potato fields on various farms.
3) To measure the *in vitro* sensitivity/resistance of isolates of *Alternaria alternata* and *Alternaria solani* to the main foliar fungicides used to control brown spot and early bight in southern Alberta potato fields.
4) To examine to relative effectiveness of current management practices employed by growers for controlling foliar diseases caused by *Alternaria* species in potatoes.

STATEMENT OF WORK

Alberta Agriculture, Food & Rural Development is willing to undertake the specified study for the PGA, which hereby agrees to contribute toward the costs of generating and reporting the information required as described in the attached research proposal.

PERIOD OF WORK

The research project will commence on or about July 1, 2004 and a final report will be completed by January 31, 2005.

BASIS OF PAYMENT

As a sponsor of the project, the PGA will provide **$3,210** upon finalization of this memorandum to AAFRD, to cover the following estimated costs for the duration of the trial:

Technical Manpower	$2,500
Materials & Supplies	$ 500
GST (7%)	$ 210
TOTAL	**$3,210**

This budget can be adjusted and used at the discretion of the project manager.

Payment of research project expenditures will be made from funds made available to AAFRD up to the maximum amount of funds received from the sponsor.

Upon request, AAFRD will provide a record of revenue and expenditure upon project completion or depletion of funds. Any remaining funds after completion or termination of the project can be used for research at the discretion of the project manager.

RESPONSIBILITY OF PROJECT MANAGER

The project manager for this study is Dr. Ron Howard. He will provide all reports to the sponsor, AAFRD and other parties at the discretion of the sponsor.

The project manager will authorize expenses and submit them to the appropriate AAFRD department for processing payment.

The project manager is not eligible for any manpower funds himself.

AMENDMENTS OR TERMINATION

This Memorandum of Understanding may be amended by mutual consent of the parties as evidenced by an exchange of letters.

Either AAFRD or PGA may terminate this Memorandum of Understanding by providing two weeks notice in writing to the other party.

NOTICES AND REPRESENTATIVES

Notices for all purposes of or incidental to this Memorandum of Understanding shall be effectively given if delivered personally, or sent by registered or certified mail to the representatives of the parties designated as follows:

Potato Growers of Alberta:

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1
403-223-2262

Alberta Agriculture, Food & Rural Development:

Dr. Christine Murray
Branch Head
Crop Diversification Centre South
S. S. #4
Brooks, AB T1R 1E6
403-362-1313

The Department of Agriculture, Food & Rural Development, Potato Growers of Alberta, and other sponsors of the project may use information generated from the project.

The sponsor, Potato Growers of Alberta, relinquishes ownership of any materials, supplies and assets purchased with the project funds to Alberta Agriculture, Food & Rural Development, which assigns control to the project manager's departmental division.

The parties affirm their acceptance of the terms of this Memorandum of Understanding by signing below.

Copies bearing original signatures of this Memorandum will be kept by each party.

R.J. Howard
Dr. Ron Howard, Project Manager

Sept. 3, 2004
Date

I agree that the project manager named above may supervise this project.

Dr. Christine Murray, Branch Head
Crop Diversification Centre South

Date

Mr. Vern Warkentin, Executive Director
Potato Growers of Alberta

Sept 7/04
Date

Potato Growers of Alberta
Tel. 403 223-2262
Fax 403 223-2268
6008 46Th Av Taber Alberta
T1G 2B1

Memo

To: Vern Warkentin

From: Alfonso Parra

Date: September 07, 2004

Re: Early Blight Survey

Vern,

I have received the memorandum of understanding of the Early Blight Survey from Ron Howard.
This survey was already discussed with the members of the research committee and they initially agreed on the concept. The proposal came in almost three weeks ago and was sent to the members for review.
The results from the survey will help growers to know the types of pathogens that are causing Early Blight in southern Alberta and the levels of control provided by the commercial fungicides.
I would appreciate your green light to this proposal by approving the submitted budget.

Thanks.

Alfonso Parra
Technical Director

Taber, Sept 07 2004.

Ron Howard
Plant Pathologist
Alberta Agriculture, Food and Rural Development
Crop Diversification Centre South
Brooks

Re: "A Survey to Assess the Distribution, Incidence and Severity of Alternaria Species Causing Leaf Blight on potatoes in Southern Alberta in 2004."

Dear Ron

We are pleased to advise that the Board of the Potato Growers of Alberta has approved your application in the amount of, $5000.00, and the funds are available to meet the timelines specified in your application.
When requesting the funds for the project, please provide an invoice that specifies the amount, GST and to whom payable.
We appreciate your commitment and dedication to the potato industry.

Yours truly,

Alfonso Parra
Technical Director

A Survey to Assess the Distribution, Incidence and Severity of *Alternaria* species Causing Leaf Blight on Potatoes in Southern Alberta in 2004
July 25, 2004

Purpose of the Survey

- To assess the distribution, incidence (% affected plants) and severity (proportion of leaf area affected) of brown spot (*Alternaria alternata*) and early blight (*Alternaria solani*) in commercial fields of processing potatoes grown under irrigation in southern Alberta.
- To determine the relative frequency of brown spot and early blight in individual fields on various farms.
- To measure the *in vitro* sensitivity/resistance of isolates of *Alternaria alternata* and *Alternaria solani* to the main foliar fungicides used to control brown spot and early bight in southern Alberta potato fields.
- To examine to relative effectiveness of current management practices employed by growers for controlling foliar diseases caused by *Alternaria* species in potatoes.

Survey Team and Responsibilities

- Alfonso Parra, Potato Growers of Alberta, Taber – Select survey fields, obtain cultural information from growers, survey fields to collect incidence and severity data, gather plant samples, interview growers to assess the effectiveness of disease control practices, and compile survey data.
- Andrew Ronald, McCain Foods, Coaldale - Assist with the selection of survey fields.
- Kal Basu, BioVision Seed Labs, Edmonton – Isolate and identify *Alternaria* species from plant samples, prepare cultures for fungicide sensitivity testing, and compile data on species occurrence.
- Ron Howard, Sharon Lisowski and David Slomp, Plant Pathology Program, Crop Diversification Centre South, Brooks – Develop survey protocols, train surveyors, assist with disease severity assessments on leaf samples, conduct fungicide sensitivity testing, and prepare the final report.

Survey Procedures

- Contact growers to obtain permission to survey fields and to gather background information on cultural practices and the history of alternaria diseases on their farms.
- Survey individual potato fields in August – September. Walk a diagonal transect through each field stopping a five sites and rating disease incidence (% plants with brown spot/early blight symptoms) and disease severity (0-5 canopy rating, where 0 = no blight on canopy, 1 = < 1% blighted, 2 = 1-10% blighted, 3 = 11-25% blighted, 4 = 26-50% blighted and 5 = >50% blighted). Twenty compound leaves will be collected at random from the middle and upper parts of the canopy in a 5 m section of row at each site. These leaves will be visually evaluated for disease severity using the 0 to 5 scale described above as it pertains to individual leaves.
- Isolate and identify *Alternaria* species in each sample submitted for analysis. Prepare single-spore cultures and place them on half-strength slants of potato dextrose agar (PDA) for submission to CDC South.

- Conduct *in vitro* screening to determine the sensitivity of *Alternaria* species to the top three or four fungicides used for controlling early blight on potatoes in Alberta. Special focus will be placed on strobilurin fungicides. Other fungicides may be tested depending on interest from pesticide companies. Compare ED_{50} and ED_{95} values obtained in this study with the published results of other workers.

Time Lines

- Preparation, Field Survey and Related Activities – June to September, 2004
- Isolation and Identification of Pathogens – September to October
- *In Vitro* Sensitivity Tests – November to December
- Preparation of Final Report – January, 2005

Budget

- Contact growers, survey fields, rate disease incidence and severity and compile data (Potato Growers of Alberta) – In-kind support.
- Receive leaf samples, isolate and identify *Alternaria* species and prepare cultures for fungicide sensitivity testing (BioVision Seed Labs) - $2000
- Conduct fungicide sensitivity tests and prepare a final report (CDC South) - $3000

MINIMUM BUDGET FOR PROJECT - $5000

Results

- Prepare reports for presentation to PGA members, cooperators and other interested individuals.

Alternaria Species from 2004 Surveyed Potato leaf samples for the detection of Leaf Blight.

Materials and Methods : Composite samples from each of the 30 fields were dried and surface sterilized with 2% bleach solution. Leaves were then placed in a moist chamber for 7 to 10 days with paper towel damp but not soaked.
After sporulation, spores were picked up by a needle which was dipped in sterile water. Spores were identified and few spores were plated on PDAA plate and incubated for 7 days. *Alternaria* cultures were then transferred to agar slants to be given to CDC south for fungicide sensitivity tests.

Alternaria species were identified by observing shape and size of the conidia. The following criteria was used for identifying *Alternaria solani* and *Alternaria alternata.*

Alternaria solani : Fungus culture pale to brown. Conidia with long beak solitary on each conidiophore. 150-300 µm x 15-19 µm with beaks, 9-11 transverse septa. Culture looks yellow in the edges.

Alternaria alternata : Brown to black cultural growth on PDAA consisting of conidia in long chains. Chains can be simple or branched. 10 - 58 µm x 7-9 µm.

Leaves from some of the fields show *Alternaria alternata* growing along with *Alternaria solani*

Results are as follows,

Field # 1 --- *Alternaria alternata*

Field # 2 ---- *Alternaria alternata, Alternaria solani*

Field # 3 --- *Alternaria alternata, Alternaria solani*

Field # 4 ---- *Alternaria alternata, Alternaria solani*

Field # 5 ---- *Alternaria alternata, Alternaria solani*

Field # 6 ---- *Alternaria alternata*

Field # 7 ----- *Alternaria alternata, Alternaria solani*

Field # 8 ----- *Alternaria alternata, Alternaria solani*

Field # 9 ------ *Alternaria alternata, Alternaria solani*

Field # 10 ----- *Alternaria alternata*

Field # 11 ---- *Alternaria solani*

Field # 12 ---- *Alternaria alternata,*

Field # 13 ---- *Alternaria alternata, Alternaria solani*

Field # 14 ---- *Alternaria alternata, Alternaria solani*

Field # 15----- *Alternaria alternata*

Field # 16 ---- *Alternaria alternata, Alternaria solani*

Field # 17----- *Alternaria alternata*

Field # 18----- *Alternaria alternata*

Field # 19---- *Alternaria solani*

Field # 20----- *Alternaria alternata*

Field # 21----- *Alternaria alternata*

Field # 22----- *Alternaria alternata*

Field # 23----- *Alternaria alternata*

Field # 24 ---- *Alternaria alternata, Alternaria solani*

Field # 25---- *Alternaria alternata*

Field # 26 ---- *Alternaria alternata, Alternaria solani*

Field # 27---- *Alternaria alternata, Alternaria solani*

Field # 28---- *Alternaria alternata, Alternaria solani*

Project # 629122
New: **X** Renewal:

MEMORANDUM OF UNDERSTANDING

Between: The Potato Growers of Alberta
(hereafter referred to as the "PGA")
and
Alberta Agriculture, Food & Rural Development
(hereafter referred to as "AAFRD")

PROJECT TITLE

Diagnosis, Characterization and Management of Powdery Scab on Commercial Potatoes in Alberta

OBJECTIVES

1) To develop methods for reliably detecting *Spongospora subterranea*, the cause of powdery scab, on potato tubers and in soil, and for predicting the potential risk for disease development in fields selected for potato production.
2) To characterize the strains of *S. subterranea* occurring in central and southern Alberta in order to determine their genetic diversity, virulence on potato cultivars and lines, and ability to act as vectors of Potato Mop Top Virus.
3) To investigate methods for reducing scab incidence and severity in seed, processing and table potatoes, including varietal resistance, seed and soil treatments, irrigation management, soil amendments, and rotational crops.
4) To use the information generated in this study to enhance our knowledge of the biology of powdery scab and to improve the techniques for managing this disease, thereby reducing potential yield and quality losses for growers and processors.

STATEMENT OF WORK

Alberta Agriculture, Food & Rural Development is willing to undertake the specified study for the PGA, which hereby agrees to contribute toward the costs of generating and reporting the information required as described in the attached research proposal.

PERIOD OF WORK

The research project will commence on or about April 1, 2005 and interim report will be completed by March 31 of 2006 and 2007. A final report will be submitted by March 31, 2008

BASIS OF PAYMENT

As a sponsor of the project, the PGA will provide **$15,000** + GST upon finalization of this memorandum to AAFRD to cover the following estimated annual costs for the three-year duration of the project:

Technical Manpower	$10,000
Materials & Supplies	$ 5,000
GST (7%)	$ 1,050
TOTAL	**$16,050**

This budget can be adjusted and used at the discretion of the project manager. A portion of these funds can be disbursed to other members of the research team as may be required to complete work specified in the project proposal.

Payment of research project expenditures will be made from funds made available to AAFRD up to the maximum amount of funds received from the sponsor and subject to satisfactory reviews of the interim progress reports by the sponsor.

Upon request, AAFRD will provide a record of revenue and expenditure upon project completion or depletion of funds. Any remaining funds after completion or termination of the project can be used for research at the discretion of the project manager.

RESPONSIBILITY OF PROJECT MANAGER

The project manager for this study is Dr. Ron Howard. He will provide all reports to the sponsor, AAFRD and other parties at the discretion of the sponsor.

The project manager will authorize expenses and submit them to the appropriate AAFRD department for processing payment.

The project manager is not eligible for any manpower funds himself.

AMENDMENTS OR TERMINATION

This Memorandum of Understanding may be amended by mutual consent of the parties as evidenced by an exchange of letters.

Either AAFRD or the PGA may terminate this Memorandum of Understanding by providing two weeks notice in writing to the other party.

NOTICES AND REPRESENTATIVES

Notices for all purposes of or incidental to this Memorandum of Understanding shall be effectively given if delivered personally, or sent by registered or certified mail to the representatives of the parties designated as follows:

The Potato Growers of Alberta:

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1
Phone: 403-223-2262

Alberta Agriculture, Food & Rural Development:

Dr. Christine Murray
Branch Head
Crop Diversification Centre South
S. S. #4
Brooks, AB T1R 1E6
Phone: 403-362-1313

The Department of Agriculture, Food & Rural Development, the Potato Growers of Alberta, and other sponsors of the project may use information generated from the project.

The sponsor, the PGA, relinquishes ownership of any materials, supplies and assets purchased with the project funds to Alberta Agriculture, Food & Rural Development, which assigns control to the project manager's departmental division.

The parties affirm their acceptance of the terms of this Memorandum of Understanding by signing below.

Copies bearing original signatures of this Memorandum will be kept by each party.

R.J. Howard — Oct. 26, 2005

Dr. Ron Howard, Project Manager — Date

I agree that the project manager named above may supervise this project.

Christine Murray — Nov 14/05

Dr. Christine Murray, Branch Head
Crop Diversification Centre South — Date

Nov 2/05

Mr. Vern Warkentin, Executive Director
Potato Growers of Alberta — Date

Alberta
AGRICULTURE, FOOD AND
RURAL DEVELOPMENT

Crop Diversification Centre South

S.S. #4
Brooks, Alberta
Canada T1R 1E6

Main Switchboard: 403/362-1300
Phone: 403/362-1328
Fax: 403/362-1326

September 2, 2005

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1

Dear Vern,

I am pleased that the PGA Board has agreed to help fund the research project *Diagnosis, Characterization and Management of Powdery Scab on Commercial Potatoes in Alberta*. This study is progressing well and I would like to access the money that the PGA has been allocated. For 2005/06, I would like the $15,000 grant split into three parts as follows:

Detection of Powdery Scab on Tubers and in Soil – This phase of the study is being carried out by Dr. Larry Kawchuk, AAFC, who will receive $5,000 for the work that he will be doing. There is no need to add the GST to this amount. The cheque should be made out to the *Receiver General of Canada* and mailed directly to Dr. Kawchuk at the following address: Agriculture and Agri-Food Canada, Research Centre, P.O. Box 3000 Main, Lethbridge, AB T1J 4B1.

Management of Powdery Scab with Fungicides - Dr. Jill Thomson, University of Saskatchewan, is carrying out a fungicide efficacy trial for us and has been allocated $3,000 for this work. There is no need to add the GST to this contribution. The cheque should be made out to the *University of Saskatchewan* and mailed directly to Dr. Doug Waterer at: Plant Sciences, College of Agriculture, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK S7N 5A8.

Epidemiology and Management of Powdery Scab – My staff and several cooperators will be collecting samples of soil and plant material for Dr. Kawchuk's studies and also documenting the cultural practices in fields with PS outbreaks. We will be doing some fungicide and variety screening trials in the greenhouse as well. Our share of the grant will be $7,000 + GST. An invoice for this amount is enclosed.

Sincerely,

Ron

Ron Howard, Ph.D., P.Ag.
Plant Pathologist

Encl.

POTATO GROWERS OF ALBERTA

6008, 46th Avenue
Taber, Alberta T1G 2B1

Phone (403) 223-2262
Fax (403) 223-2268
e-mail: pga@albertapotatoes.ca
www.albertapotatoes.ca

April 28, 2005

Ron Howard
Plant Pathologist
Alberta Agriculture, Food and Rural Development
Crop Diversification Centre South
S.S. #4
Brooks, AB T1R 1E6

Re: "Diagnosis, Characterization and Management of Powdery Scab on Commercial (seed and processing) Potatoes in Alberta"

Dear Ron:

We are pleased to advise that the Board of the Potato Growers of Alberta has approved your application in the requested amount of $15,000.00. The funds are available to meet the timelines specified in your application.

When requesting the funds for the project, please provide an invoice that specifies the amount, GST and to whom payable.

We appreciate your commitment to the potato industry.

Yours truly,

Vern Warkentin
Executive Director

POTATO GROWERS OF ALBERTA

6008, 46th Avenue
Taber, Alberta T1G 2B1

Phone (403) 223-2262
Fax (403) 223-2268
e-mail: pga@albertapotatoes.ca
www.albertapotatoes.ca

April 28, 2005

Ron Howard
Plant Pathologist
Alberta Agriculture, Food and Rural Development
Crop Diversification Centre South
S.S. #4
Brooks, AB T1R 1E6

Re: "Diagnosis, Characterization and Management of Powdery Scab on Commercial (seed and processing) Potatoes in Alberta"

Dear Ron:

We are pleased to advise that the Board of the Potato Growers of Alberta has approved your application in the requested amount of $15,000.00. The funds are available to meet the timelines specified in your application.

When requesting the funds for the project, please provide an invoice that specifies the amount, GST and to whom payable.

We appreciate your commitment to the potato industry.

Yours truly,

Vern Warkentin
Executive Director

Potato Growers of Alberta

Proposal application for Research funding 2005-2006

Instructions

To assess the proposals consistently, they must be completed according to the parameters contained in this form. Proposals may be rejected for incomplete information or lack of compliance with the instructions. This application could use other sources of forms only if it will be presented to other funding consortiums.
Please jump between boxes using the "Tab" key and avoid the use of the "enter" key. The PGA Research Committee will set dates for project presentations and result reports.

Confidentiality

This Proposal is confidential and the information contained in it may not be disclosed with other organizations or research groups. ☐

1. Research Team Information

Team Leader: Dr. Ron Howard		
Organization: AAFRD	Section/Department: CDC South	
Address: S.S.#4	City: Brooks	Province:AB
Postal Code:T1R 1E6	E-mail : ron.howard@gov.ab.ca	
Phone Number: 403-362-1328	Fax Number: 403-362-1326	

Team Member: Dr. Larry Kawchuk		
Organization: AAFC	Section/Department:Plant Pathology	
Address: P.O. Box 3000 Main	City: Lethbridge	Province:AB
Postal Code:T1J 4B1	E-mail: kawchuk@agr.gc.ca	
Phone Number: 403-317-2271	Fax Number: 403-382-3156	

Team Member: Dr. Piara Bains		
Organization: Agri-Research	Section/Department:	
Address:15708-76 Street	City: Edmonton	Province:AB
Postal Code:T5Z 2X2	E-mail address:piara.bains@agri-research.co	
Phone Number: 780-475-7955	Fax Number: 780-475-7955	

2. Project Information

Title:Diagnosis, Characterization and Management of Powdery Scab on Commercial Potatoes in Alberta
Category of the project (Please check more than one box if necessary): ☒ Pest Management ☐ Water and Irrigation Management ☐ Potato Storage ☐ Potato Breeding ☐ Potato Plant Physiology ☐ Potato Fertility Plant ☐ Nutrition/Soil management ☐ Green House ☐ Environment ☐ Potato Marketing and Economics ☐ Potato Cultural Management
Research Location (s): Brooks, Lethbridge, Edmonton, Saskatoon
Duration (Y):3 Start Date (YY/MM):05/05Ending Date (YY/MM):08/12

Is the project linked to other applications / Research projects Y ☒ N ☐
(Please identify related projects)

1.Project: Diagnosis and Management of Potato Diseases
Team Leader: Dr. Larry Kawchuk

Start Date: 2000

2.Project: Effects of Green Manures on Potato Diseases
Team Leader: Dr. Michele Konschuh

Start Date: 2005

Background.
(Max 2000 characters)

Powdery scab (PS), caused by the fungus Spongospora subterranea (Ss), is a serious disease in many potato-growing areas of the world. PS seems to be increasing in incidence and severity in Western Canada and there have been several outbreaks in AB, SK and MB since 2000. Ss is long-lived in the soil (20 yr), and has alternative hosts such as tomato, pepper and nightshade. Disease development is favored by cool, wet conditions. PS can reduce plant vigor, tuber number and yield, and lead to the rejection of tubers for seed and other uses. Effective control measures for PS are very limited, but some new techniques appear promising.

A severe limitation in diagnosing and managing PS has been an inability to reliably detect Ss in soil and on seed tubers. The inability to culture Ss is also a hindrance in studying PS. Current methods for detecting Ss include baiting, serology and PCR (polymerase chain reaction). To enable accurate risk assessment, it is first necessary to quantify the level of infection in potato roots and tubers, and to relate this information to the spore concentration in the soil. Available detection methods have not been critically evaluated for their efficiency in detecting the strains of Ss that occur in Alberta. Access to a reliable and cost-effective diagnostic test

would enable potato growers to select fields with a low risk of disease development. Characterization of the genetic variability in Ss strains could help potato breeders develop resistant varieties.

Very few strategies for managing PS have been evaluated under Alberta conditions. No single approach has proven to be effective for preventing or controlling PS in other parts of the world where it occurs. The integration of cultural, chemical and biological control practices, e.g. resistant varieties, seed and soil treatments, irrigation management, soil amendments and crop rotation, might create a cost-effective management program for this disease.

Objectives (Measurable-Deliverables)
(Please use Bullets) (Max 1000 characters)

1) To develop methods for reliably detecting Ss on tubers and in soil, and for predicting the potential risk for PS development in fields selected for potato production.
2) To characterize the strains of Ss occurring in central and southern Alberta in order to determine their genetic diversity, virulence on potato cultivars and lines, and ability to act as vectors for Potato Mop Top Virus (PMTV).
3) To investigate methods for reducing PS incidence and severity in seed, processing and table potatoes, including varietal resistance, seed and soil treatments, irrigation management, soil amendments, and rotational crops.
4) To use the information generated in this study to enhance our knowledge of the biology of PS and to improve the techniques for managing this disease, thereby reducing potential yield and quality losses for growers and processors.

Economical/Environmental Benefits

(Please mention how the results of this project will benefit potato production economically and environmentally.(Max. 1000 characters) .

Concerns over an apparent increase in the occurrence of PS and the damage it causes have been heightened by the capability of Ss to also vector PMTV, one of the so-called potato tuber necrosis viruses that is included under a Joint Potato Virus Management Plan between the U.S.A. and Canada. Diseases such as PMTV are often used as non-tariff trade barriers. Freedom from PMTV would be advantageous to Alberta's seed potato industry. The presence of PS in seed potatoes can result in a reduction or loss of certification status. Severe PS infection can reduce the yield and quality of table and processing potatoes, and predispose tubers to soft rot. Although reliable estimates of losses due to PS infection are unavailable, there were reports of significant damage to some chipping cultivars in Alberta in 2003-04 because affected tubers decayed in storage. Effective management of PS would reduce the risk of field and storage losses and improve profit margins for producers and processors.

Methodology Description

(Please describe the scientific process you will follow to achieve project objectives).(Max 2000 Characters)

1) Detection and Quantification - A PCR assay will be developed that should reliably detect and quantify DNA from sporeballs, zoospores and plasmodia/zoosporangia of Ss. The assay will be used to measure the viability of sporeballs in soil. Together with a tomato bait plant technique, infection levels in potatoes grown under various environmental conditions will be examined. The influence of temperature, soil type, inoculum levels, and soil moisture on infection will be determined. Testing for PS in field soil and on tubers will be done using this method.

2) Strain Characterization - The PCR assay described above will be used to ananalyze genetic variability within Ss and to identify different strains. A PCR assay specific to PMTV will be used to confirm the presence or absence of the virus in isolates of Ss. Because the symptoms of PMTV infection are similar to those of Tobacco Rattle Virus (TRV) and include spraing (brown-colored arcs or spots) in the tubers, yellow blotching or chlorotic V-shapes in the leaves and stunting of the stems, a PCR test for

TRV will also be carried out on samples tested for PMTV.
3) Disease Management - Tissue-cultured plantlets from the Alberta Seed Potato Bank will be screened for resistance to PS, as will a selection of advanced lines from the Western Canadian Potato Breeding Program, using aggressive Alberta strains of Ss. Those exhibiting resistance will be advanced to confirmatory field trials. Several seed and soil treatments (e.g. Zonix, fluazinam, mancozeb, boron) will be tested for efficacy against PS in the greenhouse and the most promising materials advanced to field trials. The effects of irrigation scheduling and amounts on PS incidence and severity will be monitored in two commercial fields with a history of PS and the results compared to the those of other researchers. The effects of green manure crops on PS development will be assessed as part of a field study by M. Konschuh, as well as in greenhouse trials at CDCS.

Technology Transfer Plan.
(Please describe the proposed method to communicate findings and results) (Max. 1000 characters)
Interim and final results will be presented to the PGA, potato growers and project cooperators through oral and poster presentations at events such as the PGA and ASPGA annual meetings, field days, area and/or breakfast meetings. Written reports, newsletter articles and scientific publications will be prepared and made available to the PGA, growers and cooperators.

3. Project Budget

		Year 1	Year 2	Year 3	**Total**
PGA	Cash	15000	15000	15000	45000
	In-Kind	2500	2500	2500	7500
	Total	17500	17500	17500	52500
Other					
	Cash				
AAFRD					

	In-Kind	30000	30000	30000	90000
	Total	30000	30000	30000	90000

Other

	Cash				
	In-Kind	30000	30000	30000	90000
AAFC	Total	30000	30000	30000	90000

Other

	Cash				
	In-Kind	2500	2500	2500	7500
Univ. Sask.	Total	2500	2500	2500	7500

Other

	Cash	4000	4000	4000	12000
	In-Kind	1000	1000	1000	3000
Companies	Total	5000	5000	5000	15000

Total	**85000**	**85000**	**85000**	**255000**

Project Cost Distribution	Year 1	Year 2	Year 3	**Total**
Personnel	50000	50000	50000	150000
Travel expenses	1000	1000	1000	3000
Capital goods	2000	2000	2000	6000
Materials	8000	8000	8000	24000
TOT	1000	1000	1000	3000
Overhead	23000	23000	23000	69000
Total	**85000**	**85000**	**85000**	**255000**

*TOT (Transference of Technology)

Research Project Manager

Signature **Date**

POTATO GROWERS OF ALBERTA

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April 28, 2005

Ted Harms
Soil & Water Resource Engineer
Alberta Agriculture, Food and Rural Development
Crop Diversification Centre South
S.S. #4
Brooks, AB T1R 1E6

Re: "Evaluation and Adaptation of Early Blight Prediction Methods for Irrigated Potatoes in Southern Alberta"

Dear Ted

We are pleased to advise that the Board of the Potato Growers of Alberta has approved your application in the amount of $10,000.00. The funds are available to meet the timelines specified in your application.

When requesting the funds for the project, please provide an invoice that specifies the amount, GST and to whom payable.

We appreciate your commitment to the potato industry.

Yours truly,

Vern Warkentin
Executive Director

Potato Growers of Alberta

Proposal application for Research funding 2005-2006

Instructions

To assess the proposals consistently, they must be completed according to the parameters contained in this form. Proposals may be rejected for incomplete information or lack of compliance with the instructions. This application could use other sources of forms only if it will be presented to other funding consortiums.
Please jump between boxes using the "Tab" key and avoid the use of the "enter" key. The PGA Research Committee will set dates for project presentations and result reports.

Confidentiality

This Proposal is confidential and the information contained in it may not be disclosed with other organizations or research groups. ☐

1. Research Team Information

Team Leader:Ted Harms		
Organization:AAFRD	Section/Department:Irrigation	
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Phone Number:362-1347	Fax Number:362-1306	

Team Member: Ron Howard		
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Postal Code:T1R 1E6	E-mail:ron.howard@gov.ab.ca	
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Team Member:Michele Konshuh		
Organization:AAFRD	Section/Department:Agronomist	
Address:SS#4	City:Brooks	Province:AB
Postal Code:	E-mail address:michele.konshuh@gov.ab.ca	
Phone Number:362-1314	Fax Number:362-1306	

2. Project Information

Title:Evaluation and Adaptation of Early Blight Prediction Methods for Irrigated Potatoes in Southern Alberta
Category of the project (Please check more than one box if necessary): ☒ Pest Management ☒ Water and Irrigation Management ☐ Potato Storage ☐ Potato Breeding ☐ Potato Plant Physiology ☐ Potato Fertility Plant ☐ Nutrition/Soil management ☐ Green House ☒ Environment ☐ Potato Marketing and Economics ☐ Potato Cultural Management
Research Location (s): Southern Alberta
Duration (Y):1 Start Date (YY/MM):05/04Ending Date (YY/MM):05/12

Is the project linked to other applications / Research projects Y ☐ N ☒
(Please identify related projects)

1.Project:
Team Leader:

Start Date:

2.Project:
Team Leader:

Start Date:

Background.
(Max 2000 characters)

The appearance of early blight (Alternaria solaria) in potato fields in Southern Alberta is a yearly occurrence. There are effective fungicides available to control early blight but the timing of application is crucial. Early fungicide applications prior to flowering have shown to be ineffective in controling early blight. Additionally, multiple fungicide applications can be costly.

Methods available to predict the initiation of early blight include some measure of either Physiological Day (P-Day) and/or Growing Degree Days (GDD). Most predictive models (e.g. WISDOM) use 300 P-Days as the threshold to start fungicide applications. Applications based on GDD with minimum temperature of 7.8 C vary depending on the area but values of 361 and 625 cumulative GDD were used in southern and northern Colorado respectively, as the GDD threshold. The Plant-plus system uses a combination of potato plant growth stages with P-Day and field humidity to predict onset of early blight.

Gent and Schwartz (2002) concluded that early blight forecasts were just as accurate when the source of the meteorological data for the P-Day or GDD

calculation was from a nearby meteorological station than if the data was obtained from within-field meteorological station.

Objectives (Measurable-Deliverables)
(Please use Bullets) (Max 1000 characters)

The objectives of this research project will be to evaluate 3 methods for the prediction of early blight. They include:

1) Plant-plus system offered by Dacom from the Netherlands
2) Wisdom
3) 300 Cumulative PDay Threshold
4) Producer scheduled

Additionally, all models will be operated on hourly data from both in-field meteorological monitoring and the nearest AAFRD Irrigation Branch meteorological station to assess the differences and/or value of either sources of meterological data.

Economical/Environmental Benefits
(Please mention how the results of this project will benefit potato production economically and environmentally.(Max. 1000 characters) .

The value of this project will be for assessment and identification of an early blight prediction model/procedure that can be adopted for use by potato growers. Timely and necessary fungicide applications can then be scheduled according to model results thereby avoiding either unnecessary fungicide applications or yield and quality loss due to early blight infection.

Additionally, if previous work (Gent and Swartz, 2002) is confirmed, and timing of fungicide applications can be obtained reliably from meteorological data from a nearby off-site weather station, then model results could be extended to most potato growing areas of southern Alberta.

Methodology Description

(Please describe the scientific process you will follow to achieve project objectives).(Max 2000 Characters)

Two potato fields will be selected by the PGA in the potato growing areas of southern Alberta. The fields selected should have in-field meteorological stations (Adcon) and be in fairly close proximity to an Irrigation Branch off-site meteorological station. Additionally, the fields should be located such that the incidence of early blight is probable.

A different model/procedure will be used for each half of each field using hourly data from both the in-field and off-site meteorological stations. Spraying for early blight will be done as recommended from the models. A small check strip will be left near the center of each field to assess the effectiveness of the model predictions as well as the incidence and severity of early blight.

Weekly visits to assess plant growth and other parameters for the various prediction models must be done either by the PGA field personnel or AAFRD's potato technologist.

Three visits per field for gathering plant material and assessing early blight infection will be done throughout the season. The first sampling will be done in conjunction with CDCS pathology staff. Subsequent samplings will be carried out by the PGA summer technician.

Harvest will be done by the potato agronomy staff from CDCS and analysis will include:
- yield and quality
- incidence of disease
- economic assessments (product usage rate time price of product.

Daily model simulations from both the in-field and off-site meteorological stations for early blight prediction will be done by irrigation staff from CDCS. Data will be communicated to the cooperators at the frequency and method dictated by the PGA.

Hopefully, a method/model will be selected based on the first year of testing. For subsequent years, the selected model/method will be validated for varying meteorological conditions on a variety of fields to improve the confidence level with the method chosen.

Technology Transfer Plan.
(Please describe the proposed method to communicate findings and results) (Max. 1000 characters)
A year-end report will be prepared by the research team and the findings will be submitted to the PGA. A presentation to the PGA membership would be appropriate at a convenient meeting once all data is collected, analyzed and the report written.

3. Project Budget

		Year 1	Year 2	Year 3	**Total**
PGA	Cash	10000	10000	10000	30000
	In-Kind				
	Total	10000	10000	10000	30000
Other					
Dacom	Cash				
	In-Kind	7500	7500	7500	22500
	Total	7500	7500	7500	22500
Other					
AAFRD	Cash				
	In-Kind	4700	4700	4700	14100
	Total	4700	4700	4700	14100
Other					
	Cash				
	In-Kind				
	Total				

Other

	Cash				
	In-Kind				
	Total				

Total	**22200**	**22200**	**22200**	**22200**

Project Cost Distribution	Year 1	Year 2	Year 3	**Total**
Personnel	10000	10000	10000	30000
Travel expenses	9500	9500	9500	28500
Capital goods	1500	1500	1500	4500
Materials	1200	1200	1200	3600
TOT				
Overhead				
Total	**22200**	**22200**	**22200**	**66600**

*TOT (Transference of Technology)

Research Project Manager

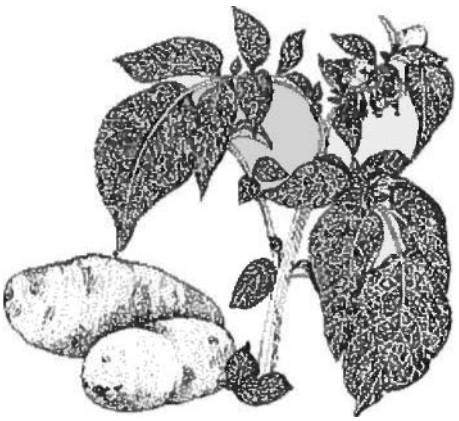
Signature **Date**

Diagnosis, Characterization and Management of Powdery Scab on Commercial Potatoes in Alberta

A Research Progress Report Submitted to

The Potato Growers of Alberta
6008 – 46th Avenue
Taber, Alberta T1G 2P1

February 28, 2006



Prepared by

Ron Howard, Plant Pathologist
Alberta Agriculture, Food and Rural Development
Crop Diversification Centre South
SS #4, Brooks, Alberta T1R 1E6

Introduction

Powdery scab (PS), caused by the fungus *Spongospora subterranea* f.sp. *subterranea* (Ss), is a serious disease in many potato-growing areas of the world. PS seems to be increasing in incidence and severity in Western Canada and there have been several outbreaks in AB, SK and MB since 2000. Ss is long-lived in soil (20 yr), and has alternative hosts such as tomato, pepper and nightshade. Disease development is favored by cool, wet soil conditions. PS can reduce plant vigor, tuber number and yield, and lead to the rejection of tubers for seed and other uses. Effective control measures for PS are very limited, but some new techniques appear promising.

A severe limitation in diagnosing and managing PS has been an inability to reliably detect Ss in soil and on seed tubers. The inability to culture Ss is also a hindrance in studying PS. Current methods for detecting Ss include baiting, serology and PCR (polymerase chain reaction). To enable accurate risk assessment, it is first necessary to quantify the level of infection in potato roots and tubers, and to relate this information to the spore concentration in the soil. Available detection methods have not been critically evaluated for their efficiency in detecting the strains of Ss that occur in Alberta. Access to a reliable and cost-effective diagnostic test would enable potato growers to select fields with a low risk of disease development. Characterization of the genetic variability in Ss strains could help potato breeders develop resistant varieties.

Very few strategies for managing PS have been evaluated under Alberta conditions. No single approach has proven to be effective for preventing or controlling PS in other parts of the world where it occurs. The integration of cultural, chemical and biological control practices, e.g. resistant varieties, seed and soil treatments, irrigation management, soil amendments and crop rotation, might create a cost-effective management program for this disease.

Project Objectives

1) To develop methods for reliably detecting Ss on tubers and in soil, and for predicting the potential risk for PS development in fields selected for potato production.
2) To characterize the strains of Ss occurring in central and southern Alberta in order to determine their genetic diversity, virulence on potato cultivars and lines, and ability to act as vectors for Potato Mop Top Virus (PMTV).
3) To investigate methods for reducing PS incidence and severity in seed, processing and table potatoes, including varietal resistance, seed and soil treatments, irrigation management, soil amendments, and rotational crops.
4) To use the information generated in this study to enhance our knowledge of the biology of PS and to improve the techniques for managing this disease, thereby reducing potential yield and quality losses for growers and processors.

Results for 2005-06

1. Disease Surveys

Approximately 25 samples of potato tubers were submitted to the CDC South for PS diagnosis in 2005. These samples were collected by project team members and growers, and were comprised of several varieties of table, processing and seed potatoes from central and southern Alberta. While most had PS, some were infected only with common scab (CS), or had both PS and CS. The two diseases have similar symptoms at the early stages of their development. Samples of PS-infected tubers were sent to the Lethbridge Research Center for molecular diagnosis.

Background information on the fields from which the PS samples were taken is being collected and summarized. These data will be reviewed to see if any common factors are evident that may have promoted the development of PS.

2. Detection, Quantification and Strain Characterization of Spongospora subterranea

Introduction

Dr. Larry Kawchuk and colleagues at the Lethbridge Research Center are developing assay techniques that can be used to determine the host range of Ss, to examine pathogen levels in soil from fields that will be planted with potatoes, and to confirm the presence or absence of Ss in asymptomatic tubers. This assay will be useful in determining the effectiveness of control procedures and assist in determining the strain populations of the PS pathogen in western Canada. Results of the assay can be obtained within 24 h and may therefore help expedite the certification of seed tubers.

Results

The nuclear ribosomal DNA (rDNA) regions of two hypervariable internal transcribed spacers (ITS1 and ITS2) and the 5.8S rRNA gene from 29 Alberta and Saskatchewan field isolates of SS were obtained with primers to the conserved sequences of the small subunit (SSU) rDNA and large subunit (LSU) rDNA with the polymerase chain reaction (PCR). Amplified sequences are being cloned and sequenced to determine the genetic variation amongst the isolates. The assay is sensitive and able to detect a single SS spore ball in 1 g of soil and in tuber lesions with no detectable spore balls.

SSU

1 **ggaaggatca ttaacactga** gtcggttcta ccggcagacc ccaaaaccac atgagaacct

ITS1

61 gggtgcgatt gtctgttgaa gggtgacgcc cgctctgggg ctagctcgaa accttatgca

121 aaccgtatta ctgaacttac taaagtggat cgtttaacta **aatacaactc ttaacagtgg**

181 **atatcttggt tcccacaacg atgaagaacg cagcgaaatg cgatacgtaa tgcgaattgc** **5.8S**

241 **agaattcagt gaatcatcaa atctttgaac gcaagttgcg ctttcgagat atccttgaaa**

301 **gcatgcctct ttgagtgtcg gtttctattc** tcccggaaac gccctgtgcg tggaagggga

ITS2

361 ctatgagctc tggtcggtcc atggcttgaa agattatcca acccggtgcg cgtctctggc

421 ttctgattcg tctctaacca ttggcgtgcc cggtcatata gaaccatttt **ttgactctag**

LSU

481 **atctcaaatg aggtaagact acccgctgaa tttaagcata tcaataagcg**

Figure 1. An Alberta Ss internal transcribed spacer (ITS) and 5.8S rDNA sequence. Conserved sequences of the three rDNA genes, small subunit rDNA (SSU), 5.8S rDNA, and a large subunit (LSU) rDNA are shown in bold text and underlined.

Discussion
Modification of the developed diagnostic assay will allow characterization of the strains of Ss in western Canada. The determined sequences should provide details that assist in examining the lifecycle of the pathogen and determining effective control of the disease. Similar diagnostics are also being developed to examine the 29 powdery scab isolates for the potato mop top furovirus that causes spraing in tubers and is vectored by Ss.

3. Disease Management: Chemical Control
Introduction
Six fungicides were evaluated for the control of soil-borne powdery scab by Drs. Jill Thomson and Doug Waterer, Department of Plant Sciences, University of Saskatchewan, Saskatoon, SK. A field trial site naturally infested with high levels of common scab (*Streptomyces scabies*) and powdery scab at the university was used for this study. Black scurf (*Rhizoctonia solani*) was also present. This site was used to evaluate the efficacy of six chemicals, applied on the seed, in the furrow at planting, or at hilling for the control of scab (powdery and common) and black scurf. This site featured a Sutherland Series sandy loam soil (pH 8.1, E.C. <1.0 dS, with 3.8% O.M.). The site was in a three-year potato rotation for 20 years, but beginning three years ago, it was switched to continuous potatoes in an effort to further exacerbate scab problems.

Methods
The trial was managed using conventional production practices. Machine cut Norland E2 seed was planted on May 27 using a single row planter. Row length was 6 m, with 1 m between rows and 25 cm between seed-pieces within the row. The treatments were arranged in a randomized block design with four replicates. A 3 m path separated the replicate blocks. Four side-by-side rows were used for each treatment. Root samples were taken from the outer rows and the two center rows were harvested and assessed for yield and disease.

A 30-tuber sample of the seed used to plant this trial was evaluated for disease levels prior to planting. Three percent of the tubers had more than 5% of the surface infected with black scurf. No scab was present on the seed. Rows were hilled twice – once prior to emergence and again at emergence. Irrigation was applied when the soil moisture potential fell below –60 kPa. Weeds were controlled by preplant application of metribuzin plus linuron applied prior to ground crack.

Six fungicides were applied to the seed prior to planting, as an in-furrow treatment and/or at hilling. The seed treatments were applied to cut seed-pieces as per the experimental protocol. The in-furrow products were applied with a hand-held pressurized sprayer, with the nozzle being held between the opener discs of the planter. The spray was directed over the area of the opened furrow where the seed dropped. The in-furrow and hilling treatments were applied in 3 L of water/24 m of row. The Ranman and Blinix treatments made at hilling (June 15) were applied at the same rate as used for the in-furrow treatments applied at planting. The at-hilling treatments were sprayed as a 15 cm wide band over the top of the hill. The rows were hilled immediately after the spray treatment. A heavy thundershower occurred after hilling, which presumably washed the chemical into the soil.

The fungicide treatments were:
1. Allegro 500F applied as a liquid in-furrow (40% fluazinam, Syngenta, 5.25 g product in 3 L

water/24 m row)
2. Tuberseal applied as a dust on the seed (16% mancozeb, United Agri Products, 7 g/25 seed pieces)
3. Dithane DG applied as a liquid in-furrow (75% mancozeb, Dow AgroSciences, 4.4 g product in 3 L /24 m row)
4. Ranman 400SC applied as a liquid in-furrow at planting and prior to hilling (34.5% cyazofamid, ISK Biosciences, 12 g product in 3 L/24 m row at both applications)
5. Blinix applied as a liquid in-furrow (8.5% Rhamnolipid Biosurfactant, Jeneil Biosurfactant Co., 6 mL in 3 L/24 m row)
6. Blinix applied prior to hilling (same rate as treatment 5)
7. Check – no chemicals applied.

Three hills were dug from one row of each treatment/replicate in early September and the incidence of powdery scab galls on the roots was assessed. The roots from each individual stem were rated for galls using the following scoring system, and the average score for all stems from the three hills was recorded. The system was 0= no galls present, 1 = < 5 galls on the whole root system, 2 = 5-30 galls on whole root system, and 3 = >30 galls on whole root system.

Plants were top-killed at the beginning of September with Reglone and the trial was harvested on September 26, using a single row plot harvester. The harvested tubers were suberized at 15°C with high airflow for several weeks after harvest, then cooled and stored at 5°C. Disease assessments were conducted in November 2005.

Samples consisting of 30 randomly selected tubers were assessed for each row harvested. Tubers were washed under running water before being visually evaluated for the level of disease. The levels of all three diseases – common and powdery scab and black scurf - were determined. Common and powdery scab lesions can have a very similar appearance. Common scab lesions tend to be more raised and superficial, with an irregular outline. Powdery scab lesions are more circular, tend to be clustered in one area of the tuber, penetrate through the tuber skin, and have a slight rim of tuber skin around lesions that may contain distinctive spore balls (cystosori). Lesions were examined carefully for the presence of cystosori, using a dissecting microscope, to identify powdery scab.

The following data were collected:
Disease incidence – the number of tubers infected with each disease, expressed as a percentage of the total number of tubers sampled.
Disease severity – the percentage tuber surface infected by each disease was assessed using rating scales provided by the Canadian Food Inspection Agency. Disease severity was then expressed as the average percentage tuber surface infected for the total number of tubers in a sample.
Percentage of tubers with >5% surface area affected – the number of tubers with more than 5% of the tuber surface area infected, expressed as a percentage of the total number of tubers sampled. This is an important measure of disease development as tubers with more than 5% of the surface area infected are considered to be moderately diseased and only 5% of such tubers are allowed in either seed or Grade A table potatoes.
Total yield – total weight of tubers harvested from each row.
Marketable size yield – the weight of tubers of marketable size, falling between 48 and 88 mm in

diameter, without taking into account grading-out due to disease infection.

Data were analyzed using the SAS GLM procedure. The values for the two rows in each treatment were averaged, and the averages analyzed. Tuber samples for disease analysis were missing for four rows. In two of these cases, a single row was used instead of the average, but both rows were missing from one replicate of the Ranman treatment. Analysis of data with missing values is possible with the GLM procedure. Treatment means were compared using the Duncan Multiple Range test at P=0.05.

Results and Discussion

The 2005 growing season at Saskatoon was cool and wet during May and June. Precipitation and temperatures were near normal in July and August. Crop establishment was slow, but conditions were excellent during tuber set and bulking. Thirty-seven cm of rainfall was received over the growing season (normal = 20 cm). A total of 13 cm of supplemental irrigation was applied to the plots. Yields were relatively high in all trials conducted in 2005. No significant problems with diseases or insects were observed in the trial.

Visual examination of the plots showed no effect of the various treatments on emergence, plant growth or vitality. Plant counts were not taken. There were no significant ($P \leq 0.05$) treatment effects on total or marketable size yield (Table 1). The coefficient of variance for the yield parameters was reasonably low.

Table 1. Total and marketable yield of tubers harvested from a chemical control trial at Saskatoon, SK in 2005.

Treatment (chemical applied)	Average yield of tubers (kg/6 m row)	
	Total weight of tubers (kg)	Weight of marketable tubers (kg)
Allegro	40.2	27.2
Tuberseal	38.4	27.3
Dithane	36.4	24.3
Ranman	37.1	25.2
Blinix in-furrow	36.0	25.0
Blinix at hilling	40.8	27.6
None (check)	39.7	25.7
Coefficient of variance (%)	*10.8*	*10.0*

The incidence of root galls formed by the powdery scab organism was significantly lower in the Ranman-treated hills than in the control, Allegro-, Tuberseal- and Dithane-treated hills (Table 2). Blinix-treated hills had relatively fewer galls, but the values were not significantly ($P \leq 0.05$) different from any other treatment. There was no difference between the hills receiving the Blinix at either planting or hilling. The relatively high variance in the root gall data likely reflects non-uniform distribution of powdery scab within both the plot area and the potato root system. The relationship between the incidence and severity of root galls and tuber damage by powdery scab is not clear. However, as root galls represent a significant inoculum source for powdery scab, any treatments that limit root gall formation could help moderate future problems with powdery scab.

Table 2. Effect of chemical treatments on the incidence of powdery scab galls on potato roots sampled in September 2005.

Treatment (chemical applied)	Average gall score
Allegro	2.5 a*
Tuberseal	2.3 a
Dithane	2.4 a
Ranman	1.3 b
Blinix in-furrow	2.0 ab
Blinix at hilling	2.1 ab
None (check)	2.6 a
Coefficient of variance (%)	*29.7*

* Values followed by the same letter are not significantly different using Duncan's Multiple Range Test ($P \leq 0.05$).

The levels of black scurf on harvested tubers were not affected by the chemical treatments (Table 3). The average incidence of black scurf was not high, with a range of 18 to 36 % of tubers being infected. The severity of black scurf on the harvested tubers was consistently low. No tubers had more than 5% of the surface area infected by *Rhizoctonia*. The coefficient of variance for the black scurf data was high; this reflects the infrequent and sporadic occurrence of *Rhizoctonia* in this trial.

Table 3. Effect of chemical treatments on disease incidence and severity on tubers harvested in September, 2005.

Treatment (chemical applied)	% of tubers infected with			% of tubers with > 5% surface area infected with	
	Black scurf	Common scab	Powdery scab	Common Scab	Powdery scab
Allegro	18.5	90.5 a*	76.9 ab	33.3 ab	25.5 a
Tuberseal	35.9	90.8 a	79.5 ab	32.4 ab	33.6 a
Dithane	28.4	91.3 a	83.1 a	33.9 ab	23.0 a
Ranman	20.0	77.2 b	30.7 c	18.3 b	4.5 b
Blinix in-furrow	26.8	89.6 ab	83.3 a	36.6 ab	31.8 a
Blinix at hilling	22.9	91.6 a	68.4 b	39.1 ab	18.0 ab
None (check)	26.5	93.9 a	77.1 ab	54.5 a	31.0 a
Coefficient of variance (%)	*44.6*	*9.1*	*48.4*	*9.7*	*46.7*

* Values followed by the same letter are not significantly different using Duncan's Multiple Range Test, p=0.05.

The application of Ranman significantly ($P \leq 0.05$) reduced the incidence and severity of both

powdery and common scab when compared with the levels seen on the untreated check (Table 3). The Ranman treatment appeared particularly effective against powdery scab. The reduction in percentage of tubers with > 5% surface area infected would have reduced losses to grade-out, and thus would have significantly increased the market value of the crop. The coefficients of variance for the common scab ratings were low – this reflects the uniform and high levels of infestation of the site by this pathogen. Although the overall incidence of powdery scab was almost as high as for common scab, the powdery scab is less uniformly distributed across the plot area – resulting in greater variation in the data. More replication and/or larger sample sizes may be required to clarify treatment effects for powdery scab control at this site.

The application of Blinix at hilling significantly reduced both the incidence and severity of powdery scab (P=0.09). It should be noted that while Ranman was applied at both planting and hilling, the Blinix treatment was applied either at planting or hilling, but not at both stages. Applying Blinix at both planting and hilling may produce more significant scab control. Further evaluation of both Ranman and Blinix is recommended.

Conclusions

Currently registered seed treatment products, such as Tuberseal, were not effective for the control of soil-borne scab. In-furrow applications of fluazinam (Allegro) and mancozeb (Dithane) were also ineffective at the rates used. Application of Ranman (cyazofamid) in-furrow and at-hilling appeared very promising as it provided a reasonable level of control of both common and powdery scab on a moderately scab sensitive variety growing in very heavily infested soil. Blinix (Rhamnolipid Biosurfactant) also appeared to have some potential; it should be tested at higher rates and/or in multiple applications.

4. Disease Management – Cultivar Resistance

Introduction

Tricia McAllister noted high levels of PS in certain potato trials at the Crop Diversification Centre North, Edmonton and took the opportunity to measure disease incidence (DI) and severity (DS) in tubers from three trials, i.e. Pre-Plant Handling of Seed (PPHS), Lutein Production, and the Prairie Main Crop Replicated Trial (PMRT).

Results

The origin of the infection could not be precisely determined, but the most heavily infested lots were observed in the PPHS trial. In the most severely affected areas, the DI was ≥20% (5 of 25 tubers) the DS was ≥3% of the total surface covered. DI and DS ratings (based on an average of 4 replications) are given below. Russet Burbank had very little tuber infection and Atlantic also appeared to be somewhat resistant to tuber infection. AC Glacier Chip was highly susceptible.

Trial	Variety/Line	Disease Incidence (% tubers infected with powdery scab)	Disease Severity (% tuber surface covered with scabs)
PPHS	Shepody	52.5	10.8
	AC Glacier Chip	42.3	5.9
	Atlantic	25.5	3.0
	Russet Burbank	0.8	0.1
Lutein	Sinora	18.0	2.5
PMRT	CV97085-1	42.0	6.3
	Shepody	34.8	6.3
	CV97112-4	21.0	2.8
	WV3252-1	18.0	2.5

Project Cooperators

The following individuals, organizations and companies provided technical assistance and/or financial/in-kind contributions:

- Dow AgroSciences Canada Inc.
- ISK BioSciences Corp.
- Jeneil Biosurfactant Co.
- Old Dutch Foods Ltd.
- Potato Growers of Alberta
- Syngenta Crop Protection Canada Inc.
- United Agri-Products Ltd.

Project Team Members

- Ron Howard, Sharon Lisowski, Michele Konschuh, Ted Harms and Lori Delanoy, Alberta Agriculture, Food and Rural Development, Crop Diversification Centre South, Brooks
- Piara Bains, Agri-Research Ltd., Edmonton
- Larry Kawchuk, Agriculture and Agri-Food Canada, Research Centre, Lethbridge
- Tricia McAllister, Alberta Agriculture, Food and Rural Development, Crop Diversification Centre North, Edmonton
- Terry Morishita, Old Dutch Foods Ltd., Rosemary
- Hal Reed, Taber Home and Farm Centre, Taber
- Kal Basu, BioVision Seed Labs, Edmonton

[redacted]

Potato Growers of Alberta
Research Tracking

Title of Research Application: Diagnosis characterization, management of powdery scab on commercial Potatoes in So. Ab. and yr.

Name of Researcher: Dr. Ron Howard

Employer: Ab. Agriculture

Date application was received by PGA _____

Date application was reviewed by PGA April 3/06

A) approved ✓ B) declined _____

Project start date: _____ Project finish date: _____

Total amount requested:$ _____ Amount requested per year: $ 15,000

MOU received and signed. Once copy returned to research agency, one copy filed in current year Research Binder

Date completed _____

Invoice received: # 4182006 Date funds advanced May 2, 2006 Cheque# 4238 $15,000-

Invoice received:# _____ Date funds advanced _____ Cheque# _____

Invoice received:# _____ Date funds advanced _____ Cheque# _____

Invoice received:# _____ Date funds advanced _____ Cheque# _____

Were reports received from the researcher? _____

What was done with the reports?

Presented at PGA meeting? _____ Put on PGA website? _____ Filed? _____

NOTES: _____

INVOICE

GOVERNMENT OF ALBERTA

Payable to: Minister of Finance
Please Remit To:
Agriculture, Food & Rural Dev
7000 113 ST
EDMONTON AB T6H 5T6
Canada

Bill To:
POTATO GROWERS OF ALBERTA
6008 46 AVE
TABER AB T1G 2B1
Canada

Page: 1 of 1

Invoice: 011LA012160
Invoice Date: November/16/2007
Customer No: C031892
Payment Terms: 30 Days
Period Covered -
Due Date: December/16/2007

AMOUNT DUE: **15,900.00 CAD**

Amount Remitted

Please cut along line and return top portion with payment

For billing questions, please call: **780-422-4911**

Invoice Number	Invoice Date	Customer Number	Payment Terms	Period Covered	Due Date
011LA012160	November/16/2007	C031892	30 Days	-	December/16/2007

Line	Description	Contract No.	Order No.	Quantity	UOM	Order Date	Unit Amt	GST Amt	PO Reference No.	Extended Amount
1	Research Project			1.00	EA		15,000.00	900.00		15,000.00

onsorship of the "Diagnosis, Characterization, & Management of the Powdery Scab on Commercial Potatoes in Alberta".

			Subtotal:		**15,000.00**
Total (GST):					
Net Amount:	15,000.00	GSTReg	6.00 %		900.00
			AMOUNT DUE:		**15,900.00**

pd

Government of Alberta - GST Registration Number: 124072513

Original

RECEIVED NOV 21 2007

17507 Fort Road N.W.
Edmonton AB T5Y 6H3
Phone: (780) 422-0653

5. **AF** will use the funds paid by **PGA** only for the purpose of conducting the Research Project. **AF** will provide a record of revenues and expenditures to **PGA** upon completion of the Research Project or depletion of funds.

RESPONSIBILITY OF PROJECT MANAGER

6. The project manager for this Research Project is Dr. Ron Howard of **AF** who will supervise the Research Project and provide all reports to **PGA.** The project manager will authorize expenses and submit them to the appropriate **AF** office for payment to be processed.

AMENDMENTS OR TERMINATION

7. This Agreement may only be amended upon mutual consent of the parties and evidenced in writing.

8. Either **AF** or **PGA** may terminate this Agreement in the event of a material default or breach of a substantive term, condition or provision of this Agreement, by providing two weeks notice in writing to the other party. In such event **AF** is in default then any and all amounts of the funds advanced by **PGA** hereunder that represent payment for work or services hereunder that have not been performed by **AF** up to the date of termination shall be refunded to **PGA.**

NOTICES AND REPRESENTATIVES

9. Notices for all purposes of or incidental to this Agreement shall be effectively given if delivered personally, or sent by registered or certified mail to the representatives of the parties designated as follows:

PGA Biosciences:
Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1
Phone: 403-223-2262

Alberta Agriculture and Food:
Dr. Ron Howard
Plant Pathology Research Scientist
Crop Diversification Centre South
301 Horticultural Station Road East
Brooks, Alberta T1R 1E6
Phone : (403) 362-1328

Alberta Agriculture and Food:

Cornelia Kreplin, Director, Agriculture Research Division

2007 09 25
Date

Potato Growers of Alberta:

Vern Warkentin, Executive Director, Potato Growers of Alberta

Sept 13/07
Date

Research Plan

The research plan for this project was briefly described in the original project proposal to the PGA in 2005 (see attached copy).

Potato Growers of Alberta

Proposal application for Research funding 2005-2006

Instructions

To assess the proposals consistently, they must be completed according to the parameters contained in this form. Proposals may be rejected for incomplete information or lack of compliance with the instructions. This application could use other sources of forms only if it will be presented to other funding consortiums.
Please jump between boxes using the "Tab" key and avoid the use of the "enter" key. The PGA Research Committee will set dates for project presentations and result reports.

Confidentiality

This Proposal is confidential and the information contained in it may not be disclosed with other organizations or research groups. ☐

1. Research Team Information

Team Leader: Dr. Ron Howard		
Organization: AAFRD	Section/Department: CDC South	
Address: S.S.#4	City: Brooks	Province:AB
Postal Code:T1R 1E6	E-mail : ron.howard@gov.ab.ca	
Phone Number: 403-362-1328	Fax Number: 403-362-1326	

Team Member: Dr. Larry Kawchuk		
Organization: AAFC	Section/Department:Plant Pathology	
Address: P.O. Box 3000 Main	City: Lethbridge	Province:AB
Postal Code:T1J 4B1	E-mail: kawchuk@agr.gc.ca	
Phone Number: 403-317-2271	Fax Number: 403-382-3156	

Team Member: Dr. Piara Bains		
Organization: Agri-Research	Section/Department:	
Address:15708-76 Street	City: Edmonton	Province:AB
Postal Code:T5Z 2X2	E-mail address:piara.bains@agri-research.co	
Phone Number: 780-475-7955	Fax Number: 780-475-7955	

2. Project Information

Title:Diagnosis, Characterization and Management of Powdery Scab on Commercial Potatoes in Alberta
Category of the project (Please check more than one box if necessary): ☒ Pest Management ☐ Water and Irrigation Management ☐ Potato Storage ☐ Potato Breeding ☐ Potato Plant Physiology ☐ Potato Fertility Plant ☐ Nutrition/Soil management ☐ Green House ☐ Environment ☐ Potato Marketing and Economics ☐ Potato Cultural Management
Research Location (s): Brooks, Lethbridge, Edmonton, Saskatoon
Duration (Y):3 Start Date (YY/MM):05/05Ending Date (YY/MM):08/12

Is the project linked to other applications / Research projects Y ☒ N ☐
(Please identify related projects)

1.Project: Diagnosis and Management of Potato Diseases
Team Leader: Dr. Larry Kawchuk

Start Date: 2000

2.Project: Effects of Green Manures on Potato Diseases
Team Leader: Dr. Michele Konschuh

Start Date: 2005

Background.
(Max 2000 characters)

Powdery scab (PS), caused by the fungus Spongospora subterranea (Ss), is a serious disease in many potato-growing areas of the world. PS seems to be increasing in incidence and severity in Western Canada and there have been several outbreaks in AB, SK and MB since 2000. Ss is long-lived in the soil (20 yr), and has alternative hosts such as tomato, pepper and nightshade. Disease development is favored by cool, wet conditions. PS can reduce plant vigor, tuber number and yield, and lead to the rejection of tubers for seed and other uses. Effective control measures for PS are very limited, but some new techniques appear promising.

A severe limitation in diagnosing and managing PS has been an inability to reliably detect Ss in soil and on seed tubers. The inability to culture Ss is also a hindrance in studying PS. Current methods for detecting Ss include baiting, serology and PCR (polymerase chain reaction). To enable accurate risk assessment, it is first necessary to quantify the level of infection in potato roots and tubers, and to relate this information to the spore concentration in the soil. Available detection methods have not been critically evaluated for their efficiency in detecting the strains of Ss that occur in Alberta. Access to a reliable and cost-effective diagnostic test

would enable potato growers to select fields with a low risk of disease development. Characterization of the genetic variability in Ss strains could help potato breeders develop resistant varieties.

Very few strategies for managing PS have been evaluated under Alberta conditions. No single approach has proven to be effective for preventing or controlling PS in other parts of the world where it occurs. The integration of cultural, chemical and biological control practices, e.g. resistant varieties, seed and soil treatments, irrigation management, soil amendments and crop rotation, might create a cost-effective management program for this disease.

Objectives (Measurable-Deliverables)
(Please use Bullets) (Max 1000 characters)

1) To develop methods for reliably detecting Ss on tubers and in soil, and for predicting the potential risk for PS development in fields selected for potato production.
2) To characterize the strains of Ss occurring in central and southern Alberta in order to determine their genetic diversity, virulence on potato cultivars and lines, and ability to act as vectors for Potato Mop Top Virus (PMTV).
3) To investigate methods for reducing PS incidence and severity in seed, processing and table potatoes, including varietal resistance, seed and soil treatments, irrigation management, soil amendments, and rotational crops.
4) To use the information generated in this study to enhance our knowledge of the biology of PS and to improve the techniques for managing this disease, thereby reducing potential yield and quality losses for growers and processors.

Economical/Environmental Benefits

(Please mention how the results of this project will benefit potato production economically and environmentally.(Max. 1000 characters) .

Concerns over an apparent increase in the occurrence of PS and the damage it causes have been heightened by the capability of Ss to also vector PMTV, one of the so-called potato tuber necrosis viruses that is included under a Joint Potato Virus Management Plan between the U.S.A. and Canada. Diseases such as PMTV are often used as non-tariff trade barriers. Freedom from PMTV would be advantageous to Alberta's seed potato industry. The presence of PS in seed potatoes can result in a reduction or loss of certification status. Severe PS infection can reduce the yield and quality of table and processing potatoes, and predispose tubers to soft rot. Although reliable estimates of losses due to PS infection are unavailable, there were reports of significant damage to some chipping cultivars in Alberta in 2003-04 because affected tubers decayed in storage. Effective management of PS would reduce the risk of field and storage losses and improve profit margins for producers and processors.

Methodology Description

(Please describe the scientific process you will follow to achieve project objectives).(Max 2000 Characters)

1) Detection and Quantification - A PCR assay will be developed that should reliably detect and quantify DNA from sporeballs, zoospores and plasmodia/zoosporangia of Ss. The assay will be used to measure the viability of sporeballs in soil. Together with a tomato bait plant technique, infection levels in potatoes grown under various environmental conditions will be examined. The influence of temperature, soil type, inoculum levels, and soil moisture on infection will be determined. Testing for PS in field soil and on tubers will be done using this method.

2) Strain Characterization - The PCR assay described above will be used to ananalyze genetic variability within Ss and to identify different strains. A PCR assay specific to PMTV will be used to confirm the presence or absence of the virus in isolates of Ss. Because the symptoms of PMTV infection are similar to those of Tobacco Rattle Virus (TRV) and include spraing (brown-colored arcs or spots) in the tubers, yellow blotching or chlorotic V-shapes in the leaves and stunting of the stems, a PCR test for TRV will also be carried out on samples tested for PMTV.

3) Disease Management - Tissue-cultured plantlets from the Alberta Seed Potato Bank will be screened for resistance to PS, as will a selection of advanced lines from the Western Canadian Potato Breeding Program, using aggressive Alberta strains of Ss. Those exhibiting resistance will be advanced to confirmatory field trials. Several seed and soil treatments (e.g. Zonix, fluazinam, mancozeb, boron) will be tested for efficacy against PS in the greenhouse and the most promising materials advanced to field trials. The effects of irrigation scheduling and amounts on PS incidence and severity will be monitored in two commercial fields with a history of PS and the results compared to the those of other researchers. The effects of green manure crops on PS development will be assessed as part of a field study by M. Konschuh, as well as in greenhouse trials at CDCS.

Technology Transfer Plan.

(Please describe the proposed method to communicate findings and results) (Max. 1000 characters)

Interim and final results will be presented to the PGA, potato growers and project cooperators through oral and poster presentations at events such as the PGA and ASPGA annual meetings, field days, area and/or breakfast meetings. Written reports, newsletter articles and scientific publications will be prepared and made available to the PGA, growers and cooperators.

3. Project Budget

		Year 1	Year 2	Year 3	**Total**
PGA	Cash	15000	15000	15000	45000
	In-Kind	2500	2500	2500	7500
	Total	17500	17500	17500	52500
Other					
AAFRD	Cash				
	In-Kind	30000	30000	30000	90000
	Total	30000	30000	30000	90000

Other

	Cash				
	In-Kind	30000	30000	30000	90000
AAFC	Total	30000	30000	30000	90000

Other

	Cash				
	In-Kind	2500	2500	2500	7500
Univ. Sask.	Total	2500	2500	2500	7500

Other

	Cash	4000	4000	4000	12000
	In-Kind	1000	1000	1000	3000
Companies	Total	5000	5000	5000	15000

Total	**85000**	**85000**	**85000**	**255000**

Project Cost Distribution	Year 1	Year 2	Year 3	**Total**
Personnel	50000	50000	50000	150000
Travel expenses	1000	1000	1000	3000
Capital goods	2000	2000	2000	6000
Materials	8000	8000	8000	24000
TOT	1000	1000	1000	3000
Overhead	23000	23000	23000	69000
Total	**85000**	**85000**	**85000**	**255000**

*TOT (Transference of Technology)

Research Project Manager

Signature **Date**

POTATO GROWERS OF ALBERTA

April 20, 2007

Dr. Ron Howard
Alberta Agriculture, Food & Rural Development
301 – Horticultural Station Rd. E.
Brooks, AB T1R 1E6

Re: Diagnostic, Characterization and Management of Powdery Scab on Commercial Potatoes in Alberta

Dear Ron:

We are pleased to advise that the Board of Directors of The Potato Growers of Alberta has reviewed and approved continuing funding for your research project.

For the period of April 1, 2007 – March 31, 2008, the amount of $15,000 is available to meet the timelines specified in your application. When requesting the funds for the project, please provide an invoice that specifies the amount, GST and to whom payable.

We appreciate your commitment and dedication to the potato industry.

Yours truly,

Vern Warkentin
Executive Director

/pl

Potato Growers of Alberta
Research Tracking

Title of Research Application: Evaluation and Adaptation of Early Blight Prediction for Irrigated Potatoes

Name of Researcher: Ted Harms

Employer: Ab. Agriculture

Date application was received by PGA _____

Date application was reviewed by PGA April 3/06

A) approved ✓ B) declined _____

Project start date: _____ Project finish date: _____

Total amount requested: $ _____ Amount requested per year: $10,000-

MOU received and signed. Once copy returned to research agency, one copy filed in current year Research Binder

Date completed _____

Invoice received: # 5292006 Date funds advanced June1/06 Cheque# 4283 $10,000-

Invoice received: # _____ Date funds advanced _____ Cheque# _____

Invoice received: # _____ Date funds advanced _____ Cheque# _____

Invoice received: # _____ Date funds advanced _____ Cheque# _____

Were reports received from the researcher? _____

What was done with the reports?

Presented at PGA meeting? _____ Put on PGA website? _____ Filed? _____

NOTES: _____

POTATO GROWERS OF ALBERTA

6008, 46th Avenue
Taber, Alberta T1G 2B1

Phone (403) 223-2262
Fax (403) 223-2268
e-mail: pga@albertapotatoes.ca
www.albertapotatoes.ca

April 3, 2006

Ted Harms
Soil & Water Resource Engineer
Alberta Agriculture, Food and Rural Development
Crop Diversification Centre South
S.S. #4
Brooks, AB T1R 1E6

Re: "Evaluation and Adaptation of Early Blight Prediction Methods for Irrigated Potatoes in Southern Alberta" 2nd Year

Dear Ted:

We are pleased to advise that the Board of Directors of the Potato Growers of Alberta has approved the continuity of your application in the amount requested.

For the period of April 1, 2006 – March 31, 2007 the amount of $10,000 is available to meet the timelines specified in your application. When requesting the funds for the project, please provide an invoice that specifies the amount, GST and to whom payable.

We appreciate your commitment and dedication to the potato industry.

Yours truly,

Vern Warkentin
Executive Director

MEMORANDUM OF UNDERSTANDING

Between: Potato Growers of Alberta (hereafter referred to as "PGA")

and

Alberta Agriculture, Food & Rural Development
(hereafter referred to as "AAFRD")

PROJECT TITLE
Evaluation and Adaptation of Early Blight Prediction Methods for Irrigated Potatoes in Southern Alberta

OBJECTIVES
1) The objectives of this research project will be to evaluate 3 methods for the prediction of early blight. They include:
1) Plant-plus system offered by Dacom from the Netherlands
2) Wisdom (provided by SureHarvest for Potatoes from California)
3) P-Day or GDD forecast
Additionally, all models will be operated on hourly data from both near-field meteorological monitoring and the nearest AAFRD Irrigation Branch meteorological station to assess the differences and/or value of either sources of meterological data.

STATEMENT OF WORK
AAFRD is willing to undertake the proposed study for the PGA, which hereby agrees to contribute toward the costs of generating the information required as described in the research protocol.

PERIOD OF WORK
This research project will commence on **May 1, 2006** and a year-end report will be provided to PGA by **Dec 31, 2006**.

BASIS OF PAYMENT
PGA has made a commitment of $10,000 for the project in 2006.

The funds within this budget can be adjusted between the expenditure categories and used at the discretion of the project manager.

Payment of research project expenditures will be made from funds made available to AAFRD up to the maximum amount of funds received from the sponsor.

AAFRD is willing to provide a revenue and expenditure report upon project completion or depletion of funds, if requested by the sponsor. Any remaining funds after completion or termination of the project can be used for research at the discretion of the project manager.

RESPONSIBILITIES
a) AAFRD IRRIGATION BRANCH

Manage the project.
Acquire all necessary meteorological data and distribute for model runs.
Secure models for testing and run models daily using hourly meteorological data.
Communicate with Dacom from the Netherlands to ensure necessary parameters for their Plant-plus system are met.
Regular reporting of model outputs to cooperators, PGA representative and AAFRD Potato agrologist.
Coordinate weekly field visits.
Analyze economics at end of season based on spray frequency.
Coordinate preparation and completion of year-end report.
Present findings to PGA members as requested.

b) AAFRD INDUSTRY DEVELOPMENT SECTOR

Pathology

- scout fields 4 times per year, gather samples from all treatments and check and assess plants for incidence and severity of disease.

Agronomy

- Sample field for yield and quality analysis.

c) PGA

- arrange for cooperators
- arrange for access to meteorological data from Adcon

AMENDMENTS OR TERMINATION

This Memorandum of Understanding may be amended by mutual consent of the parties as evidenced by an exchange of letters.

Either AAFRD or PGA may terminate this Memorandum of Understanding by providing two weeks notice in writing to the other party.

The Department of Agriculture, Food & Rural Development, PGA and other sponsors of this project may use information generated from the project.

The sponsor, PGA, relinquishes ownership of any materials, supplies and assets purchased with the project funds to the AAFRD, which assigns control to the project manager's departmental division.

The purpose of the Memorandum of Understanding is to address the operational and staffing needs of the project for the period May 1, 2006 to October 31, 2006.

The parties affirm their acceptance of the terms of this Memorandum of Understanding by signing below.

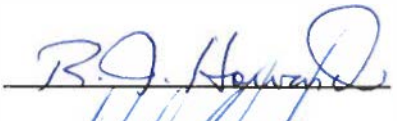
Copies bearing the original signatures of this Memorandum will be kept by each party.

Alberta Agriculture, Food and Rural Development:

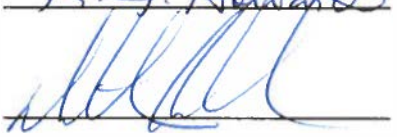
Ted Harms, Project Leader
Irrigation Branch

Brent Paterson, Head
Irrigation Branch

Dr. Ron Howard, Pathology
CDC South



Dr. Michelle Konshuh, Agronomy,
CDC South



Potato Growers of Alberta:

Vern Warkentin. Executive Director
Potato Growers of Alberta

Potato Growers of Alberta
Research Tracking

Title of Research Application: Early Dying and Oomycete Analysis & Control

Name of Researcher: Larry Kawchuk

Employer: Agriculture and AgriFood Canada

Date application was received by PGA March 2, 2006

Date application was reviewed by PGA April 3, 2006

A) approved ✓ B) declined _____

Project start date: April 1, 2006 Project finish date: March 31, 2009

Total amount requested: $ 18,000- Amount requested per year: $6,000

MOU received and signed. Once copy returned to research agency, one copy filed in current year Research Binder

Date completed Sept. 21, 2006

Invoice received: #_____ Date funds advanced Oct 20/06 Cheque# 4522 $6,000-

Invoice received: #83004684 Date funds advanced May 1/07 Cheque# 4857 - $6000-

Invoice received: #83007412 Date funds advanced May 22/08 Cheque# 5529 - $6000-

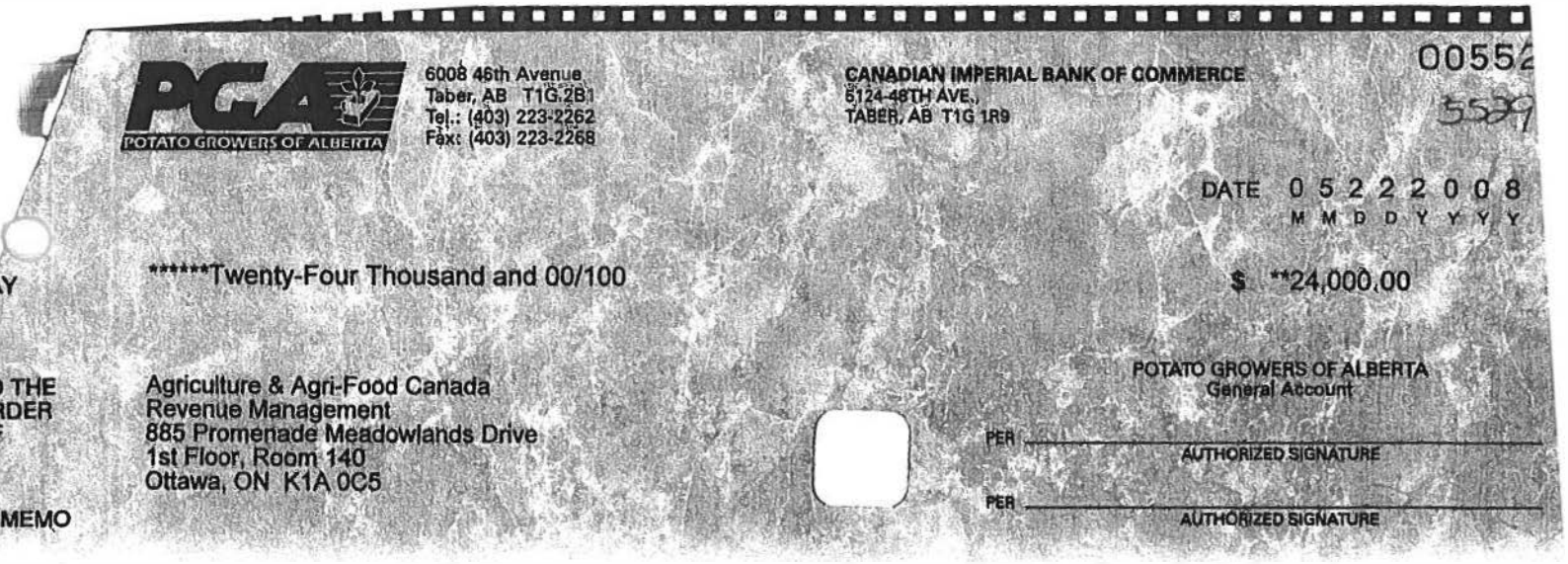
Invoice received: #_____ Date funds advanced _____ Cheque# _____

Were reports received from the researcher? _____

What was done with the reports?

Presented at PGA meeting? _____ Put on PGA website? _____ Filed? _____

NOTES: _____



POTATO GROWERS OF ALBERTA
6008 46th Avenue
Taber, AB T1G 2B1
Tel.: (403) 223-2262
Fax: (403) 223-2268

CANADIAN IMPERIAL BANK OF COMMERCE
5124-48TH AVE.,
TABER, AB T1G 1R9

00552
5539

DATE 0 5 2 2 2 0 0 8
M M D D Y Y Y Y

******Twenty-Four Thousand and 00/100

$ **24,000.00

Agriculture & Agri-Food Canada
Revenue Management
885 Promenade Meadowlands Drive
1st Floor, Room 140
Ottawa, ON K1A 0C5

POTATO GROWERS OF ALBERTA
General Account

PER _____ AUTHORIZED SIGNATURE

PER _____ AUTHORIZED SIGNATURE

⑈005529⑈ ⑆00139⑉010⑆ 72⑉05317⑈

OTATO GROWERS OF ALBERTA

Agriculture & Agri-Food Canada

5/22/2008

005529

Date	Type	Reference	Original Amt.	Balance Due	Discount	Payment
5/21/2008	Bill	8307697	18,000.00	18,000.00		18,000.00
5/21/2008	Bill	83007412	6,000.00	6,000.00		6,000.00
					Cheque Amount	24,000.00

Main Operating Accou

24,000.00

ATO GROWERS OF ALBERTA

Agriculture & Agri-Food Canada

5/22/2008

005529

ate	Type	Reference	Original Amt.	Balance Due	Discount	Payment
/21/2008	Bill	8307697	18,000.00	18,000.00		18,000.00
/21/2008	Bill	83007412	6,000.00	6,000.00		6,000.00
					Cheque Amount	24,000.00

Operating Accou

24,000.00

POTATO GROWERS OF ALBERTA

6008, 46th Avenue
Taber, Alberta T1G 2B1

Phone (403) 223-2262
Fax (403) 223-2268
e-mail: pga@albertapotatoes.ca
www.albertapotatoes.ca

April 20, 2007

Dr. Larry Kawchuk
Agriculture and Agri-Food Canada
5403 – 1 Avenue South
P.O. Box 3000, Main
Lethbridge, AB T1J 4B1

Re: Early Dying and Oomycete Analysis & Control

Dear Larry:

We are pleased to advise that the Board of Directors of the Potato Growers of Alberta has reviewed and approved continuing funding for your research project.

For the period of April 1, 2007 – March 31, 2008 the amount of $6,000 is available to meet the timelines specified in your application. When requesting the funds for the project, please provide an invoice that specifies the amount, GST and to whom payable.

We appreciate your commitment and dedication to the potato industry.

Yours truly,

Vern Warkentin
Executive Director

/pl

Potato Growers of Alberta
Research Tracking

Title of Research Application: Evaluation of Incidence & Control of Blackleg & BRR

Name of Researcher: Larry Kawchuk

Employer: Agriculture and AgriFood Canada

Date application was received by PGA March 2, 2006

Date application was reviewed by PGA April 3, 2006

A) approved ✓ B) declined _____

Project start date: April 1, 2006 Project finish date: March 31, 2007

Total amount requested: $54,000 - Amount requested per year: $18,000

MOU received and signed. Once copy returned to research agency,
one copy filed in current year Research Binder

Date completed August 18, 2006

Invoice received: # _____ Date funds advanced Oct 9/06 Cheque# 4870

Invoice received:# 83005331 Date funds advanced July 31/07 Cheque# 5007

Invoice received:# 83076 97 Date funds advanced May 22/08 Cheque# 5529

Invoice received:# _____ Date funds advanced _____ Cheque# _____

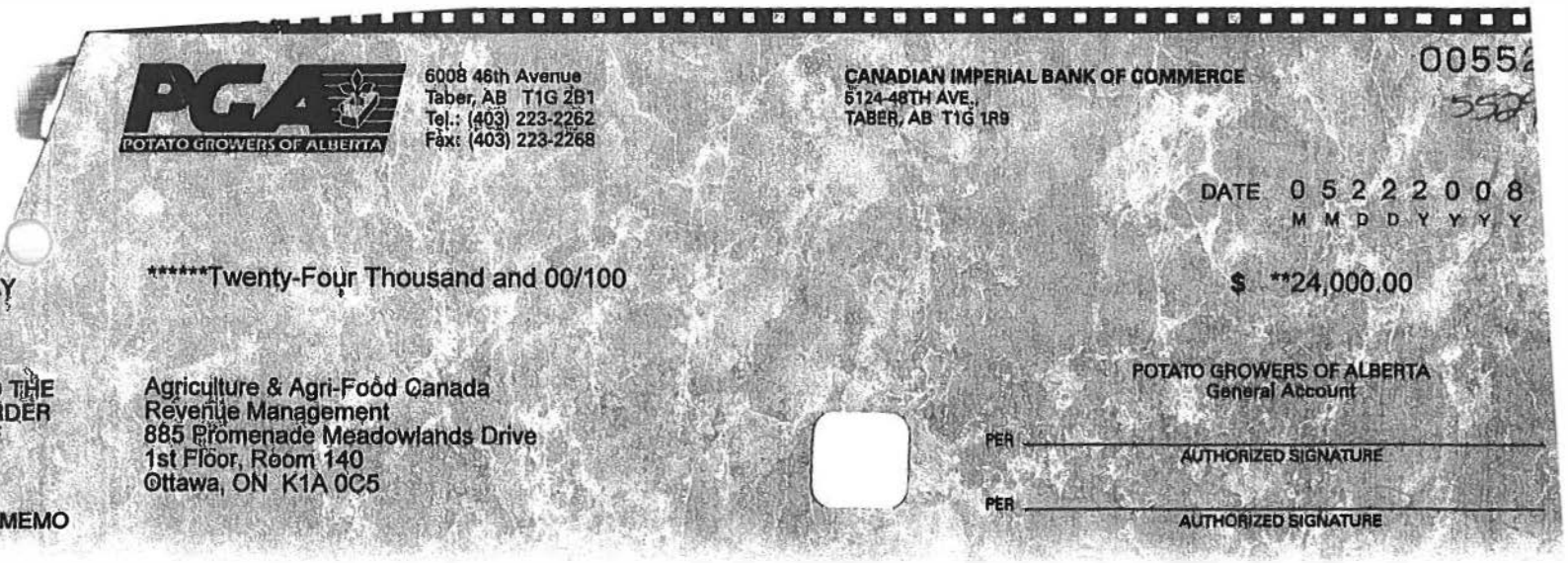
complete

Were reports received from the researcher? _____

What was done with the reports?

Presented at PGA meeting? _____ Put on PGA website? _____ Filed? _____

NOTES: _____



POTATO GROWERS OF ALBERTA

6008 46th Avenue
Taber, AB T1G 2B1
Tel.: (403) 223-2262
Fax: (403) 223-2268

CANADIAN IMPERIAL BANK OF COMMERCE
5124-48TH AVE.,
TABER, AB T1G 1R9

005529

DATE 0 5 2 2 2 0 0 8
M M D D Y Y Y Y

******Twenty-Four Thousand and 00/100

$ **24,000.00

Agriculture & Agri-Food Canada
Revenue Management
885 Promenade Meadowlands Drive
1st Floor, Room 140
Ottawa, ON K1A 0C5

POTATO GROWERS OF ALBERTA
General Account

PER _____ AUTHORIZED SIGNATURE

PER _____ AUTHORIZED SIGNATURE

⑈005529⑈ ⑆00139⑉010⑆ 72⑉05317⑈

OTATO GROWERS OF ALBERTA

Agriculture & Agri-Food Canada

5/22/2008

005529

Date	Type	Reference	Original Amt.	Balance Due	Discount	Payment
5/21/2008	Bill	8307697	18,000.00	18,000.00		18,000.00
5/21/2008	Bill	83007412	6,000.00	6,000.00		6,000.00
					Cheque Amount	24,000.00

Main Operating Accou

24,000.00

TO GROWERS OF ALBERTA

Agriculture & Agri-Food Canada

5/22/2008

005529

ate	Type	Reference	Original Amt.	Balance Due	Discount	Payment
/21/2008	Bill	8307697	18,000.00	18,000.00		18,000.00
21/2008	Bill	83007412	6,000.00	6,000.00		6,000.00
					Cheque Amount	24,000.00

Operating Accou

24,000.00

Agriculture and Agri-Food Canada / Agriculture et Agro-alimentaire Canada

FACSIMILE TRANSMITTAL NOTICE

To: Mr. Vern Warkentin

Potato Growers of Alberta
Taber, AB

Telephone (403) 223-2262
Facsimile (403 223-2268

FROM: L.M. Kawchuk
Research Centre
Agriculture and Agri-Food Canada
5403 - 1 Avenue South
P.O. Box 3000
Lethbridge, Alberta
CANADA T1J 4B1

Phone No.: (403) 317-2271
Facsimile No.: (403) 382-3156
E-mail: kawchukl@agr.gc.ca

SUBJECT: **Potato Samples - In-Kind**

# of Pages (including cover sheet): 1

Dear Vern,

We need your signature for the in-kind contribution of $15,000 that the Potato Growers of Alberta provides each year for our work on blackleg and bacterial ring rot. We are able to match these contributions each year through the Federal Matching Investment Initiative (MII53536).

Please sign below and fax back to me. Do not hesitate to contact me if you have any questions.

Thank you,

Mr. Vern Warkentin

Dr. L.M. Kawchuk, Research Scientist

Date: January 23, 2008

FAXED Jan 23/08

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Research Branch | Direction générale de la recherche

Office of Intellectual Property and Commercialization
Commercialization Officer: **Ryan Wilkes**
Agriculture and Agri-Food Canada
Room 1058, K.W. Neatby Building
960 Carling Avenue
Ottawa, Ontario K1A 0C6
Telephone: (613) 759-7761
Facsimile: (613) 759-1765
E-mail: wilkesr@agr.gc.ca

By Courier

July 16, 2007

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008-46 Avenue
Taber, AB
T1G 2B1

Dear Mr. Warkentin;

You will find enclosed two original Research Support Agreements for: **"Evaluation of Incidence and Control of Blackleg and Bacterial RingRot."** Please have an authorized representative sign both copies, retain one for your records and return one to me in the self-addressed envelope provided for your convenience.

If you have any questions or concerns, do not hesitate to contact me at (613) 759-7761.

Sincerely,

Signed & Returned
Aug 17/07

Ryan Wilkes
Office of Intellectual Property
& Commercialization

Encl.

Canada

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Research Branch | Direction générale de la recherche

Office of Intellectual Property and Commercialization
Agriculture and Agri-Food Canada
Commercialization Officer: **Ryan Wilkes**
Tel: **613-759-7761**
Fax: **613-759-1765**
Research Scientist: Dr. L. Kawchuk
Office of Intellectual Property File: STAT #487095

July 16, 2007

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008-46 Avenue
Taber, AB
T1G 2B1

Dear Mr. Warkentin:

RE: Research Support Agreement
Between: Agriculture and Agri-Food Canada AND Potato Growers of Alberta ("Contributor")
Project: Evaluation of Incidence and Control of Blackleg and Bacterial RingRot MII 53536

1. This is a Research Support Agreement (RSA) between the Contributor and Her Majesty the Queen in Right of Canada as represented by the Minister of Agriculture and Agri-Food ("AAFC") whereby the Contributor pays to AAFC cash support of **CDN $36,000** ("Contribution") for the Project detailed in Appendix "A" (Description of Research Project). The Contributor will advance funds to AAFC in two payments of CDN $18,000 per year according to Schedule "B" (Contributor's Contribution). The level of support indicated above for this Project is in addition to the $18,000 support the Contributor already provided for this Project in 2006 under another agreement.

2. The Contribution will be directed toward the Project conducted at the Lethbridge Research Centre, Lethbridge, Alberta and led by the Principal Investigator (PI), Dr. L. Kawchuk.

3. The Contribution will assist in conducting the Project, and the AAFC research will be of direct or indirect benefit to the Contributor.

4. The Project will be conducted from April 1, 2006 to March 31, 2009, inclusive.

5. You, the Contributor, agree that:
   (a) The Contribution will be used to fund the Project as outlined in Appendix "A";
   (b) AAFC's only obligation is to use the Contribution for the Project mentioned above;
   (c) If appropriate, research results will be published, subject to any patent or trade secret concerns;
   (d) Any and all intellectual property arising from the Project is the sole property of AAFC;
   (e) The Contribution is irrevocable; and

(f) There are no other understandings or agreements regarding this contribution or Project except as stated in this RSA.

If you find these terms and conditions acceptable, please have the appropriate authority in your organization date and sign both copies of this RSA (in any colour of ink other than black), keep one original for your records, and return the other to us for our files.

This Research Support Agreement has been executed, in duplicate, by duly authorized representatives of the parties and effective on the date of the last signature.

John Culley, Ph.D.
Director, Office of Intellectual Property and Commercialization
Agriculture and Agri-Food Canada

Date: 2007-07-18

Potato Growers of Alberta:

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta

Date: Aug 17/07

APPENDIX "A"
DESCRIPTION OF RESEARCH PROJECT

Background:

Blackleg and tuber soft rot of potato are caused by pectolytic gram negative Erwinia species. These diseases are found wherever potatoes are grown. The incidence and severity of blackleg appears to be increasing in western Canada potato producing areas. Blackleg is favoured by cool wet soils at planting and spread through seed, irrigation, and insects. Blackleg can cause severe yield losses and symptoms may appear at any stage of plant development. Symptoms progress from a decaying seed piece to lesions extending from the base of the stem into the canopy. Several species of Erwinia are known to cause disease but many factors contributing to the disease are poorly understood. Additional information on the transmission, detection, and control of blackleg would improve yields and quality.

Bacterial ring rot has plagued the potato industry and is a zero tolerance pathogen. It is caused by a gram positive tuber-borne bacterium, Clavibacter michiganenesis subsp. sepedonicus. The bacterium can overwinter in potato debris, may reside in other hosts such as sugar beets, can be spread by insects, and survives on equipment for up to 5 years. Symptoms vary amongst potato varieties and environmental conditions. Unfortunately, the identification of a single infected tuber can result in decertification, sometimes bankruptcy, and negatively impacts trade. Our understanding of bacterial ring rot is still quite limited and alternatives for detection and control are required.

Phagetherapy has recently emerged as an important tool in the control of human and animal bacterial diseases. Bacteriophage are nature's tiniest viruses, they naturally occur for each bacterium, and represent a cost-effective prevention strategy for blackleg and bacterial ring rot. Diagnostics that identify pathogen sources and strains and disease control strategies based on management and biocontrol, should reduce the occurrence of blackleg and bacterial ring rot.

Objectives:

1) Develop sensitive diagnostic tests that reliably detect the pathogens causing blackleg and bacterial ring rot. Assays will be applied to determine sources, vectors, and pathogen strain distribution in soils selected for potato production.

2) Characterize the pathogen populations causing blackleg and bacterial ring rot in Alberta. Forensic samples will be obtained from diseased tissues, soils, equipment, storages, and collections to determine virulence, aggressiveness, and other characteristics such as transmission.

3) Develop strategies to control of blackleg and bacterial ring rot. This will involve a mangement approach based on the diagnostic monitoring information, the screening of AAFC advanced lines and commercial varieties for symptom expression, and seed and soil phage biocontrol amendments.

4) Improve the competitiveness and sustainability of producers and processors by advancing our understanding of these diseases to curtail their occurrence and improve yield and quality.

Impact/Benefits:

Apparent increases in blackleg and bacterial ring rot in western Canada are associated with reduced yields and quality or decertification that adversely impacts producers and processors. These pathogens, especially bacterial ring rot, also adversely impact trade and are sometimes used as a non-tariff trade barrier. Acquisition and characterization of endogenous pathogen populations will facilitate the development of diagnostic procedures to assist in reliable early detection and to reduce disease occurrence. Results will advance our understanding of host-pathogen interactions and identify effective disease control strategies that help reduce the occurrence of blackleg and bacterial ring rot such as cost-effective phage biocontrol. Control measures for blackleg and bacterial ring rot in western Canada will improve the sustainability and competitiveness of the potato industry in Alberta.

Science Plan:

1) Pathogen identification, and isolation: Industry, CFIA, and collaborators will assist in collection of diseased samples and blackleg and bacterial ring rot pathogen identification/isolation. Additional pathogen populations will be obtained from existing regional, National, and International culture collections for comparison.

2) Detection and quantification: Sensitive pathogen-specific polymerase chain reaction (PCR) assays will be developed to detect and quantify nucleic acid from each pathogen. Universal primers designed for highly conserved rDNA sequences have proven effective for reliable identification of pathogens. Testing will examine various sources of the pathogens including field soil, potential vectors, alternative hosts, equipment, storages, and potatoes.

3) Strain characterization: AAFC will develop PCR assays of genetic variability within each pathogen and to identify different strains. Hypervariable intergenic regions are capable of distinguishing even small variations in pathogen populations. PCR amplifications will be performed under stringent conditions and amplified products cloned and sequenced. Sequence comparisons and analyses can be performed with various available software programs.

4) Disease management: Management practices and pathogen threshold values will be evaluated to determine strategies to control pathogen reservoirs, vectors, and minimize disease losses. Advanced lines from the AAFC and commercial cultivars will be screened with aggressive strains of blackleg and bacterial ring rot pathogens in storage, greenhouse, and/or field trials for sypmptom expression. Soil, storage, and seed treatments, irrigation, and crop rotations will be assessed to identify and recommend strategies to reduce disease. Phagetherapy with isolated natural viruses from this study for blackleg and bacterial ring rot will be evaluated as a cost-effective biocontrol to prevent disease.

The bacterial ring rot field trial at the AAFC Stavely Substation was established 30 years ago by Dr. G. Nelsen. Advanced lines will be planted in field trials by industry and AAFC to evaluate symptom expression for blackleg and bacterial ring rot. Harvested tubers will be evaluated for disease in storage and effectiveness of control. Reports that summarize diagnostic capabilities, control strategies, and symptom expression will be collected, analyzed, and distributed to the industry. A report will be prepared and submitted.

The PGA will provide an in-kind support of $18,000 per year to aid in the completion of the above Science Plan.

APPENDIX "B"
CONTRIBUTOR'S CONTRIBUTION

Schedule of Payments:

Payment #	Due Date	Amount
1	Upon Execution	$18,000.00
2	April 30, 2008	$18,000.00
Total		$36,000.00

For Invoicing Purposes:

Potato Growers of Alberta
Attn: Mr. Vern Warkentin, Executive Director
6008-46 Avenue
Taber, Alberta T1G 2B1
Telephone: 403-223-2262
Facsimile: 403-223-2268
Email Address: vern@albertapotatoes.ca

MII 53836

POTATO GROWERS OF ALBERTA

6008, 46th Avenue
Taber, Alberta T1G 2B1

Phone (403) 223-2262
Fax (403) 223-2268
e-mail: pga@albertapotatoes.ca
www.albertapotatoes.ca

April 20, 2007

Dr. Larry Kawchuk
Agriculture and Agri-Food Canada
5403 – 1 Avenue South
P.O. Box 3000, Main
Lethbridge, AB T1J 4B1

Re: Evaluation of Incidence and Control of Blackleg & Bacterial Ring Rot

Dear Larry:

We are pleased to advise that the Board of Directors of the Potato Growers of Alberta has reviewed and approved continuing funding for your research project.

For the period of April 1, 2007 – March 31, 2008 the amount of $18,000 is available to meet the timelines specified in your application. When requesting the funds for the project, please provide an invoice that specifies the amount, GST and to whom payable.

We appreciate your commitment and dedication to the potato industry.

Yours truly,

Vern Warkentin
Executive Director

/pl

Potato Growers of Alberta
Research Tracking

Title of Research Application: Early Dying and Oomycete Analysis & Control

Name of Researcher: Larry Kawchuk

Employer: Agriculture and AgriFood Canada

Date application was received by PGA March 2, 2006

Date application was reviewed by PGA April 3, 2006

A) approved ✓ B) declined ____

Project start date: April 1, 2006 Project finish date: March 31, 2009

Total amount requested:$ 18,000- Amount requested per year: $6,000

MOU received and signed. Once copy returned to research agency, one copy filed in current year Research Binder

Date completed Sept. 21, 2006

Invoice received: #____ Date funds advanced Oct 20/06 Cheque# 4522 $6,000-

Invoice received:# 83004684 Date funds advanced May 1/07 Cheque# 4857 - $6000-

Invoice received:#____ Date funds advanced____ Cheque#____

Invoice received:#____ Date funds advanced____ Cheque#____

Were reports received from the researcher?____

What was done with the reports?

Presented at PGA meeting?____ Put on PGA website?____ Filed?____

NOTES:____

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Research Branch | Direction générale de la recherche

Office of Intellectual Property and Commercialization
Commercialization Officer: **Ryan Wilkes**
Agriculture and Agri-Food Canada
Room 1058, K.W. Neatby Building
960 Carling Avenue
Ottawa, Ontario K1A 0C6
Telephone: (613) 759-7761
Facsimile: (613) 759-1765
E-mail:wilkesr@agr.gc.ca

By Courier

September 7, 2006

RECEIVED SEP 1 5 2006

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008-46 Avenue
Taber, AB
T1G 2B1

Dear Mr. Warkentin;

You will find enclosed two original Research Support Agreements for: **"Early Dying and Oomycete Analysis and Control"** Please have an authorized representative sign both copies, retain one for your records and return one to me in the self-addressed envelope provided for your convenience.

If you have any questions or concerns, do not hesitate to contact me at (613) 759-7761.

Sincerely,

for Ryan Wilkes
Office of Intellectual Property
& Commercialization

Encl.

Canada

Office of Intellectual Property and Commercialization
Agriculture and Agri-Food Canada
Commercialization Officer: **Ryan Wilkes**
Tel: **613-759-7761**
Fax: **613-759-1766**
Research Scientist: Dr. L. Kawchuk
Office of Intellectual Property File: STAT #494635

September 7, 2006

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008-46 Avenue
Taber, AB
T1G 2B1

Dear Mr. Warkentin:

RE: Research Support Agreement
Between: Agriculture and Agri-Food Canada AND Potato Growers of Alberta ("Contributor")
Project: Early Dying and Oomycete Analysis and Control

1. This is a Research Support Agreement (RSA) between the Contributor and Her Majesty the Queen in Right of Canada as represented by the Minister of Agriculture and Agri-Food ("AAFC") whereby the Contributor pays to AAFC cash support of **CDN $18,000** ("Contribution") for the Project detailed in Appendix "A" (Description of Research Project). The Contributor will advance funds to AAFC according to Schedule "B" (Contributor's Contribution).

2. The Contribution will be directed toward the Project conducted at the Lethbridge Research Centre, Lethbridge, Alberta and led by the Principal Investigator (PI), Dr. L. Kawchuk.

3. The Contribution will assist in conducting the Project, and the AAFC research will be of direct or indirect benefit to the Contributor.

4. The Project will be conducted from April 1, 2006 to March 31, 2009, inclusive.

5. You, the Contributor, agree that:
   (a) The Contribution will be used to fund the Project as outlined in Appendix "A";
   (b) AAFC's only obligation is to use the Contribution for the Project mentioned above;
   (c) If appropriate, research results will be published, subject to any patent or trade secret concerns;
   (d) Any and all intellectual property arising from the Project is the sole property of AAFC;
   (e) The Contribution is irrevocable; and
   (f) There are no other understandings or agreements regarding this contribution or Project except as stated in this RSA.

If you find these terms and conditions acceptable, please have the appropriate authority in your organization date and sign both copies of this RSA (in any colour of ink other than black), keep one original for your records, and return the other to us for our files.

This Research Support Agreement has been executed, in duplicate, by duly authorized representatives of the parties and effective on the date of the last signature.

Yours truly,

for

John Culley, Ph.D.
Director, Office of Intellectual Property and Commercialization
Agriculture and Agri-Food Canada

Date: September 15, 2006

Potato Growers of Alberta:

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta

Date: September 21, 2006

APPENDIX "A"
DESCRIPTION OF RESEARCH PROJECT

Background:
Early dying is a common disease, caused by several different species of Verticillium and influenced by nematodes. It occurs in most potato growing areas of the world. The incidence and severity of early dying appears to be increasing in western Canada potato producing areas. Verticillium species have a wide host range and are known pathogens of many crops and other plants. Disease development impedes water movement within the plant and is influenced by many abiotic and biotic factors. Early dying can cause severe yield losses and leads to internal net necrosis in many potato varieties. Soil fumigants are sometimes used to control the disease but they are expensive and essentially sterilize the soils. Several species of Verticillium are known to cause disease but the factors contributing to the disease are poorly understood. Additional information on the potential transmission, detection, and control of early dying is required.

Late blight, pink rot, and leak are caused by the oomycetous fungi Phytophthora infestans, Phytophthora erythroseptica, and Pythium ultimum, respectively. They represent potentially the most devastating group of potato pathogens. The incidence of pink rot and late blight is increasing in incidence and possibly severity in western Canada but the exact cause or population dynamics remain to be determined. Late blight can decimate a crop within a few days and like pink rot, it can infect a healthy tuber. Control in some countries involves up to 40 applications of fungicide in a single growing season but these pathogens have developed pesticide resistance. Our understanding of the oomycetes is still quite limited and alternatives for detection and control are required.

Diagnostics that identify pathogen/pest sources and strains and disease control strategies based on management and biocontrol, will reduce disease losses, eliminate pesticides that can adversely impact environment, and help improve the competitiveness of the Alberta product.

Objectives:
1) Develop diagnostic tests for reliably detecting the pathogens and pests contributing to early dying, leak, late blight and pink rot. Assays will help determine sources, vectors, and pathogen strain distribution in fields selected for potato production.
2) Characterize the pathogen/pest populations causing early dying, leak, late blight and pink rot in Alberta. Samples will be obtained from diseased tissues, soils, soil debris, and culture collections to determine virulence, aggressiveness, and other characteristics such as pesticide reaction.
3) Develop strategies for the control of early dying, leak, late blight and pink rot. This will involve a management approach based on diagnostic information, the screening of germplasm and advanced lines for resistance, storage and soil monitoring and amendments, and crop rotations.
4) Improve the competitiveness and sustainability of producers and processors by advancing our understanding of these pathogens/pests to improve yield and quality.

Impact/Benefits:
Apparent increases in early dying, leak, late blight and pink rot in western Canada are associated with reduced yields and quality that adversely impact producers and processors.

These diseases also often compromise healthy tubers, predisposing potatoes to secondary diseases such as fusarium dry rot. Acquisition and characterization of endogenous pathogen/pest populations will facilitate the development/application of cost-effective multiplex diagnostic procedures to assist in early reliable detection of the pathogen/pests in soils, seed, and other sources to avoid disease. Results will advance our understanding of host-pathogen interactions and identify effective alternative disease control strategies that help reduce pesticide applications thereby addressing growing health and environmental concerns. Better control measures for early dying, leak, late blight and pink rot in western Canada will improve the sustainability and competitiveness of the potato industry in Alberta.

Science Plan:
1) Pathogen/Pest identification, and isolation: Industry, CFIA, and collaborators will assist in collection of diseased samples and early dying, leak, late blight, and pink rot pathogen/pest identification/isolation. Additional pathogen/pest populations will be obtained from existing regional, National, and International culture collections for comparison.

2) Detection and risk levels: Sensitive pathogen/nematode polymerase chain reaction (PCR) assays will be developed/applied to detect each pathogen and pest. Universal primers designed for highly conserved rDNA sequences have proven effective in reliable identifications of pathogens and other organisms. Testing will examine various sources of the pathogens and nematodes including field soil, alternative hosts, and seed to determine inoculum loads and risk.

3) Strain characterization: AAFC will develop PCR assays to analyse genetic variability within each pathogen/pest to identify different strains. Hypervariable intergenic spacer regions such as the rDNA ITS regions are capable of distinguishing even small variations in populations. Results will help develop multplex assays to detect several pathogens/pests and reduce test costs. PCR amplifications will be conducted under stringent conditions and amplified products cloned and sequenced. Sequence comparisons and analyses can be performed with various available software programs.

4) Disease management: Management practices and pathogen threshold values will be evaluated to determine strategies to control pathogen reservoirs and vectors and minimize disease losses. True potato seed from accessions held in germplasm repositories and advanced lines from the AAFC Potato Breeding Program will be screened with aggressive strains of early dying, late blight, and pink rot pathogens in storage, greenhouse, and/or field trials. Monitor pathogen/pest changes in soil and seed after vine removal, deep tillage, green manures, and crop rotations to reduce disease.

Disease control information and strategies will be communicated through a report.

APPENDIX "B"
CONTRIBUTOR'S CONTRIBUTION

Schedule of PGA Payments:

Payment #	Due Date	Amount
1	Upon Execution	$6,000.00
2	April 15, 2007	$6,000.00
3	April 15, 2008	$6,000.00
Total		$18,000.00

For Invoicing Purposes:

Potato Growers of Alberta
Attn: Mr. Vern Warkentin, Executive Director
6008-46 Avenue
Taber, Alberta T1G 2B1
Telephone: 403-223-2262
Facsimile: 403-223-2268
Email Address: vern@albertapotatoes.ca

POTATO GROWERS OF ALBERTA

6008, 46th Avenue
Taber, Alberta T1G 2B1

Phone (403) 223-2262
Fax (403) 223-2268
e-mail: pga@albertapotatoes.ca
www.albertapotatoes.ca

May 3, 2006

Mr. Larry Kawchuk
Plant Pathologist
Agriculture and Agri-Food Canada
AAFC Research Centre
PO Box 3000
Lethbridge AB T1J 4B4

Re: "Early Dying and Oomycete Analysis and Control"

Dear Larry:

In response to your request for clarification, please feel free to seek funding from other sources as well. We did not intend to restrict funding options. The wording of our letter should have been clearer to indicate other sources as well.

We apologize for any inconvenience.

Yours truly,

Vern Warkentin
Executive Director

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Research Branch | Direction générale de la recherche

AAFC Research Centre
PO Box 3000
LETHBRIDGE AB T1J 4B1
Telephone: (403) 317-2271
Facsimile: (403) 382-3156
Email: kawchuk@agr.gc.ca

Mr. V. Warkentin
Executive Director
Potato Growers of Alberta
6008-46 Avenue
Taber, Alberta
T1G 2B1

April 25, 2006

Dear Mr. ~~Warkentin~~ Vern,

Thank you for your letter indicating conditional approval for the application "Early Dying and Oomycete Analysis and Control" by Kawchuk, Howard, and Platt. Please advise if the remaining funds must be obtained from the Agricultural Funding Consortium or if they may be sought from other sources e.g. Federal MII or NSERC. This could facilitate the project starting earlier and improves our chances of obtaining the remaining funds.

We appreciate the PGA support and are excited to help the potato industry.

Sincerely,

L.M. Kawchuk, Ph.D.
Research Scientist

LK:mk

Canada

POTATO GROWERS OF ALBERTA

6008, 46th Avenue
Taber, Alberta T1G 2B1

Phone (403) 223-2262
Fax (403) 223-2268
e-mail: pga@albertapotatoes.ca
www.albertapotatoes.ca

April 3, 2006

Mr. Larry Kawchuk
Plant Pathologist
Agriculture and AgriFood Canada
Lethbridge Research Centre
Box 3000, Main
Lethbridge, AB T1J 4B4

Re: "Early Dying and Oomycete Analysis and Control"

Dear Larry:

We are pleased to advise that the Board of Directors of the Potato Growers of Alberta has reviewed and approved conditional funding for your research application.

The PGA will support this project if you decide to apply for the remaining cash portion from the Agricultural Funding Consortium. The PGA funding will be accessible for a three year period in the amount $18,000.

We appreciate your commitment and dedication to the potato industry.

Yours truly,

Vern Warkentin
Executive Director

Potato Growers of Alberta

Proposal application for Research funding 2006-2007

Instructions

To assess the proposals consistently, they must be completed according to the parameters contained in this form. Proposals may be rejected for incomplete information or lack of compliance with the instructions. This application could use other sources of forms only if it will be presented to other funding consortiums.
Please jump between boxes using the "Tab" key and avoid the use of the "enter" key. The PGA Research Committee will set dates for project presentations and result reports.

Confidentiality

This Proposal is confidential and the information contained in it may not be disclosed with other organizations or research groups. ☐

1. Research Team Information

Team Leader:Larry Kawchuk		
Organization:AAFC	Section/Department:Research	
Address:PO Box 3000	City:Lethbridge	Province:AB
Postal Code:T1J 4B1	E-mail :kawchuk@agr.gc.ca	
Phone Number:403-317-2271	Fax Number:403-382-3156	

Team Member:Ron Howard		
Organization:AAFRD	Section/Department:CDC South	
Address:SS #4	City:Brooks	Province:AB
Postal Code:T1R 1E6	E-mail:ron.howard@gov.ab.ca	
Phone Number:403-362-1328	Fax Number:403-362-1326	

Team Member:Bud Platt		
Organization:AAFC	Section/Department:Research	
Address:PO Box 1210	City:Charlottetow	Province:PE
Postal Code:C1A 7M8	E-mail address:platth@agr.gc.ca	
Phone Number:902-566-6839	Fax Number:902-566-6821	

2. Project Information

Title: Early Dying and Oomycete Analysis and Control
Category of the project (Please check more than one box if necessary): ☒ Pest Management ☐ Water and Irrigation Management ☒ Potato Storage ☐ Potato Breeding ☐ Potato Plant Physiology ☐ Potato Fertility Plant ☐ Nutrition/Soil management ☐ Green House ☐ Environment ☐ Potato Marketing and Economics ☐ Potato Cultural Management
Research Location (s): Lethbridge, Brooks, Charlottetown, Vauxhall, and Stavely
Duration (Y):3 Start Date (YY/MM):06/04Ending Date (YY/MM):09/03

Is the project linked to other applications / Research projects Y ☒ N ☐
(Please identify related projects)

1.Project:Diagnosis, Characterization and Management of Powdery Scab on Commercial Potatoes in Alberta
Team Leader:Dr. Ron Howard

Start Date:2005

2.Project: Use of Green Manure Crops to Reduce Pests and Diseases in Alberta
Team Leader:Dr. Michele Konschuh

Start Date:2006

Background.
(Max 2000 characters)

Early dying is a common disease, caused by several different species of Verticillium and influenced by nematodes. It occurs in most potato growing areas of the world. The incidence and severity of early dying appears to be increasing in western Canada potato producing areas. Verticillium species have a wide host range and are known pathogens of many crops and other plants. Disease development impedes water movement within the plant and is influenced by many abiotic and biotic factors. Early dying can cause severe yield losses and leads to internal net necrosis in many potato varieties. Soil fumigants are sometimes used to control the disease but they are expensive and essentially sterilize the soils. Several species of Verticillium are known to cause disease but the factors contributing to the disease are poorly understood. Additional information on the potential transmission, detection, and control of early dying is required.

Late blight, pink rot, and leak are caused by the oomycetous fungi Phytophthora infestans, Phytophthora erythroseptica, and Pythium ultimum, respectively. They represent potentially the most devastating group of potato pathogens. The incidence of pink rot and late blight is increasing in incidence and possibly severity in western Canada but the exact cause or

population dynamics remain to be determined. Late blight can decimate a crop within a few days and like pink rot, it can infect a healthy tuber. Control in some countries involves up to 40 applications of fungicide in a single growing season but these pathogens have developed pesticide resistance. Our understanding of the oomycetes is still quite limited and alternatives for detection and control are required.

Diagnostics that identify pathogen/pest sources and strains and disease control strategies based on management and biocontrol, will reduce disease losses, eliminate pesticides that can adversely impact environment, and help improve the competitiveness of the Alberta product.

Objectives (Measurable-Deliverables)
(Please use Bullets) (Max 1000 characters)

1) Develop diagnostic tests for reliably detecting the pathogens and pests contributing to early dying, leak, late blight and pink rot. Assays will help determine sources, vectors, and pathogen strain distribution in fields selected for potato production.
2) Characterize the pathogen/pest populations causing early dying, leak, late blight and pink rot in Alberta. Samples will be obtained from diseased tissues, soils, soil debris, and culture collections to determine virulence, aggressiveness, and other characteristics such as pesticide reaction.
3) Develop strategies for the control of early dying, leak, late blight and pink rot. This will involve a mangement approach based on diagnostic information, the screening of germplasm and advanced lines for resistance, storage and soil monitoring and amendments, and crop rotations.
4) Improve the competitiveness and sustainability of producers and processors by advancing our understanding of these pathogens/pests to improve yield and quality.

Economical/Environmental Benefits

(Please mention how the results of this project will benefit potato production economically and environmentally.(Max. 1000 characters) .

Apparent increases in early dying, leak, late blight and pink rot in western Canada are associated with reduced yields and quality that adversely impact producers and processors. These diseases also often compromise healthy tubers, predisposing potatoes to secondary diseases such as fusarium dry rot. Acquisition and characterization of endogenous pathogen/pest populations will facilitate the development/application of cost-effective multiplex diagnostic procedures to assist in early reliable detection of the pathogen/pests in soils, seed, and other sources to avoid disease. Results will advance our understanding of host-pathogen interactions and identify effective alternative disease control strategies that help reduce pesticide applications thereby addressing growing health and environmental concerns. Better control measures for early dying, leak, late blight and pink rot in western Canada will improve the sustainability and competitiveness of the potato industry in Alberta.

Methodology Description

(Please describe the scientific process you will follow to achieve project objectives).(Max 2000 Characters)

1) Pathogen/Pest identification, and isolation: Industry, CFIA, and collaborators will assist in collection of diseased samples and early dying, leak, late blight, and pink rot pathogen/pest identification/isolation. Additional pathogen/pest populations will be obtained from existing regional, National, and International culture collections for comparison.

2) Detection and risk levels: Sensitive pathogen/nematode polymerase chain reaction (PCR) assays will be developed/applied to detect each pathogen and pest. Universal primers designed for highly conserved rDNA sequences have proven effective in reliable identifications of pathogens and other organisms. Testing will examine various sources of the pathogens and nematodes including field soil, alternative hosts, and seed to determine inoculum loads and risk.

3) Strain characterization: AAFC will develop PCR assays to analyse genetic variability within each pathogen/pest to identify different strains. Hypervariable intergenic spacer regions such as the rDNA ITS regions are capable of distinguishing even small variations in populations. Results will

help develop multplex assays to detect several pathogens/pests and reduce test costs. PCR amplifications will be conducted under stringent conditions and amplified products cloned and sequenced. Sequence comparisons and analyses can be performed with various available software programs.
4) Disease management: Management practices and pathogen threshold values will be evaluated to determine strategies to control pathogen reservoirs and vectors and minimize disease losses. True potato seed from accessions held in germplasm repositories and advanced lines from the AAFC Potato Breeding Program will be screened with aggressive strains of early dying, late blight, and pink rot pathogens in storage, greenhouse, and/or field trials. Monitor pathogen/pest changes in soil and seed after vine removal, deep tillage, green manures, and crop rotations to reduce disease.

Technology Transfer Plan.
(Please describe the proposed method to communicate findings and results) (Max. 1000 characters)
Disease control information and strategies will be communicated to producers and industry through presentations at producer meetings, field days, and in publications. Advanced lines will be planted in field trials at various locations by industry and AAFC to evaluate agronomic performance and disease resistance. Harvested tubers will be evaluated for disease in storage. Reports that summarize diagnostic capabilities, control strategies, and disease/pest resistance will be collected, analyzed, and distributed to the industry. Licenses will be obtained for the various products that are commercializable and diagnostics transferred to service labs in western Canada. Patent applications will be prepared as warranted to capture commercializable products and technologies. Progress reports will be prepared annually and a final report submitted at the conclusion of the study.

3. Project Budget

		Year 1	Year 2	Year 3	Total
PGA	Cash	18000	18000	18000	54000
	In-Kind	15000	15000	15000	45000
	Total	33000	33000	33000	99000
Other					
AAFC Lethbridge	Cash				
	In-Kind	45000	45000	45000	135000
	Total	45000	45000	45000	135000
Other					
AAFRD	Cash				
	In-Kind	15000	15000	15000	45000
	Total	15000	15000	15000	45000
Other					
AAFC PEI	Cash				
	In-Kind	15000	15000	15000	45000
	Total	15000	15000	15000	45000
Other					
Companies	Cash				
	In-Kind	7500	7500	7500	22500
	Total	7500	7500	7500	22500
Total		**115500**	**115500**	**115500**	**346500**

Project Cost Distribution	Year 1	Year 2	Year 3	Total
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Capital goods	5000	5000	5000	15000
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TOT	2000	2000	2000	6000
Overhead	18000	18000	18000	54000
Total	**115500**	**115500**	**115500**	**346500**

*TOT (Transference of Technology)

Research Project Manager

Signature **Date 28/02/06**

Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada

Invoice - Facture

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ATTN: Vern Warkentin
Potato Growers of Alberta
6008-46th Avenue
TABER AB T1G 2B1
CANADA

Originator-Expéditeur
Lethbridge Research Center
Lethbridge, AB
ATTN: LORI SCHWARTZENBERGER
TEL: (403) 317-3353

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Description	Quantity	Unit Price	Amount
A04771 Dr. Larry Kawchuk **NVR Collaborative agreements research** 2007-08 Funding for RSA entitled "Early Dying and Oomycete Analysis & Control" with Dr. Larry Kawchuk	1 EA	6,000.00	6,000.00
Sub-Total (CAD)			6,000.00
Total (CAD)			6,000.00

PAID

PAID

RECEIVED APR 30 2007

Canada

POTATO GROWERS OF ALBERTA

6008 46th Avenue
Taber, AB T1G 2B1
Tel: (403) 223-2262 Fax: (403) 223-2268

CANADIAN IMPERIAL BANK OF COMMERCE
5124-48TH AVE.,
TABER, AB T1G 1R9

004857

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PAY ******Fourteen Thousand and 00/100 $**14,000.00

TO THE ORDER OF Receiver General of Canada

POTATO GROWERS OF ALBERTA
General Account

PER _____
AUTHORIZED SIGNATURE

PER _____
AUTHORIZED SIGNATURE

MEMO

⑈004857⑈ ⑆00139⑈010⑆ 72⑈05317⑈

POTATO GROWERS OF ALBERTA
Receiver General of Canada

5/1/2007

004857

Date	Type	Reference	Original Amt.	Balance Due	Discount	Payment
05/01/2007	Bill	20003758	8,000.00	8,000.00		8,000.00
05/01/2007	Bill	83004684	6,000.00	6,000.00		6,000.00
					Cheque Amount	14,000.00

Main Operating Accou

Can$14,000.00

POTATO GROWERS OF ALBERTA
Receiver General of Canada

5/1/2007

004857

Date	Type	Reference	Original Amt.	Balance Due	Discount	Payment
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Main Operating Accou

Can$14,000.00

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Research Branch | Direction générale de la recherche

Office of Intellectual Property and Commercialization
Commercialization Officer: **Ryan Wilkes**
Agriculture and Agri-Food Canada
Room 1058, K.W. Neatby Building
960 Carling Avenue
Ottawa, Ontario K1A 0C6
Telephone: (613) 759-7761
Facsimile: (613) 759-1765
E-mail:wilkesr@agr.gc.ca

519-738-2251

By Courier

August 3, 2006

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008-46 Avenue
Taber, AB
T1G 2B1

Dear Mr. Warkentin;

You will find enclosed two original Research Support Agreements for: **"Evaluation of Incidence and Control of Blackleg and Bacterial RingRot."** Please have an authorized representative sign both copies, retain one for your records and return one to me in the self-addressed envelope provided for your convenience.

If you have any questions or concerns, do not hesitate to contact me at (613) 759-7761.

Sincerely,

Ryan Wilkes
Office of Intellectual Property
& Commercialization

Encl.

signed + returned one copy
Aug 18/06

Canada

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Research Branch | Direction générale de la recherche

Office of Intellectual Property and Commercialization
Agriculture and Agri-Food Canada
Commercialization Officer: **Ryan Wilkes**
Tel: **613-759-7761**
Fax: **613-759-1765**
Research Scientist: Dr. L. Kawchuk
Office of Intellectual Property File: STAT #487095

July 21, 2006

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008-46 Avenue
Taber, AB
T1G 2B1

Dear Mr. Warkentin:

RE: Research Support Agreement
Between: Agriculture and Agri-Food Canada AND Potato Growers of Alberta ("Contributor")
Project: Evaluation of Incidence and Control of Blackleg and Bacterial RingRot

1. This is a Research Support Agreement (RSA) between the Contributor and Her Majesty the Queen in Right of Canada as represented by the Minister of Agriculture and Agri-Food ("AAFC") whereby the Contributor pays to AAFC cash support of **CDN $18,000** ("Contribution") for the Project detailed in Appendix "A" (Description of Research Project).

2. The Contribution will be directed toward the Project conducted at the Lethbridge Research Centre, Lethbridge, Alberta and led by the Principal Investigator (PI), Dr. L. Kawchuk.

3. The Contribution will assist in conducting the Project, and the AAFC research will be of direct or indirect benefit to the Contributor.

4. The Project will be conducted from April 1, 2006 to March 31, 2007, inclusive.

5. You, the Contributor, agree that:
   (a) The Contribution will be used to fund the Project as outlined in Appendix "A";
   (b) AAFC's only obligation is to use the Contribution for the Project mentioned above;
   (c) If appropriate, research results will be published, subject to any patent or trade secret concerns;
   (d) Any and all intellectual property arising from the Project is the sole property of AAFC;
   (e) The Contribution is irrevocable; and
   (f) There are no other understandings or agreements regarding this contribution or Project except as stated in this RSA.

If you find these terms and conditions acceptable, please have the appropriate authority in your

organization date and sign both copies of this RSA (in any colour of ink other than black), keep one original for your records, and return the other to us for our files.

This Research Support Agreement has been executed, in duplicate, by duly authorized representatives of the parties and effective on the date of the last signature.

Yours truly,

John Culley, Ph.D.
Director, Office of Intellectual Property and Commercialization
Agriculture and Agri-Food Canada

Date: 24-07-2006

Potato Growers of Alberta:

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta

Date: Aug 18/06

APPENDIX "A"
DESCRIPTION OF RESEARCH PROJECT

Background:

Blackleg and tuber soft rot of potato are caused by pectolytic gram negative Erwinia species. These diseases are found wherever potatoes are grown. The incidence and severity of blackleg appears to be increasing in western Canada potato producing areas. Blackleg is favoured by cool wet soils at planting and spread through seed, irrigation, and insects. Blackleg can cause severe yield losses and symptoms may appear at any stage of plant development. Symptoms progress from a decaying seed piece to lesions extending from the base of the stem into the canopy. Several species of Erwinia are known to cause disease but many factors contributing to the disease are poorly understood. Additional information on the transmission, detection, and control of blackleg would improve yields and quality.

Bacterial ring rot has plagued the potato industry and is a zero tolerance pathogen. It is caused by a gram positive tuber-borne bacterium, Clavibacter michiganenesis subsp. sepedonicus. The bacterium can overwinter in potato debris, may reside in other hosts such as sugar beets, can be spread by insects, and survives on equipment for up to 5 years. Symptoms vary amongst potato varieties and environmental conditions. Unfortunately, the identification of a single infected tuber can result in decertification, sometimes bankruptcy, and negatively impacts trade. Our understanding of bacterial ring rot is still quite limited and alternatives for detection and control are required.

Phagetherapy has recently emerged as an important tool in the control of human and animal bacterial diseases. Bacteriophage are nature's tiniest viruses, they naturally occur for each bacterium, and represent a cost-effective prevention strategy for blackleg and bacterial ring rot. Diagnostics that identify pathogen sources and strains and disease control strategies based on management and biocontrol, should reduce the occurrence of blackleg and bacterial ring rot.

Objectives:

1) Develop sensitive diagnostic tests that reliably detect the pathogens causing blackleg and bacterial ring rot. Assays will be applied to determine sources, vectors, and pathogen strain distribution in soils selected for potato production.

2) Characterize the pathogen populations causing blackleg and bacterial ring rot in Alberta. Forensic samples will be obtained from diseased tissues, soils, equipment, storages, and collections to determine virulence, aggressiveness, and other characteristics such as transmission.

3) Develop strategies to control of blackleg and bacterial ring rot. This will involve a mangement approach based on the diagnostic monitoring information, the screening of AAFC advanced lines and commercial varieties for symptom expression, and seed and soil phage biocontrol amendments.

4) Improve the competitiveness and sustainability of producers and processors by advancing our understanding of these diseases to curtail their occurrence and improve yield and quality.

Impact/Benefits:

Apparent increases in blackleg and bacterial ring rot in western Canada are associated with reduced yields and quality or decertification that adversely impacts producers and processors. These pathogens, especially bacterial ring rot, also adversely impact trade and are sometimes used as a non-tariff trade barrier. Acquisition and characterization of endogenous pathogen populations will facilitate the development of diagnostic procedures to assist in reliable early detection and to reduce disease occurrence. Results will advance our understanding of host-pathogen interactions and identify effective disease control strategies that help reduce the occurrence of blackleg and bacterial ring rot such as cost-effective phage biocontrol. Control measures for blackleg and bacterial ring rot in western Canada will improve the sustainability and competitiveness of the potato industry in Alberta.

Science Plan:

1) Pathogen identification, and isolation: Industry, CFIA, and collaborators will assist in collection of diseased samples and blackleg and bacterial ring rot pathogen identification/isolation. Additional pathogen populations will be obtained from existing regional, National, and International culture collections for comparison.

2) Detection and quantification: Sensitive pathogen-specific polymerase chain reaction (PCR) assays will be developed to detect and quantify nucleic acid from each pathogen. Universal primers designed for highly conserved rDNA sequences have proven effective for reliable identification of pathogens. Testing will examine various sources of the pathogens including field soil, potential vectors, alternative hosts, equipment, storages, and potatoes.

3) Strain characterization: AAFC will develop PCR assays of genetic variability within each pathogen and to identify different strains. Hypervariable intergenic regions are capable of distinguishing even small variations in pathogen populations. PCR amplifications will be performed under stringent conditions and amplified products cloned and sequenced. Sequence comparisons and analyses can be performed with various available software programs.

4) Disease management: Management practices and pathogen threshold values will be evaluated to determine strategies to control pathogen reservoirs, vectors, and minimize disease losses. Advanced lines from the AAFC and commercial cultivars will be screened with aggressive strains of blackleg and bacterial ring rot pathogens in storage, greenhouse, and/or field trials for sypmptom expression. Soil, storage, and seed treatments, irrigation, and crop rotations will be assessed to identify and recommend strategies to reduce disease. Phagetherapy with isolated natural viruses from this study for blackleg and bacterial ring rot will be evaluated as a cost-effective biocontrol to prevent disease.

The bacterial ring rot field trial at the AAFC Stavely Substation was established 30 years ago by Dr. G. Nelsen. Advanced lines will be planted in field trials by industry and AAFC to evaluate symptom expression for blackleg and bacterial ring rot. Harvested tubers will be evaluated for disease in storage and effectiveness of control. Reports that summarize diagnostic capabilities, control strategies, and symptom expression will be collected, analyzed, and distributed to the industry. A report will be prepared and submitted.

Potato Growers of Alberta

Proposal application for Research funding 2006-2007

Instructions

To assess the proposals consistently, they must be completed according to the parameters contained in this form. Proposals may be rejected for incomplete information or lack of compliance with the instructions. This application could use other sources of forms only if it will be presented to other funding consortiums.
Please jump between boxes using the "Tab" key and avoid the use of the "enter" key. The PGA Research Committee will set dates for project presentations and result reports.

Confidentiality

This Proposal is confidential and the information contained in it may not be disclosed with other organizations or research groups. ☐

1. Research Team Information

Team Leader:Larry Kawchuk		
Organization:AAFC	Section/Department:Research	
Address:PO Box 3000	City:Lethbridge	Province:AB
Postal Code:T1J 4B1	E-mail :kawchuk@agr.gc.ca	
Phone Number:403-317-2271	Fax Number:403-382-3156	

Team Member:Ron Howard		
Organization:AAFRD	Section/Department:CDC South	
Address:SS #4	City:Brooks	Province:AB
Postal Code:T1R 1E6	E-mail:ron.howard@gov.ab.ca	
Phone Number:403-362-1328	Fax Number:403-362-1326	

Team Member:Benoit Bizimungu		
Organization:AAFC	Section/Department:Research	
Address:PO Box 3000	City: Lethbridge	Province:AB
Postal Code:T1J 4B1	E-mail address:bizimungu@agr.gc.ca	
Phone Number:403-317-2276	Fax Number:403-382-3156	

2. Project Information

Title: Evaluation of Incidence and Control of Blackleg and Bacterial RingRot

Category of the project (Please check more than one box if necessary):

- ☒ Pest Management
- ☐ Water and Irrigation Management
- ☒ Potato Storage
- ☐ Potato Breeding
- ☐ Potato Plant Physiology
- ☐ Potato Fertility Plant
- ☐ Nutrition/Soil management
- ☐ Green House
- ☐ Environment
- ☐ Potato Marketing and Economics
- ☐ Potato Cultural Management

Research Location (s): Lethbridge, Brooks, Vauxhall, and Stavely

Duration (Y):3 Start Date (YY/MM):06/04Ending Date (YY/MM):09/03

Is the project linked to other applications / Research projects Y ☒ N ☐
(Please identify related projects)

1.Project:Diagnosis, Characterization and Management of Powdery Scab on Commercial Potatoes in Alberta
Team Leader:Dr. Ron Howard

Start Date:2005

2.Project:Use of Green Manure Crops to Reduce Pests and Diseases in Alberta
Team Leader:Dr. Michele Konschuh

Start Date:2006

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(Please mention how the results of this project will benefit potato production economically and environmentally.(Max. 1000 characters) .

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(Please describe the proposed method to communicate findings and results) (Max. 1000 characters)

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AAFRD	Cash				
	In-Kind	15000	15000	15000	45000
	Total	15000	15000	15000	45000

Other

	Cash				
	In-Kind				
	Total				

Other

	Cash				
	In-Kind	7500	7500	7500	22500
Companies	Total	7500	7500	7500	22500

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*TOT (Transference of Technology)

Research Project Manager

Signature **Date 28/02/06**

Evaluation of Incidence and Prevention

of

Blackleg and Bacterial Ring Rot

Potato Growers of Alberta
Progress Report 2006/07

L.M. Kawchuk, R. Howard, and B. Bizimungu

Research Centre, Agriculture and Agri-Food Canada, Lethbridge, AB

Alberta Agriculture, Food and Rural Development, CDC South, Brooks, AB

Summary

Sensitive diagnostics have been developed that are capable of detecting trace levels of the blackleg and bacterial ring rot pathogens. The procedure works on extremely small samples of only a few milligrams, may be used to examine any sample including soil, and results can be available within only a few hours. The procedures are quantitative facilitating the estimation of pathogen levels in seed or soils before planting and are capable of differentiating between strains with different characteristics such as aggressiveness and symptom expression. Initial results show little variation in the pathogen causing bacterial ring rot but a surprisingly large level of variation has been observed in the blackleg samples. Furthermore, several virulent soil phage that aggressively attack blackleg and bacterial ring rot pathogens have been isolated and are being characterized for application as a seed treatment and in furrow amendment that prevents blackleg and ring rot. Greenhouse and field trials have been established for the evaluation of disease symptom expression in potato varieties, characterization of the diagnostics, and determination of the most effective application parameters for the prevention measures. Producers are encouraged to submit suspect samples for confidential evaluation and thereby assist in characterizing the diagnostics and prevention strategies. Agriculture and Agri-Food Canada has approved an application to match the Potato Growers of Alberta contributions.

Background

Blackleg and tuber soft rot of potato are caused by pectolytic gram negative *Erwinia* species. These diseases are found wherever potatoes are grown. The incidence and severity of blackleg appears to be increasing in western Canada potato producing areas. Blackleg is favoured by cool wet soils at planting and spread through seed, irrigation, and insects. Blackleg can cause severe yield losses and symptoms may appear at any stage of plant development. Symptoms progress from a decaying seed piece to lesions extending from the base of the stem into the canopy. Several species of *Erwinia* are known to cause disease but many factors contributing to the disease are poorly understood. Additional information on the transmission, detection, and control of blackleg would improve yields and quality.

Bacterial ring rot has plagued the potato industry and is a zero tolerance pathogen. It is caused by a gram positive tuber-borne bacterium, *Clavibacter michiganenesis*

subsp. *sepedonicus*. The bacterium can overwinter in potato debris, may reside in other hosts such as sugar beets, can be spread by insects, and survives on equipment for up to 5 years. Symptoms vary amongst potato varieties and environmental conditions. Unfortunately, the identification of a single infected tuber can result in decertification, sometimes bankruptcy, and negatively impacts trade. Our understanding of bacterial ring rot is still quite limited and alternatives for detection and control are required.

Phagetherapy has recently emerged as an important tool in the control of human and animal bacterial diseases. Bacteriophage are nature's bacterial control mechanism, naturally occur for each bacterium, and represent a cost-effective prevention strategy for blackleg and bacterial ring rot. Diagnostics that identify pathogen sources and strains and disease control strategies based on management and biocontrol, should reduce the occurrence of blackleg and bacterial ring rot.

Objectives

1) Develop sensitive diagnostic tests that reliably detect the pathogens causing blackleg and bacterial ring rot. Assays will be applied to determine sources, vectors, and pathogen strain distribution in soils selected for potato production.
2) Characterize the pathogen populations causing blackleg and bacterial ring rot in Alberta. Forensic samples will be obtained from diseased tissues, soils, equipment, storages, and collections to determine virulence, aggressiveness, and other characteristics such as transmission.
3) Develop strategies to control of blackleg and bacterial ring rot. This will involve a mangement approach based on the diagnostic monitoring information, the screening of AAFC advanced lines and commercial varieties for symptom expression, and seed and soil phage biocontrol amendments.
4) Improve the competitiveness and sustainability of producers and processors by advancing our understanding of these diseases to curtail their occurrence and improve yield and quality.

Materials and Methods

1) Pathogen identification, and isolation: Industry, CFIA, and collaborators are assisting in the collection of diseased samples and blackleg and bacterial ring rot pathogen identification/isolation. Additional pathogen populations will be

obtained from existing regional, National, and International culture collections for comparison.
2) Detection and quantification: Sensitive pathogen-specific polymerase chain reaction (PCR) assays have been developed to detect and quantify nucleic acid from each pathogen. Universal primers designed for highly conserved rDNA sequences have proven effective for reliable identification of the pathogens. Testing is examining various sources of the pathogens including field soil, potential vectors, alternative hosts, equipment, storages, and potatoes.
3) Strain characterization: AAFC has developed PCR assays of genetic variability within each pathogen to determine strain populations. Hypervariable intergenic regions are capable of distinguishing even small variations in pathogen populations. PCR amplifications are performed under stringent conditions and amplified products cloned and sequenced. Sequence comparisons and analyses are performed with various available software programs such as Mulialign.
4) Disease management: Management practices and pathogen threshold values will be evaluated to determine strategies to control pathogen reservoirs, vectors, and minimize disease losses. Advanced lines from the AAFC and commercial cultivars are being screened with aggressive strains of blackleg and bacterial ring rot pathogens in storage, greenhouse, and/or field trials for symptom expression. Soil, storage, and seed treatments, irrigation, and crop rotations will be assessed to identify and recommend strategies to reduce disease. Phagetherapy with isolated natural viruses from this study for blackleg and bacterial ring rot will be evaluated as a cost-effective biocontrol to prevent disease.

Results and Discussion

The project commenced in the spring of 2006. Agriculture and Agri-Food Canada has approved an application to match the Potato Growers of Alberta contributions. Excellent progress has been made in both the development of diagnostics and the isolation of aggressive virulent blackleg and ring rot phage. Producers are encouraged to continue submitting suspect samples for confidential evaluation and thereby assist in characterizing the diagnostics and prevention strategies.

Isolates and Diagnostics

Industry, the Canadian food Inspection Agency, and collaborators assisted with the collection of diseasesd blackleg and BRR samples for pathogen identification

and isolation. Approximately 100 samples of blackleg and BRR from North America were collected for development of diagnostics, characterization, and prevention strategies. Cultures were evaluated for aggressiveness and suitability in greenhouse and field trials. Several of the most aggressive isolates selected for screening advanced lines and varieties for symptom expression and eventually effectiveness of diagnostic and prevention measures. Additional pathogen strains will be obtained from existing regional, National, and International culture collections for comparison.

Figure 1. Agricuture and Agri-Food Canada Stavely Substation 2006 field plots for screening advanced lines, diagnostics, and biocontrol products to BRR and blackleg. This is the only site in Canada for field BRR analysis. Some advanced lines and varieties show no disease symptoms, however, most lines show some degree of foliage and tuber symptoms but this is influenced by the environment and weather.

Figure 2. Typical disease symptoms of BRR in Russet Burbank tubers. External cracks are evident on the tuber with breakdown of the tuber extending from the vascular tissues.

Table 1. Disease ratings for bacterial ring rot from the hand planted and harvested 2006 field plots at the AAFC Stavely Substation.

Cultivar	07/18/06	08/01/06	08/28/06
Red Norland Control	0.0	0.0	0.0
Red Norland	**0.2**	**1.7**	**4.3**
Russet Burbank Control	0.0	0.0	0.0
Russet Burbank	**0.0**	**0.0**	**1.8**
Sangre Control	0.0	0.0	0.0
Sangre	**0.0**	**0.6**	**3.3**

0 - no visible symptoms
1 - wilt only on the lower leaves
2 - wilt and chlorosis on the lower leaves
3 - wilt to the top of the plant
4 - wilt and chlorosis to the top of the plant
5 - plant dead

Control - planted into BRR plot but not inoculated.

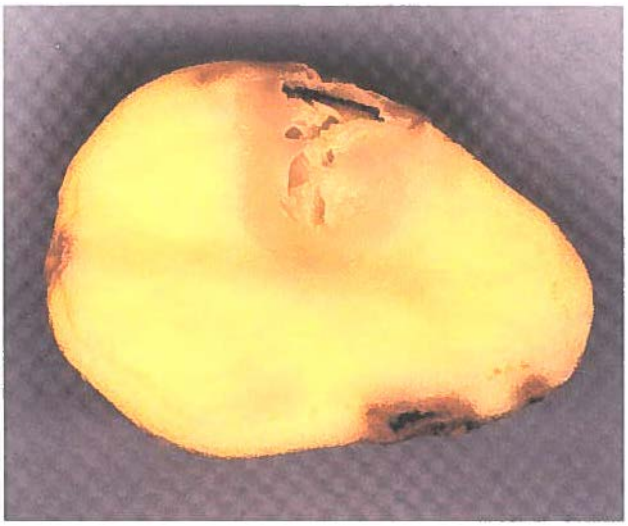


Figure 3. Typical disease symptoms produced in tubers of Shepody inoculated with species of *Erwinia.* Tissue rapidly degrades in the seed piece following infection.

Sensitive pathogen-specific polymerase chain reaction diagnostics have been developed that are capable of quickly detecting trace levels of nucleic acid from the blackleg and bacterial ring rot pathogens. The procedure works on extremely small samples of only a few milligrams, may be used to examine any sample including soil, and results can be available within only a few hours. The procedures are quantitative facilitating the estimation of pathogen levels in seed or soils before planting and are capable of differentiating between strains with different characteristics such as aggressiveness and symptom expression. Initial results show little variation in the hypervariable intergenic regions of the ribosomal DNA from the pathogen causing bacterial ring rot but a surprisingly large level of variation has been observed in the blackleg samples. This may explain why the blackleg in some areas has been relatively difficult to eradicate and suggests there may need to be different strain specific treatments.

Figure 4. Alignment of several rDNA intergenic sequences from BRR isolates. Each of the four nucleotides is indicated by a different colour. Each of the isolates are differentiated and may be identified by the nucleotide sequence.

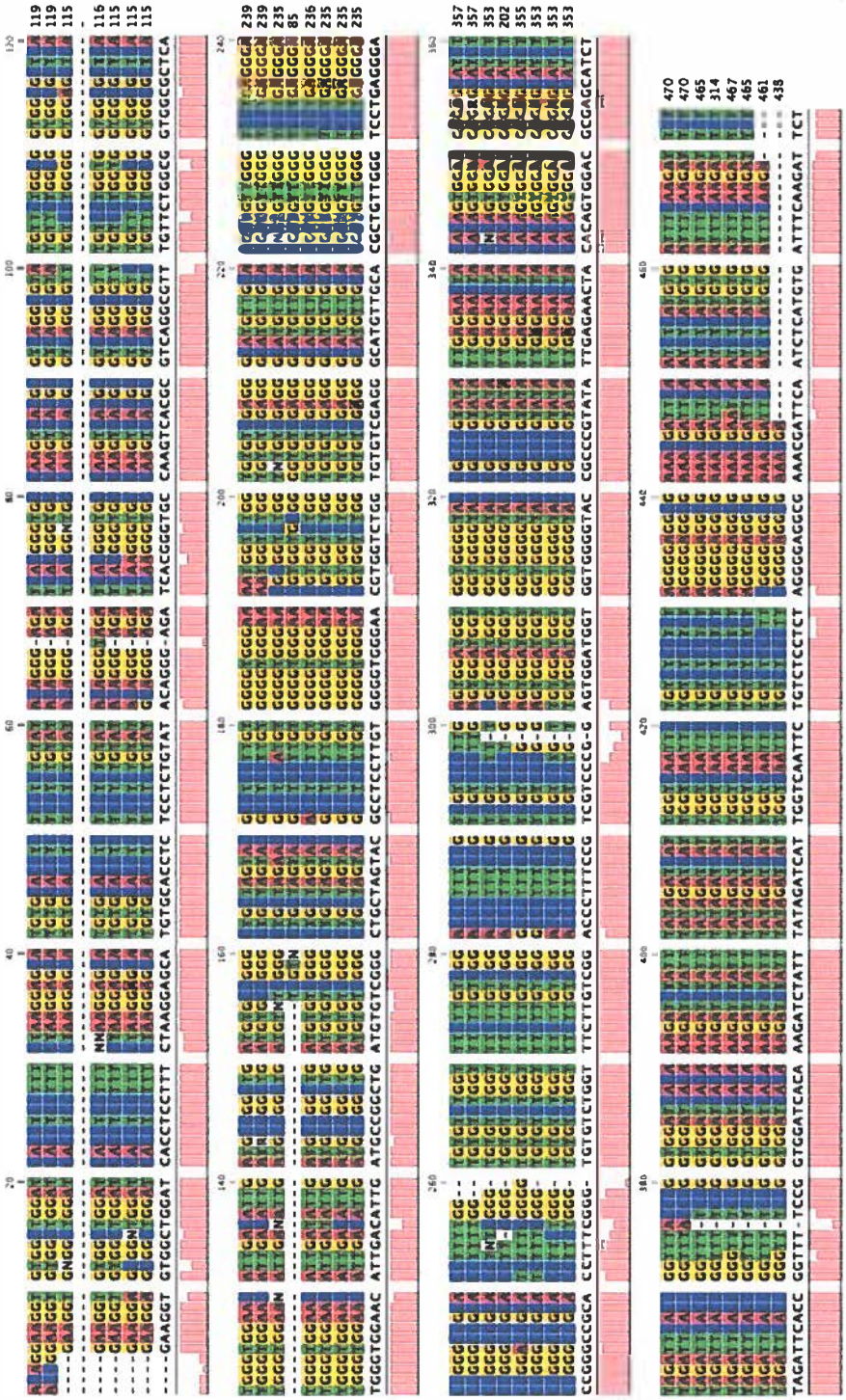
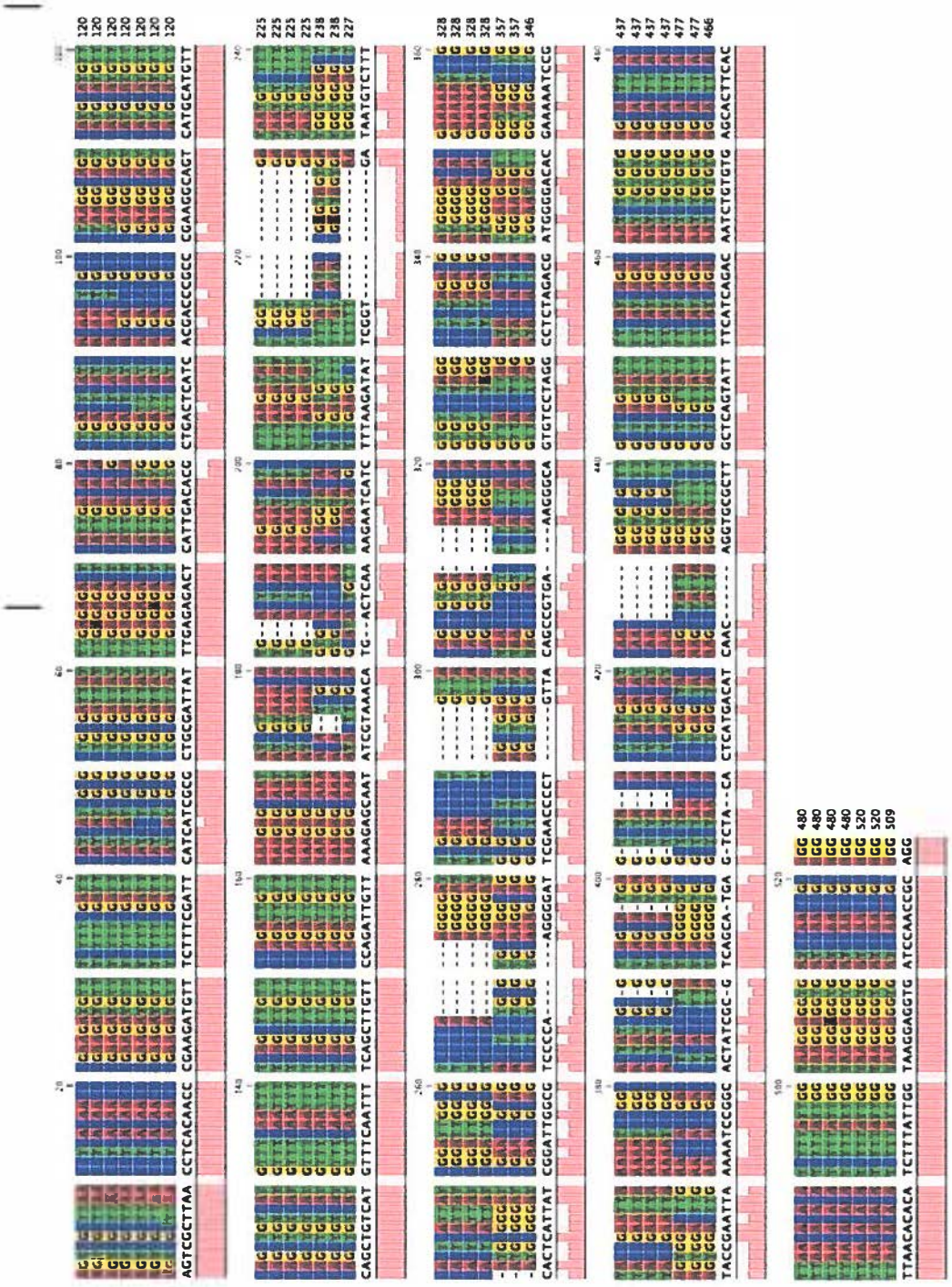


Figure 5. Alignment of several rDNA intergenic sequences from Eca isolates. Each of the four nucleotides is indicated by a different colour. At least three types of blackleg pathogen have been identified by the nucleotide sequence.



Several virulent soil phage that aggressively attack blackleg and bacterial ring rot pathogens have been isolated and are being characterized for application as a seed treatment and in furrow amendment that prevents blackleg and ring rot. Greenhouse and field trials have been established for the evaluation of disease symptom expression in potato varieties, characterization of the diagnostics, and determination of the most effective application parameters for the prevention measures. Producers are encouraged to continue submitting diseased tissues and soil samples for confidential evaluation and thereby assist in increasing the number of isolates and strains available for characterizing the diagnostics and prevention strategies.

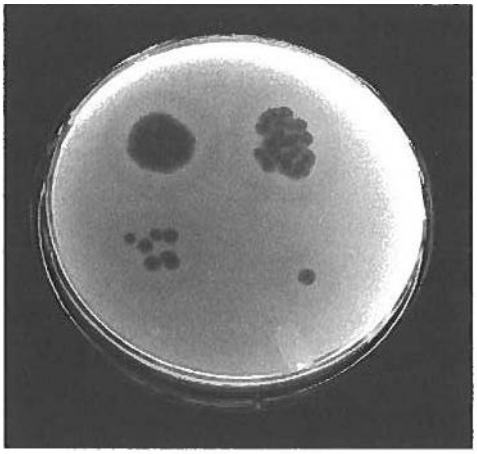


Figure 4. A plate overgrown with the blackleg pathogen *Pectobacterium atroseptica* (Syn. *Erwinia carotovora atroseptica*) treated with increasing titre of one aggressive virulent phage isolated from Canadian soil. As the titre of the phage reaches the desired levels a confluent clear zone appears free of bacteria. Initial results suggest the phage will also be effective against biofilms that have made ring rot and blackleg more difficult to prevent.

Technology Transfer

Disease control information and strategies have been communicated to producers and industry through presentations at the PGA Annual Meeting in Red Deer, research tours, and in publications. The bacterial ring rot field trial at the AAFC Stavely Substation is the only such site in Canada and was re-established to continue 30 years of screening. Advanced lines planted in field trials by industry and AAFC to evaluate symptom expression for blackleg and bacterial ring rot. Harvested tubers were evaluated for disease in storage and effectiveness of control. Reports that summarize diagnostic capabilities, control strategies, and symptom expression are being collected, analyzed, and distributed to industry. Licenses will be obtained for commercializable products and the diagnostics transferred to service labs in western Canada. Patent applications will be prepared as warranted to capture commercializable products and technologies. Progress reports will be prepared annually and a final report submitted at the conclusion of the study.

L. Kawchuk, R. Howard, and B. Bizimungu. 2006. Evaluation of incidence and prevention of blackleg and bacterial ring rot. PGA Annual Meeting Poster. Red Deer, AB.

L. Kawchuk. 2006. Potato Molecular Improvement Tools. Bulletin. Lethbridge, AB.

L. Kawchuk. 2006. Poatato Disease Prevention. Maple Leaf Potatoes Invited Presentation. Lethbridge, AB.

Economical and Environmental Benefits

Apparent increases in blackleg and bacterial ring rot in western Canada are associated with reduced yields and quality or decertification that adversely impacts producers and processors. These pathogens, especially bacterial ring rot, also adversely impact trade and are sometimes used as a non-tariff trade barrier. Acquisition and characterization of endogenous pathogen populations will facilitate the development of diagnostic procedures to assist in reliable early detection and to reduce disease occurrence. Results will advance our understanding of host-pathogen interactions and identify effective disease control strategies that help reduce the occurrence of blackleg and bacterial ring rot such as cost-effective phage biocontrol. Control measures for blackleg and bacterial ring rot in western Canada will improve the sustainability and competitiveness of the potato industry in Alberta.

Acknowledgements

We gratefully acknowledge the support of the Potato Growers of Alberta, Maple Leaf Potatoes, and the Agriculture and Agri-Food Canada Matching Investment Initiative. Industry is invited to continue submitting samples for confidential evaluation to assist with the development of diagnostics and prevention measures.

Diagnosis, Characterization and Management of Powdery Scab on Commercial Potatoes in Alberta

A Research Progress Report Submitted to

The Potato Growers of Alberta
6008 – 46th Avenue
Taber, Alberta T1G 2P1

February 28, 2006

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Introduction

Powdery scab (PS), caused by the fungus *Spongospora subterranea* f.sp. *subterranea* (Ss), is a serious disease in many potato-growing areas of the world. PS seems to be increasing in incidence and severity in Western Canada and there have been several outbreaks in AB, SK and MB since 2000. Ss is long-lived in soil (20 yr), and has alternative hosts such as tomato, pepper and nightshade. Disease development is favored by cool, wet soil conditions. PS can reduce plant vigor, tuber number and yield, and lead to the rejection of tubers for seed and other uses. Effective control measures for PS are very limited, but some new techniques appear promising.

A severe limitation in diagnosing and managing PS has been an inability to reliably detect Ss in soil and on seed tubers. The inability to culture Ss is also a hindrance in studying PS. Current methods for detecting Ss include baiting, serology and PCR (polymerase chain reaction). To enable accurate risk assessment, it is first necessary to quantify the level of infection in potato roots and tubers, and to relate this information to the spore concentration in the soil. Available detection methods have not been critically evaluated for their efficiency in detecting the strains of Ss that occur in Alberta. Access to a reliable and cost-effective diagnostic test would enable potato growers to select fields with a low risk of disease development. Characterization of the genetic variability in Ss strains could help potato breeders develop resistant varieties.

Very few strategies for managing PS have been evaluated under Alberta conditions. No single approach has proven to be effective for preventing or controlling PS in other parts of the world where it occurs. The integration of cultural, chemical and biological control practices, e.g. resistant varieties, seed and soil treatments, irrigation management, soil amendments and crop rotation, might create a cost-effective management program for this disease.

Project Objectives

1) To develop methods for reliably detecting Ss on tubers and in soil, and for predicting the potential risk for PS development in fields selected for potato production.
2) To characterize the strains of Ss occurring in central and southern Alberta in order to determine their genetic diversity, virulence on potato cultivars and lines, and ability to act as vectors for Potato Mop Top Virus (PMTV).
3) To investigate methods for reducing PS incidence and severity in seed, processing and table potatoes, including varietal resistance, seed and soil treatments, irrigation management, soil amendments, and rotational crops.
4) To use the information generated in this study to enhance our knowledge of the biology of PS and to improve the techniques for managing this disease, thereby reducing potential yield and quality losses for growers and processors.

Results for 2005-06

1. Disease Surveys

Approximately 25 samples of potato tubers were submitted to the CDC South for PS diagnosis in 2005. These samples were collected by project team members and growers, and were comprised of several varieties of table, processing and seed potatoes from central and southern Alberta. While most had PS, some were infected only with common scab (CS), or had both PS and CS. The two diseases have similar symptoms at the early stages of their development. Samples of PS-infected tubers were sent to the Lethbridge Research Center for molecular diagnosis. Background information on the fields from which the PS samples were taken is being collected

and summarized. These data will be reviewed to see if any common factors are evident that may have promoted the development of PS.

2. Detection, Quantification and Strain Characterization of Spongospora subterranea

Introduction

Dr. Larry Kawchuk and colleagues at the Lethbridge Research Center are developing assay techniques that can be used to determine the host range of Ss, to examine pathogen levels in soil from fields that will be planted with potatoes, and to confirm the presence or absence of Ss in asymptomatic tubers. This assay will be useful in determining the effectiveness of control procedures and assist in determining the strain populations of the PS pathogen in western Canada. Results of the assay can be obtained within 24 h and may therefore help expedite the certification of seed tubers.

Results

The nuclear ribosomal DNA (rDNA) regions of two hypervariable internal transcribed spacers (ITS1 and ITS2) and the 5.8S rRNA gene from 29 Alberta and Saskatchewan field isolates of SS were obtained with primers to the conserved sequences of the small subunit (SSU) rDNA and large subunit (LSU) rDNA with the polymerase chain reaction (PCR). Amplified sequences are being cloned and sequenced to determine the genetic variation amongst the isolates. The assay is sensitive and able to detect a single SS spore ball in 1 g of soil and in tuber lesions with no detectable spore balls.

SSU

1 **ggaaggatca tta**acactga gtcggttcta ccggcagacc ccaaaaccac atgagaacct

ITS1

61 gggtgcgatt gtctgttgaa gggtgacgcc cgctctgggg ctagctcgaa accttatgca

121 aaccgtatta ctgaacttac taaagtggat cgtttaacta aata**caactc ttaacagtgg**

181 **atatcttggt tcccacaacg atgaagaacg cagcgaaatg cgatacgtaa tgcgaattgc** **5.8S**

241 **agaattcagt gaatcatcaa atctttgaac gcaagttgcg ctttcgagat atccttgaaa**

301 **gcatgcctct ttgagtgtcg gtt**tctattc tcccggaaac gccctgtgcg tggaagggga

ITS2

361 ctatgagctc tggtcggtcc atggcttgaa agattatcca acccggtgcg cgtctctggc

421 ttctgattcg tctctaacca ttggcgtgcc cggtcatata gaaccatttt ttgact**ctag**

LSU

481 **atctcaaatg aggtaagact acccgctgaa tttaagcata tcaataagcg**

Figure 1. An Alberta Ss internal transcribed spacer (ITS) and 5.8S rDNA sequence. Conserved sequences of the three rDNA genes, small subunit rDNA (SSU), 5.8S rDNA, and a large subunit (LSU) rDNA are shown in bold text and underlined.

Discussion

Modification of the developed diagnostic assay will allow characterization of the strains of Ss in western Canada. The determined sequences should provide details that assist in examining the

lifecycle of the pathogen and determining effective control of the disease. Similar diagnostics are also being developed to examine the 29 powdery scab isolates for the potato mop top furovirus that causes spraing in tubers and is vectored by Ss.

3. Disease Management: Chemical Control

Introduction

Six fungicides were evaluated for the control of soil-borne powdery scab by Drs. Jill Thomson and Doug Waterer, Department of Plant Sciences, University of Saskatchewan, Saskatoon, SK. A field trial site naturally infested with high levels of common scab (*Streptomyces scabies*) and powdery scab at the university was used for this study. Black scurf (*Rhizoctonia solani*) was also present. This site was used to evaluate the efficacy of six chemicals, applied on the seed, in the furrow at planting, or at hilling for the control of scab (powdery and common) and black scurf. This site featured a Sutherland Series sandy loam soil (pH 8.1, E.C. <1.0 dS, with 3.8% O.M.). The site was in a three-year potato rotation for 20 years, but beginning three years ago, it was switched to continuous potatoes in an effort to further exacerbate scab problems.

Methods

The trial was managed using conventional production practices. Machine cut Norland E2 seed was planted on May 27 using a single row planter. Row length was 6 m, with 1 m between rows and 25 cm between seed-pieces within the row. The treatments were arranged in a randomized block design with four replicates. A 3 m path separated the replicate blocks. Four side-by-side rows were used for each treatment. Root samples were taken from the outer rows and the two center rows were harvested and assessed for yield and disease.

A 30-tuber sample of the seed used to plant this trial was evaluated for disease levels prior to planting. Three percent of the tubers had more than 5% of the surface infected with black scurf. No scab was present on the seed. Rows were hilled twice – once prior to emergence and again at emergence. Irrigation was applied when the soil moisture potential fell below –60 kPa. Weeds were controlled by preplant application of metribuzin plus linuron applied prior to ground crack.

Six fungicides were applied to the seed prior to planting, as an in-furrow treatment and/or at hilling. The seed treatments were applied to cut seed-pieces as per the experimental protocol. The in-furrow products were applied with a hand-held pressurized sprayer, with the nozzle being held between the opener discs of the planter. The spray was directed over the area of the opened furrow where the seed dropped. The in-furrow and hilling treatments were applied in 3 L of water/24 m of row. The Ranman and Blinix treatments made at hilling (June 15) were applied at the same rate as used for the in-furrow treatments applied at planting. The at-hilling treatments were sprayed as a 15 cm wide band over the top of the hill. The rows were hilled immediately after the spray treatment. A heavy thundershower occurred after hilling, which presumably washed the chemical into the soil.

The fungicide treatments were:

1. Allegro 500F applied as a liquid in-furrow (40% fluazinam, Syngenta, 5.25 g product in 3 L water/24 m row)
2. Tuberseal applied as a dust on the seed (16% mancozeb, United Agri Products, 7 g/25 seed pieces)
3. Dithane DG applied as a liquid in-furrow (75% mancozeb, Dow AgroSciences, 4.4 g

product in 3 L /24 m row)
4. Ranman 400SC applied as a liquid in-furrow at planting and prior to hilling (34.5% cyazofamid, ISK Biosciences, 12 g product in 3 L/24 m row at both applications)
5. Blinix applied as a liquid in-furrow (8.5% Rhamnolipid Biosurfactant, Jeneil Biosurfactant Co., 6 mL in 3 L/24 m row)
6. Blinix applied prior to hilling (same rate as treatment 5)
7. Check – no chemicals applied.

Three hills were dug from one row of each treatment/replicate in early September and the incidence of powdery scab galls on the roots was assessed. The roots from each individual stem were rated for galls using the following scoring system, and the average score for all stems from the three hills was recorded. The system was 0= no galls present, 1 = < 5 galls on the whole root system, 2 = 5-30 galls on whole root system, and 3 = >30 galls on whole root system.

Plants were top-killed at the beginning of September with Reglone and the trial was harvested on September 26, using a single row plot harvester. The harvested tubers were suberized at 15^{o}C with high airflow for several weeks after harvest, then cooled and stored at 5^{o}C. Disease assessments were conducted in November 2005.

Samples consisting of 30 randomly selected tubers were assessed for each row harvested. Tubers were washed under running water before being visually evaluated for the level of disease. The levels of all three diseases – common and powdery scab and black scurf - were determined. Common and powdery scab lesions can have a very similar appearance. Common scab lesions tend to be more raised and superficial, with an irregular outline. Powdery scab lesions are more circular, tend to be clustered in one area of the tuber, penetrate through the tuber skin, and have a slight rim of tuber skin around lesions that may contain distinctive spore balls (cystosori). Lesions were examined carefully for the presence of cystosori, using a dissecting microscope, to identify powdery scab.

The following data were collected:
Disease incidence – the number of tubers infected with each disease, expressed as a percentage of the total number of tubers sampled.
Disease severity – the percentage tuber surface infected by each disease was assessed using rating scales provided by the Canadian Food Inspection Agency. Disease severity was then expressed as the average percentage tuber surface infected for the total number of tubers in a sample.
Percentage of tubers with >5% surface area affected – the number of tubers with more than 5% of the tuber surface area infected, expressed as a percentage of the total number of tubers sampled. This is an important measure of disease development as tubers with more than 5% of the surface area infected are considered to be moderately diseased and only 5% of such tubers are allowed in either seed or Grade A table potatoes.
Total yield – total weight of tubers harvested from each row.
Marketable size yield – the weight of tubers of marketable size, falling between 48 and 88 mm in diameter, without taking into account grading-out due to disease infection.

Data were analyzed using the SAS GLM procedure. The values for the two rows in each treatment were averaged, and the averages analyzed. Tuber samples for disease analysis were

missing for four rows. In two of these cases, a single row was used instead of the average, but both rows were missing from one replicate of the Ranman treatment. Analysis of data with missing values is possible with the GLM procedure. Treatment means were compared using the Duncan Multiple Range test at *P*=0.05.

Results and Discussion

The 2005 growing season at Saskatoon was cool and wet during May and June. Precipitation and temperatures were near normal in July and August. Crop establishment was slow, but conditions were excellent during tuber set and bulking. Thirty-seven cm of rainfall was received over the growing season (normal = 20 cm). A total of 13 cm of supplemental irrigation was applied to the plots. Yields were relatively high in all trials conducted in 2005. No significant problems with diseases or insects were observed in the trial.

Visual examination of the plots showed no effect of the various treatments on emergence, plant growth or vitality. Plant counts were not taken. There were no significant ($P \leq 0.05$) treatment effects on total or marketable size yield (Table 1). The coefficient of variance for the yield parameters was reasonably low.

Table 1. Total and marketable yield of tubers harvested from a chemical control trial at Saskatoon, SK in 2005.

Treatment (chemical applied)	Average yield of tubers (kg/6 m row)	
	Total weight of tubers (kg)	Weight of marketable tubers (kg)
Allegro	40.2	27.2
Tuberseal	38.4	27.3
Dithane	36.4	24.3
Ranman	37.1	25.2
Blinix in-furrow	36.0	25.0
Blinix at hilling	40.8	27.6
None (check)	39.7	25.7
Coefficient of variance (%)	*10.8*	*10.0*

The incidence of root galls formed by the powdery scab organism was significantly lower in the Ranman-treated hills than in the control, Allegro-, Tuberseal- and Dithane-treated hills (Table 2). Blinix-treated hills had relatively fewer galls, but the values were not significantly ($P \leq 0.05$) different from any other treatment. There was no difference between the hills receiving the Blinix at either planting or hilling. The relatively high variance in the root gall data likely reflects non-uniform distribution of powdery scab within both the plot area and the potato root system. The relationship between the incidence and severity of root galls and tuber damage by powdery scab is not clear. However, as root galls represent a significant inoculum source for powdery scab, any treatments that limit root gall formation could help moderate future problems with powdery scab.

Table 2. Effect of chemical treatments on the incidence of powdery scab galls on potato roots sampled in September 2005.

Treatment (chemical applied)	Average gall score

Allegro	2.5 a*
Tuberseal	2.3 a
Dithane	2.4 a
Ranman	1.3 b
Blinix in-furrow	2.0 ab
Blinix at hilling	2.1 ab
None (check)	2.6 a
Coefficient of variance (%)	*29.7*

* Values followed by the same letter are not significantly different using Duncan's Multiple Range Test (P≤0.05).

The levels of black scurf on harvested tubers were not affected by the chemical treatments (Table 3). The average incidence of black scurf was not high, with a range of 18 to 36 % of tubers being infected. The severity of black scurf on the harvested tubers was consistently low. No tubers had more than 5% of the surface area infected by *Rhizoctonia*. The coefficient of variance for the black scurf data was high; this reflects the infrequent and sporadic occurrence of *Rhizoctonia* in this trial.

Table 3. Effect of chemical treatments on disease incidence and severity on tubers harvested in September, 2005.

Treatment (chemical applied)	% of tubers infected with			% of tubers with > 5% surface area infected with	
	Black scurf	Common scab	Powdery scab	Common Scab	Powdery scab
Allegro	18.5	90.5 a*	76.9 ab	33.3 ab	25.5 a
Tuberseal	35.9	90.8 a	79.5 ab	32.4 ab	33.6 a
Dithane	28.4	91.3 a	83.1 a	33.9 ab	23.0 a
Ranman	20.0	77.2 b	30.7 c	18.3 b	4.5 b
Blinix in-furrow	26.8	89.6 ab	83.3 a	36.6 ab	31.8 a
Blinix at hilling	22.9	91.6 a	68.4 b	39.1 ab	18.0 ab
None (check)	26.5	93.9 a	77.1 ab	54.5 a	31.0 a
Coefficient of variance (%)	*44.6*	*9.1*	*48.4*	*9.7*	*46.7*

* Values followed by the same letter are not significantly different using Duncan's Multiple Range Test, p=0.05.

The application of Ranman significantly (P≤0.05) reduced the incidence and severity of both powdery and common scab when compared with the levels seen on the untreated check (Table 3). The Ranman treatment appeared particularly effective against powdery scab. The reduction in percentage of tubers with > 5% surface area infected would have reduced losses to grade-out, and thus would have significantly increased the market value of the crop. The coefficients of variance for the common scab ratings were low – this reflects the uniform and high levels of infestation of the site by this pathogen. Although the overall incidence of powdery scab was

almost as high as for common scab, the powdery scab is less uniformly distributed across the plot area – resulting in greater variation in the data. More replication and/or larger sample sizes may be required to clarify treatment effects for powdery scab control at this site.

The application of Blinix at hilling significantly reduced both the incidence and severity of powdery scab (P=0.09). It should be noted that while Ranman was applied at both planting and hilling, the Blinix treatment was applied either at planting or hilling, but not at both stages. Applying Blinix at both planting and hilling may produce more significant scab control. Further evaluation of both Ranman and Blinix is recommended.

Conclusions

Currently registered seed treatment products, such as Tuberseal, were not effective for the control of soil-borne scab. In-furrow applications of fluazinam (Allegro) and mancozeb (Dithane) were also ineffective at the rates used. Application of Ranman (cyazofamid) in-furrow and at-hilling appeared very promising as it provided a reasonable level of control of both common and powdery scab on a moderately scab sensitive variety growing in very heavily infested soil. Blinix (Rhamnolipid Biosurfactant) also appeared to have some potential; it should be tested at higher rates and/or in multiple applications.

4. Disease Management – Cultivar Resistance

Introduction

Tricia McAllister noted high levels of PS in certain potato trials at the Crop Diversification Centre North, Edmonton and took the opportunity to measure disease incidence (DI) and severity (DS) in tubers from three trials, i.e. Pre-Plant Handling of Seed (PPHS), Lutein Production, and the Prairie Main Crop Replicated Trial (PMRT).

Results

The origin of the infection could not be precisely determined, but the most heavily infested lots were observed in the PPHS trial. In the most severely affected areas, the DI was ≥ 20% (5 of 25 tubers) the DS was ≥ 3% of the total surface covered. DI and DS ratings (based on an average of 4 replications) are given below. Russet Burbank had very little tuber infection and Atlantic also appeared to be somewhat resistant to tuber infection. AC Glacier Chip was highly susceptible.

Trial	Variety/Line	Disease Incidence (% tubers infected with powdery scab)	Disease Severity (% tuber surface covered with scabs)
PPHS	Shepody	52.5	10.8
	AC Glacier Chip	42.3	5.9
	Atlantic	25.5	3.0
	Russet Burbank	0.8	0.1
Lutein	Sinora	18.0	2.5
PMRT	CV97085-1	42.0	6.3
	Shepody	34.8	6.3
	CV97112-4	21.0	2.8
	WV3252-1	18.0	2.5

Project Cooperators

The following individuals, organizations and companies provided technical assistance and/or financial/in-kind contributions:

- Dow AgroSciences Canada Inc.
- ISK BioSciences Corp.
- Jeneil Biosurfactant Co.
- Old Dutch Foods Ltd.
- Potato Growers of Alberta
- Syngenta Crop Protection Canada Inc.
- United Agri-Products Ltd.

Project Team Members

- Ron Howard, Sharon Lisowski, Michele Konschuh, Ted Harms and Lori Delanoy, Alberta Agriculture, Food and Rural Development, Crop Diversification Centre South, Brooks
- Piara Bains, Agri-Research Ltd., Edmonton
- Larry Kawchuk, Agriculture and Agri-Food Canada, Research Centre, Lethbridge
- Tricia McAllister, Alberta Agriculture, Food and Rural Development, Crop Diversification Centre North, Edmonton
- Terry Morishita, Old Dutch Foods Ltd., Rosemary
- Hal Reed, Taber Home and Farm Centre, Taber
- Kal Basu, BioVision Seed Labs, Edmonton

Potato Growers of Alberta
Research Tracking

Title of Research Application: Improved methods of Chemical Control for Silver Scurf in field & storag

Name of Researcher: Ron Howard

Employer: Ab Ag, Food & Rural Development

Date application was received by PGA Feb 28, 2006

Date application was reviewed by PGA April 3, 2006

A) approved ✓ B) declined

Project start date: April 2006 Project finish date: March 2008

Total amount requested: $ 18,000- Amount requested per year: $6,000-

MOU received and signed. Once copy returned to research agency,
one copy filed in current year Research Binder

Date completed

Invoice received: # 1242007 Date funds advanced Feb 20, 2007 Cheque# 4756 $6,000-

Invoice received:# Date funds advanced Cheque#

Invoice received:# Date funds advanced Cheque#

Invoice received:# Date funds advanced Cheque#

Were reports received from the researcher?

What was done with the reports?

Presented at PGA meeting? Put on PGA website? Filed?

NOTES:

POTATO GROWERS OF ALBERTA

6008, 46th Avenue
Taber, Alberta T1G 2B1

Phone (403) 223-2262
Fax (403) 223-2268
e-mail: pga@albertapotatoes.ca
www.albertapotatoes.ca

April, 03 2006.

Ron Howard
Plant Pathologist
Alberta Agriculture, Food and Rural Development
Crop Diversification Centre South
Brooks

Re: "Developing Improved Methods of Chemical Control for Silver scurf on Potatoes in Field and Storage"

Dear Ron

We are pleased to advise that the Board of Directors of the Potato Growers of Alberta has reviewed and approved conditional funding for your research application.
The PGA will support this project if you decide to apply for the remaining cash portion to the Agricultural Funding Consortium.
The PGA funding will be accessible for a three year period in the amount 18,000.
We appreciate your commitment and dedication to the potato industry.

Yours truly,

Vern Warkentin
Executive Director

Project # 81902-819079
New: Renewal: X

MEMORANDUM OF UNDERSTANDING

Between: The Potato Growers of Alberta
(hereafter referred to as the "PGA")

and

Alberta Agriculture and Food
(hereafter referred to as "AF")

PROJECT TITLE

Developing Improved Methods of Chemical Control for Silver Scurf on Potatoes in the Field and in Storage

OBJECTIVES

1. Collect tubers of various varieties of seed, table and processing potatoes showing silver scurf (SS)-like symptoms from fields and storages across Alberta to determine whether *Helminthosporium solani* or *Colletotrichum coccodes* is the primary cause.
2. Compare agar plate and molecular techniques for the isolation and characterization of *H. solani* and *C. coccodes* isolates to determine their speed, accuracy and cost.
3. Assess whether currently registered seed treatment and post-harvest fungicides are effective against the strains of *H. solani* present in Alberta fields and storages.
4. Determine the efficacy of promising new chemical treatments (conventional and reduced risk) against SS in replicated trials in the lab, field and storage.
5. Use the information generated in this study to help improve the techniques for managing SS, thereby reducing potential yield and quality losses for growers and processors.

STATEMENT OF WORK

Alberta Agriculture and Food is willing to undertake the specified study for the PGA, which hereby agrees to contribute toward the costs of generating and reporting the information required as described in the attached research proposal.

PERIOD OF WORK

The research project will commence on or about April 1, 2006 and interim report will be completed by February 28 of 2007 and 2008. A final report will be submitted by June 30, 2008

BASIS OF PAYMENT

As a sponsor of the project, the PGA will provide **$6,000** + GST per annum upon finalization of this memorandum to AF to cover the following estimated costs for this project:

Technical Manpower	$5,000
Materials & Supplies	$1,000
GST (6%)	$ 360
TOTAL	**$6,360**

6

Potato Growers of Alberta

Proposal application for Research funding 2006-2007

Instructions

To assess the proposals consistently, they must be completed according to the parameters contained in this form. Proposals may be rejected for incomplete information or lack of compliance with the instructions. This application could use other sources of forms only if it will be presented to other funding consortiums. Please jump between boxes using the "Tab" key and avoid the use of the "enter" key. The PGA Research Committee will set dates for project presentations and result reports.

Confidentiality

☐ This Proposal is confidential and the information contained in it may not be disclosed with other organizations or research groups. ☐

1. Research Team Information

Team Leader:Dr. Ron Howard		
Organization:AAFRD	Section/Department:CDC South	
Address:S.S. #4	City:Brooks	Province:AB
Postal Code:T1R 1E6	E-mail :ron.howard@gov.ab.ca	
Phone Number:403-362-1328	Fax Number:403-362-1326	

Team Member:Dr. Michael Harding		
Organization:AAFRD	Section/Department:CDC South	
Address:S.S. #4	City:Brooks	Province:AB
Postal Code:T1R 1E6	E-mail:michael.harding@gov.ab.ca	
Phone Number:403-362-1338	Fax Number:403-362-1326	

Team Member:Dr. Larry Kawchuk		
Organization:AAFC	Section/Department:Research	
Address:P.O. Box 3000	City:Lethbridge	Province:AB
Postal Code:T1J 4B1	E-mail address:kawchuk@agr.gc.ca	
Phone Number:403-317-2271	Fax Number:403-382-3156	

2. Project Information

Title:Developing Improved Methods of Chemical Control for Silver Scurf on Potatoes in the Field and in Storage

Category of the project (Please check more than one box if necessary):

- ☒ Pest Management
- ☐ Water and Irrigation Management
- ☒ Potato Storage
- ☐ Potato Breeding
- ☐ Potato Plant Physiology
- ☐ Potato Fertility Plant
- ☐ Nutrition/Soil management
- ☐ Green House
- ☐ Environment
- ☐ Potato Marketing and Economics
- ☐ Potato Cultural Management

Research Location (s): CDC South, Brooks

Duration (Y):2 Start Date (YY/MM):06/04Ending Date (YY/MM):08/06

☐Is the project linked to other applications / Research projects Y ☒N ☐
(Please identify related projects)

1.Project:Development of Pesticides and Disinfectants for Prevention and Control of Microbial Biofilms Associated with Plant Diseases and Seed Pathology

Team Leader:Dr. Lyriam Marques

Start Date:2005

2.Project:Use of Green Manure Crops to to Reduce Pests and Diseases in Alberta Potato Crops

Team Leader:Dr. Michele Konschuh

Start Date:2006

Background.
(Max 2000 characters)

Silver scurf (SS), caused by the fungus Helminthosporium solani, emerged as an economically important disease of tablestock and processing potatoes in Canada in the 1990s. Prior to that, it had mostly been considered a minor problem. SS causes metallic, silvery patches on tuber skins, which can reduce their suitability for direct sales and processing. Seed growers are also concerned about SS because it can be easily spread on seed tubers. Control recommendations for SS centre mainly on chemical and cultural practices. Holley and Kawchuk (1993, 1996) demonstrated the widespread ocurrence of resistant strains of H. solani to the fungicide Mertect (thiabendazole) in Alberta. Mertect was widely used as a post-harvest treatment on potato tubers to prevent various storage diseases. Similar findings were reported from the U.S.A. and Europe, and prompted researchers to look at alternative products, e.g. imazilil, prochloraz, propiconazole, fludioxonil, L-carvone, and organic and inorganic salts. Several of these products looked promising, but few have been tested in Alberta. At present, three seed treatments (Senator PSPT, Maxim PSP and Maxim MZ) and one post-harvest fungicide (OxiDate) are registered in Canada for controlling SS. Despite the availability of these products, SS remains a widespread and serious problem. The inability of currently available products to control SS may be due to several factors, e.g. the development of resistant strains of H. solani, chemical dosages that are too low to be effective, improper application techniques to seed pieces or tubers in storage, or poor residual chemical activity. The possibility also exists that SS-like symptoms on tubers may be caused by another fungus, Colletotrichum coccodes, the black dot (BD) pathogen. BD can cause symptoms on tubers that are easily confused with SS, and the two diseases often occur together in the same fields. BD may not respond to fungicide treatments in the same way that SS does and vice versa.

Objectives (Measurable-Deliverables)
(Please use Bullets) (Max 1000 characters)

1. Surveys - Collect tubers of various varieties of seed, table and processing potatoes showing SS-like symptoms from fields and storages across Alberta to determine whether H. solani or C. coccodes is the primary cause.

2. Diagnostic Methods - Compare agar plate and molecular techniques for the isolation and characterization of H. solani and C. coccodes isolates to determine their speed, accuracy and cost.
3. Fungicide Performance - Assess whether currently registered seed treatment and post-harvest fungicides are effective against the strains of H. solani present in Alberta fields and storages.
4. New Product Development - Determine the efficacy of promising new chemical treatments (conventional and reduced risk) in replicated trials in the lab, field and storage.
5. To use the information generated in this study to help improve the techniques for managing SS, thereby reducing potential yield and quality losses for growers and processors.

Economical/Environmental Benefits

(Please mention how the results of this project will benefit potato production economically and environmentally.(Max. 1000 characters) .

1. Disease surveys will document the incidence, severity and economic impact of SS on seed, table and processing potatoes in Alberta. These kinds of assessments have never been done in Alberta.
2. Validation of diagnostic tests will allow researchers and commercial diagnostic labs to select and use the most rapid, reliable and cost-effective testing methods. Labs will be able to offer reliable and affordable testing services to clients.
3. Evaluation of the effectiveness of existing seed and post-harvest fungicides will provide information that will help producers and processors select the most effective products for use in the field and storage. Identifying products that are no longer effective should help save money and reduce needless applications.
4. Identification of promising new fungicides may lead to full or minor use registrations that will increase the variety of products available to producers and processors. These new products may replace older, less effective ones.

Methodology Description

(Please describe the scientific process you will follow to achieve project objectives).(Max 2000 Characters)

Disease Surveys – Samples of SS-infected potatoes will be obtained from ca. 15 growers and processors (100 tubers/sample). Fifty tubers will be kept in cold storage on reserve in case any tests need to be redone. Half of the other 50 tubers will be washed and examined for skin diseases. Disease incidence and severity will be rated visually. Twenty tubers will be placed in humid chambers and incubated for 2 weeks to determine if SS, BD or both are present. Five tubers will be sent to AAFC, Lethbridge for molecular diagnosis of SS and BD. The remaining 25 unwashed tubers will be placed in storage (15°C and 95% RH) for 6-8 weeks, then rated for SS/BD incidence and severity. Humid chambers and molecular diagnoses will also be done.

Pathogen Identifications - Isolates of H. solani and C. coccodes will be purified and identified using standard taxonomic keys. Representative cultures will be retained for in vitro fungicide resistance testing.

Seed Treatment Efficacy Trials - Samples of registered and unregistered fungicides will be obtained from chemical companies and applied to a seedlot infested with SS. Replicated trials will be planted at CDC South. Emergence, stem number and tuber yield data will be taken. Tuber subsamples will be stored at 12°C and 95% RH for 2-3 months. SS incidence and severity will be measured.

Storage Treatment Efficacy Trials – Fungicides will be applied to tubers naturally infested with SS prior to storage at 12°C and 95% RH for 4-5 months. SS incidence and severity will be measured.

Review of Production/Storage Practices – Growers and processors who provided samples will be interviewed to determine the impact that SS has had on their crops. Information on varieties, seed sources, crop rotations, fertilizer and pesticide applications, irrigation, and harvesting, handling and storage practices will be collected. Efforts will be made to correlate data between operations to identify factors that may have favored disease outbreaks.

Technology Transfer Plan.

(Please describe the proposed method to communicate findings and results) (Max. 1000 characters)

Interim and final results will be presented to the PGA, potato growers and project cooperators through oral and poster presentations at events such as the PGA and ASPGA annual meetings, field days, area and/or breakfast meetings. Written reports, newsletter articles and scientific publications will be prepared and made available to the PGA, growers and cooperators. Diagnostic protocols and some staff training will be provided to commercial plant health labs so they can do commercial SS testing for clients.

3. Project Budget

		Year 1	Year 2	Year 3	**Total**
PGA	Cash	12000	12000		24000
	In-Kind				
	Total	12000	12000		24000
Other					
AAFRD	Cash	1000	1000		2000
	In-Kind	79000	79000		158000
	Total	80000	80000		160000
Other					
AAFC	Cash				
	In-Kind	8000	8000		16000
	Total	5000	5000		10000
Other					
Industry	Cash	10000	10000		20000
	In-Kind	2000	2000		4000
	Total	12000	12000		24000
Other					
	Cash				
	In-Kind				
	Total				

Total	**112000**	**112000**		**224000**

Project Cost Distribution	Year 1	Year 2	Year 3	**Total**
Personnel	40500	41500		82000
Travel expenses	1500	1500		3000
Capital goods	0	0		0
Materials	8000	8000		16000
TOT	1000	2000		3000
Overhead	60000	60000		120000
Total	**111000**	**113000**		**224000**

*TOT (Transference of Technology)

Research Project Manager

Signature R.J. Howard **Date** **February 28, 2006**

arthur.yochim@syngenta.com
04/07/2006 02:03 PM

To <ron.howard@gov.ab.ca>
cc <myron.kopec@syngenta.com>
bcc
Subject Participation in Silver Scurf project

History: This message has been replied to.

Ron,

Randy Retzlaff has contacted me regarding participating in your study on chemical control methods for Silver Scurf. Syngenta would like to include three treatments at a cost of $1,000/treatment. The details are in the attached Word document.

Thanks,

Budget confirmation

Art Yochim
Field Development Biologist - Calgary
Syngenta Crop Protection Canada, Inc.
403-219-5411 (office)
403-510-3815 (cell)

<<SS Trial Conf Letter.doc>> SS Trial Conf Letter.doc

Syngenta $3,000 commitment

Arthur Yochim
Syngenta Crop Protection Canada, Inc.
300-6700 Macleod Trail S.
Calgary, AB.
T2H 0L3

April 7, 2006

Ron Howard, PhD.
Plant Pathologist
Crop Diversification Centre South
Alberta Agriculture, Food and Rural Development
S.S. #4, Brooks, AB T1R 1E6

Dear Ron:

Thank-you for contacting Syngenta about participating in the project entitled "Developing Improved Methods of Chemical Control for Silver Scurf on Potatoes in the Field and in Storage." We would like to submit three treatments to the project and will provide funding for our participation.

Here are the details on the three treatments we would like to see included:

Product	**Rate**	**Timing**	**Funding**
Maxim MZ	31 g ai/100 kg seed	Seed pieces	$1000
Maxim MZ + Quadris	31 g ai/100 kg seed + 1 g ai/100m seed row	Seed pieces (Maxim MZ) In-row (Quadris)	$1000
Quadris	4.9 g ai/tonne	Post-harvest	$1000

The total funding for the three treatments would be $3,000. We will also forward samples of Maxim MZ and Quadris for the treatments.

Give me a call at 403-219-5411 (office) or 403-510-3815 (cell) to discuss.

Sincerely,

Arthur Yochim
Field Development Biologist - Alberta
Syngenta Crop Protection Canada, Inc.

Alberta Agriculture and Food

Crop Diversification Centre South
301 Horticultural Station Road East
Brooks, Alberta, Canada T1R 1E6
Telephone (403) 362-1300, Fax (403) 362-1306

October 4, 2007

Vern Warkentin
Executive Director
Potato Growers of Alberta
6008 – 46th Ave
Taber, Alberta T1G 2B1

Dear Vern:

Enclosed are two copies of a memorandum of agreement which has been created for the project to evaluate and adapt Early Blight prediction methods for Irrigated Potatoes in Southern Alberta.

Please review the document and if the terms are acceptable to you, please **sign both copies** where indicated and **return one copy** to me in the self-addressed envelope. You may retain the other copy for your files.

As indicated in the agreement, once you have provided your signature, your payment of $10,600.00 is due. Should you require us to invoice you for this amount, please indicate that in a note to me when you return my signed copy.

Thank you for your continued support in our research projects!

Yours truly,

Anna Moeller
~~Centre Administrator~~

/alm

enclosures (2)

RECEIVED OCT 10 2007

Project # 819213

MEMORANDUM OF AGREEMENT

Between:
Potato Growers of Alberta

(Hereafter referred to as "**PGA**")

And

Her Majesty, the Queen, in right of the Province of Alberta
as represented by the
Minister of Agriculture and Food

(Hereafter referred to as "**AF**")

Project Title: Evaluation and Adaptation of Early Blight Prediction Methods for Irrigated Potatoes in Southern Alberta

Objectives:
To evaluate 3 methods for the prediction of early blight;1) Plant-plus system offered by Dacom from the Netherlands, 2) Wisdom and 3) Producer scheduled

Additionally, all models will be operated on hourly data from both in-field meteorological monitoring and the nearest AAFRD Irrigation Branch meteorological station to assess the differences and/or value of either sources of meterological data.

SCOPE OF WORK

1. **AF** will conduct the Research Project according to the research plan, which is attached to and forms part of this Agreement.

PERIOD OF WORK

2. This Agreement will commence on 04/01/2007 and will terminate on 12/31/2007 unless extended upon agreement of both parties.

BASIS OF COSTS and PAYMENT

3. The total expense for this Research Project is $10,600.00 to cover the following estimated total costs:

Labour, materials, travel, &technology transfer	$10,000.00
GST	$600.00
Total Cost	$10,600.00

4. **PGA** will provide to **AF**, upon execution by both parties of this Agreement, the sum of $10,600.00.

Cheques shall be made payable to **"Minister of Finance"** and forwarded to:

Attention: Anna Moeller
Alberta Agriculture and Food
Crop Diversification Centre South
302 Horticultural Station Road East
Brooks, AB T1R 1E6

5. **AF** will use the funds paid by **PGA** only for the purpose of conducting the Research Project. **AF** will provide a record of revenue and expenditure to **PGA** upon completion of the Research Project or depletion of funds.

RESPONSIBILITY OF PROJECT MANAGER

6. The project manager for this Research Project is Dr. Ted Harms of **AF** who will coordinate the Research Project and provide all reports to **PGA** and other sponsors. Dr. Michele Konschuh will authorize expenses and submit them to the appropriate **AF** office for payment to be processed.

AMENDMENTS OR TERMINATION

7. This Agreement may only be amended upon mutual consent of the parties and evidenced in writing.

8. Either **AF** or **PGA** may terminate this Agreement in the event of a material default or breach of a substantive term, condition or provision of this Agreement, by providing two weeks notice in writing to the other party. In such event **AF** is in default then any and all amounts of the funds advanced by **PGA** hereunder that represent payment for work or services hereunder that have not been performed by **AF** up to the date of termination shall be refunded to **PGA**.

NOTICES AND REPRESENTATIVES

9. Notices for all purposes of or incidental to this Agreement shall be effectively given if delivered personally, or sent by registered or certified mail to the representatives of the parties designated as follows:

PGA:
Vern Warkentin
Executive Director
6008 – 46th Avenue
Taber, AB T1G 2B1

Agriculture and Food:
Henry Najda, Branch Head
Food Crops Branch, Agriculture Research Division
301 Horticultural Station Rd. E
Brooks, AB T1R 1E6

AF and PGA may use information generated from the project. The sponsor, **PGA**, relinquishes ownership of any materials, supplies and assets purchased with the project funds to **AF** who assigns control to the project manager's branch.

Agriculture and Food

Michele Konschuh, Project Manager — Date: Sept 24/07

Henry Najda, Branch Head, Food Crops Branch — Date: Sept 24/07

Dr. Cornelia Kreplin, Division Director
Agriculture Research Division, AF — Date: 20071001

Potato Growers of Alberta

Vern Warkentin, Executive Director — Date: Oct 15/07

AAFRD Project Proposal / Charter

Project Name Evaluation and Adaptation of Early Blight Prediction Methods for Irrigated Potatoes in Southern Alberta	**Project #** (assigned once project is approved)	
Project Sponsor Henry Najda	**Target Project Completion Date** 2007/12/31	
Project Lead Ted Harms	**Version No.** 1.0	**Version Date** 2006/11/24
Theme(s) Crop Products		
Ministry Goal /Strategy Sustainable growth of the agriculture and food industry		

Purpose Statement (Please use plain language)

The value of this project will be for assessment and identification of an early blight prediction model/procedure that can be adopted for use by potato growers. Timely and necessary fungicide applications can then be scheduled according to model results thereby avoiding either unnecessary fungicide applications or yield and quality loss due to early blight infection.

Additionally, if previous work (Gent and Swartz, 2002) is confirmed, and timing of fungicide applications can be obtained reliably from meteorological data from a nearby off-site weather station, then model results could be extended to most potato growing areas of southern Alberta.

Project Description/Background (Please use plain language)

The appearance of early blight (Alternaria solaria) in potato fields in Southern Alberta is a yearly occurrence. There are effective fungicides available to control early blight but the timing of application is crucial. Early fungicide applications prior to flowering have shown to be ineffective in controlling early blight. Additionally, multiple fungicide applications can be costly.

Methods available to predict the initiation of early blight include some measure of either Physiological Day (P-Day) and/or Growing Degree Days (GDD). Most predictive models (e.g. WISDOM) use 300 P-Days as the threshold to start fungicide applications. Applications based on GDD with minimum temperature of 7.8 C vary depending on the area but values of 361 and 625 cumulative GDD were used in southern and northern Colorado respectively, as the GDD threshold. The Plant-plus system uses a combination of potato plant growth stages with P-Day and field humidity to predict onset of early blight.

Gent and Schwartz (2002) concluded that early blight forecasts were just as accurate when the source of the meteorological data for the P-Day or GDD calculation was from a nearby meteorological station than if the data was obtained from within-field meteorological station.

Project Goals, Deliverables, & Performance Measures

Goals

A. The objectives of this research project will be to evaluate 3 methods for the prediction of early blight, Plant Plus, Wisdom and producer scheduled.

B. Additionally, all models will be operated on hourly data from both in-field meteorological monitoring and the nearest AAFRD Irrigation Branch meteorological station to assess the differences and/or value of either sources of meterological data.

C.

Deliverables *(for goals listed above)*	*Start Date*	*End Date*
A. The research team will prepare a report and the findings will be submitted to the PGA. A presentation to the PGA membership would be appropriate at a convenient meeting once all data is collected, analyzed and the report written.		Dec 2007
B.		
C.		

Performance Measures *(for goals listed above)*

A.

B.

C.

Scope

"IN" Scope

- evaluation of existing blight prediction systems
- comparison of weather station information
-

"OUT" of Scope

- development of a blight prediction system
-
-

Core Team Members

Team Member	***Branch / Division / External***	***FTE*** *(Internal)*	***Role On Project*** *(Types of work they will do)*
Dr. Ted Harms	Irrigation Branch		Project lead, work with computer models, data analyses and report writing.

Core Team Members			
Dr. Michele Konschuh	Crop Development - Food	0.05	Assist with potato aspects of project, harvest and evaluations, data interpretation.
Simone Dalpe	Crop Development - Food	0.05	Potato harvest and evaluations.
Dr. Ron Howard	Pest Management	0.01	Advisor on project, assist with disease evaluations of crop, interpretation of data
Sharon Lisowski	Pest Management	0.05	Blight evaluations of crop.

Proposed Project Budget – Year 1 (2005)	
Category	***Total Cost***
Materials/Equipment	1,200
Facilities	
Casual labor	10,000
Consultants	
Travel	9,500
Other (capital goods)	1,500
Total A	***$22,200***

Leveraged / external funding – Year 1 *(Do not include theme or in-kind contributions. You may include NIF in this section)*		
Source	***Requested $***	***Confirmed $***
PGA	10,000	10,000
Total B	***$10,000***	***$10,000***

Total $ amount requested from theme for year 1 *(Total part A – Total part B requested)*	***$0***

Proposed Project Budget – Year 2 (2006)	
Category	***Total Cost***
Materials/Equipment	1,200
Facilities	
Casual Labour	10,000
Consultants	
Travel	9,500
Other (capital goods)	1,500
Total A	***$22,200***

Leveraged / external funding – Year 2 *(Do not include theme or in-kind contributions. You may include NIF in this section)*		
Source	***Requested $***	***Confirmed $***
PGA	10,000	10,000
Total B	***$10,000***	***$10,000***

Total $ amount requested from theme for year 2 *(Total part A – Total part B requested)*	***$0***

Proposed Project Budget – Year 3 (2007)	
Category	***Total Cost***
Materials/Equipment	1,200
Facilities	
Casual labor	10,000
Consultants	
Travel	9,500
Other (capital goods)	1,500
Total A	***$22,200***

Leveraged / external funding – Year 3 *(Do not include theme or in-kind contributions. You may include NIF in this section)*		
Source	***Requested $***	***Confirmed $***
PGA	10,000	10,000
Total B	***$10,000***	***$10,000***

Proposed Project Budget – Year 3 (2007)	**Leveraged / external funding – Year 3** *(Do not include theme or in-kind contributions. You may include NIF in this section)*
Total $ amount requested from theme for year 3 *(Total part A – Total part B requested)*	***$0***

Total Project Budget – Sum of all years (Only complete this table if this is a multi-year project)

Total Budget	**$66,600**	*Total $ requested from external sources*	**$66,600**	*Total $ requested from theme*	**$0**

Other Potential Funding Sources

Source
N/A

In-Kind Contributions

Source	***Type of contribution (time, etc.)***	**Equivalent $ amount**
Dacom		**22,500**

Assumptions & Constraints

Assumptions	***Constraints***
• Funding is available. • •	• This project hinges on grower cooperation. Each year a minimum of 2 locations are required. • •

Acceptance & Sign-Off

Prepared By:	**Dr. Michele Konschuh** Research Scientist		**Nov. 22, 06**
	Name & Title		*Date*
Approved By: (Branch Head or Division)			
	Name & Title		*Date*
Approved By: (Theme)			
	Name & Title	*Signature*	*Date*

Comments

☐	Approved as is, with the condition that amount of leveraged (external) funding requested is secured. Please proceed with the planning phase
☐	Approved with modifications and/or special instructions provided below. Revised Project Proposal/Charter is requested for file purposes
☐	Not approved at this time. Project Proposal/Charter will be put on file for future consideration

POTATO GROWERS OF ALBERTA

6008, 46th Avenue
Taber, Alberta T1G 2B1

Phone (403) 223-2262
Fax (403) 223-2268
e-mail: pga@albertapotatoes.ca
www.albertapotatoes.ca

April 20, 2007

Dr. Ted Harms
Alberta Agriculture, Food & Rural Development
301 – Horticultural Station Rd. E.
Brooks, AB T1R 1E6

Re: Evaluation & Adaptation Early Blight Prediction Methods for Irrigated Potatoes in Southern Alberta

Dear Ted:

We are pleased to advise that the Board of Directors of The Potato Growers of Alberta has reviewed and approved continuing funding for your research project.

For the period of April 1, 2007 – March 31, 2008, the amount of $10,000 is available to meet the timelines specified in your application. When requesting the funds for the project, please provide an invoice that specifies the amount, GST and to whom payable.

We appreciate your commitment and dedication to the potato industry.

Yours truly,

Vern Warkentin
Executive Director

/pl

Early Dying and Oomycete Analysis and Control

Potato Growers of Alberta
Progress Report 2006/07

L. Kawchuk, R. Howard, and H. Platt

Research Centre, Agriculture and Agri-Food Canada, Lethbridge, AB

Alberta Agriculture, Food and Rural Development, CDC South, Brooks, AB

Research Centre, Agriculture and Agri-Food Canada, Charlottetown, PEI

Summary

Sensitive diagnostics have been developed that are capable of detecting trace levels of the early dying and oomycete pathogens. The procedures work on extremely small samples of only a few milligrams, may be used to examine any sample including soil, and results can be available within only a few hours. The procedures are quantitative facilitating the estimation of pathogen levels in seed or soils before planting and are capable of differentiating between strains with different characteristics such as aggressiveness and symptom expression. Initial results show different strains and species variation in the pathogens from diseased samples. Several species of *Verticillium* were isolated from early dying samples that may complicate control and a surprisingly large number of strains of the late blight pathogen were observed compared to the lack of variation seen in the pink rot isolates. Greenhouse and field trials have been established for the evaluation of disease symptom expression in potato varieties, characterization of the diagnostics, and determination of the most effective application parameters for the control measures. Producers are encouraged to submit suspect samples for confidential evaluation and thereby assist in characterizing the diagnostics and prevention strategies. Agriculture and Agri-Food Canada has approved an application to match the Potato Growers of Alberta project contributions.

Background

Early dying is a common disease, caused by several different species of *Verticillium* fungi and influenced by nematodes. It occurs in most potato growing areas of the world. The incidence and severity of early dying appears to be increasing in western Canada potato producing areas. *Verticillium* species have a wide host range and are known pathogens of many crops and other plants. Disease development impedes water movement within the plant and is influenced by many abiotic and biotic factors. Early dying can cause severe yield losses and leads to internal net necrosis in many potato varieties. Soil fumigants are sometimes used to control the disease but they are expensive and essentially sterilize the soils. Several species of *Verticillium* are known to cause disease but the factors contributing to the disease are poorly understood. Additional information on the potential transmission, detection, and control of early dying is required.

Late blight, pink rot, and leak are caused by the oomycetous fungi *Phytophthora infestans, Phytophthora erythroseptica*, and *Pythium ultimum*, respectively. They

represent potentially the most devastating group of potato pathogens. The incidence of pink rot and late blight is increasing in incidence and possibly severity in western Canada but the exact cause or population dynamics remain to be determined. Late blight can decimate a crop within a few days and like pink rot, it can infect a healthy tuber. Control involves several applications of fungicide applied in a preventative manner but these pathogens have developed pesticide resistance. Our understanding of the oomycetes is still quite limited and alternatives for detection and control are required.

Diagnostics that identify pathogen/pest sources and strains and disease control strategies based on management and biocontrol, will reduce disease losses, eliminate pesticides that can adversely impact environment, and improve the competitiveness of the Alberta product.

Objectives

1) Develop diagnostic tests for reliably detecting the pathogens and pests contributing to early dying, leak, late blight and pink rot. Assays will help determine sources, vectors, and pathogen strain distribution in fields selected for potato production.

2) Characterize the pathogen/pest populations causing early dying, leak, late blight and pink rot in Alberta. Samples will be obtained from diseased tissues, soils, soil debris, and culture collections to determine virulence, aggressiveness, and other characteristics such as pesticide reaction.

3) Develop strategies for the control of early dying, leak, late blight and pink rot. This will involve a mangement approach based on diagnostic information, the screening of germplasm and advanced lines for resistance, storage and soil monitoring and amendments, and crop rotations.

4) Improve the competitiveness and sustainability of producers and processors by advancing our understanding of these pathogens/pests to improve yield and quality.

Methods and Materials

1) Pathogen/Pest identification, and isolation: Industry, CFIA, and collaborators will assist in collection of diseased samples and early dying, leak, late blight, and pink rot pathogen/pest identification/isolation. Additional pathogen/pest populations will be obtained from existing regional, National, and International culture collections for comparison.

2) Detection and risk levels: Sensitive pathogen/nematode polymerase chain reaction (PCR) assays will be developed/applied to detect each pathogen and pest. Universal primers designed for highly conserved rDNA sequences have proven effective in reliable identifications of pathogens and other organisms. Testing will examine various sources of the pathogens and nematodes including field soil, alternative hosts, and seed to determine inoculum loads and risk.

3) Strain characterization: AAFC will develop PCR assays to analyse genetic variability within each pathogen/pest to identify different strains. Hypervariable intergenic spacer regions such as the rDNA ITS regions are capable of distinguishing even small variations in populations. Results will help develop multplex assays to detect several pathogens/pests and reduce test costs. PCR amplifications will be conducted under stringent conditions and amplified products cloned and sequenced. Sequence comparisons and analyses can be performed with various available software programs.

4) Disease management: Management practices and pathogen threshold values will be evaluated to determine strategies to control pathogen reservoirs and vectors and minimize disease losses. True potato seed from accessions held in germplasm repositories and advanced lines from the AAFC Potato Breeding Program will be screened with aggressive strains of early dying, late blight, and pink rot pathogens in storage, greenhouse, and/or field trials. Monitor pathogen/pest changes in soil and seed after vine removal, deep tillage, green manures, and crop rotations to reduce disease.

Results and Discussion

The project commenced in the spring of 2006. Agriculture and Agri-Food Canada has approved an application to match the Potato Growers of Alberta contributions. Excellent progress has been made in both the development of diagnostics and the

isolation of aggressive virulent isolates of early dying, pink rot, late blight, and leak. Producers are encouraged to continue submitting suspect samples for confidential evaluation and thereby assist in characterizing the diagnostics and prevention strategies.

Industry, the Canadian food Inspection Agency, and collaborators assisted with the collection of diseased samples for pathogen identification and isolation. Approximately 100 samples from North America were collected for development of diagnostics, characterization, and prevention strategies. Cultures were evaluated for aggressiveness and suitability in greenhouse and field trials. Several of the more aggressive isolates were selected for screening advanced lines and varieties for symptom expression and eventually effectiveness of diagnostic and control measures. Additional pathogen strains will be obtained from existing regional, National, and International culture collections for comparison.

Several species of *Verticillium* were recovered from early dying samples. This appears to include species previously not known to infect potato. Each species has intrinsic properties that may influence the damage inflicted on the crop. For example, *Verticillium dahliae* produces a tough thick walled resting stage microsclerotia that can potentially overwinter in soils. Further analysis will determine the prevalence of each species and characteristics that may assist in controlling each pathogen.

Surprisingly, a large number of strains were observed amongst the *Phytophthora infestans*, providing the ability to track strain distribution and spread. Interestingly *Phytophthora erythroseptica* showed relatively little variation amongst strains and suggests a relatively uniform pathogen population. Analysis of association of observed differences with pathogen traits such as pesticide resistance are underway. Analysis of several leak isolates is also in progress.

Figure 1. Screening of potato varieties and advanced lines with isolated verticillium wilt pathogen assists in developing resistance and determining the strains of pathogen present. The two plants on the left are resistant to a local aggressive virulent isolate of a *Verticillium* spp. and do not show symptoms of early dying whereas the susceptible plants on the right are showing severe wilt symptoms.

Table 1. Late blight tuber disease in potato varieties and advanced lines (N=10). Assays performed with an aggressive and highly virulent US8 *Phytophthora infestans* genotype (LRC05.2).

Tuber Variety	Average	Rating	Standard Error
Shepody	3.06	S	0.29
Russet Burbank	2.30	M	0.20
CV97192-1	**1.40**	**R**	**0.29**
CV95002-1	2.00	M	0.35
CV97065-1	2.60	M	0.32
CV97112-5	**1.70**	**R**	**0.40**
CV92028-1	2.10	M	0.33
V1102-1	3.10	S	0.33
FV12469-1	3.00	S	0.24
FV12486-2	**1.60**	**R**	**0.32**
CV97105-2	2.40	M	0.45
CV96047-1	3.00	S	0.28
CV97006-1	2.90	M	0.22

Disease Ratings: 0 = 0%; 1<10%; 2<25%, 3<50%; 4<75%; 5<100%

Figure 2. Tubers inoculated with the late blight pathogen produce rapid breakdown of the tuber allowing secondary pathogens such as those causing fusarium dry rot. The diagnostics will facilitate the monitoring for the presence of the pathogen in advance of the disease appearing in the field and may assist in reducing the number of proactive pesticide applications required.

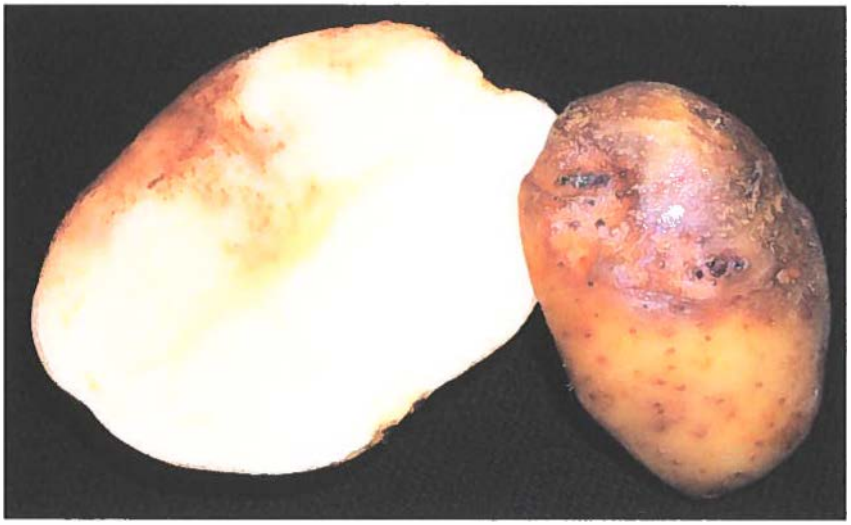


Figure 3. Tubers incoculated with the leak pathogen quickly develop distinctive tuber symptoms. Sources of the pathogen and methods to reduce disease are being examined with the help of the developed diagnostics. The diagnostics should provide a valuable tool for checking field samples for levels of the pathogen prior to planting.

Figure 4. Alignment of several rDNA intergenic sequences from early dying verticillium wilt pathogen isolates. Each of the four nucleotides is indicated by a different colour and several different species appear to be involved in the disease.

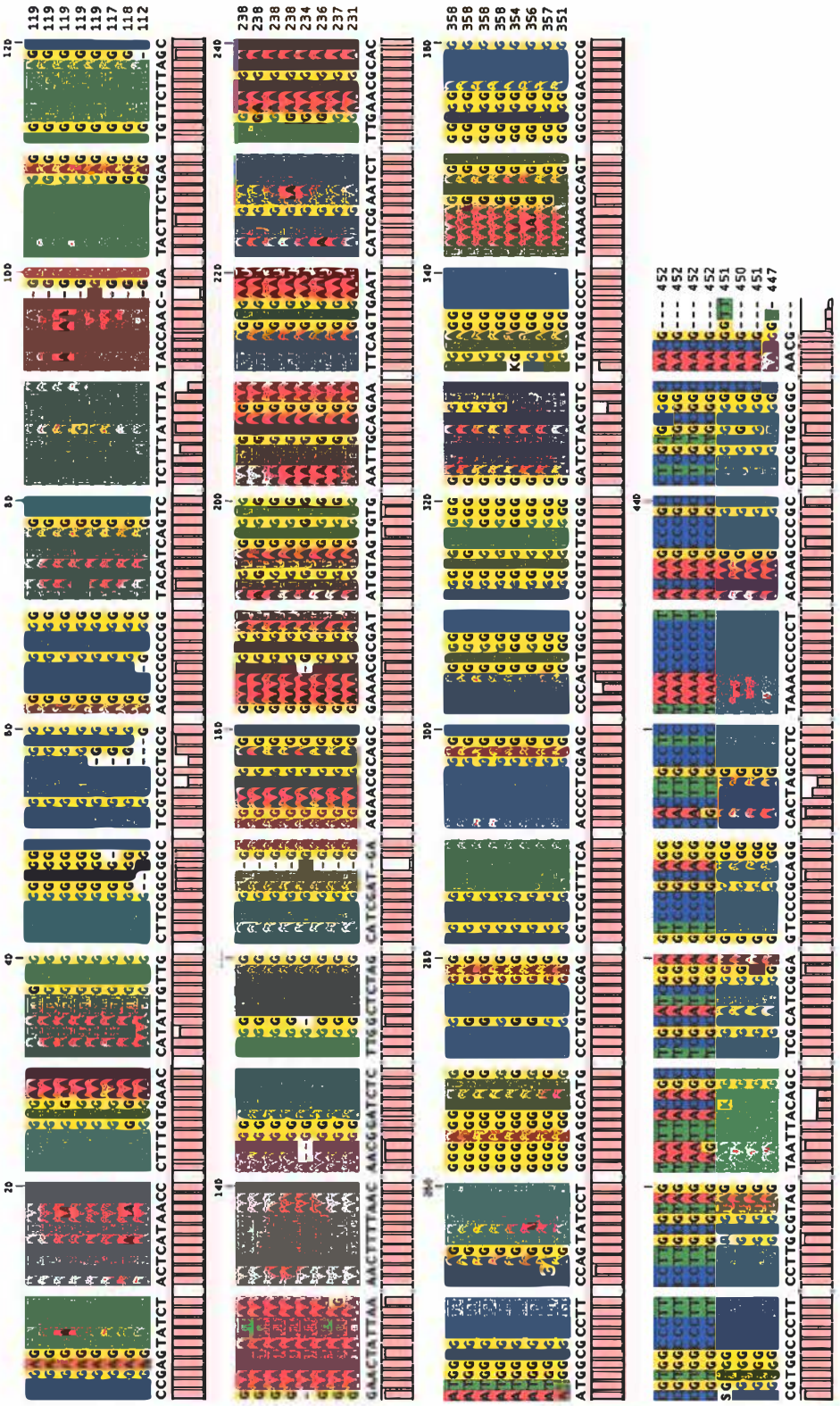


Figure 5. Alignment of several rDNA intergenic sequences from isolates of the late blight pathogen. Each of the four nucleotides is indicated by a different colour. Several strains of the pathogen are evident and these differences should facilitate tracking and avoidance.

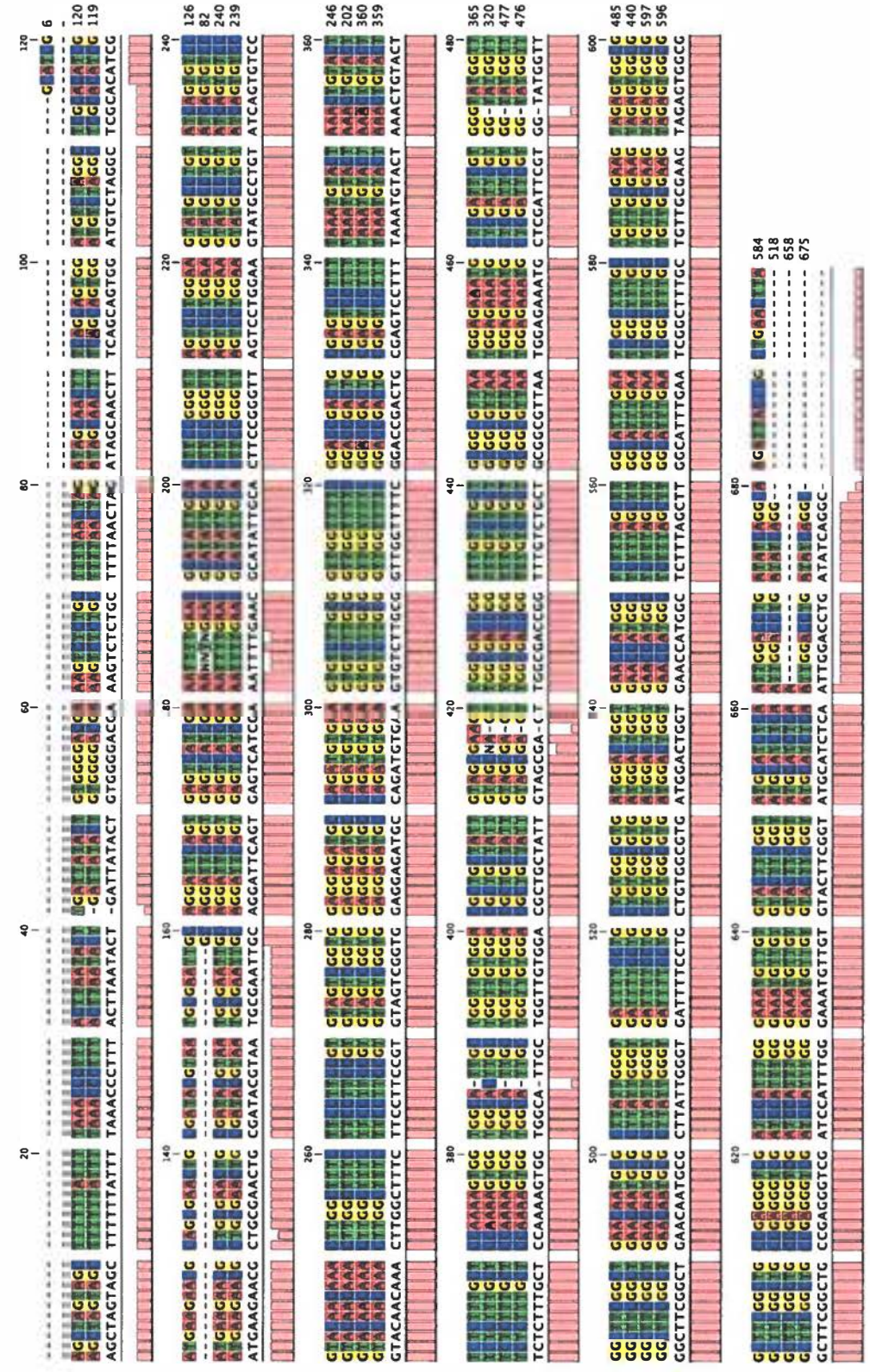
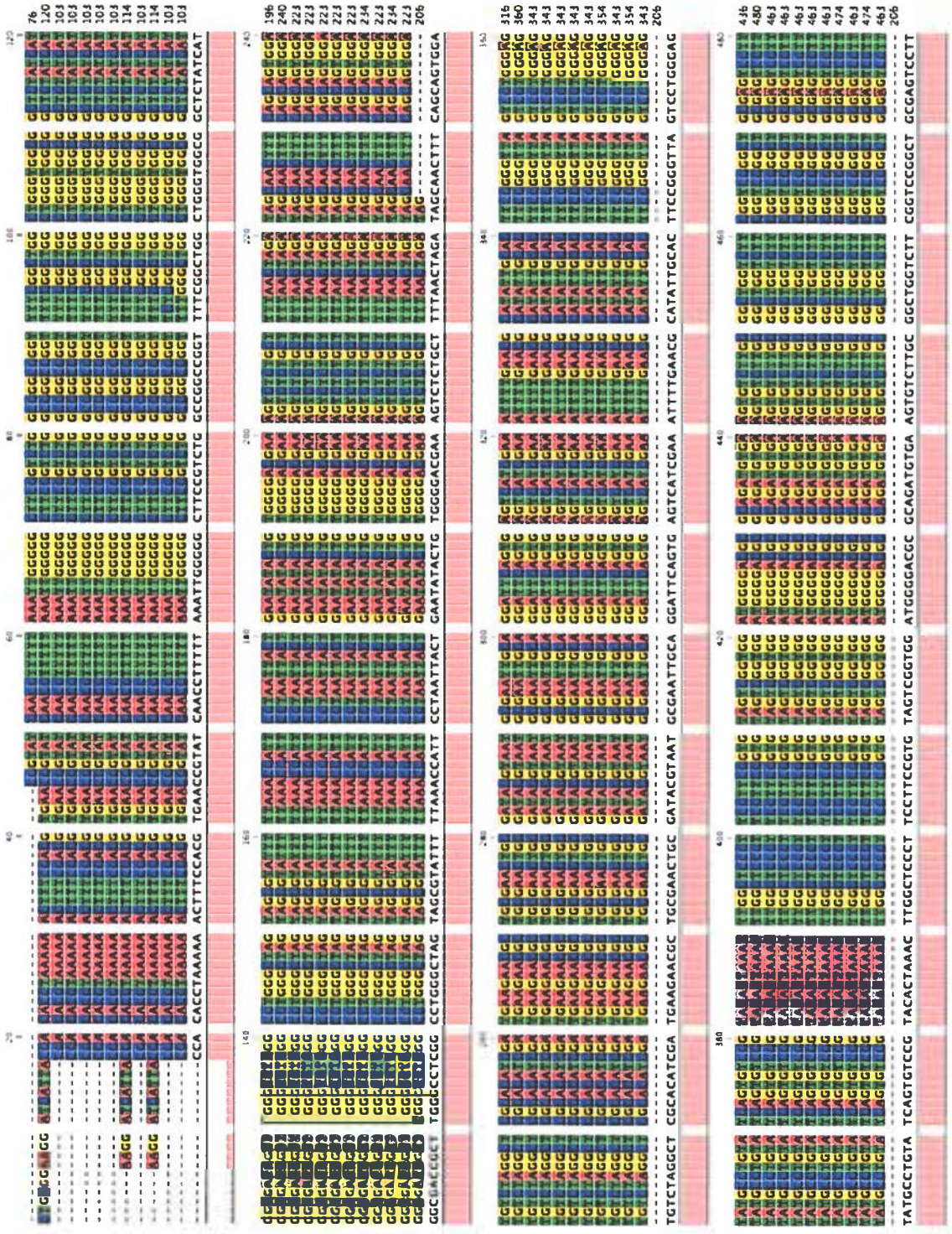


Figure 6. Alignment of several rDNA intergenic sequences from isolates of the pink rot pathogen. Each of the four nucleotides is indicated by a different colour. Few strains of the pathogen are evident suggesting that control may be relatively simple and involve restriction of movement of disease material.



Technology Transfer

Disease control information and strategies have been communicated to producers and industry through presentations and publications. Advanced lines will be planted in field trials at various locations by industry and AAFC to evaluate agronomic performance and disease resistance. Harvested tubers will be evaluated for disease in storage. Reports that summarize diagnostic capabilities, control strategies, and disease/pest resistance will be collected, analyzed, and distributed to the industry. Licenses will be obtained for the various products that are commercializable and diagnostics transferred to service labs in western Canada. Patent applications will be prepared as warranted to capture commercializable products and technologies. Progress reports will be prepared annually and a final report submitted at the conclusion of the study.

L. Kawchuk. 2006. Potato Molecular Improvement Tools. Bulletin. Lethbridge, AB.

L. Kawchuk. 2006. Poatato Disease Prevention. Maple Leaf Potatoes Invited Presentation. Lethbridge, AB.

Economical and Environmental Benefits

Apparent increases in early dying, leak, late blight and pink rot in western Canada are associated with reduced yields and quality that adversely impact producers and processors. These diseases also often compromise healthy tubers, predisposing potatoes to secondary diseases such as fusarium dry rot. Acquisition and characterization of endogenous pathogen/pest populations will facilitate the development/application of cost-effective multiplex diagnostic procedures to assist in early reliable detection of the pathogen/pests in soils, seed, and other sources to avoid disease. The identified differences allow the pathogens to be tracked and management decisions may be made in regards to levels of the pathogen in advance of planting or application of pesticides. Results have advanced our understanding of host-pathogen interactions and identify effective alternative disease control strategies that help reduce pesticide applications thereby addressing growing health and environmental concerns. Better control measures for early dying, leak, late blight and pink rot in western Canada will improve the sustainability and competitiveness of the potato industry in Alberta.

Acknowledgements

We gratefully acknowledge the support of the Potato Growers of Alberta, Maple Leaf Potatoes, and the Agriculture and Agri-Food Canada Matching Investment Initiative. Industry is invited to continue submitting samples for confidential evaluation to assist with the development of diagnostics and prevention measures.

Project # 87925-819232

MEMORANDUM OF AGREEMENT

Between:

Potato Growers of Alberta

(Hereafter referred to as "**PGA**")

and

Her Majesty, the Queen, in right of the Province of Alberta
as represented by the
Minister of Agriculture and Food

(Hereafter referred to as "**AF**")

Project Title: Management of Silver Scurf and Fusarium Dry Rot of Potatoes in Storage Using Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*)

Objectives:

1. Collect potato tissue samples infected with silver scurf or dry rot from NB, AB and PEI, and isolate and identify pathogens.
2. Assess the efficacy of Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*) on different isolates of the silver scurf and dry rot pathogens.
3. Conduct potato storage trials assessing the efficacy of Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*) applied post harvest for the control of silver scurf and dry rot..
4. Present findings at industry and scientific meetings.

SCOPE OF WORK

1. **AF** will conduct the Research Project according to the research plan which is attached to and forms part of this Agreement.

PERIOD OF WORK

2. This Agreement will commence on September 1, 2007 and will terminate on March 31, 2008 unless extended upon agreement of both parties.

BASIS OF COSTS and PAYMENT

3. The total expense for this Research Project is $5,300 to cover the following estimated total costs:

Technologist (halftime position at $2000/month for 2.0 months)	$ 4,000
Materials and supplies	$ 1,000
GST	300
Total Cost	$ 5,300

4. **PGA** will provide to **AF**, upon execution by both parties of this Agreement, the sum of $5,300.

Cheques shall be made payable to **"Minister of Finance"** and forwarded to:

Mrs. Joan Seath
Alberta Agriculture and Food
Crop Diversification Centre North
17507 Fort Road N.W.
Edmonton AB T5Y 6H3
Phone: (780) 422-0653

5. **AF** will use the funds paid by **PGA** only for the purpose of conducting the Research Project. **AF** will provide a record of revenues and expenditures to **PGA** upon completion of the Research Project or depletion of funds.

RESPONSIBILITY OF PROJECT MANAGER

6. The project manager for this Research Project is Dr. Ron Howard of **AF** who will supervise the Research Project and provide all reports to **PGA.** The project manager will authorize expenses and submit them to the appropriate **AF** office for payment to be processed.

AMENDMENTS OR TERMINATION

7. This Agreement may only be amended upon mutual consent of the parties and evidenced in writing.

8. Either **AF** or **PGA** may terminate this Agreement in the event of a material default or breach of a substantive term, condition or provision of this Agreement, by providing two weeks notice in writing to the other party. In such event **AF** is in default then any and all amounts of the funds advanced by **PGA** hereunder that represent payment for work or services hereunder that have not been performed by **AF** up to the date of termination shall be refunded to **PGA.**

NOTICES AND REPRESENTATIVES

9. Notices for all purposes of or incidental to this Agreement shall be effectively given if delivered personally, or sent by registered or certified mail to the representatives of the parties designated as follows:

PGA Biosciences:
Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1
Phone: 403-223-2262

Alberta Agriculture and Food:
Dr. Ron Howard
Plant Pathology Research Scientist
Crop Diversification Centre South
301 Horticultural Station Road East
Brooks, Alberta T1R 1E6
Phone : (403) 362-1328

Alberta Agriculture and Food:

Cornelia Kreplin, Director, Agriculture Research Division — Date: 2007 09 25

Potato Growers of Alberta:

Vern Warkentin, Executive Director, Potato Growers of Alberta — Date: Sept/13/07

Research Plan

The research plan for this project was briefly described in the original project proposal submitted to the PGA in 2007 (see attached copy).

Project Code: BPI07-170

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

2007-04-01 to 2008-03-31

Collaborators

Dr. Rick Peters, Ph.D., Agriculture and Agri-Food Canada, Charlottetown, PEI
Role: Supervise and conduct research trials in PEI
Dr. Ron Howard, Ph.D., Alberta Agriculture, Food and Rural Development, AB
Role: Supervise and conduct research trials in AB
Lucie Grant, JET Harvest Solutions, Longwood, FL 32791
Role: Registrant of Bio-Save 10LP and Bio-Save11LP (*Pseudomonas syringae*); provide products and trial validation
Grower Groups: Potatoes New Brunswick, PEI Potato Board, and Potato Growers of Alberta
Role: Project support
Kelvin Lynch, New Brunswick Department of Agriculture and Aquaculture, NB
Role: Facilitate communication among project partners to optimize studies for product registration in Canada.

Statement of problem and brief literature review

Silver scurf of potatoes caused by the fungus *Helminthosporium solani* is an important disease in Canada and worldwide. It is characterized by dark metallic discoloration of the periderm in irregular patterns. The lesions increase in size, coalesce, and may cover a major portion of tuber surface. This disease often adversely affects the appearance and skin color of potato tubers, ultimately resulting in reduced consumer acceptance (Secor & Gudmestad, 1999). Primary infection occurs in the field and secondary lesions develop from conidia dispersed during storage. It is considered a problem of storage potatoes even though infection often takes place before harvest (Jellis & Taylor, 1977; Lennard, 1980; Carnegie et al. 2003). Light brown to gray spots develop on the tuber surface, gradually taking on a leathery appearance. The spots enlarge to cover the entire tuber, appearing as a 'silvery sheen' when the tubers are wet. The primary sources of inoculum are diseased seed-pieces, infested crop residue and field soil. Soil borne inoculum infects tubers through the lenticels or directly through the skin. The severity of the disease can increase in storage if relative humidity levels are above 90% and temperatures are greater than 3C. The disease will continue to develop and spread in storage as aerial spores are produced at the margins of tuber lesions. Over a period of time, the diseased tubers may lose moisture and shrivel resulting in weight loss (Tsror and Peretz-Alon 2002). Very few fungicides are effective against the silver scurf pathogen (Errampalli et al. 2001) and pathogen resistance has developed for some such as thiabendazole (Mertect) (Merida and Loria, 1994). Fusarium dry rot caused by *Fusarium sambucinum* is another important postharvest disease of potato. It is characterized by an internal light to dark brown or black rot of the potato tuber and it is usually dry. The rot may develop due to an injury caused by bruises or cuts on tuber surface. In this case the pathogen penetrates the tuber and often causing rotting in the center of the tuber. Extensive rotting causes the tissue to shrink and collapse while leaving a dark sunken area on the outside of the tuber showing internal cavities. Traditionally, management of these diseases has been done with the use of thiabendazole. But over the years resistance to thiabendazole in isolates of *F. sambucinum* has been recorded in Europe, United States and Canada (Hide et al. 1992; Hanson et al. 1996; Platt 1997; Peters *et al.* 2001). No other options for post-harvest disease management have proven to be sufficiently efficacious against Fusarium dry rot. This kind of siutation prompts for the search of new and efficient methods to control silver scurf and dry rot in potato. In the U.S.A., Bio-Save 10LP and 11LP (*Pseudomonas syringae*) are registered for control of silver scurf and dry rot. The company is also pursuing registration of the product in Canada. The objective of the study is to assess the efficacy of the biopesticides Bio-

Save 10LP and Bio-Save 11LP against silver scurf and dry rot of potatoes. Results from this study will provide sufficient data needed for the registration of these biopesticides for silver scurf and dry rot management in Canada. Bio-Save is registered in the USA for the control of both silver scurf and Fusarium dry rot. Since dry rot is a big problem in potato storages, it was added to this trial. Serenade Max (*Bacillus subtilis*) was removed from this proposal upon request of the manufacturer. In January 2007, the EPA found an inert material in the product that is not allowed for post-harvest treatment. The post-harvest method of application of Serenade Max has been taken off the label.

Carnegie, S.F., J.W. Cholseul, and A.M.I. Roberts. 2003. Detection of *Colletotrichum coccodes* and *Helminthosporium sol*ani in soils by bioassay. Plant Pathology 52: 13–21.
Errampalli, D., J.D. Saunders, and J.D. Holley. 2001. Emergence of silver scurf (*Helminthosporium solani*) as an economically important disease of potato. Plant Pathology 50:141-153.
Jellis, G.J. and G.S. Taylor. 1977. The development of silver scurf (*Helminthosporium solani*) disease of potato. Annals of Applied Biology 86: 19–28.
Hanson, L.E., S.J. Schwager, and R. Loria. 1996. Sensitivity to thiabendazole in *Fusarium* species associated with dry rot of potato. Phytopathology 86: 378-384.
Hide, G.A., P.J. Read, and S.M. Hall. 1992. Resistance to thiabendazole in *Fusarium* species isolated from potato tubers affected with dry rot. Plant Pathology 41: 745-748.
Lennard, J.H., 1980. Factors affecting the development of silver scurf (*Helminthosporium solani*) on potato tubers. Plant Pathology 29: 87-92.
Merida, C. L. and R. Loria. 1994. Comparison of Thiabendazole-sensitive and –resistant *Helminthosporium solani* isolates from New York. Plant Disease 78:187-192.
Peters, R.D., I.K. Macdonald, K.A. Macisaac, and S. Woodworth. 2001. First report of thiabendazole-resistant isolates of *Fusarium sambucinum* infecting stored potatoes in Nova Scotia, Canada. Plant Disease 85: 1030.
Platt, H.W. 1997. Resistance to thiabendazole in *Fusarium* species and *Helminthosporium solani* in potato tubers treated commercially in eastern Canada. Phytoprotection 78: 1-10.
Secor, G.A. and N.C. Gudmestad. 1999. Managing fungal diseases of potato. Canadian Journal of Plant Pathology 21: 213-221.
Tsror, L. and I. Peretz-Alon. 2002. Reduction of silver scurf on potatoes by pre- and post-storage treatment of seed tubers with imazalil. American Journal of Potato Research 79: 33-37.

Contribution of project to solving the problem

More than 70% of total potato production in Canada comes from PEI, NB, Manitoba and Alberta, and the majority of potatoes are stored for varying periods of time. This project will aid in managing of an already identified priority crop and disease of potatoes by the PMRA. The outcome of this study will aid in providing data required for registration of biopesticides for the management of silver scurf and dry rot. The registration of effective biopesticides is urgently needed because silver scurf and dry rot pathogens have developed resistance to available fungicides, and to avoid growers' reliance on chemicals.

This study involves:
1. Collection of tissue samples infected with silver scurf and dry rot from NB, AB and PEI and identification of the pathogens. A culture collection of silver scurf and dry rot pathogens will be developed.
2. Storage trials will be conducted to assess the efficacy of Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*) for the control of silver scurf and dry rot.

The use of biopesticides is a promising perspective for safe and sustainable disease management. They are environmentally friendly and can reduce the need for synthetic pesticides thereby preventing adverse effects on human health and environment. Potato growers from NB, AB and PEI will benefit immensely from this new tool of post-harvest disease management of silver scurf and dry rot. The success of this trial will aid in the reduction of use of harmful and ineffective pesticides in silver scurf and dry rot control. The results of this work will provide Canadian data to

support the registration of Bio-Save 10LP and 11LP for potato silver scurf and Fusarium dry rot control in Canada.

Methods and Experimental Design

Pathogen collection
Potato tubers infected by silver scurf or Fusarium dry rot will be collected from NB, PEI and AB, and will be used for isolating the pathogens. A set of isolated pathogens will be sent to National Fungal Identification Service in Ottawa for identification using molecular techniques and another set will be used for identification in the lab by standard micromorphological techniques. The efficacy of the biopesticides on different isolates of silver scurf and dry rot pathogens will be tested *in vitro*.

Tuber disease studies
Silver scurf: A source of naturally-infected tubers will be used for the studies. Tubers are then sprayed with the respective treatments (Bio-Save LP10 or Bio-Save LP11) at the label rates as outlined below. The treated tubers are then stored at 10ºC and 95% RH for a period of 3-5 months. After storage, the tubers will be assessed for the presence of silver scurf. Disease incidence (number of diseased tubers) and severity (% tuber surface diseased) will be assessed.

Dry rot: Tubers will be wounded in a bruise box and then inoculated with a spore suspension of either *Fusarium sambucinum*, *F. coeruleum*, or *F. avenaceum* prior to treatments as outlined below. Tubers will then be stored at 10ºC and 95% RH for a period of 5-8 weeks. Following storage, dry rot incidence (number of diseased tubers) and severity (depth of internal necrosis) will be assessed.

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

During the trial some samples will be marked and treated with Bio-Save. After two days in storage the samples will be sent JET Harvest Solutions in Florida for analysis of Bio-Save (*Pseudomonas syringae*) population level in the treated samples. The same procedure is followed at the end of the storage with a marked and inoculated sample.

Treatments

1. Untreated un-inoculated
2. Untreated inoculated with *Helminthosporium solani*
3. Untreated inoculated with *Fusarium* sp.
4. Bio-Save 10LP (150 g in 25 gallons of water; 1gallon/2000-4000 lbs of potato)
5. Bio-Save 11LP (250 g in 40 gallons of water; 1gallon / 2000-4000 lbs of potato)
6. Mertect (7.5 L in 170 L of water; 2 L of suspension / 1000 kg of potato
7. Mertect + Bio-Save 10LP (treatments 4 + 6)
8. Mertect + Bio-Save 11LP (treatments 5 + 6)

The data obtained from the study will be analyzed statistically using standard techniques.

Resources

Human resources for this project are provided by the experts listed in the collaborators section. These experts provide support in project planning and oversee trials in their respective provinces. Due to the heavy work requirements in fall/winter, a research assistant is required. Laboratory facilities at NBDAA in Wicklow will be used for the isolation, storage and characterization of plant pathogens and to generate inoculum for tuber storage studies. In addition, AAFC in Charlottetown, PEI laboratory and Alberta Agriculture, Food and Rural Development, AB laboratory will also be used to generate pathogen inoculum. The provinces' of NB, AB and PEI will provide a source of tubers for tuber disease studies and climate-controlled potato storage facilities will also be utilized

in the three provinces. Bio-Save 10LP and Bio-Save 11LP will be supplied by JET Harvest Solutions. Testing for bacterial populations on treated tubers will be organized by JET Harvest Solutions.

Schedule and Milestones

Summer/Fall 2007

1. Collect potato tissue samples infected with silver scurf or dry rot from NB, AB and PEI, and isolate and identify pathogens.
2. Create and store culture collection.
3. Assess the efficacy of Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*) on different isolates of silver scurf and dry rot pathogens.
4. Begin storage trials examining the efficacy of Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*) applied post harvest for the control of silver scurf and dry rot.

Winter/Spring 2008

1. Conduct potato storage trials assessing the efficacy of Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*) applied post harvest for the control of silver scurf and dry rot.
2. Analyze data; annual report.
3. Attend industry and scientific meetings.

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September 30, 2007 - Submit half yearly report which includes outline of trials and preliminary data

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- Production of a technology transfer factsheet wherein the target audience would include potato growers and other members of the potato industry.
- Progress towards preparation of a scientific paper.

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Summaries of the results will be conveyed to producers through on-going extension and research reporting activities. 'Tuber disease' has been identified as an issue by the national potato silver scurf working group and Dr. Al-Mughrabi (NB), Dr. Rick Peters (PEI, and Dr. Ron Howard (AB) are representatives in that group which will aid in dissemination of project results.

Cash and In-Kind Contributions

Dr. Khalil Al-Mughrabi, Ph.D., New Brunswick Dept. of Agriculture and Aquaculture, NB.
In-kind contribution: Time devoted to storage studies and collection of diseased samples; potato storage facility (30% of project needs).
Dr. Rick Peters, Ph.D., Agriculture and Agri-Food Canada, Charlottetown, PEI.
In-kind contribution: Time devoted to storage studies and collection of diseased samples; potato storage facility (30% of project needs).
Dr. Ron Howard, Ph.D., Alberta Agriculture, Food and Rural Development, AB.
In-kind contribution: Time devoted to storage studies and collection of diseased samples; potato storage facility (30% of project needs).
Lucie Grant, JET Harvest Solutions, Longwood, FL 32791, USA.

In-kind contribution: Supply Bio-Save 10LP and Bio-Save11LP, assessing bacterial populations at the beginning and end of the trials, and trial validation.
Kelvin Lynch, New Brunswick Dept. of Agriculture and Aquaculture, NB.
In-kind contribution: Time devoted to facilitate communication among project partners to optimize studies for product registration.

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Spring 2009
- Presentation of information at the Northeast Potato Technology Forum.
- Completion and publication of factsheet for general distribution.
- Completion of an article for a grower magazine.
- Initial drafting of a scientific paper.
- Submit final data to registrant.

Budget

	Fiscal Year 2007/2008
Labor (NB)	$25,000.00
Materials and Supplies (NB)	$5,000.00
Travel and transportation	$5,000.00
Manpower (PEI)	$4500.00
Materials and Supplies (PEI)	$500.00
Manpower (AB)	$4500.00
Materials and Supplies (AB)	$500.00
Total	$45,000.00

Justification for Equipment Purchase (>$2,000.00 value)
Not applicable.

Project Code: BPI07-170

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

2007-04-01 to 2008-03-31

Collaborators

Dr. Rick Peters, Ph.D., Agriculture and Agri-Food Canada, Charlottetown, PEI
Role: Supervise and conduct research trials in PEI
Dr. Ron Howard, Ph.D., Alberta Agriculture, Food and Rural Development, AB
Role: Supervise and conduct research trials in AB
Lucie Grant, JET Harvest Solutions, Longwood, FL 32791
Role: Registrant of Bio-Save 10LP and Bio-Save11LP (*Pseudomonas syringae*); provide products and trial validation
Grower Groups: Potatoes New Brunswick, PEI Potato Board, and Potato Growers of Alberta
Role: Project support
Kelvin Lynch, New Brunswick Department of Agriculture and Aquaculture, NB
Role: Facilitate communication among project partners to optimize studies for product registration in Canada.

Statement of problem and brief literature review

Silver scurf of potatoes caused by the fungus *Helminthosporium solani* is an important disease in Canada and worldwide. It is characterized by dark metallic discoloration of the periderm in irregular patterns. The lesions increase in size, coalesce, and may cover a major portion of tuber surface. This disease often adversely affects the appearance and skin color of potato tubers, ultimately resulting in reduced consumer acceptance (Secor & Gudmestad, 1999). Primary infection occurs in the field and secondary lesions develop from conidia dispersed during storage. It is considered a problem of storage potatoes even though infection often takes place before harvest (Jellis & Taylor, 1977; Lennard, 1980; Carnegie et al. 2003). Light brown to gray spots develop on the tuber surface, gradually taking on a leathery appearance. The spots enlarge to cover the entire tuber, appearing as a 'silvery sheen' when the tubers are wet. The primary sources of inoculum are diseased seed-pieces, infested crop residue and field soil. Soil borne inoculum infects tubers through the lenticels or directly through the skin. The severity of the disease can increase in storage if relative humidity levels are above 90% and temperatures are greater than 3C. The disease will continue to develop and spread in storage as aerial spores are produced at the margins of tuber lesions. Over a period of time, the diseased tubers may lose moisture and shrivel resulting in weight loss (Tsror and Peretz-Alon 2002). Very few fungicides are effective against the silver scurf pathogen (Errampalli et al. 2001) and pathogen resistance has developed for some such as thiabendazole (Mertect) (Merida and Loria, 1994). Fusarium dry rot caused by *Fusarium sambucinum* is another important postharvest disease of potato. It is characterized by an internal light to dark brown or black rot of the potato tuber and it is usually dry. The rot may develop due to an injury caused by bruises or cuts on tuber surface. In this case the pathogen penetrates the tuber and often causing rotting in the center of the tuber. Extensive rotting causes the tissue to shrink and collapse while leaving a dark sunken area on the outside of the tuber showing internal cavities. Traditionally, management of these diseases has been done with the use of thiabendazole. But over the years resistance to thiabendazole in isolates of *F. sambucinum* has been recorded in Europe, United States and Canada (Hide et al. 1992; Hanson et al. 1996; Platt 1997; Peters *et al.* 2001). No other options for post-harvest disease management have proven to be sufficiently efficacious against Fusarium dry rot. This kind of siutation prompts for the search of new and efficient methods to control silver scurf and dry rot in potato. In the U.S.A., Bio-Save 10LP and 11LP (*Pseudomonas syringae*) are registered for control of silver scurf and dry rot. The company is also pursuing registration of the product in Canada. The objective of the study is to assess the efficacy of the biopesticides Bio-

Save 10LP and Bio-Save 11LP against silver scurf and dry rot of potatoes. Results from this study will provide sufficient data needed for the registration of these biopesticides for silver scurf and dry rot management in Canada. Bio-Save is registered in the USA for the control of both silver scurf and Fusarium dry rot. Since dry rot is a big problem in potato storages, it was added to this trial. Serenade Max (*Bacillus subtilis*) was removed from this proposal upon request of the manufacturer. In January 2007, the EPA found an inert material in the product that is not allowed for post-harvest treatment. The post-harvest method of application of Serenade Max has been taken off the label.

Carnegie, S.F., J.W. Choiseul, and A.M.I. Roberts. 2003. Detection of *Colletotrichum coccodes* and *Helminthosporium sol*ani in soils by bioassay. Plant Pathology 52: 13–21.
Errampalli, D., J.D. Saunders, and J.D. Holley. 2001. Emergence of silver scurf (*Helminthosporium solani*) as an economically important disease of potato. Plant Pathology 50:141-153.
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Hanson, L.E., S.J. Schwager, and R. Loria. 1996. Sensitivity to thiabendazole in *Fusarium* species associated with dry rot of potato. Phytopathology 86: 378-384.
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Peters, R.D., I.K. Macdonald, K.A. MacIsaac, and S. Woodworth. 2001. First report of thiabendazole-resistant isolates of *Fusarium sambucinum* infecting stored potatoes in Nova Scotia, Canada. Plant Disease 85: 1030.
Platt, H.W. 1997. Resistance to thiabendazole in *Fusarium* species and *Helminthosporium solani* in potato tubers treated commercially in eastern Canada. Phytoprotection 78: 1-10.
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Tsror, L. and I. Peretz-Alon. 2002. Reduction of silver scurf on potatoes by pre- and post-storage treatment of seed tubers with imazalil. American Journal of Potato Research 79: 33-37.

Contribution of project to solving the problem

More than 70% of total potato production in Canada comes from PEI, NB, Manitoba and Alberta, and the majority of potatoes are stored for varying periods of time. This project will aid in managing of an already identified priority crop and disease of potatoes by the PMRA. The outcome of this study will aid in providing data required for registration of biopesticides for the management of silver scurf and dry rot. The registration of effective biopesticides is urgently needed because silver scurf and dry rot pathogens have developed resistance to available fungicides, and to avoid growers' reliance on chemicals.

This study involves:
1. Collection of tissue samples infected with silver scurf and dry rot from NB, AB and PEI and identification of the pathogens. A culture collection of silver scurf and dry rot pathogens will be developed.
2. Storage trials will be conducted to assess the efficacy of Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*) for the control of silver scurf and dry rot.

The use of biopesticides is a promising perspective for safe and sustainable disease management. They are environmentally friendly and can reduce the need for synthetic pesticides thereby preventing adverse effects on human health and environment. Potato growers from NB, AB and PEI will benefit immensely from this new tool of post-harvest disease management of silver scurf and dry rot. The success of this trial will aid in the reduction of use of harmful and ineffective pesticides in silver scurf and dry rot control. The results of this work will provide Canadian data to

support the registration of Bio-Save 10LP and 11LP for potato silver scurf and Fusarium dry rot control in Canada.

Methods and Experimental Design

Pathogen collection
Potato tubers infected by silver scurf or Fusarium dry rot will be collected from NB, PEI and AB, and will be used for isolating the pathogens. A set of isolated pathogens will be sent to National Fungal Identification Service in Ottawa for identification using molecular techniques and another set will be used for identification in the lab by standard micromorphological techniques. The efficacy of the biopesticides on different isolates of silver scurf and dry rot pathogens will be tested *in vitro*.

Tuber disease studies
Silver scurf: A source of naturally-infected tubers will be used for the studies. Tubers are then sprayed with the respective treatments (Bio-Save LP10 or Bio-Save LP11) at the label rates as outlined below. The treated tubers are then stored at 10ºC and 95% RH for a period of 3-5 months. After storage, the tubers will be assessed for the presence of silver scurf. Disease incidence (number of diseased tubers) and severity (% tuber surface diseased) will be assessed.

Dry rot: Tubers will be wounded in a bruise box and then inoculated with a spore suspension of either *Fusarium sambucinum*, *F. coeruleum*, or *F. avenaceum* prior to treatments as outlined below. Tubers will then be stored at 10ºC and 95% RH for a period of 5-8 weeks. Following storage, dry rot incidence (number of diseased tubers) and severity (depth of internal necrosis) will be assessed.

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

During the trial some samples will be marked and treated with Bio-Save. After two days in storage the samples will be sent JET Harvest Solutions in Florida for analysis of Bio-Save (*Pseudomonas syringae*) population level in the treated samples. The same procedure is followed at the end of the storage with a marked and inoculated sample.

Treatments

1. Untreated un-inoculated
2. Untreated inoculated with *Helminthosporium solani*
3. Untreated inoculated with *Fusarium* sp.
4. Bio-Save 10LP (150 g in 25 gallons of water; 1gallon/2000-4000 lbs of potato)
5. Bio-Save 11LP (250 g in 40 gallons of water; 1gallon / 2000-4000 lbs of potato)
6. Mertect (7.5 L in 170 L of water; 2 L of suspension / 1000 kg of potato
7. Mertect + Bio-Save 10LP (treatments 4 + 6)
8. Mertect + Bio-Save 11LP (treatments 5 + 6)

The data obtained from the study will be analyzed statistically using standard techniques.

Resources

Human resources for this project are provided by the experts listed in the collaborators section. These experts provide support in project planning and oversee trials in their respective provinces. Due to the heavy work requirements in fall/winter, a research assistant is required. Laboratory facilities at NBDAA in Wicklow will be used for the isolation, storage and characterization of plant pathogens and to generate inoculum for tuber storage studies. In addition, AAFC in Charlottetown, PEI laboratory and Alberta Agriculture, Food and Rural Development, AB laboratory will also be used to generate pathogen inoculum. The provinces' of NB, AB and PEI will provide a source of tubers for tuber disease studies and climate-controlled potato storage facilities will also be utilized

in the three provinces. Bio-Save 10LP and Bio-Save 11LP will be supplied by JET Harvest Solutions. Testing for bacterial populations on treated tubers will be organized by JET Harvest Solutions.

Schedule and Milestones

Summer/Fall 2007

1. Collect potato tissue samples infected with silver scurf or dry rot from NB, AB and PEI, and isolate and identify pathogens.
2. Create and store culture collection.
3. Assess the efficacy of Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*) on different isolates of silver scurf and dry rot pathogens.
4. Begin storage trials examining the efficacy of Bio-Save 10LP and Bio-Save 11LP (*Pseudomonas syringae*) applied post harvest for the control of silver scurf and dry rot.

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Justification for Equipment Purchase (>$2,000.00 value)
Not applicable.

POTATO GROWERS OF ALBERTA

6008, 46th Avenue
Taber, Alberta T1G 2B1

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May 30, 2007

Dr. Ron Howard
Alberta Agriculture, Food & Rural Development
301 – Horticultural Station Rd. E.
Brooks, AB T1R 1E6

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

Dear Ron:

We are pleased to advise that the Board of Directors of The Potato Growers of Alberta has reviewed and approved your research funding application.

The funding will be accessible for a one year period in the total amount requested of $5000. When requesting the funds for the project, please provide an invoice that specifies the amount, GST and to whom payable.

We appreciate your commitment and dedication to the potato industry.

Yours truly,

Vern Warkentin
Executive Director

/pl

Developing Improved Methods of Chemical Control for Silver Scurf on Potatoes in the Field and in Storage

A Research Progress Report Submitted to

The Potato Growers of Alberta
6008 – 46th Avenue
Taber, Alberta T1G 2P1

March 15, 2007

Prepared by

Ron Howard, Plant Pathology Research Scientist
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Alberta Agriculture and Food
Crop Diversification Centre South
301 Horticultural Station Road East
Brooks, Alberta T1R 1E6

Introduction

Silver scurf (SS), caused by the fungus *Helminthosporium solani*, emerged as an economically important disease of tablestock and processing potatoes in Canada in the 1990s. Prior to that, it had mostly been considered a minor problem. SS causes metallic, silvery patches on tuber skins, which can reduce their suitability for direct sales and processing. Seed growers are also concerned about SS because it can be easily spread on seed tubers. Control recommendations for SS centre mainly on fungicides and cultural practices. Holley and Kawchuk (1993, 1996) demonstrated the widespread ocurrence of strains of *H. solani* resistant to the commonly used fungicide Mertect (thiabendazole) in Alberta. Mertect was widely used as a post-harvest treatment on potato tubers to prevent various storage diseases. Similar findings were reported from the U.S.A. and Europe, and prompted researchers to look at alternative products, e.g. imazilil, prochloraz, propiconazole, fludioxonil, L-carvone, and organic and inorganic salts. Several of these products have looked promising in research trials elsewhere, but few of them have been tested in Alberta. At present, three seed treatments (Senator PSPT, Maxim PSP and Maxim MZ) and two post-harvest fungicides (Mertect SC and StorOx) are registered in Canada for controlling SS. Despite the availability of these products, SS remains a widespread and serious problem. The inability of currently available products to control SS may be due to several factors, e.g. the development of resistant strains of *H. solani*, chemical dosages that are too low to be effective, improper application techniques to seed pieces or tubers in storage, or poor residual chemical activity. The possibility also exists that SS-like symptoms on tubers may be caused by another fungus, *Colletotrichum coccodes*, the black dot (BD) pathogen. BD can cause symptoms on tubers that are easily confused with SS, and the two diseases often occur together in the same fields. BD may not respond to fungicide treatments in the same way that SS does and vice versa.

Project Objectives

1. Surveys - Collect tubers of various varieties of seed, table and processing potatoes showing SS-like symptoms from fields and storages across Alberta to determine whether *H. solani* or *C. coccodes* is the primary cause.
2. Diagnostic Methods - Compare agar plate and molecular techniques for the isolation and characterization of *H. solani* and *C. coccodes* isolates to determine their speed, accuracy and cost.
3. Fungicide Performance - Assess whether currently registered seed treatment and post-harvest fungicides are effective against the strains of *H. solani* present in Alberta fields and storages.
4. New Product Development - Determine the efficacy of promising new chemical treatments (conventional and reduced risk) in replicated trials in the lab, field and storage.
5. Technology Transfer - Use the information generated in this study to improve the techniques for managing SS, thereby reducing yield and quality losses for growers and processors.

Trials Conducted in 2006-07

1. Disease Surveys

No formal disease surveys were carried out in 2006; however, several samples of plants and tubers with symptoms of silver scurf and black dot were randomly collected from fields and storages. Isolates of the causal agents were obtained in the laboratory and stored for later use in developing diagnostic testing procedures and for testing their sensitivity to fungicides *in vitro*.

Organized surveys will be conducted in fields and storages in 2007-08.

2. Diagnostic Methods

The development of new diagnostic testing methods for silver scurf will be initiated in 2007-08.

3. Disease Management Trials at CDC South, Brooks

Efficacy of Nine Seed Treatments in a Field Trial

Nine different fungicide treatments were compared to each other and to an untreated check in a replicated trial at the Crop Diversification Centre South (CDCS), Brooks, AB in 2006 (Table 1). Russet Norkotah seed potatoes, which were naturally infested with the silver scurf pathogen (*Helminthosporium solani*), were obtained from Sunnycrest Seed Potatoes Inc., Lacombe, AB. The seed was planted in June 2006 in a field plot at CDC South, Brooks. The survival of silver scurf pathogen on both unplanted and planted, and treated and untreated, seed was evaluated. The survival trial will be repeated on tubers harvested from this trial in the laboratory in 2007. In March 2007, untreated tubers from the guard rows will receive fungicide treatments to assess whether they can control silver scurf in storage.

A randomized complete block (RCB) plot plan was prepared for this trial using the Agricultural Research Manager Version 7 computer software program (ARM 7). The experiment had four replications and ten treatments. Data collection sheets, plot plans and a treatment list were printed for future use. A field map was also designed using the MS Excel program, which consisted of a detailed the plot plan. The plan specified a 3-m spacing between replications, 8-m row lengths, 0.9-m spacing between rows, and 30.5-cm between seed-pieces within rows. In each replicate, there were two treatments per eight rows, with a guard row on either side of the block (10 rows; total block width = 9-m). A 3.2-m spacing was allowed between each block to allow for in-season pesticide applications.

Hand-cut Russet Norkotah seed was treated with seed piece fungicides as per Table 1. The seed was warmed prior to cutting to promote early stage sprout development. Treated seed pieces were placed into labeled paper bags, each containing 27 pieces. In addition to the four bags of seed prepared for each subplot (16 bags/replicate), four extra bags per treatment were also filled with treated seed pieces for later experiments aimed at recovering *H. solani* from the pieces. Seed treatments were applied as per the manufacturers' label instructions. In-furrow treatments were applied at planting. Treatments 1 (Maxim MZ PSP), 2 (Maxim MZ PSP + Quadris) and 3 (Maxim PSP) were applied within two-hours after cutting. Treatments 4 (Senator PSPT) and 7 (Captan 10% DU) were applied within half a day after cutting. Treatments 5 (Tuberseal) and 6 (Polyram 16D) were applied a few days after cutting. Treatment 9 (Heads-Up Plant Protectant) was prepared as a 1-L solution and each batch of 27 seed pieces was dipped in this solution to insure complete coverage. The tubers were left to dry in tote bins overnight and then were bagged the next day. Treatment 8 (AgGrand in-furrow and foliar spray), Treatment 10 (untreated check), and seed pieces for all guard rows were left in the paper bags and were not treated. The bags of seed were held in a controlled environment storage room until planting.

The trial was planted on June 1 and 2 using a double-row, three-point hitch potato planter for treatments 1, 3-7, 9 and 10, or by hand for treatments 2 and 8. The furrows for the latter two treatments were opened using a double-shank corrugator and the in-furrow treatments were applied to the open row using a CO_2-propelled hand sprayer. The seed pieces in these furrows

were hand-planted at a spacing of 30-cm and potato hiller was used to cover them. The trial was managed using conventional production practices for the remainder of the growing season.

Interim samples of seed pieces were taken from the outer rows of each subplot for disease observations. Plant emergence data were taken from all four rows in each subplot on July 4. The mean percent emergence was calculated for each subplot and recorded on a MS Excel spreadsheet. The Applied Research Manager Program Release 7 (ARM 7) was used to analyze these data (Table 2).

During the first week in August, symptoms of verticillium wilt were noticed in the plot, so visual disease ratings of the plant canopies were done on both August 10 and 21. The percentage of wilted plants per subplot was determined. Data for wilt incidence (DI %) were transformed and subjected to analysis of variance (ANOVA). Duncan's Multiple Range Test was used to compare entry means where F-tests were statistically significant ($P \leq 0.05$) (Table 3).

Treatment 8, AgGrand, was also applied to the foliage on both July 18 and August 18 with a backpack sprayer using 1200-mL of solution per subplot. The entire experiment was top-killed at maturity with Reglone on September 6, and a single-row harvester was used to dig the potatoes in the two middle rows of each subplot on September 27. All of the harvested tubers were bagged by hand. Potatoes from guard rows were also dug and retained for future storage experiments.

The harvested tubers were gradually suberized in storage, with the final environmental conditions set at 8°C and 95% relative humidity. The tubers were weighed and graded on November 22-23 to obtain total and marketable yields. Total yields were the weights (kg) of all tubers harvested per subplot, whereas marketable weights did not include smalls, deformed tubers and culls. Tubers with a diameter of a least 1⅞" and at least 2" long with no growth cracks or extensive knobbiness (deformed) and not rotted or severely sliced (culls) were considered to be marketable. Yield data were summarized and analyzed using ARM 7. Duncan's Multiple Range Test was used to compare entry means where F-tests were statistically significant ($P \leq 0.05$).

Assessing the Survival of Helminthosporium solani on Unplanted Seed
On June 12, two weeks after fungicide treatments, ten seed pieces from the four spare bags of unplanted, treated and untreated check seed /subplot were placed into two moist chambers, after first being washed free of the adhering seed piece treatments. The bags were then placed into a storage room set at 15°C and 90% RH until June 21, when they were examined microscopically for the presence of *H. solani* conidiophores and conidia on the skin. Disease incidence (DI%) and disease severity (DS) ratings were taken. DS was rated on each tuber using a 0-3 point scale, where 0 = no colonization by *H. solani*, 1 = slight colonization (<10% tuber surface covered), 2 = 10-30% of surface colonized, and 3 = ≥30% colonized. These data were entered into an Excel spreadsheet where the average DS values for each subplot were calculated using the formula:

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

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, and N_t = total number of tubers examined per subplot. DI was then calculated

from the DS ratings as the percentage of tubers colonized by *H. solani*. The tubers were re-examined on July 12 and rated using the same criteria as before, and all results were recorded on a spreadsheet. This procedure was repeated after ca. five weeks post-treatment (June 28). There were insufficient tubers to do a 6-week sampling. All data were summarized and statistical analyses were performed with the ARM 7 program.

Assessing the Survival of Helminthosporium solani on Planted Seed
On June 27 and July 14, at 4 and 6 weeks after planting, respectively, ten seed pieces were dug up from the two outside rows of each subplot, bagged and taken into the laboratory where they were washed free of adhering soil and fungicide. The washed pieces were placed into high humidity plastic bags (5 pieces/bag) and the bags were then placed into a storage room set at 15°C and 90% RH. The seed pieces were rated for growth of *H. solani* at 10 and 21-day intervals as described above for the unplanted seed. The 4-week samples were rated on July 10 and 19, and the 6-week samples on Aug. 4 only. All data were summarized and analyzed with the ARM 7 program. Duncan's Multiple Range Test was used to compare means where F-tests were statistically significant ($P \leq 0.05$).

Silver Scurf Ratings on Tubers from the Replicated Field Trial at CDC South
During grading, a 100-tuber sample from each subplot was removed and bagged for initial silver scurf evaluations. A 50-tuber subsample was randomly selected from each of these bags and visually examined for both silver scurf and black scurf DI and DS levels. Each tuber was rated on a 0-5 point scale, where 0 = no colonization by *H. solani*; 1 = sparse colonization (<1% tuber surface covered); 2 = slight colonization (1-10% tuber surface covered); 3 = moderate colonization (>10-25% tuber surface covered), 4 = moderate to heavy colonization (>25-50% tuber surface covered), and 5 = very heavy colonization (>50% tuber surface covered). These data were recorded onto a MS Excel spreadsheet, where the average DS for each 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 per subplot.

DI, the percentage of tubers with black scurf or silver scurf infection, was also calculated for each subplot. Data for all ratings were summarized and analyzed using the ARM 7 program.

A 10-tuber subsample was removed from the 100-tuber sample described above and placed into two moist chambers, which were held in a storage room at room temperature, on December 1. An initial evaluation for silver scurf only was done on December 21, using the same rating criteria described above for DS and DI. After the tubers were rated, they were placed back into storage and received a second silver scurf evaluation after 4 weeks of incubation (January 23, 2007). Data for all ratings were summarized and analyzed as per the 50-tuber sample described above. Duncan's Multiple Range Test was used to compare entry means where F-tests were statistically significant ($P \leq 0.05$) for all disease rating data.

Post-harvest Quadris Application

On January 11, a 400-tuber subsample was removed from the guard row bags, which had been placed into storage after harvest, and the potatoes were divided equally into four replications for a post-harvest application of Quadris fungicide. The rate used was 19.55 mL of Quadris + 2 L water /tonne of potatoes and this mixture was applied with a 600-mL spray bottle. After drying, the tubers were placed into a storage room, where they will be evaluated for silver scurf DI and DS in late March, 2007.

Post-harvest Fungicide Evaluations (to be completed)
StorOx (hydrogen dioxide), Mertect (thiabendazole) and several unregistered fungicides will be applied to silver scurf-infected tubers harvested from the guard rows of the 2006 field trial to compare their efficacy against silver scurf in storage. DI and DS data will be taken over a three-month period and used to determine the relative performance of these products.

Survival of Helminthosporium solani on Fungicide-treated Seed Pieces (to be completed)
Seed piece treatments will be applied onto naturally infested silver scurf tubers from the harvested guard rows of the 2006 field trial described previously. Half of the treated tubers will be planted in totes of field soil in a greenhouse and allowed to grow for two weeks. A portion of these seed pieces will then be dug up and washed free of the adhering soil and seed treatments, while others will be left unwashed. The washed and unwashed seed pieces will be placed in a moist chamber for 7-10 days and examined for *H. solani*. This protocol will be repeated at a 4-week interval. The other half of the treated tubers will not be planted, but instead will be placed between moistened burlap sacks on the floor in a storage room set at 15°C. At 2- and 4-week intervals, tuber samples will be removed and some will be washed free of the adhering seed treatments, while others will not be washed. The seed pieces will be placed in a plastic bag moist chamber for 7-10 days and examined microscopically for the presence of conidiophores and conidia of *H. solani* on the skin.

Data Summaries
Data collected from the experiments described above are summarized in Tables 2-6.
Table 2 – Percentage of plants that had emerged from the field trial at CDCS by July 4 and the total and marketable yields after harvest on September 27.
Table 3 – Verticillium wilt evaluations (DI %) on plants in the field trial at CDCS on August 9 and 21.
Table 4 – DI and DS ratings for silver scurf on unplanted treated seed pieces examined at 2-week (June 12) and 5-week (June 28) intervals. For June 12, the potatoes were first rated on June 21 and again on July 12. The 5-week sampling was rated only on July 26.
Table 5 – DI and DS ratings for silver scurf on planted treated seed pieces where the pieces were dug up at 4-week (June 27) and 6-week (July 14) intervals after planting. The 4-week samples were rated on July 10 and July 25, while the 6-week samples were evaluated only on August 4.
Table 6 – Post-harvest DI and DS ratings for silver scurf on harvested tubers. A 50-tuber sample from each subplot was rated directly out of storage without a moist chamber treatment. The same tubers were also rated for black scurf on November 30. A 10-tuber sample from each subplot was placed in moist chambers and rated for silver scurf on December 21, 2006 and January 23, 2007.

Interim Results and Discussion
Efficacy of Nine Seed Treatments in a Field Trial at CDC South

There was abundant rainfall at Brooks in June 2006, which helped to establish the plot. During July and August, however, there was very little precipitation, so irrigation was necessary. The experiment was watered only when the soil moisture levels became depleted. Emergence ratings taken on July 4 showed that subplots treated with AgGrand and Maxim MZ PSP + Quadris (treatments 2 and 8) had significantly ($P \leq 0.05$) higher stand counts than the untreated check (treatment 9) (Table 2). The next best stands occurred in treatments 5, 6 and 7 (Tuberseal, Polyram 16D and Captan 10% DU, respectively); however, these treatments were not significantly different from the check. Total and marketable yield data failed to show any statistically significant ($P \leq 0.05$) differences between the ten treatments. Maxim MZ PSP + Quadris (treatment 2) had the highest marketable yield amongst treatments, with fewer culls, smalls and deformed tubers. The other treatments had 5-9 kg fewer tubers per plot compared to treatment 2. All of the chemical treatments had more marketable tubers than the check treatment.

Verticillium wilt occurred at moderately high levels in this trial (Table 3). Infection may have resulted from soil-borne inoculum of *Verticillium albo-atrum* and *V. dahliae* carried over from potato trials done in this field at various times over the previous 20 years. DI ratings taken at 2-week intervals (August 9 and 21) failed to show any significant ($P \leq 0.05$) differences between treatments. Subplots grown from seed treated with Maxim MZ PSP + Quadris (treatment 2) had about one-half the amount of wilt as the untreated check. All of the chemical treatments had less wilt than the check on both of the dates that disease assessments were made.

Assessing the Survival of Helminthosporium solani on Unplanted Seed

Fungicide efficacy evaluations for the unplanted seed pieces revealed statistically significant ($P \leq 0.05$) differences between treatments, except for the DI readings taken on July 26, when all the tubers were found to be diseased (Table 4). The moist chambers set up on June 12 and examined on June 21 showed that treatments 3 (Maxim PSP) and 8 (AgGrand) had DS and DI readings that were not significantly different from the untreated check. By contrast, significantly lower DS and DI readings were seen in treatments 1, 2, 4, 5 and 6 (Maxim MZ PSP, Maxim MZ PSP + Quadris, Senator PSPT, Tuberseal, and Polyram 16D, respectively) compared to the check. The lowest DS and DI ratings were seen in treatment 5 (Tuberseal). When these same tubers were placed back into moist chambers and re-examined on July 12, treatment 10 (untreated check) had higher DS ratings than all nine of the chemical treatments. Regrettably, it was not possible to compare the DS means statistically as the Bartlett's Test for homogeneity of variance was significant ($P \leq 0.05$). DI ratings were significantly lower than the check in only two treatments, i.e. nos. 4 (Senator PSPT) and 5 (Tuberseal). Once again, Tuberseal had the lowest DS and DI ratings amongst the nine chemical treatments. For the moist chambers prepared on June 28 and rated on July 26, the untreated check still had the highest DS rating (2.75), which was significantly greater than all nine of the chemical treatments. Polyram 16D (treatment 6) had the lowest DS rating amongst the nine chemical treatments, but it was not significantly different from treatments 2, 5 and 8 (Maxim PSP + Quadris, Tuberseal and AgGrand, respectively). All of the tubers examined on July 26 had a DI of 100%. Under the conditions of this trial, none of the seed treatments tested was able to eradicate tuber-borne silver scurf infection; however, several were able to significantly reduce infection levels compared to the untreated check.

Assessing the Survival of Helminthosporium solani on Planted Seed

The analysis of variance for the DS and DI ratings of seed pieces dug on June 27 and examined on July 10 was statistically significant ($P \leq 0.05$), as was the ANOVA for DS ratings taken on

July 25 (Table 5). Unfortunately, however, it was not possible to compare the DS means for July 10 statistically as the Bartlett's Test for homogeneity of variance was significant ($P \leq 0.05$). On July 10, DS ratings for the nine chemical treatments were all lower that the untreated check. The lowest DS values were seen on the Tuberseal and Polyram 16D (treatments 5 and 6) treated seed pieces, followed by Maxim MZ PSP + Quadris and AgGrand (treatments 2 and 8). Tuberseal (treatment 5) had the lowest DI rating on July 10 and was the only one of the nine chemical treatments that was significantly different from the check. The were no significant differences between treatments for DI ratings of the seed pieces examined on July 25 or for DS and DI ratings for seed pieces dug on July 4 and examined on August 4. By July 25, DI ratings were extremely high (97-100%) in all treatments. For the seed pieces examined on August 4, the lowest DS and DI ratings were seen in treatments 2 (Maxim MZ + Quadris) and 3 (Maxim PSP), while the highest DS and DI ratings occurred in treatments 7 (Captan 10% DU) and 9 (Heads Up Plant Protectant). Under the conditions of this trial, none of the seed treatments tested was able to eradicate tuber-borne silver scurf infection, although several brought about a small reduction in DS and/or DI levels.

Silver Scurf Ratings on Harvested Tubers from the Replicated Field Trial at CDC South
As the silver scurf evaluations were being done on the harvested tubers on November 30, it was noted that black scurf was much more prevalent; therefore, it was decided to rate the DI and DS for this disease as well. There were no significant ($P \leq 0.05$) differences in DS or DI between treatments for either silver scurf or black scurf (Table 6). Disease levels for silver scurf were extremely low for the November 30 ratings, whereas levels were moderately high for black scurf. Treatments 3 and 4 (Maxim PSP and Senator PSPT) had even higher DS and DI ratings for black scurf than the untreated check did. Treatment 2 **(**Maxim MZ PSP + Quadris) had much lower DS and DI levels for black scurf than the other eight chemical treatments. When the 10-tuber subsamples were examined for silver scurf on December 21, 2006 and January 23, 2007, disease levels had increased substantially over those seen in November, and statistically significant differences in DS and DI were noted between treatments. On December 21, five of the nine chemical treatments had DS and DI ratings that were not significantly different from the check. In contrast, the other four treatments, i.e. Polyram 16D, Captan 10% DU, Maxim MZ PSP, and Maxim MZ PSP + Quadris (treatments 6, 7, 1 and 2, respectively), had significantly lower DS and DI ratings than the check. By January 23, only treatment 6 (Polyram 16D) still had significantly lower DS and DI levels compared to the check.

Conclusions
None of the seed treatments evaluated in these trials succeeded in eradicating *Helminthosporium solani* from the skin of infected seed pieces, although several significantly reduced the incidence and/or severity of silver scurf compared to an untreated check and/or some of the other chemical treatments. On unplanted treated seed, Maxim MZ PSP, Maxim MZ PSP + Quadris, Senator PSPT, Tuberseal and Polyram 16D were generally did the best job of suppressing *H. solani* growth and sporulation on the skin. On planted seed, Tuberseal and Maxim MZ PSP + Quadris had the greatest impact on reducing the incidence and severity of silver scurf. On tubers harvested from the field trial at CDCS, Maxim MX PSP, Maxim MZ PSP + Quadris, Polyram 16D and Captan 10% DU had the lowest levels of silver scurf after about five months of refrigerated storage. Maxim MZ PSP + Quadris also seemed to retard the development of verticillium wilt on plants in the field and on black scurf on tubers in storage. A second season of evaluation of these products will be undertaken in 2007 to confirm the results obtained in 2006.

4. Disease Management Trials at CDC North, Edmonton

A replicated field trial originally designed to test the efficacy of seed- and soil-applied chemical treatments against powdery scab, caused by the fungus *Spongospora subterranea* ssp. *subterranea*, was conducted by Mrs. Patricia McAllister and staff at the Crop Diversification Centre North, Edmonton, during the 2006 growing season. At harvest, it was noted that there was a heavy silver scurf infection on the tubers, so it was decided to critically assess the incidence and severity of SS on these tubers. There were seven chemical treatments and one untreated check in this trial (Table 7).

Sixty-four small bags of potatoes (two bags per subplot) were shipped to the CDCS on January 9, 2007. Upon receipt, the potatoes were stored at 8°C and 93% RH. On January 15, an initial evaluation of the untreated control showed very little evidence of growth and/or sporulation of *Helminthosporium solani*, so plastic bag moist chambers containing a 10-tuber subsample for each treatment in every replicate were set up on January 17. The moist chambers were kept at room temperature in a dark storage room for two weeks to promote sporulation. On January 31, the potatoes were examined for the presence the pathogen by using a magnification lamp and a microscope. A sample of tubers from each subplot was rated for DI (% tubers infected) and DS (0–5 scale). These ratings were repeated on February 14 after four weeks of incubation. All data were summarized and a statistical analysis was performed with the ARM 7 program.

None of the products evaluated effectively controlled silver scurf infection on the harvested tubers (Table 8). DS and DI ratings were relatively high on both examination dates. There were no statistically significant ($P \leq 0.05$) differences between treatments for DS and DI on either date. The Tuberseal, Ranman 400 SC and Blinix treatments consistently had amongst the lowest disease ratings on both dates, with Tuberseal being the best-performing product overall.

Project Cooperators

The following individuals, organizations and companies provided technical assistance and/or financial/in-kind contributions

- BASF Canada Inc.
- Engage Agro Corporation
- Heads Up Plant Protectants Inc.
- ISK Biosciences Corp.
- Jeneil Biosurfactant Co.
- Norac Concepts Inc.
- Potato Growers of Alberta
- Sunnycrest Seed Farms and Parkland Seed Potatoes, Lacombe, AB
- Syngenta Crop Protection Canada Inc.

Project Team Members

- Dr. Ron Howard, Sharon Lisowski, Stacie Mobbs, Brenda Scherger, Carol Pugh, Tetyana Matviyenko, Dustin Burke and Dr. Michael Harding, Alberta Agriculture and Food, Crop Diversification Centre South, Brooks
- Dr. Larry Kawchuk, Agriculture and Agri-Food Canada, Research Centre, Lethbridge
- Mrs. Tricia McAllister, Alberta Agriculture and Food, Crop Diversification Centre North, Edmonton

Table 1. Treatment list for silver scurf fungicide trials at the Crop Diversification Centre South, Brooks, AB in 2006.

Treatment No.	**Product Name**	**Application Rate/100 kg seed**
1	Maxim MZ PSP *Syngenta Crop Protection Canada Inc.*	500g
2	Maxim MZ PSP + Quadris *Syngenta Crop Protection Canada Inc.*	500 g Maxim + 4 mL Quadris/100 m of row
3	Maxim PSP *Syngenta Crop Protection Canada Inc.*	500 g
4	Senator PSPT *Engage Agro Corporation*	500 g
5	Tuberseal *Norac Concepts Inc.*	500 g
6	Polyram 16D *BASF Canada Inc.*	550 g
7	Captan 10% DU* *ICI Americas Inc.*	780 g
8	AgGrand *Amsoil Inc.*	4.0 L/150 L water/ha + 3.0 L/150 L water/ha
9	Heads-Up Plant Protectant *Heads Up Plant Protectants Inc.*	1 g/L water
10	Untreated check	- -

* Captan 10% DU was made up of 437.5 g of potato /cornstarch + 62.5 g of Captan 80-WP.

Table 2. Mean plant emergence and total and marketable yields of tubers from a silver scurf fungicide trial in an experimental field plot at the Crop Diversification Centre South, Brooks, AB in 2006.

Treatment number (see Table 1)	Emergence on July 4 (%)[1]	Total weight of harvested tubers ($kg/14.4m^2$)[2,4]	Marketable weight of harvested tubers ($kg/14.4m^2$)[3,4]
1	90.98 cd *	73.45	56.45
2	97.48 ab	73.46	64.50
3	90.98 cd	71.31	55.96
4	89.35 d	68.63	58.28
5	93.50 bcd	72.50	59.11
6	93.53 bcd	70.59	55.99
7	94.43 bc	71.07	56.50
8	98.83 a	68.18	55.66
9	90.05 d	70.39	58.54
10	91.20 cd	67.76	55.58
ANOVA P-Value	0.0001	0.9958	0.9946
LSD (0.05)	3.727	14.587	13.331
CV (%)	2.76	14.21	15.99

[1]Plant emergence ratings were performed on July 4 and were based on the percentage of plants per subplot that had emerged by this date. Raw data were used for analysis and were significantly different according to Duncan's Multiple Range Test at $P \leq 0.05$.
[2]Total yields were the tuber weights (kg/subplot) that were harvested on September 21.
[3]Marketable yields were the tuber weights (kg/subplot) that were harvested on September 21 and did not include deformed, small or cull tubers.
[4]Raw data were used for analysis and were not significantly different according to Duncan's Multiple Range Test at $P \leq 0.05$.
* Values followed by the same letter are not significantly different using Duncan's Multiple Range Test ($P \leq 0.05$).

Table 3. Mean disease incidence (DI) of plants displaying verticillium wilt symptoms on August 9 and 21 in a silver scurf fungicide trial in an experimental field plot at the Crop Diversification Centre South, Brooks, AB in 2006.

Treatment number (see Table 1)	**Wilt DI on Aug. 9 (%)[1]**	**Wilt DI on Aug. 21 (%)[1]**
1	29.53	30.57
2	21.38	23.26
3	13.88	19.58
4	25.28	26.88
5	22.56	25.03
6	25.80	27.73
7	25.77	28.85
8	26.89	30.65
9	24.25	24.25
10	31.54	34.02
ANOVA P-Value	0.6628	0.8472
LSD (0.05)	16.219	16.957
CV (%)	45.28	43.15

[1]DI ratings were based upon the percent of plants per subplot that had wilt symptoms by Aug. 9. Raw data were used for analysis and were not significantly different according to Duncan's Multiple Range Test at $P \leq 0.05$.

Table 4. Silver scurf disease severity and disease incidence levels on unplanted potato seed treated with nine fungicide treatments placed into moist chambers on June 12 and 28 in a silver scurf fungicide trial at the Crop Diversification Centre South, Brooks, AB in 2006.

Treatment number (see Table 1)	Moist chambers set up on June 12				Moist chambers set up June 28	
	Examined June 21*		Examined July 12*		Examined July 26*	
	Tuber DS (0-3)[1,2]	Tuber DI (%)[3,4]	Tuber DS (0-3)[1,5]	Tuber DI (%)[3,4]	Tuber DS (0-3)[1,2]	Tuber DI (%)[3]
1	0.13 c	12.23 b	1.23	96.19 ab	2.18 b	100.00
2	0.20 c	12.91 b	1.05	96.19 ab	1.80 bcd	100.00
3	2.00 a	100.00 a	2.03	100.00 a	2.13 b	100.00
4	0.33 c	21.61 b	0.75	76.29 bc	1.95 bc	100.00
5	0.13 c	9.44 b	0.65	65.45 c	1.78 bcd	100.00
6	0.30 c	18.76 b	1.10	92.53 ab	1.48 d	100.00
7	1.28 b	90.56 a	1.50	100.00 a	2.10 b	100.00
8	1.73 a	100.00 a	1.95	100.00 a	1.63 cd	100.00
9	1.33 b	96.19 a	1.30	99.35 a	2.20 b	100.00
10	2.05 a	100.00 a	2.45	100.00 a	2.75 a	100.00
ANOVA P-Value	0.0001	0.0001	0.0001	0.0016	0.0001	1.0000
LSD (0.05)[6]	0.380	-	0.323	-	0.376	0.000
CV (%)	27.73	30.25	15.91	15.82	12.98	0.00

[1]Silver scurf disease severity (DS) means per treatment are on a 0-3 point scale, where 0 = no colonization of the tuber surface by *Helminthosporium solani*, 1 = <5% colonization, 2 = 5-30% colonization, and 3 = > 30% colonization.
[2]Raw data were used for analysis and means were significantly different according to a Duncan's Multiple Range Test at $P \leq 0.05$.
[3]Silver scurf disease incidence (DI) means were based upon the percentage of tubers evaluated per treatment that displayed symptoms of infection.
[4]Arcsine-transformed data were used for analysis and means were significantly different according to Duncan's New Multiple Range test at $P \leq 0.05$. Detransformed means are presented.
[5]Raw data were used for analysis. Bartlett's Test for homogeneity of variance was significant ($P = 0.05$), so DMRT was not conducted.
[6]Least significant differences were not calculated for transformed data.
* Values followed by the same letter are not significantly different using Duncan's Multiple Range Test ($P \leq 0.05$).

Table 5. Silver scurf disease severity and incidence levels on potato seed that was planted on June 1-2 in a silver scurf fungicide trial in an experimental field plot at the Crop Diversification Centre South, Brooks, AB in 2006.

Treatment number (see Table 1)	Dug up from the soil on June 27				Dug up from the soil July 14	
	Examined July 10*		Examined July 25*		Examined August 4	
	Tuber DS (0-3)[1,2]	Tuber DI (%)[3,4]	Tuber DS (0-3)[1,5]	Tuber DI (%)[3]	Tuber DS (0-3)[1]	Tuber DI (%)[3]
1	1.73	100.00 a	1.60 e	100.00	1.15	97.50
2	1.35	100.00 a	1.13 f	97.50	0.95	92.50
3	1.55	100.00 a	1.95 cd	100.00	1.00	87.50
4	1.48	99.35 a	1.20 f	100.00	1.03	90.00
5	0.90	91.83 b	1.28 f	100.00	1.20	92.50
6	0.98	99.35 a	1.83 de	100.00	1.10	97.50
7	1.65	100.00 a	1.30 f	100.00	1.15	100.00
8	1.33	100.00 a	2.63 b	100.00	1.23	97.50
9	2.05	100.00 a	2.23 c	100.00	1.28	97.50
10	2.70	100.00 a	3.00 a	100.00	1.18	97.50
ANOVA P-Value	0.0001	0.0407	0.0001	0.4635	0.2875	0.3169
LSD (0.05)[6]	0.367	-	0.278	2.294	0.268	10.670
CV (%)	16.09	7.87	10.58	1.59	16.4	7.74

Subsamples were pulled from the ground at 4 and 6 weeks after planting (June 27 and July 14) and were incubated and examined at various intervals.

[1]Silver scurf disease severity (DS) means are on a 0-3 scale, where 0 = no colonization of the tuber surface by *Helminthosporium solani*, 1 = <5% colonization, 2 = 5-30% colonization, and 3 = > 30% colonization.
[2]Raw data were used for analysis. Bartlett's Test for homogeneity of variance was significant (P = 0.05), so a Duncan's New Multiple Range Test was not conducted.
[3]Silver scurf disease incidence (DI) means were based upon the percentage of tubers evaluated per treatment that displayed symptoms of infection.
[4]Arcsine-transformed data were used for analysis and means were significantly different according to Duncan's Multiple Range test at $P \leq 0.05$. Detransformed means are presented.
[5]Raw data were used for analysis and means were significantly different according to Duncan's Multiple Range test at $P \leq 0.05$.
[6]Least significant differences were not calculated for transformed data.
* Values followed by the same letter are not significantly different using Duncan's Multiple Range Test ($P \leq 0.05$).

Table 6. Silver scurf and black scurf disease severity and disease incidence levels on stored tubers harvested from a silver scurf fungicide trial in an experimental field plot at the Crop Diversification Centre South, Brooks, AB in 2006.

Treatment number (see Table 1)	50-tuber subsample ratings on November 30				Moist chambers set up on November 30			
	Black scurf		Silver scurf		Examined December 21*		Examined January 23, 2007*	
	DS (0-5)[1]	DI (%)[2]	DS (0-5)[1]	DI (%)[2]	Tuber DS (0-5)[1,3]	Tuber DI (%)[2,3]	Tuber DS (0-5)[1,3]	Tuber DI (%)[2,3]
1	0.58	52.00	0.00	0.00	0.25 cde	25.00 bc	0.70 bc	67.50 ab
2	0.35	28.50	0.01	0.50	0.33 b-e	27.50 bc	0.78 abc	67.50 ab
3	0.88	78.50	0.00	0.00	0.55 ab	52.50 a	1.10 a	87.50 a
4	1.08	79.00	0.00	0.00	0.48 abc	45.00 ab	1.00 ab	85.00 a
5	0.60	52.50	0.00	0.00	0.50 ab	45.00 ab	0.93 ab	85.00 a
6	0.73	65.00	0.00	0.00	0.13 e	12.50 c	0.48 c	47.50 b
7	0.63	54.50	0.00	0.00	0.23 de	22.50 bc	0.83 ab	72.50 a
8	0.70	67.00	0.00	0.00	0.50 ab	45.00 ab	0.98 ab	82.50 a
9	0.60	57.50	0.01	0.50	0.45 a-d	45.00 ab	0.95 ab	85.00 a
10	0.75	68.00	0.00	0.00	0.63 a	60.00 a	1.05 ab	85.00 a
ANOVA P-Value	0.2528	0.3477	0.4635	0.4635	0.0010	0.0006	0.0115	0.0090
LSD (0.05)	0.481	39.757	0.006	0.612	0.220	19.864	0.311	20.671
CV (%)	48.18	45.48	421.64	421.64	37.73	36.03	24.45	18.62

DS and DI were evaluated on a 50-tuber subsample on Nov. 30 after ca. two months of storage. A 10-tuber subsample was later placed into moist chambers and rated on two dates.

[1]Black scurf/silver scurf disease severity (DS) means are on a 0-5 point scale, where 0 = no colonization by the pathogen; 1 = sparse colonization (<1% tuber surface covered); 2 = slight colonization (1-10% tuber surface covered); 3 = moderate colonization (>10-25% tuber surface covered), 4 = moderate to heavy colonization (>25-50% tuber surface covered), and 5 = heavy colonization (>50% tuber surface covered).
[2]Black scurf/silver scurf disease incidence (DI) means were based on the percentage of tubers evaluated per treatment that displayed symptoms of infection.
[3]Raw data were used for analysis and were significantly different according to Duncan's Multiple Range test at $P \leq 0.05$.
* Values followed by the same letter are not significantly different using Duncan's Multiple Range Test ($P \leq 0.05$).

Table 7. Treatment list for the powdery scab fungicide field trial at the Crop Diversification Centre North, Edmonton, AB in 2006.

Treatment number	Product name	Application rate (per ha)
1	Allegro 500F (in furrow)	3.5 L ha
2	Tuberseal (SPT) [1]	0.5 kg/100 kg
3	Dithane DG (in furrow)	4.0 kg/ha
4	Ranman 400 SC (in furrow /at hilling)	0.45 L/ha (in furrow) 0.20 L /ha (at hilling)
5	Ranman 400 SC (in furrow /at hilling)	1.43 L/ha (in furrow) 0.20 L/ha (at hilling)
6	Blinix (SPT and at hilling)[1]	4.0 mL /45.4 kg of seed (SPT) [1] 593 mL/ha (at hilling)
7	Blinix (at hilling)	593 mL/ha (at hilling)
8	Untreated check	- -

[1]SPT = Seed piece treatment.

Table 8. Silver scurf disease severity and incidence levels on potatoes harvested from the 2006 powdery scab fungicide field trial at the Crop Diversification Centre North, Edmonton, AB.

Treatment number	Moist chambers set up on January 17, 2007			
	Examined January 31		Examined February 14	
	Tuber DS (0-5)[1,3]	Tuber DI (%)[2,3]	Tuber DS (0-5)[1,3]	Tuber DI (%)[2,4]
1	1.98	97.50	3.50	100.00
2	1.28	85.00	2.78	100.00
3	2.35	92.50	3.40	100.00
4	1.98	92.50	3.33	100.00
5	2.08	92.50	3.33	97.45
6	1.98	92.50	3.13	97.45
7	1.95	95.00	3.35	97.45
8	2.48	95.00	3.38	100.00
ANOVA P-Value	0.5352	0.8542	0.7624	0.6320
LSD (0.05)[5]	1.111	15.856	0.873	-
CV (%)	37.65	11.62	18.14	01.54

DS and DI were evaluated on a 50-tuber subsample on January 15 after ca. four months of storage. A 10-tuber subsample was placed into moist chambers and rated on two dates.

[1]Silver scurf disease severity (DS) means are on a 0-5 point scale, where 0 = no colonization by *Helminthosporium solani*; 1 = sparse colonization (<1% tuber surface covered); 2 = slight colonization (1-10% tuber surface covered); 3 = moderate colonization (>10-25% tuber surface covered), 4 = moderate to heavy colonization (>25-50% tuber surface covered), and 5 = very heavy colonization (>50% tuber surface covered).
[2]Silver scurf disease incidence (DI) means were based upon the percentage of tubers evaluated per treatment that displayed symptoms of infection.
[3]Raw data were used for analysis.
[4]Square root-transformed data were used for analysis and means were not significantly different according to Duncan's New Multiple Range test at $P \leq 0.05$. Detransformed means are presented.
[5]Least significant differences were not calculated for transformed data.

Potato Growers of Alberta
Research Tracking

Title of Research Application: Field Applications of Phosphogypsum for Scab Control in Potatoes

Name of Researcher: Tricia McAllister

Employer: AB Agriculture + Food

Date application was received by PGA_____

Date application was reviewed by PGA_____

A) approved ✓ B) declined_____

Project start date:_____ Project finish date:_____

Total amount requested:$ 9,000 Amount requested per year:_____

MOU received and signed. Once copy returned to research agency,
one copy filed in current year Research Binder

Date completed _____

Invoice received: #_____ Date funds advanced_____ Cheque#_____

Invoice received:#_____ Date funds advanced_____ Cheque#_____

Invoice received:#_____ Date funds advanced_____ Cheque#_____

Invoice received:#_____ Date funds advanced_____ Cheque#_____

Were reports received from the researcher?_____

What was done with the reports?

Presented at PGA meeting?_____ Put on PGA website?_____ Filed?_____

NOTES:_____

Potato Growers of Alberta

Proposal application for Research funding 2007-2008

Instructions

To assess the proposals consistently, they must be completed according to the parameters contained in this form. Proposals may be rejected for incomplete information or lack of compliance with the instructions.

Please jump between boxes using the "Tab" key and avoid the use of the "enter" key. The PGA Research Committee will set dates for project proposal submissions, presentations and result reports.

This application could use other sources of forms only if they will be presented to other funding consortiums.

This proposal is confidential ☐

TITLE:
Field Applications of Phosphogypsum for scab control in potatoes.

Team Leader: Patricia McAllister		
Organization: Alberta Agriculture and Food	Section/Department:Ag Research Division Crop-Food Use	
Address:17507 Fort Road NW	City: Edmonton	Province: AB
Postal Code: T5Y 6H3	E-mail : tricia.mcallister@gov.ab.ca	
Phone Number: 780-415-2315	Fax Number: 780-422-6096	

Category of the project (Please check more than one box if necessary):

X Pest Management
☐ Water and Irrigation Management
☐ Potato Storage
☐ Potato Breeding
☐ Potato Plant Physiology
X Potato Fertility Plant
X Nutrition/Soil management
☐ Green House
X Environment
☐ Potato Marketing and Economics
☐ Potato Cultural Management

1. Project Information

Research Location (s): Hoogland Farms, Millet, AB and Northbank Potato Farms Ltd., Fort Saskatchewan, AB

Duration (Y):1+ Start Date (YY/MM): 07/04Ending Date (YY/MM):08/03

Is the project linked to other applications / Research projects Y ☐N X
(Please identify related projects)

1.Project:
Team Leader:

Start Date:

2.Project:
Team Leader:

Start Date:

Background.
(Max 2000 characters)

Common scab is a wide-spread and frequently occurring pest of potato. *Streptomyces scabies* is the main casual agent although *Streptomyces acidiscabies* (acid scab) and *Streptomyces aureofaciens* (russet scab) have also been associated with potato scab in the United States and Canada. Symptoms of acid scab and common scab are round, irregular brown lesions on the tuber surface. The symptoms can be divided into three types: shallow, raised and dip-pitted. Infection can range from a few spots to coverage of the entire tuber. Symptoms depend on the strain of *Streptomyces*, the potato cultivar, soil organic matter content, crop rotation practices, weather conditions and moisture availability. *Streptomyces* can survive in the soil indefinitely living off decaying plant material in the soil. They can be spread by rain and wind-blown soil and on infected tubers. Infection is through the lenticels and usually occurs within the first 5 weeks of tuber development. If tubers are dry during this time the bacteria antagonistic to *Streptomyces* usually present in the lenticels disappear allowing the scab organism to infect. Common scab is usually not a problem in acidic soils but its severity can increase with increasing soil pH. Soil acidification with sulphur and acid-forming fertilizers may be effective in reducing pH and the incidence of

common scab but tends to be impractical in highly buffered organic soils and may increase the severity of acid scab. (Howard, Garland and Seaman eds. 1994. Diseases and Pests of Vegetable Crops in Canada)

Currently there is no method for consistent control of potato scab. What works in one area may not work in other areas. The recommended practice of applying sulphur-containing fertilizers has produced variable results. In Alberta, growers believe they are seeing reductions in scab through the addition of sulphur in the form of ammonium sulphate or as phosphogypsum. The purpose of this trial is to evaluate field applications of phosphogypsum for their ability to reduce scab incidence and severity. Secondary benefits of phosphogypsum application including increases in tuber calcium and improvements to soil tilth will also be explored. This is the preliminary year of this study and if initial results are favourable a larger scale multi-year project will be developed to begin in 2008.

Objectives (Measurable-Deliverables)
(Please use Bullets) (Max 1000 characters)

- Evaluate phosphogypsum for its ability to decrease common scab in susceptible varieties.

Determine if tuber calcium content increases in tubers grown in fields where phosphogypsum has been applied.

Methodology Description
(Please describe the scientific process you will follow to achieve project objectives).(Max 2000 Characters)
In the fall of 2006, phosphogypsum was applied to two fields using a Lowlander widespread wagon. In Fort Saskatchewan, the field was divided into 3 blocks with rates of 0, 2 and 4 tonnes per acre of phosphogypsum supplied by Agrium in Fort Saskatchewan. The field in Millet was divided into 4 blocks with the same rates of phosphogypsum applied plus an additional block where Ammonium sulphate fertilizer was applied. In Millet we plan to have multiple varieties planted in each treatment block.

In the spring of 2007, both fields will be planted and managed using practices common on the respective farms. Two soil samples will be taken from each block (0-6 inches and 6-12 inches) in the spring prior to planting and results will include sulphur and soluble calcium. Growers will keep accurate records of all field activities and will communicate them to the project lead. This will include comments on any differences in soil structure observed during harvest i.e. are there fewer lumps where gypsum has been applied.

Following vine-kill a minimum of ten 10 foot strips will be hand harvested from each treatment block and will be evaluated for total yield and tuber number, yield and tuber profile, specific gravity, and internal defects. A tuber sample from each 10 foot strip will be washed and evaluated for scab intensity and severity. A sub-sample from each treatment will be evaluated for tuber calcium levels to determine if future work examining the impact of tuber calcium on bruising and storability is warranted.

Economical/Environmental Benefits

(Please mention how the results of this project will benefit potato production economically and environmentally.(Max. 1000 characters) .

Potato scab is a common occurring and costly pest of potatoes throughout the world. The greatest losses due to this disease are felt in the fresh-pack and seed industries where thousands of tonnes of potatoes are discarded each year due to the pest. Not only is the product not suitable for sale but growers and packers must discard this cull product. A consistent method to decrease potato scab would reduce grade-out and could potentially open new markets for Alberta product.

Applications of phosphogypsum have been shown to have numerous benefits on soil quality. It has been shown to improve soil structure thereby reducing soil compaction and water logging of soils. It can also reduce wind and water erosion. It has been widely used in soil reclamation projects.

Technology Transfer Plan.

(Please describe the proposed method to communicate findings and results)

Grower co-operators participating in this project will share their first hand experience with fellow growers and the team leader will present the information in poster and/or presentation form at grower meetings throughout the province.

3. Research Team Information

Team Member: Patricia McAllister		
Organization: Alberta Agriculture and Food	Section/Department: Ag Research / Crop, Food U	
Address: 17507 Fort Road NW	City: Edmonton	Province: AB
Postal Code: T5Y 6H3	E-mail : tricia.mcallister@gov.ab.ca	
Phone Number: 780-415-2315	Fax Number: 780-422-6096	

Team Member: Connie Nichol, Environmental Scientist		
Organization: Agrium	Section/Department:	
Address: 11751 River Road	City: Fort Saskatchewan	Province: AB
Postal Code: T8L 4J1	E-mail: cnichol@agrium.com	
Phone Number: 780-998-6659	Fax Number: 780-998-6983	

Team Member: Jeff Nonay		
Organization: Lakeside Potatoes	Section/Department:	
Address: R.R. # 1	City: Legal	Province: AB
Postal Code: T0G 1L0	E-mail address: jeff@cruzinternet.com	
Phone Number: 870-961-4038	Fax Number: 780-961-3412	

Team Member: Ernie Van Boom and Cecil Goutbeck		
Organization: Northbank Potato Farms Ltd.	Section/Department:	
Address: R.R. # 3	City: Fort Saskatchewan	Province: AB
Postal Code: T8L 2N9	E-mail address: cecilg@albertacom.com	
Phone Number:	Fax Number:	

Team Member: Jake Hoogland		
Organization: Hoogland Farms	Section/Department:	
Address: R.R. # 2	City: Millet	Province: AB
Postal Code: T7P 2P6	E-mail address: jakejh@telusplanet.net	
Phone Number: 780-387-5315	Fax Number: 780-387-4351	

3. Project Budget

		Year 1	Year 2	Year 3	**Total**
PGA	Cash	$9000			$9000
	In-Kind				
	Total	$9000			$9000

Other

Agrium	Cash	$1000			$1000
	In-Kind	$3400			$3400
	Total	$4400			$4400
Northbank Farms Ltd.	Cash				
	In-Kind	$2500			$2500
	Total	$2500			$2500
Hoogland Farms Ltd.	Cash				
	In-Kind	$2500			$2500
	Total	$2500			$2500
Lakeside Potatoes	Cash				
	In-Kind	$500			$500
	Total	$500			$500
Total		**$17,900**			**$17,900**

Project Cost Distribution	Year 1	Year 2	Year 3	**Total**
Personnel	$3000			$3000
Travel expenses	$500			$500
Capital goods				
Materials	$500			$500
TOT				
Contract Services	$6000			$6000
Total	**$10000**			**$10000**

*TOT (Transference of Technology)

Research Project Manager

Signature **Date**

POTATO GROWERS OF ALBERTA

6008, 46th Avenue
Taber, Alberta T1G 2B1

Phone (403) 223-2262
Fax (403) 223-2268
e-mail: pga@albertapotatoes.ca
www.albertapotatoes.ca

April 20, 2007

Patricia McAllister
Alberta Agriculture, Food and Rural Development
17502 – Fort Rd. NW
Edmonton, AB T5Y 6H3

Re: Field Applications of Phosphogypsum for Scab Control in Potatoes

Dear Tricia:

We are pleased to advise that the Board of Directors of The Potato Growers of Alberta has reviewed and approved your research funding application.

The funding will be accessible for a one year period in the amount requested of $9,000. When requesting the funds for the project, please provide an invoice that specifies the amount, GST and to whom payable.

We appreciate your commitment and dedication to the potato industry.

Yours truly,

Vern Warkentin
Executive Director

/pl

POTATO GROWERS OF ALBERTA

International Year of the POTATO 2008

May 14, 2008

Dr. Anne Smith
Agriculture and Agri- Food Canada
5403 - 1 Avenue South
PO Box 3000
Lethbridge, AB T1J 4B1

Re: Developing Diagnostic Tools for Nitrogen Management in Potatoes

Dear Anne:

We are pleased to advise that the Board of Directors of The Potato Growers of Alberta has reviewed and approved your research funding application.

For the 2008 season the amount of $10,000 plus GST is available to meet the timelines specified in your application.

Please submit an invoice for the mentioned amount prior to July 31st, 2008. The invoice should indicate the net amount, the total GST, and to whom the invoice is payable.

We appreciate your commitment and dedication to the potato industry.

Yours truly,

Vern Warkentin
Executive Director

/pl

6008 - 46 Avenue, Taber, AB T1G 2B1 • Office 403.223.2262 • Fax 403.223.2268
pga@albertapotatoes.ca • www.albertapotatoes.ca

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Research Branch | Direction générale de la recherche

Office of Intellectual Property and Commercialization
Commercialization Officer: **Charmaine Ross**
Agriculture and Agri-Food Canada
Lethbridge Research Centre
5403 1st Avenue South
Lethbridge, Alberta T1J 4B1
Telephone: (403) 317-2214
Facsimile: (403) 317-2185
E-mail:rosscm@agr.gc.ca

July 8, 2008

Mr. Jeff Bronsch
Technical Director
Potato Growers of Alberta
6008-46 Avenue
Taber, AB T1G 2B1

Dear Jeff:

You will find enclosed **one** original copy of the executed Research Support Agreement between Agriculture and Agri-Food Canada and the Potato Growers of Alberta for the Project, "Developing Diagnostic Tools for Nitrogen (N) Management in Potatoes" for the 2008-2009 fiscal year. Please retain this copy for PGA's records.

If you have any questions or concerns, do not hesitate to contact me at (403) 317-2214 or by email.

It has been a pleasure working with the Potato Growers of Alberta.

Sincerely,

Charmaine

Charmaine Ross
Office of Intellectual Property
& Commercialization

Canada

Office of Intellectual Property and Commercialization
Agriculture and Agri-Food Canada
Commercialization Officer: **Charmaine Ross**
Tel: **403-317-2214**
Fax: **403-317-2185**
Research Scientist: **Dr. Anne M. Smith**
Office of Intellectual Property File: **STAT 1360150**

June 3, 2008

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008-46 Avenue
Taber, AB
T1G 2B1

Dear Mr. Warkentin:

RE: Research Support Agreement
Between: Agriculture and Agri-Food Canada AND Potato Growers of Alberta ("Contributor")
Project: Developing Diagnostic Tools for Nitrogen Management in Potatoes

1. This is a Research Support Agreement (RSA) between the Contributor and Her Majesty the Queen in Right of Canada as represented by the Minister of Agriculture and Agri-Food ("AAFC") whereby the Contributor pays to AAFC cash support of **CDN $10,000** ("Contribution") for the Project detailed in Appendix "A" (Description of Research Project). The funds will be due upon the signing of this RSA.

2. The Contribution will be directed toward the Project conducted at the Lethbridge Research Centre, Lethbridge, Alberta and led by the Principal Investigator, Dr. Anne Smith.

3. The Contribution will assist in conducting the Project, and the AAFC research will be of direct or indirect benefit to the Contributor.

4. The Project will be conducted from June 1, 2008 to March 31, 2009, inclusive.

5. You, the Contributor, agree that:
   (a) The Contribution will be used to fund the Project as outlined in Appendix "A";
   (b) AAFC's only obligation is to use the Contribution for the Project mentioned above;
   (c) If appropriate, research results will be published, subject to any patent or trade secret concerns;
   (d) Any and all intellectual property arising from the Project is the sole property of AAFC;
   (e) The Contribution is irrevocable; and
   (f) There are no other understandings or agreements regarding this contribution or Project except as stated in this RSA.

If you find these terms and conditions acceptable, please have the appropriate authority in your organization date and sign both copies of this RSA (in any colour of ink other than black), keep one original for your records, and return the other to us for our files.

This Research Support Agreement has been executed, in duplicate, by duly authorized representatives of the parties and effective on the date of the last signature.

Yours truly,

John Culley, Ph.D.
Director, Office of Intellectual Property and Commercialization
Agriculture and Agri-Food Canada

For: Potato Growers of Alberta:

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta

Date: JUNE 12, 2008

APPENDIX "A"
DESCRIPTION OF RESEARCH PROJECT:
Developing Diagnostic Tools for Nitrogen Management in Potatoes

Background:

Optimization of nitrogen (N) application in potatoes offers economic and environmental advantages. Although N fertilizer is applied in the seeding preparations, in-season N fertilizer may also be required to maximize yield. Whether additional N is applied through fertigation, banding or top-dressing, it is usually initiated following nitrate (NO_3-N) analyses of petiole samples. Petiole sampling is the "standard" for in-season monitoring of N levels in potato, but disadvantages to this technique include the NO_3-N levels can vary with the experience of the sampler, the time of day of sampling, the method of sampling, the laboratory assay methods employed and there is also a delay between petiole sampling and obtaining the necessary information for management decisions. In recent years, there had been considerable interest in the use of various hand held and tractor mounted instruments for "real-time" estimation of N deficiencies in a variety of crops including potatoes. These instruments include the hand-held Greenseeker, chlorophyll meter (SPAD-502), and Dualex meters. Depending on the crop, cost savings have been estimated at $10 to $20 per acres using in-season fertilization.
In 2007, with funding from the PGA, a pilot study was undertaken to (a) evaluate the use of the Greenseeker, SPAD-502, and Dualex meters for measuring in-season N deficiency in potatoes and (b) determine the relationship amongst the Greenseeker, SPAD-502 and Dualex readings and petiole NO_3-N values. The study was superimposed on an existing experiment designed to examine petiole nutrient recommendations for Russet Burbank potatoes. The results from this one year study showed these instruments, in particular the Dualex which showed a good relationship with petiole NO_3-N readings, could be useful alternatives to petiole sampling. Consequently, funding is being sought to continue the study into a second year.

Objectives:
To obtain a second year of data in support of investigating the SPAD, Greenseeker and Dualex meters as alternative tools to petiole NO_3-N sampling for in-season estimation of N-levels in potatoes.

Various instruments will be used, along with traditional petiole sampling, to assess N sufficiency of the potato crop to determine their effectiveness in predicting the need for in-crop N applications to optimize yield. Ultimately, the use of these instruments, either hand held or tractor mounted, may offer the potential to reduce negative environmental effects from nutrients and improve the economics of production for the producer both of which are national Science priorities within Agriculture and Agri-Food Canada.

Impacts/Benefits:
Nitrogen (N) fertilization in annual cropping is key to maximizing yield and quality. In crops such as potatoes which is a high user of N, optimization of N application offers economic and environmental advantages. Excessive N reduces quality of the tubers thereby reducing economic returns. In addition over fertilization can potentially have a high environmental cost as a result of contamination of both surface and groundwater resources and contributing to greenhouse gas emissions. In contrast, too little N leads to stunted growth, premature death of

the vines, increased susceptibility to diseases such as early blight or *Verticillium* and consequently reduced yields. In-season application of N fertilizer whether through fertigation, banding or top-dressing is usually initiated following nitrate (NO3-N) analyses of petiole samples (Zhang et al. 1996, Waterer and Heard 2005). Although petiole sampling is the "standard" for inseason monitoring of N levels in potato, there are some disadvantages to this technique. The NO3-N levels can vary with the experience of the sampler, the time of day of sampling, the method of sampling, and the laboratory assay methods employed. There is also a delay between petiole sampling and obtaining the necessary information for management decisions. In recent years, there had been considerable interest in the use of various hand held and tractor mounted instruments for"real-time" estimation of N deficiencies in a variety of crops including potatoes. A number of studies reported in the literature indicate the use of a chlorophyll meter or the Greenseeker which measure plant leaf chlorophyll content and canopy "greenness" respectively have potential for managing in-season N fertilization on potatoes (Olivier et al. 2006, Bowen et al. 2005). More recently investigations into the use of fluorescence excitation and the Dualex field portable instrument for N management have appeared in the literature (Cartelat et al. 2005). The Dualex offers a potential tool for in-season nitrogen management (Tremblay and Bélec 2006) but to date there is no data in potatoes. The use of these instruments has not to our knowledge been tested in southern Alberta conditions with varieties grown in this region. Ultimately, the use of hand held or tractor mounted tools may help producers achieve self-sufficiency and "real-time" results for N management.

Science Plan:

In 2008, the study be superimposed on an on-going study being funded in part by the Alberta Potato Growers and led by Michele Konschuh of Alberta Agriculture and Food to examine the application of polymer-coated urea (ESN) in potato production in southern Alberta. The on-going experiment includes 10 treatments of varying N levels and application methods at two locations in southern Alberta. Petiole samples will be collected from each plot, at each site 3 times throughout the growing season and NO_3-N measurements made to ascertain when N from the coated urea becomes available. Coincident to the collection of the petiole samples by Dr. Konschuh's team, our team will collect SPAD, Dualex and Greenseeker measurements in each plot. Multiple samples for each instrument will be taken in each plot, to provide a measure of variability within as opposed to across treatments. The values from the various instruments will be correlated with the petiole samples and also final yield and used with the results from 2007 to further the development of hand-held tools for "in-season" N assessment in potatoes. As the main test site will involve small plots, we will endeavour, depending upon time and labour availability, to conduct limited tests in growers' fields in association with one of the agricultural sector suppliers to mimic application of the technology in commercial potato sites.

Deliverable:
A report outlining the work undertaken, the relationship between the various instrument readings and (a) petiole N-samples and (b) final yield and the potential for further work to develop real-time diagnostic tools for N management in potatoes.

AAFC=s Commitment and Role in the Project:
The objectives and work are consistent with those outlined by the lead AAFC scientist within the approved peer reviewed project entitled "Integrated Nutrient Management for Improved Productivity and Environmental Sustainability". As indicated AAFC will be responsible for

acquiring the measurements with the various hand-held instruments, for analysis of the data and delivery of a report to the Potato Growers of Alberta outlining the work undertaken, the relationship between the various instrument readings and (a) petiole N-samples and (b) final yield and the potential for further work to develop real-time diagnostic tools for N management in potatoes. Agriculture and Agri-Food Canada will not be responsible for establishing the field sites.

Company=s Commitment and Role in the Project:
The Potato Growers of Alberta will provide $10,000 in order for Agriculture and Agri-Food Canada to conduct the work outlined above.

Evaluation of Early Blight (*Alternaria solani)* Prediction Techniques for Southern Alberta

Ted Harms[1], Ron Howard[2], Michele Konschuh[2]
[1]Technology and Innovation, [2]Pest Management, [3]Industry Development
AF Crop Diversification Center South, Brooks AB.

EXECUTIVE SUMMARY

The infection risk from early blight (*Alternaria solani*) in potato fields is widespread throughout Alberta during the growing season. Control with an appropriate fungicide is necessary and research has indicated that applications prior to the appearance of airborne spores do not contribute to disease suppression. Protectant fungicides applied after the appearance of the disease also result in diminished disease control. Therefore, timing of fungicide applications is crucial. Various predictive models are available to assist with the timing of fungicide applications for early blight. Many predictive models are based on an initial application of fungicide after an accumulated 300 P-Days (physiological days) (e.g. WISDOM, TOMCAST, SureHarvest for Potatoes). Subsequent applications are based on factors such as hours of leaf wetness, temperature, and continuous relative humidity above a certain threshold. Other models are referred to as biological models (PLANT-Plus) and include plant factors (new growth, wear-off of chemical), factors about the nature of the disease (infection of unprotected leaves, spore formation and dispersal), as well as meteorological factors.

This research project was conducted initially to evaluate the performance of three models in prediction of early blight in potato fields. Two models used the 300 P-Day factor (WISDOM and TOMCAST) and one biological model considered plant, disease, and meteorological factors (PLANT-Plus) to initiate fungicide applications. The study was conducted in the Grassy Lake/Fincastle/Bow Island area of southern Alberta. In 2005, a field was divided into thirds and a different model was used to time fungicide applications on each third of the field. In 2006 and 2007, two cooperator's fields were divided in half and the WISDOM and PLANT-Plus models were used for early blight prediction. Two additional fields in the area in each year were monitored and evaluated for early blight infection, but the timing of fungicide and the product used was left to the discretion of the producer. The research team evaluated all fields for the presence of early blight and degree of infection on four occasions throughout the growing season in 2005 and 2006 and twice in 2007.

The source for meteorological data was also assessed and six meteorological stations were included in the evaluation for timing of fungicide application. The six meteorological stations included: Bow Island SubStation, Bow Island Provincial Building, Barnwell, Fincastle, a stand-alone meteorological station adjacent to the monitored field, and a stand-alone meteorological station within the field.

The cost of control for early blight varied with the product used, rate applied, and the frequency of application. In 2005, the highest cost ($263.37 ha^{-1}) for early blight control was on Field 3, which had six fungicide applications. The lowest cost ($72.12 ha^{-1}) for control was the PLANT-Plus system, which recommended two sprays. In 2006 and 2007, again the highest cost of early blight fungicide control was on fields where no prediction model was used ($221.40 ha^{-1} and $313.93 ha^{-1}, respectively). The fewest sprays and the lowest cost for early blight control occurred using the PLANT-Plus system.

A general trend was that disease development was lower on fields with the highest frequency of fungicide application; however, the highest number of fungicide applications for early blight control did not necessarily translate into statistically significant reduction in incidence and severity of early blight infection.

The TOMCAST model is not suitable for early blight prediction in southern Alberta without more rigorous calibration and validation to identify the temperature intervals most appropriate for semi-arid and irrigated conditions.

The WISDOM model is insensitive to seasonal weather patterns. Recommendations for spray intervals and fungicide rates (low, medium, high) were similar regardless of the source of the meteorological data. Recommendations appeared to be biased towards the accumulated P-Day calculation, even in the absence of threshold late blight disease severity values (DSV's) being attained. Using the WISDOM model for timing of fungicide applications would follow a program of prevention, independent of disease risk, and there would be no opportunity to reduce fungicide applications.

PLANT-Plus is the one prediction technique evaluated that scheduled fungicide applications based on disease risk. Thus, the opportunity for lowering the frequency and cost of sprays for early blight in years when the weather is not conducive for early blight development, may be realized.

There were no significant differences in the yield and quality of tubers in any year on the fields that used the predictive models.

The TOMCAST model requires within-field meteorological data, whereas the WISDOM and PLANT-Plus system require accurate and timely data obtained from the nearest meteorological station.

INTRODUCTION

Rising international standards for food safety and a growing demand among consumers and corporate clients to reduce the use of pesticides in food production necessitates investigation of pesticide use protocols in various food production systems.

Potato (*Solanum tuberosum* L.) is currently one of the more economically important crops grown in the irrigated areas of southern Alberta contributing more than $150 million to farm cash receipts in 2006 and approximately $300 million to the provincial economy due to value added processing. Production costs are high for potatoes (averaging $6200 ha^{-1} in 2006). The cost of pesticides to control the various insect, fungal and bacteria diseases that are common in potato production contribute to these high costs of production. Reduction in any one of the pesticide inputs to potato production would lead to both a savings for the producer and an improvement in food safety for the consumer.

The appearance of early blight (*Alternaria solani*) in potato fields in southern Alberta is a yearly occurrence. The severity of infection in any one year is variable depending on, among other things, weather conditions throughout the growing season.

Several fungicides are available to effectively control early blight, but the timing of application is crucial. Fungicide applications, prior to flowering, or before the appearance of airborne spores, are ineffective in controlling early blight (Franc et al., 1988; Gent and Schwartz, 2003). Protectant fungicides applied after appearance of early blight lesions results in diminished disease suppression and may result in yield loss (Gent and Schwartz, 2003). Thus, the timing of fungicide applications is crucial for the effective control and reduction of early blight infections.

Numerous methods have been developed to assist producers in timing fungicide applications. Methods available to predict the initiation of early blight include some measure of either Physiological Day (P-Day) (Pscheidt and Stevenson, 1988) and/or Growing-Degree Days (GDD) (Franc et al., 1988). Most predictive models (e.g. WISDOM, TOMCAST) use 300 P-Days as the threshold to start fungicide applications. Timing of subsequent applications is based either on a fixed spray schedule or on a combination of certain meteorological parameters. The PLANT-Plus technique provided by Dacom Plant Service, Emmen, the Netherlands, uses a combination of potato plant growth stages, local weather conditions, and weather forecasts to predict susceptibility of potato plants to early blight infection (Raatjes et al., 2003).

Stevenson and James (2004) compared the predictions from the WISDOM model to those of PLANT-Plus in a replicated potato trial at Hancock, WI. They concluded that the use of a disease prediction technique or decision support system (DSS) resulted in a reduction in the number of fungicide applications while attaining similar disease control compared to a regular weekly fungicide application schedule. Similar results were reported by Dowley and Burke (2005) comparing disease prediction models to a regular weekly

fungicide application schedule to control late blight in potatoes in Ireland. They concluded that all DSS resulted in a decrease in fungicide use and no loss of blight control. Use of a DSS resulted in fungicide application reductions by as much as 58% compared to the weekly application schedule.

One of the impediments of widespread adoption of disease prediction techniques was identified by Gent and Schwartz (2003) as the requirement for an in-field meteorological station to provide the necessary temperature, relative humidity and/or leaf wetness parameters as input to the various models. Disease predictions obtained from regional meteorological stations would be more convenient, cover a wider geographic area and be included with general crop information via the web or some other communication medium. They concluded that early blight forecasts were just as accurate when the source of the meteorological data for the P-Day or GDD calculation was a nearby meteorological station than if the data were obtained from an in-field meteorological station.

The objectives of this research project were:
1) To evaluate three methods for prediction of the presence and prevalence of early blight in potatoes, including:
    a) PLANT-Plus
    b) WISDOM
    b) TOMCAST
2) To assess the effect of the source of the meteorological data (either in-field or off-field) on model predictions.

METHODS

Background

In 2005, three early blight prediction techniques (WISDOM, TOMCAST and PLANT-Plus) were chosen for evaluation on one potato field in southern Alberta.

The field was divided into thirds and each third of the field used one of the prediction models to predict timing of fungicide application (Fig. 1).

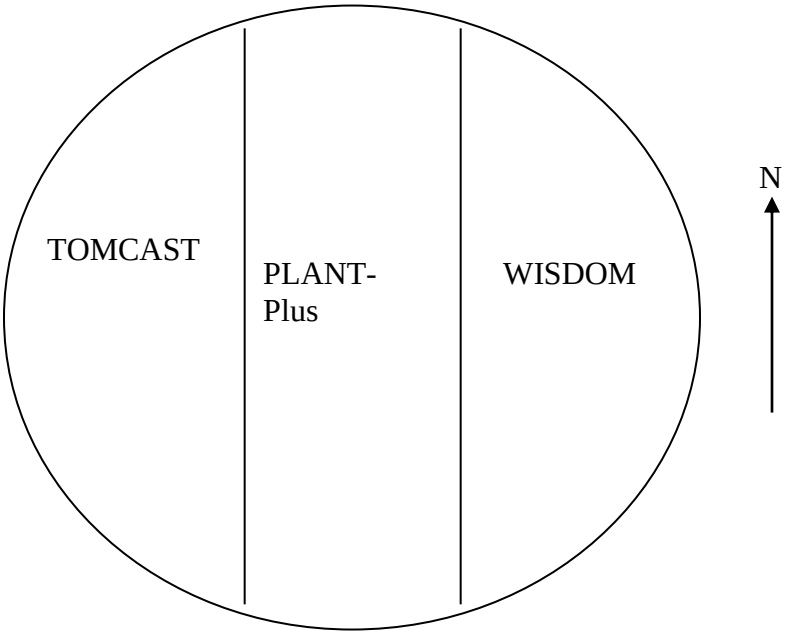

Fig. 1. Location of early blight prediction models in field.

Two additional potato fields were chosen in southern Alberta whereby the grower applied fungicide control on their own schedule without influence from any prediction technique.

Two fields were selected in 2006 and 2007 to test the early blight prediction models, WISDOM and PLANT-Plus. Based on the results of 2005, the TOMCAST model was dropped from the evaluation in 2006 and 2007. In 2006 and 2007, the fields were divided in half and spraying for early blight was based on the individual model predictions (WISDOM and PLANT-Plus).

Similar to 2005, two additional potato fields were chosen in each year whereby the grower applied fungicide control on their own schedule without influence from any prediction technique.

All fields included in the evaluation grew the Russet Burbank variety of potato. Field operations, other than timing of fungicide, were left to the discretion or "normal practice" of the cooperators. That included the type of fungicide to use for early blight control.

Crop observations and pictures for all fields were taken weekly by the technologist from Bow Island and the information was entered into the PLANT-Plus system.

Meteorological data from six different stations were used and compared. Meteorological stations used included: stations owned, maintained and operated by the Alberta Agriculture and Food (Fincastle, Barnwell and Bow Island North), a station owned and maintained by Atmospheric Environment Service (Bow Island South), and two stations owned and maintained by TruElements (in-field and off-field).

Field scouting for infection was done four times during the growing season in 2005 and 2006 and twice in 2007, with leaf samples taken to evaluate disease frequency and severity.

Tuber samples were harvested from four random locations within each treatment. At each location, a 7 m section was delineated and the tubers were collected with a two-row mechanical potato digger. Quantity and quality determinations were done for each sample.

Mean comparisons ($p < 0.05$) for yield, quality and disease were done using Tukeys means test provided the data passed the normality and equal variance test. Mean comparisons for disease were done using Kruskal-Wallis rank test when equal variance test failed (SPSS Inc, 1997).

Background on Models

Physiological Day (P-Day). The P-Day procedure was proposed by Sands et al. (1979) to predict potato yield and modified by Pscheidt and Stevenson (1986) for application to potato development and early blight appearance. The P-Day calculation requires only daily maximum and minimum temperatures as input. The algorithm is:

P-Days ={1/24[5P(Tmin) + 8P(2Tmin/3 + Tmax/3) + 8P(2Tmax/3 + Tmin/3) + 3P(Tmax)]}

Where:
P(T) = 0 if T < 7°C
$P(T) = 10[1 - (T - 21)^2/(21 - 7)^2]$ if 7°C < T < 21°C
$P(T) = 10[1 - (T - 21)^2/(30 - 21)^2]$ if 21°C < T < 30°C starting at emergence.
P(T) = 0 if T >30°C

Tmin – minimum daily temperature (°C)
Tmax – maximum daily temperature (°C)

The model assumes 7°C minimum, 21°C optimum and 30°C maximum growth temperatures for potato plant development, as well as diurnal fluctuations.

Growing Degree Day. The Growing Degree Day (GDD) method was modified by Franc et al. (1988) for initiation of fungicide applications to control early blight in Colorado. The proposed base temperature of 7.2°C resulted in the subsequent equation:

$$GDD = \left[\frac{(T\max + T\min)}{2} \right] + 7.2$$

They reported that primary lesions could be expected to appear at cumulative 361 GDD in the San Luis Valley area of Colorado, whereas primary lesions would only be expected to appear after 625 GDD in northeastern Colorado.

TOMCAST. The TOMCAST model was derived from the FAST model (Madden et al.,1978) developed at the University of Pennsylvania. Although it was developed to predict early blight, septoria leaf spot, and anthracnose development on tomatoes, the model has been used successfully to predict early blight development on potatoes (Pscheidt and Stevenson, 1988; Christ and Maczuga, 1989).

The first fungicide application for early blight occurs once cumulative P-Days after emergence reach 300. For subsequent sprays, the model generates disease severity values (DSVs) as units of disease development for pathogens. The DSVs are a numerical representation of the rate at which disease pressure is accumulating on the potato plant leaf tissue. The DSV is determined by two factors: leaf wetness and temperature during the leaf-wet hours. As the number of leaf wet hours and temperature increases, DSVs accumulate at a faster rate, i.e., increased disease pressure. Conversely, when there are fewer leaf-wet hours and the temperature is lower, DSV accumulate slowly if at all, i.e., decreased disease pressure (Table 1).

Table 1. Disease severity value chart.

Average Temperature (°C) During Leaf Wet Hours	Leaf Wetness per Day (h)				
13-17	0-6	7-15	16-20	21 +	
18-20	0-3	4-8	9-15	16-22	23+
21-25	0-2	3-5	6-12	13-20	21+
26-29	0-3	4-8	9-15	16-22	23+
Daily DSV =	**0**	**1**	**2**	**3**	**4**

When the total number of accumulated DSV exceeds a pre-determined limit, the spray threshold, a fungicide spray is recommended to protect the foliage from disease development. The spray threshold can range between 15-20 DSV and for this study we used 17.

WISDOM. The WISDOM model was developed by the University of Wisconsin Extension in Madison, Wisconsin, as a four module Integrated Pest Management and Irrigation Scheduling decision support tool (Stevenson, 1993). Advice on timing and application rate (low, medium, and high) of fungicides for both early blight (*Alternaria solani*) and late blight (*Phytophthora infestans*) disease development on potatoes is contained in the disease management module. Insect management, weed management, and irrigation scheduling are the other modules contained within the WISDOM model (Fig. 2).

Fig. 2. User interface for the WISDOM model.

Like TOMCAST, the first fungicide application for early blight, within the WISDOM model, occurs once cumulative P-Days after emergence reach 300. Subsequent sprays for early blight are on a fixed-spray schedule (depending on time of season and how fast P-Days are accumulating). The spray schedule varies from 14 days immediately after the first fungicide application to 7 days later in the season.

PLANT-Plus. Plant-Plus is a decision support system (DSS) provided by Dacom Plant Service, Emmen, the Netherlands. The system aids in the timing of fungicide applications by predicting infection events using fungal life-cycle models and weather prediction models. PLANT-Plus integrates the rate of crop development with infection pressure, local weather data, and weather forecasts to provide fungicide application advice (Raatjes et al., 2003).

The model can be divided into three submodels:

1) Unprotected part of the crop
   a. Growth of new leaves
   b. Degradation and wear off of chemicals

2) Infection events of the disease
   a. Formation of spores on each infected leaf
   b. Ejection and dispersal of spores into the air
   c. Germination of spores and penetration into unprotected leaves

3) A combination of unprotected leaf area and infection events into treatment recommendations.

Integrating local meteorological data of temperature, wind speed, rainfall, and humidity; five-day meteorological forecasts and input from the grower on crop conditions, PLANT-Plus calculates when an infection event is likely to occur and advises on when to apply a spray and what type of chemical to use. The PLANT-Plus system depends on ratings to assess how much of the crop is unprotected from previous fungicide applications. The spray thresholds are portrayed as a graph that indicates the disease pressure (Fig. 3).

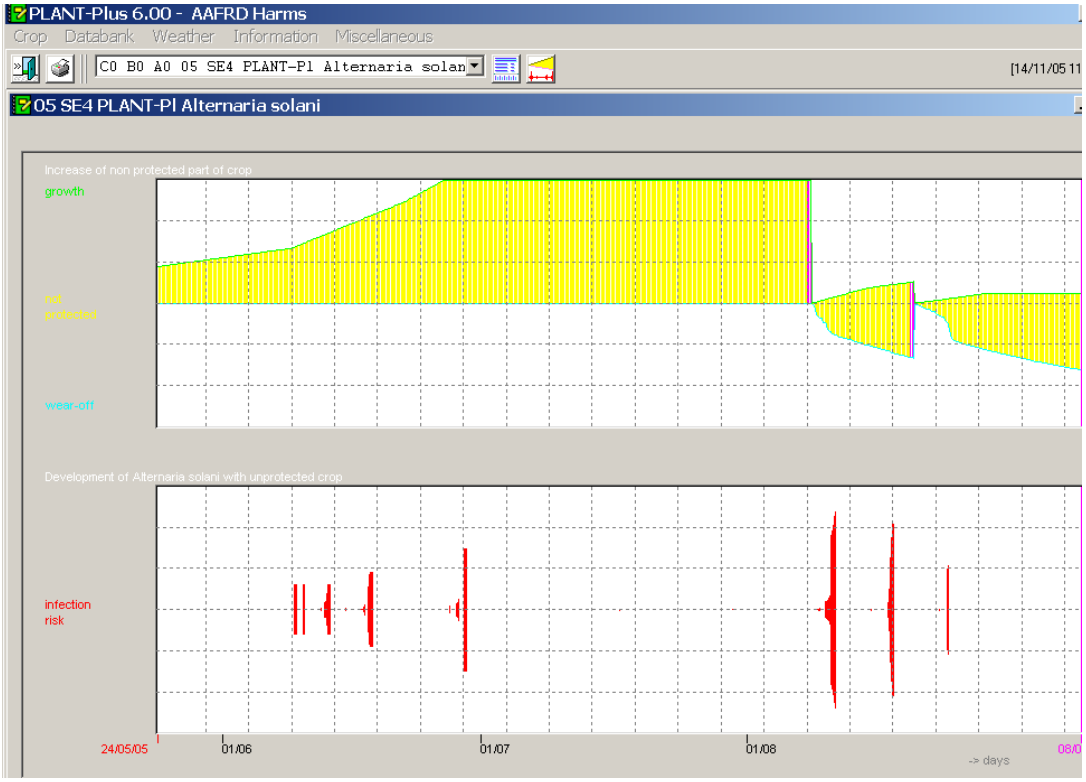

Fig. 3. Display from PLANT-Plus system indicating disease infection risk.

RESULTS

Meteorology

Growing season weather conditions for 2005 to 2007 were quite variable, but the critical months for early blight development, typically July and August in southern Alberta, had well below the long normal precipitation (LTN) in July in all years, and in August in 2006 and 2007 (Table 2).

Table 2. Monthly precipitation amounts for Fincastle and Bow Island for 2005-2007.

	May 31	June 30	July 31	August 31
Bow Island				
2005	3.0	149.8	1.6	49.2
2006	39.6	156.1	13.7	16.1
2007	74.1	53.3	3.6	24.8
LTN	26.8	61.4	55.3	46.9
Fincastle				
2005	11.6	173.0	2.0	53.0
2006	27.8	151.1	9.5	26.7
2007	73.5	23.5	0.8	33.9
LTN	47	62.7	34.1	42.8

Cumulative P-Days were more consistent at month-ending in all years (Table 3) compared to cumulative growing degree days (Table 4). The lowest cumulative P-Days and growing-degree days were calculated in 2005, a reflection of lower average seasonal temperatures.

Table 3. Cumulative P-Days from May 20 emergence to month ending.

	May 31	June 30	July 31	August 31
Bow Island				
2005	61	263	504	707
2006	72	310	569	799
2007	47	270	513	744
LTN	87	331	592	829
Fincastle				
2005	66	280	512	723
2006	72	310	569	799
2007	47	270	513	744
LTN	71	293	554	799

Table 4. Cumulative growing degree days from May 1 to month ending.

	May 31	June 30	July 31	August 31
Bow Island				
2005	199	490	922	1260
2006	259	623	1114	1527
2007	215	559	1094	1499
LTN	330	707	1159	1552
Fincastle				
2005	214	533	942	1285
2006	255	610	1094	1500
2007	227	565	1098	1491
LTN	212	541	957	1342

Fungicide Applications

In 2005, the 300 P-Day threshold from all meteorological stations was reached between July 5 and July 9. The first sprays for the east and west third of the field using schedules predicted with the WISDOM and TOMCAST techniques occurred on July 5. Subsequent sprays occurred on July 25, August 8, and August 20. The first spray for the center third using the PLANT-Plus system for prediction occurred on August 8 (535 cumulative P-Days, 796 cumulative GDD), with a subsequent spray on August 20 (Table 5).

In 2006, the 300 P-Day threshold from all meteorological stations was reached between June 29 and July 4. The first sprays for early blight, as predicted by the WISDOM model,

occurred on June 29. In 2007, similar to the previous years, 300 cumulative P-Days occurred the first week of July for all meteorological stations. The subsequent sprays and chemicals used by the individual cooperators are detailed in Table 5.

Table 5. Timing of fungicide application, chemical used, and rate.

Field No.	Model Used	Spray Date and Product Used					
				2005			
One	WISDOM	July 5 Quadris 0.49L/ha	July 25 Bravo 1.6 L/ha	August 8 Bravo 2.5 L/ha	August 20 Bravo 2.5 L/ha		
One	TOMCAST	July 5 Quadris 0.49 L/ha	July 25 Bravo 1.6 L/ha	August 8 Bravo 2.5 L/ha	August 20 Bravo 2.5 L/ha		
One	PLANT-Plus			August 8 Bravo 2.5 L/ha	August 20 Bravo 2.5 L/ha		
Two	None	July 14 Bravo 1.6 L/ha *Ridomil 2.47 kg/ha*	Aug 3 Quadris 0.98 L/ha				
Three	None	June 20 Bravo 2.47 L/ha	June 29 Quadris 0.98 L/ha *Ridomil 2.2 L/ha*	July 13 Manzate 2.22 Kg/ha	July 20 Bravo 2.47 L/ha *Curzate 0.22 kg/ha*	Aug 6 Bravo 2.47 L/ha	Aug 20 Manzate 2.22 kg/ha
				2006			
One	WISDOM	June 29 Bravo 2.2 L/ha	July 13 Penncozeb 1.5 kg/ha	July 30 Bravo 1.7 L/ha	August 14[b]	August 28[b]	
One	PLANT-Plus		July 13[a] Penncozeb 1.5 kg/ha	July 30[a] Bravo 1.7 L/ha	August 8[b]	August 23[b]	
Two	WISDOM	July 1 Quadris 0.74 L/ha	July 15[b]	July 31 Bravo 2.2L/ha	August 10[b]	Aug 27 Bravo 2.2 L/ha	
Two	PLANT-Plus		July 31[a] Bravo 2.2L/ha		August 8[b]	Aug 27 Bravo 2.2 L/ha	
Three	None	June 21 Quadris 0.98 L/ha	July 10 Bravo 2.47 L/ha	July 25 Bravo 2.47 L/ha	Aug 8 Bravo 2.47 L/ha		
Four	None	June 12 Bravo 2.2L/ha	July 8 Bravo 2.2L/ha				
				2007			
One	WISDOM	June 29 Ridomil Gold 2.2 L/ha	July 19 Ridomil Gold 2.2 L/ha	Aug 8 Hail damage ended trial			
One	PLANT-Plus	June 29[a] Ridomil Gold 2.2 L/ha		Hail damage ended trial			
Two	WISDOM	July 4 Ridomil Gold 2.2 L/ha	July 20 Ridomil Gold 2.2 L/ha	Aug 9 Quadris 0.98 L/ha	Aug 18[b]	Aug 29[b]	
Two	PLANT-Plus	July 4[a] Ridomil Gold 2.2 L/ha	July 20[a] Ridomil Gold 2.2 L/ha	Aug 9[a] Quadris 0.98 L/ha	Aug 18[b]		
Three	None	June 22 Quadris 0.98 L/ha	July 6 Bravo 2.47 L/ha	July 20 Manzate 2.2 kg/ha	Aug 4 Quadris 0.98 L/ha	Aug 24 Manzate 2.2 kg/ha	
Four	None	June 25 Ridomil Gold 2.2 L/ha	July 3 Quadris 0.98 L/ha	July 30 Bravo 2.47 L/ha	Aug 16 Bravo 2.47 L/ha	Aug 25 Bravo 2.47 L/ha	

Note: Chemical in italics not for early blight control. Not included in calculations for spray costs.
[a] – spray applied but not dictated by prediction program. [b] – spray dictated but not applied by cooperator.

Growing-Degree Days

Cumulative GDD from planting for all stations, up until the first spray (July 5, 2005; June 29, 2006; July 4, 2007) are listed in Table 6. Cumulative GDD were less variable among stations in a given year but more variable for a given station in comparitive years.

Table 6. Cumulative growing-degree days from May 15 to 300 cumulative P-Days for individual stations.

Station	Bow Island Substation	Bow Island Provincial Bldg	Fincastle	Adcon On-Field	Adcon Off-field	Barnwell
2005	468	456	466	No data	434	Missing data
2006	Missing data	542	529	557	557	508
2007	508	528	506	No data	No data	493

TOMCAST (2005)

The within-field leaf wetness sensor failed in mid-July of 2005, and it was felt that the off-field leaf wetness sensor underestimated the parameters to initiate a spray. Therefore, the TOMCAST field received its second fungicide application on July 25 based on the timing of the WISDOM field. The off-field leaf wetness sensor failed in mid-August and recorded continuous wet conditions.

The PLANT-Plus prediction model identified two fungicide applications in both 2005 and 2006 and one application in 2007. In all three years, the PLANT-Plus system did not identify a fungicide application until early August.

Dacom personnel made the fungicide application timing decisions for PLANT-Plus based on model results and the crop observations of the field technologist. In 2005, the Bow Island North meteorological station was used as the primary, near-field meteorological station; however, access to any other station was available. There were problems expressed in obtaining timely meteorological data. Personnel both from Alberta Agriculture and Dacom worked to resolve many of the initial data acquisition problems.

Economics

The cost of control for early blight varied with the product used, rate applied, and the frequency of application. In 2005, the highest cost per acre for early blight control was on Field 3, which had six fungicide applications. The lowest cost per acre for control was the PLANT-Plus system, which recommended two sprays (Table 7). In 2006 and 2007, again the highest cost of early blight fungicide control was on fields where no prediction model

was used. The fewest sprays and the lowest cost for early blight control occurred using the PLANT-Plus system.

Table 7. Cost of fungicide to control early blight.

2005	
Field One	
WISDOM	$144.86/ha
TOMCAST	$144.86/ha
PLANT-Plus	$72.12/ha
Field Two	
No prediction model used	$122.03/ha
Field Three	
No prediction model used	$263.37/ha
2006	
Field One	
WISDOM	$184.50/ha**
PLANT-Plus	$81.76/ha**
Field Two	
WISDOM	$238.10/ha**
PLANT-Plus	$81.76/ha**
Field Three	
No prediction model used	$221.40/ha
Field Four	
No prediction model used	$81.76/acre
2007	
Field One	
WISDOM	$145.38/ha*
PLANT-Plus	No application initiated*
Field Two	
WISDOM	$244.15/ha
PLANT-Plus	$40.88/ha**
Field Three	
No prediction model used	$280.38/ha
Field Four	
No prediction model used	$313.93/ha

* hail damage ended trial

** based on recommended application schedule of contact fungicide.

Note: Pricing of chemical based on suggested retail price.

Disease Incidence and Severity

In 2005, there were no significant differences among the treatments on the first and second sampling dates. By the August 16 sampling dates, significant differences ($P<0.05$) were seen among the PLANT-Plus, TOMCAST, and Field 2 compared to the WISDOM and Field 3 ratings. For the Sept 1 sampling date, ratings for WISDOM and

Field 3 were still significantly different from PLANT-Plus and TOMCAST, but not from Field 2 (Table 8).

It was unexpected the disease ratings for the TOMCAST and WISDOM treatments would be significantly different for the last two sampling dates since both treatments were sprayed at the same time with the same chemical throughout the season. A prevailing wind phenomenon may have exposed the west part of the field to airborne spores from adjacent fields first, thereby increasing the disease incidence on that part of the field.

In 2006, right from the first sampling date on June 29, Field 3 consistently had the highest incidence and severity of disease. There were some anomalies in the evaluations but by the end of the season, Field 3 and both prediction methods in Field 2 had higher disease severity. All samples collected at the last sampling date (August 30) showed evidence of early blight.

Table 8. Disease incidence and severity.

2005

Sample Dates		4-Jul		26-Jul		16-Aug		1-Sep	
	No. of leaves evaluated	DS[1]	DI[2]	DS[1]	DI[2]	DS[2]	DI[2]	DS[1]	DI[2]
Field 1 WISDOM	100	0	0.0%	0	4.0%	0.2a	24.0%	1.3a	84.8%
Field 1 TOMCAST	100	0	0.8%	0.1	6.0%	0.8b	71.0%	1.6b	96.0%
Field 1 PLANT-Plus	100	0	0.0%	0.1	8.0%	0.5b	41.0%	2.3b	99.2%
Field 2	200	0	4.4%	0.2	14.5%	0.5b	49.5%	1.5b	93.6%
Field 3	200	0	0.0%	0.2	17.5%	0.2a	23.5%	0.9a	70.0%

2006

Sample Dates		June 29		July 19		August 10		August 30	
	No. of leaves evaluated	DS[1]	DI[2]	DS[1]	DI[2]	DS[2]	DI[2]	DS[1]	DI[2]
Field 1 WISDOM	125	0.5a	49%	0.2a	15%	0.5a	43%	2.0a	99%
Field 1 PLANT-Plus	125	0.2b	23%	0.1a	6%	0.4a	34%	1.9a	99%
Field 2 WISDOM	125	0.1b	9%	0.2a	18%	0.6a	46%	2.2b	100%
Field 2 PLANT-Plus	125	0.1b	14%	0.5a	65%	0.4a	43%	2.3b	98%
Field 3	250	0.6a	49%	0.8b	70%	1.9b	98%	3.4b	99%
Field 4	250	0.2b	19%	0.3a	32%	0.6a	50%	2.2ab	100%

2007

Sample Dates		July 11		Aug 8	
	No. of leaves evaluated	DS[1]	DI[2]	DS[1]	DI[2]
Field 1 WISDOM	120	0.08	8%	0.9ab	80%
Field 1 PLANT-Plus	125	0.10	10%	0.8ab	70%
Field 2 WISDOM	125	0.02	4%	1.1a	89%
Field 2 PLANT-Plus	125	0.02	5%	1.0ab	86%
Field 3	250	0.06	6%	0.8ab	70%
Field 4	250	0.02	2%	0.7b	59%

[1]Disease severity (DS) ratings scale of 0-5 based on the percent area of the compound leaf showing blight.
[2]Disease incidence (DI) is calculated by dividing the number of infected compound leaves by the total number of compound leaves collected and expressed as a percent.
Column means followed by the same letter are not significantly different at the $P< 0.05$ probability level.

Potato Yield and Quality

There were no significant differences ($P<0.05$) in yield or quality among any of the treatments in any year.

Table 6. Yield and quality assessment.

Treatment	Total yield (tons/acre)	Marketable yield (tons/acre)	Specific gravity
2005			
Field 1 WISDOM	19.8	14.3	1.099
Field 1 TOMCAST	21.3	15.6	1.101
Field 1 PLANT-Plus	22.7	17.2	1.096
2006			
Field 1 WISDOM	32.9	22.4	1.083
Field 1 PLANT-Plus	29.3	19.8	1.085
Field 2 WISDOM	30.1	21.3	1.088
Field 2 PLANT-Plus	31.7	22.9	1.084
2007			
Field 1	No yield taken due to hail		
Field 2 WISDOM	28.5	20.4	1.103
Field 2 PLANT-Plus	32.9	21.1	1.104

DISCUSSION

It was difficult in all years ensuring the cooperators followed the fungicide application regime based on the advice of the prediction models. A general comment from all cooperators was they were uncomfortable waiting for a fungicide application based on PLANT-Plus. PLANT-Plus did not call for a fungicide to be applied until sometime in August in all years. Cooperators used to putting on a first fungicide application in late June or early July did not want to risk disease development waiting for the conditions necessary to recommend a fungicide application according to the PLANT-Plus system.

The first fungicide application in late June or early July, as called for by WISDOM after 300 P-Days had accumulated, corresponded with a typical first fungicide application for early blight, cooperators were accustomed to apply. However, cooperators felt the timing of subsequent fungicide applications, as predicted by the WISDOM model, were excessive and often did not apply the fungicide according to model output.

An additional complication was with the use of Ridomil Gold. Ridomil was typically used for controlling pink rot and is applied late June or early July as the tubers start to develop. With the introduction of Ridomil Gold, an application timed to control pink rot also includes metalaxyl, the active ingredient in Bravo, which controls early blight.

TOMCAST (2005)

The TOMCAST procedure was developed in Ohio and modified for potatoes in Ontario. The minimum temperature required, with conditions of sustained leaf wetness, was 13^{o}C in the TOMCAST model. In the semi-arid region of southern Alberta, even under irrigated conditions, the 13^{o}C threshold with sustained leaf wetness occurred on one day in 2005 thus, it was felt the model would not identify blight risk. The four temperature thresholds were arbitrarily lowered by 3^{o}C (e.g. 13^{o}C minimum temperature was lowered to 10^{o}C) to more closely coincide with output from other prediction techniques. A reduction of 3^{o}C to the temperature ranges helped to reach 17 DSVs on a couple of occasions through the growing season in 2005, but the reduction was somewhat arbitrary by evaluating the hours of leaf wetness and temperatures observed during the growing season. A more thorough calibration and verification of the model, in an environment where temperature and leaf wetness hours could be varied, would have to be done before the model could be considered for early blight prediction for the semi-arid and irrigated conditions of southern Alberta. It was felt the calibration and validation work required for the model were outside the scope of this study.

WISDOM

The WISDOM model is somewhat insensitive to hourly temperature and relative humidity conditions for early blight prediction. Recommendations are based on cumulative P-Days and how fast they are accumulating or on the time of year. Following the initial spray after 300 cumulative P-Days, the recommendation was to spray on a 14-day schedule (regardless of the meteorological station used or weather conditions). Later in July, after the second spray, the WISDOM model reduced the spray schedule to 10 days and finally to 7 days near the middle of August. The WISDOM model also predicts late blight based on hourly temperature and hours with RH above 90%. The threshold for spraying for late blight is 15 and although the 15 DSV threshold was only reached for the in-field meteorological station in 2005, the WISDOM model would still recommend to shorten the spray schedule, and increase application rates, independent of the source of meteorological data (whether in-field, off-field or regional).

The WISDOM model recommendations of fixed spray schedules of 14 days, reduced to 7 days during the season, is a fairly easy program for producers to adopt. However, being insensitive to meteorological conditions translates into a spray program of prevention, rather than a program whereby the fungicide is applied as the risk of disease increases. The advantage of the WISDOM model is that the calculation of cumulative P-Days does not require an in-field weather station. The nearest meteorological station would provide adequate and similar data to an in-field meteorological station.

PLANT-Plus

The PLANT-Plus system seems to be the only one evaluated that bases the spray timing and rate on current meteorological conditions, future meteorological conditions and plant

growth factors. Unlike the WISDOM or TOMCAST models, where no plant specific information is required, the PLANT-Plus system requires weekly input from the producer on growth and canopy density ratings. The advantage of the PLANT-Plus system is that fungicide applications are based on disease risk. Therefore, the potential to reduce fungicide applications and reduce costs is real. In-field meteorological stations are not necessary since a nearby, representative meteorological station will provide adequate data.

Early Blight Infection and Control

A general trend was that disease development was lower on fields with the highest frequency of fungicide application; however, the highest number of fungicide applications for early blight control did not necessarily translate into a statistically significant reduction in incidence and severity of early blight infection.

Early blight was detected in nearly all leaf samples at the end of season sampling in 2005 and 2006 and on the August 8 sampling date in 2007. Six fungicide applications resulted in similar early blight control as four applications in 2005, and disease development was similar in a field with three fungicide applications by August 8, 2007 compared to a field that had one application. In 2006, Field 3 had the highest disease development for all sampling dates, yet the highest number of fungicide applications at the greatest cost was for this field.

Factors such as fertility, rotations, proximity to other potato fields and reduced soil moisture can result in a potato plant being more susceptible to early blight infection (Miller and Miller, 2004). Application of fungicide should be a part of an integrated approach to reduce early blight infection.

The complication with TOMCAST and WISDOM disease ratings in 2005 made it difficult to be definitive about the difference between two sprays with the PLANT-Plus system versus four sprays with WISDOM and TOMCAST. The disease ratings were lower for the WISDOM model, but it could have easily been from other factors, none of them related to the fungicide applications.

CONCLUSIONS

Different threshold Growing-Degree Days (GDD) were accumulated in all years from May 15 to a total of 300 cumulated P-Days using the same source for the meteorological data. Timing of initial fungicide sprays based on GDD would require many more years of data to obtain a degree of consistency, or to obtain a reasonable average. Cumulative P-Days was less variable and, similar to the conclusions reached by Gent and Swartz (2002), would be a better value to use when initiating fungicide applications.

The TOMCAST model is not suitable for early blight prediction in southern Alberta without more rigorous calibration and validation to identify the temperature intervals most appropriate for semi-arid and irrigated conditions.

The WISDOM model is insensitive to seasonal weather patterns. Recommendations for spray intervals and fungicide rates (low, medium, high) were similar regardless of the source of the meteorological data. Recommendations appeared to be biased towards the accumulated P-Day calculation, even in the absence of threshold late blight DSV being attained. Using the WISDOM model for timing of fungicide applications would follow a program of prevention, independent of disease risk.

PLANT-Plus is the one prediction technique evaluated that scheduled fungicide applications based on disease risk. Thus, the opportunity for lowering the frequency and cost of sprays for early blight in years when the weather is not conducive for early blight development, may be realized.

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Early Dying and Oomycete Analysis and Control

Potato Growers of Alberta
Progress Report 2007/08

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Summary

Sensitive diagnostics have been developed that are capable of detecting trace levels of the early dying and oomycete pathogens. The procedures work on extremely small samples of only a few milligrams, may be used to examine any sample including soil, and results can be available within only a few hours. The procedures are quantitative facilitating the estimation of pathogen levels in seed or soils before planting and are capable of differentiating between strains with different characteristics such as aggressiveness and symptom expression. Application of the developed procedures for the detection of nematodes has proven extremely useful. Over 200 diseased tissue and soil samples have been examined to date. Several species of *Verticillium* were isolated from early dying samples and a number of strains of the late blight pathogen were observed compared to the lack of variation seen in the pink rot isolates. Greenhouse and field trials have facilitated evaluation of disease symptom expression in potato varieties, characterization of the diagnostics, and determination of the most effective application parameters for the control measures. Several potential probiotics have been isolated from endemic soils that are being evaluated for disease prevention. Producers are encouraged to continue submitting diseased samples for confidential evaluation and thereby assist in characterizing the diagnostics and prevention strategies. Agriculture and Agri-Food Canada approved an application to match the Potato Growers of Alberta contributions for this project through support of a competitive Matching Investment Initiative application. This project is now entering the third and final year.

Background

Early dying is a common disease, caused by several different species of *Verticillium* fungi and influenced by nematodes. It occurs in most potato growing areas of the world. The incidence and severity of early dying appears to be increasing in western Canada potato producing areas. *Verticillium* species have a wide host range and are known pathogens of many crops and other plants. Disease development impedes water movement within the plant and is influenced by many abiotic and biotic factors. Early dying can cause severe yield losses and leads to internal net necrosis in many potato varieties. Soil fumigants are sometimes used to control the disease but they are expensive and essentially sterilize the soils. Several species of *Verticillium* are known to cause disease but the factors

contributing to the disease are poorly understood. Additional information on the potential transmission, detection, and control of early dying is required.

Late blight, pink rot, and leak are caused by the oomycetous fungi *Phytophthora infestans, Phytophthora erythroseptica*, and *Pythium ultimum*, respectively. They represent potentially the most devastating group of potato pathogens. The incidence of pink rot and late blight is increasing in incidence and possibly severity in western Canada but the exact cause or population dynamics remain to be determined. Late blight can decimate a crop within a few days and like pink rot, it can infect a healthy tuber. Control involves several applications of fungicide applied in a preventative manner but these pathogens have developed pesticide resistance. Our understanding of the oomycetes is still quite limited and alternatives for detection and control are required.

Diagnostics that identify pathogen/pest sources and strains and disease control strategies based on management and biocontrol, will reduce disease losses, eliminate pesticides that can adversely impact environment, and improve the competitiveness of the Alberta product.

Objectives

1) Develop diagnostic tests for reliably detecting the pathogens and pests contributing to early dying, leak, late blight and pink rot. Assays will help determine sources, vectors, and pathogen strain distribution in fields selected for potato production.

2) Characterize the pathogen/pest populations causing early dying, leak, late blight and pink rot in Alberta. Samples will be obtained from diseased tissues, soils, soil debris, and culture collections to determine virulence, aggressiveness, and other characteristics such as pesticide reaction.

3) Develop strategies for the control of early dying, leak, late blight and pink rot. This will involve a management approach based on diagnostic information, the screening of germplasm and advanced lines for resistance, storage and soil monitoring and amendments, and crop rotations.

4) Improve the competitiveness and sustainability of producers and processors by advancing our understanding of these pathogens/pests to improve yield and quality.

Methods and Materials

1) Pathogen/Pest identification, and isolation: Industry, CFIA, and collaborators will assist in collection of diseased samples and early dying, leak, late blight, and pink rot pathogen/pest identification/isolation. Additional pathogen/pest populations will be obtained from existing regional, National, and International culture collections for comparison.

2) Detection and risk levels: Sensitive pathogen/nematode polymerase chain reaction (PCR) assays will be developed/applied to detect each pathogen and pest. Universal primers designed for highly conserved rDNA sequences have proven effective in reliable identifications of pathogens and other organisms. Testing will examine various sources of the pathogens and nematodes including field soil, alternative hosts, and seed to determine inoculum loads and risk.

3) Strain characterization: AAFC will develop PCR assays to analyse genetic variability within each pathogen/pest to identify different strains. Hypervariable intergenic spacer regions such as the rDNA ITS regions are capable of distinguishing even small variations in populations. Results will help develop multplex assays to detect several pathogens/pests and reduce test costs. PCR amplifications will be conducted under stringent conditions and amplified products cloned and sequenced. Sequence comparisons and analyses can be performed with various available software programs.

4) Disease management: Management practices and pathogen threshold values will be evaluated to determine strategies to control pathogen reservoirs and vectors and minimize disease losses. True potato seed from accessions held in germplasm repositories and advanced lines from the AAFC Potato Breeding Program will be screened with aggressive strains of early dying, late blight, and pink rot pathogens in storage, greenhouse, and/or field trials. Monitor pathogen/pest changes in soil and seed after vine removal, deep tillage, green manures, and crop rotations to reduce disease.

Results and Discussion

The project commenced in the spring of 2006. Agriculture and Agri-Food Canada approved an application to match the Potato Growers of Alberta contributions. Excellent progress has been made in both the development of diagnostics, the isolation of early dying, pink rot, late blight, and leak pathogens, and the identification of probiotics that prevent disease. Producers are encouraged to continue submitting suspect samples for confidential evaluation and thereby assist in characterizing the diagnostics and prevention strategies (Table 1).

Industry, the Canadian food Inspection Agency, and collaborators assisted with the collection of diseased samples for pathogen identification and isolation. Over 200 samples from North America were collected for development of diagnostics, characterization, and prevention strategies. Isolates were evaluated for aggressiveness and suitability in greenhouse and field trials (Table 2). Several of the more aggressive isolates were selected for screening advanced lines and varieties for symptom expression and eventually effectiveness of diagnostic and control measures. Additional pathogen strains will be obtained from existing regional, National, and International culture collections for comparison.

Several species of *Verticillium* were recovered from early dying samples. This appears to include species previously not known to infect potato. Each species has intrinsic properties that may influence the damage inflicted on the crop. For example, *Verticillium dahliae* produces a tough thick walled resting stage microsclerotia that can potentially overwinter in soils. Further analysis will determine the prevalence of each species and characteristics that may assist in controlling each pathogen. Comparison of rotations by Dr. F. Larney at the AAFC Vauxhall Substation has resulted in the prevention of early dying (Figure 1). Initial soil analysis has shown little variation in the pathogen levels but changes in the beneficial microflora including the increased presence of a probiotic *Plectosphaerella cucumerina* that is known to attack nematodes. Nematodes are an important component of the early dying complex.

Figure 1. Pictures from adjacent plots in 2007 of a 5 yr sustainable rotation (right) versus a 3 year conventional rotation (left). Although the soil samples showed only a slight reduction in the level of the verticillium wilt pathogen in the sustainable rotation, the microflora has changed with an increase in beneficial microorganisms as determined with the developed diagnostics.

No *Phytophthora infestans* was detected in any of the samples obtained from Alberta in 2006/07 and 2007/08. A number of strains were observed amongst the *Phytophthora infestans* from other provinces, providing the ability to track strain distribution and spread (Table 1). Surprisingly pink rot appears to be increasing and the *Phytophthora erythroseptica* from all provinces showed relatively little variation amongst strains and suggests a relatively uniform pathogen population. Analysis of association of observed differences with pathogen traits such as pesticide resistance has not been observed to date. Analysis of several leak isolates has also shown limited strain variation (Figure 3).

Table 1. Characterization of Canadian *Phytophthora infestans* isolates.

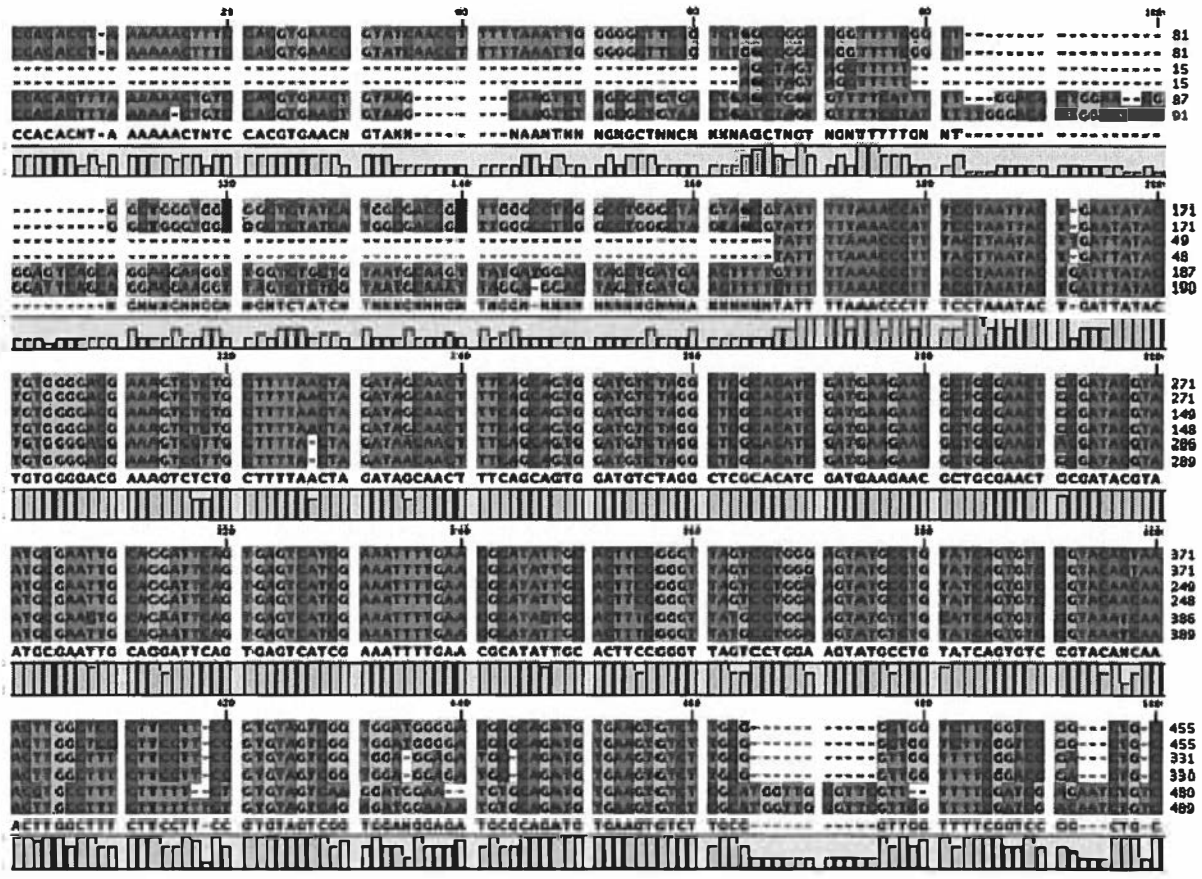
Mating Type	Metalaxyl Response	Genotype	Pathotype
A1	Intermediate	US11	2,4,6,9/1,3,5,7,8,10,11
A1	Resistant	US11	2,6,9,10/1,3,4,5,7,8,11
A1	Sensitive	US6	2,4,6,9/1,3,5,7,8,10,11
A1	Sensitive	US6	2,9/1,3,4,5,6,7,8,10,11
A1	Intermediate	US6	2,4,6,9/1,3,5,7,8,10,11
A1	Resistant	US11	2,9,10/1,3,4,5,6,7,8,11

Allozyme analysis of the *P. infestans* isolates was performed on pre-treated cellulose acetate gel stained for the *Glucose phosphate isomerase* (*Gpi*) locus. Results from the CAE of *Gpi* closely correspond with the expected mating type and metalaxyl response for US-6 and US-11 genotypes. Further analysis revealed five different pathotype races for the six isolates (Table 1). Mating type determination of isolates was made with isolates of known A1 or A2 genotypes and the presence of oospores. Only A1 mating types were observed. Metalaxyl response was determined by comparing the growth rate of isolates on modified CRA plates (mCRA) made with 1g glucose/l augmented at 100 ug/ml metalaxyl M (active isomer of metalaxyl) as found in Ridomil Gold (49.5% w/w) liquid formulation, and the growth rate on mCRA plates with no metalaxyl present. Percent growth was calculated and the response rated as Metalaxyl Sensitive: <10%, Metalaxyl Intermediate: 10-60%, and Metalaxyl Resistant: >60%. Metalaxyl response revealed that two of the three US-6 isolates were sensitive and one was intermediate (Table 1). Of the three US-11 isolates two were resistant and one was intermediate to metalaxyl. Race profiles of the *P. infestans* isolates were determined by screening for pathogenicity on eleven single R-gene differentials of *Solanum demissum.*

Table 2. Late blight foliage 2007 disease in potato varieties and advanced lines. Assays used an isoloated aggressive and highly virulent US8 *Phytophthora infestans* genotype.

Cultivar or Line	Reaction	Rating
CV96022-3	Moderate	**2.8**
CV96053-4	Moderate Resistant	**2.0**
CV97006-1	Moderate Susceptible	**3.8**
CV97050-3	Moderate	**2.6**
CV97065-1	Moderate	**2.8**
CV97112-5	Moderate	**2.2**
CV97123-1	Moderate	**2.2**
CV99279-1	Moderate	**2.6**
V0319-1	Moderate	**2.4**
V0379-2	Susceptible	**4.0**
V0950-3	Moderate	**2.2**
V1102-1	Moderate Resistant	**1.6**
WV3667-1	Moderate	**2.4**
Stirling CP487	Resistant	**0.2**
Shepody CP633	Susceptible	**4.4**
Russet Burbank	Moderate Susceptible	**3.0**

Figure 2. Alignment of several rDNA intergenic sequences from isolates of the oomycete pathogens: first 2 sequences are *Phytophthora erythroseptica*, middle 2 sequences are *Phytophthora infestans,* and the last 2 sequences are *Pythium ultimum.* Each of the four nucleotides is indicated by a different colour. Several strains of the pathogen are evident and these differences should facilitate tracking and avoidance.



Technology Transfer

Disease control information and strategies have been communicated to producers and industry through presentations and publications. Advanced lines will be planted in field trials at various locations by industry and AAFC to evaluate agronomic performance and disease resistance. Harvested tubers will be evaluated for disease in storage. Reports that summarize diagnostic capabilities, control strategies, and disease/pest resistance will be collected, analyzed, and distributed to the industry. Licenses will be obtained for the various products that are commercializable and diagnostics transferred to service labs in western Canada. Patent applications will be prepared as warranted to capture commercializable products and technologies. Progress reports will be prepared annually and a final report submitted at the conclusion of the study.

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Economical and Environmental Benefits

Apparent increases in early dying, leak, late blight and pink rot in western Canada are associated with reduced yields and quality that adversely impact producers and processors. These diseases also often compromise healthy tubers, predisposing potatoes to secondary diseases such as fusarium dry rot. Acquisition and characterization of endogenous pathogen/pest populations will facilitate the development/application of cost-effective multiplex diagnostic procedures to assist in early reliable detection of the pathogen/pests in soils, seed, and other sources to avoid disease. The identified differences allow the pathogens to be

tracked and management decisions may be made in regards to levels of the pathogen in advance of planting or application of pesticides. Results have advanced our understanding of host-pathogen interactions and identify effective alternative disease control strategies that help reduce pesticide applications thereby addressing growing health and environmental concerns. Better control measures for early dying, leak, late blight and pink rot in western Canada through integrated pest management and probiotics will improve the sustainability and competitiveness of the potato industry in Alberta.

Acknowledgements

We gratefully acknowledge the support of the Potato Growers of Alberta, Maple Leaf Potatoes, and the Agriculture and Agri-Food Canada Matching Investment Initiative. The assistance of Dr. Rick Peters and the Canadian Food Inspection Agency is also acknowledged. Industry is invited to continue submitting samples for confidential evaluation to assist with the development of diagnostics and prevention measures.

Evaluation of Incidence and Prevention

of

Blackleg and Bacterial Ring Rot

Potato Growers of Alberta
Progress Report 2007/08

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Summary

Sensitive diagnostics have been developed that are capable of detecting trace levels of the blackleg and bacterial ring rot pathogens. The procedure works on extremely small samples of only a few milligrams, may be used to examine any sample including soil, and results can be available within only a few hours. The procedures are quantitative facilitating the estimation of pathogen levels in seed or soils before planting and are capable of differentiating between strains with different characteristics such as aggressiveness and symptom expression. Results from over 200 samples show few occurrences of the pathogen causing bacterial ring rot but an increasing incidence of blackleg samples. Several virulent soil probiotics that aggressively attack blackleg and bacterial ring rot pathogens have been isolated and are being offered for application as a seed treatment that prevents blackleg and ring rot. Greenhouse and field trials have been established for the evaluation of disease symptom expression models in potato varieties, characterization of the diagnostics, and determination of the most effective application parameters for the prevention measures. Pesticide Management Regulatory Agency has provided for application of the proactive seed treatments and producers are encouraged to continue to submit diseased samples for confidential evaluation and thereby assist in characterizing the diagnostics and prevention strategies. Agriculture and Agri-Food Canada continues to match the Potato Growers of Alberta contributions for this project through support of a competitive Matching Investment Initiative application. This project is now entering the third and final year.

Background

Blackleg and tuber soft rot of potato are caused by pectolytic gram negative *Erwinia* species. These diseases are found wherever potatoes are grown. The incidence and severity of blackleg appears to be increasing in western Canada potato producing areas. Blackleg is favoured by cool wet soils at planting and spread through seed, irrigation, and insects. Blackleg can cause severe yield losses and symptoms may appear at any stage of plant development. Symptoms progress from a decaying seed piece to lesions extending from the base of the stem into the canopy. Several species of *Erwinia* are known to cause disease but many factors contributing to the disease are poorly understood. Additional information on the transmission, detection, and control of blackleg would improve yields and quality.

Bacterial ring rot has plagued the potato industry and is a zero tolerance pathogen. It is caused by a gram positive tuber-borne bacterium, *Clavibacter michiganenesis* subsp. *sepedonicus*. The bacterium can overwinter in potato debris, may reside in other hosts such as sugar beets, can be spread by insects, and survives on equipment for up to 5 years. Symptoms vary amongst potato varieties and environmental conditions. Unfortunately, the identification of a single infected tuber can result in decertification, sometimes bankruptcy, and negatively impacts trade. Our understanding of bacterial ring rot is still quite limited and alternatives for detection and control are required.

Probiotics have recently emerged as an important tool in the control of human and animal bacterial diseases. Probiotics are nature's control mechanism, naturally occuring for each bacterium, and represent a cost-effective prevention strategy for blackleg and bacterial ring rot. Diagnostics that identify pathogen sources and strains and disease control strategies based on management and biocontrol, should reduce the occurrence of blackleg and bacterial ring rot.

Objectives

1) Develop sensitive diagnostic tests that reliably detect the pathogens causing blackleg and bacterial ring rot. Assays will be applied to determine sources, vectors, and pathogen strain distribution in soils selected for potato production.

2) Characterize the pathogen populations causing blackleg and bacterial ring rot in Alberta. Forensic samples will be obtained from diseased tissues, soils, equipment, storages, and collections to determine virulence, aggressiveness, and other characteristics such as transmission.

3) Develop strategies to control of blackleg and bacterial ring rot. This will involve a management approach based on the diagnostic monitoring information, the screening of AAFC advanced lines and commercial varieties for symptom expression, and seed and soil phage biocontrol amendments.

4) Improve the competitiveness and sustainability of producers and processors by advancing our understanding of these diseases to curtail their occurrence and improve yield and quality.

Materials and Methods

1) Pathogen identification, and isolation: Industry, CFIA, and collaborators are assisting in the collection of diseased samples and blackleg and bacterial ring rot pathogen identification/isolation. Additional pathogen populations will be obtained from existing regional, National, and International culture collections for comparison.
2) Detection and quantification: Sensitive pathogen-specific polymerase chain reaction (PCR) assays have been developed to detect and quantify nucleic acid from each pathogen. Universal primers designed for highly conserved rDNA sequences have proven effective for reliable identification of the pathogens. Testing is examining various sources of the pathogens including field soil, potential vectors, alternative hosts, equipment, storages, and potatoes.
3) Strain characterization: AAFC has developed PCR assays of genetic variability within each pathogen to determine strain populations. Hypervariable intergenic regions are capable of distinguishing even small variations in pathogen populations. PCR amplifications are performed under stringent conditions and amplified products cloned and sequenced. Sequence comparisons and analyses are performed with various available software programs such as Mulialign.
4) Disease management: Management practices and pathogen threshold values will be evaluated to determine strategies to control pathogen reservoirs, vectors, and minimize disease losses. Advanced lines from the AAFC and commercial cultivars are being screened with aggressive strains of blackleg and bacterial ring rot pathogens in storage, greenhouse, and/or field trials for symptom expression. Soil, storage, and seed treatments, irrigation, and crop rotations will be assessed to identify and recommend strategies to reduce disease. Phagetherapy with isolated natural viruses from this study for blackleg and bacterial ring rot will be evaluated as a cost-effective biocontrol to prevent disease.

Results and Discussion

This project commenced in the spring of 2006. Agriculture and Agri-Food Canada approved an application to match the Potato Growers of Alberta cash and in-kind contributions. Excellent progress has been made in both the development of diagnostics and the isolation of aggressive virulent probiotics for blackleg and ring rot. Producers are encouraged to continue submitting diseased samples for confidential evaluation and thereby assist in characterizing the diagnostics and prevention strategies.

Isolates and Diagnostics

Industry, the Canadian food Inspection Agency, and collaborators assisted with the collection of diseasesd blackleg and BRR samples for pathogen identification and isolation. Over 200 samples of blackleg and BRR from North America were collected for development of diagnostics, characterization, and prevention strategies. Cultures were evaluated for aggressiveness and suitability in greenhouse and field trials (Figure 1). Several of the most aggressive isolates selected for screening advanced lines and varieties for symptom expression and eventually effectiveness of diagnostic and prevention measures (Table 1). Additional pathogen strains will be obtained from existing regional, National, and International culture collections for comparison.

Figure 1. Agricuture and Agri-Food Canada Stavely Substation 2007 field plots for screening advanced lines, diagnostics, and biocontrol products to BRR and blackleg. This is the only site in Canada for field BRR analysis. Some advanced lines and varieties show no disease symptoms, however, most lines show some degree of foliage and tuber symptoms but this is clearly influenced by the environment and weather.

Table 1. Disease ratings for bacterial ring rot from the hand planted and harvested 2007 field plots at the AAFC Stavely Substation. The BRR model correctly predicted pronounced symptom expression this year.

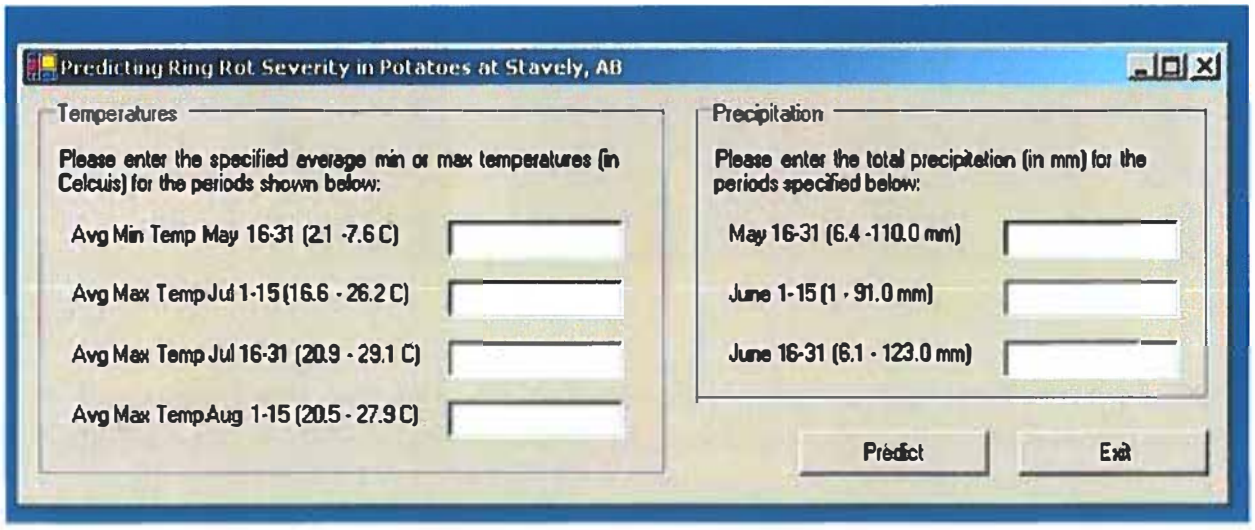
Foliage	**Mean**	**S.E.**	
Alpha/R	0.00	0.00	0 - no visible symptoms
Russet Burbank/R	1.80	0.20	1 - wilt only on lower leaves
Norland/R	4.47	0.22	2 - wilt/chlorosis on lower leaves
FV11579-3/R	3.07	0.23	3 - wilt to the top of plant
FV12228-5/R	4.00	0.31	4 - wilt/chlorosis to top of plant
FV12272-3/R	2.93	0.25	5 - plant dead
V0379-2/R	0.47	0.17	Controls uninoculated
Tubers			
Alpha/R	0.9	0.9	Tuber Rating (30 max) =
Russet Burbank/R	3.7	0.1	[(Rot Tuber/Total) x 3
Norland/R	4.4	1.0	+ (Surface-Internal/Total) x 2
FV11579-3/R	6.6	2.5	+ (Internal Only/Total) x 1)] x 10
FV12228-5/R	7.8	1.0	
FV12272-3/R	8.8	1.4	
V0379-2/R	0.1	0.1	

Results indicate that cultural practices may be contributing to the increased occurrence of blackleg (Figure 2). Most seed has low levels of the *Erwinia* species causing blackleg according to Canadian Food Inspection Agency results but the incidence is too low to produce disease under typical circumstances. However, management practices such as fall irrigation provides a moist cool environment during seed planting and conditions conducive to the occurrence of blackleg. This observation will be further investigated and the benefits of the probiotics in eliminating all traces of the pathogens evaluated.

Figure 2. Typical disease symptoms produced in by blackleg in a commercial field (left) resulting in misses and stunted plants. Tissue rapidly degrades in the seed piece following infection and spreads up through the crown of the stem (right).

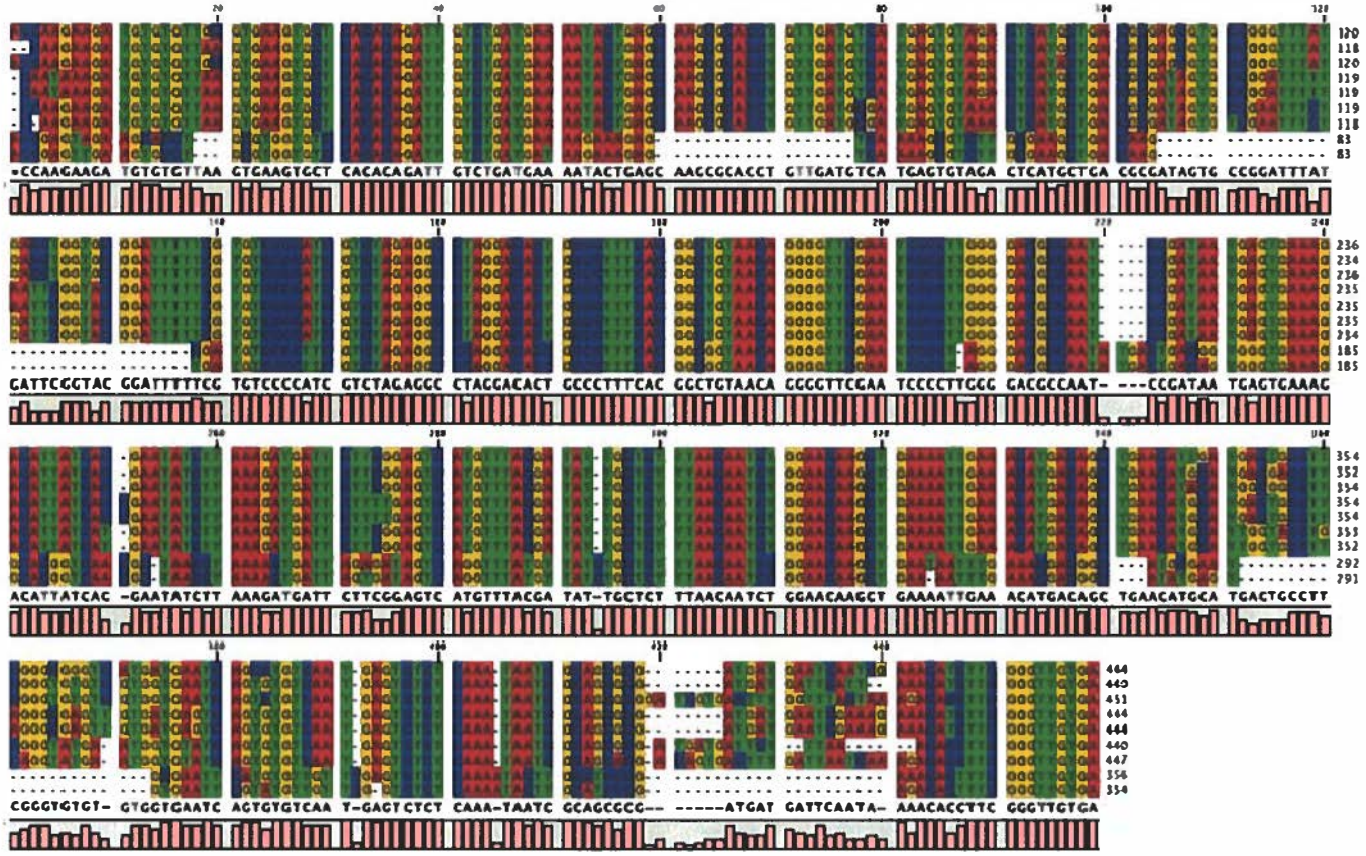
An executable program developed from 12 years of BRR data generated by neural analysis of the 384 genotypes evaluated at the only Canadian field testing facility, facilitates the prediction of symptom expression (Figure 3). The input of temperatures and precipitation allows the producer to determine the likelihood that visual inspection will detect BRR symptoms in foliage or tubers. This should help determine if immunological or nucleic acid testing is sufficient to detect any traces of the BRR pathogen. For example, in a year that results in poor BRR expression, it may be prudent to increase the level of testing to avoid an undetected increase in BRR infected material. A beta version of the program is available to PGA producers.

Figure 3. An executable program developed from BRR data facilitating the prediction of symptom expression and vigilance in testing required to ensure absence. A beta version of the program is available to PGA members.



Sensitive pathogen-specific polymerase chain reaction diagnostics have been developed that are capable of quickly detecting trace levels of nucleic acid from the blackleg and bacterial ring rot pathogens. The procedure works on extremely small samples of only a few milligrams, may be used to examine any sample including soil, and results can be available within only a few hours. The procedures are quantitative facilitating the estimation of pathogen levels in seed or soils before planting and are capable of differentiating between strains with different characteristics such as aggressiveness and symptom expression. Initial results show little variation in the hypervariable intergenic regions of the ribosomal DNA from the pathogen causing bacterial ring rot but a surprisingly large level of variation has been observed in the blackleg samples (Figure 4). This may explain why the blackleg in some areas has been relatively difficult to eradicate and suggests there may need to be different strain specific treatments. However, no samples of *Erwinia chrysanthemi* causing stem wet rot in rapidly expanding areas of Europe or *Erwinia braziliensis*, an aggressive species found in South America.

Figure 4. Alignment of several rDNA intergenic sequences from *Erwinia* species isolates. The first 3 sequences represent *E. braziliensis*, the following 4 sequences are from *E. carotovora*, and the last 2 sequences are from *E. chrysanthemi*. Each of the four nucleotides is indicated by a different colour. At least three types of blackleg pathogen have been identified by the nucleotide sequence.



Probiotics

Several virulent soil probiotics that aggressively attack blackleg and bacterial ring rot pathogens have been isolated and are being characterized for application as a seed treatment and in furrow amendment that prevents blackleg and ring rot (Figure 5). Greenhouse and field trials have been established for the evaluation of disease symptom expression in potato varieties, characterization of the diagnostics, and determination of the most effective application parameters for the prevention measures. Producers are encouraged to continue submitting diseased tissues and soil samples for confidential evaluation and thereby assist in increasing the number of isolates and strains available for characterizing the diagnostics and prevention strategies. The Pesticide Management Regulatory Agency has approved the application of the probiotics by the seed industry for evaluation and producers are encouraged to contact us to arrange shipment and collaborative testing.

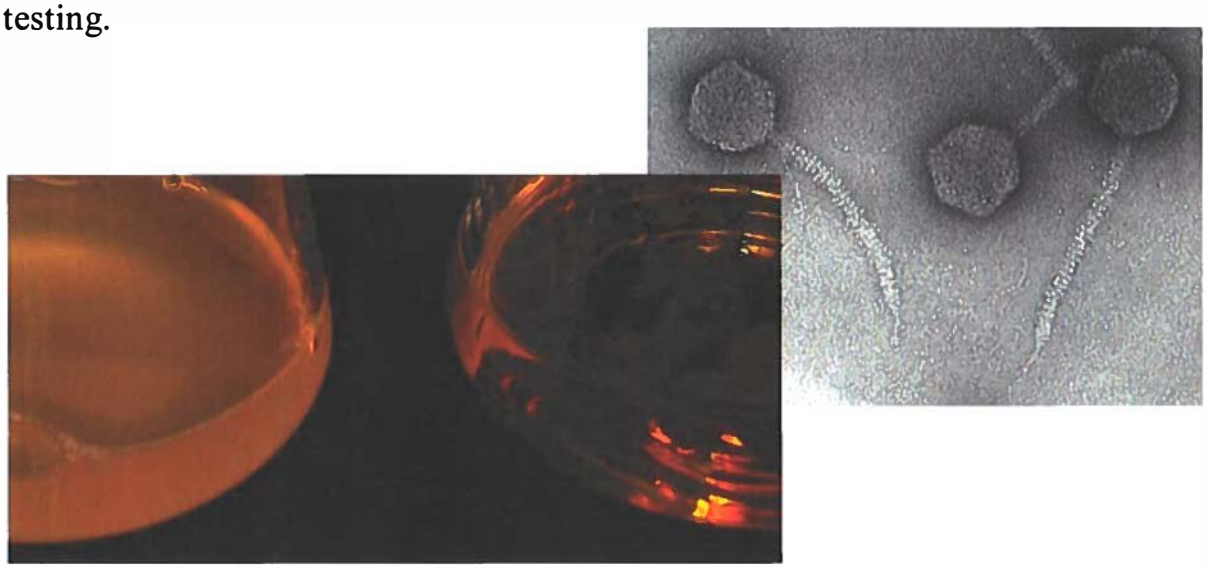


Figure 5. An overnight culture of the blackleg pathogen *Pectobacterium atroseptica* (Syn. *Erwinia carotovora atroseptica*) (left) treated with an aggressive virulent phage isolated from Canadian soil (right). Greenhouse trials have confirmed the efficacy of the proactive cultures and Pest Management Regulatory Agency has approved commercial seed trials. Initial results also suggest the phage will be effective against biofilms that have made ring rot and blackleg difficult to prevent.

Technology Transfer

Disease control information and strategies have been communicated to producers and industry through presentations at the PGA Annual Meeting in Kananaskis, research tours, and in publications. The bacterial ring rot field trial at the AAFC Stavely Substation is the only such site in Canada and was re-established to continue 30 years of screening. Advanced lines planted in field trials by industry and AAFC to evaluate symptom expression for blackleg and bacterial ring rot. Harvested tubers were evaluated for disease in storage and effectiveness of control. Reports that summarize diagnostic capabilities, control strategies, and symptom expression are being collected, analyzed, and distributed to industry. Licenses will be obtained for commercializable products and the diagnostics transferred to service labs in western Canada. Patent applications will be prepared as warranted to capture commercializable products and technologies. Progress reports will be prepared annually and a final report submitted at the conclusion of the study.

L. Kawchuk. 2007. Evolution and Eradication of Blackleg. Invited Symposium Presentation. PGA Annual Meeting. Kananaskis, AB.

L. Kawchuk, R. Howard, and B. Bizimungu. 2007. Evaluation of incidence and prevention of blackleg and bacterial ring rot. PGA Annual Meeting Poster. Kananaskis, AB.

L. Kawchuk, R. Howard, B. Bizimungu, and S. H. De Boer. 2007. Characterization of the blackleg pathogen in potato. Plant Pathology Society of Alberta Annual Meeting Presentation. Lethbridge, AB.

L. Kawchuk. 2007. Potato Molecular Improvement Tools. Western Potato Council, Vancouver, BC.

Bizimungu, B., Lynch, D.R., Kawchuk, L.M., Chen, Q., Konschuh, M., Holley, J., Fujimoto, D.K., Driedger, D., Wolfe, H., Dunbar, L., Waterer, D., Bains, P., Wahab, J. and McAllister, P. 2007. Northstar: A high yielding white cold-storage chipping potato cultivar with attractive, oval tubers resistant to late blight. American Journal of Potato Research 84: 457-465.

Kawchuk, L.M. and Kalischuk, M.L. 2007. Plant disease resistance genes. In *"Recent Research Developments in Plant Genetics"*. Ed. S.G. Pandalai. Research Signpost. (in press)

Economical and Environmental Benefits

Apparent increases in blackleg and bacterial ring rot in western Canada are associated with reduced yields and quality or decertification that adversely impacts producers and processors. These pathogens, especially bacterial ring rot, also adversely impact trade and are sometimes used as a non-tariff trade barrier. Acquisition and characterization of endogenous pathogen populations will facilitate the development of diagnostic procedures to assist in reliable early detection and to reduce disease occurrence. Results will advance our understanding of host-pathogen interactions and identify effective disease control strategies that help reduce the occurrence of blackleg and bacterial ring rot such as cost-effective phage biocontrol. Control measures for blackleg and bacterial ring rot in western Canada will improve the sustainability and competitiveness of the potato industry in Alberta.

Acknowledgements

We gratefully acknowledge the support of the Potato Growers of Alberta, Maple Leaf Potatoes, the Canadian Food Inspection Agency, and the Agriculture and Agri-Food Canada Matching Investment Initiative. Industry is invited to test the probiotic seed treatment and continue submitting samples for confidential evaluation to assist with the development of diagnostics and prevention measures.

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Part 1B – Corporation/Cooperative/Partnership

ADVANCE PAYMENTS PROGRAM (APP)
APPLICATION & REPAYMENT AGREEMENT – CORPORATION/COOPERATIVE/PARTNERSHIP INFORMATION
PROTECTED "A" ONCE COMPLETED

1.1 DOCUMENTATION

✓ Administrators must request documentation from the Shareholders, Members or Partners.

☒ X Identity verified (Photo identification required, i.e. driver's license. Medicare card cannot be accepted.)

Type of documentation provided: Drivers License's

☐ Certificate of incorporation / Proof of Partnership

1.2 BASIC INFORMATION

✓ Identify the legal name of the Corporation/Cooperative/Partnership applying for the advance and indicate the type.
✓ List all Shareholders, Members or Partners of the Corporation/Cooperative/Partnership. Attach a separate sheet if required.
✓ If the ownership structure has changed from the previous application please attach the new Incorporation/Cooperative/Partnership document that reflects the correct ownership structure.

Legal Name of Business:	APP ID of Corporation/Cooperative/Partnership:
Chin Coulee Farms Ltd.	79521

Indicate type of business: ☐ Corporation ☐ Cooperative ☐ Partnership ☐ Other:

APP ID	First Name	Last Name	Address	Phone Number	Date of Birth (yyyy/mm/dd)	% Interest in Operation
46486[illegible]58	Anne John	Vanrobaeys	Box 1314, Coaldale, AB T1M 1N3 Box 1859 Enchant AB. T0K 0V0	403-345-2146403-7[illegible] 3785	1952-11-08[illegible] 07-04	50 % 50 %
460463258?	JohnGuylle	Vanrobaeys	Box 1314, Coaldale, AB T1M 1N3 Box 1859 Enchant AB T0K 0V0	403-345-2146403-7[illegible] 3785	1949-0[illegible]-29 19[illegible]5-12-08	49 %%50 %
						%
						%

Mailing Address of Corporation/Cooperative/Partnership

Street Address	City/Town	Province	Postal Code
4910 40 St As Above	Taber	AB	T1G 1C8

Business Phone # (Ext.)	Business Fax #

1.3 DECLARATION OF APP ADVANCE RECEIVED FROM OTHER PRODUCER ORGANIZATIONS

✓ Outstanding advances previously issued or attributed to any Shareholder, Member or Partner will affect the amount of the advance the applicant may be eligible to receive.
✓ List all advances issued by other organizations for this production period and previous production periods to each Shareholder, Member or Partner of the business, including advances attributed by percentage of ownership in any Corporation/Cooperative/Partnership.
✓ Attach a separate sheet if required.

Name of Shareholder, Member or Partner	Name of Producer Organization from which an advance has been received	Agricultural Product for which an advance has been received	Production Period	Amount of Advance Received
			20	$
			20	$
			20	$
			20	$

1.4 LENDER INFORMATION

Name of Lending Institution
First Choice Credit Union Bank of Nova Scotia

Street Address	City/Town	Province	Postal Code
45 Fairmont Blvd 1921 20 Ave	Coaldale Lethbridge	AB	T1M 1N2 T1K 1T1

Any personal information provided to Agriculture and Agri-Food Canada will be protected under the provisions of the Privacy Act and will be stored in Personal Information Bank AAFC-PPU-140.

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Part 1B – Corporation/Cooperative/Partnership

ADVANCE PAYMENTS PROGRAM (APP)
APPLICATION & REPAYMENT AGREEMENT – CORPORATION/COOPERATIVE/PARTNERSHIP INFORMATION
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Phone # (Ext.)	Business Fax #
03-320-460045-0130	

.5 RELATED PRODUCERS

Producers are related if they do not deal with each other at arm's length.
In the absence of proof to the contrary, producers are presumed not to deal with each other at arm's length if they are related as follows:

- ✓ Individuals who are cohabitating or are connected by blood relationship, marriage, common law partnership or adoption;
- ✓ A corporation and a person who holds shares in the corporation, is a member of a group of persons that holds shares in the corporation, or is related to a person who holds shares in the corporation or to the member of the group;
- ✓ Any two corporations if one person or group of persons holds shares in both corporations, a person who holds shares in one of the corporations is related to a person who holds shares in the other corporation, a person who holds shares in one of the corporations is related to a member of a group of persons that holds shares in the other corporation, or if they are both related to a third corporation;
- ✓ Members of the same group of persons; or
- ✓ Persons related to members of the same group of persons.

Relatedness affects the applicant's eligibility to receive an advance, as well as the amount of an advance.
If you answer "yes" to question 1 below, complete section 1.5.1 which is a declaration of relatedness.
If you answer "yes" to question 2, you may not be eligible to receive an APP advance, unless you are able to rebut the presumption of relatedness.
If you answer "no" to questions 1 and 2, you are not required to complete section 1.5.1.

. Has a related producer a) applied for an APP advance in this production period or b) have an outstanding APP advance from a previous production period?	YES	NO
Is any related producer ineligible as a result of a default under APP, SCAP or ESCAP?	YES	NO

1.5.1 RELATED PRODUCER DECLARATION

- ✓ List all related producers who received an advance for this or previous production periods, including advances issued by other APP Administrators.
- ✓ Attach a separate sheet if required

Name of the related producer that received an advance	APP ID	Name of Administrator which issued the advance	Production period (yyyy)

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Part 1B – Corporation/Cooperative/Partnership

ADVANCE PAYMENTS PROGRAM (APP)
APPLICATION & REPAYMENT AGREEMENT – CORPORATION/COOPERATIVE/PARTNERSHIP INFORMATION
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List all related producers who received advances for this or previous production periods, including advances issued by other APP Administrators. Attach a separate sheet if required.

Name of the related producer that received an advance	APP ID	Name of Administrator which issued the advance	Production period (YYYY)

1 6 GUARANTEE DECLARATION

PERSONAL GUARANTEE (for Corporation with sole shareholder)

I, being the sole shareholder of the Corporation stated in Section 1.2 of this Application for an Advance in consideration of an advance being made to it by the Administrator, for the amount stated in Part 2 of this Application for an Advance, for the 2013-2014APP production period and the Minister of Agriculture and Agri-Food Canada guaranteeing the repayment of such advance and interest thereon, do hereby agree to be personally liable to the Administrator or the Minister of Agriculture and Agri-Food Canada for any amount owing by the Corporation, under the APP.

By signing this document, you understand and agree that action may be taken against you personally to be liable under Section 5.0 of the Terms and Conditions of the Repayment Agreement and to repay the full amount of any defaulted advance.

IN WITNESS WHEREOF I hereunto set my hand and seal

Dated at _____ _____

Location Date (YYYY-MM-DD)

_____ _____

Print name of shareholder clearly Signature of shareholder

_____ _____

Print name of witness clearly (Must not be a relative) Signature of witness

JOINT AND SEVERAL GUARANTEE (for Cooperative, Partnership or Corporation with multiple shareholders)

We, being Shareholders, Members or Partners, as the case may be, of the Corporation, Cooperative or Partnership as stated in Section 1.2 of this Application for an Advance, in consideration of an advance being made to the Corporation, Cooperative or Partnership, as the case may be, by the Administrator for the amount stated in Part 2 of this Application for an Advance, for the 2013-2014 APP production period and the Minister of Agriculture and Agri-Food Canada guaranteeing the repayment of such advance and interest thereon, do hereby agree to be jointly and severally liable to the Administrator, or the Minister of Agriculture and Agri-Food Canada, for any amount owing by the Corporation, Cooperative or Partnership, as the case may be, pursuant to the APP.

By signing this document, you understand and agree that action may be taken against you personally to be liable under Section 5.0 of the Terms and Conditions of the Repayment Agreement to repay the full amount of any defaulted advance.

IN WITNESS WHEREOF I hereunto set my hand and seal

Dated at AB 2014/06/11 Formatted: Left

Location Date (YYYY-MM-DD)

John Cailliau

Print name of shareholder, member or partner clearly Signature of shareholder, member or partner

_____ _____

Print name of witness clearly (Must not be a relative) Signature of witness

Giselle Cailliau

Print name of shareholder, member or partner clearly Signature of shareholder, member or partner

_____ _____

Print name of witness clearly (Must not be a relative) Signature of witness

Any personal information provided to Agriculture and Agri-Food Canada will be protected under the provisions of the Privacy Act and will be stored in Personal Information Bank AAFC-PPU-140.

ADVANCE PAYMENTS PROGRAM (APP)
APPLICATION & REPAYMENT AGREEMENT – CORPORATION/COOPERATIVE/PARTNERSHIP INFORMATION
PROTECTED "A" ONCE COMPLETED

Print name of shareholder, member or partner clearly	Signature of shareholder, member or partner
Print name of witness clearly (Must not be a relative)	Signature of witness

Petiole Nutrient Recommendations for Russet Burbank Potatoes Grown in Southern Alberta (2004-2007)

Shelley Woods[1], Len Hingley[2], and Michele Konschuh[3]

[1] Soil and Water Research Scientist, Irrigation and Farm Water Division, ARD. Lethbridge, Alberta.
[2] Soil and Water Technologist, Irrigation and Farm Water Division, ARD. Brooks, Alberta.
[3] Potato Research Scientist, Crop Diversification Centre South, ARD. Brooks, Alberta.

Alberta Agriculture and Rural Development
Lethbridge, Alberta
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2008

Citation
Woods, S. A., Hingley, L. E., and Konschuh, M. N. 2008. Petiole nutrient recommendations for Russet Burbank potatoes grown in southern Alberta (2004-2007). Alberta Agriculture and Rural Development, Lethbridge, Alberta, Canada. 40 pp.

Published by
Alberta Agriculture and Rural Development
Lethbridge, Alberta, Canada

Printed in Canada

Copies of this report are available from
Alberta Agriculture and Rural Development
Agriculture Centre
100, 5401 – 1 Avenue South
Lethbridge, Alberta
Canada, T1J 4V6
Phone (403) 381-5140

ABSTRACT

A 3-yr project was conducted by Alberta Agriculture and Rural Development (ARD) staff, with financial support from the Potato Growers of Alberta (PGA). The goals of the project were: to determine the optimal petiole nutrient concentrations for Russet Burbank potatoes in southern Alberta; to determine the relationship, if any, between potato petiole nutrient concentrations and tuber specific gravity; and to compare these relationships to those found in previously-collected, field-scale petiole data. The collection and analysis of potato petiole samples are used to monitor the nutrient status of potato crops throughout the growing season. This can be a useful and timely technique for identifying any crop deficiencies that may occur mid-season; however, the currently-recommended petiole nutrient concentrations have come from research conducted in the northwest USA and previous studies in southern Alberta have indicated that these recommendations may be high for potassium (K) and somewhat high for phosphorus (P), especially early in the growing season. Based on results from this study, new optimal petiole nutrient ranges have been proposed and the suggested petiole nitrate nitrogen (NO_3-N) range is slightly lower than the northwest USA standards at the beginning of the growing season (Days After Planting (DAP) < 80) and late in the growing season (DAP > 105). The proposed optimal petiole phosphorus ranges are substantially less than the northwest USA standards. The proposed petiole potassium ranges are broader than the northwest USA standards overall, are similar early in the growing season (DAP < 80), and the upper limits are greater later in the growing season. The proposed petiole nutrient recommendations were compared to previously-collected data and gave reasonable results for P and K. There was a great deal of scatter in the previously-collected NO_3-N data, as petiole nitrate nitrogen can be affected by many factors in addition to available soil nitrogen, such as climate (temperature and precipitation), soil texture, weed competition, insects, petiole sampling technique, location of samples within the field, and laboratory analysis techniques. Potassium fertilizer did not have a consistent impact on specific gravity. Petiole nutrient concentrations should be considered on a field-specific basis. Spatial variability exists across any field, even if the entire field receives identical fertilizer application, so care must be taken to choose petioles from benchmark locations that are representative of the field, in terms of location and plant appearance. The proposed petiole nutrient recommendations drawn from this study are based on three years of experimental data and it is suggested that the potato industry continue to refine these recommendations.

ACKNOWLEDGEMENTS

This project was made possible with the financial support of the Potato Growers of Alberta (PGA) and Alberta Agriculture and Rural Development (ARD). The PGA also provided equipment, manpower, and expertise to assist with the tuber harvest. McCain Foods provided funding to allow an additional petiole sampling to be added each year of the study. Sandberg Laboratories Ltd. provided a discounted analysis rate. Jerry Zeinstra, Greg Nakamura, and Tony Bos are kindly acknowledged for hosting the trials. Numerous staff assisted with the collection and processing of petiole and tuber samples: Simone Dalpe, Sarah Williams, Shauna Pow, Linda Wenger, Alfonso Parra, Wendy Frank, Nicole Seto, Pamela Moeller, Lucinda Noronha, Corrine Thiessen-Hepner, Brent Nicol, Jonathan Peters, Darren Peterson, Rod Bennett, Jeff Bronsch, Mitchell Froyman, Miranda Mathies, Ryan Moeller, and Ralaina Virostek.

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INTRODUCTION

Background

Precise fertilizer application rates are critical for optimal potato production. Sufficient nutrients are necessary to maximize tuber yield, quality, and uniformity, while issues of economy and environment make excess fertilizer undesirable. The analysis of potato petiole samples has been used to monitor the nutrient status of potato crops throughout the growing season. This can be a useful and timely technique for monitoring any crop deficiencies that may occur mid-season that were not identified in spring soil samples. Many of the current recommended petiole nutrient (NO_3-N, P, and K) concentrations have come from research conducted in the northwest United States (Schaupmeyer *pers. commun.*), where longer growing seasons and different soil conditions and climate prevail. Petiole analysis results from previous Russet Burbank studies in southern Alberta (McKenzie et al. 2002; Woods et al. 2002) indicated that the current recommendations may be high for potassium (K) and somewhat high for phosphorus (P), especially early in the growing season. Results also indicated that recommended nitrate nitrogen (NO_3-N) concentrations may need fine-tuning to suit southern Alberta growing conditions. This was the impetus behind a project to determine petiole nutrient recommendations for Russet Burbank potatoes grown in southern Alberta.

Objectives

A three-year research project was initiated by Alberta Agriculture and Rural Development (ARD), in 2004, with the support of the Potato Growers of Alberta (PGA) to address the discrepancies between current petiole recommendations and previous data. The main objective was to determine the optimal petiole nutrient concentrations for Russet Burbank potatoes in southern Alberta. Another objective was to determine the relationship, if any, between potato petiole nutrient concentrations and tuber specific gravity. The third objective was to compare these relationships to those found in field-scale petiole data.

METHODS AND MATERIALS

Site Selection

Cooperating growers were chosen based on their willingness to participate in the project and allow a small potion of their field to be reserved for differential fertilizer applications. Preference was given to sites where spring nitrogen applications had not yet been applied. The 2004 site was approximately 15 km east of Taber, Alberta (Fig. 1), on a coarse-textured Orthic Brown Chernozemic soil. In 2005, the project was conducted on a field 10 km south of Taber, Alberta (Fig. 1), on a medium-textured Orthic Brown Chernozemic soil. In 2006, a suitable field was not located, so the final year of the study was completed in 2007, on a field approximately 10 km northeast of Coaldale, Alberta (Fig. 1), on a medium-textured Orthic Dark Brown Chernozemic soil.

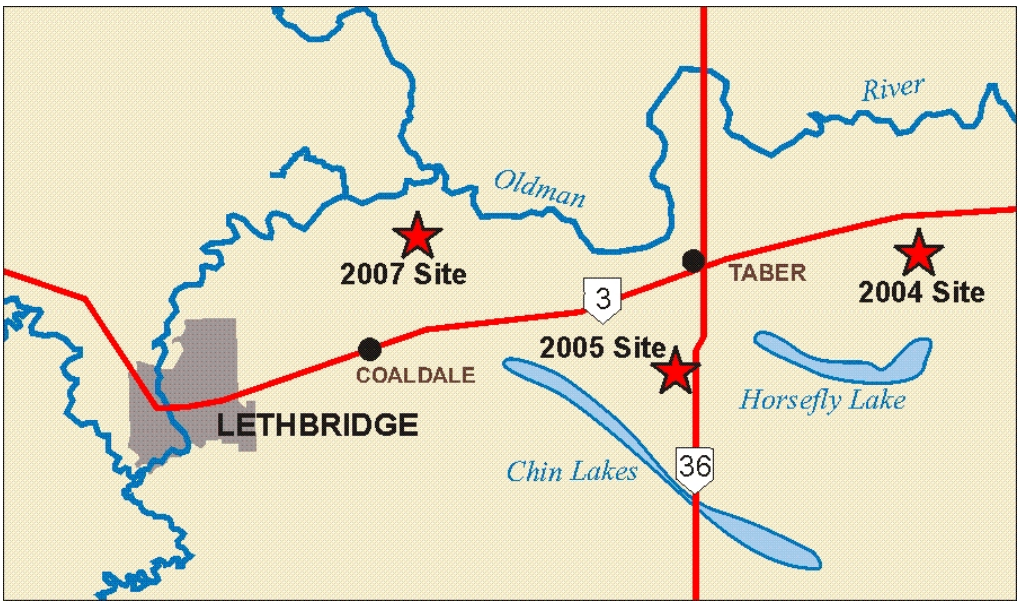


Figure 1. Petiole study site (map courtesy of Brian Coffey, ARD).

Current Petiole Standards

Information on current recommendations for petiole nutrient concentrations is difficult to find and the northwest USA standards used for comparison in this study were collected and kindly supplied by Clive Schaupmeyer in his former capacity as potato specialist with Alberta Agriculture and Rural Development (Table 1).

Table 1. Current petiole nutrient (NO_3-N, P, and K) recommendations based on information from the northwest United States (NW USA) (Schaupmeyer *pers. commun.*).

Days After Planting (DAP)	NW USA minimum	NW USA maximum
Nitrate Nitrogen (ppm)		
60	16000	24000
69	16000	24000
76	14000	22000
83	14000	22000
89	12000	18000
106	10000	16000
Phosphorus (%)		
69	0.62	0.22
89	0.5	0.2
106	0.4	0.2
Potassium (%)		
69	9	7
89	7	5
106	5.5	3.5

Experimental Design

Ten rates of N, P, and K fertilizers were surface applied on April 20, 2004 (Table 2), April 20-21, 2005 (Table 3), and April 17, 2007 (Table 4), to strips in a small portion of fields of grower-managed Russet Burbank potatoes in southern Alberta (Fig. 1). The 10 treatments consisted of four different rates each of N, P, and K fertilizer, where the other nutrients were held constant. In 2004 and 2005, each treatment plot was eight rows wide (24 ft) and 115 ft long. In 2007, each treatment plot was six rows wide (18 ft) and 115 ft long. All plots ran adjacent to a pivot road. There were a total of four randomized replications of the experiment and the plots covered a total area of 2.5 ac in 2004 and 2005, and 1.9 ac in 2007.

Because of flooding in the study field in 2005, the cooperating grower was forced to plough out a low area of the south end of the field that included Rep 1, Treatments 1 and 6, and Rep 2, Treatments 9 and 7, so no petiole or yield data could be collected from those four plots. Late-season flooding also made an additional four low-lying plots inaccessible at harvest (Rep 3, Treatments 7 and 10 and Rep 4, Treatments 4 and 5), so yield data were not collected for them.

Due to an error in the application rate of K on several plots in Rep 2, data from four plots were not used in results calculations. On August 10, 2007, the crop was damaged by a hail storm that swept through southern Alberta. Crop damage was slightly worse on the north half of the field than the south half. The hail likely had a detrimental effect on overall yields; however, the methodology used in this experiment compares the relative differences in yield between fertilizer treatments, not absolute yield values. Therefore, the hail should not have a detrimental effect on the veracity of the experimental results.

Fertilizer Applications

Taber 2004. In the fall of 2003, the field received a fertilizer application of 130 lb/ac N and 50 lb/ac K_2O. Soil samples taken on April 5, 2004, after the grower applied fall fertilizer and just prior to the individual plot fertilization, indicated that there was a total of 192 lb NO_3-N /ac, 144 lb P/ac, and 1647 lb K/ac in the surface 2 ft of soil.

The experimental rates of fertilizer were applied on April 20, 2004. The fertilizer rates for the experimental treatments were chosen to create four increasing amounts of one nutrient, while holding the other two nutrients constant. Treatments 1, 2, 3, and 4 had increasing levels of N, while P and K were kept the same; Treatments 5, 6, 3, and 7 received increasing amounts of fertilizer P, while N and K remained the same; and Treatments 8, 9, 3, and 10 received increasing amounts of fertilizer K, while N and P applications were the same (Table 2). These increasing amounts are shown in colour and correspond to the colours used in subsequent figures. At hilling in the spring of 2004, starter fertilizer (34 lb/ac N and 10 lb/ac P_2O_5) was applied to the entire field, including the research plot. The plot also received three applications of fertigation and one application of foliar feed (Table 2).

Table 2. Fertilizer schedule (lb/ac) in 2003-2004.

Treatments		Grower Applied 2003-2004										Experiment Amts			Total		
		Fall 2003 (130-0-50) Oct 18/03		Hilling (34-0-0) +P		Foliar Feed (20-20-20) July 9/04			Fertigation (20-0-0)			Apr 20/04					
									Jn 25	Jl 5	Jl 15						
		N	K_2O	N	P_2O_5	N	P_2O_5	K_2O	N	N	N	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Nitrogen	**1**	130	50	34	10	5	5	5	15	15	15	**29**	122	62	**243**	137	117
	2	130	50	34	10	5	5	5	15	15	15	**41**	122	62	**255**	137	117
	3	130	50	34	10	5	5	5	15	15	15	**58**	122	62	**272**	137	117
	4	130	50	34	10	5	5	5	15	15	15	**153**	122	62	**367**	137	117
Phosphorus	**5**	130	50	34	10	5	5	5	15	15	15	60	**0**	62	274	**15**	117
	6	130	50	34	10	5	5	5	15	15	15	58	**57**	62	272	**72**	117
	3	130	50	34	10	5	5	5	15	15	15	58	**122**	62	272	**137**	117
	7	130	50	34	10	5	5	5	15	15	15	54	**231**	62	268	**246**	117
Potassium	**8**	130	50	34	10	5	5	5	15	15	15	58	122	**0**	272	137	**55**
	9	130	50	34	10	5	5	5	15	15	15	58	122	**29**	272	137	**85**
	3	130	50	34	10	5	5	5	15	15	15	58	122	**62**	272	137	**117**
	10	130	50	34	10	5	5	5	15	15	15	58	122	**183**	272	137	**238**

Taber 2005. In the fall of 2004, the field received a fertilizer application of 75 lb/ac N, 30 lb/ac P_2O_5, and 115 lb/ac K_2O. Soil samples taken April 22, 2005, after the grower applied fall fertilizer and just outside of the individual fertilized plots, indicated there was a total of 297 lb NO_3-N/ac, 145 lb P/ac, and 1994 lb K/ac in the surface 2 ft of soil. The experimental rates of fertilizer were applied on April 20-21, 2005. The fertilizer rates for the treatments were chosen to create four increasing amounts of one nutrient, while holding the other two constant (Table 3).

Table 3. Fertilizer schedule (lb/ac) in 2004-2005.

Trtmt		Grower Applied 2004-2005						Experiment Amts			Total		
		Fall 2004			Planting	Top dressed	Fertigation	Apr 20-21/05					
		N	P_2O_5	K_2O	P_2O_5	N	N	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Nitrogen	**1**	75	30	115	60	80	30	**16**	69	22	**201**	159	137
	2	75	30	115	60	80	30	**77**	69	22	**262**	159	137
	3	75	30	115	60	80	30	**126**	69	22	**311**	159	137
	4	75	30	115	60	80	30	**177**	69	22	**362**	159	137
Phosphorus	**5**	75	30	115	60	80	30	127	**0**	22	312	**90**	137
	3	75	30	115	60	80	30	127	**69**	22	311	**159**	137
	6	75	30	115	60	80	30	126	**174**	22	312	**264**	137
	7	75	30	115	60	80	30	99	**258**	22	284	**348**	137
Potassium	**8**	75	30	115	60	80	30	126	69	**0**	311	159	**115**
	3	75	30	115	60	80	30	126	69	**22**	311	159	**137**
	9	75	30	115	60	80	30	126	69	**133**	311	159	**248**
	10	75	30	115	60	80	30	126	69	**234**	311	159	**349**

Coaldale 2007. In the fall of 2006, the entire field received an application of composted manure. Fall 2006 and spring 2007 applications of mineral fertilizer were not applied to the area where the experiment was conducted. Soil samples taken on September 18, 2006, indicated there

was a total of 32 lb NO_3-N/ac in the surface 2 ft and 21 lb P/ac and 1123 lb K/ac in the surface foot of soil.

The experimental rates of fertilizer were applied on April 17, 2007. The fertilizer rates for the experimental treatments were chosen to create four increasing amounts of one nutrient, while holding the other two constant (Table 4). These increasing amounts are shown in colour and correspond to the colours used in subsequent figures. The field also received eight applications of fertigation between June 15 and August 18, 2007 (Table 4).

Table 4. Fertilizer schedule (lb/ac) in 2006-2007.

Trtmt		Grower Applied 2006-2007*					Experiment Amts			Total		
		Fall 2006 Compost			Fertigation		Apr 17/07					
		N	P_2O_5	K_2O	N	P_2O_5	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Nitrogen	**1**	50	60	105	101	17	**24**	101	75	**175**	178	180
	2	50	60	105	101	17	**151**	101	75	**302**	178	180
	3	50	60	105	101	17	**200**	101	75	**351**	178	180
	4	50	60	105	101	17	**250**	101	75	**401**	178	180
Phosphorus	**5**	50	60	105	101	17	200	**0**	75	351	**77**	180
	3	50	60	105	101	17	200	**101**	75	351	**178**	180
	6	50	60	105	101	17	201	**151**	75	352	**228**	180
	7	50	60	105	101	17	200	**201**	75	351	**278**	180
Potassium	**8**	50	60	105	101	17	200	101	**0**	351	178	**105**
	3	50	60	105	101	17	200	101	**75**	351	178	**180**
	9	50	60	105	101	17	200	101	**152**	351	178	**257**
	10	50	60	105	101	17	200	101	**206**	351	178	**311**

Petiole Sampling

Petiole samples were collected and analyzed for each plot on June 29, July 6, 13, 20, and 25, and August 12 and 26, 2004; on June 30, July 6, 13, 20, and 27, and August 10 and 24, 2005; and on June 27, July 4, 11, 18, and 25, and August 8 and 22, 2007. The fourth leaf stem (petiole) from the top of the main stem was taken and leaflets were removed in the field (Fig. 2). Approximately 80 petioles were collected from each plot, at each sampling date.

Within each plot, approximately 20 petioles were collected from the second, third, sixth, and seventh potato rows in 2004 and 2005 and from either the second or the sixth rows on alternating weeks in 2007. Unlike previous years, the 2007 plots consisted of six rows instead of eight. This was because the cooperating grower utilized a six-row harvester, so this size of plot was most suitable. Staff were instructed to sample representative plants only and to avoid any unhealthy or overly advanced plants. Staff were instructed to only walk in furrows between the second and third rows and between the sixth and seventh rows in 2004 and 2005 and between the first and second or the fifth and sixth in 2007, in order to preserve the middle two rows for tuber harvest. Field staff were also instructed to only walk between rows at the border between two plots. In order to maintain consistency, whenever possible, the same person sampled the same plots at approximately the same time of day and in the same order. The outside two rows were designated guard rows and were not sampled. Petiole samples were kept in a cooler and then air dried overnight in a tobacco dryer (45-50 °C). Samples were ground and sent to a laboratory for

analysis of nitrate nitrogen (NO_3-N), phosphorus (P), and potassium (K). Because of a problem with laboratory equipment in 2005, initial K results were low and samples required re-analysis during the winter.

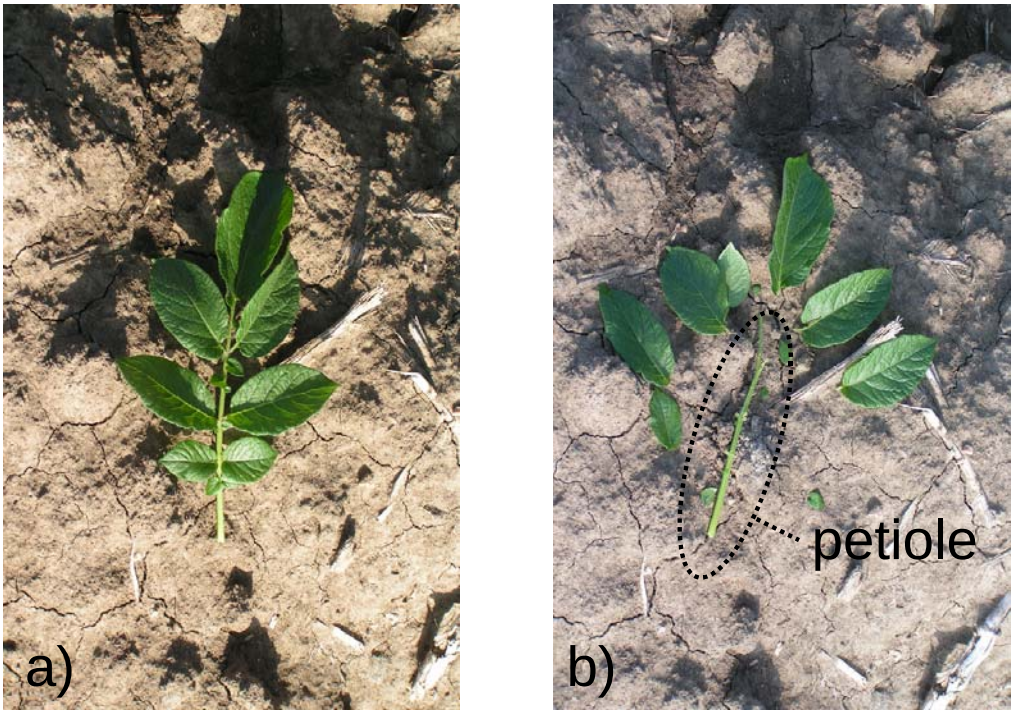


Figure 2. Russet Burbank fourth leaf stem a) before and b) after removal of leaves (petiole shown in dashed circle).

Tuber Harvest

Tuber samples (2 x 25 ft strips) were collected on September 22 and 23, 2004; September 21 and 22, 2005; and September 13 and 14, 2007. The harvest was conducted with the PGA two-row harvester. Field staff collected, bagged, and labelled samples in the field. In the laboratory, samples were washed, graded, and weighed to calculate total yield, marketable yield, mean tuber weight, and percent smalls. Grading categories used were small (<$1^7/_8$ in), medium ($1^7/_8$ – 3½ in), over-size (> 3½ in), and deformed. Clean weights and tuber numbers were recorded for each category and each sample and then converted to yield (short tons per acre) based on sample area (2 rows = 6 ft x 25 ft long = 150 sq ft). Marketable yield was defined as total yield minus yield of small (undersize) tubers. Specific gravity was calculated as the weight in air divided by weight in water method (Schippers 1976) on 25 medium tubers for each sample.

Data Analysis

Results were analyzed as a randomized complete block design, with six treatments and four replicates, using an analysis of variance (ANOVA) procedure (SAS Institute Inc. 2004). The Student-Newman-Keuls multiple range test ($P < 0.05$) was used to determine if differences existed among treatments.

Critical Petiole Nutrient Concentrations

Belanger et al. (2001 and 2003) proposed a technique for determining critical petiole nitrate nitrogen concentrations from experimental data. In addition to petiole nutrient concentrations, the Belanger technique requires several other measurements, such as shoot biomass and shoot nutrient concentration, that were not collected as part of this study due to cost constraints. The Belanger technique was adapted and applied to the project data. Only paired petiole and yield data were available, so rather than using a nitrogen nutrition index compared to yield as Belanger did, yield was compared to petiole nutrient concentration at each petiole sampling date.

1. For the first step, a second order polynomial curve was fitted to the yield *versus* petiole nutrient relationship and the petiole concentration at the maximum yield value for the curve was recorded. This maximum occurred where the slope of the second order polynomial equalled zero. This was called the 100% relative yield (100%RY) petiole concentration. The maximum yield, designated as 100%RY, was multiplied by 0.9 to calculate the 90% relative yield (90%RY). The corresponding petiole nutrient concentration was calculated for each petiole sampling date, from the formula for the second order polynomial best-fit line. The intercept of the best-fit lines was set to zero, in order to fix the shape of the second order polynomial as an inverted "U". This gives a relationship where yield increases with increasing petiole nutrient concentration to a point (100%RY), beyond which, yield actually decreases with increasing petiole nutrient concentration, as concentrations reach a level that is detrimental to tuber formation.

2. For the second step of the adaptation of the Belanger procedure, the petiole nutrient concentrations at 100% and 90% relative yields are plotted as a function of the days after planting (DAP) for each corresponding sampling date. These plots indicate the optimal ranges for petiole nutrients throughout the growing season.

RESULTS AND DISCUSSION

Meteorological Observations

Early in the first growing season of the study (2004), just as flowering initiated (July 7), the potato crop was damaged by hail but recovered well. Overall, 2004 temperature and rainfall were similar to long-term (1950-2000) averages (Table 5).

The 2005 growing season in southern Alberta was remarkable for the record rainfalls in June and September (Table 5). Many growers were forced to pump out portions of fields that were flooded. Saturated conditions can lead to nitrogen losses through runoff, deep drainage, and microbial denitrification. Although the cool temperatures likely slowed denitrification, the potential for nitrogen losses was still present. Other nutrients can also be lost with water that is removed by pumping and through runoff and deep drainage. The potential for nutrient losses in 2005 made it difficult to be certain that the applied rates of fertilizer remained within the root zone of their designated plot sites. Additionally, eight of the 40 plots were not harvested due to the wet conditions.

Overall, growing season (May to August) temperatures in 2007 were somewhat higher than long-term averages and total precipitation was close to the long-term average (Table 5). June and July 2007 were hotter and drier than long-term averages with no precipitation falling in July. On August 10, 2007, the crop was damaged by hail.

Table 5. Monthly average temperature and rainfall at Taber in 2004, 2005, and 2007 compared to long-term (1950-2000) averages (Environment Canada, 2008).

	Average Temperatures (°C)				Total Precipitation (mm)			
Month	2004	2005	2007	1950-2000 Average	2004	2005	2007	1950-2000 Average
April	8.1	7.6	4.6	5.7	25.6	26.3	83.6	31.6
May	10.3	12.5	12.8	11.7	78.4	17.4	89.4	44.0
June	15.3	15.0	17.0	15.8	57.8	198.4	34.3	69.9
July	19.6	19.3	23.5	18.7	51.8	5.0	0.0	37.9
August	17.9	15.8	18.7	18.0	76.9	58.8	47.6	38.5
September	12.8	12.4	11.5	12.8	8.2	116.4	36.4	34.5
Average/Total	14.0	13.8	14.7	13.8	298.7	422.3	291.3	256.4

Crop Growth and Development

Taber 2004. The potato crop was planted on April 28, 2004, and it was flowering on July 7, 2004, the same date a hailstorm damaged the field. The grower responded to the hail with a foliar feed application of 20-20-20 on July 9, 2004, which was in addition to three scheduled fertigation applications of 20-0-0 (June 25, July 5, and July 15, 2004).

Taber 2005. The potato crop was planted on April 22, 2005, and it had begun flowering by July 13, 2005. At planting in the spring of 2005, the grower applied starter fertilizer (60 lb/ac P_2O_5) to the entire field, including the research plots. An additional 80 lb/ac N was top dressed and a total of 30 lb/ac N was applied through fertigation.

Coaldale 2007. The crop was planted on April 22, 2007, and it had begun flowering by July 11, 2007. The plot area was avoided by the grower during the spring and planting fertilizer applications. A total of 101 lb/ac N and 17 lb/ac P_2O_5 were applied through fertigation. The field was impacted by a hail storm on August 10, 2007. Crop damage was more extensive on the north half of the field.

Average Petiole Nitrate Nitrogen Compared to Marketable Yield and Specific Gravity

Average petiole nitrate nitrogen (NO_3-N), marketable yield, and specific gravity for each of the variable nitrogen treatments for 2004, 2005, and 2007 are summarized in Fig. 3, 4, and 5. On all graphs, the colour of lines and bars corresponds to the colours designated for treatments in the fertilizer schedules (Tables 2, 3, and 4). In all cases, there were no statistically significant differences among treatments, in marketable yield or specific gravity; however, there are some notable trends.

Petiole Nitrate Nitrogen. There was an increasing concentration of petiole NO_3-N with increasing fertilizer N and this was seen in all three years of the study. Throughout 2004, the highest N rate (367 lb N/ac) consistently showed the greatest petiole NO_3-N concentration (Fig. 3a). Early in the growing season, petiole NO_3-N concentration in all but the greatest N treatment fell below the USA standard range, yet this did not have a detrimental effect on yield for the 272 lb N/ac treatment. Petiole NO_3-N initially decreased for the first three sample dates until 76 days after planting (DAP), with a large increase noted on the fourth petiole sampling date (83 DAP). The initial decline in petiole NO_3-N possibly coincided with the tuber initiation stage of growth, where rapid formation and growth of stems and leaves was taking place. The jump in petiole NO_3-N may coincide with tuber bulking, where above-ground plant growth has stabilized and the plant root uptake of N is able to "catch-up" to optimal levels. Growers typically begin to monitor petiole nutrients at this stage.

The greatest N rate (Treatment 4: 362 lb N/ac) in 2005 consistently showed the greatest petiole NO_3-N concentration (Fig. 3b), but not by a large margin. The lowest N rate (Treatment 1: 201 lb N/ac) actually had the second-greatest average petiole NO_3-N concentration for the first, second, and fourth sampling dates (June 30, July 6, and 20). For the remainder of the sampling dates, Treatment 1 had the lowest average petiole NO_3-N concentration. These inconsistencies may have resulted from N losses from the large amounts of rainfall in 2005. Despite the record rainfall, all petiole NO_3-N results were within or above the suggested adequate ranges for the northwest USA. Petiole NO_3-N initially decreased until 75 DAP, increased dramatically at 82 DAP, and then decreased for the remainder of the growing season.

In 2007, all but the lowest N fertilizer treatment (Treatment 1: 175 lb N/ac) fell within the USA standards (Fig. 3c). The three highest N treatments had very similar petiole NO_3-N concentrations, despite representing a range in fertilizer N (302 to 401 lb N/ac). Overall petiole NO_3-N initially decreased and then levelled-off between 73 and 94 DAP, then decreased for the final two petiole samplings in August 2007. The sharp increase in petiole NO_3-N seen at 83 DAP in 2004 and 82 DAP in 2005, respectively, was not seen. This may be due to crop stress due to the extreme heat and lack of precipitation seen in July 2007 (Table 5). The hail storm on August 10, 2007, did not seem to have an effect on the petiole NO_3-N concentrations for the subsequent sampling date (August 22, 2007) (Fig. 3c) and petiole NO_3-N concentrations followed a similar declining pattern that was observed in August of previous years (Fig. 3a and 3b).

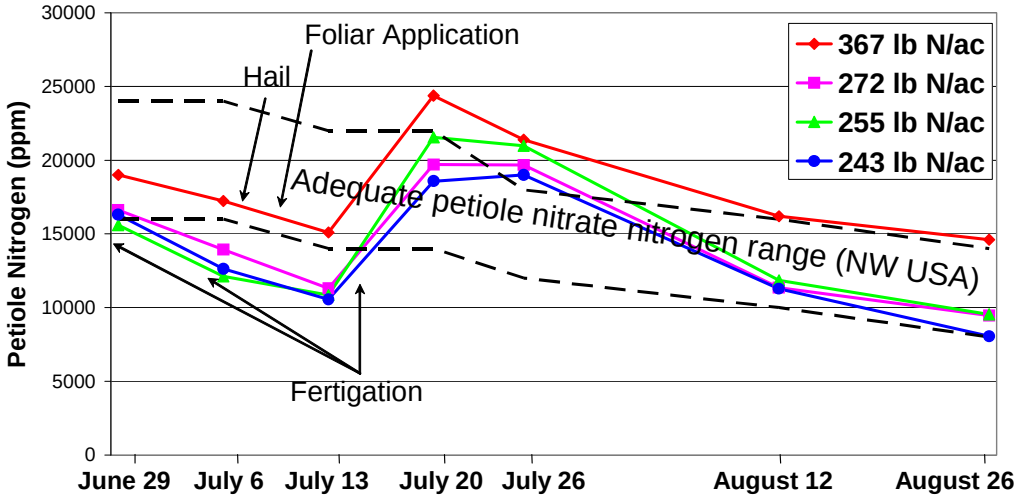
Marketable Yield. In 2004, Treatment 3 (272 lb N/ac) had the greatest overall yield; however, the treatments were not significantly different (Fig. 4a). Treatment 3 was designed to approximate the typical grower-applied rate of fertilizer. In 2005, Treatment 2 (262 lb N/ac) had the greatest overall yield; however, the treatments were not significantly different (Fig. 4b). Yield data for this treatment were quite variable.

In 2007 on Reps 1 and 2 (north half of the field), plots that received the lowest N fertilizer rates (Treatment 1) were visibly different (lighter green) than all of the surrounding treatments. Fig. 6 shows the Treatment 1, Rep 1 plot just next to the Treatment 9 Rep 2 plot. Treatment 3 was meant to approximate the grower fertilizer rates and gave the greatest yield of all 10 treatments in 2007 (Fig. 4c).There was no significant yield difference among treatments;

however, there was a trend to increasing yield with increased fertilizer (Fig. 4c), with a decreased yield at the highest rate of N.

Tuber Specific Gravity. In 2004, the two higher rates of N fertilizer (Treatments 3 and 4) had slightly greater specific gravities (Fig. 5a). This result is contrary to the findings of Waterer and Heard (2005) who stated that excess fertilizer N may lead to low specific gravity. In 2005, a slight decrease in specific gravity was found for fertilizer rates greater than 262 lb N/ac (Fig. 5b). In 2007, there was also a slight trend to decreasing specific gravity with increased fertilizer N (Fig. 5c). Although these results were not statistically significant, this observation is similar to other findings wherein excess nitrogen fertilizer can have the unwanted consequences of low specific gravity (Waterer and Heard, 2005). Because lowered specific gravity is a goal for some Alberta producers, further research into the link between specific gravity and amounts and timing of excess N fertilizer may be useful.

a)



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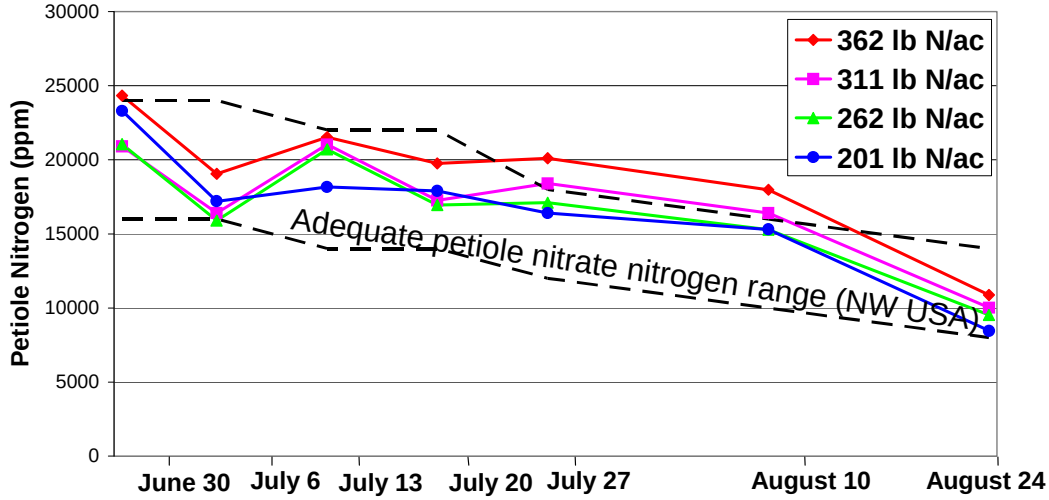

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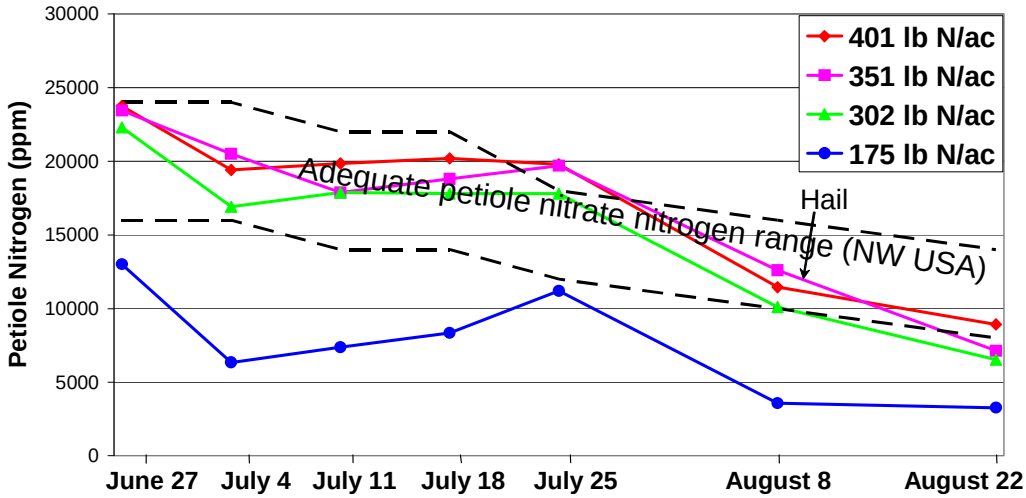


Figure 3. Russet Burbank potato petiole nitrate nitrogen (NO_3-N) concentrations (ppm) for four different N fertilizer rates, in (a) 2004, (b) 2005, and (c) 2007. Dashed black lines correspond to upper and lower suggested limits used in the northwest USA.

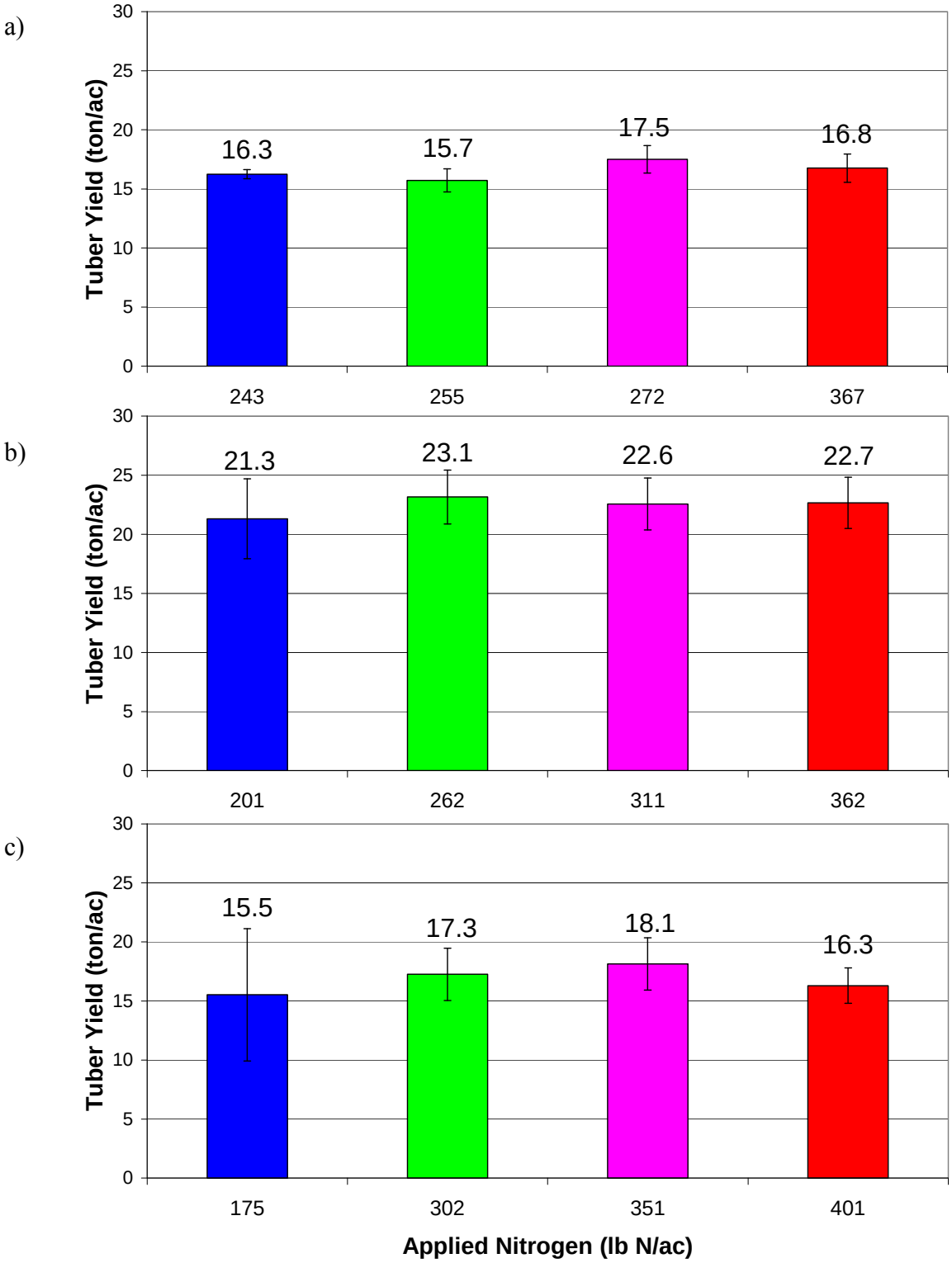


Figure 4. Russet Burbank potato marketable yield (ton/ac) for four different N fertilizer rates, in (a) 2004, (b) 2005, and (c) 2007. Error bars indicate standard deviations. Differences among treatments for which error bars overlap are not statistically significant.

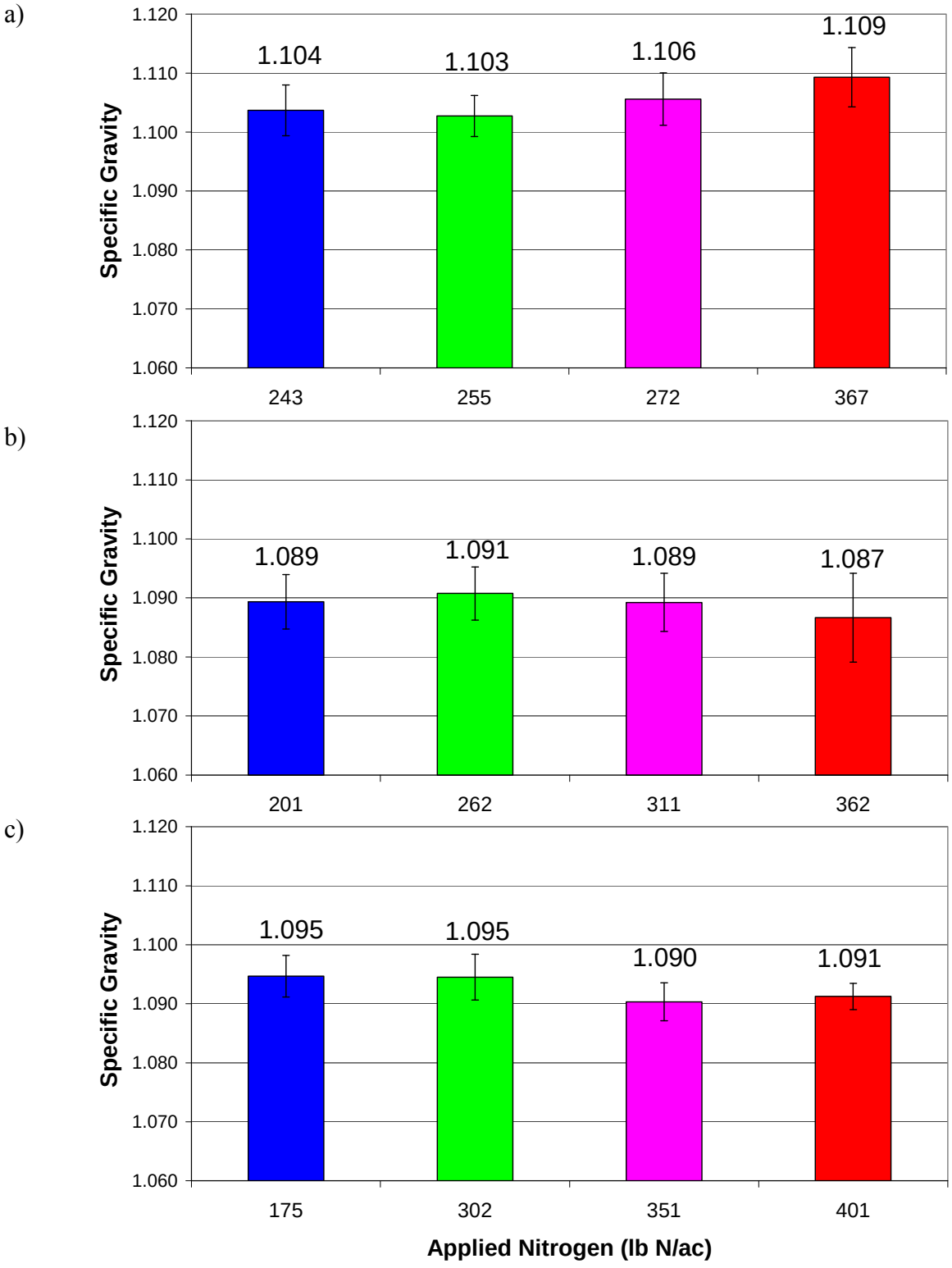


Figure 5. Russet Burbank potato tuber specific gravity for four different N fertilizer rates, in (a) 2004, (b) 2005, and (c) 2007. Error bars indicate standard deviations. Differences among treatments for which error bars overlap are not statistically significant.

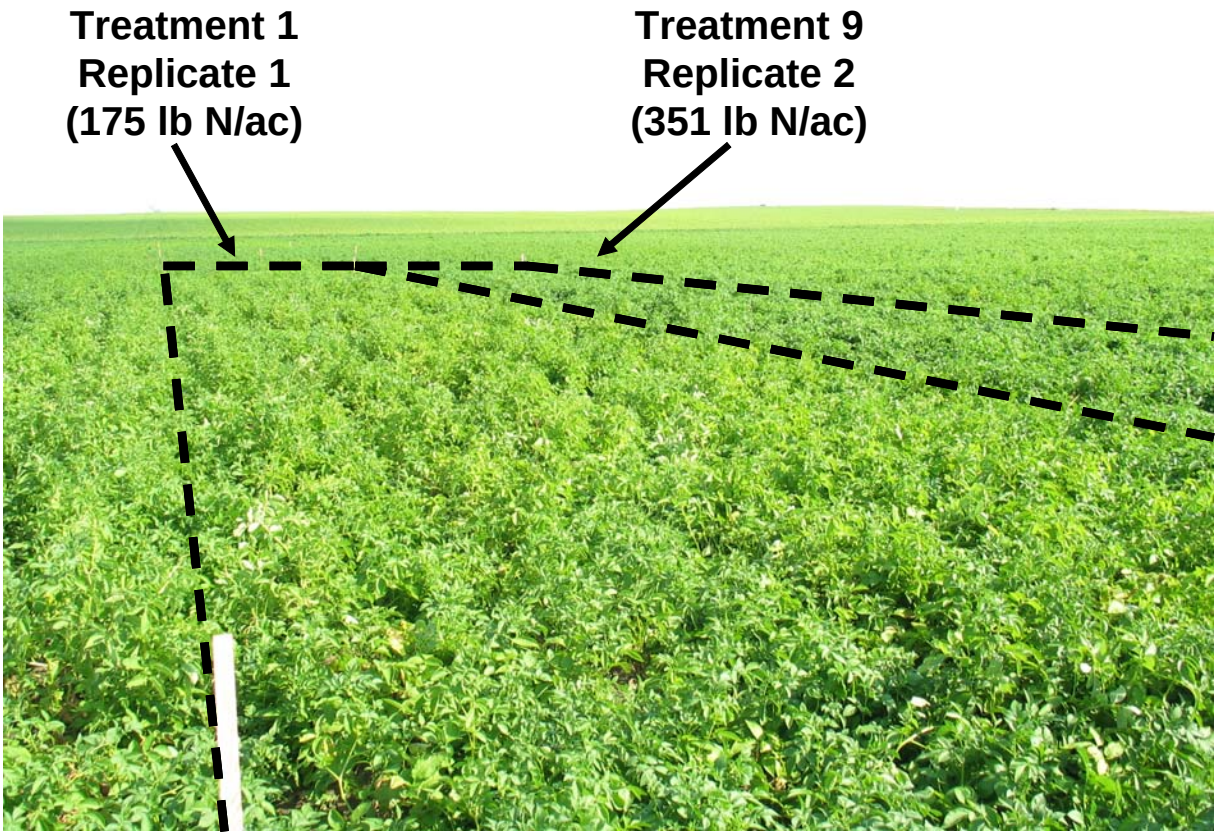


Figure 6. Visible difference in colour of Treatment 1, Rep 1 (175 lb/ac N fertilizer, including 24 lb/ac N added on April 17, 2007) compared to Treatment 9, Rep 2 (351 lb/ac N fertilizer, including 200 lb/ac N added on April 17, 2007), looking north on August 8, 2007 (photo courtesy of Gary Larson, AAFC).

Average Petiole Phosphorus Compared to Marketable Yield and Specific Gravity

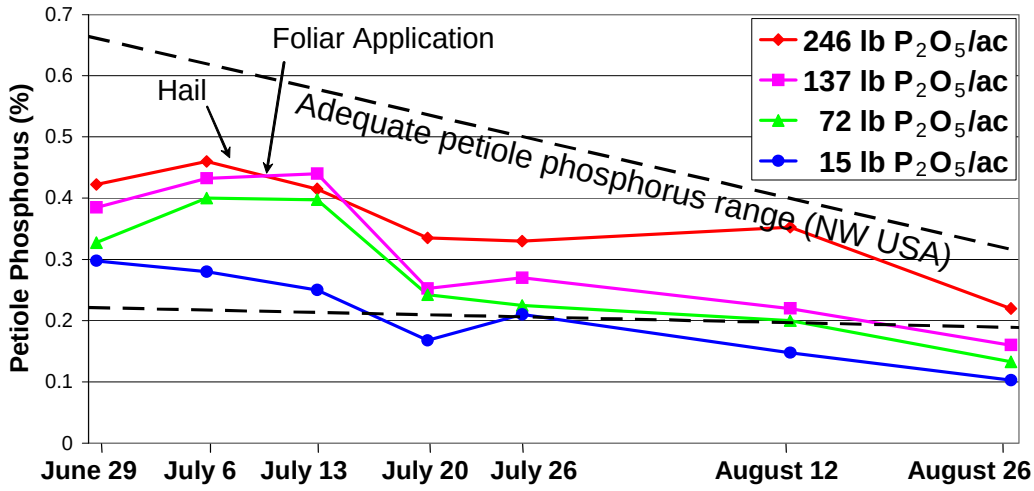
Average petiole phosphorus, marketable yield, and specific gravity for each of the phosphorus (P) treatments are summarized in Fig. 7, 8, and 9. As with the N treatments, there were no statistically significant differences among P treatments, in yield or specific gravity; however, there are some notable trends.

Petiole Phosphorus. In 2004, increasing rates of fertilizer P gave increasing amounts of petiole P (Fig. 7a). This held true throughout the growing season, with the exception of the petiole samples taken immediately following the hail. This may be because of a spatially variable impact of the hail. The lower rates of P fertilizer gave petiole P concentrations in the lower half of the USA standard range, yet yields were not significantly impacted. In 2005, the two highest rates of fertilizer P gave greater amounts of petiole P (Fig. 7b). Overall, petiole P initially decreased until 89 DAP, when it took a sharp increase (especially for the two highest fertilizer P rates). Petiole P then decreased at 96 DAP and levelled-off or increased slightly for the remainder of the growing season. All but a few points were beneath the lower limit for the adequate USA petiole P standard range, yet yields were not significantly impacted. This indicates that the lower limits for petiole P are likely too high for Alberta fields. Because soil P is not very mobile, it is unlikely that the heavy rains of 2005 led to significant leaching of P. In 2007, all petiole P results were in the low range, within and slightly below the USA standards (Fig. 7c). The lowest fertilizer P rate had the lowest petiole P content until 108 DAP (August 8, 2007); however, on most petiole sample dates, the highest rate of fertilizer P gave the second-lowest petiole P content and the lowest on the last sampling date (Fig. 7c).

Marketable Yield. In 2004, the two highest rates of fertilizer P (137 and 246 lb P_2O_5/ac) had a slightly greater yield than the two lower rates of fertilizer P (15 and 72 lb P_2O_5/ac), but results were not significantly different (Fig. 8a). In 2005, the highest rate of fertilizer P (Treatment 7: 348 lb P_2O_5/ac) had a slightly greater yield than the other three rates of fertilizer P, but results were not significantly different (Fig. 8b). Incidentally, this treatment had a slightly lower amount of fertilizer N applied (99 lb N/ac) on April 20-21, 2005 (Table 3), compared to the other three treatments (126-127 lb N/ac) because of limitations in the application rates of the fertilizer spreader used. Treatment 7 had 258 lb P_2O_5/ac applied on April 20-21, 2005, as 506 lb/ac of monoammonium phosphate (12-51-0), which also provided 61 lb N/ac. This left 65 lb N/ac (188 lb/ac product) to be applied as ammonium nitrate (34.5-0-0) to give a total application of 126 lb N/ac. The nearest to this amount that the chain settings on the fertilizer spreader could achieve was 111 lb/ac product or 38 lb N/ac, which gave a total of 99 lb N/ac for Treatment 7, applied April 20-21, 2005 (Table 3). In 2007, the greatest tuber yield was found on the plots that received the second-lowest P fertilizer rate (Treatment 3: 178 lb P_2O_5/ac) (Fig. 8c).

Tuber Specific Gravity. There was no discernible trend in tuber specific gravity in relation to fertilizer P rates in 2004 (Fig. 9a). In 2005, the specific gravity was variable, did not show any statistically significant relationships, and did not appear to be affected by fertilizer P (Fig. 9b). In 2007, there was virtually no difference in the specific gravity for the different P rates (Fig. 9c).

a)



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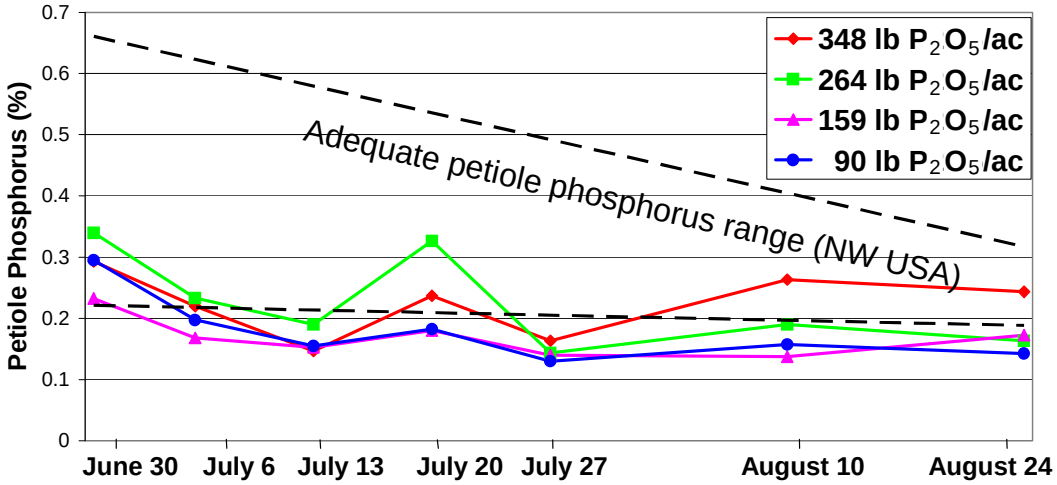

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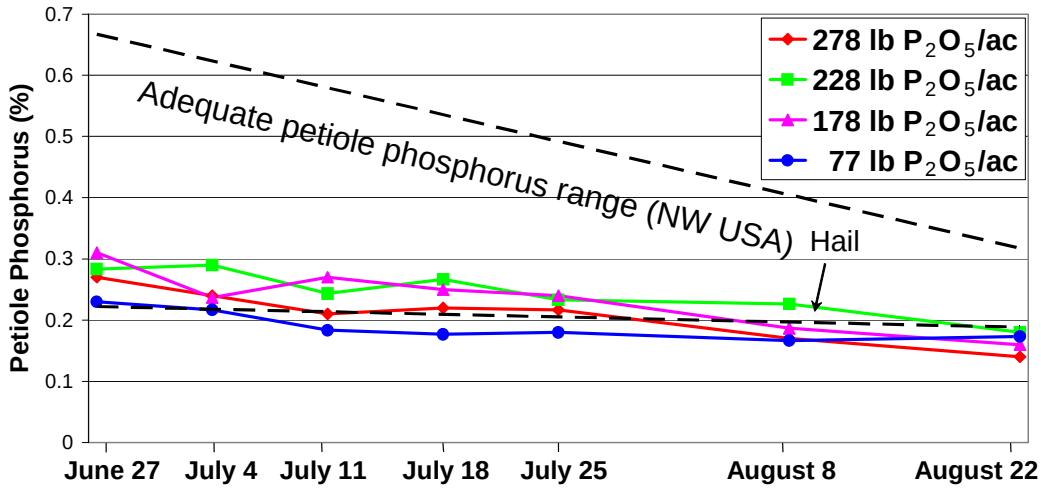

Figure 7. Russet Burbank potato petiole phosphorus concentrations (%) for four different P_2O_5 fertilizer rates, in (a) 2004, (b) 2005, and (c) 2007. Dashed black lines correspond to upper and lower suggested limits used in the northwest USA.

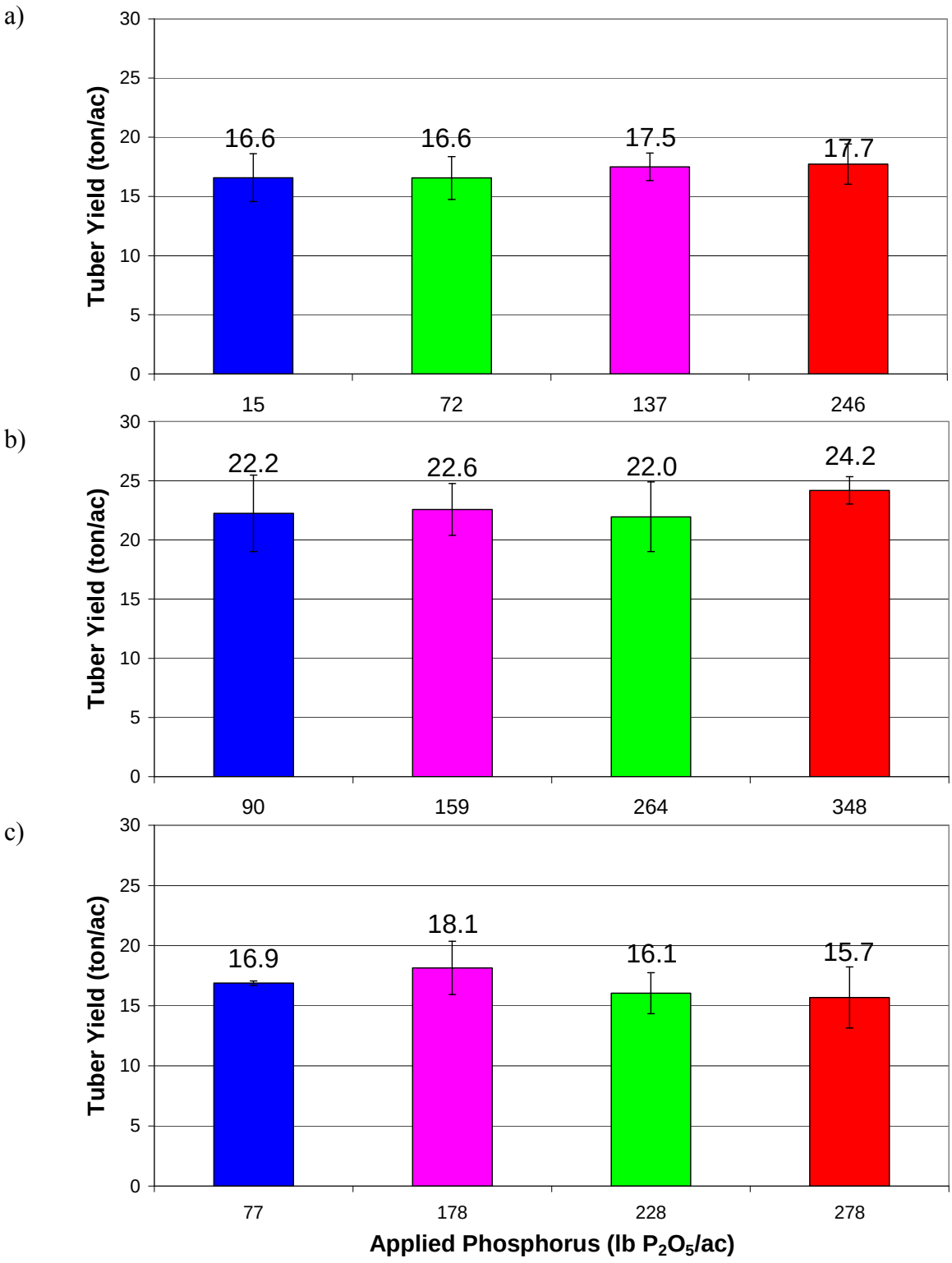

Figure 8. Russet Burbank potato marketable yield (ton/ac) for four different P_2O_5 fertilizer rates, in (a) 2004, (b) 2005, and (c) 2007. Error bars indicate standard deviations. Differences among treatments for which error bars overlap are not statistically significant.

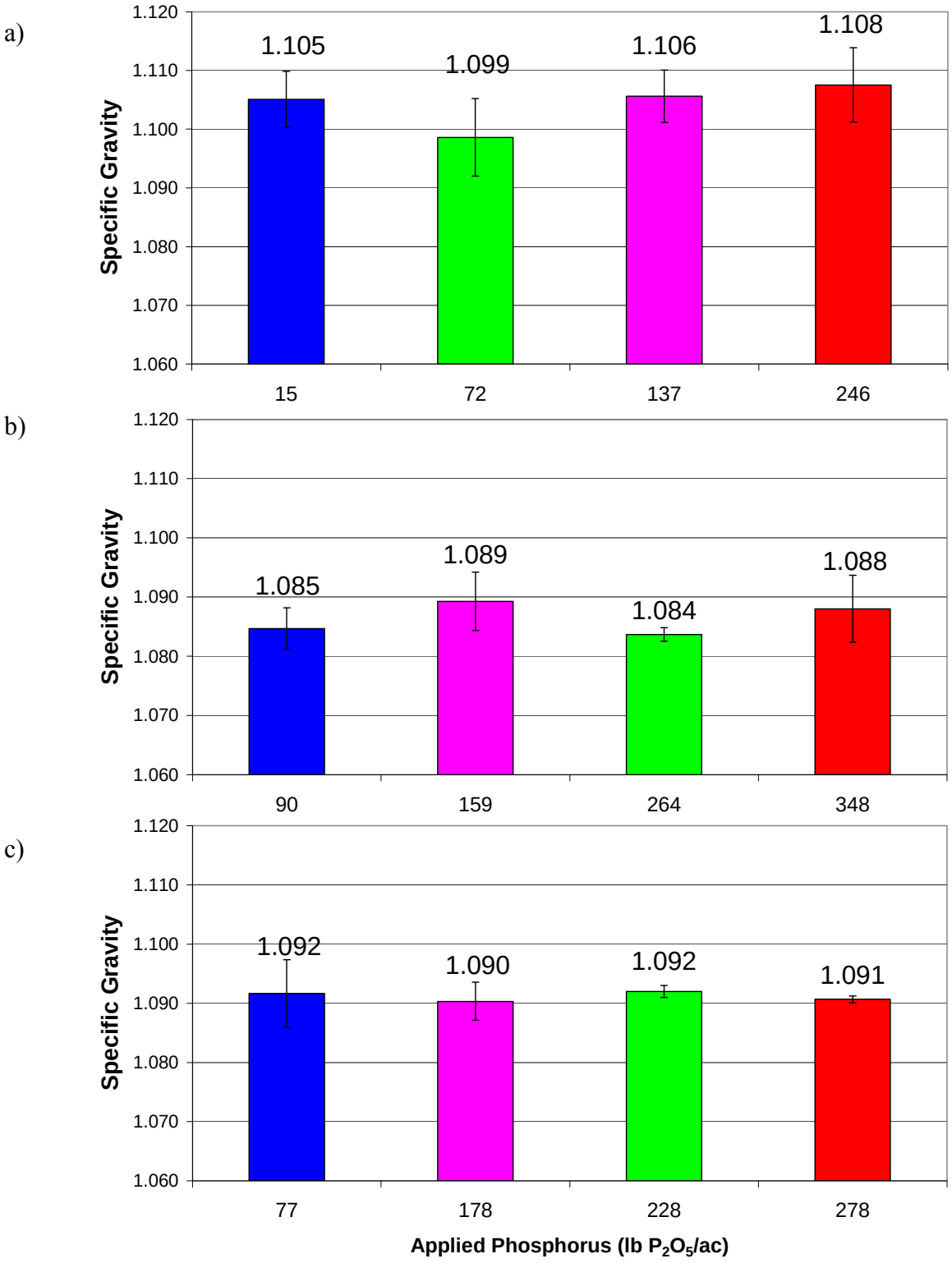

Figure 9. Russet Burbank potato tuber specific gravity for four different P_2O_5 fertilizer rates, in (a) 2004, (b) 2005, and (c) 2007. Error bars indicate standard deviations. Differences among treatments for which error bars overlap are not statistically significant.

Average Petiole Potassium Compared to Marketable Yield and Specific Gravity

Average petiole potassium, marketable yield, and specific gravity for each of the potassium (K) treatments are summarized in Fig. 10, 11, and 12. As with the N and P treatments, there were no statistically significant differences among K treatments, in yield or specific gravity; however, there are some notable trends.

Petiole Potassium. In 2004, increasing rates of fertilizer K had no observable effect on petiole K concentration (Fig. 10a). Most average petiole K concentrations were above the USA standard ranges at this site. Similar to 2004 results, the 2005 data showed that increasing rates of fertilizer K had no observable effect on petiole K (Fig. 10b). Also, like the 2004 results, most average petiole K concentrations were above the USA standard ranges at the 2005 site. Similar to previous years, petiole K results in 2007 were above the USA adequate range and there was no relationship between fertilizer K and petiole K (Fig. 10c). Together, these results confirm those of previous published (Dubetz and Bole 1975; Mackay and Carefoot 1987; and Mackay et al. 1989) and unpublished studies (Konschuh 2001 and McKenzie et al. 2002) that have shown no relationship between fertilizer K, yield, and petiole K. This may be a function of the potassium buffering effects of the soils found in southern Alberta. With the exception of very sandy soils, most soils found in southern Alberta have high levels of K, much of which (90-98%) is in an unavailable/nonexchangeable form within soil minerals (Dubetz and Dudas 1981). During a period of years, this unavailable K can move into available forms and vice-versa, depending on crop use and fertilizer K rates. The exchangeable form of K can then rapidly move into the soil solution in response to depleted K levels, where it can be taken up by plant roots (Brady and Weil 1999). This dynamic equilibrium creates a labile pool of K in the soil, which is capable of maintaining a constant supply of plant-available K and which is also capable of masking the effects of different application rates of fertilizer K.

Marketable Yield. In 2004, there was a trend toward slightly increased yield with increasing fertilizer K up to 117 lb K_2O/ac, with a small decrease for the highest rate (238 lb K_2O/ac), but results were not significantly different (Fig. 11a). In 2005, there was a trend toward slightly increased yield with increasing fertilizer K up to 248 lb K_2O/ac with a small decrease for the highest rate (349 lb K_2O/ac), but results were not significantly different and were all within a narrow range between 21.5 and 23.1 ton/ac (Fig. 11b). In 2007, there was no relationship between yield and fertilizer K (Fig. 11c).

Tuber Specific Gravity. There was a slight trend toward decreasing specific gravity with increasing fertilizer K in 2004, but differences were not statistically significant (Fig. 12a), even at the highest rate of fertilizer K. In 2005, there was a trend toward increasing specific gravity with increasing fertilizer K, but differences were not statistically significant (Fig. 12b). These results are contrary to those seen in 2004, where a trend toward decreasing specific gravity with increasing fertilizer K was observed. In 2007, there was no statistically significant trend in specific gravity with increasing fertilizer K (Fig. 12c); however, specific gravity decreased slightly for the highest rate of fertilizer K (311 lb K_2O/ac).

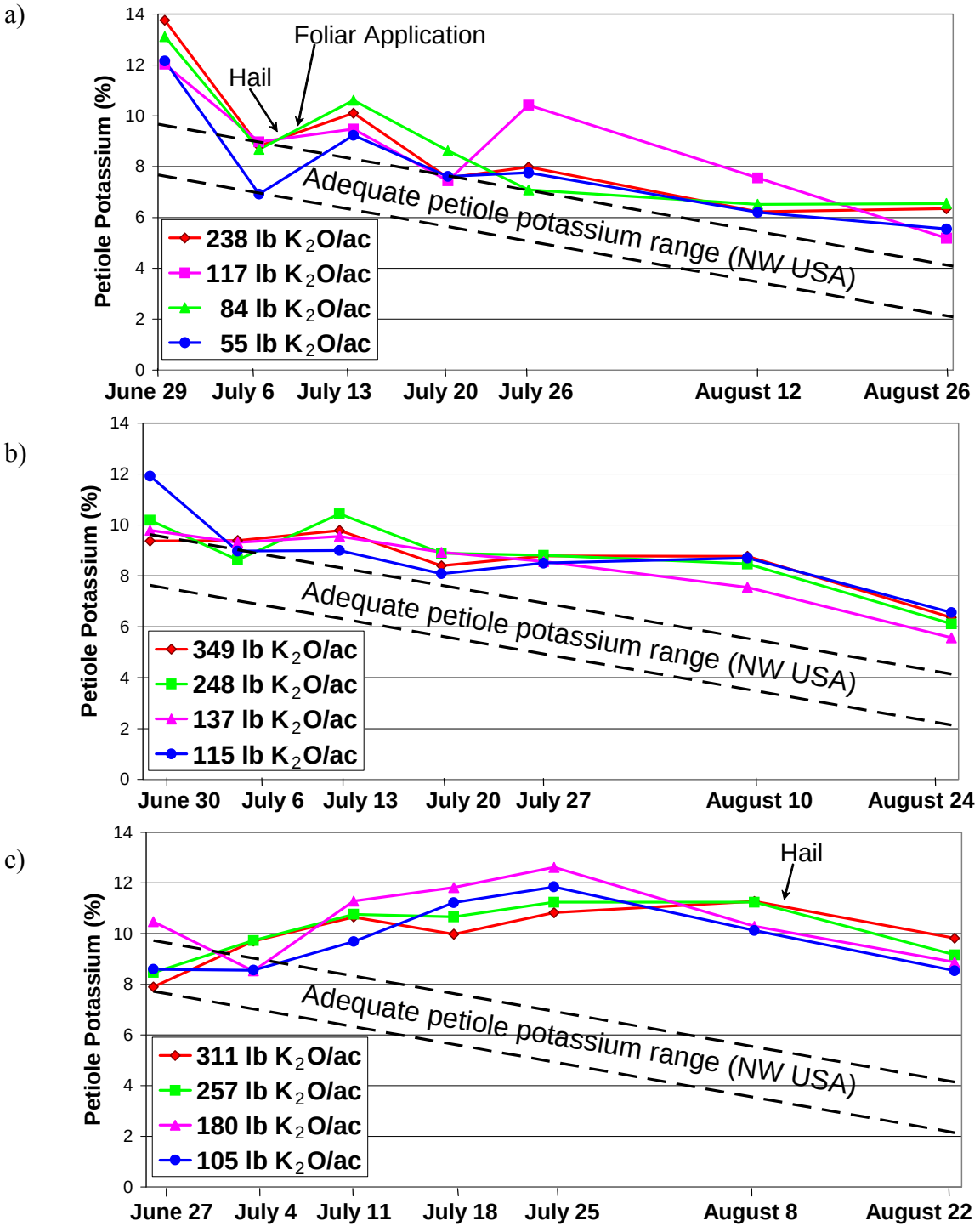

Figure 10. Russet Burbank potato petiole potassium concentrations (%) for four different K2O fertilizer rates, in (a) 2004, (b) 2005, and (c) 2007. Dashed black lines correspond to upper and lower suggested limits used in the northwest USA.

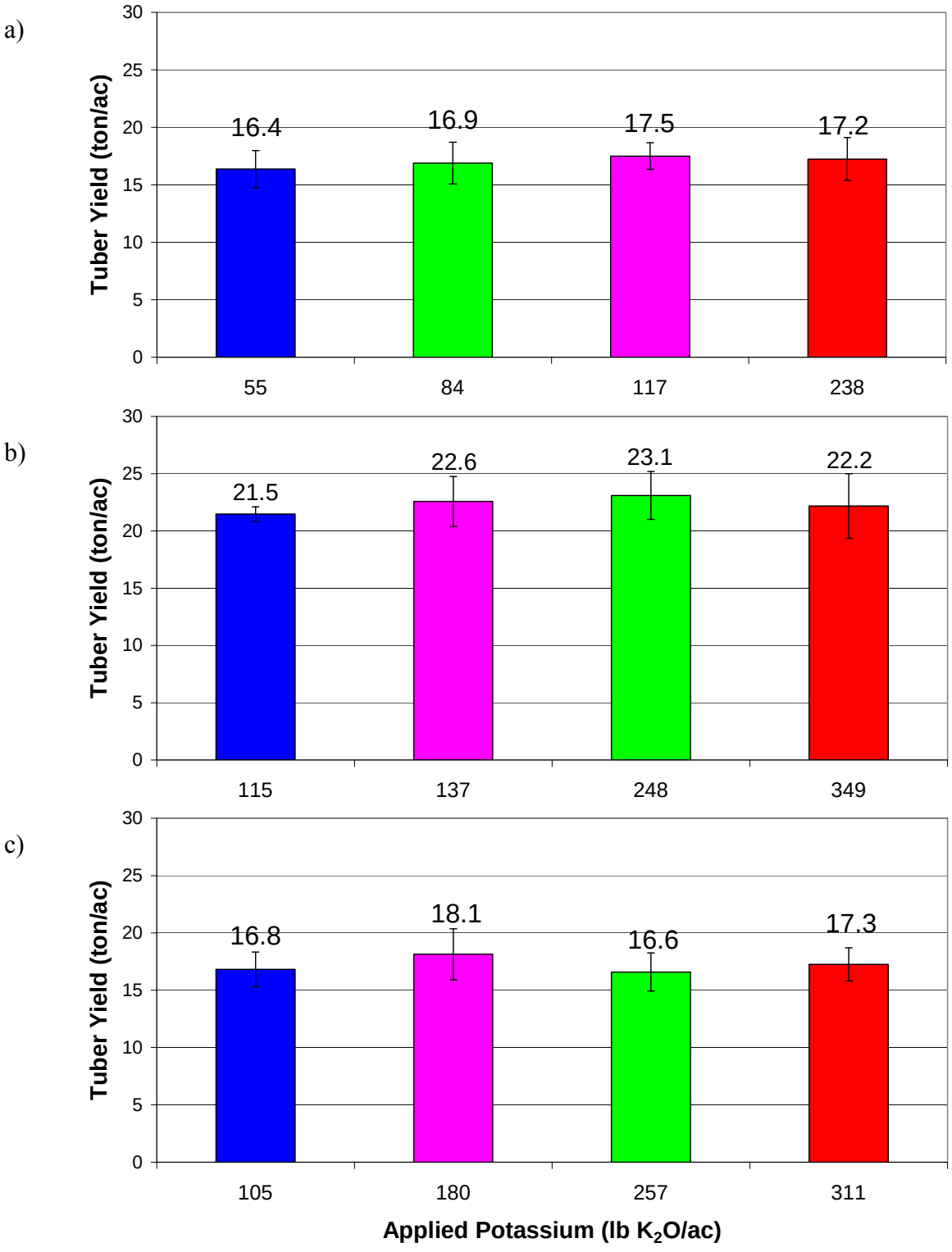

Figure 11. Russet Burbank potato marketable yield (ton/ac) for four different K_2O fertilizer rates, in (a) 2004, (b) 2005, and (c) 2007. Error bars indicate standard deviations. Differences among treatments for which error bars overlap are not statistically significant.

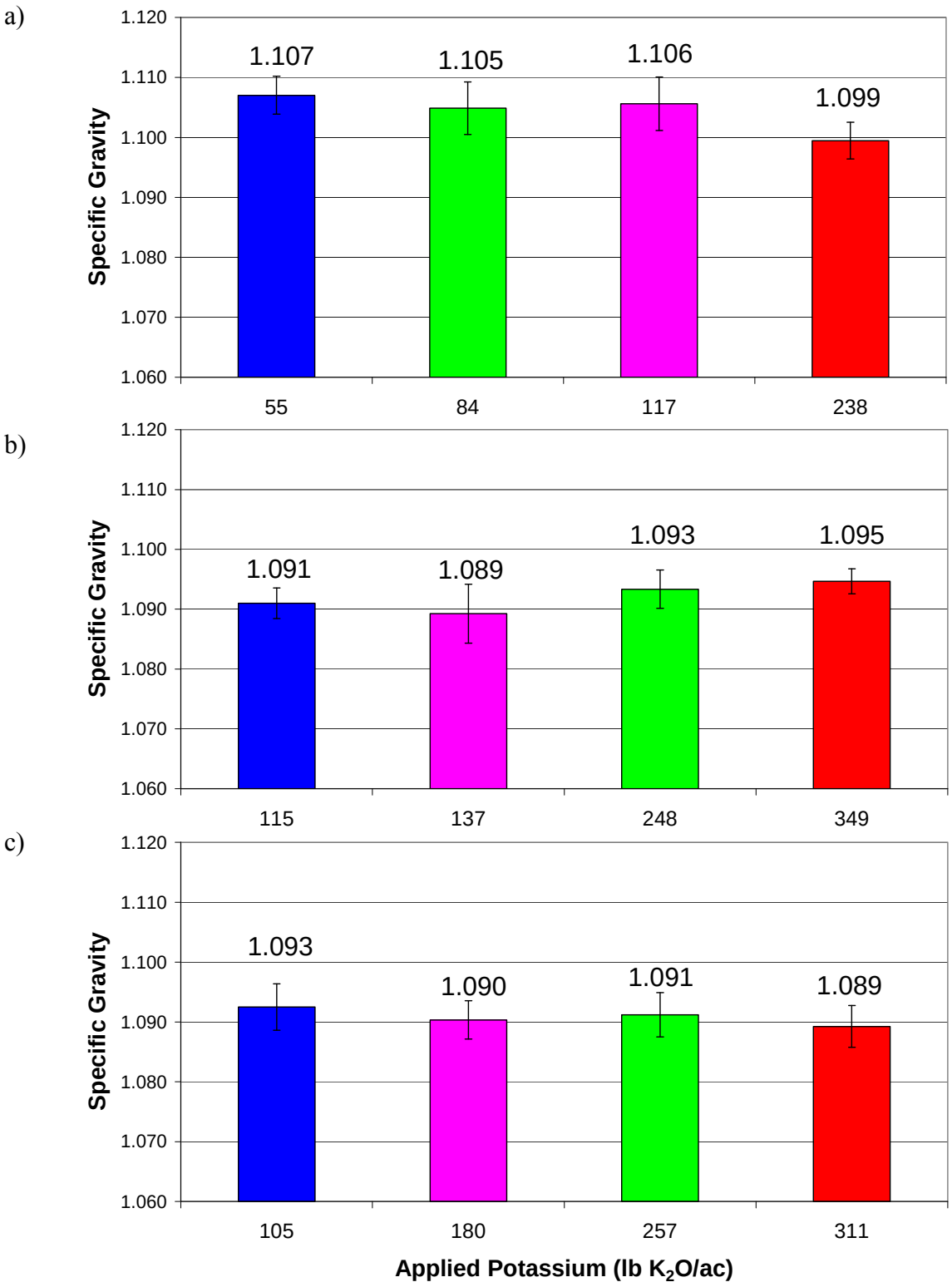

Figure 12. Russet Burbank potato tuber specific gravity for four different K_2O fertilizer rates, in (a) 2004, (b) 2005, and (c) 2007. Error bars indicate standard deviations. Differences among treatments for which error bars overlap are not statistically significant.

Critical Petiole Nutrient Concentrations

As described in the Methods and Materials section, a second order polynomial curve was fitted to the yield *versus* petiole nutrient relationship (Belanger et al. 2001, 2003). Examples of these graphs are shown in Fig. 13 for the petiole phosphorus on seven petiole sampling dates in 2005. The fit of these lines was highly variable.

The 100%RY and 90%RY values were plotted as a function of DAP and these graphs depict the optimal petiole nutrient concentration throughout the growing seasons (Fig. 14 to 16), including the 100%RY and 90%RY and their respective best-fit lines. Also shown on these graphs are the optimal ranges that have been suggested for the northwest USA (Schaupmeyer, *pers. commun.*).

Petiole Nitrate Nitrogen. The USA standard ranges are greater than the 2004 optimal petiole NO_3-N concentrations. For the 100%RY, the optimal petiole NO_3-N was approximately 19,000 ppm at 60 DAP and declined to 13,000 ppm by 120 DAP (Fig. 14a). The data appear to follow two linear trends, one for the tuber initiation growth stage (<80 DAP) and the other from the beginning of tuber bulking and onward (>80 DAP).

The USA standard ranges are very similar to the 2005 optimal petiole NO_3-N concentrations. For the 100%RY, the optimal petiole NO_3-N was nearly 24,000 ppm at 60 DAP and declined to 14,000 ppm by 125 DAP (Fig. 14b). As discussed before, however, the actual relationship is more likely two lines, one for the tuber initiation growth stage and the other from the beginning of tuber bulking and onward.

The USA standard ranges are somewhat high compared to the 2007 optimal petiole NO_3-N concentrations (Fig. 14c). For the 100%RY, the optimal petiole NO_3-N was nearly 19,700 ppm at 60 DAP and declined to approximately 6,400 ppm by 125 DAP (Fig. 14c). In 2007, there was not a dramatic increase in petiole NO_3-N at around 80 DAP. Instead, the petiole NO_3-N concentration increased gradually between 80 and 94 DAP and then decreased until 122 DAP (Fig. 14c). A difference in petiole nutrient concentrations has been noted in past studies between fields and between years (climate-effect) (Woods et al. 2004). This year-to-year difference is also noticeable in Fig. 14.

The following are the formulae for the linear best-fit 100%RY relationships between petiole NO_3-N and DAP, which hold for approximately DAP = 60-125.

2004 Petiole NO_3-N (ppm) = -98.7*DAP + 24982 ($r^2 = 0.32$)
2005 Petiole NO_3-N (ppm) = -153.7*DAP + 32826 ($r^2 = 0.43$)
2007 Petiole NO_3-N (ppm) = -204.4*DAP + 31955 ($r^2 = 0.73$)

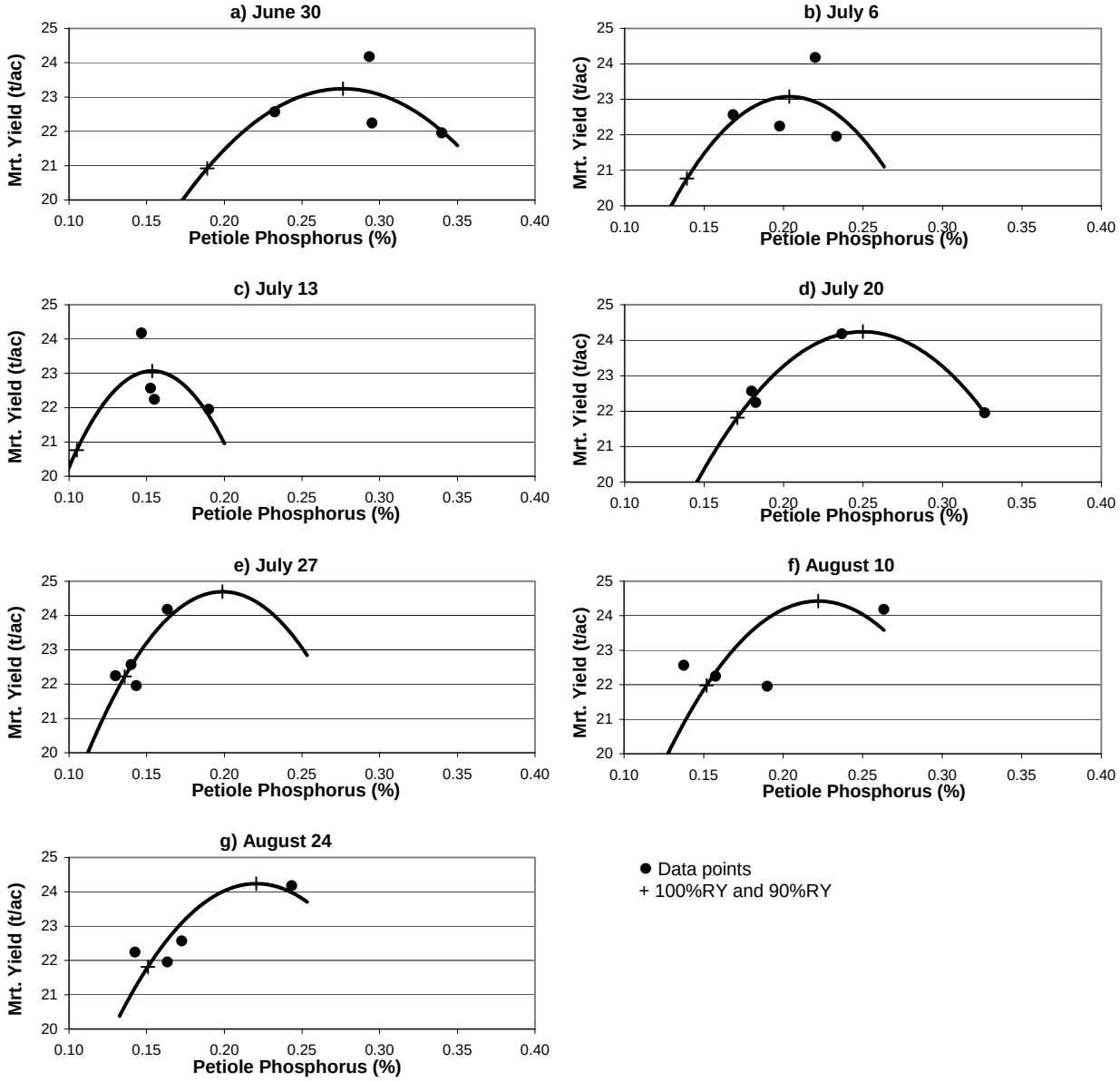

Figure 13. Russet Burbank potato tuber yield (ton/ac) as a function of petiole phosphorus (%), showing actual data points, the fitted second order curve, and the 100% relative yield (100%RY) and 90% relative yield (90%RY) values for seven petiole sampling dates in 2005.

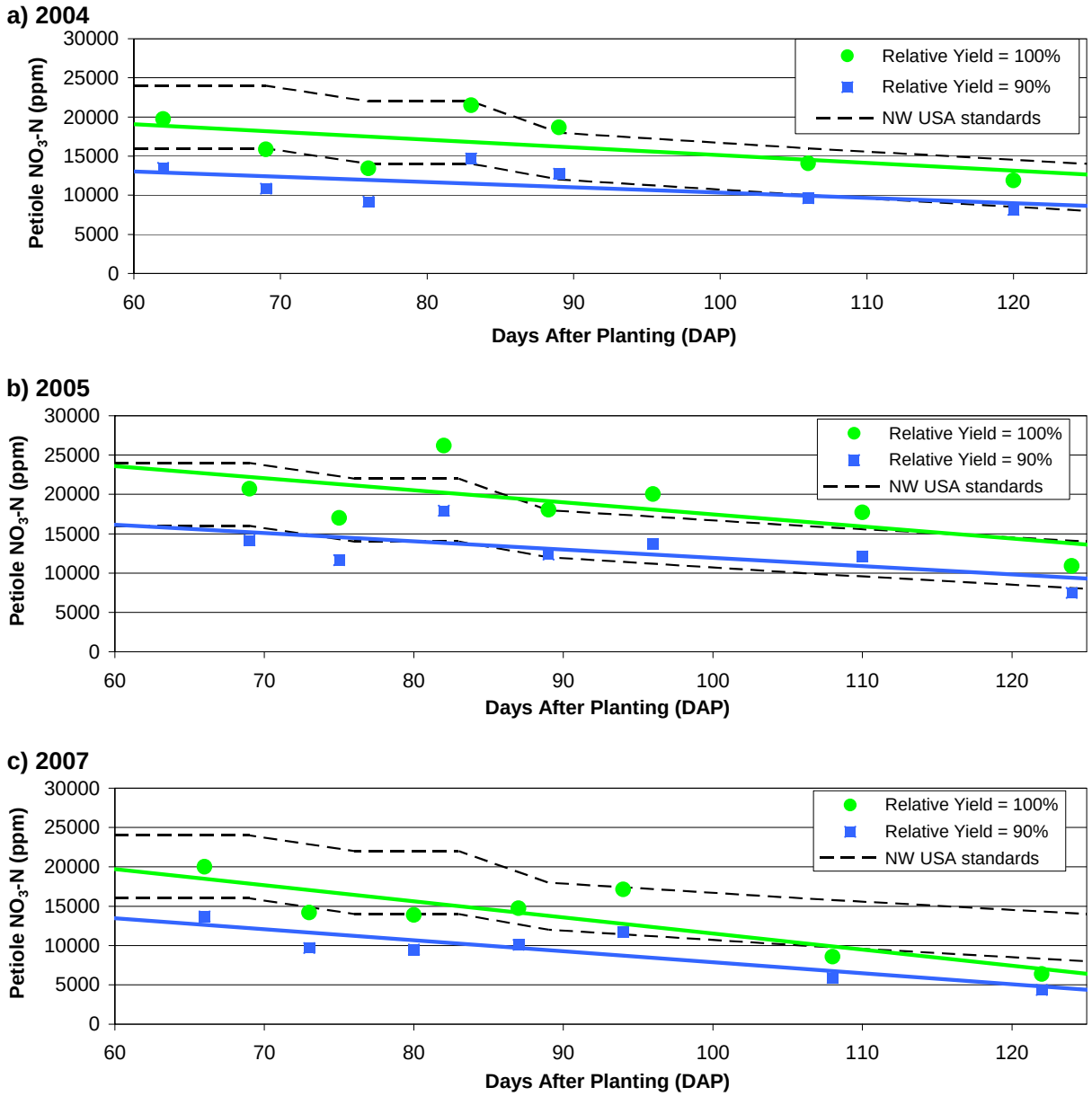

Figure 14. 100% relative yield (RY) and 90% relative yield petiole nitrate nitrogen (NO_3-N) concentration as a function of days after planting in (a) 2004, (b) 2005, and (c) 2007.

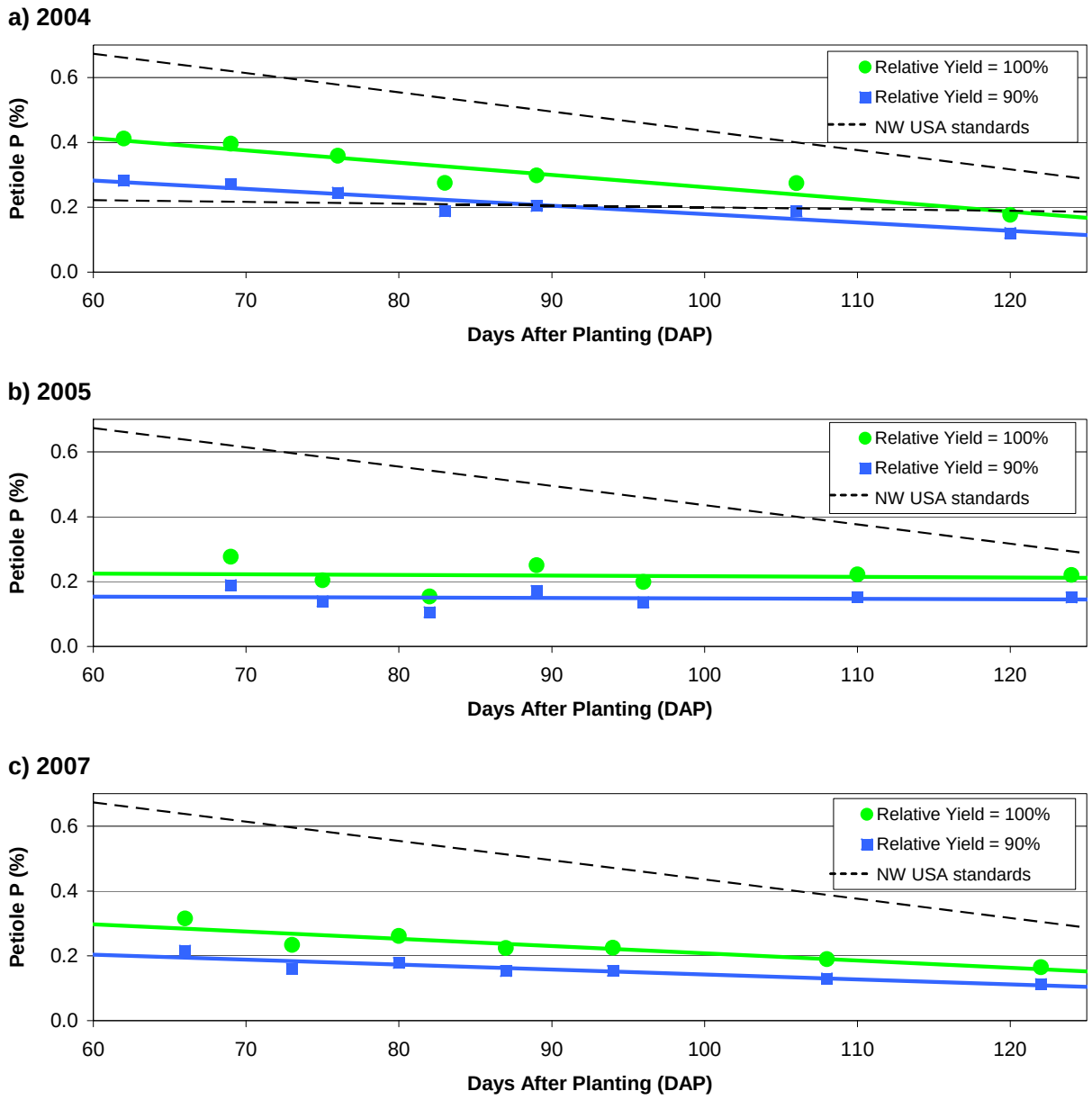

Figure 15. 100% relative yield (RY) and 90% relative yield petiole phosphorus concentration as a function of days after planting in (a) 2004, (b) 2005, and (c) 2007.

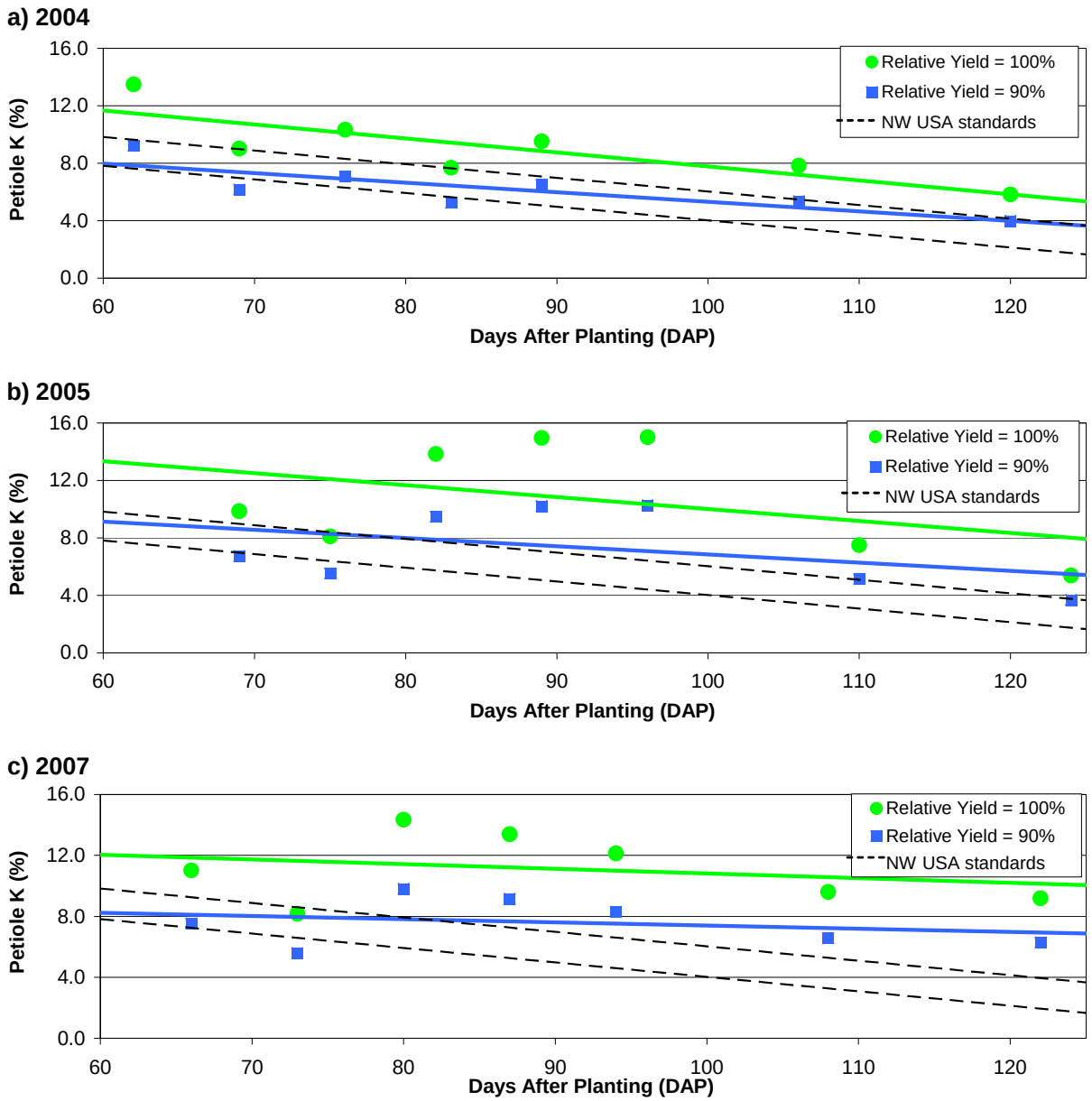

Figure 16. 100% relative yield (RY) and 90% relative yield petiole potassium concentration as a function of days after planting in (a) 2004, (b) 2005, and (c) 2007.

Petiole Phosphorus. The USA standard ranges are higher than the 2004 optimal petiole P concentrations. The 100%RY optimal P was approximately 0.42% at 60 DAP and declined to 0.18% by 120 DAP (Fig. 15a).

The USA standard ranges are much higher than the 2005 optimal petiole P concentrations. The 100%RY optimal P was approximately 0.24% at 60 DAP and declined a small amount to 0.21% by 125 DAP (Fig. 15b). This relationship was nearly a flat line in 2005 and overall values were much smaller than in 2004, yet no negative impacts on yield were observed.

The USA standard ranges are much higher than the 2007 optimal petiole P concentrations (Fig. 15c). The 100%RY optimal P was approximately 0.30% at 60 DAP and declined a small amount to 0.16% by 125 DAP (Fig. 15c). The optimal petiole P values in 2007 were similar to the 2005 results and are at the lowest end of the range of adequate NW USA standards, yet no negative impacts on yield were observed. For this reason, and because of corroborating data from past studies (Woods et al. 2004), it is felt that the upper and lower limits for petiole P (as given by NW USA standards) are too high.

The following formulae are for the linear best-fit 100%RY relationship between petiole P and DAP, which hold for approximately DAP = 60-125.

2004 Petiole P (%) = -0.0038*DAP + 0.64 ($r^2 = 0.89$)
2005 Petiole P (%) = -0.00021*DAP + 0.24 ($r^2 = 0.01$)
2007 Petiole P (%) = -0.0022*DAP + 0.43 ($r^2 = 0.83$)

Petiole Potassium. The USA standard ranges are slightly lower than the 2004 optimal petiole K concentrations. The 100%RY optimal K was approximately 11.5% at 60 DAP and declined to 5.5% by 120 DAP (Fig. 16a).

The USA standard ranges are slightly lower than the 2005 optimal petiole K concentrations. The 100%RY optimal K was approximately 13.3% at 60 DAP and declined to 7.9% by 125 DAP (Fig. 16b). The 2005 petiole K results were much higher than the 2004 results and than the adequate range from the NW USA. In 2005, the laboratory experienced problems with their equipment used for measuring K and results were re-analysed in January 2006. Results were adjusted to much higher than initial estimates. Similar to NO_3-N, 2005 petiole K optimal levels appear to follow two stages, one for prior to tuber bulking (<80 DAP) and the other from the beginning of tuber bulking and onward (>80 DAP) (Fig. 16b).

The USA standard ranges are slightly lower than the 2007 optimal petiole K concentrations (Fig. 16c). The 100%RY optimal K was approximately 12.0% at 60 DAP and declined to 10.1% by 125 DAP (Fig. 16c). Similar to NO_3-N, petiole K optimal levels appear to follow two stages, one prior to tuber bulking (<80 DAP) and the other from the beginning of tuber bulking and onward (≥80 DAP) (Fig. 16c). The 2007 petiole K results are higher than the adequate range from the NW USA, especially after 80 DAP. Results from previous studies (Konschuh 2001; McKenzie et al. 2002; and Woods et al. 2002) have indicated that a wider range for adequate petiole K would be more suitable in southern Alberta (Woods et al. 2004).

The following formulae are for the linear best-fit 100%RY relationship between petiole K and DAP, which hold for approximately DAP = 60-125.

2004 Petiole K (%) = -0.0973*DAP + 17.5 (r^2 = 0.32)
2005 Petiole K (%) = -0.0834*DAP + 18.3 (r^2 = 0.17)
2007 Petiole K (%) = -0.0307*DAP + 13.9 (r^2 = 0.07)

Optimal Petiole Nutrient Concentrations for Southern Alberta

The study was conducted during a growing season with temperature and precipitation close to long-term averages (2004), a growing season that was cool and wet (2005), and a growing season that was hot and dry (2007). When the values of 100%RY and 90%RY were compared to DAP for all three years combined, they were used to determine optimal petiole nutrient concentrations specific for southern Alberta. Fig. 17 shows the three years of project data compared to the current NW USA standards and the suggested optimal petiole NO_3-N (Fig. 17a), P (Fig. 17b), and K (Fig. 17c) concentrations during the southern Alberta growing season. It is important to remember that these upper and lower limits are for optimal yield (90-100% of relative yield) of Russet Burbank potatoes and are merely guidelines. Actual petiole nutrient concentrations will be affected by genotype, climate, irrigation amount, soil type, planting date, petiole sample collection technique, and laboratory analysis (Doll et al. 1971; MacKay and Carefoot 1987, Westcott et al. 1991; and Lewis and Love 1994).

Nitrate Nitrogen (NO_3-N). The suggested optimal petiole NO_3-N concentrations are quite similar to the current NW USA standards, especially for greater than 80 DAP (Fig. 17a). It is suggested that there should be two sets of ranges, one set for prior to and including approximately 80 DAP and another set for after approximately 80 DAP. The following formulae can be used to calculate the ranges for NO_3-N in units of parts per million (ppm) from the known DAP.

Prior to 80 DAP	**Petiole NO_3-N (ppm) = -290*DAP + 38800**	**for 100%RY**
Prior to 80 DAP	**Petiole NO_3-N (ppm) = -290*DAP + 30400**	**for 90%RY**
After 80 DAP	**Petiole NO_3-N (ppm) = -244*DAP + 41156**	**for 100%RY**
After 80 DAP	**Petiole NO_3-N (ppm) = -244*DAP + 33756**	**for 90%RY**

Another way to compare petiole NO_3-N to the suggested optimal ranges is to refer to the ranges given in Table 6, which gives the 100%RY and 90%RY values that correspond to between 60 and 125 DAP.

Phosphorus (P). The suggested optimal petiole P concentrations are substantially lower than the current NW USA standards, particularly early in the growing season (Fig. 17b). The following formulae can be used to calculate the Alberta-specific optimal ranges for P in units of percent (%) as a function of DAP.

Petiole P (%) = -0.00308*DAP + 0.485	**for 100%RY**
Petiole P (%) = -0.00077*DAP + 0.196	**for 90%RY**

Sample values for optimal petiole P are also given in Table 6 for between 60 and 125 DAP.

Potassium (K). The suggested optimal petiole K concentrations have a wider range than the current NW USA standards (Fig. 17c). Similar to NO_3-N, it is suggested that there be two sets of ranges of petiole K concentrations, one set for prior to approximately 80 DAP and another set for after approximately 80 DAP. The following formulae can be used to calculate the Alberta-specific optimal ranges for K in units of percent (%), as a function of DAP.

Prior to 80 DAP	**Petiole K (%) = -0.17*DAP + 22.6**	**for 100%RY**
Prior to 80 DAP	**Petiole K (%) = -0.14*DAP + 15.7**	**for 90%RY**
After 80 DAP	**Petiole K (%) = -0.18*DAP + 29.0**	**for 100%RY**
After 80 DAP	**Petiole K (%) = -0.17*DAP + 23.1**	**for 90%RY**

Sample values for optimal petiole K are also given in Table 6 for between 60 and 125 DAP.

Table 6. Suggested optimal Russet Burbank petiole nutrient (NO_3-N, P, and K) contents based on information from southern Alberta (2004, 2005, and 2007).

Days After Planting (DAP)	Optimal Petiole Nutrient Concentrations					
	NO3-N (ppm)		P (%)		K (%)	
	90%RY	100%RY	90%RY	100%RY	90%RY	100%RY
60	13000	21400	0.15	0.30	7.3	12.4
65	11550	19950	0.15	0.28	6.6	11.6
70	10100	18500	0.14	0.27	5.9	10.7
75	8650	17050	0.14	0.25	5.2	9.9
80	7200	15600	0.13	0.24	4.5	9.0
85	12978	20378	0.13	0.22	8.8	14.1
90	11756	19156	0.13	0.21	7.9	13.2
95	10533	17933	0.12	0.19	7.1	12.4
100	9311	16711	0.12	0.18	6.2	11.5
105	8089	15489	0.12	0.16	5.4	10.6
110	6867	14267	0.11	0.15	4.5	9.7
115	5644	13044	0.11	0.13	3.7	8.9
120	4422	11822	0.10	0.12	2.8	8.0
125	3200	10600	0.10	0.10	2.0	7.1

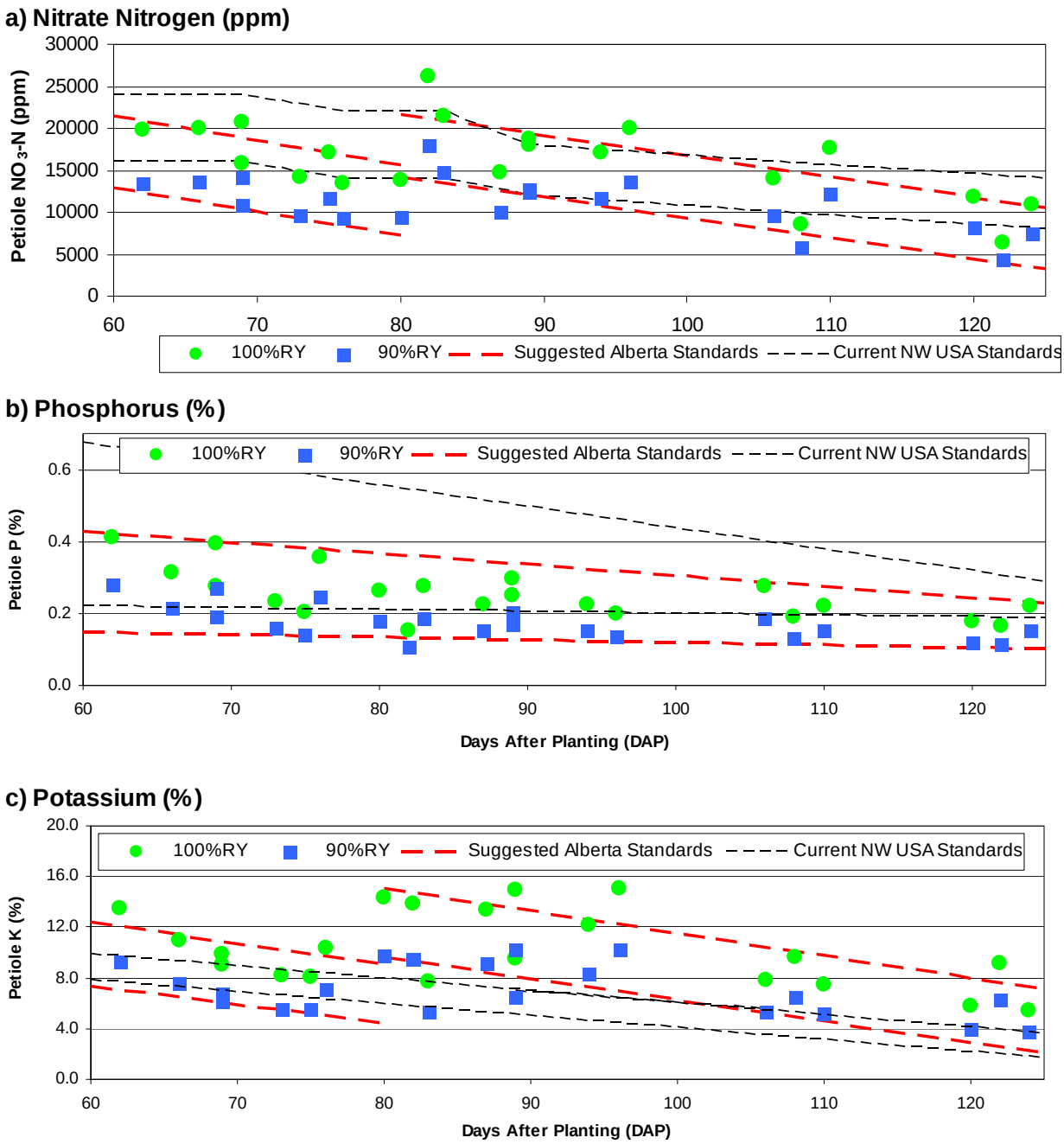

Figure 17. Suggested optimal petiole NO_3-N, P, and K concentrations for southern Alberta compared to current northwest USA recommendations and to the 100%RY and 90%RY data collected in 2004, 2005, and 2007.

Comparison to Previously Collected Data

The Belanger technique was adapted and applied to existing data sets accumulated from previous PGA-sponsored studies, where plot-scale petiole and corresponding yield and specific gravity data were available. These studies included projects on the precision farming of potatoes (McKenzie et al. 2002), effects of phosphorus and compost on Russet Burbank potatoes (Woods et al. 2002), and the effects of potassium on Russet Burbank potatoes (Konschuh 2001).

None of these studies consisted of variable rates of fertilizer N. In all cases, N was held constant for all treatments; therefore, results were inconclusive for N. The precision farming study demonstrated that spatial variability exists across any field, even if the entire field receives identical fertilizer application (McKenzie et al. 2002). The phosphorus and compost study (Woods et al. 2002) had variable rates of P, so the results of this study were used for P assessment. For this study, six experiments were conducted during three years (1999-2001). In all cases, P fertilizer rates were varied while other nutrients were held constant. Fig. 18 shows the 100%RY and 90%RY petiole P concentration as a function of days after planting for these six sites. There was variability in the results, but overall the new standards seem to fit quite well, especially early in the growing season.

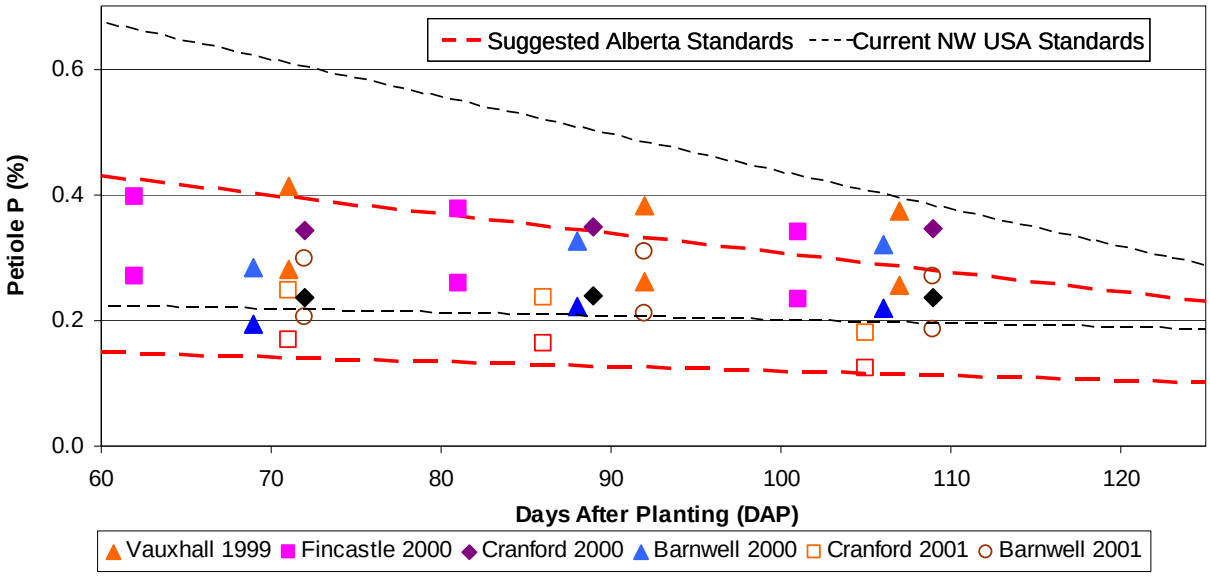

Figure 18. 100% relative yield (RY) phosphorus concentration as a function of days after planting for six previously-completed PGA-sponsored studies.

Results for several previous studies were unsuitable for the Belanger technique, as a second degree polynomial could not be fit to the data. Because this was the case, a simplified process was applied to these data (Konschuh 2001; Woods et al. 2002). For each site, the average petiole nutrient (NO_3-N, P, and K) concentrations for the treatment with the highest average marketable yield were taken as the optimal (Stark, *pers. commun.*). This eliminated the need to fit a polynomial to the data. NO_3-N, P, and K results shown are from the P and compost project (1999-2001) and the K results also include data from the K study (Konschuh 2001).

The NO_3-N results show (Fig. 19a) a great deal of scatter and that the suggested Alberta optimal range is about in the middle of the data points. Again, the N fertilizer rates were held constant for all of these studies, so results from these data and this simplified technique are uncertain.

The P results for this simplified method (Fig. 19b) support the previous results, using the Belanger technique, and fit within the suggested Alberta optimal range for petiole P quite well.

The K results for the simplified method (Fig. 19c) indicate that the suggested Alberta optimal range for petiole K may be too high for data from the P project.

One point to bear in mind regarding Fig. 19 is that this simplified technique for determining optimal petiole concentrations only takes into account the actual rates used in the study and does not "fill-in the blanks" for concentrations between the tested rates. So if one of the treatments did not achieve the exact optimal concentration-yield combination, it may have over or under estimated the optimal concentration and yield by just choosing the best one. The Belanger technique fits a curve to the data to determine the precise point at which the optimal yield should occur.

Effects of Climate

Although it was not a part of the initial objectives of the project, the effects of climate were examined using data from previously-completed PGA-sponsored studies done between 1997 and 2001 and using data from this study (2004, 2005, and 2007). The petiole NO_3-N data as a function of DAP were fit to a single linear regression equation, for each individual year. The intercept and slope of the best-fit line were then compared to temperature and precipitation data for the entire growing season and for various combinations of months during the growing season. Although the results of this analysis were not highly significant, there were some overall trends that were notable. Fig. 20 shows the results compared to average temperatures of June and July. The 40-yr mean temperature (1950-1990) for June and July was 17.4 °C and only the 2005 average was below this value.

In years when June and July are hotter than average, petiole NO_3-N concentrations may be greater than usual at the start of the measuring dates, as indicated by a greater intercept (Fig. 20a) from the petiole NO_3-N *versus* DAP best-fit line. Comparison of the slope of the petiole NO_3-N *versus* DAP best-fit line to temperature (Fig. 20b) indicates that petiole NO_3-N concentrations may decrease at a greater rate in hotter than average years than in cooler years. This may be due to the plant growing faster in hotter June-July weather and being unable to sustain sufficient rates of nitrogen uptake or it may be an artefact of heat-stress. Regardless, these trends hint at the impact of climate on petiole nitrate nitrogen concentrations.

Temperature effects could possibly be seen in other petiole nutrients. Only a cursory analysis of the effects of climate data was done here and it is recommended that the effects of climate on petiole nutrients be examined in more detail.

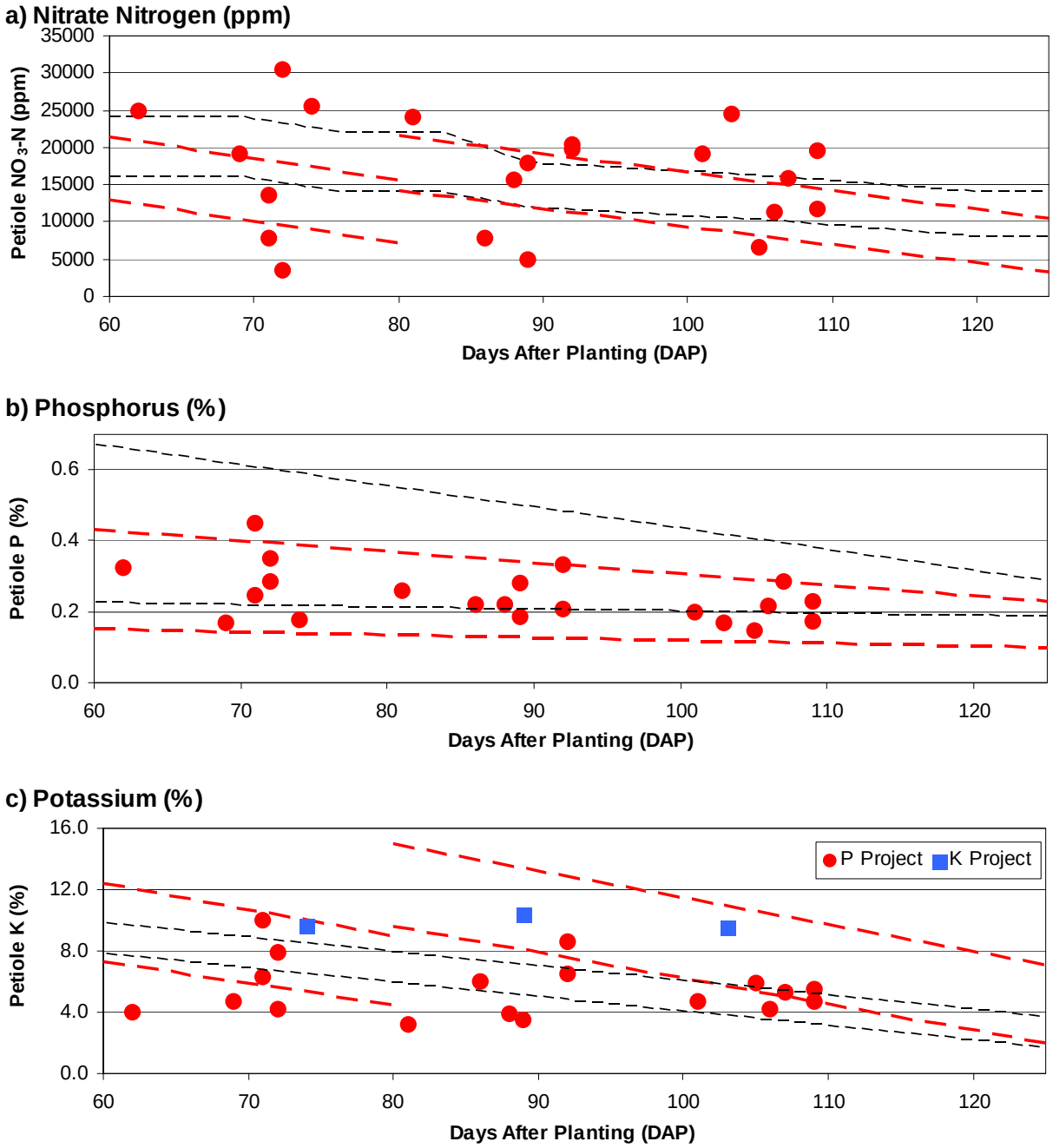

Figure 19. Petiole (a) nitrate nitrogen, (b) phosphorus, and (c) potassium concentration for treatment with highest yield as a function of days after planting for previously-completed PGA-sponsored studies.

The potential effects of climate reinforce the notion that petiole nutrient recommendations should only be treated as guidelines that will be impacted by climate, soil, and other environmental factors, as well as human factors.

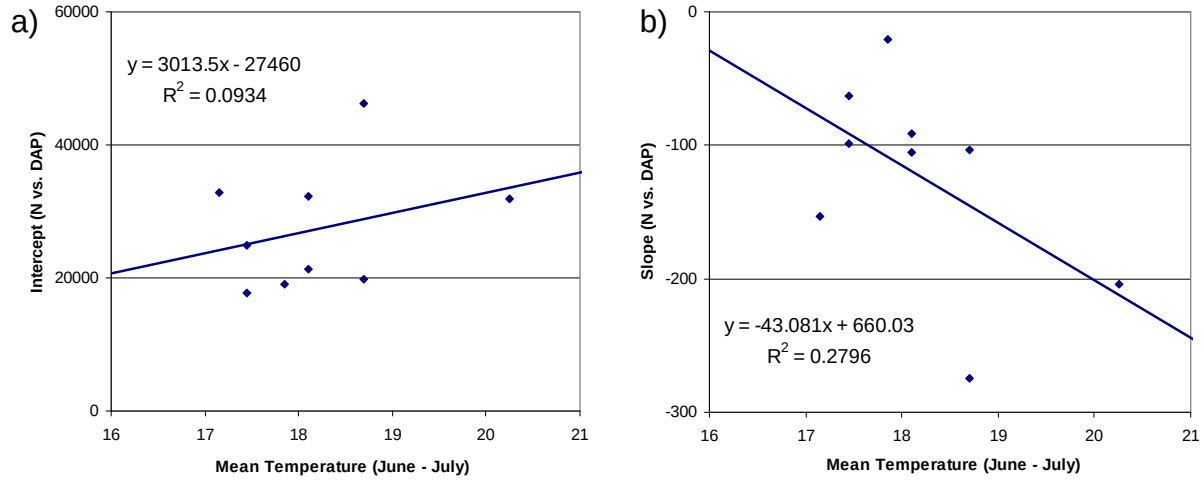

Figure 20. Climate effects on petiole nitrate nitrogen as exhibited by the relationship between the (a) intercept and (b) slope of the NO_3-N *versus* DAP best-fit lines as a function of mean temperatures in June and July for each year that data were available.

Petiole Nutrient Concentration Recommendations

Current Alberta Russet Burbank potato petiole NO_3-N, P, and K recommendations are based on information from the northwest United States (Table 1; Fig. 21). A technique for determining critical petiole nitrate nitrogen concentrations from experimental data (Belanger et al. 2001 and 2003) was applied to three years of data collected in southern Alberta in 2004, 2005, and 2007. Based on these data, new petiole nutrient concentration ranges have been proposed (Fig. 22). When these suggested petiole nutrient recommendations were compared to previously-collected data, they gave reasonable results for P and K. There was a great deal of scatter in the previously-collected N data, as petiole NO_3-N can be affected by many factors.

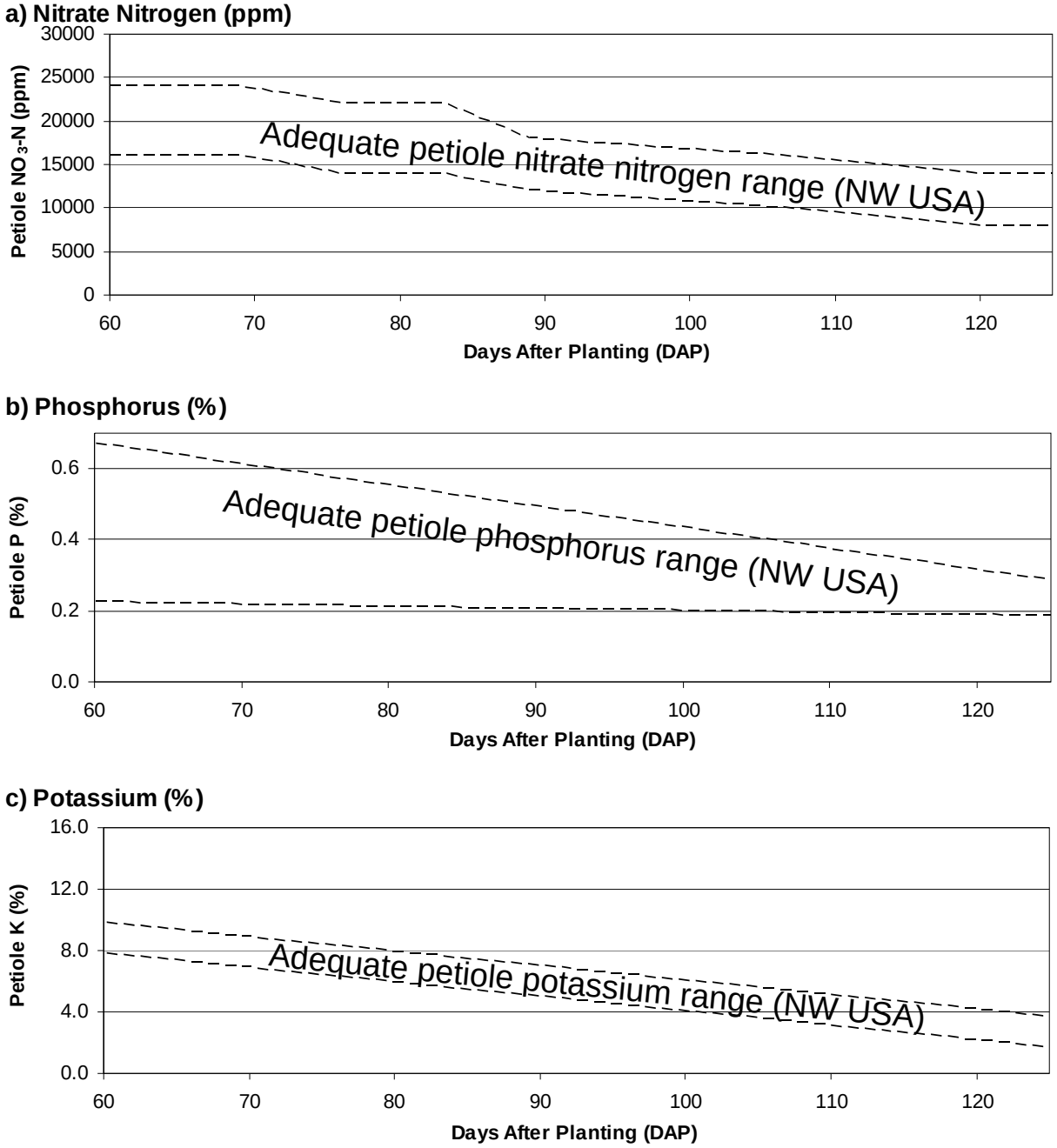

Figure 21. Current petiole nutrient (NO_3-N, P, and K) concentration recommendations based on information from the northwest United States (NW USA).

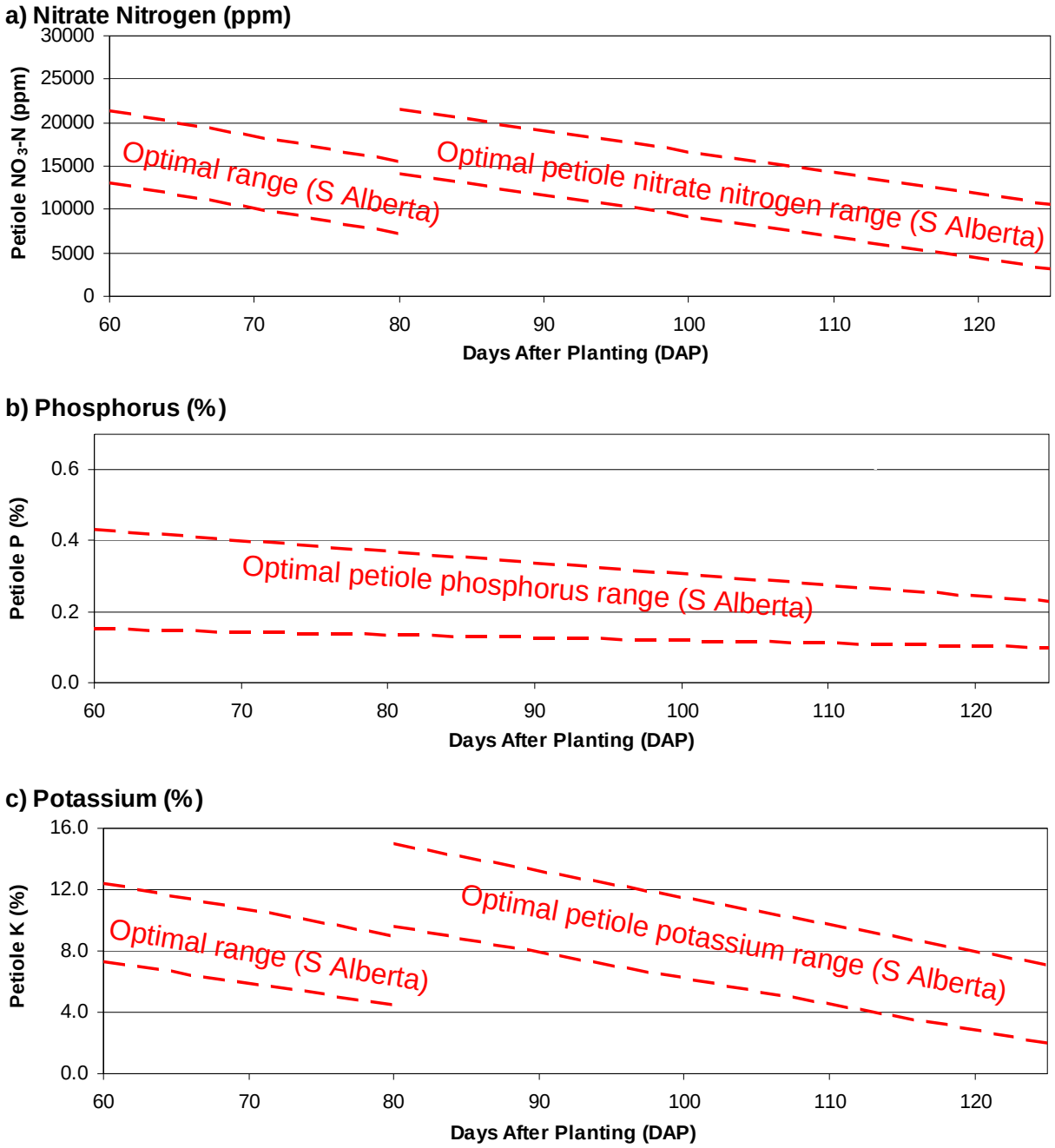

Figure 22. Suggested Russet Burbank petiole nutrient (NO_3-N, P, and K) concentration recommendations based on information from southern Alberta.

CONCLUSIONS

New optimal petiole nutrient concentration ranges for optimal marketable yield have been developed that are specific to Russet Burbank potatoes grown in southern Alberta's soil and climatic conditions. These proposed optimal petiole nutrient concentrations were compared to data collected in previously-completed studies and were found to be valid. No consistent or significant relationships between petiole nutrient concentration and specific gravity were observed. Potassium fertilizer did not have a consistent impact on specific gravity.

The suggested petiole nitrate nitrogen range is slightly lower than the northwest USA standards at the beginning of the growing season (DAP < 80) and late in the growing season (DAP > 105). The revised optimal petiole phosphorus ranges are substantially lower than the northwest USA standards. The recommended petiole potassium ranges are wider than the northwest USA standards overall and are similar early in the growing season (DAP < 80). Later in the growing season, the upper limits of the new petiole potassium recommendations are greater than for the northwest USA standards.

The new suggested optimal ranges should be considered as guidelines only and should be viewed in the context of previous years' data from any given site. Petiole nutrient concentrations will be affected by many factors, in addition to available soil nutrients. Some of these factors include temperature, precipitation, soil texture, and other environmental factors, as well as human factors such as petiole sampling technique, irrigation management, location of samples within the field, and laboratory analysis. Petiole nutrient concentrations should be considered on a field-specific basis. Spatial variability exists across any field, so care must be taken to choose petioles from benchmark locations that are representative of the field, in terms of location and plant appearance.

The conclusions drawn in this study are based on three years of experimental data and it is suggested that the PGA, along with growers and processors, continue to refine these recommendations based on petiole nutrient concentrations they observe currently and in the future.

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Woods, S. A., Hingley, L. E., and Konschuh, M. N. 2004. Petiole nutrient (N, P, and K) recommendations for Russet Burbank potatoes grown in southern Alberta (2004). Report prepared for the Potato Growers of Alberta. January 2004.

Potato Growers of Alberta
Research Tracking

Title of Research Application: Improved methods of Chemical Control for Silver Scurf in field & stora

Name of Researcher: Ron Howard

Employer: Ab Ag, Food & Rural Development

Date application was received by PGA Feb 28, 2006

Date application was reviewed by PGA April 3, 2006

A) approved ✓ B) declined _____

Project start date: April 2006 Project finish date: March 2008

Total amount requested: $ 18,000- Amount requested per year: $6,000-

MOU received and signed. Once copy returned to research agency,
one copy filed in current year Research Binder

Date completed _____

Invoice received: # 1242007 Date funds advanced Feb 20, 2007 Cheque# 4756 $6,000-

Invoice received:# _____ Date funds advanced _____ Cheque# _____

Invoice received:# _____ Date funds advanced _____ Cheque# _____

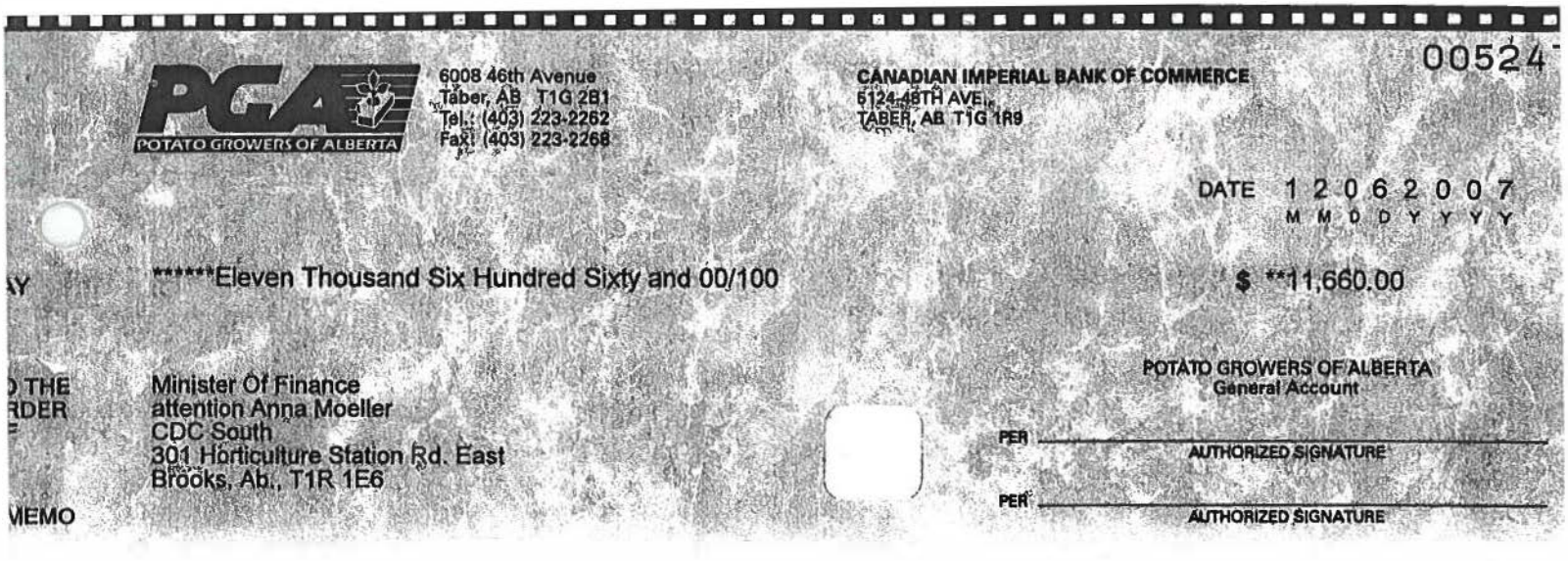
Invoice received:# _____ Date funds advanced _____ Cheque# _____

Were reports received from the researcher? _____

What was done with the reports?

Presented at PGA meeting? _____ Put on PGA website? _____ Filed? _____

NOTES: _____



POTATO GROWERS OF ALBERTA
6008 46th Avenue
Taber, AB T1G 2B1
Tel.: (403) 223-2262
Fax: (403) 223-2268

CANADIAN IMPERIAL BANK OF COMMERCE
5124 48TH AVE
TABER, AB T1G 1R9

00524

DATE 12062007
M M D D Y Y Y Y

*****Eleven Thousand Six Hundred Sixty and 00/100

$ **11,660.00

Minister Of Finance
attention Anna Moeller
CDC South
301 Horticulture Station Rd. East
Brooks, Ab., T1R 1E6

POTATO GROWERS OF ALBERTA
General Account

PER _____ AUTHORIZED SIGNATURE

PER _____ AUTHORIZED SIGNATURE

⑈00524 7⑈ ⑆00139⑉010⑆ 72⑉05317⑈

POTATO GROWERS OF ALBERTA

Minister Of Finance

12/6/2007

005247

Date	Type	Reference	Original Amt.	Balance Due	Discount	Payment
12/06/2007	Bill	011LA012276	5,300.00	5,300.00		5,300.00
12/06/2007	Bill	011LA012275	6,360.00	6,360.00		6,360.00
					Cheque Amount	11,660.00

Developing Improved Methods of Chem. Control for Silver Scurf on potatoes in field & in Storage

Main Operating Accou

Can$11,660.00

POTATO GROWERS OF ALBERTA

Minister Of Finance

12/6/2007

005247

Date	Type	Reference	Original Amt.	Balance Due	Discount	Payment
12/06/2007	Bill	011LA012276	5,300.00	5,300.00		5,300.00
12/06/2007	Bill	011LA012275	6,360.00	6,360.00		6,360.00
					Cheque Amount	11,660.00

Main Operating Accou

Can$11,660.00

For billing questions, please call: 780-422-6165

Invoice Number	Invoice Date	Customer Number	Payment Terms	Period Covered	Due Date
011LA012275	November/23/2007	C031892	30 Days	-	December/23/2007

Line	Description	Quantity	UOM	Unit Amt	GST Amt	Extended Amount
	Contract No. / Order No. / Order Date / PO Reference No.					
1	Research Project	1.00	EA	6,000.00	360.00	6,000.00

Sponsorship of the "Developing Improved Methods of Chemical Control for Silver Scurf on Potatoes in the Field and in Storage".

			Subtotal:	**6,000.00**
Total (GST):				
Net Amount:	6,000.00	GSTReg	6.00 %	360.00
			AMOUNT DUE:	**6,360.00**

PAID

Government of Alberta - GST Registration Number: 124072513

RECEIVED NOV 29 2007

Original

upon agreement of both parties.

BASIS OF COSTS and PAYMENT

3. The total expense for this Research Project is $6,360 to cover the following estimated total costs:

Technologist (halftime position at $2000/month for 2.5 months)	$ 5,000
Materials and supplies	$ 1,000
GST	360
Total Cost	$ 6,360

4. **PGA** will provide to **AF**, upon execution by both parties of this Agreement, the sum of $6,360.

Cheques shall be made payable to **"Minister of Finance"** and forwarded to:

Mrs. Joan Seath
Alberta Agriculture and Food
Crop Diversification Centre North
17507 Fort Road N.W.

Project # 87925-819232

MEMORANDUM OF AGREEMENT

Between:

Potato Growers of Alberta

(Hereafter referred to as "**PGA**")

and

Her Majesty, the Queen, in right of the Province of Alberta
as represented by the
Minister of Agriculture and Food

(Hereafter referred to as "**AF**")

Project Title: Developing Improved Methods of Chemical Control for Silver Scurf on Potatoes in the Field and in Storage

Objectives:
1) Surveys - Collect tubers of various varieties of seed, table and processing potatoes showing silver scurf (SS)-like symptoms from fields and storages across Alberta to determine whether *Helminthosporium solani* or *Colletotrichum coccodes* is the primary cause.
2) Diagnostic Methods - Compare agar plate and molecular techniques for the isolation and characterization of *H. solani* and *C. coccodes* isolates to determine their speed, accuracy and cost.
3) Fungicide Performance - Assess whether currently registered seed treatment and post-harvest fungicides are effective against the strains of *H. solani* present in Alberta fields and storages.
4) New Product Development - Determine the efficacy of promising new chemical treatments (conventional and reduced risk) in replicated trials in the lab, field and storage.
5) To use the information generated in this study to help improve the techniques for managing SS, thereby reducing potential yield and quality losses for growers and processors.

SCOPE OF WORK

1. **AF** will conduct the Research Project according to the research plan which is attached to and forms part of this Agreement.

PERIOD OF WORK

2. This Agreement will commence on April 1, 2007 and will terminate on March 31, 2008 unless extended upon agreement of both parties.

BASIS OF COSTS and PAYMENT

3. The total expense for this Research Project is $6,360 to cover the following estimated total costs:

Technologist (halftime position at $2000/month for 2.5 months)	$ 5,000
Materials and supplies	$ 1,000
GST	360
Total Cost	$ 6,360

4. **PGA** will provide to **AF**, upon execution by both parties of this Agreement, the sum of $6,360.

Cheques shall be made payable to **"Minister of Finance"** and forwarded to:

Mrs. Joan Seath
Alberta Agriculture and Food
Crop Diversification Centre North
17507 Fort Road N.W.

Edmonton AB T5Y 6H3
Phone: (780) 422-0653

5. **AF** will use the funds paid by **PGA** only for the purpose of conducting the Research Project. **AF** will provide a record of revenues and expenditures to **PGA** upon completion of the Research Project or depletion of funds.

RESPONSIBILITY OF PROJECT MANAGER

6. The project manager for this Research Project is Dr. Ron Howard of **AF** who will supervise the Research Project and provide all reports to **PGA.** The project manager will authorize expenses and submit them to the appropriate **AF** office for payment to be processed.

AMENDMENTS OR TERMINATION

7. This Agreement may only be amended upon mutual consent of the parties and evidenced in writing.

8. Either **AF** or **PGA** may terminate this Agreement in the event of a material default or breach of a substantive term, condition or provision of this Agreement, by providing two weeks notice in writing to the other party. In such event **AF** is in default then any and all amounts of the funds advanced by **PGA** hereunder that represent payment for work or services hereunder that have not been performed by **AF** up to the date of termination shall be refunded to **PGA.**

NOTICES AND REPRESENTATIVES

9. Notices for all purposes of or incidental to this Agreement shall be effectively given if delivered personally, or sent by registered or certified mail to the representatives of the parties designated as follows:

PGA Biosciences:
Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1
Phone: 403-223-2262

Alberta Agriculture and Food:
Dr. Ron Howard
Plant Pathology Research Scientist
Crop Diversification Centre South
301 Horticultural Station Road East
Brooks, Alberta T1R 1E6
Phone : (403) 362-1328

Alberta Agriculture and Food:

Cornelia Kreplin, Director, Agriculture Research Division

2007 09 25
Date

Potato Growers of Alberta:

Vern Warkentin, Executive Director, Potato Growers of Alberta

Sept 13/07
Date

Research Plan

The research plan for this project was briefly described in the original project proposal to the PGA in 2006 (see attached copy).

Potato Growers of Alberta

Proposal application for Research funding 2006-2007

Instructions

To assess the proposals consistently, they must be completed according to the parameters contained in this form. Proposals may be rejected for incomplete information or lack of compliance with the instructions. This application could use other sources of forms only if it will be presented to other funding consortiums.
Please jump between boxes using the "Tab" key and avoid the use of the "enter" key. The PGA Research Committee will set dates for project presentations and result reports.

Confidentiality

This Proposal is confidential and the information contained in it may not be disclosed with other organizations or research groups. ☐

1. Research Team Information

Team Leader:Dr. Ron Howard		
Organization:AAFRD	Section/Department:CDC South	
Address:S.S. #4	City:Brooks	Province:AB
Postal Code:T1R 1E6	E-mail :ron.howard@gov.ab.ca	
Phone Number:403-362-1328	Fax Number:403-362-1326	

Team Member:Dr. Michael Harding		
Organization:AAFRD	Section/Department:CDC South	
Address:S.S. #4	City:Brooks	Province:AB
Postal Code:T1R 1E6	E-mail:michael.harding@gov.ab.ca	
Phone Number:403-362-1338	Fax Number:403-362-1326	

Team Member:Dr. Larry Kawchuk		
Organization:AAFC	Section/Department:Research	
Address:P.O. Box 3000	City:Lethbridge	Province:AB
Postal Code:T1J 4B1	E-mail address:kawchuk@agr.gc.ca	
Phone Number:403-317-2271	Fax Number:403-382-3156	

2. Project Information

Title:Developing Improved Methods of Chemical Control for Silver Scurf on Potatoes in the Field and in Storage

Category of the project (Please check more than one box if necessary):

- ☒ Pest Management
- ☐ Water and Irrigation Management
- ☒ Potato Storage
- ☐ Potato Breeding
- ☐ Potato Plant Physiology
- ☐ Potato Fertility Plant
- ☐ Nutrition/Soil management
- ☐ Green House
- ☐ Environment
- ☐ Potato Marketing and Economics
- ☐ Potato Cultural Management

Research Location (s): CDC South, Brooks

Duration (Y):2 Start Date (YY/MM):06/04Ending Date (YY/MM):08/06

Is the project linked to other applications / Research projects Y ☒ N ☐
(Please identify related projects)

1.Project:Development of Pesticides and Disinfectants for Prevention and Control of Microbial Biofilms Associated with Plant Diseases and Seed Pathology

Team Leader:Dr. Lyriam Marques

Start Date:2005

2.Project:Use of Green Manure Crops to to Reduce Pests and Diseases in Alberta Potato Crops

Team Leader:Dr. Michele Konschuh

Start Date:2006

Background.
(Max 2000 characters)

Silver scurf (SS), caused by the fungus Helminthosporium solani, emerged as an economically important disease of tablestock and processing potatoes in Canada in the 1990s. Prior to that, it had mostly been considered a minor problem. SS causes metallic, silvery patches on tuber skins, which can reduce their suitability for direct sales and processing. Seed growers are also concerned about SS because it can be easily spread on seed tubers. Control recommendations for SS centre mainly on chemical and cultural practices. Holley and Kawchuk (1993, 1996) demonstrated the widespread ocurrence of resistant strains of H. solani to the fungicide Mertect (thiabendazole) in Alberta. Mertect was widely used as a post-harvest treatment on potato tubers to prevent various storage diseases. Similar findings were reported from the U.S.A. and Europe, and prompted researchers to look at alternative products, e.g. imazilil, prochloraz, propiconazole, fludioxonil, L-carvone, and organic and inorganic salts. Several of these products looked promising, but few have been tested in Alberta. At present, three seed treatments (Senator PSPT, Maxim PSP and Maxim MZ) and one post-harvest fungicide (OxiDate) are registered in Canada for controlling SS. Despite the availability of these products, SS remains a widespread and serious problem. The inability of currently available products to control SS may be due to several factors, e.g. the development of resistant strains of H. solani, chemical dosages that are too low to be effective, improper application techniques to seed pieces or tubers in storage, or poor residual chemical activity. The possibility also exists that SS-like symptoms on tubers may be caused by another fungus, Colletotrichum coccodes, the black dot (BD) pathogen. BD can cause symptoms on tubers that are easily confused with SS, and the two diseases often occur together in the same fields. BD may not respond to fungicide treatments in the same way that SS does and vice versa.

Objectives (Measurable-Deliverables)
(Please use Bullets) (Max 1000 characters)

1. Surveys - Collect tubers of various varieties of seed, table and processing potatoes showing SS-like symptoms from fields and storages across Alberta to determine whether H. solani or C. coccodes is the primary cause.

2. Diagnostic Methods - Compare agar plate and molecular techniques for the isolation and characterization of H. solani and C. coccodes isolates to determine their speed, accuracy and cost.
3. Fungicide Performance - Assess whether currently registered seed treatment and post-harvest fungicides are effective against the strains of H. solani present in Alberta fields and storages.
4. New Product Development - Determine the efficacy of promising new chemical treatments (conventional and reduced risk) in replicated trials in the lab, field and storage.
5. To use the information generated in this study to help improve the techniques for managing SS, thereby reducing potential yield and quality losses for growers and processors.

Economical/Environmental Benefits

(Please mention how the results of this project will benefit potato production economically and environmentally.(Max. 1000 characters) .

1. Disease surveys will document the incidence, severity and economic impact of SS on seed, table and processing potatoes in Alberta. These kinds of assessments have never been done in Alberta.
2. Validation of diagnostic tests will allow researchers and commercial diagnostic labs to select and use the most rapid, reliable and cost-effective testing methods. Labs will be able to offer reliable and affordable testing services to clients.
3. Evaluation of the effectiveness of existing seed and post-harvest fungicides will provide information that will help producers and processors select the most effective products for use in the field and storage. Identifying products that are no longer effective should help save money and reduce needless applications.
4. Identification of promising new fungicides may lead to full or minor use registrations that will increase the variety of products available to producers and processors. These new products may replace older, less effective ones.

Methodology Description

(Please describe the scientific process you will follow to achieve project objectives).(Max 2000 Characters)

Disease Surveys – Samples of SS-infected potatoes will be obtained from ca. 15 growers and processors (100 tubers/sample). Fifty tubers will be kept in cold storage on reserve in case any tests need to be redone. Half of the other 50 tubers will be washed and examined for skin diseases. Disease incidence and severity will be rated visually. Twenty tubers will be placed in humid chambers and incubated for 2 weeks to determine if SS, BD or both are present. Five tubers will be sent to AAFC, Lethbridge for molecular diagnosis of SS and BD. The remaining 25 unwashed tubers will be placed in storage (15°C and 95% RH) for 6-8 weeks, then rated for SS/BD incidence and severity. Humid chambers and molecular diagnoses will also be done.

Pathogen Identifications - Isolates of H. solani and C. coccodes will be purified and identified using standard taxonomic keys. Representative cultures will be retained for in vitro fungicide resistance testing.

Seed Treatment Efficacy Trials - Samples of registered and unregistered fungicides will be obtained from chemical companies and applied to a seedlot infested with SS. Replicated trials will be planted at CDC South. Emergence, stem number and tuber yield data will be taken. Tuber subsamples will be stored at 12°C and 95% RH for 2-3 months. SS incidence and severity will be measured.

Storage Treatment Efficacy Trials – Fungicides will be applied to tubers naturally infested with SS prior to storage at 12°C and 95% RH for 4-5 months. SS incidence and severity will be measured.

Review of Production/Storage Practices – Growers and processors who provided samples will be interviewed to determine the impact that SS has had on their crops. Information on varieties, seed sources, crop rotations, fertilizer and pesticide applications, irrigation, and harvesting, handling and storage practices will be collected. Efforts will be made to correlate data between operations to identify factors that may have favored disease outbreaks.

Technology Transfer Plan.

(Please describe the proposed method to communicate findings and results) (Max. 1000 characters)

Interim and final results will be presented to the PGA, potato growers and project cooperators through oral and poster presentations at events such as the PGA and ASPGA annual meetings, field days, area and/or breakfast meetings. Written reports, newsletter articles and scientific publications will be prepared and made available to the PGA, growers and cooperators. Diagnostic protocols and some staff training will be provided to commercial plant health labs so they can do commercial SS testing for clients.

3. Project Budget

		Year 1	Year 2	Year 3	**Total**
	Cash	12000	12000		24000
	In-Kind				
PGA	Total	12000	12000		24000
Other					
	Cash	1000	1000		2000
	In-Kind	79000	79000		158000
AAFRD	Total	80000	80000		160000
Other					
	Cash				
	In-Kind	8000	8000		16000
AAFC	Total	5000	5000		10000
Other					
	Cash	10000	10000		20000
	In-Kind	2000	2000		4000
Industry	Total	12000	12000		24000
Other					
	Cash				
	In-Kind				
	Total				

Total	**112000**	**112000**		**224000**

Project Cost Distribution	Year 1	Year 2	Year 3	**Total**
Personnel	40500	41500		82000
Travel expenses	1500	1500		3000
Capital goods	0	0		0
Materials	8000	8000		16000
TOT	1000	2000		3000
Overhead	60000	60000		120000
Total	**111000**	**113000**		**224000**

*TOT (Transference of Technology)

Research Project Manager

Signature **DateFebruary 28, 2006**

Project # 81902-819079
New: Renewal: X

MEMORANDUM OF UNDERSTANDING

Between: The Potato Growers of Alberta
(hereafter referred to as the "PGA")

and

Alberta Agriculture and Food
(hereafter referred to as "AF")

PROJECT TITLE

Developing Improved Methods of Chemical Control for Silver Scurf on Potatoes in the Field and in Storage

OBJECTIVES

1. Collect tubers of various varieties of seed, table and processing potatoes showing silver scurf (SS)-like symptoms from fields and storages across Alberta to determine whether *Helminthosporium solani* or *Colletotrichum coccodes* is the primary cause.
2. Compare agar plate and molecular techniques for the isolation and characterization of *H. solani* and *C. coccodes* isolates to determine their speed, accuracy and cost.
3. Assess whether currently registered seed treatment and post-harvest fungicides are effective against the strains of *H. solani* present in Alberta fields and storages.
4. Determine the efficacy of promising new chemical treatments (conventional and reduced risk) against SS in replicated trials in the lab, field and storage.
5. Use the information generated in this study to help improve the techniques for managing SS, thereby reducing potential yield and quality losses for growers and processors.

STATEMENT OF WORK

Alberta Agriculture and Food is willing to undertake the specified study for the PGA, which hereby agrees to contribute toward the costs of generating and reporting the information required as described in the attached research proposal.

PERIOD OF WORK

The research project will commence on or about April 1, 2006 and interim report will be completed by February 28 of 2007 and 2008. A final report will be submitted by June 30, 2008

BASIS OF PAYMENT

As a sponsor of the project, the PGA will provide **$6,000** + GST per annum upon finalization of this memorandum to AF to cover the following estimated costs for this project:

Technical Manpower	$5,000
Materials & Supplies	$1,000 MB
GST (6%)	$ 300
TOTAL	**$6,300**

This budget can be adjusted and used at the discretion of the project manager. A portion of these funds can be disbursed to other members of the research team as may be required to complete work specified in the project proposal.

Payment of research project expenditures will be made from funds made available to AF up to the maximum amount of funds received from the sponsor and subject to satisfactory reviews of the interim progress reports by the sponsor.

Upon request, AF will provide a record of revenue and expenditure upon project completion or depletion of funds. Any remaining funds after completion or termination of the project can be used for research at the discretion of the project manager.

RESPONSIBILITY OF PROJECT MANAGER

The project manager for this study is Dr. Ron Howard. He will provide all reports to the sponsor, AF and other parties at the discretion of the sponsor.

The project manager will authorize expenses and submit them to the appropriate AF division for processing payment.

The project manager is not eligible for any manpower funds himself.

AMENDMENTS OR TERMINATION

This Memorandum of Understanding may be amended by mutual consent of the parties as evidenced by an exchange of letters.

Either AF or the PGA may terminate this Memorandum of Understanding by providing two weeks notice in writing to the other party.

NOTICES AND REPRESENTATIVES

Notices for all purposes of or incidental to this Memorandum of Understanding shall be effectively given if delivered personally, or sent by registered or certified mail to the representatives of the parties designated as follows:

The Potato Growers of Alberta:

Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1
Phone: 403-223-2262

Alberta Agriculture and Food:

Mr. Henry Najda
Acting Branch Head
Crop Diversification Centre South
301 Horticultural Station Road East
Brooks, AB T1R 1E6
Phone: 403-362-1346

The Department of Agriculture and Food, the Potato Growers of Alberta, and other sponsors of the project may use information generated from the project.

The sponsor, the PGA, relinquishes ownership of any materials, supplies and assets purchased with the project funds to AF, which assigns control to the project manager's departmental division.

The parties affirm their acceptance of the terms of this Memorandum of Understanding by signing below.

Copies bearing original signatures of this Memorandum will be kept by each party.

Dr. Ron Howard, Project Manager	Date

I agree that the project manager named above may supervise this project.

Mr. Henry Najda, Acting Branch Head Crop Diversification Centre South	Date
Mr. Vern Warkentin, Executive Director Potato Growers of Alberta	Feb 15/07 Date

POTATO GROWERS OF ALBERTA

April 20, 2007

Dr. Ron Howard
Alberta Agriculture, Food & Rural Development
301 – Horticultural Station Rd. E.
Brooks, AB T1R 1E6

Re: Chemical Control of Silver Scurf in Field and Storage

Dear Ron:

We are pleased to advise that the Board of Directors of The Potato Growers of Alberta has reviewed and continuing funding for your research project.

For the period of April 1, 2007 – March 31, 2008 the amount of $6,000 is available to meet the timelines specified in your application. When requesting the funds for the project, please provide an invoice that specifies the amount, GST and to whom payable.

We appreciate your commitment and dedication to the potato industry.

Yours truly,

Vern Warkentin
Executive Director

/pl

Fusarium dry rot and seed-piece decay in Canada

Rick Peters, Agriculture and Agri-Food Canada, Charlottetown, PEI

Fusarium spp. are important pathogens of potato that cause yield losses at planting and in storage following harvest. Spores of the fungus are found in all soils where potatoes are grown and can survive for many years. Seed potatoes infected with *Fusarium* can rot after planting (seed-piece decay) causing "misses" in the field. Even if plants grown from infected seed do emerge, they often have reduced vigour and yield. The fungus can spread from infected to healthy seed during the cutting and handling process. After harvest, *Fusarium* spp. cause a dry rot in storage which reduces crop quality.

Potatoes infected with *Fusarium* spp. develop a spreading external decay that usually becomes shrunken and wrinkled in appearance (Fig.1.). When diseased tubers are cut open, the brown decay can be seen spreading into the internal tissues of the tuber (Fig.2.). The internal decay is usually marked by open cavities which contain the white mycelium of the fungus. *Fusarium* spp. can only infect potatoes through wounds. Thus, infection can occur when inoculum is spread from diseased to healthy seed during seed cutting and handling. As well, inoculum in soil attached to the surface of tubers can infect potatoes through wounds made during harvest and handling operations prior to storage.

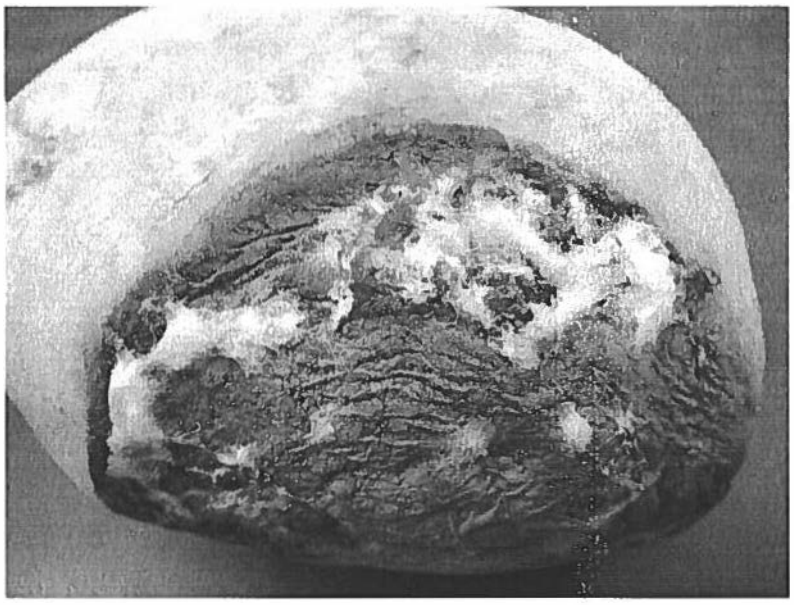


Figure 1. External symptoms of Fusarium dry rot.

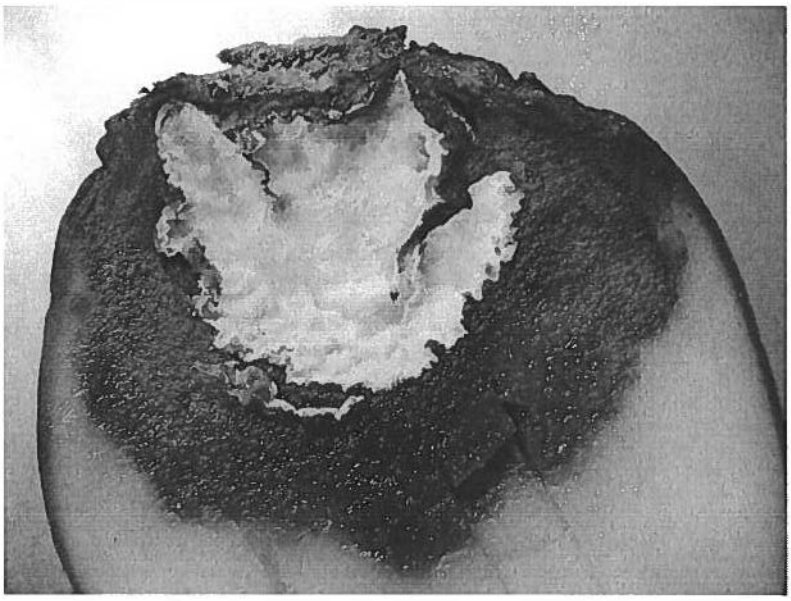


Figure 2. Internal symptoms of Fusarium dry rot showing cavities filled with white mycelium of the fungus within the tuber tissue.

Although spores of *Fusarium* spp. can be found in all soils where potatoes are grown, our research has shown that diseased seed is the most important source of inoculum to infect daughter tubers. High levels of seed infection does not always translate into high levels of dry rot in storage, because the amount of tuber wounding at harvest is normally the biggest factor determining post-harvest dry rot. However, high levels of seed infection can lead to significant seed-piece decay with resulting yield impacts.

Fusarium species causing dry rot and seed-piece decay

Our research has shown that the predominant *Fusarium* species found on seed pieces provide inoculum for infection of daughter tubers and therefore, these species are also the predominant ones found in storage. Surveys from 2007-2010 in Canada indicate that three *Fusarium* spp. are the most common as causal agents of seed-piece decay and dry rot. Results from these surveys showed that *Fusarium sambucinum* is the most predominant pathogen, followed by *Fusarium coeruleum* and *Fusarium avenaceum.* Although mixed infections of several *Fusarium* spp. did commonly occur, one species was usually clearly predominant in a particular sample of tubers (either seed tubers or samples taken from storage). Some other *Fusarium* spp. that were pathogenic to tubers were also recovered in the surveys including *Fusarium acuminatum*, *Fusarium crookwellense*, *Fusarium sporotrichiodes, Fusarium oxysporum* and *Fusarium graminearum. Fusarium graminearum,* an important pathogen of wheat, was found for the first time in Canadian potatoes in several provinces in 2008. It is an aggressive pathogen of potato tubers, and we are continuing our monitoring to see if it becomes a more important potato pathogen in Canada, as it has in North Dakota, USA.

Potatoes are commonly grown in rotation with cereal and forage crops. To test the potential of these crops to harbour *Fusarium* spp. that are pathogenic to potato, a study was initiated where isolates of *Fusarium* spp. obtained from cereal and forage crops were inoculated into wounded potato tubers which were subsequently stored for 5 weeks to allow disease symptoms to develop. We found that some species of *Fusarium* from cereal and forage crops could indeed cause disease in potatoes. In particular, *Fusarium avenaceum* and *Fusarium oxysporum,* isolated from forage crops, and *Fusarium sporotrichiodes* and *Fusarium graminearum,* isolated from cereal crops, could cause disease in potato tubers. Thus, crops grown in rotation with potato may harbour *Fusarium* spp. that cause disease in potato tubers, although the importance of this inoculum source in a production system is unknown.

Resistance to control products

Isolates of the various *Fusarium* spp. collected during Canadian surveys have also been tested for their sensitivity to thiophanate-methyl (Senator ® PSPT) and fludioxonil (Maxim® PSP - common potato seed piece treatments) and thiabendazole (Mertect ® SC- a common post-harvest treatment). About 50-65% of the isolates of *Fusarium sambucinum*, the major dry rot pathogen, recovered in surveys across Canada in 2008 and 2009 were resistant to all products. By contrast, most other *Fusarium* spp. were sensitive to these products. Isolates of *Fusarium oxysporum* recovered in these surveys were always sensitive to thiabendazole and thiophanate-methyl, but resistant to fludioxonil. Therefore, species composition in a tuber lot plays a large role in determining how effective a chemical treatment will be. In Alberta, resistance to fludioxonil in various *Fusarium* spp. was more common than in other parts of the country. Results of chemical sensitivity testing for various species of *Fusarium* isolated from potato seed pieces in Alberta in 2009 can be found in Table 1.

Table 1. Results of chemical sensitivity testing of isolates of various *Fusarium* spp. isolated from potato seed pieces from Alberta in 2009.*

		Fludioxonil (Maxim®PSP)		Thiabendazole (Mertect®SC)	
Species	No. of isolates	Sensitive	Resistant	Sensitive	Resistant
F. sambucinum	11	1	10	5	6
F. coeruleum	5	5	0	5	0
F. avenaceum	3	0	3	3	0
F. oxysporum	2	0	2	2	0
F. acuminatum	2	0	2	2	0

* Note: isolates resistant to thiabendazole (Mertect®SC) are also resistant to thiophanate-methyl (Senator®PSPT)

Potato seed treatment trials

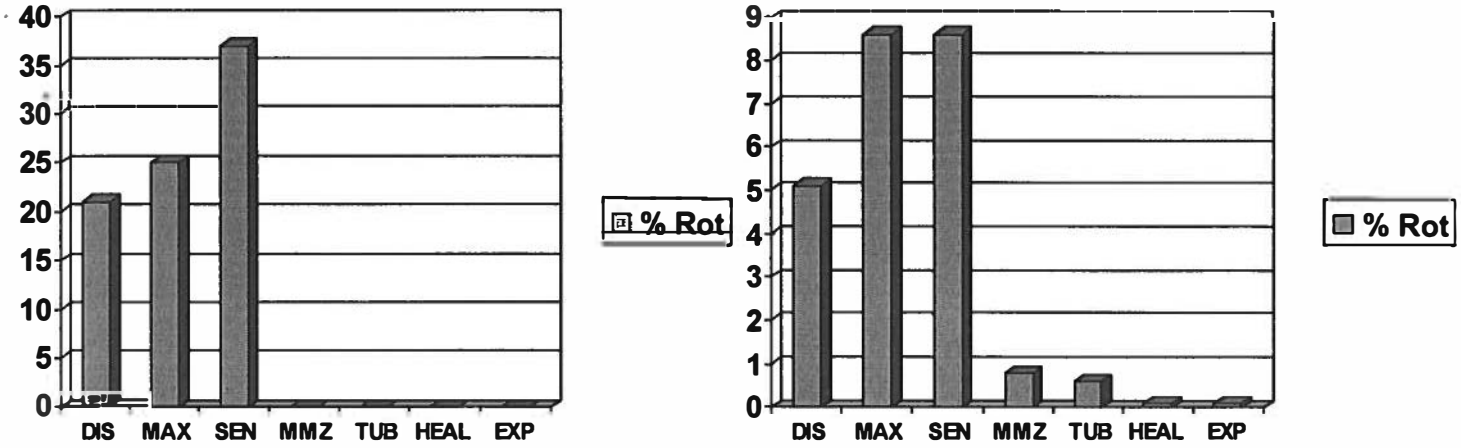
Field and storage studies were conducted in Prince Edward Island, Canada to ascertain the impact of fungicide-resistant strains on crop loss and to define potential management strategies. Potato seed-pieces were inoculated with a fungicide resistant strain of *F. sambucinum* and then treated with various seed treatments including:

1. Healthy control = not inoculated [HEAL]
2. Diseased control = inoculated but no seed treatment [DIS]
3. Senator (10% thiophanate-methyl) [SEN]
4. Maxim PSP (0.5% fludioxonil) [MAX]
5. Maxim MZ PSP (0.5% fludioxonil; 7% mancozeb) [MMZ]
6. Tuberseal (16% mancozeb) [TUB]
7. Difenoconazole [EXP=experimental product, not registered for potato seed treatment in Canada]

Seed pieces were then incubated at 10°C for 6 weeks after which they were rated for disease (Figure 3). In summary, inoculation of potato seed pieces with an isolate of *F. sambucinum* possessing multi-class fungicide resistance followed by application of thiophanate-methyl or fludioxonil as seed treatments, resulted in the complete loss of efficacy of both products. In all cases, treatment of potato seed pieces with mancozeb or difenoconazole completely controlled seed-piece decay caused by this isolate of *F. sambucinum* (Figure 4). We are also exploring the use of difenoconazole as a post-harvest treatment as potatoes enter storage to control Fusarium dry rot in storage.

A. **B.**

Figure 3. Inoculation of potato seed-pieces with fungicide resistant *F. sambucinum* followed by seed-piece treatment. **A.** good disease control **B.** poor disease control



A. B.

Figure 4. Percentage of rot in potato seed-pieces after inoculation with fungicide resistant *F. sambucinum* followed by application of various seed treatments. **A**=2008 trial; **B**=2009 trial

Disease management

Based on our research, knowing the predominant *Fusarium* spp. in a particular seedlot and their sensitivities to various chemical products would provide growers with important information to use to make disease management decisions. Thus, diagnostic testing of samples of tubers from seedlots could be a useful tool in the management of this important disease. Since fungicide resistance is a concern, alternating products from different chemical classes becomes an important strategy. In our trials, mancozeb used as a seed treatment was able to control fungicide resistant strains. Down the road, difenoconazole and other products may become available for seed treatment and post-harvest application.

Ultimately, the management of Fusarium dry rot and seed-piece decay depends upon an integrated approach that takes advantage of a number of control options and information generated by research studies. A summary of some of these control options would include:

At planting:

1. Use clean seed; store seed in a facility that has been properly disinfected
2. Warm seed tubers prior to cutting to promote rapid healing
3. Remove any diseased seed tubers prior to cutting
4. Disinfect seed cutting and handling equipment often and ensure that cutters are sharp to make a clean cut that heals quickly
5. Don't store cut seed for more than 10 days before planting
6. Determine the *Fusarium* spp. present by having seed tested by a diagnostic clinic if available
7. Use a registered fungicide seed treatment and access any available local information on pesticide resistance; rotate products of different chemical classes; mancozeb has been shown to control fungicide resistant strains; new seed treatment products are in development

8. Plant when soil and temperature conditions promote rapid sprout growth and emergence

At harvest and in storage:
1. Reduce tuber injury during harvest and handling operations
2. Provide conditions for rapid wound healing early in storage, then drop temperatures
3. Monitor storage conditions
4. Post-harvest treatments with thiabendazole will control most *Fusarium* spp., but not thiabendazole-resistant *Fusarium sambucinum*, therefore, access any available local information on pesticide resistance
5. New post-harvest treatments to manage dry rot in storage are in development and should be available in the next few years

For more information contact:
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Website: http://www.agr.gc.ca/science/charlottetown

A Survey for Late Blight Disease in Solanaceous Vegetables and Ornamental Plants in Garden Centres, Retail Outlets, Fields and Greenhouses in Alberta

A Research Proposal Submitted to the

Alberta Professional Horticultural Growers Congress and Foundation Society

Ron Howard[1], Larry Kawchuk[2], Robert Spencer[3] and Michele Konschuh[1]

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October 22, 2010

Background

Late blight is caused by the fungal pathogen *Phytophthora infestans* (Mont.) and is found in most potato and vegetable-growing areas of Canada, although it does not occur every year on the Prairies. It can infect potato, tomato, eggplant, petunia and some solanaceous weeds, such as nightshade and wild tomato. Late blight is an aggressive disease that, if left unchecked, can cause significant and rapid losses in gardens, greenhouses, fields and in controlled environment storages, e.g. potato bins.

Late blight was reported in a number of commercial potato fields, market gardens and many urban residential plantings of potatoes and tomatoes in southern and central Alberta in 2010 (Spencer, 2010). The last major outbreak of this disease in Alberta was in 1992-93. Persistent wet weather and high humidity conditions were prevalent in southern and central Alberta in 2010 and this situation significantly favored infection and spread of the disease. While late blight progression was slowed in most commercial potato fields with fungicidal sprays, delayed identification and limited control options for home gardeners meant that the disease went largely unchecked in urban and rural locations alike. While the initial sources of inoculum that started outbreaks in areas where late blight was severe are still under investigation, infected tomato plants sold by some garden centres and retail box stores have been implicated (Sands, 2010).

Rationale for the Project

The potential for spread of late blight from urban gardens and market gardens to commercial potato fields and tomato greenhouses is a serious concern for producers of these crops. Likewise, gardeners are concerned about the potential for the introduction and rapid spread of late blight in urban areas with a high density of vegetable gardens. To avoid the potential for a recurrence of late blight in 2011, early surveillance for the disease in tomato transplants and potato seed offered for sale in garden centres, retail stores and bedding plant greenhouses is required. These surveys need to be coupled with an active awareness campaign for staff working in these businesses, for their customers, and for the general public at large. This campaign could take the form of employee training sessions and the availability of color posters, factsheets, webinars, press releases and online information resources describing diagnostic features of the disease and strategies to prevent the introduction and spread of late blight in urban and rural settings.

Objectives

This project will be carried out from January to September, 2011. The key objectives will be:

- To conduct targeted surveys to determine if solanaceous plants, such as potato, eggplant, pepper, tomato and petunia transplants and seed potato tubers, sold in garden centres, retail outlets (box stores) and bedding plant greenhouses are infected with late blight and therefore represent a threat to introduce the disease to home and market gardens, potato fields and commercial vegetable greenhouses.
- To undertake an awareness campaign to make home and market gardeners and greenhouse tomato and bedding plant growers aware of the serious risk that late blight poses to solanaceous plants and crops in urban and rural areas, and especially to local commercial seed, tablestock and processing potato growers. This initiative will compliment efforts by the Potato Growers of Alberta to make their members aware of late blight forecasting, surveillance and management strategies.
- To conduct follow-up investigations of positive late blight finds to determine the mating type, genotype and fungicide sensitivity profile of *P. infestans* isolates present and to insure

that efforts are being made to contain the disease in an effort to prevent local and widespread epidemics from occurring.

Protocols

Late Blight Surveys

Organizations such as the Alberta Farm Producers Association, Alberta Greenhouse Growers Association and Landscape Alberta Nursery Trades Association will be contacted and asked for assistance in pinpointing prospective garden centres, retail outlets and greenhouses in southern and central Alberta to survey for late blight in spring 2011. The survey will target approximately 100 locations in and around urban and rural areas where late blight was observed in 2010. Specified locations will be visited and solanceous plants examined for symptoms of late blight one or more times during the sales season. Symptomatic plants will be sent to CDC South, Brooks or the Lethbridge Research Centre for a confirmatory diagnosis. Positive test results will be followed up on and producers will be informed of control options pertinent to their situations. Survey data will be compiled and documented in a written report. Data will also be entered into the Alberta Pest Surveillance Network database for future reference. Interim survey results will be used to prepare press releases, website updates and the like to inform gardeners and commercial producers of the status of late blight finds in their areas.

Awareness Campaign

Communication tools, such as factsheets, webinars, newsletters, seminars, YouTube postings and the like, will be used to inform garden centres, retail outlets, garden clubs, grower organizations and others of the risks of late blight in solanaceous plants and crops and techniques to scout for, diagnose and control it in commercial and non-commercial production situations. Contact lists will be developed to identify resource staff to answer inquiries from commercial growers, home and market gardeners and the general public.

Investigation of Late Blight Finds

Positive cases of late blight will be reported to the Pest Surveillance Branch, Alberta Agriculture and Rural Development, Edmonton for further investigation. For minor occurrences, this could take the form of a letter, email message or phone call to the client. For major outbreaks, a follow-up site visit and one-one discussions of mitigation strategies with the grower, garden centre/greenhouse operator or retailer could take place. Although commercial potato fields and storages will not be included in the survey, the Potato Growers of Alberta will be kept informed of any late blight finds so they can alert members in those areas. Advanced warning will enable potato growers to schedule fungicide sprays and other mitigation strategies. Similar notices will be sent to the Alberta Greenhouse Growers Association so they can alert tomato growers of any imminent risks of late blight in their respective areas.

Timetable

This project will run from April to September, 2011 and the work plan will be as follows:

January-February

- Prepare lists of potential survey locations in collaboration with AFFPA, AGGA, LANTA, PGA and other relevant horticulture industry organizations.
- Contact garden centres, retail outlets and greenhouses to make them aware of the survey and to provide them with factsheets and diagnostic aids to assist them in recognizing late blight on solanaceous plants that they may be selling.
- Prepare information products for use in surveys, training sessions and general public awareness of late blight.

March-April
- Survey Alberta greenhouses producing solanaceous plants for sale in garden centres and retail outlets for plants displaying late blight symptoms.
- Survey garden centres, retail outlets for late blight-infected plants and, if found, collect samples for confirmation of the late blight pathogen.

May-August
- Conduct follow-up surveys of gardens, fields and greenhouseswhere late blight is suspected.
- Characterize mating type, genotype and fungicide sensitivity profile of any *P. infestans* isolates found.

September
- Prepare a final report on the survey project.
- Submit the final report to project sponsors and cooperators.
- Enter survey data into the Alberta Pest Surveillance Network database.

Budget

Manpower (two technologists – 6 months each, half time)	$ 25,000
Materials and supplies (pathogen diagnosis, testing)	$ 10,000
Travel (vehicle lease, fuel, meals, accommodations)	$ 6,000
Technology transfer (information products, hosting)	$ 4,000
Subtotal	**$ 45,000**
Total requested from APHGCFS	**$ 45,000**
ARD/AAFC in-kind contributions	$ 60,000

References

Sands, A. 2010. Blight wiping out Alberta tomatoes. Edmonton Journal, September 13 edition, Edmonton, AB.

Spencer, R.C.J. 2010. Late blight of potatoes and tomatoes. Agri-News, September 13 edition, Alberta Agriculture and Rural Development, Edmonton, AB.

Cooperative Agreement

By signing as a representative of the applicant's employing organization, the undersigned hereby verifies acceptance of the terms and conditions specified in this proposal. They further agree to allow the applicant to devote time to the project and use the facilities of the organization to conduct the proposed research.

Principal Researcher's Organization

Name: Mr. Paul Laflamme

Title: Head, Pest Surveillance Branch, Alberta Agriculture and Rural Development, Edmonton

Signature_____ Date_____

Personnel

- Ron Howard, Sharon Lisowski and Greg Daniels, Plant Pathology Program, Alberta Agriculture and Rural Development, Crop Diversification Centre South, Brooks. [Expertise in project management, disease surveys, disease diagnosis and control, technology transfer, and staff training]
- Dr. Larry Kawchuk, Plant Pathologist, Agriculture and Agri-Food Canada, Lethbridge Research Station, Lethbridge, AB. [Expertise in late blight biology and diagnosis, and determination of mating types, genotypes and fungicide sensitivity]
- Dr. Robert Spencer, Alberta Agriculture and Rural Development, Alberta Ag-Info Centre, Stettler, AB. [Expertise in horticultural crop production and plant pathology, technology transfer, staff development training]
- Dr. Michele Konschuh, Potato Program, Alberta Agriculture and Rural Development, Crop Diversification Centre South, Brooks. [Expertise in seed, table and processing potato production, technology transfer]

Personal Data Sheet for Research Team Members

Name:
Last Name: Howard **First Name:** Ron

Position / Organization / Dept.: Plant Pathologist/CDC South/Alberta Agriculture and Rural Development

Address: 301 Horticultural Station Road East **City:** Brooks **Prov.:** AB **Postal Code:** T1R 1E6

E-mail: ron.howard@gov.ab.ca

Phone: 403-362-1328 **Fax:** 403-362-1326

Past experience relevant to project: (Point form, concise.)

- Research and extension plant pathologist at CDC South 1975 – present.
- Specialized in diseases of horticultural, forage and special crops.
- Conducted trials related to management of fungal diseases in saskatoons and black currants.
- Authored numerous articles and publications on plant disease diagnosis and management.

Degrees / Certificates / Diplomas:	**Institution:**
Bachelor of Science in Agriculture (B.S.A.)	University of Saskatchewan, Saskatoon
Master of Science (M.Sc.)	University of Saskatchewan, Saskatoon
Doctor of Philosophy (Ph.D.)	University of Wisconsin, Madison

Publications and Presentations:

Cao, T., Manolli, V.P., Hwang, S.F., Howard, R.J., and Strelkov, S.E. 2010. Virulence and spread of *Plasmodiophora brassicae* [clubroot] in Alberta, Canada. Can. J. Plant Pathol. 31: 321-329.

Harding, M.W., Butler, N., den Brok, K., Rajput, S., and Howard, R.J. 2009. Characterization of food-spoilage pathogens from fresh produce in Alberta. Can. J. Plant Pathol. 31: 122.

Harding, M.W., Howard, R.J., Burke, D.A., Daniels, G.C., Mobbs, S.L., Sowa, D.A., and Olson, M.E. 2009. Efficacy and phytotoxicity of copper- and silver-based bactericides for controlling seed-borne and foliar bacterial plant pathogens. Can. J. Plant Pathol. 31: 487.

Harding, M.W., Howard, R.J., and Olson, M.E. 2009. Impact of microbial biofilms and importance of surface testing methodology in plant pathology research. Can. J. Plant Pathol. 31: 122.

Harding, M.W., Howard, R.J., Pugh, C.A., Snider, M.D., Daniels, G.C., Strelkov, S.E., and Spencer, R.C.J. 2009. Incidence of clubroot on cruciferous vegetables in Alberta in 2008. Can. Plant Dis. Survey, 89: 136-139.

Harding, M.W., Marques, L.L.R., Howard, R.J., and Olson, M.E. 2009. Can filamentous fungi form biofilms? Trends in Microbiology 17: 475-480.

Howard, R.J., Strelkov, S.E., and Harding, M.W. 2010. Clubroot of cruciferous crops – new perspective on an old disease. Can. J. Plant Pathol. 32: 43-57.

Howard, R.J., Strelkov, S.E., Hartman, M., and Hwang, S.F. 2010. Clubroot survey and research update. Pp. 92-99 *in* Proceedings of the Agronomy Update 2010 Conference, Stettler, AB.

# of Refereed papers: 15/six yrs.	**Conference proceedings:** 10 abstracts/six yrs.
Relevant Patents obtained: None	**Other relevant citations:** >50 research reports/six yrs.

Other evidence of productivity during past 6 years: (Point form, concise)

- Leader or collaborator on over 20 research projects
- Authored or co-authored over 100 publications and presentations
- Active member of five professional organizations (Agricultural Institute of Canada, , American Phytopathological Society, Canadian Phytopathological Society, Plant Pathology Society of Alberta, and Western Committee on Plant Diseases)

Alberta Agriculture and Rural Development

Agriculture Research Division

Room 201, JG O'Donoghue Building
7000 – 113 Street NW
Edmonton, Alberta, Canada T6H 5T6

March 19, 2009

Mr. Edzo Kok
Executive Director
Potato Growers of Alberta
6008 – 46 Avenue
Taber, AB T1G 2B1

Dear Mr ~~Kuhl~~ Kok

Please find attached, two original copies of the Memorandum of Agreement between the Potato Growers of Alberta and Alberta Agriculture and Rural Development for the "Effective Sanitation of Potato Storages and Equipment" project.

Please sign both documents and return one to me for processing.

Thank you,

Joanne Phillips
Branch Administrator
Pest Management Branch

cc: Ron Howard
~~Elaine Lacroix~~

Alberta Agriculture and Rural Development

Agriculture Research Division

Room 201, JG O'Donoghue Building
7000 – 113 Street NW
Edmonton, Alberta, Canada T6H 5T6

March 13, 2009

Mr. Edzo Kok
Executive Director
Potato Growers of Alberta
60008 – 46 Avenue
Taber, AB T1G 2B1

Dear Mr. Kok:

Please find attached, two original copies of the Memorandum of Agreement between the Potato Growers of Alberta and Alberta Agriculture and Rural Development for "Preventing the Spread of Clubroot Spores on Seed Potatoes".

Please sign both documents and return one to me for processing.

Thank you,

Joanne Phillips
Branch Administrator
Pest Management Branch

cc: Ron Howard
Elaine Lacroix

POTATO GROWERS OF ALBERTA

September 1, 2011

Mr. Jack Bates, President
Canadian Horticultural Council
9 Corvus Court
Ottawa, ON K2E 7Z4

Re: Support for the Canadian Agri-Science Cluster for Horticulture

Mr. Bates:

On behalf of the Potato Growers of Alberta, I wish to pledge our support for the wireworm in potatoes research project, conducted by Bob Vernon, Todd Kabaluk and Christine Noronha of Agriculture and Agri-Food Canada, as part of the Canadian Horticultural Council's Agri-Science Cluster for Horticulture. The Potato Growers of Alberta agrees to commit $20,000.00 over the life of the project.

Canadian horticultural producers grow excellent quality fruits and vegetables and the PGA strongly supports the agri-science cluster which will support innovation for enhanced profitability and competitiveness of the horticultural sector.

Additionally, I commend you on the excellent partnerships you have assembled to help make this initiative a success, and wish you all the best in implementing a key component of our collective future.

Sincerely,

Potato Growers of Alberta

Edzo Kok,
Executive Director

6008 - 46 Avenue, Taber, AB T1G 2B1 • Office 403.223.2262 • Fax 403.223.2268
pga@albertapotatoes.ca • www.albertapotatoes.ca

Management of Wireworms on potatoes in Canada - Research Plan

Objective: The overall objective is to advance wireworm management strategies so that farmers who have wireworm problems can access a range of techniques that will provide sustainable mitigation to economic losses caused by wireworms. The strategies proposed are comprehensive and span approaches that are fundamental in any integrated management plan: i) Cultural techniques, ii) chemical control, and iii) biological control.

Specific objectives are listed below with each activity.

Background of the problem and strategies proposed for mitigation:

Agricultural production areas throughout Canada are facing increased economic losses due to wireworm damage. Wireworms, the larvae of click beetles, feed on the root and underground parts of several crop plants. Root crops such as, potato, rutabaga, and carrot are particularly susceptible because wireworm feeding damage easily becomes cosmetic, resulting in categorical rejection of otherwise productive and healthy crops. Wireworm damage to root crops is a serious problem not only to farmers but also to the processing industry. Damaged potatoes cannot be sold for table-stock and can be below premium quality for French fries and chips, resulting in growers who sell to a processor being financially penalized. In severe cases, growers have terminated harvest because of the severity of damage. Once land is infested with wireworms, it is difficult to break the reinfestation cycle and good agricultural land may have to be abandoned.

There are several species of wireworms but only a few are pests, the most important of these belonging to the genus Agriotes. In Canada, at least nine species of Agriotes are known to cause economic damage in several crops including oats, wheat, barley, clover, corn, carrots, lettuce, onions, peas, potatoes, and parsnips. Losses due to wireworm damage can range from 5% to 90%. Over the last five years, growers, extension personnel, processors, and researchers have noted an increase in wireworm damage, especially in PEI, NB and NS. In PEI, crop insurance has reported a steady increase in payouts because of wireworm damage and in 2010 paid out 3 million for wireworm damage.

Wireworms are particularly difficult to control because of their long life cycle. Females lay their eggs singly or in clusters in the soil in early summer. The eggs hatch and the larvae begin feeding on the organic matter and roots of the crop. In the fall the larvae feed voraciously before burrowing into the soil to hibernate, and return to the surface in the spring where they once again begin feeding on the roots of their host plants. The time to complete larval development can vary between 4 to 5 years. Most damage occurs in the fall and a grower planting his crop in the spring may not be aware of wireworm feeding until harvest.

Growers have mainly depended on insecticides for wireworm management, however, the lack of effective insecticides and their unpredictable efficacy puts the long term management of wireworms at risk. Currently there are no pesticides registered for use against wireworms in carrots in Canada. The main wireworm control currently being used in potatoes nationally (except BC) is Thimet 15G, and this product is scheduled to be phased out by PMRA in 2012. At the present time, there are only two other registered alternatives (i.e. clothianidin (Titan) and chlorpyrifos (Pyrinex)). Titan registered for wireworm suppression is unpredictable in controlling wireworms across Canada, and does not work in PEI, and there is no MRL for chlorpyrifos on potatoes entering the USA, so chlorpyrifos-treated crops cannot be exported. Therefore, there are no effective registered products available to replace Thimet 15G when it is phased out. In 2009, crop insurance in PEI paid out 3 million for wireworm damage. They estimate that a 20% loss due to wireworm of the insured crop in 2010 would result in a loss of about 29.6 million in value.

Because this insect has a five year life cycle, control would best be achieved with the use of an integrated pest management strategy. There is an urgent need to develop and evaluate several control techniques. Some options that should be evaluated are

1) Continued evaluation of the efficacy of new products to control wireworms
2) Efficacy of a one-year vs two-year rotation with Brown Mustard or Buckwheat
3) Planting small grain such as oats, barley, or winter wheat treated with insecticide in early fall (September) to eliminate wireworm populations prior to planting potatoes.
4) Eradicating wireworms from fields using lethal cereal seed treatments in rotation with potatoes
5) Effect of time of plowing (fall vs spring), and use of (roundup vs no roundup), before plowing cover/rotational crops to enhance effectiveness of existing or new control products.
6) Canada-wide wireworm/click beetle survey
7) Monitoring wireworm populations to develop reliable risk assessment strategies for crop protection.
8) Use of Biocontrol organisms such as Entomopathogenic nematodes and the fungal pathogens *Metarhizium anisopliae*. and *Beauvaria bassiana*

This research proposes to evaluate the above management practices to prevent/reduce wireworm damage to crops in agricultural land across Canada.

Study 1.

Efficacy evaluation of potential insecticides to control wireworms

Background: Currently potato growers are controlling wireworms with Thimet 15G, which is scheduled to be phased out by PMRA in 2012. There are currently no registered pesticides for use on carrots. In potatoes there are only two registered alternatives: clothianidin (Titan) and chlorpyrifos (Pyrinex). However, Titan was found to be ineffective against the wireworm species in PEI and there is no MRL for chlorpyrifos on potatoes entering the USA so crops treated with chlorpyrifos cannot be exported. Recent preliminary studies have shown a certain level of efficacy with some pyrethroids (i.e. bifenthrin and lambda cyhalothrin), which will protect daughter tubers from late season wireworm feeding and when combined with a neonicotinoid (imidacloprid, clothianidin or thiamethoxam), provides wireworm protection as well as the control of most above ground foliar pests. Studies at AAFC, Agassiz and London, have also shown that wheat seed treated with various insecticidal blends and applied in-furrow at planting as living attract-and-kill (A&K) strategies can control wireworm damage and eliminate wireworms from potatoes. Since previous AAFC work has also shown that various insecticide strategies will vary from species to species of wireworms, it is imperative to expand efficacy studies to all key species occurring in the key production regions of Canada before new registrations can occur.

Objective: To evaluate several registered and new insecticide chemistries for their efficacy to control wireworm populations under field conditions in BC, Alberta and PEI.

Activity 1.1 Evaluate the field efficacy of various insecticides, insecticide combinations and Attract-and-kill (A&K) methods on wireworm control. This work entails

determining the efficacy of candidate treatments in reducing potato damage to acceptable levels, and in actually killing wireworms.

Timetable:
May-October, 2012: To conduct multi-site (BC (Dr. R.S. Vernon), Alberta (Dr. H. Carcamo), PEI (Dr. C. Noronha)), harmonized field trials testing promising combinations of insecticides (e.g. pyrethroids + neonicotinoids) and various application procedures for control of key wireworm species. To evaluate low risk A&K strategies applied in-furrow for wireworm control in potatoes.
April-May, 2013: Conduct follow-up wireworm surveys in 2012 trials to determine mortality of wireworms by various treatments.
May-October, 2013: Continue with field trials as directed by 2012 results.

2014: Work will continue as above pending continued funding until replacements for Thimet 15G are identified.

Anticipated results:
The data will be used by industry partners to obtain new registrations (i.e. bifenthrin, lambda cyhalothrin, fipronil) and novel application strategies for control of wireworms and above ground insect pests to facilitate the replacement of Thimet 15G in Canada. The data collected will ultimately be used aid PMRA in the registration process of new chemicals.

Estimated costs:

Summer students (4, spread over the 3 sites (AAFC Agassiz, Lethbridge, PEI)	**= $40,000**
Additional costs (potatoes, bait traps, misc)	**= $10,000**
Contract for potato grading in Agassiz, BC	**= $ 6,000**
Total cost/year	= **$56,000**

Study 2.

<u>Evaluate the efficacy of planting buckwheat and mustard as a one year vs two year rotation</u>

Background: Studies have shown that potatoes tubers grown after a two your rotation with either brown mustard or buckwheat sustain significantly less damage with 80% of the tubers being marketable and 40% sustaining **no** damage from wireworms compared to the normal rotation (14% marketable, 8% no damage). It is believed that chemicals in the roots and shoots of these plants are toxic to wireworms and thus reduce wireworm damage. Most studies suggest that the mustard is killing the wireworms but further studies are required to confirm this. The following sub-activities will be conducted under this activity.

Objective: To determine if feeding on Brown Mustard or buckwheat roots is killing or repelling the wireworms. This study will be conducted in the greenhouse

Activity 2.1: Evaluate the effect of brown mustard and buckwheat on wireworms in the laboratory and greenhouse

Objective: To determine if a one year rotation with brown mustard and buckwheat is sufficient to reduce wireworm damage to crop.

Activity 2.2: Field evaluation of a one year and two year crop rotation cycle with Brown Mustard and Buckwheat on wireworm damage to the following potato or carrot crop

Timetable:
2011: Select fields and determine wireworm populations.
2012-13: Begin activity 2.1 (greenhouse house trial to determine the effects of brown mustard and buckwheat on wireworms).
2012-2015: Conduct crop rotation trial.
A best practices manual will be developed for growers to provide information on the variety, fertilization and management of these rotation crops.

Anticipated results:
Results from this trial will provide information on the effectiveness of a one year vs two year Brown Mustard or Buckwheat crop rotation on wireworm populations and damage and will aid in developing a management strategy for growers having wireworm problems. It will also confirm if the rotation crops, brown mustard or buckwheat, are killing the wireworms, and if either one of these crops can be used not only to manage but also to clean up heavily infested fields.

Estimated costs:
PEI : (includes students, supplies and travel to sites) **$15,000/yr**

Study 3:

<u>Planting small grain cover crops such as barley, winter wheat or oats with insecticide in early fall (September).</u>

Background: Insects in the northern hemisphere, where winters are very cold, hibernate (diapause) over the winter. In Canada the time for diapause can last for 6-8 months depending on the insect species. Insects need to feed to a greater extent in the fall to build enough reserves to hibernate successfully. It is this intensive feeding activity in the fall on tubers, and other root crops before harvest that causes economic losses to growers. However, if the only food source available at this time is insecticide treated seed such as wheat or oats seeds, the wireworms will be forced to feed on these seeds which would either kill or paralyze the wireworms preventing successfully diapause preparation and increased mortality over the winter months.

Objective: To determine if wireworms feeding on treated grain seeds in the fall can survive the winter and cause damage to the tubers the following year.

Activity 3.1: Field evaluation of planting barley or winter wheat seeds treated with an insecticide to control wireworms.

Objective: To determine if planting insecticide treated seed in the fall for one year reduces wireworm populations or if several plantings are necessary to achieve acceptable control and clean up heavily infested fields.

Activity 3.2: One year vs two year trials with fall planted treated grain seeds.

Timetable: This could be a two (one grain crop) or three (two grain crops) year. In PEI it will be conducted on farmers field.

April - December 2011-15
- Conduct lab studies with two wireworm species (*A. obscurus* and *A. sputator*) to determine rates of registered cereal seed treatments (thiamethoxam, imidacloprid) required to kill wireworms or immobilize them for long periods of time (AAFC, Agassiz)
- Select infested fields to conduct the trials and determine wireworm levels in fall (BC and PEI)
- Plant treated cereal crop(s) in mid-September
- In the following spring, conduct wireworm surveys to determine wireworm mortality over winter from treated cereal crops. Kill and remove winter cereal crop debris.
-Plant potatoes in May in the treated cereal plots to determine if economic wireworm damage can be reduced
- Harvest tubers in September and evaluate wireworm damage relative to Thimet 15G and untreated checks.
- collect, enter data and analyse data

January- March 2012 - 2015
- Analyse data
- Prepare and submit reports
- Present research results at grower association meetings and scientific conferences

Anticipated results:
This trial will provide information on the effectiveness of targeting populations of this insect in the fall, and will provide another strategy that growers can use to combat wireworm issues.

Estimated costs:
a) PEI (Students, supplies and travel, and evaluating tubers) **$ 18,000.00**
b) BC Assuming funding available as requested in study 1, no costs for students
Operating costs (Wheat seed, fertilizer, bait traps, etc) **$ 1000.00**

Study 4:

<u>Eradicating wireworms from fields using lethal cereal seed treatments in rotation with potatoes</u>

Background: Wireworms are a primary, chronic and expanding pest of cereal crops in Canada, especially in the prairies and PEI. Prior to 2004, wireworm damage to cereals was mitigated by the use of lindane seed treatments (e.g. Vitavax Dual). Lindane applied to wheat seed reportedly reduced wireworm damage by 90% and wireworm numbers (i.e. *Ctenicera destructor* and *Hypnoides nocturnus*) by about 70% on the Canadian prairies. At present, no new insecticidal seed treatments have been registered in Canada that will significantly reduce wireworm populations, which is the main reason why populations and cereal crop damage are reaching epidemic proportions. The rapid buildup of wireworms in cereal crops (a preferred host) also has serious implications for potato production (and other crops) on the prairies and in PEI, since wireworms live for 4-5 years in the soil and can cause serious damage to potato crops in typical rotations with cereals (i.e. barley and wheat). Damage can also occur in other key crops such as canola, pulses, forages, vegetables, etc. Recently, AAFC researchers in Agassiz have developed a number of patent pending wheat seed treatments that will both protect wheat stand

and yield, and will reduce wireworm populations of all key wireworm species even more effectively than lindane.

In PEI, a cereal crop is commonly planted the autumn or spring following a potato crop. With this type of rotation, the presence of a cereal crop the year following potatoes serves as an excellent host in which the adult, click beetle stage of a number of serious pest wireworm species (i.e. predominantly *Agriotes sputator*, an introduced species from Europe) will lay eggs in late spring and early summer. These eggs will hatch in 2-3 weeks and the neonate wireworm larvae will feed on the developing cereal crop. By the end of summer, neonates will be about 4-5mm long. These wireworms will continue to feed on crops grown the following year (i.e. clover), and by the end of summer that year they will be about 9-11mm long. The following spring, growers generally plow under the cover crops in the field and plant potatoes. At this time, wireworms are about 1cm long, but will grow to about 1.4cm long by summers' end, at which time daughter tubers are being formed. It is thought that if wireworms can be functionally eradicated from fields during the cereal crop rotation, this would prevent damage from occurring to potatoes that would be planted two years down the road.

The purpose of this study is to attempt to control wireworm damage in both wheat and potato crops (in rotation) with a single application of an AAFC-developed wheat seed treatment (there are several developed, but only one will be demonstrated in PEI) applied to wheat seed during the wheat crop rotation. As has been shown at AAFC, Agassiz, these wheat seed treatments preserve wheat stand and yield, and remove > 90% of wireworms (both existing wireworms already in the field, and neonate wireworms produced in the field that year) from the field. The following year, there would not be significant numbers of wireworms surviving in the field, and depending on the crop, if other than a cereal crop (i.e. clover), egg laying would be reduced, and any neonate wireworms produced that year would be only 4mm by end of that growing season. When potatoes are planted the following spring, wireworm populations would be low, and wireworms too small to cause significant damage to daughter tubers that year.

Objective: To develop rotational strategies whereby wireworm populations are controlled for 3-4 years by eradicating resident and neonate wireworm populations by lethal cereal crop seed treatments in spring plantings.

Activity 4.1: To determine if wheat seed treated with various insecticidal blends will functionally eradicate wireworm populations such that subsequent potato crops will not require insecticides for wireworm control in key production areas of Canada (i.e. Prairies, Atlantic Canada).

Timetable: This could be a two year or multiple year project, depending on results in the first year

April - December 2011

- 8 lethal cereal crop trials have been established in key potato production regions across Canada (BC = 2; Alberta = 2; Saskatchewan = 2; Manitoba = 2; PEI = 2). Stand counts have been done to determine wireworm activity and treatment effectiveness in reducing cereal crop damage.
- Pending funding, all treatments in all trials will be sampled for wireworms in fall to determine wireworm mortality (2011).

April - December 2012

- In the following spring, conduct wireworm surveys to determine wireworm mortality in the lethal cereal crop treatment plots. Remove any cereal crop debris.
-In a number of the 8 cereal crop trials across Canada (to be determined by funding), plant potatoes in May in the treated cereal plots to determine if enough wireworms killed in previous year to prevent economic wireworm damage.

- Harvest tubers in September and evaluate wireworm damage relative to Thimet 15G and untreated checks.
- collect, enter data and analyse data.
- Analyse data
- Prepare and submit reports
- Present research results at grower association meetings and scientific conferences

April - December 2013-2015
- Pending continued funding, additional sites will be identified to continue this study in order to determine the effectiveness of this strategy on all key wireworm species across Canada, and to generate data for new registrations of insecticidal blends as wheat seed treatments.

Anticipated results:
This trial will provide information on the effectiveness of targeting the removal of wireworm populations during cereal crop rotations, and if successful will provide a major strategy that most growers can use to combat wireworm problems across Canada
It is assumed, through earlier trials at AAFC, Agassiz, that this strategy will be successful in reducing wireworm populations to sub-economic levels across Canada. It will essentially replace the now banned Lindane as a cereal seed treatment option, which in the past kept wireworm populations in check. In fact, the new strategies are even more effective and far less risk to the environment and man than Lindane.
An industry partner is currently developing a strategy with AAFC to register some of these lethal wireworm cereal seed treatment strategies in Canada and the USA. A decision to pursue these registrations will be made within the next year depending on a market/cost analysis. Data generated in the proposed studies above will help determine the scope of crops and acreage that would be covered by these strategies, and thus the market potential.

Estimated costs:
These costs based on a per research site basis, and that AAFC personnel or University professionals can be involved to oversee the planting and maintenance of wheat and potatoes.

Operating costs (Wheat seed, potato seed, fertilizer, bait traps, etc)	= **$3000.00/site**
Contract to grade potatoes for damage	= **$2000.00/site**
Total cost per site	= **$5,000.00/site**

Study 5:

Effect of time of plowing (fall vs spring), and use of (roundup vs no roundup) before plowing

Background: It is believed that plowing a field in the fall will allow the green matter to deteriorate over the winter, preventing it from being a food source and forcing the wireworms to come to the surface and feed in the insecticide treated areas in the spring. However, plowing in the fall can also result in erosion and nitrate leaching. Killing the above ground matter with roundup and then plowing in the spring may be a better option. There is not much information available on the value and effectiveness of this strategy

Objective: To determine which strategy, spring or fall plowing with or without roundup, is the best option for growers to reduce wireworm damage in the potato crop.

Activity 5.1: Effects of spring vs fall plowing with or without the use of roundup.

Anticipated results: The results from this trial will provide much needed information on the effectiveness of this strategy and will be helpful in providing growers with a strategy that would aid in reducing wireworm populations but also prevent erosion during the winter and reduce nitrate leaching.

Timetable:
September 2011 – December 2012
- select field(s)
- plow or roundup sections of the field in the fall and spring.
- harvest tubers and evaluate damage caused by wireworm feeding
- collect and enter data

January March 2013 - 2013
- Analyse data
- Prepare and submit reports
- Present research results at grower association meetings and scientific conferences

Anticipated results:
Results will allow growers to make informed decisions on the best way to prepare field for spring planting while reducing the potential for wireworm damage to their crop.

Estimated costs:
PEI (Supplies and travel, assuming students from above trials are approved) **$ 7,000**

Study 6:

Canada-wide wireworm/click beetle survey

A Canada-wide survey to determine the key wireworm species occurring in agricultural areas has been underway with AAFC and industry since 2005. This survey is critical in that there are > 30 pest wireworm species across Canada, all occupying specific and often overlapping regions. It has also been found that different species may react differently to some of the new insecticides and strategies under development, and surveys will determine what strategies will work best in specific agricultural regions. Surveys are also being conducted to determine the spread of 3 exotic wireworm species (introduced from Europe in the early 1900s). This is especially important in PEI and BC, where these species are spreading and causing increasing damage to various crops, especially potato (PEI). Previous surveys have deployed Vernon Beetle traps (with pheromones for these 3 species) in fields across Canada to determine the spread of these species, and more comprehensive surveys have been conducted in BC and PEI. Additional surveys, however, are required to continue developing wireworm species maps for all agricultural areas in Canada.

Objective: Conduct wireworm/click beetle surveys to determine the key pest species occurring in key agricultural lands across Canada and develop a sampling plan.

Activity 6.1: Establish a network of industry, growers and professionals to collect wireworms from sites across Canada for identification by AAFC researchers

Objective: The main objective is to develop a reliable risk assessment technique for growers to determine wireworm populations within their fields and make informed pest control decisions in advance of planting potatoes

Activity 6.2: Wireworm risk assessment for crop protection using the new wireworm ~~bait~~ probe trap. Develop a sampling plan for wireworm risk.

Timetable:

This is a continuing project

March-July 2012 – 2013
- Canada-wide survey (AAFC, Agassiz, R. Vernon) involves wireworm survey kits provided to growers and extension people by Syngenta CropProtection Canada and Bayer CropScience Inc. These are sent out in spring and collected wireworms sent to AAFC, Agassiz for identification by Dr. Van Herk (North American expert on wireworm taxonomy). New maps of wireworm distributions are made in winter.
- PEI survey (AAFC, Charlottetown, C. Noronha) will involve use of Vernon beetle traps deployed in strategic regions across the island.
- contact PEI growers and select fields
- install traps in fields
- collect and enter data

Anticipated results: The results from this trial will provide growers and extension personnel across Canada with maps of key wireworm species occurring in key agricultural regions. These species maps will ultimately be used in determining the most efficacious wireworm strategies to be deployed according to the species present. A province-wide survey was conducted on PEI three years ago to get a baseline on species distribution. This follow up survey will determine movement of the species and rate of spread in the province.

Estimated costs:

PEI: (Christine Noronha)	**$ 8000.00**
Agassiz: (Todd Kabaluk)	**$ 5000.00**

Assuming AAFC, Agassiz is involved with this study, there are no associated costs other than the pys involved (Vernon and van Herk)

Study 7:

Wireworm risk assessment for crop protection using the new wireworm probe trap.

Background: The development of a reliable technique to evaluate wireworm populations will help growers make informed pest control decisions for individual fields and prevent economic losses due to unnecessary control measures. It is difficult to assess, before planting, whether or not a field has damaging levels of wireworms. The value of accurately estimating wireworm population levels is that it can i) eliminate unnecessary prophylactic pesticide applications if populations are below a crop damage threshold; ii) lead to a choice of planting a crop that is not

affected by wireworm feeding if populations are high; and iii) lead to choice of control options (rate/type of pesticide) based on the level of infestation.

Objectives: The main objective is to develop a reliable risk assessment technique for growers to determine wireworm populations within their fields and make informed pest control decisions in advance of planting potatoes

Activity 7.1: Wireworm risk assessment for crop protection using the new wireworm probe trap.

Timetable

April 2012-March 2013

- collection of wireworms from probe traps in large-scale acquisition trial and sequential replacement and collection of traps (PARC)
- field trials to characterize the performance and use of wireworm probe traps (PARC)
- tracking of national catches of wireworms from distributed traps, and receipt of specimens (PARC)
- data entry, compilation, and analysis for all field trials (PARC)

2013-2015 – work will continue to identify the ideal bait and reliable environmental conditions for wireworm trapping and field assessment

Anticipated results:

The data collected will provide growers with information on the best method to monitor wireworm populations in order to reliably assess the risk associated with that field before planting.

Estimated costs:

Agassiz Todd Kabaluk **$ 7,000.00 / yr**

Study 8:

<u>Biocontrol with Entomopathogenic nematodes and fungal pathogen *Metarhizium anisopliae*.</u>

Background: Entomopathogenic nematodes are known to infect wireworms, however, the use of the correct species, timing of application and compatibility with insecticides can influence the viability and efficacy of these organisms. Entomopathogenic nematodes ***do not*** infect plants and are commercially available from companies selling biocontrol organisms in Canada and are presently used against several soil pests on golf courses. A cold tolerant Canadian strain is commercially available for use, however, research trials are needed to evaluate the efficacy of this strain against wireworms in Canada.

The Metarhizium isolate discovered by AAFC (the Agassiz isolate) has been tested by researchers around the world, and has always been shown to be the most virulent to wireworms compared to all other isolates tested. Previous research advances have included: a 30% reduction of wireworm feeding damage to potato using broadcast pre-plant incorporated Metarhizium spore granules, significant amplification of Metarhizium efficacy when used together with spinosad, the discovery that infected click beetles (wireworm adults) will pass on their infection to other click beetles, a new, robust Metarhizium formulation with long shelf life that is easily applied with standard farm machinery, and the discovery of a non-effect on beneficial insects according to the range of non-target insects assayed.

Objective 1: Evaluation of the efficacy of entomopathogenic nematodes and Metarhizium on key wireworm pest species in the laboratory and under field conditions

Activity 8.1 To test, in the laboratory and under field conditions, the efficacy of entomopathogenic nematodes and the fungal pathogen Metarhizium as biocontrol agents targeting larvae and adults of the wireworm species found in PEI and BC.

Objective 2: Evaluate the efficacy of different concentrations of nematodes and time of application under field conditions i.e. spring or fall application.

Activity 8.2 To determine the most efficacious concentration of these biocontrol agents first in the laboratory and then under field conditions and evaluate the appropriate timing of nematode application i.e spring or fall to achieve a high level of control i.e. spring or fall.

Objective: Application compatibility with standard farm equipment and insecticides.

Activity 8.3 To determine if standard farm equipment can be used to apply different formulations and concentrations of nematodes and Metarhizium and the feasibility and ease of modifying this equipment. Compatibility of biocontrol organisms tank mixed with other pesticides will also be determined.

This is a long term project the first phase being laboratory testing efficacy on the wireworm species found in PEI followed by small plot field studies and eventually leading to larger field scale trials.

Anticipated results:
Results will provide growers with another strategy to be used in combination with other techniques to manage wireworm populations thus, clean up heavily infested field, and prevent populations from building up to uncontrollable levels.

Estimated costs:

PEI: Christine Noronha	**$ 18,000**
Agassiz: Todd Kabaluk	**$ 25,000**

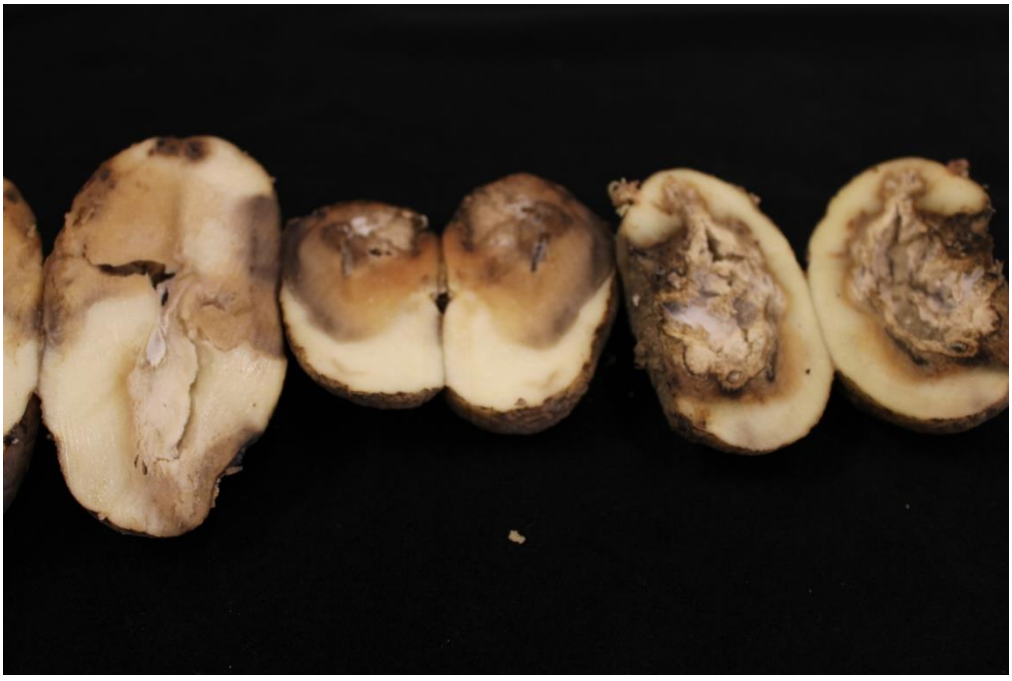
Feasibility:
All research objectives of this proposal have a high probability of success, since most of the methodologies to be used have already been developed, and the collaborators and most technical staff have all had significant experience with the pests and relevant methodologies involved. Since 2005, AAFC researchers have published 21 peer reviewed publications on wireworms, and 41 seminars at grower and scientific meetings in North America and Europe. It is anticipated that one or more highly effective combined insecticide strategies will be identified for generic species wireworm control in potatoes. The eventual registration of key insecticides involved in these blends (i.e. bifenthrin or lambda cyhalothrin) within 3-4 years is very likely, provided efficacy results on all key species can be demonstrated in the current project. In wheat, the feasibility of

adoption of the 'Blended seed treatments' and A&K strategies depends on the eventual registration of fipronil in Canada. To facilitate this, the associated IP has been secured with submission of patent applications by AAFC, and an industry partner has been identified (CRDA with Option) to bring this technology to Canada and the USA (and elsewhere in the world), which would include the registration of fipronil. The vast hectarage that would potentially be treated (e.g. wheat alone), and the tremendously low rates of fipronil required make this a very attractive endeavor for the partner, and would remove the economic threat of wireworms from most of Canada . The negligible health and environmental risks associated with this IP also make it appealing to the PMRA. If and when these new strategies are available, they will be adopted very rapidly, since there will soon be no effective pesticides left for managing wireworms in Canada. The ongoing success of the Canadian wireworm survey is guaranteed, in that industry has developed sampling kits for client growers across Canada, and the expertise for identifying large numbers of wireworms in a timely fashion has been developed at AAFC, Agassiz.
In Charlottetown, other management techniques have been studied such as crop rotation which has shown considerable success with 80% of the potato crop following mustard and buckwheat being marketable compared to 14% in the normal rotation. Because of the life history of this insect it is important to develop a more comprehensive management strategy that could be used by farmers across Canada, which is proposed in this document.

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

Agriculture Building

Lacombe, AB

by

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October 27, 2015

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.

Project Team Members

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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
1201 tggctgcttc cgacttccgc aacggtcgtt acctgacctg ctctgccatc ttccgtggcc
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.

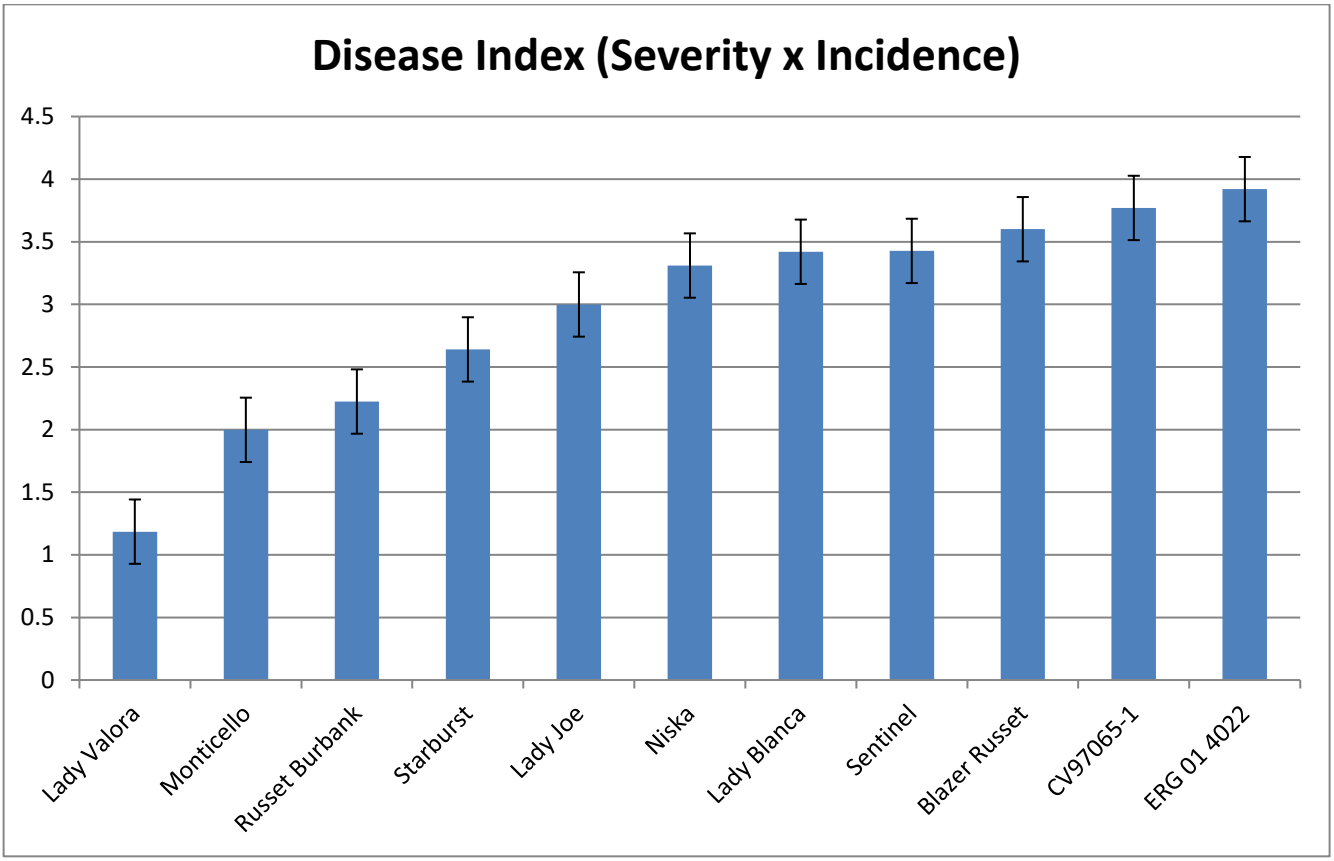


Figure 1.

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.

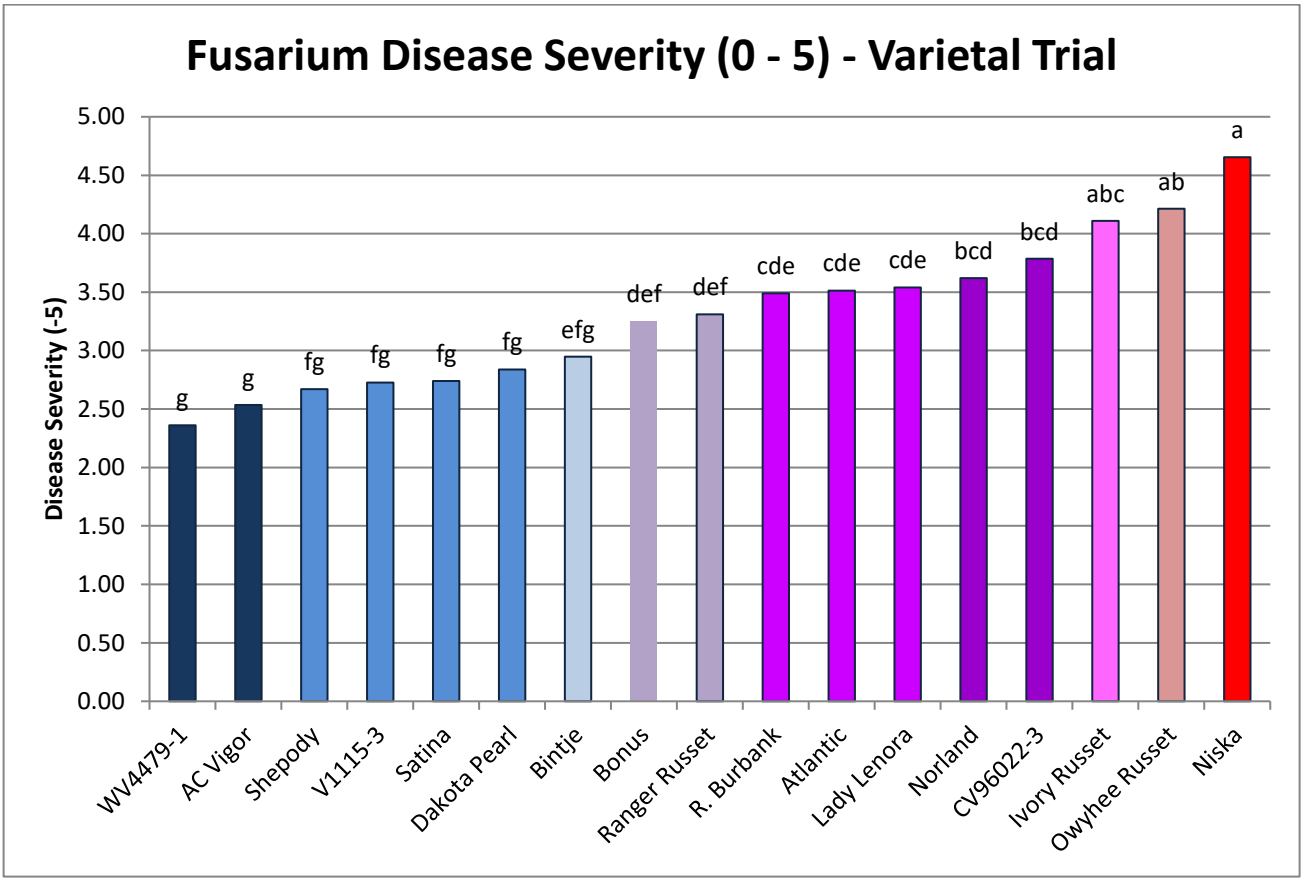
Treatment Number	Cultivar	Type	Source
1	AC Vigor	Chipper	AAFC
2	Atlantic	Chipper	CDCS
3	Bintje	Multi-purpose	PGA
4	CV96022-3	Chipper	AAFC
5	Dakota Pearl	Chipper	PGA
6	Ivory Russet	French fry	ConAgra
7	Lady Lenora	Chipper	CDCS
8	Niska	Chipper	CDCS
9	Norland	Table	CDCS
10	Owyhee Russet	French fry	CDCS
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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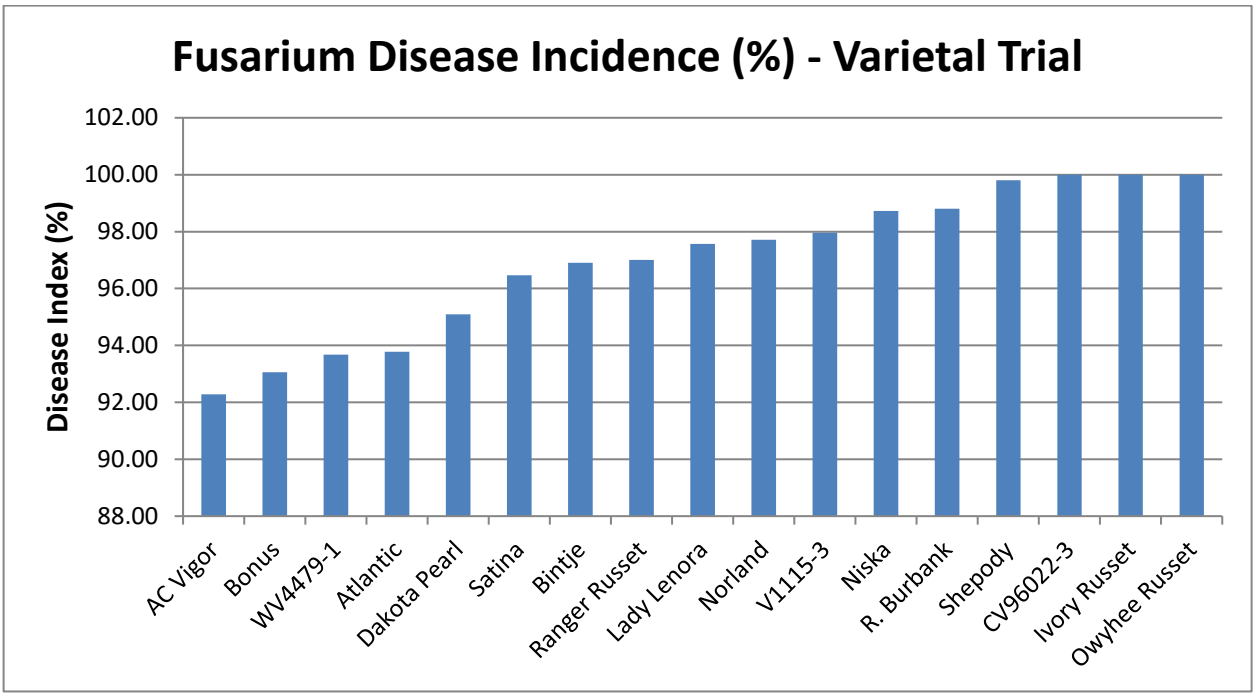
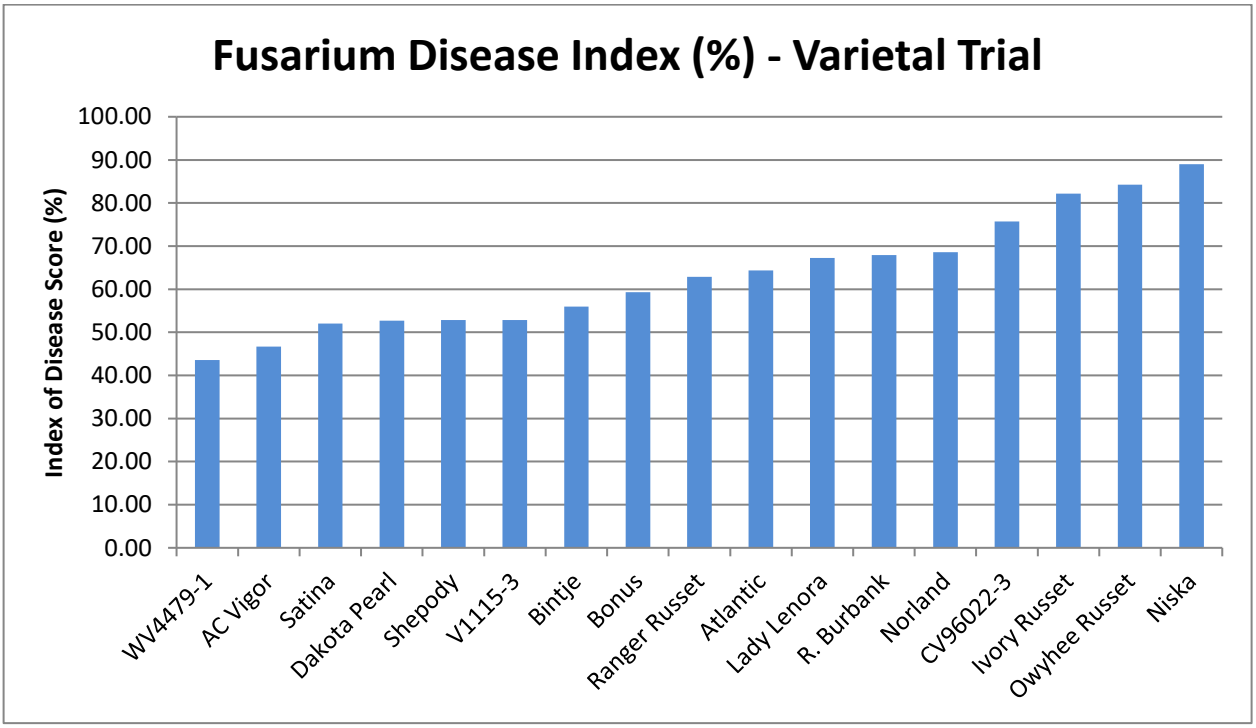


[1]All results were statistically similar based on Duncan's Multiple Range Test, so this arcsine-transformed data are shown in a deep blue color.

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.

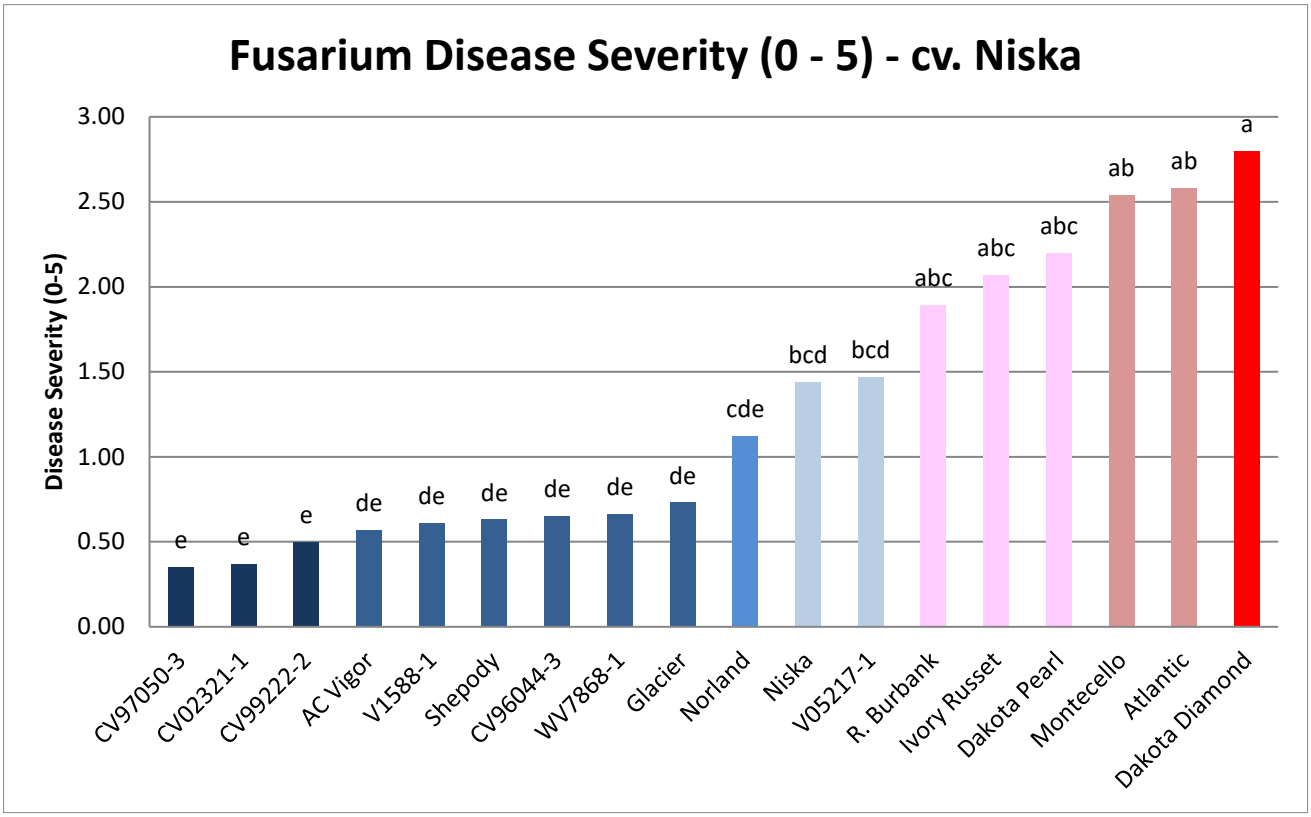
Treatment Number	Cultivar	Type	Source
1	AC Vigor	Chipper	AAFC
2	Atlantic	Chipper	CDCS
3	CV02321-1	Chipper	AAFC
4	CV96044-3	Chipper/Creamer	AAFC
5	CV97050-3	Table	AAFC
6	CV99222-2	French fry	AAFC
7	Dakota Diamond	Chipper	ODF
8	Dakota Pearl	Chipper	CDCS
9	Glacier	Chipper	PGA
10	Ivory Russet	French fry	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

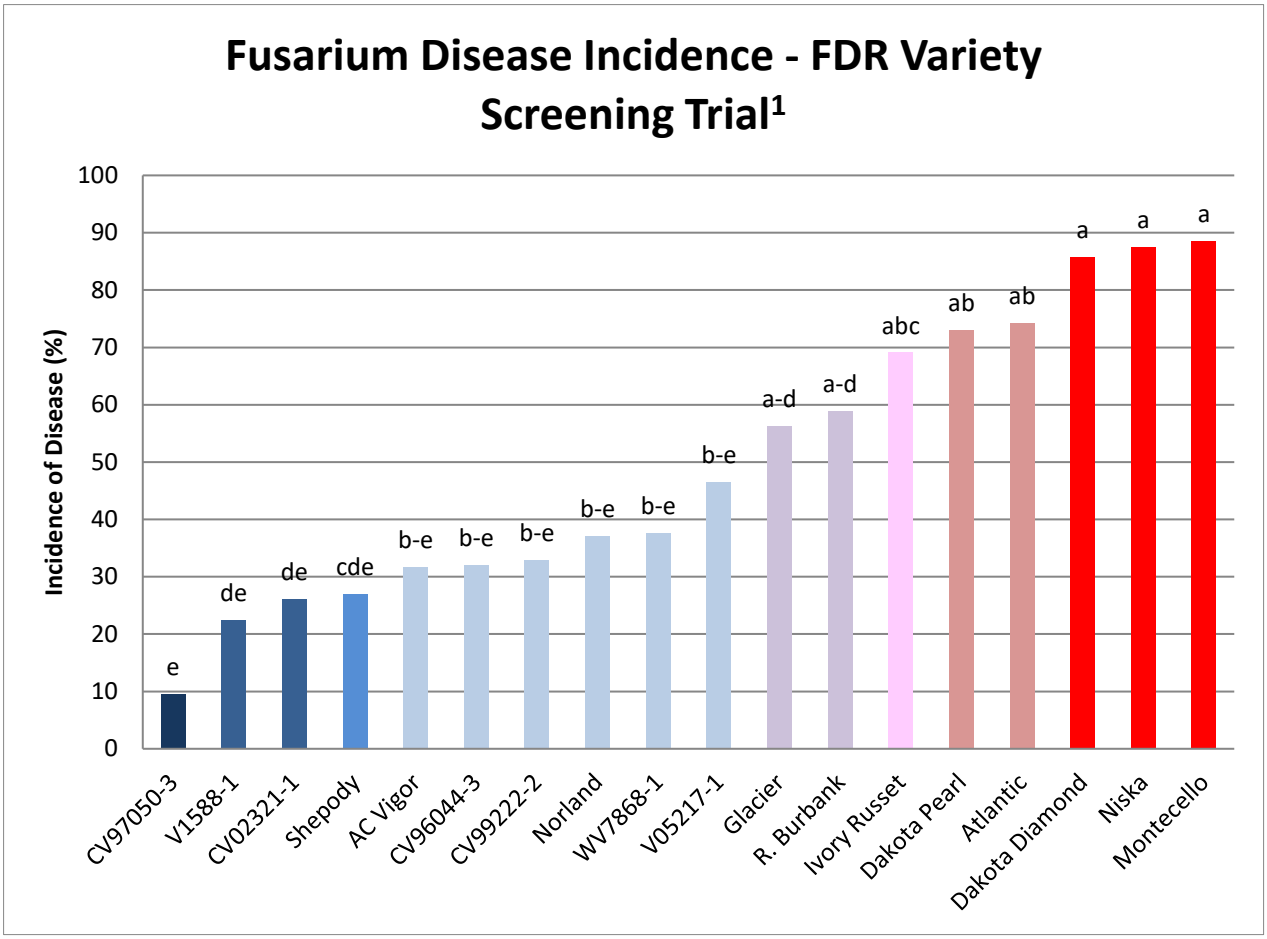
[1]Results are the means of five replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers 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.



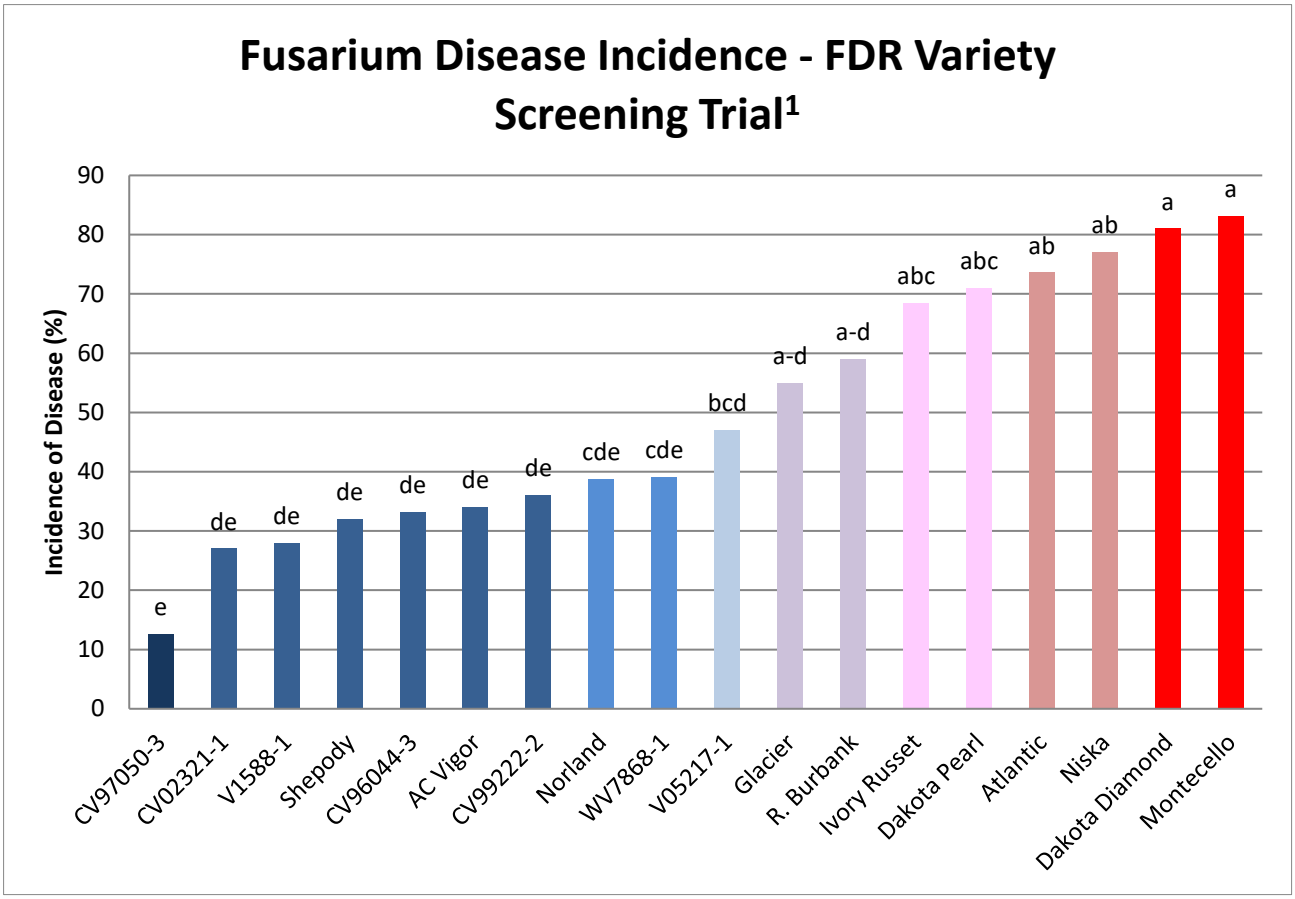
The navy blue and red columns were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. medium blue, pink and dark pink) to the navy blue and red columns.

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.

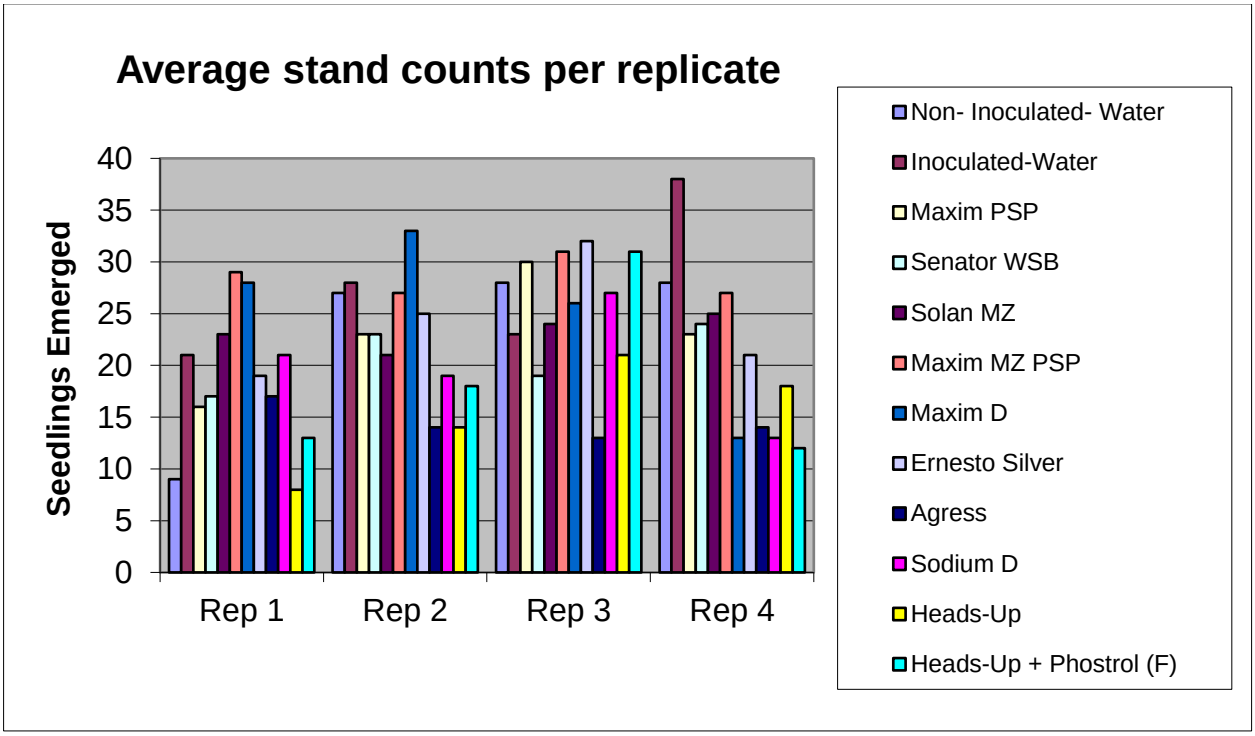


Figure 3: Average stand counts for each treatment out of 40 planted seed pieces at 39 DAP

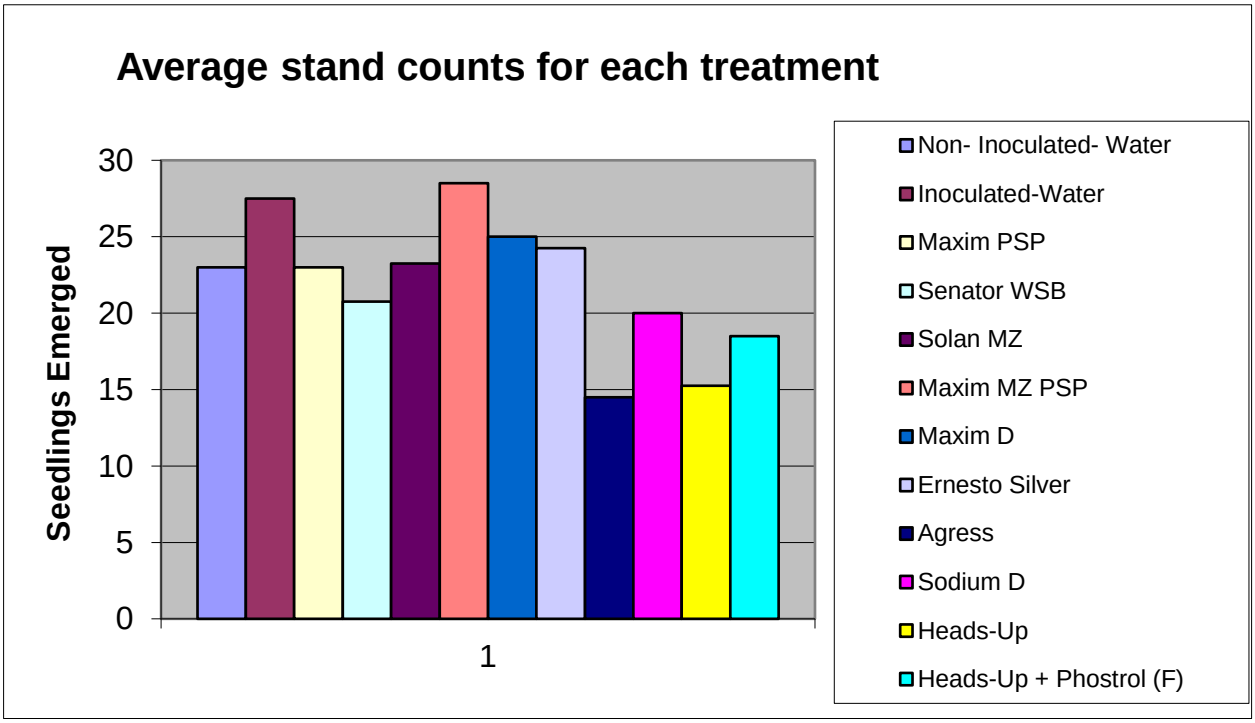


Table 4 shows the yield data (total yield; ton/ac) and specific gravities of tubers from each treatment. Although the total yield data failed the Bartlett's test of homogeneity (=0.03), trends show that the highest yield was observed when Maxim D was used as a seed treatment followed by Maxim MZ, Solan 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

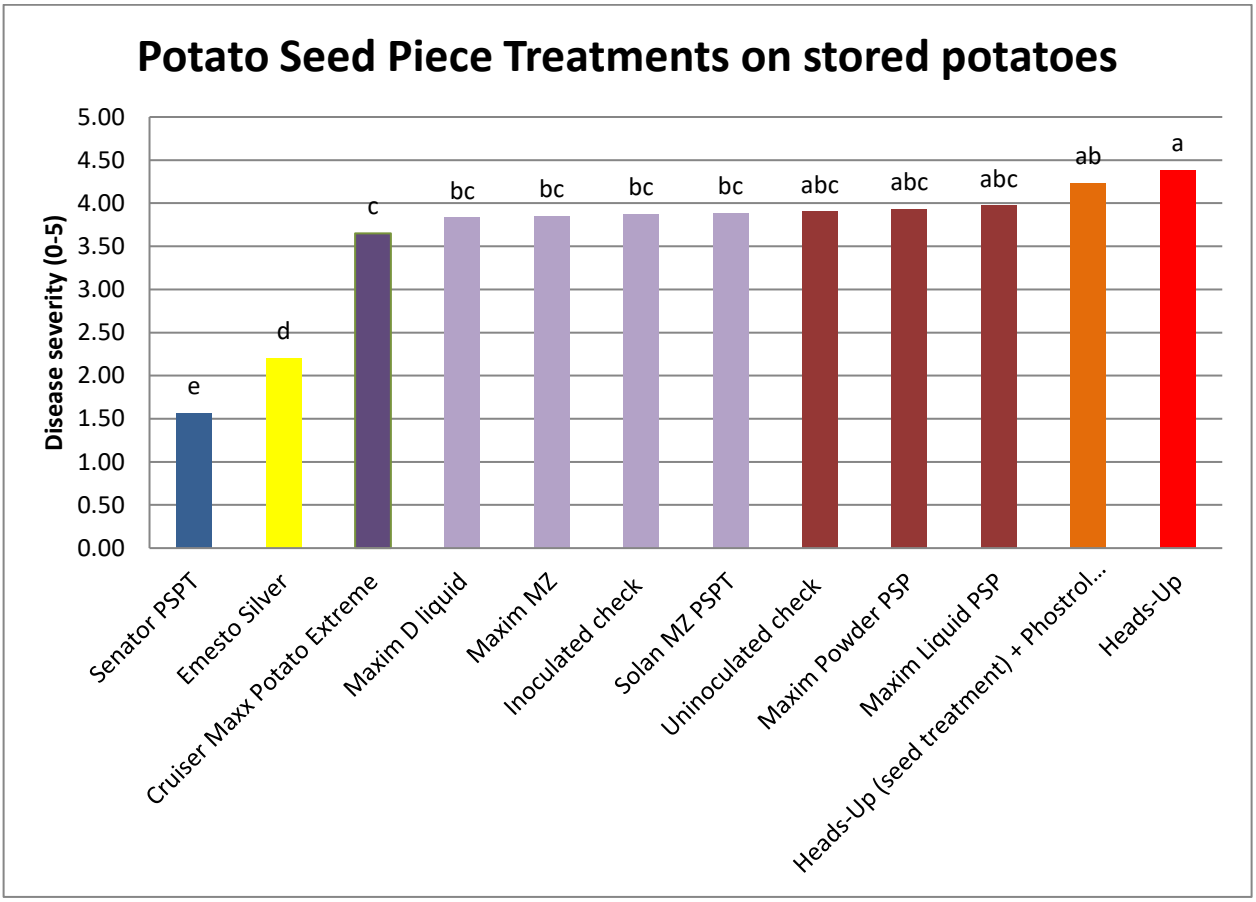
SENATOR PSPT and EMESTO SILVER both very significantly lowered dry rot on potato seed pieces that were stored at 10°C and 95% RH in a controlled environmental storage room for 49 days. This data may be helpful in situations where field planting has to be delayed.

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

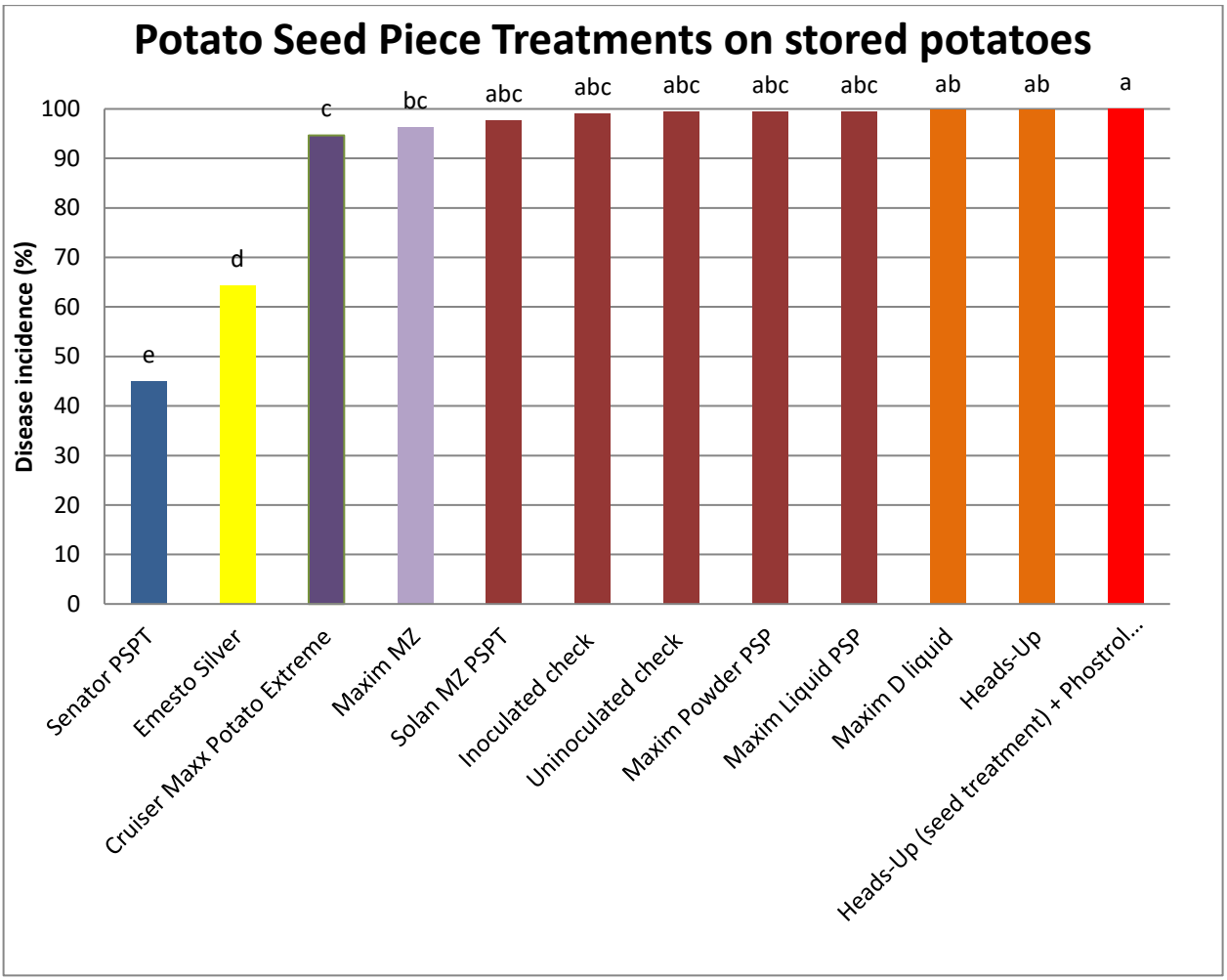
[1]Results are the means of four replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers 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.



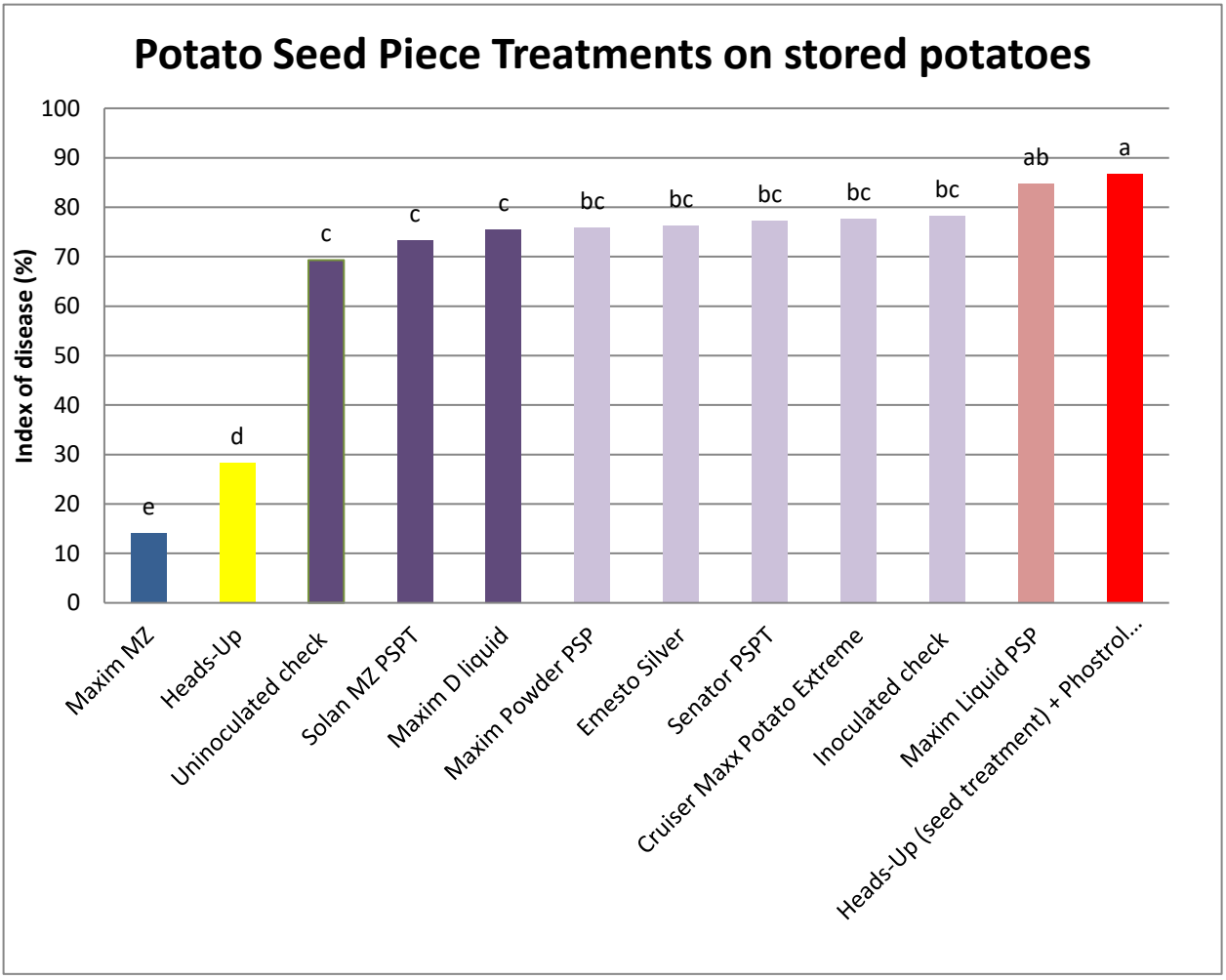
The navy blue, yellow, dark purple and red columns were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. purple and mahogany red). These columns are not statistically equivalent to navy blue, yellow, dark purple and red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

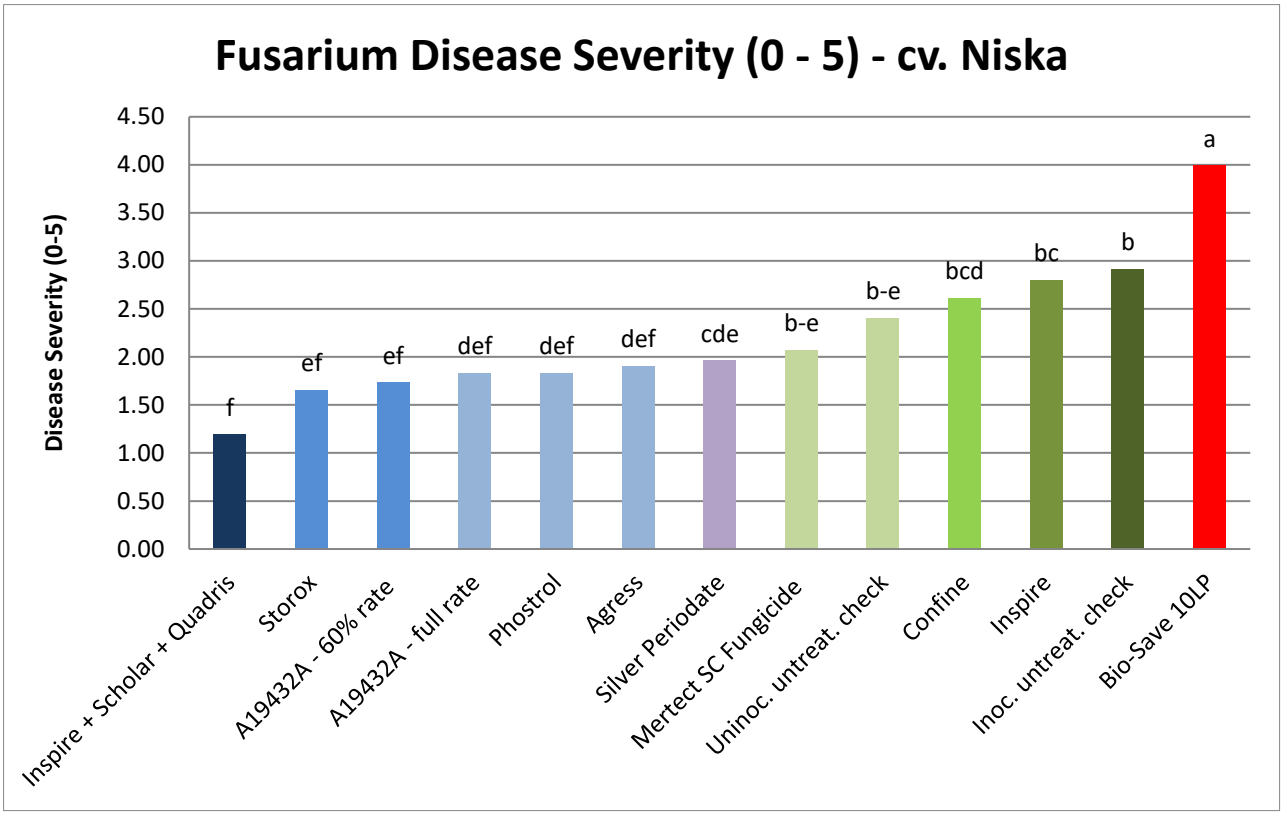
[1]Results are the means of four replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers 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

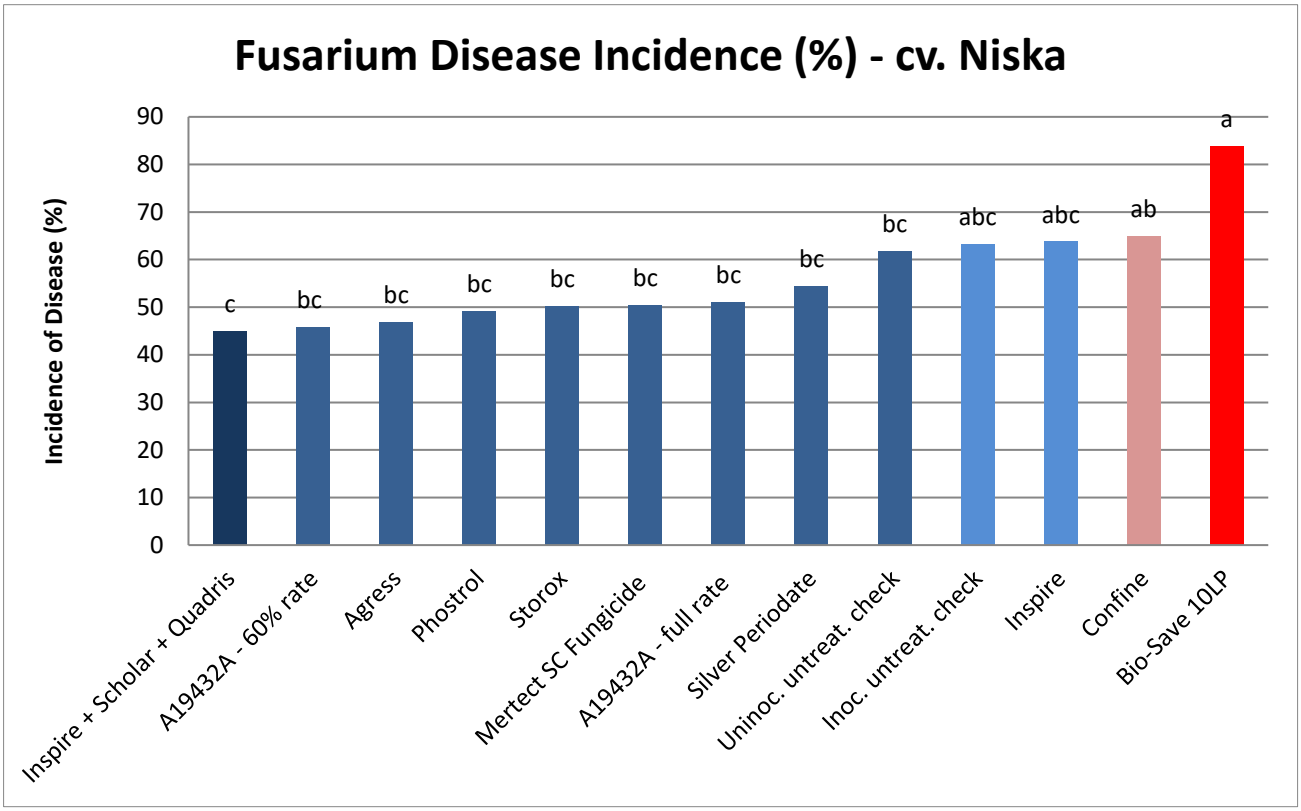
[1]Results are the means of four replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers 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.



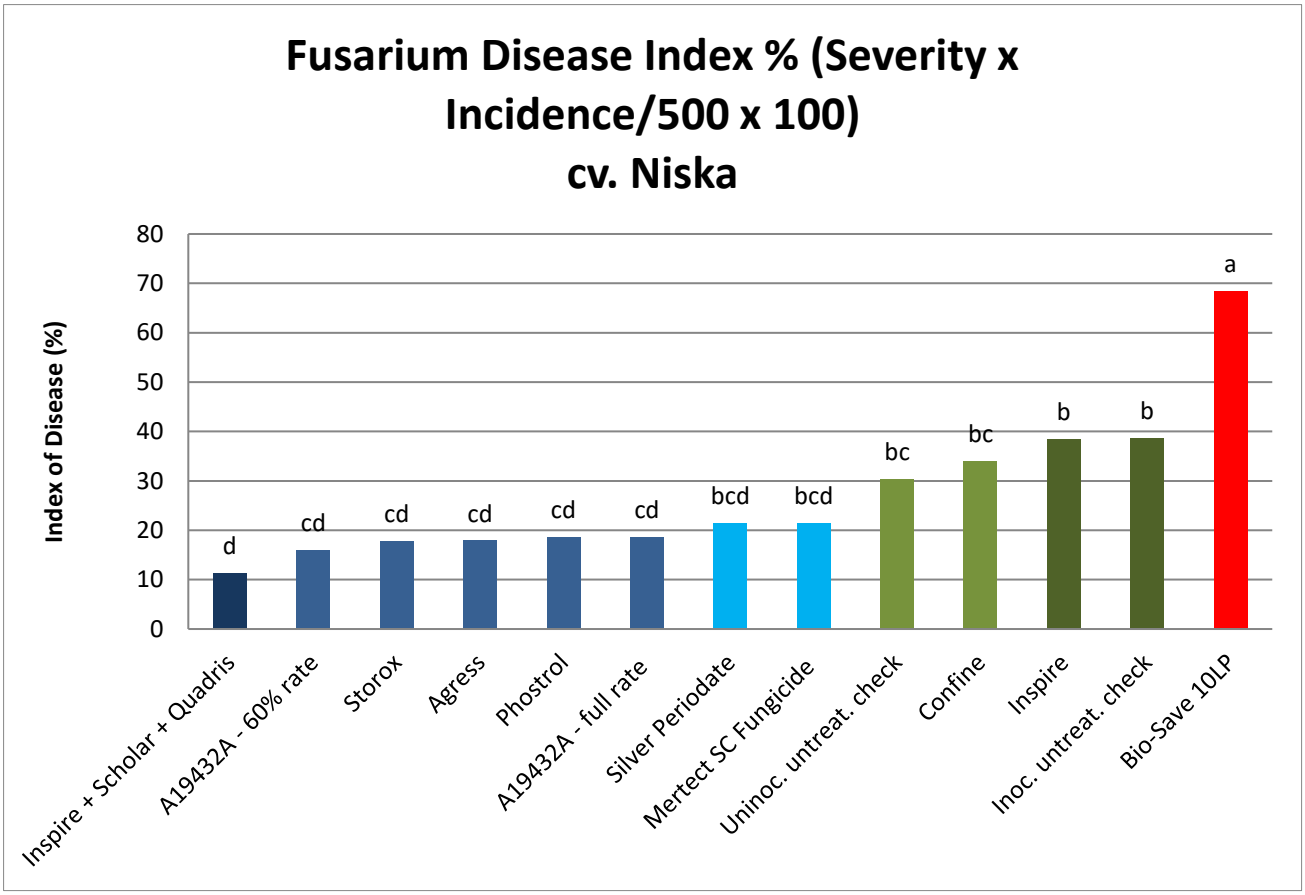
The navy blue, dark green and red colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. medium blue, light blue, olive green, bright green and light green). The purple column was not statistically equivalent to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



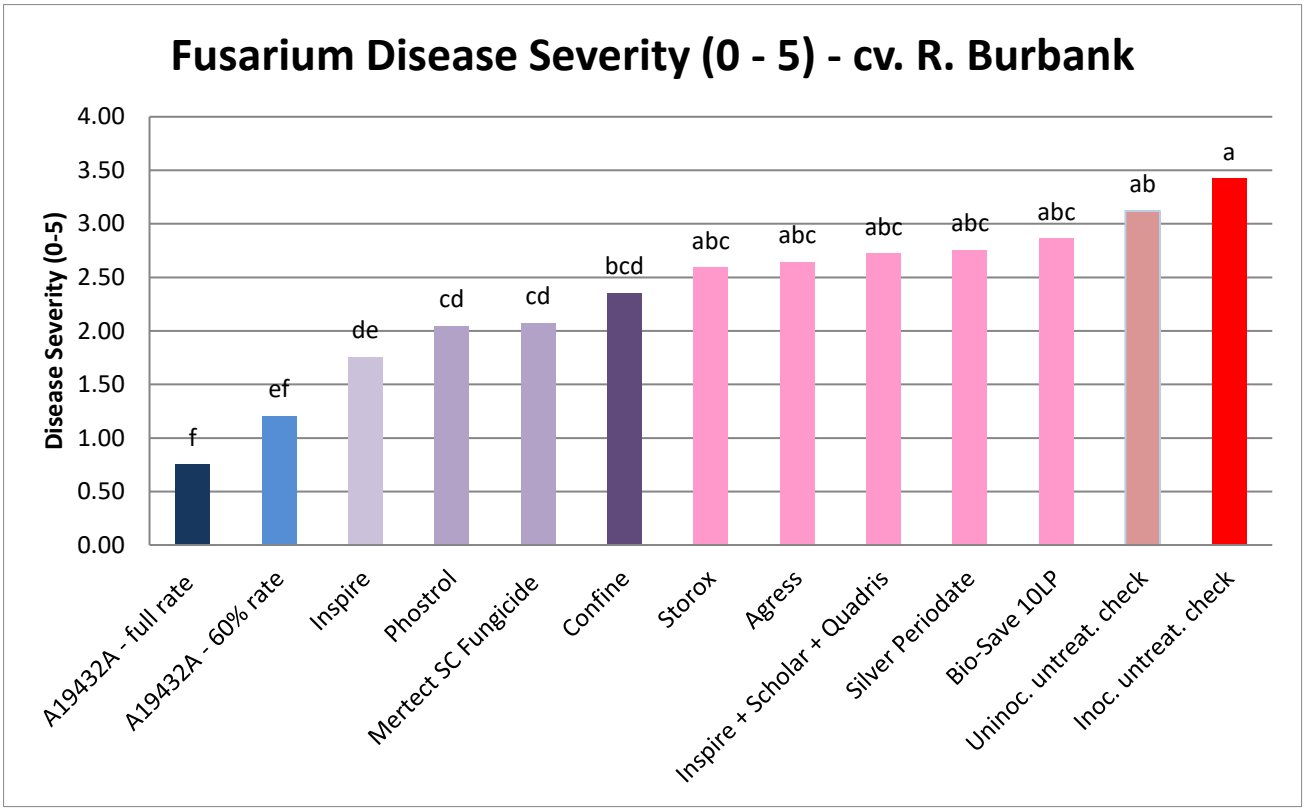
The navy blue and red colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. pink or blue and light blue).

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



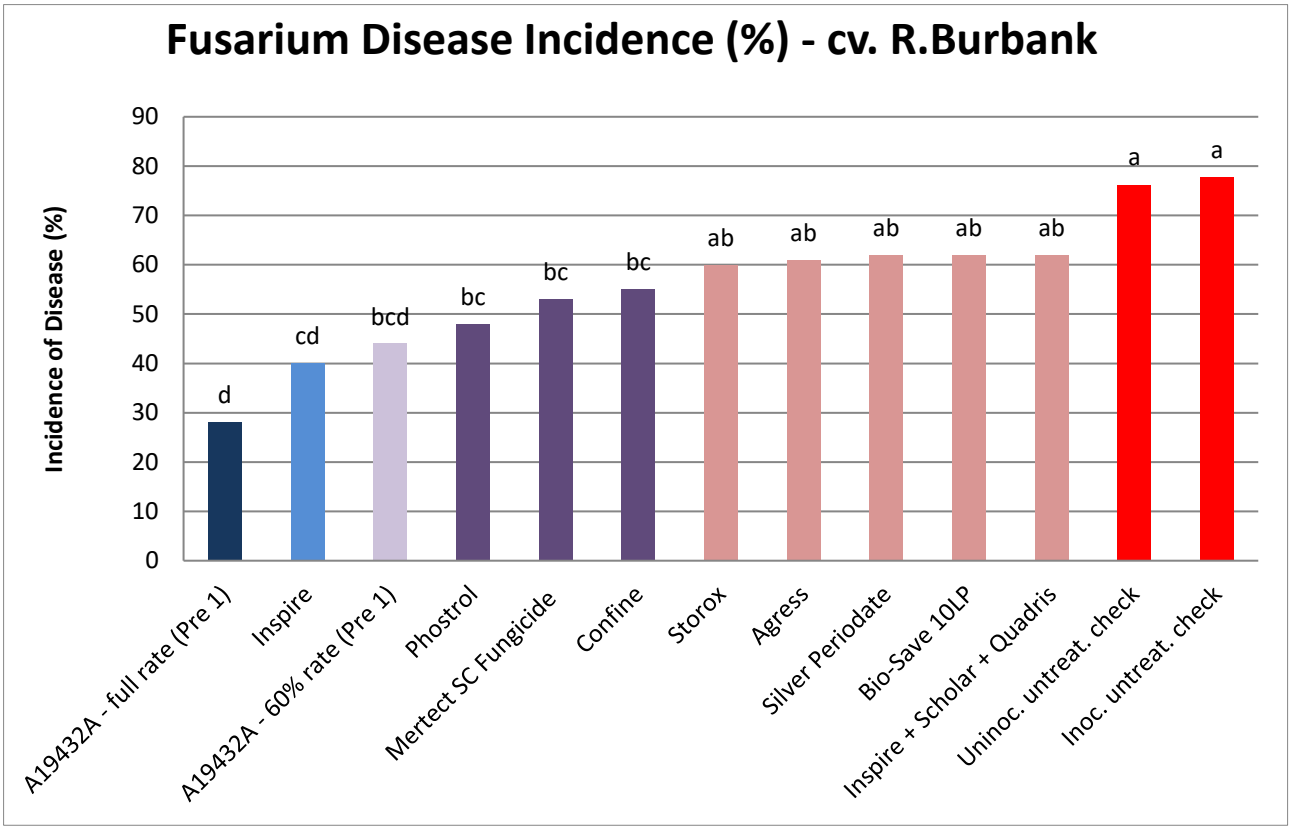
The navy blue, dark green and red colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. dark blue, turquoise and medium green).

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.



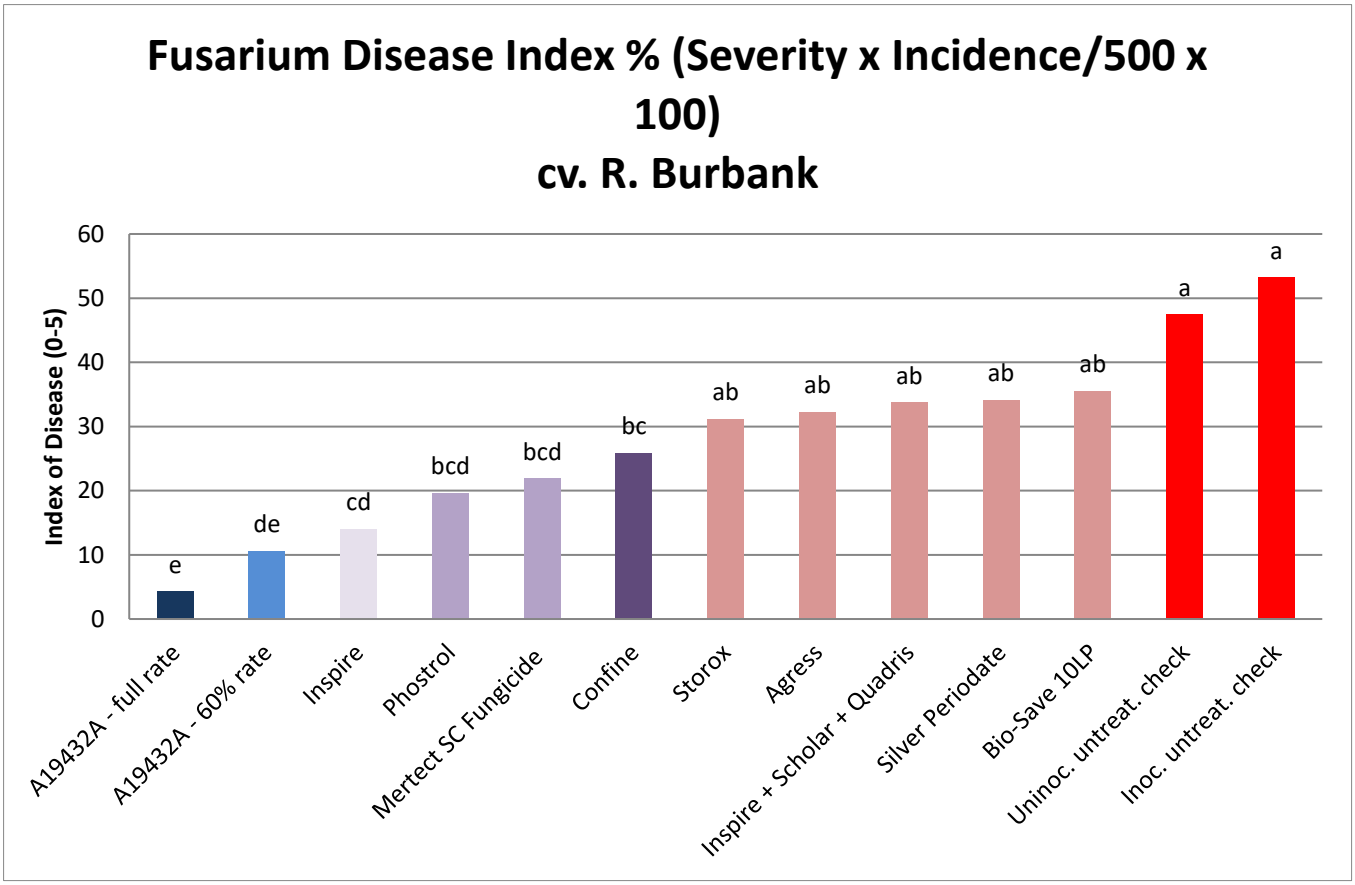
The navy blue and red colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. dark pink or bright pink or medium blue). Purple columns are not statistically equivalent to either red or blue.

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

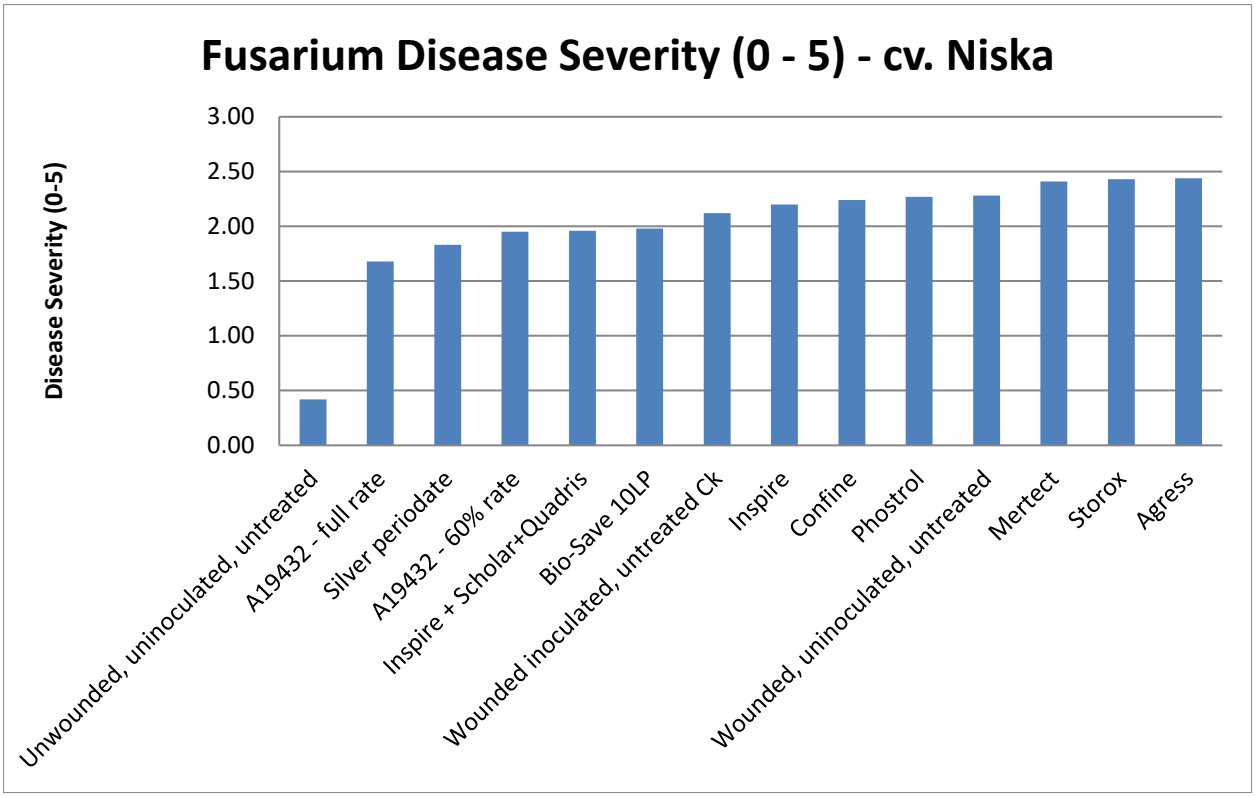
[1]Results are the means of five replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers 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

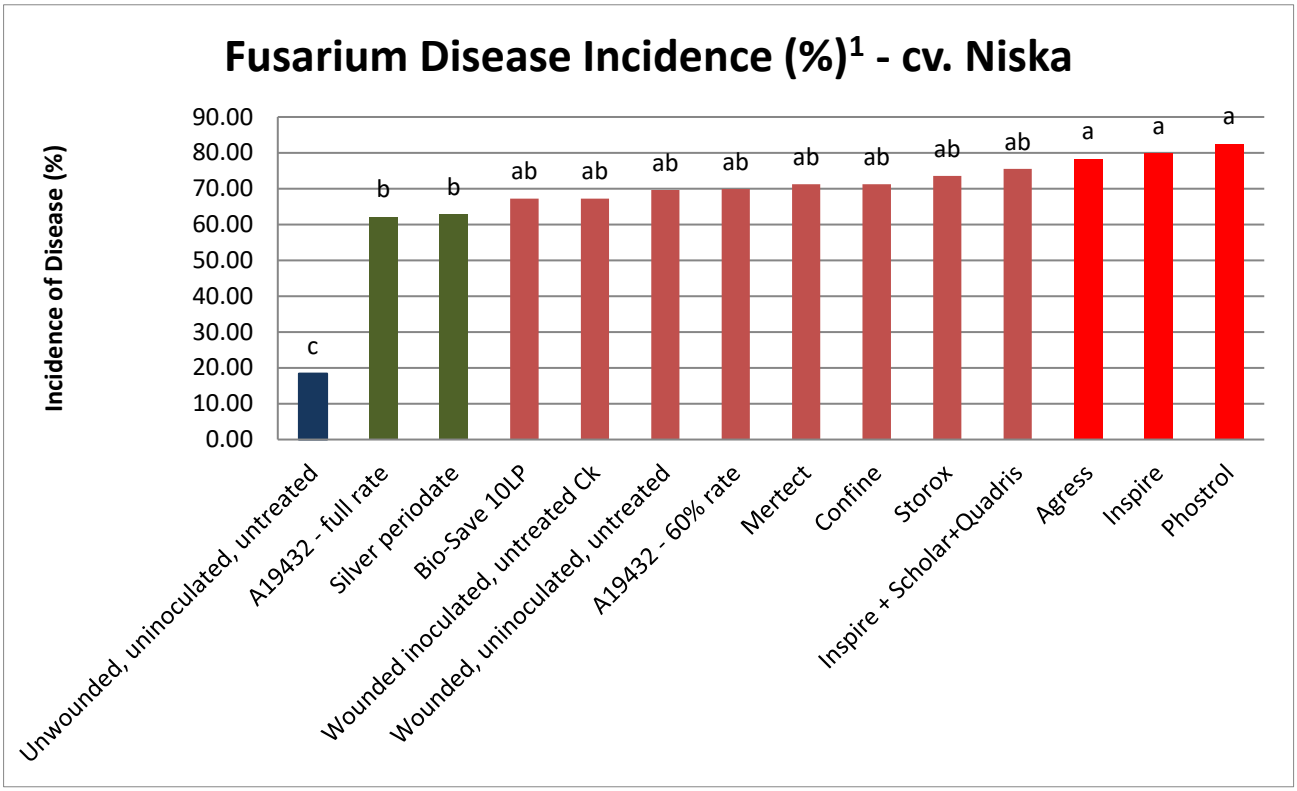
[1]Results are the means of five replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers 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.



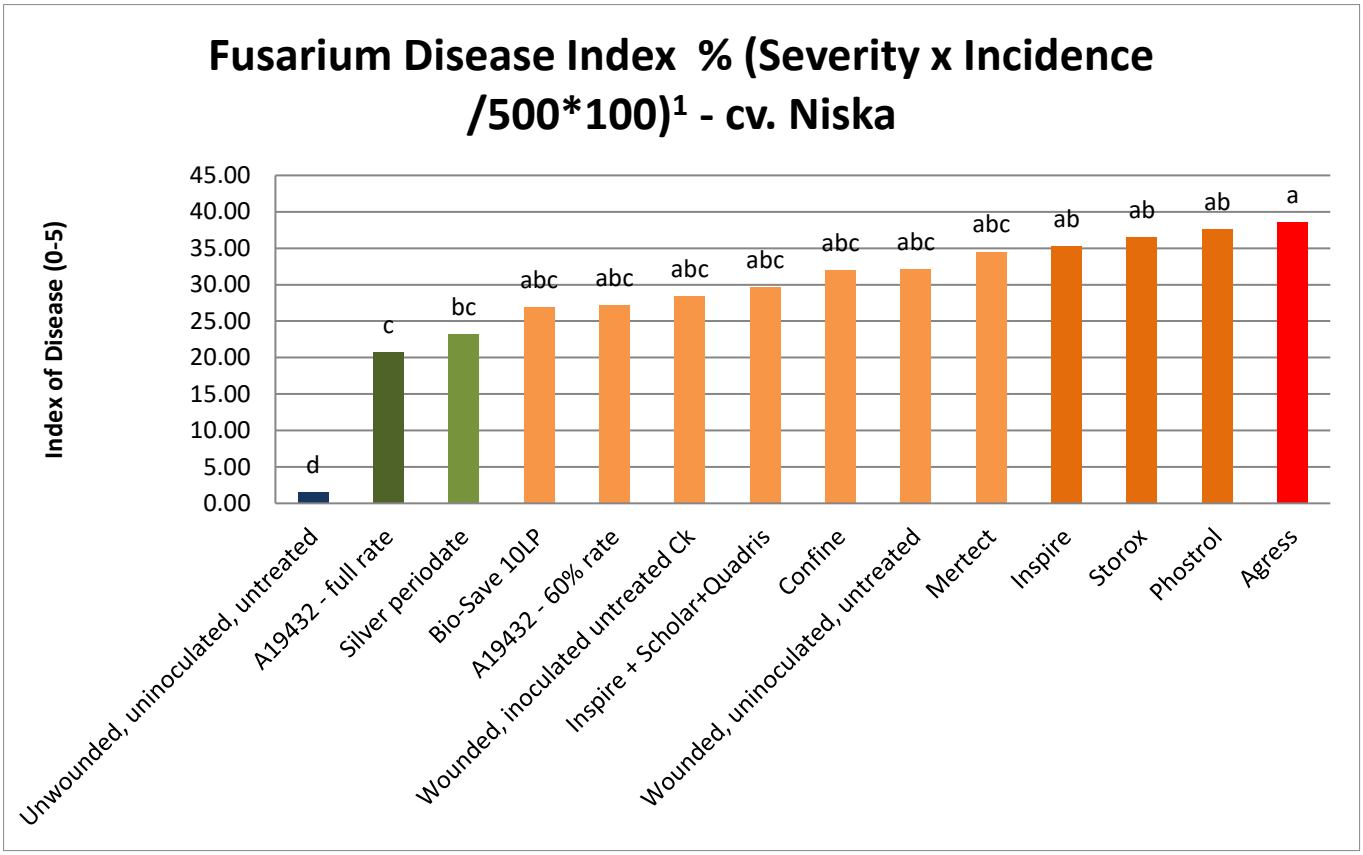
[1]Raw data failed the Bartlett's test of homogeneity, as did the transformed, so all data are shown as statistically equivalent.

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



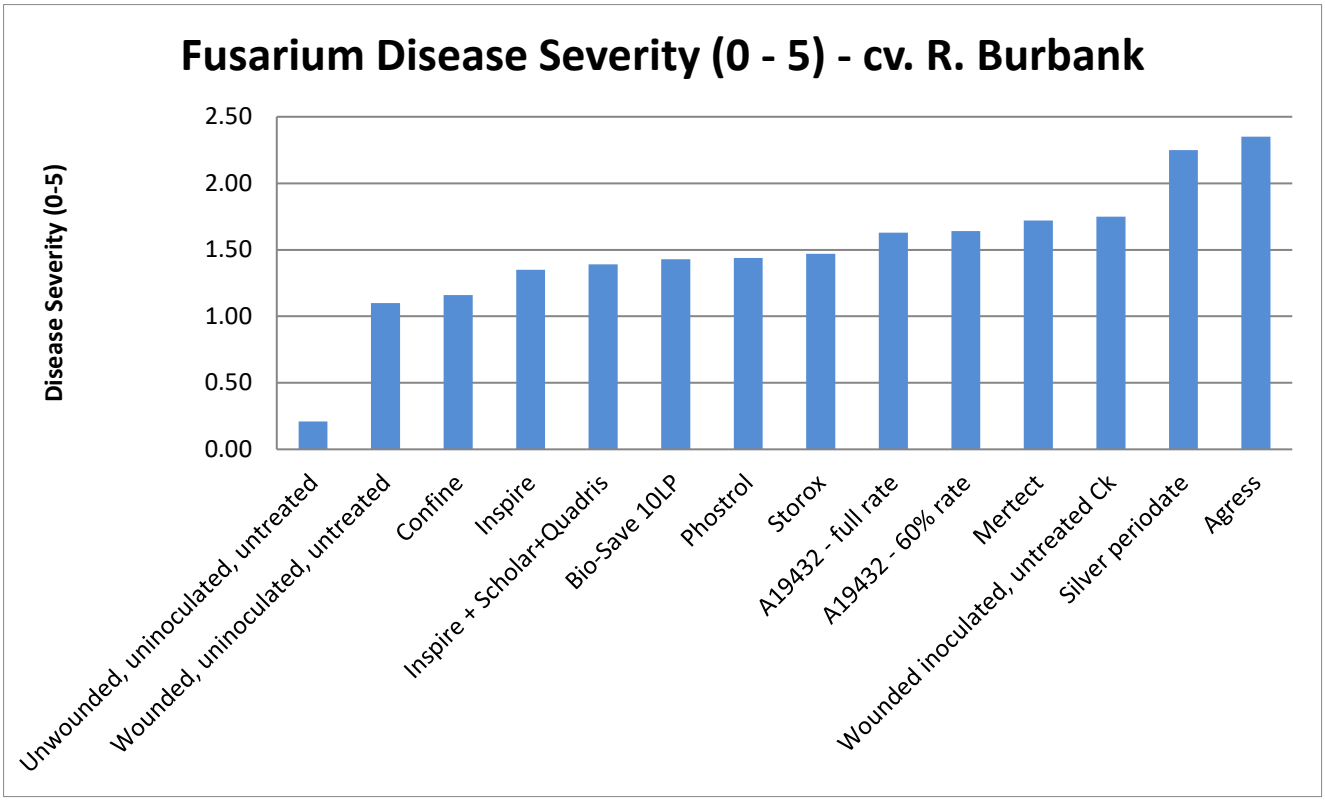
[1]Raw data were used for analysis, where the green, navy blue and red colors were statistically unique letter grades based on Duncan's Multiple Range Tests. The mahogany colors were statistically similar to the red and blue columns.

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.



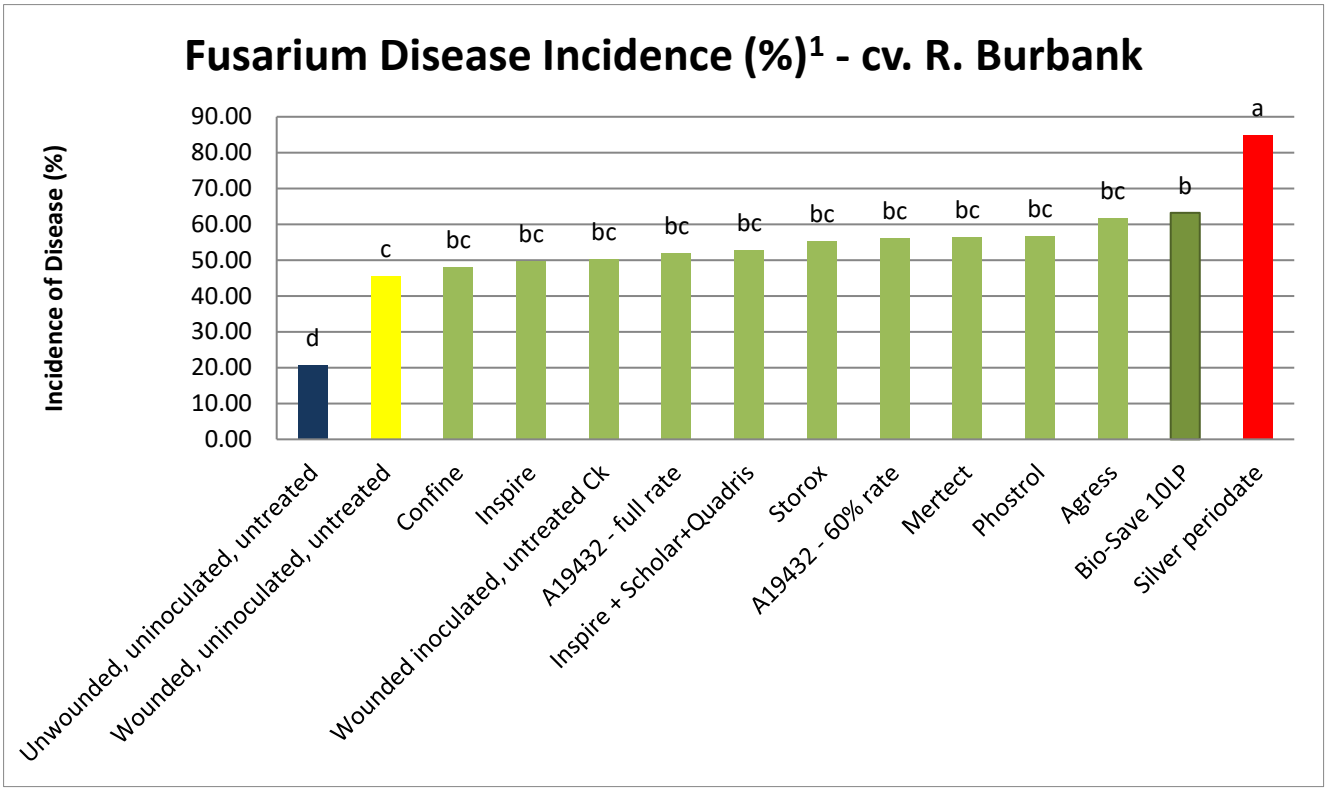
[1]Arcsine-transformed data were used for analysis, where the navy blue, green and red colors were statistically unique letter grades based upon Duncan's Multiple Range Tests. The medium green and orange shades colors were statistically similar to the green and red columns.

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.



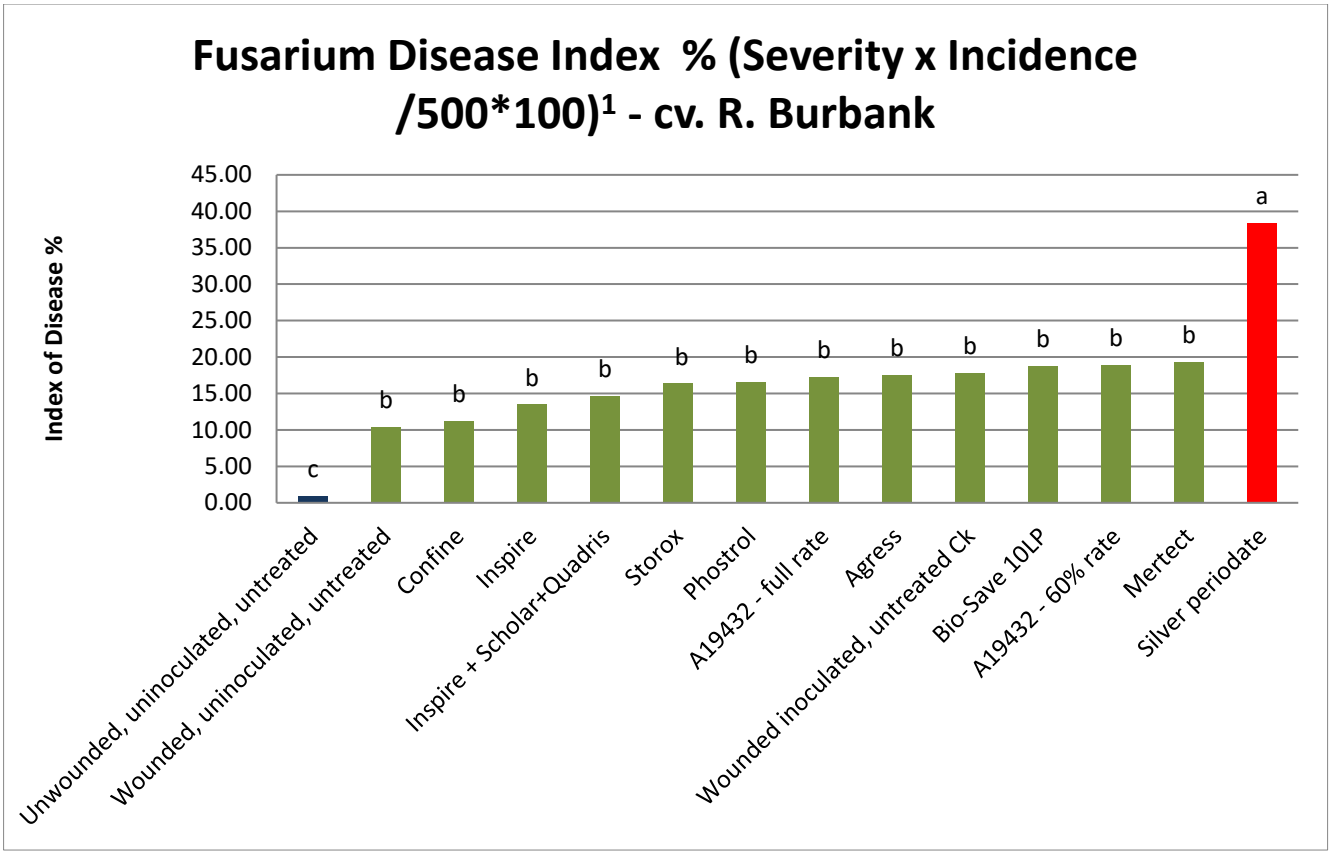
[1]Square-root transformed failed the Bartlett's test of homogeneity, as did the raw data and two other transformations, so all data are shown as statistically equivalent.

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

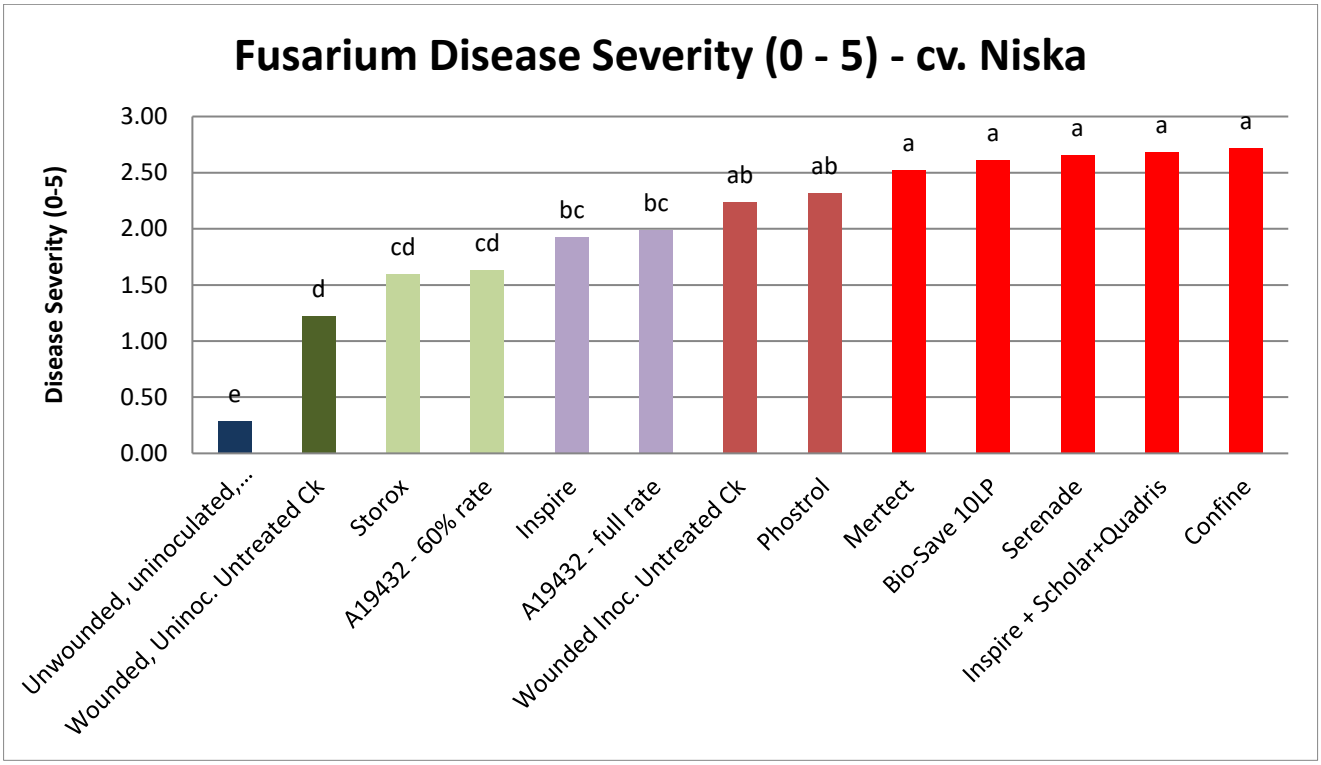
[1]Results are the means of five replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers 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

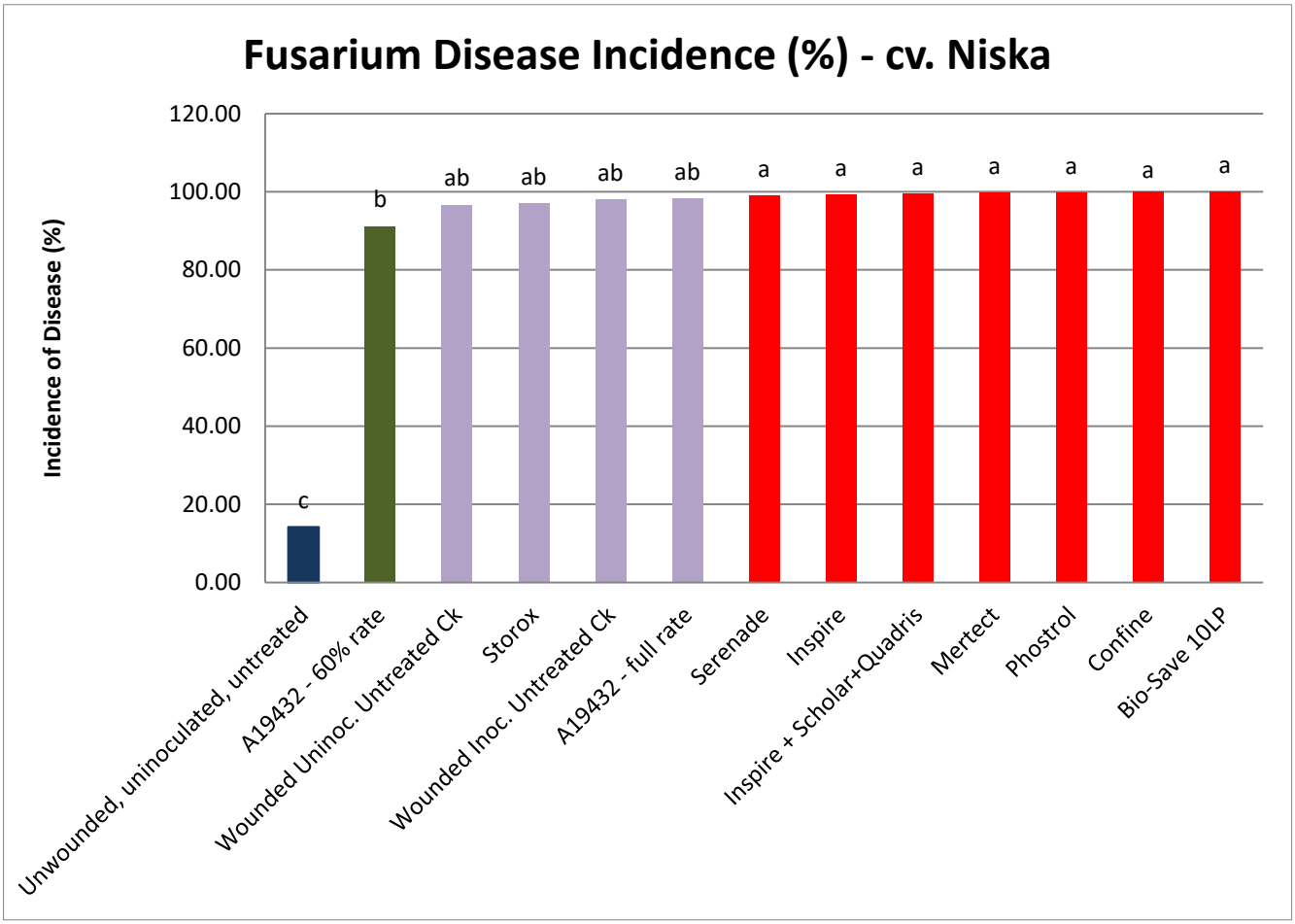
[1]Results are the means of five replications.
[2]Disease severity (DS) means are on a 1-5 point scale, where 0 – no dry rot present, 1 = <1% dry rot, 2 = 1 – 10% dry rot, 3 = 11 – 25% dry rot, 4 = 26 – 50% dry rot and 5 = >50% dry rot.
[3]Disease incidence (DI) means are based on the percentage of tubers 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.



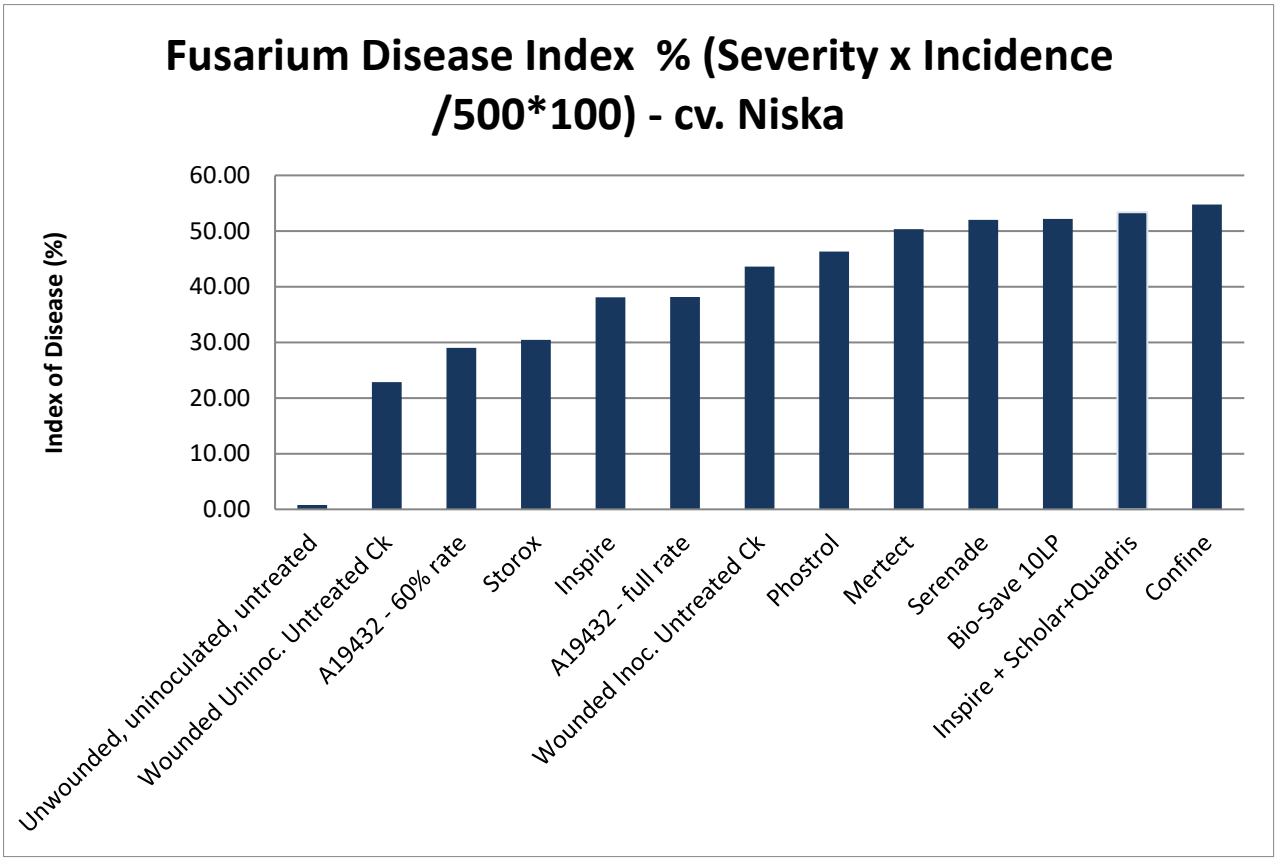
The dark green, navy blue and red columns were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. medium green and mahogany red). Purple columns are not statistically equivalent to red, navy blue and dark green columns.

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



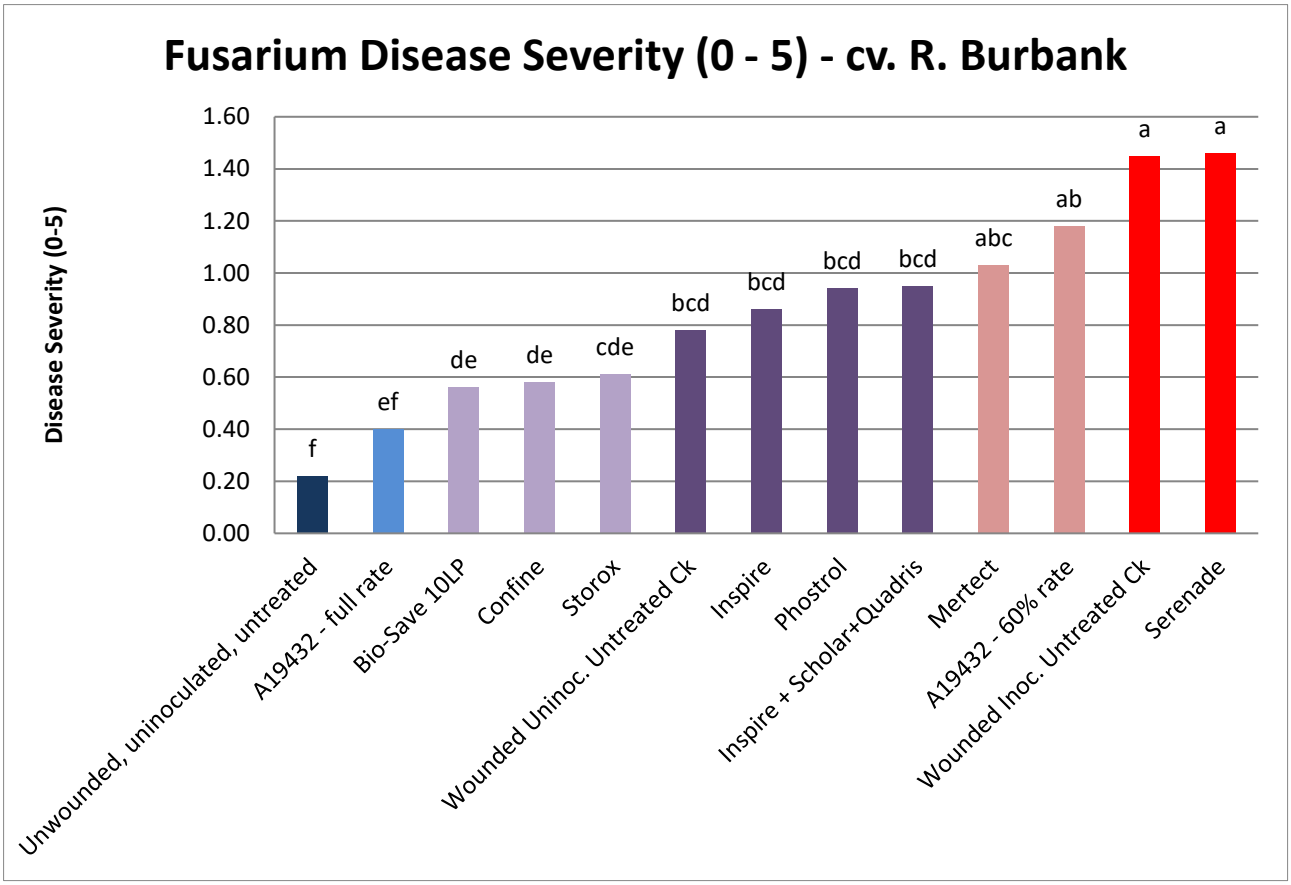
The dark green, navy blue and red colors were statistically unique letter grades based on Duncan Multiple Range Test. The purple columns are statistically similar to the red and dark green columns.

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.



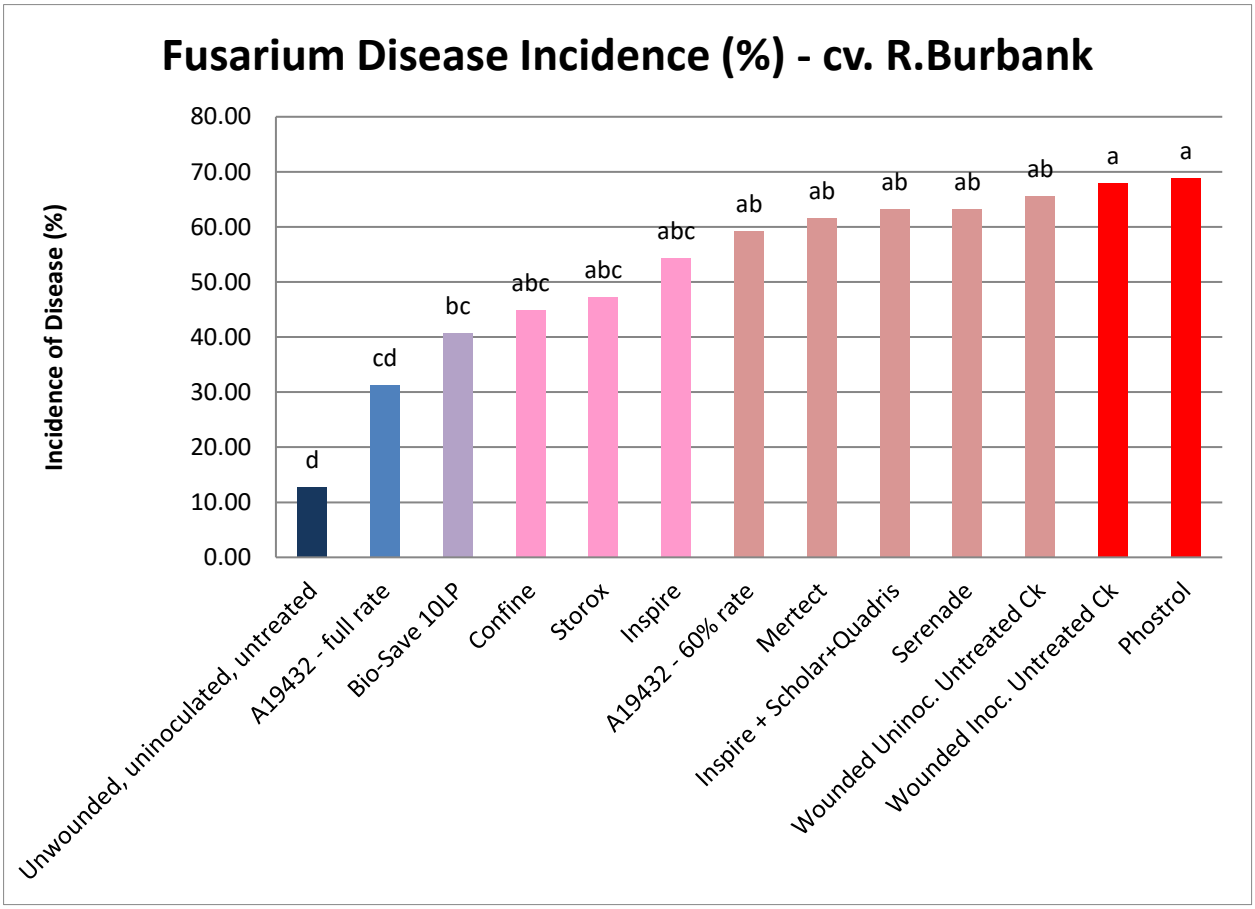
All color columns are navy blue, as this data failed the Bartlett's test of homogeneity so that statistical differences could not be reported. Arcsine-transformed data was used for this analysis.

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.



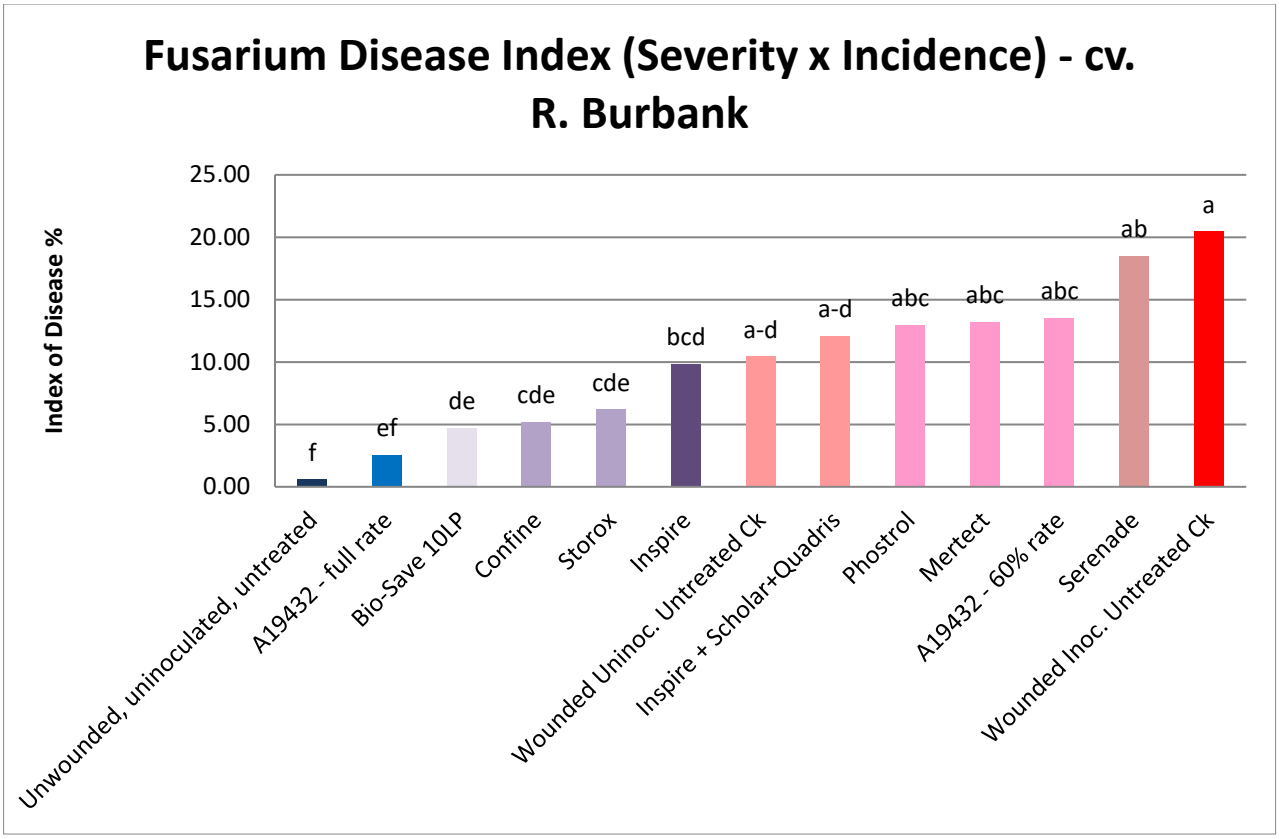
The deep red and blue colors were statistically unique letter grades based on Duncan Multiple Range Test. Shades of the same color are statistically equivalent (i.e. pink and medium blue). Purple columns are not statistically equivalent to red and blue columns.

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.

ACKNOWLEDGEMENTS

The project team extends its thanks and appreciation to the following organizations and individuals for their support of this work.

- This project was supported financially by Alberta Crop Industry Development Fund Ltd., Alberta Agriculture and Rural Development, Agriculture and Agri-Food Canada, the Potato Growers of Alberta and finally, the cash and in-kind contributions from potato industry partners.
- Mr. Paul Laflamme, Head, Pest Surveillance Branch, Alberta Agriculture and Rural Development, Edmonton, AB
- Mr. Terry Morishita, Old Dutch Foods, Duchess, AB.
- Potato Growers of Alberta, Taber,
- Agriculture and Agri-Food Canada, Lethbridge, AB for donating the AC Vigor, CV96022-3, V1115-3 and WV4479-1 (cvs.) postharvest tubers.
- ConAgra Foods, Calgary, AB for donating the Ivory Russet (cv.) postharvest tubers
- ConAgra Foods, Lamb Weston Division
- Dr. Michele Konschuh, CDCS, Brooks, AB for donating the Atlantic, Lady Lenora, Niska, Norland, Owyhee Russet, Russet Burbank and Ranger Russet (cvs.) postharvest tubers.
- Maple Leaf Potatoes, Lethbridge, AB.
- Syngenta Canada, Innovotech Inc., Engage Agro Corp, Bayer Crop Sciences, Bio-Safe Systems LLC, Winfield Solutions LLC, Austin Grant Inc. DBA Jet Harvest Solutions and finally, Engage Agro Corp. for donating the chemicals that were used in this trial.
- Mr. Roland Williams for his mechanical skills and knowledge, regarding the conveyor belt table that was used for applying the chemicals to the potatoes.
- Special thanks to Simone Dalpé for technical support of the trial in 2011. Thank you to seasonal staff Jan Lepp, Mary Lou Benci, William Lai, Bev Lesperance, Alanna Penner, Jennessa McConnell, Cody Bown and Louisa Gietz as well, for maintaining, harvesting and grading the field trial.
- Thank you to Dr. Ted Harms for assistance with statistical analyses of the data.
- Mr. Brian Storozynsky, ARD, Agricultural Technology Centre, Lethbridge AB., for his expertise regarding chemical spray systems.
- Mr. Roland Williams for his mechanical skills and knowledge, regarding the conveyor belt table that was used for applying the chemicals to the potatoes.
- This project was supported financially by Alberta Crop Industry Development Fund Ltd., Alberta Agriculture and Rural Development, Agriculture and Agri-Food Canada, the Potato Growers of Alberta and finally, the cash and in-kind contributions from potato industry partners.

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