PGA RESEARCH ARCHIVE

SOIL TILLAGE & CONSERVATION

POTATO GROWERS OF ALBERTA

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Alberta
AGRICULTURE, FOOD AND
RURAL DEVELOPMENT

Crop Diversification Centre
South

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

Telephone 403/362-1300
Fax 403/362-1306

March 8, 2002

$3,000-
March 12/02
Approved.

Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB   T1G 2B1

Attention: **Board of Directors**

Re: **Application for Funding**
"Conservation Tillage Techniques for Enhancing Irrigation Water Retention, Infiltration and Potato Yield"

Project cancelled

Dear Board Members:

Enclosed are 10 copies of the funding application for our project entitled "Conservation Tillage Techniques for Enhancing Irrigation Water Retention, Infiltration and Potato Yield. The proposal is a condensed version of the AARI application submitted in November. This is a collaborative project with the irrigation branch and the CACDI demonstration farm at Lethbridge. The results of this project may help us expand potato production into less than ideal soils (please see the note that Warren Helgason sent regarding the soil-type in the field we have been allocated at the demonstration farm). We hope to provide valuable information about soil moisture, irrigation infiltration and alternate types of conservation tillage equipment. We have discussed the possibility of conducting additional demonstration strips in growers' fields using this equipment in 2002.

We have requested $31,600 from AARI (Alberta Agricultural Research Institute) and government cooperators will contribute approximately $30,600 cash and in-kind funding for the first year of the project. We are requesting $3,000 from the PGA each year for three years. Please contact me if you have any questions (403-362-1314).

Thank you for your consideration. I look forward to hearing from you.

Sincerely,

Michele Konschuh, Ph.D.
Potato Research Agronomist

Warren Helgason
03/06/02 04:40 PM

To: Michele Konschuh/AAFRD@AAFRD
cc: Ted Harms, Alan Efetha/AAFRD@AAFRD
Subject: CACDI Lethbridge Site - soil textures

Hi Michele,

In regards to our previous discussion about the suitability of the soils at the CACDI farm for potatoes, I have attached the textural results for the area where the potato project is to go. The soils are predominantly a Sandy Clay Loam (much coarser texture than what is normally expected in the Lethbridge area). For the sake of reference, this soil is lighter than 2 of the 3 fields that I monitored last year for the PGA soil moisture sensor project. We will obtain more soil samples this spring, but from these preliminary results, this area looks quite good. Give me a call if you have any questions.

Warren

Hole # 17

	% Sand	% Clay	Texture
0-20	46	34	SCL-CL-SC
20-40	45	36	CL-SC-SCL
40-60	49	34	SCL-SC
60-80	42	37	CL
80-100	49	31	SCL

Hole # 18

	% Sand	% Clay	Texture
0-20	52	29	SCL
20-40	55	28	SCL
40-60	57	27	SCL
60-80	58	26	SCL
80-100	56	26	SCL

Agriculture Research Funding

FULL APPLICATION FOR FUNDING – 2002/2003

Date Received
For Administrative Use Only

Collaborating Funding Partners:

- **Alberta Livestock Industry Development Fund Ltd. (ALIDF)**
- **Alberta Crop Industry Development Fund Ltd. (ACIDF)**
- **Alberta Diversified Livestock Industry Development Fund (ADLIDF)**
- **Alberta Agricultural Research Institute (AARI)**

Confidentiality

Please note that the applicant's name, company, project title and amount of grant will be public Information. The Full Application will be shared with other funding groups unless otherwise directed by the applicant. Please indicate your preference:

x I would like my application to be shared with the other funding groups
☐ I would NOT like my application to be shared with other funding groups

Is a confidentiality agreement required? (Y/N, if yes explain)
No

Part A
Project Overview

1. Project Number: **(Please quote Pre-Proposal number provided in correspondence)** **2002C093R**

2. Project Title: **(max. 15 words)** Conservation tillage techniques for enhancing irrigation water retention, infiltration and potato yield

3. Abstract: **(max. ½ page)**

Potato is a high value crop requiring intensive inputs of cash, labour, fertilizer, and pesticides. Processing potatoes can only be grown in southern Alberta under irrigation. Growers are being encouraged to maximize irrigation efficiency in response to recent water shortages, hot dry growing conditions, and increased energy costs. Inefficient use of irrigation water can also result in surface water runoff, soil erosion, and degradation of surface water quality.

Water runoff is often a problem associated with sprinkler irrigation systems operated on non-uniform terrain. Soil particles, fertilizers and pesticides can become part of runoff waters and can be moved from their target locations, causing degradation of surface water quality. Other potential problems associated with runoff include a lack of soil moisture in localized areas of the field, crop nutrient deficiencies, washed-out seeds or plants, and increased irrigation water pumping costs. These problems are becoming more pronounced under potato production systems in Southern Alberta due to high-pressure sprinkler systems being converted to low-pressure for the purpose of lowering pumping costs. Runoff is a greater problem under low-pressure center-pivot systems because of the reduced wetted diameter created by either spray head or nozzles as compared to high-pressure impact sprinklers. Also the conversion from high- to low-pressure systems does not adjust the initial high flow rates because they are designed to meet the crop demands during peak water use periods. The system capacity and crop water requirements are usually considered during the conversion. However one consideration often overlooked by the designers during the conversion process is the ability of soils to absorb the applied water. In certain soils, applying the same amount of water over a smaller area (a result of smaller wetted diameter of low-pressure nozzles) can result in surface ponding, runoff, soil crusting and operational difficulties. These results would be most problematic in medium to heavy textured soils and soils that are left without cover during the irrigation season.

Pre-plant tillage and between row maintenance of potatoes grown in southern Alberta usually result in exposed soil between the rows and therefore adopting low pressure irrigation could result in some of the soil

water problems mentioned above. The type of runoff initiated when application rate exceeds infiltration rate is known as "Infiltration-excess" or "Hortonian" runoff. This kind of runoff allows for non-uniform application of irrigation water across the landscape within a given potato field. As a result, poor potato yields are harvested from both the lower (due to excess moisture) and higher (due to dry conditions) parts of the field. Various soil surface manipulating techniques are currently being used to make small dam reservoirs that limit runoff and increase soil water storage. Producers in Southern Alberta have been using the type referred to as "Dammer Dikers" and find them beneficial. There are others, such as furrow and propeller dikers, that have not been introduced in our area that seem to do a better job compared to the Dammer Diker in United States of America. Applied research work on how effective these various reservoir tillers are in reducing runoff is locally not available. There is a need, therefore, to evaluate both the current and potential reservoir tiller technologies as they pertain to improving soil moisture storage and irrigation water use efficiency. The objective of this proposed project, therefore, is to compare four soil surface manipulating techniques for improving retention and infiltration of irrigation water, soil water storage, and hence, increasing potato yield and quality. The results of this proposed project will be of great benefit to the potato irrigators as they efficiently manage the already scarce water resource. Reducing runoff and encouraging infiltration will increase water use efficiencies while conserving top-soil and reducing energy costs.
4. Key Words: (**prioritized, max. 15**) infiltration, runoff, soil water storage, irrigation scheduling, low pressure sprinkler, wetted diameter, flow rate, potato yield and quality, diker, reservoir tillage

5. Strategic Priority (select one):	
Agri-Food & Health – Functional Foods and Nutraceuticals	
Basic Research in Genomics, Proteomics and Bio-informatics	
Environmental Sustainability	X
Non-Food, Fibre & Industrial Uses, including Molecular Farming	
Primary Agriculture, Food Safety and Animal Welfare	
Value-Added Processing	
Other (Please describe)	

6. Project Start Date (year/month/day): 02/03/15	**7. Project Completion Date** (year/month/day): 05/02/28
8. Is this application linked to other submitted applications? (Y/N), if Y, please list the other applications) No	
9. Signatory Recommendation enclosed? (Y/N) No	File name:
10. Industry Endorsement? (Y/N) Yes	
11. Only Required for ACIDF Applications **Sector:** (cereals, oilseeds, forages, horticulture, special crops)	

12. Baseline Information

The personal information being collected is subject to the provisions of the Freedom of Information and Protection of Privacy Act.

a) Research Team Leader: (requires personal data sheet) Michele N. Konschuh	
Title Potato Research Agronomist	
Organization: AAFRD, Crop Diversification Centre South	
Address: S. S. #4, Brooks, AB	
Postal Code: T1R 1E6	**E-mail** Michele.Konschuh@gov.ab.ca
Phone: 403-362-1314	**Fax:** 403-362-1306

b) Research Team Members (each member requires a personal data sheet) *Additional rows may be added if necessary.*			
Name	***Institution***	***E-mail Address***	***Expertise Added***
1. Alan Efetha	AAFRD, Irrigation Branch	Alan.Efetha@gov.ab.ca	Irrigation Agrologist, Computer Modelling
2. Ted Harms	AAFRD, Irrigation Branch	Ted.Harms@gov.ab.ca	Irrigation Specialist
3. Warren Helgason	AAFRD, Irrigation Branch	Warren.Helgason@gov.ab.ca	Irrigation Specialist, Soil Moisture Monitoring
4.			
5.			
6.			

13. Research Continuum

Where does your project best fit on the Development Continuum? (Choose only one)			
Basic Research		**Investment attraction**	
Applied Research		**Commercialization**	
Development and Adaptation	X	**Extension/Training**	
Market Development			

14. Goals and Objectives ***(max. 2 pages)***

a) Overall Purpose: (What will be accomplished?)
The overall purpose of this project is to evaluate the current and potential soil surface manipulating techniques with respect to conservation of soil and water, efficiency and uniformity of irrigation water application, and improved potato yield and quality.

b) Key Objectives/Deliverables: (Point form, concise)

- Compare four soil surface manipulating techniques for improving retention of irrigation water and soil water storage.
- Monitor micro-distribution of soil water within beds, furrows, and the reservoir tillage pits in each treatment.
- Measure and compare potato quality and yield potential resulting from the four soil surface manipulation treatments.
- Demonstrate various soil surface manipulation technologies to the potato growers through technology transfer.

c) Potential Benefits to Alberta's Industry: (Production, social, environmental. Include economic estimate.)
Improving soil water storage and reducing runoff will help potato growers to produce high yields of quality potatoes while conserving valuable resources. Water restrictions may be in place in southern Alberta as a result of below normal precipitation and snow pack. Topsoil can easily be lost through erosion. Effective irrigation and adequate topsoil are fundamental for potato production. Improved irrigation efficiency will reduce pumping costs and may allow for an expansion of irrigated acres. Preventing runoff and improving soil water storage will also reduce water pollution and soil degradation.

d) Is this a new project? (Y/N) Yes.

e) Is this a continuation project (Y/N, if Y, please explain) No.

f) Please indicate all past and present research or development work completed or in progress that relates to this proposal: (Point form. Include names, companies and dates.)
None.

Part B
Progrid Evaluation

Please refer to the Instructions for specific evaluation criteria for each of the following.

1. Contributions to Advancement of Agriculture and Agri-food Knowledge

A. Please describe in point form the expected contributions to the advancement of Agriculture and Agri-food knowledge. **(max. ½ page)**

- Will provide information that allows us to develop recommendations to maintain optimal soil moisture, potato quality and yield through irrigation management and soil moisture monitoring.
- Will develop a better understanding of how different conservation tillage methods impact soil moisture, infiltration, and retention.
- Will develop recommendations for appropriate conservation tillage strategies on medium to heavy textured soils.

2. Benefits to Alberta's Agriculture and Agri-food Industry

A. Please describe in point form the potential benefits to the Agriculture and Agri-Food Industry and to society. **(max. ½ page)**

- Conservation tillage may improve soil water storage, reduce runoff, reduce soil erosion and surface water contamination.
- Soil and water are valuable resources that must be protected and maintained for sustainable potato production.
- Efficient water usage conserves valuable resources and ultimately improves net return to the growers.
- Irrigation management on medium to heavy textured soils will allow us to have several years of data by the time growers find it necessary to expand potato production acres by using these types of soils.

B. Please describe in point form the knowledge transfer plan. **(max. ½ page)**

- Results of this research will be made available to all of the industry and government participants in the form of a final report.
- Growers and industry personnel will be invited to tour the trials as part of the Canada-Alberta Crop Development Initiative, Lethbridge Demonstration Farm summer tours and the Potato Growers of Alberta (PGA) Field Day.
- Results will be presented at breakfast meetings and the annual meeting of the PGA so that all potato producers may benefit from the information gathered.
- If specific recommendations are forthcoming as a result of this research, a fact sheet outlining these recommendations will be produced and made available to producers, the PGA, and industry participants.

3. Background and Objectives

A. Please describe in point form the project background. Include related research that has already been done. **(max. ½ page)**

Potato producers in Alberta have been observing poor efficiencies of irrigated water on their potato fields. This problem has been due to increased runoff (decreased infiltration) of irrigation water under sprinkler systems. To solve this problem, producers have been using various types of reservoir tillage to increase water entry into soil. These viable soil surface manipulation technologies have never been evaluated or tested in Alberta. Work done in other parts of the world show reservoir or basin tillage to be a viable option in controlling runoff, and hence, increasing irrigation application efficiency and potato quality and yield.

Through literature review, it was found that work done by Hansen and Trimmer (1997) showed basins created by reservoir tillage to be effective in holding water and allowing it to infiltrate the soil thus preventing runoff. In comparing dammer dyker to other soil surface manipulations, Stern et al. (1992) found it to be an economical method of increasing efficiency of irrigation water under sprinkler system. Alexander (1994) compared dammer dyker to chisel for fall tillage and found no difference between them in reducing runoff under sprinkler irrigation system. He concluded, however, that both gave acceptable control of runoff. In general, reservoir tillage seems to be the best option to use for improving irrigation water application efficiency, reducing energy costs, increasing yield and quality, and protecting environment (Hobson et al. 1993; Lyle, 1997; Kranz et al., 1991).

There is little information available on the micro-distribution of soil water within a potato bed/furrow, however, in looking at micro-distribution of irrigation water within and between the potato-bed (or hills), Stieber and Shock (1995) found water distribution to be uneven below the surface due to wheel traffic compaction and hill topography. The distribution of irrigated water also changes significantly during the growing season as the potato plant matures and achieves complete canopy coverage. During the early part of the season, much of the irrigation water is shed off of the potato hill and infiltrates the furrow. Soil moisture measurements for irrigation management are typically done through the center of a hill at a depth of 25 to 50 cm. Given the chance of more water infiltrating through the furrow than the hill, there is an obvious potential for deep percolation, which could result in nutrients moving below the rooting depth of the plant, or the development of soil salinity problems. Quantifying the variation in infiltration patterns will identify the most appropriate measurement locations to base irrigation management decisions on and also allow us to quantify deep percolation rates.

Detailed work on the effectiveness of available reservoir tillage technologies and micro-distribution of applied water under low pressure sprinkler systems need to be done in Southern Alberta in order to provide producers with farm-based best management practices pertaining to sustainable potato production.

References:

1. Alexander, B. **1994**. Dammer dyker versus Chisel for Fall tillage. http://pnwsteep.wsu.edu/OFT/1994/Dammer Diker.htm
2. Hansen, H. And W. Trimmer **1997**. Making the most of Irrigation. Oregon State University Extension. PNW 287
3. Hobson, J.H., J.H. Jensen, K. Langley, C.C. Shock, T.D. Stieber, M. Thornton and T. Jensen. **1993**. OSU Extension.
4. Kranz, W., D.P. Shelton, E.C. Dickey and J.A. Smith **1991**. Water runoff control practices for sprinkler irrigation sysetms. NebGuide G91-1043-A
5. Stieber, T.D. and C.C Shock **1995**. Placement of soil moisture sensors in sprinkler irrigated potatoes
6. Stern, R., A.J. van Der Merwe, M.C. Laker and I. Shainberg **1992**. Effect of soil surface treatment on runoff and wheat yields under irrigation. Agron. J. 84:114-119

B. Please describe in point form the project objectives/deliverables. **(max. ½ page)**

- Compare four soil surface manipulating techniques for improving retention of irrigation water and soil water storage.
- Monitor micro-distribution of soil water within beds, furrows, and the reservoir tillage pits in each treatment.
- Measure and compare potato quality and yield potential resulting from the four soil surface manipulation treatments.
- Demonstrate various soil surface manipulation technologies to the potato growers through technology transfer.

4. Research Design, Method & Analysis

A. Please describe the Research Design, Methodology, Method of Analysis, and the proposed Research Plan for the entire duration of the proposed project. Include reference to the most relevant literature when discussing your research design and methodology. **(max. 1 page)**

Treatments:
1. Propeller diker
2. Furrow diker
3. Dammer Diker
4. No reservoir tillage

The above four treatments will be replicated four times in a randomized manner within a Russet Burbank potato field. The proposed location is the Canada-Alberta Crop Development Initiative, Lethbridge Demonstration Farm. The size of the available field will dictate the plot sizes, and we propose to use one quarter or a small pivot circle (approx. 8 acres). Soil moisture monitoring devices and rain gauges will be installed in each plot and measurements taken twice weekly. Rainfall, irrigation, and changes in soil moisture will be closely monitored during the growing season. Daily meteorological data will be obtained from a nearby weather station. Other information to be recorded will include field scouting observations, and petiole nutritional content as a measure of soil fertility. Crop water use will be estimated by calculating evapotranspiration (ET) using rainfall, irrigation, runoff, deep percolation and soil moisture changes. We'll also estimate crop water using Alberta Irrigation Management Model (AIMM). Potatoes will be harvested in the fall. Yield and grade of potatoes will be assessed. The data collected will be analyzed using standard statistical methods such as Analysis of Variance (ANOVA).

B. Please describe an annual work plan (including milestones) for the expected duration of the proposed project. **(max. ½ page)**

Spring 2002: Field will be chosen and plots set up, soil samples taken, potatoes planted, soil surface treatment (dyked), and soil moisture measuring devices installed.
During the growing season 2002: Moisture measurements twice per week (neutron probe and other sensors), field scouting, petiole sampling, and crop tours.
Fall 2002: Top-kill, harvest and grade potatoes to determine yield and quality; data analyses.

Winter 2002/2003: Write a progress report, present preliminary findings to potato producers and agronomists.

2003: Repeat 2002 activities

2004: Repeat 2002 and 2003 activities plus write a final report and recommendations.

5. Research Budget (see next page for budget form)

A. Please provide justification for the amount requested in each of the main budget categories. Ensure that the amounts are appropriate and consistent with the Guidelines. **(max. 1/2 page)**

<u>Personnel:</u>
The personnel requirements for this project involve providing technical staff for taking soil samples, monitoring soil moisture twice weekly, petiole samples, harvesting tubers, grading tubers, and handling data

input and analyses. Industry will be contributing in-kind through staff contributions. All supervision for the project, and a considerable amount of technical help will be provided as in-kind government contributions. Technical help will be required for the following operations:

- 1 day of soil sampling, 2 people
- 2 days of site preparation, 2 people
- 2 days per week soil moisture monitoring, 20 weeks, 1 person
- 3 petiole sample dates, 4 people
- 1 day of top-killing, 2 people
- 2 days of harvest, 6 people
- 2 days of grading, 4 people
- 10 site visits
- 8 days of data input
- analyses (soil, petiole, culinary, data, etc.)

<u>Travel:</u>
Travel requirements of the project largely involve travel to and from the research sites that will be in the Lethbridge area. Staff from CDC South (Brooks) will need to make several trips to each research site to monitor the project and to assist with petiole sampling and key data collection events.

10 site visits, fuel, lunches for staff

<u>Capital Assets:</u>
In order to compare conservation tillage methods, we will require access to two additional pieces of equipment. If no such equipment is available to rent or borrow in Alberta, we may need to consider purchasing second-hand equipment for the three-year trial.

<u>Supplies:</u>
Seed potatoes, fertilizer inputs, fuel costs, irrigation water and pesticides will run approximately $1500 per acre. Stakes, flags, bags and tags will be required for laying out research plots and harvest. Soil samples and petiole samples will need to be analyzed. Rain gauges will be required for each plot. Also, in order to collect sufficient soil moisture data from each plot, 75 additional access tubes will be required for use with the neutron probes. Potatoes from each plot will be analyzed for fry colour by the food science lab at CDC South on a contract basis.

Note: Although potato quality may not be optimal from all plots, we will actively pursue a contract to sell the potato crop grown as part of this study to a processor in southern Alberta. Proceeds would be used to offset costs for the second and third year of the project.

<u>CDL:</u>
Communication costs relate to preparing data and results for technology transfer. This will most likely take the form of slides, posters, overheads and perhaps a fact sheet on potassium fertility.

<u>Overhead:</u>
CDC South charges 5% overhead on all projects funded externally. Overhead was calculated on cash contributions from industry and granting agencies only. Overhead charges by government agencies are not eligible for funding through AARI (and ACIDF?) and these charges will be covered from the AAFRD operating budget for the potato program.

B. Anticipated Research Budget by Year

Year	Source	Type	Personnel	Travel	Capital Assets	Supplies	CDL*	Overhead	Total/year
1	AARI ACIDF ADLIDF ALIDF	Cash	8800	520	5000	17280			31600
	Gov't	Cash							0
		In-kind	22850	520	5000		500	1730	30600
	Industry	Cash				3000			3000
		In-kind	1000		500	1000			2500
Total Year 1			**32650**	**1040**	**10500**	**21280**	**500**	**1730**	**67700**
2	AARI ACIDF ADLIDF ALIDF	Cash	9240	530		12980			22750
	Gov't	Cash							0
		In-kind	23995	530			500	1290	26315
	Industry	Cash				3000			3000
		In-kind	1050		500	1000			2550
Total Year 2			**34285**	**1060**	**500**	**16980**	**500**	**1290**	**54615**
3	AARI ACIDF ADLIDF ALIDF	Cash	9702	540		12980	500		23722
	Gov't	Cash							0
		In-kind	25190	540			500	1340	27570
	Industry	Cash				3000			3000
		In-kind	1100		500	1000			2600
Total Year 3			**35992**	**1080**	**500**	**16980**	**1000**	**1340**	**56892**
4	AARI ACIDF ADLIDF ALIDF	Cash							
	Gov't	Cash							
		In-kind							
	Industry	Cash							
		In-kind							
Total Year 4									
5	AARI ACIDF ADLIDF ALIDF	Cash							
	Gov't	Cash							
		In-kind							
	Industry	Cash							
		In-kind							
Total Year 5									
Grand Total			**102927**	**3180**	**11500**	**55240**	**2000**	**4360**	**179207**

*Communication, Dissemination, and Linkage

6. A) Funding Contribution

Estimated Total Funds Requested for the Entire Duration of the Project

Source	Amount	Percentage of Total Project Cost
AARI ACIDF ADLIDF ALIDF	*78072	*44
Other Government sources: Cash		
Other Government sources: In-kind	84485	47
Industry : Cash	*9000	*5
Industry: In-kind	7650	4
Total Project Cost	**179207**	**100**

** See note on page 8 regarding sale of potatoes. If industry purchases the potato crop, our requirements from AARI, etc. would decrease, and our cash contribution from industry would increase significantly.*

Sources of Funding Contributions

B) Government Sources

Name (no abbreviations please)	*Amount Cash*	*Amount In-Kind*	*Confirmed (Y/N)*
AAFRD, Crop Diversification Centre South		*24785*	*Y*
AAFRD, Irrigation Branch		*59700*	*N*

C) Industry Sources

Name (no abbreviations please)	*Amount Cash*	*Amount In-Kind*	*Confirmed (Y/N)*
Southern Applied Research Association		*3000*	*N*
Potato Growers of Alberta	*9000*	*4650*	*N*

8) APPROVAL BY PRINCIPAL APPLICANT'S EMPLOYER

The undersigned declare the approval and support of their organization for the research project as described 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.

Christine Murray — Christine Murray — Director — March 8 2002

Name — Signature — Position — Date

9) 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 PGA Board.***

Principal Cooperator Signature

March 8, 2002

Date

PGA Executive Committee Signature

Date

Vern Warkentin

From: "Vern Warkentin" <vern@albertapotatoes.ca>
To: "Michele Konschuh" <michele.konschuh@gov.ab.ca>
Sent: Tuesday, July 23, 2002 4:59 PM
Subject: Conservation Tillage Techniques ...

Michele, as per our conversation at the Breakfast meeting last Wednesday, this message is to confirm the PGA Board's decision not to allow re-allocation of the research funds originally approved for the "Conservation Tillage Techniques for Enhancing Irrigation Water Retention, Infiltration and Potato Yield" project. The Board felt that since the original project needed to be cancelled, it would be better to retain the funds for now and to allocate them to future applications.

Regards
Vern

Margie, please file this in your file for this project!
thanks
MK

Alberta
AGRICULTURE, FOOD AND
RURAL DEVELOPMENT

Crop Diversification Centre
South

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

Telephone 403/362-1300
Fax 403/362-1306

June 7, 2002

Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1

Attention: Board of Directors

Re: Changes to funding application "Conservation Tillage Techniques for Enhancing Irrigation Water Retention, Infiltration and Potato Yield"

Dear Board Members:

Thank you for agreeing to contribute funds toward our research project entitled "Conservation Tillage Techniques for Enhancing Irrigation Water Retention, Infiltration and Potato Yield. Unfortunately, we were unsuccessful in the grant application process with the Alberta Agricultural Research Institute (AARI). After considerable discussion with Ed Van Dellen, Lori Delanoy, Roger Hohm and the co-applicants for the project, it was concluded that it would not be feasible to conduct the large-scale trial at the CACDI demonstration farm this year without AARI funding. Irrigation Branch personnel are still very interested in demonstrating the propeller diker and the furrow diker in an on-farm strip trial. We hope to provide some valuable information about soil moisture, irrigation infiltration and erosion control with alternate types of conservation tillage equipment.

We would like you to consider contributing $3,000 toward the on-farm demonstration(s) in lieu of the large-scale trial at CACDI. Warren Helgason is putting together a budget estimate and looking for two grower cooperators in the Taber area. Please let me know if the change in plans is acceptable to you (phone 403-362-1314). If not, please carry the funds forward for projects under consideration for 2003. I look forward to hearing from you.

Sincerely,

Michele Konschuh, Ph.D.
Potato Research Agronomist

RECEIVED JUN 1 1 2002

"Warren Helgason"
<warren_helgason@hotmail.com>
06/09/02 09:45 PM

To: michele.konschuh@gov.ab.ca
cc:
Subject: reservoir tillage budget etc.

Hi Michele,

Here is a brief summary of what I have planned for the reservoir tillage demo, and what it will likely end up costing us. Please add whatever you feel necessary. Because it is a demo, I won't be using the same sampling methodology as I would have for the research project Consequently it is quite a bit cheaper to conduct the demo than the $3000 initially allotted. Perhaps you can think of some other things that we should add to the estimate. Please give me a call at 223-7910 if you have any questions.

Warren

Note: please direct any correspondence to my normal AAFRD email address (I am only using this Hotmail address because my computer crashed on Friday and I don't have it up and running yet).

 Reservoir Tillage of Potatoes.d

Reservoir Tillage of Potatoes – Demonstration

Objectives:

- To demonstrate three types of reservoir tillage: (1) dammer-diker; (2) furrow-diker; and (3) propeller diker in grower fields in the Taber area.
- To assess each type of conservations tillage operation in terms of moisture retention, structural integrity of the soil reservoir, and the effect on trafficability.

Assessments:

- Moisture retention will be assessed by taking weekly measurements of moisture content with the neutron probe. Moisture content will be sampled in three locations for each treatment.
- Physical reservoir dimensions will be measured using a rill meter. The physical dimensions measured immediately following tillage will be compared to that measured prior to top-killing.
- Trafficability will be assessed by the landowner. The sprayer operator will provide qualitative evaluations of field roughness.

Schedule of Field Visits

- Following hilling - conservation tillage operations will be completed, physical properties of each treatment will be recorded
- Following plant emergence – neutron access tubes will be installed in each treatment
- Emergence – top-killing – weekly measurements of moisture content
- Immediately prior to top-killing – remove neutron access tubes

Budget Requirements

- Travel for moisture retention sampling, including installation and removal of access tubes: 12 return trips from Taber to field site – 30km x $0.35/km x 12 trips = $126
- Transport of reservoir tillage equipment: 1 return trip from Lethbridge to Taber – 100 km x $0.60/km (loaded) = $60
- Technical assistance: 24 hours x $15/hour = $360
- Sampling equipment: 24 neutron access tubes x $20/tube = $480
- Total required = $1026

Project Deliverables

- Growers will be able to evaluate the results at the PGA field day
- Final results will be presented at PGA breakfast meetings

Alberta
AGRICULTURE, FOOD AND
RURAL DEVELOPMENT

Crop Diversification Centre South

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

Telephone 403/362-1300
Fax 403/362-1306

March 8, 2002

Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1

accepted!

Attention: Board of Directors

Re: Application for Funding
"Conservation Tillage Techniques for Enhancing Irrigation Water Retention, Infiltration and Potato Yield"

Dear Board Members:

Enclosed are 10 copies of the funding application for our project entitled "Conservation Tillage Techniques for Enhancing Irrigation Water Retention, Infiltration and Potato Yield. The proposal is a condensed version of the AARI application submitted in November. This is a collaborative project with the irrigation branch and the CACDI demonstration farm at Lethbridge. The results of this project may help us expand potato production into less than ideal soils (please see the note that Warren Helgason sent regarding the soil-type in the field we have been allocated at the demonstration farm). We hope to provide valuable information about soil moisture, irrigation infiltration and alternate types of conservation tillage equipment. We have discussed the possibility of conducting additional demonstration strips in growers' fields using this equipment in 2002.

We have requested $31,600 from AARI (Alberta Agricultural Research Institute) and government cooperators will contribute approximately $30,600 cash and in-kind funding for the first year of the project. We are requesting $3,000 from the PGA each year for three years. Please contact me if you have any questions (403-362-1314).

Thank you for your consideration. I look forward to hearing from you.

Sincerely,

Michele Konschuh, Ph.D.
Potato Research Agronomist

Warren Helgason

03/06/02 04:40 PM

To: Michele Konschuh/AAFRD@AAFRD
cc: Ted Harms, Alan Efetha/AAFRD@AAFRD
Subject: CACDI Lethbridge Site - soil textures

Hi Michele,

In regards to our previous discussion about the suitability of the soils at the CACDI farm for potatoes, I have attached the textural results for the area where the potato project is to go. The soils are predominantly a Sandy Clay Loam (much coarser texture than what is normally expected in the Lethbridge area). For the sake of reference, this soil is lighter than 2 of the 3 fields that I monitored last year for the PGA soil moisture sensor project. We will obtain more soil samples this spring, but from these preliminary results, this area looks quite good. Give me a call if you have any questions.

Warren

Hole # 17

	% Sand	% Clay	Texture
0-20	46	34	SCL-CL-SC
20-40	45	36	CL-SC-SCL
40-60	49	34	SCL-SC
60-80	42	37	CL
80-100	49	31	SCL

Hole # 18

	% Sand	% Clay	Texture
0-20	52	29	SCL
20-40	55	28	SCL
40-60	57	27	SCL
60-80	58	26	SCL
80-100	56	26	SCL

Agriculture Research Funding

FULL APPLICATION FOR FUNDING – 2002/2003

Collaborating Funding Partners:

- **Alberta Livestock Industry Development Fund Ltd. (ALIDF)**
- **Alberta Crop Industry Development Fund Ltd. (ACIDF)**
- **Alberta Diversified Livestock Industry Development Fund (ADLIDF)**
- **Alberta Agricultural Research Institute (AARI)**

Date Received
For Administrative Use Only

Confidentiality

Please note that the applicant's name, company, project title and amount of grant will be public Information. The Full Application will be shared with other funding groups unless otherwise directed by the applicant. Please indicate your preference:

x I would like my application to be shared with the other funding groups

☐ I would NOT like my application to be shared with other funding groups

Is a confidentiality agreement required? (Y/N, if yes explain)

No

Part A
Project Overview

1. Project Number: **(Please quote Pre-Proposal number provided in correspondence)** **2002C093R**

2. Project Title: **(max. 15 words)** Conservation tillage techniques for enhancing irrigation water retention, infiltration and potato yield

3. Abstract: **(max. ½ page)**

Potato is a high value crop requiring intensive inputs of cash, labour, fertilizer, and pesticides. Processing potatoes can only be grown in southern Alberta under irrigation. Growers are being encouraged to maximize irrigation efficiency in response to recent water shortages, hot dry growing conditions, and increased energy costs. Inefficient use of irrigation water can also result in surface water runoff, soil erosion, and degradation of surface water quality.

Water runoff is often a problem associated with sprinkler irrigation systems operated on non-uniform terrain. Soil particles, fertilizers and pesticides can become part of runoff waters and can be moved from their target locations, causing degradation of surface water quality. Other potential problems associated with runoff include a lack of soil moisture in localized areas of the field, crop nutrient deficiencies, washed-out seeds or plants, and increased irrigation water pumping costs. These problems are becoming more pronounced under potato production systems in Southern Alberta due to high-pressure sprinkler systems being converted to low-pressure for the purpose of lowering pumping costs. Runoff is a greater problem under low-pressure center-pivot systems because of the reduced wetted diameter created by either spray head or nozzles as compared to high-pressure impact sprinklers. Also the conversion from high- to low-pressure systems does not adjust the initial high flow rates because they are designed to meet the crop demands during peak water use periods. The system capacity and crop water requirements are usually considered during the conversion. However one consideration often overlooked by the designers during the conversion process is the ability of soils to absorb the applied water. In certain soils, applying the same amount of water over a smaller area (a result of smaller wetted diameter of low-pressure nozzles) can result in surface ponding, runoff, soil crusting and operational difficulties. These results would be most problematic in medium to heavy textured soils and soils that are left without cover during the irrigation season.

Pre-plant tillage and between row maintenance of potatoes grown in southern Alberta usually result in exposed soil between the rows and therefore adopting low pressure irrigation could result in some of the soil

water problems mentioned above. The type of runoff initiated when application rate exceeds infiltration rate is known as "Infiltration-excess" or "Hortonian" runoff. This kind of runoff allows for non-uniform application of irrigation water across the landscape within a given potato field. As a result, poor potato yields are harvested from both the lower (due to excess moisture) and higher (due to dry conditions) parts of the field. Various soil surface manipulating techniques are currently being used to make small dam reservoirs that limit runoff and increase soil water storage. Producers in Southern Alberta have been using the type referred to as "Dammer Dikers" and find them beneficial. There are others, such as furrow and propeller dikers, that have not been introduced in our area that seem to do a better job compared to the Dammer Diker in United States of America. Applied research work on how effective these various reservoir tillers are in reducing runoff is locally not available. There is a need, therefore, to evaluate both the current and potential reservoir tiller technologies as they pertain to improving soil moisture storage and irrigation water use efficiency. The objective of this proposed project, therefore, is to compare four soil surface manipulating techniques for improving retention and infiltration of irrigation water, soil water storage, and hence, increasing potato yield and quality. The results of this proposed project will be of great benefit to the potato irrigators as they efficiently manage the already scarce water resource. Reducing runoff and encouraging infiltration will increase water use efficiencies while conserving top-soil and reducing energy costs.
4. Key Words: **(prioritized, max. 15)** infiltration, runoff, soil water storage, irrigation scheduling, low pressure sprinkler, wetted diameter, flow rate, potato yield and quality, diker, reservoir tillage

5. Strategic Priority (select one):	
Agri-Food & Health – Functional Foods and Nutraceuticals	
Basic Research in Genomics, Proteomics and Bio-informatics	
Environmental Sustainability	X
Non-Food, Fibre & Industrial Uses, including Molecular Farming	
Primary Agriculture, Food Safety and Animal Welfare	
Value-Added Processing	
Other (Please describe)	

6. Project Start Date (year/month/day): 02/03/15	**7. Project Completion Date** (year/month/day): 05/02/28
8. Is this application linked to other submitted applications? (Y/N), if Y, please list the other applications) No	
9. Signatory Recommendation enclosed? (Y/N) No File name:	
10. Industry Endorsement? (Y/N) Yes	
11. Only Required for ACIDF Applications **Sector:** (cereals, oilseeds, forages, horticulture, special crops)	

12. Baseline Information

The personal information being collected is subject to the provisions of the Freedom of Information and Protection of Privacy Act.

a) Research Team Leader: (requires personal data sheet) Michele N. Konschuh	
Title Potato Research Agronomist	
Organization: AAFRD, Crop Diversification Centre South	
Address: S. S. #4, Brooks, AB	
Postal Code: T1R 1E6	**E-mail** Michele.Konschuh@gov.ab.ca
Phone: 403-362-1314	**Fax:** 403-362-1306

b) Research Team Members (each member requires a personal data sheet) *Additional rows may be added if necessary.*			
Name	***Institution***	***E-mail Address***	***Expertise Added***
1. Alan Efetha	AAFRD, Irrigation Branch	Alan.Efetha@gov.ab.ca	Irrigation Agrologist, Computer Modelling
2. Ted Harms	AAFRD, Irrigation Branch	Ted.Harms@gov.ab.ca	Irrigation Specialist
3. Warren Helgason	AAFRD, Irrigation Branch	Warren.Helgason@gov.ab.ca	Irrigation Specialist, Soil Moisture Monitoring
4.			
5.			
6.			

13. Research Continuum

Where does your project best fit on the Development Continuum? (Choose only one)			
Basic Research		**Investment attraction**	
Applied Research		**Commercialization**	
Development and Adaptation	X	**Extension/Training**	
Market Development			

14. Goals and Objectives *(max. 2 pages)*

a) Overall Purpose: (What will be accomplished?)

The overall purpose of this project is to evaluate the current and potential soil surface manipulating techniques with respect to conservation of soil and water, efficiency and uniformity of irrigation water application, and improved potato yield and quality.

b) Key Objectives/Deliverables: (Point form, concise)

- Compare four soil surface manipulating techniques for improving retention of irrigation water and soil water storage.
- Monitor micro-distribution of soil water within beds, furrows, and the reservoir tillage pits in each treatment.
- Measure and compare potato quality and yield potential resulting from the four soil surface manipulation treatments.
- Demonstrate various soil surface manipulation technologies to the potato growers through technology transfer.

c) Potential Benefits to Alberta's Industry: (Production, social, environmental. Include economic estimate.)

Improving soil water storage and reducing runoff will help potato growers to produce high yields of quality potatoes while conserving valuable resources. Water restrictions may be in place in southern Alberta as a result of below normal precipitation and snow pack. Topsoil can easily be lost through erosion. Effective irrigation and adequate topsoil are fundamental for potato production. Improved irrigation efficiency will reduce pumping costs and may allow for an expansion of irrigated acres. Preventing runoff and improving soil water storage will also reduce water pollution and soil degradation.

d) Is this a new project? (Y/N) Yes.

e) Is this a continuation project (Y/N, if Y, please explain) No.

f) Please indicate all past and present research or development work completed or in progress that relates to this proposal: (Point form. Include names, companies and dates.)

None.

Part B
Progrid Evaluation

Please refer to the Instructions for specific evaluation criteria for each of the following.

1. Contributions to Advancement of Agriculture and Agri-food Knowledge

A. Please describe in point form the expected contributions to the advancement of Agriculture and Agri-food knowledge. **(max. ½ page)**

- Will provide information that allows us to develop recommendations to maintain optimal soil moisture, potato quality and yield through irrigation management and soil moisture monitoring.
- Will develop a better understanding of how different conservation tillage methods impact soil moisture, infiltration, and retention.
- Will develop recommendations for appropriate conservation tillage strategies on medium to heavy textured soils.

2. Benefits to Alberta's Agriculture and Agri-food Industry

A. Please describe in point form the potential benefits to the Agriculture and Agri-Food Industry and to society. **(max. ½ page)**

- Conservation tillage may improve soil water storage, reduce runoff, reduce soil erosion and surface water contamination.
- Soil and water are valuable resources that must be protected and maintained for sustainable potato production.
- Efficient water usage conserves valuable resources and ultimately improves net return to the growers.
- Irrigation management on medium to heavy textured soils will allow us to have several years of data by the time growers find it necessary to expand potato production acres by using these types of soils.

B. Please describe in point form the knowledge transfer plan. **(max. ½ page)**

- Results of this research will be made available to all of the industry and government participants in the form of a final report.
- Growers and industry personnel will be invited to tour the trials as part of the Canada-Alberta Crop Development Initiative, Lethbridge Demonstration Farm summer tours and the Potato Growers of Alberta (PGA) Field Day.
- Results will be presented at breakfast meetings and the annual meeting of the PGA so that all potato producers may benefit from the information gathered.
- If specific recommendations are forthcoming as a result of this research, a fact sheet outlining these recommendations will be produced and made available to producers, the PGA, and industry participants.

3. Background and Objectives

A. Please describe in point form the project background. Include related research that has already been done. **(max. ½ page)**

Potato producers in Alberta have been observing poor efficiencies of irrigated water on their potato fields. This problem has been due to increased runoff (decreased infiltration) of irrigation water under sprinkler systems. To solve this problem, producers have been using various types of reservoir tillage to increase water entry into soil. These viable soil surface manipulation technologies have never been evaluated or tested in Alberta. Work done in other parts of the world show reservoir or basin tillage to be a viable option in controlling runoff, and hence, increasing irrigation application efficiency and potato quality and yield.

Through literature review, it was found that work done by Hansen and Trimmer (1997) showed basins created by reservoir tillage to be effective in holding water and allowing it to infiltrate the soil thus preventing runoff. In comparing dammer dyker to other soil surface manipulations, Stern et al. (1992) found it to be an economical method of increasing efficiency of irrigation water under sprinkler system. Alexander (1994) compared dammer dyker to chisel for fall tillage and found no difference between them in reducing runoff under sprinkler irrigation system. He concluded, however, that both gave acceptable control of runoff. In general, reservoir tillage seems to be the best option to use for improving irrigation water application efficiency, reducing energy costs, increasing yield and quality, and protecting environment (Hobson et al. 1993; Lyle, 1997; Kranz et al., 1991).

There is little information available on the micro-distribution of soil water within a potato bed/furrow, however, in looking at micro-distribution of irrigation water within and between the potato-bed (or hills), Stieber and Shock (1995) found water distribution to be uneven below the surface due to wheel traffic compaction and hill topography. The distribution of irrigated water also changes significantly during the growing season as the potato plant matures and achieves complete canopy coverage. During the early part of the season, much of the irrigation water is shed off of the potato hill and infiltrates the furrow. Soil moisture measurements for irrigation management are typically done through the center of a hill at a depth of 25 to 50 cm. Given the chance of more water infiltrating through the furrow than the hill, there is an obvious potential for deep percolation, which could result in nutrients moving below the rooting depth of the plant, or the development of soil salinity problems. Quantifying the variation in infiltration patterns will identify the most appropriate measurement locations to base irrigation management decisions on and also allow us to quantify deep percolation rates.

Detailed work on the effectiveness of available reservoir tillage technologies and micro-distribution of applied water under low pressure sprinkler systems need to be done in Southern Alberta in order to provide producers with farm-based best management practices pertaining to sustainable potato production.

References:

1. Alexander, B. **1994**. Dammer dyker versus Chisel for Fall tillage. http://pnwsteep.wsu.edu/OFT/1994/Dammer Diker.htm
2. Hansen, H. And W. Trimmer **1997**. Making the most of Irrigation. Oregon State University Extension. PNW 287
3. Hobson, J.H., J.H. Jensen, K. Langley, C.C. Shock, T.D. Stieber, M. Thornton and T. Jensen. **1993**. OSU Extension.
4. Kranz, W., D.P. Shelton, E.C. Dickey and J.A. Smith **1991**. Water runoff control practices for sprinkler irrigation sysetms. NebGuide G91-1043-A
5. Stieber, T.D. and C.C Shock **1995**. Placement of soil moisture sensors in sprinkler irrigated potatoes
6. Stern, R., A.J. van Der Merwe, M.C. Laker and I. Shainberg **1992**. Effect of soil surface treatment on runoff and wheat yields under irrigation. Agron. J. 84:114-119

B. Please describe in point form the project objectives/deliverables. **(max. ½ page)**
- Compare four soil surface manipulating techniques for improving retention of irrigation water and soil water storage.
- Monitor micro-distribution of soil water within beds, furrows, and the reservoir tillage pits in each treatment.
- Measure and compare potato quality and yield potential resulting from the four soil surface manipulation treatments.
- Demonstrate various soil surface manipulation technologies to the potato growers through technology transfer.

4. Research Design, Method & Analysis

A. Please describe the Research Design, Methodology, Method of Analysis, and the proposed Research Plan for the entire duration of the proposed project. Include reference to the most relevant literature when discussing your research design and methodology. **(max. 1 page)**

Treatments: 1. Propeller diker
2. Furrow diker
3. Dammer Diker
4. No reservoir tillage

The above four treatments will be replicated four times in a randomized manner within a Russet Burbank potato field. The proposed location is the Canada-Alberta Crop Development Initiative, Lethbridge Demonstration Farm. The size of the available field will dictate the plot sizes, and we propose to use one quarter or a small pivot circle (approx. 8 acres). Soil moisture monitoring devices and rain gauges will be installed in each plot and measurements taken twice weekly. Rainfall, irrigation, and changes in soil moisture will be closely monitored during the growing season. Daily meteorological data will be obtained from a nearby weather station. Other information to be recorded will include field scouting observations, and petiole nutritional content as a measure of soil fertility. Crop water use will be estimated by calculating evapotranspiration (ET) using rainfall, irrigation, runoff, deep percolation and soil moisture changes. We'll also estimate crop water using Alberta Irrigation Management Model (AIMM). Potatoes will be harvested in the fall. Yield and grade of potatoes will be assessed. The data collected will be analyzed using standard statistical methods such as Analysis of Variance (ANOVA).

B. Please describe an annual work plan (including milestones) for the expected duration of the proposed project. **(max. ½ page)**

Spring 2002: Field will be chosen and plots set up, soil samples taken, potatoes planted, soil surface treatment (dyked), and soil moisture measuring devices installed.
During the growing season 2002: Moisture measurements twice per week (neutron probe and other sensors), field scouting, petiole sampling, and crop tours.
Fall 2002: Top-kill, harvest and grade potatoes to determine yield and quality; data analyses.

Winter 2002/2003: Write a progress report, present preliminary findings to potato producers and agronomists.

2003: Repeat 2002 activities

2004: Repeat 2002 and 2003 activities plus write a final report and recommendations.

5. Research Budget (see next page for budget form)

A. Please provide justification for the amount requested in each of the main budget categories. Ensure that the amounts are appropriate and consistent with the Guidelines. **(max. 1/2 page)**

Personnel:
The personnel requirements for this project involve providing technical staff for taking soil samples, monitoring soil moisture twice weekly, petiole samples, harvesting tubers, grading tubers, and handling data

input and analyses. Industry will be contributing in-kind through staff contributions. All supervision for the project, and a considerable amount of technical help will be provided as in-kind government contributions. Technical help will be required for the following operations:

- 1 day of soil sampling, 2 people
- 2 days of site preparation, 2 people
- 2 days per week soil moisture monitoring, 20 weeks, 1 person
- 3 petiole sample dates, 4 people
- 1 day of top-killing, 2 people
- 2 days of harvest, 6 people
- 2 days of grading, 4 people
- 10 site visits
- 8 days of data input
- analyses (soil, petiole, culinary, data, etc.)

Travel:

Travel requirements of the project largely involve travel to and from the research sites that will be in the Lethbridge area. Staff from CDC South (Brooks) will need to make several trips to each research site to monitor the project and to assist with petiole sampling and key data collection events.

10 site visits, fuel, lunches for staff

Capital Assets:

In order to compare conservation tillage methods, we will require access to two additional pieces of equipment. If no such equipment is available to rent or borrow in Alberta, we may need to consider purchasing second-hand equipment for the three-year trial.

Supplies:

Seed potatoes, fertilizer inputs, fuel costs, irrigation water and pesticides will run approximately $1500 per acre. Stakes, flags, bags and tags will be required for laying out research plots and harvest. Soil samples and petiole samples will need to be analyzed. Rain gauges will be required for each plot. Also, in order to collect sufficient soil moisture data from each plot, 75 additional access tubes will be required for use with the neutron probes. Potatoes from each plot will be analyzed for fry colour by the food science lab at CDC South on a contract basis.

Note: Although potato quality may not be optimal from all plots, we will actively pursue a contract to sell the potato crop grown as part of this study to a processor in southern Alberta. Proceeds would be used to offset costs for the second and third year of the project.

CDL:

Communication costs relate to preparing data and results for technology transfer. This will most likely take the form of slides, posters, overheads and perhaps a fact sheet on potassium fertility.

Overhead:

CDC South charges 5% overhead on all projects funded externally. Overhead was calculated on cash contributions from industry and granting agencies only. Overhead charges by government agencies are not eligible for funding through AARI (and ACIDF?) and these charges will be covered from the AAFRD operating budget for the potato program.

B. Anticipated Research Budget by Year

Year	Source	Type	Personnel	Travel	Capital Assets	Supplies	CDL*	Overhead	Total/year
1	AARI ACIDF ADLIDF ALIDF	Cash	8800	520	5000	17280			31600
	Gov't	Cash							0
		In-kind	22850	520	5000		500	1730	30600
	Industry	Cash				3000			3000
		In-kind	1000		500	1000			2500
Total Year 1			**32650**	**1040**	**10500**	**21280**	**500**	**1730**	**67700**
2	AARI ACIDF ADLIDF ALIDF	Cash	9240	530		12980			22750
	Gov't	Cash							0
		In-kind	23995	530			500	1290	26315
	Industry	Cash				3000			3000
		In-kind	1050		500	1000			2550
Total Year 2			**34285**	**1060**	**500**	**16980**	**500**	**1290**	**54615**
3	AARI ACIDF ADLIDF ALIDF	Cash	9702	540		12980	500		23722
	Gov't	Cash							0
		In-kind	25190	540			500	1340	27570
	Industry	Cash				3000			3000
		In-kind	1100		500	1000			2600
Total Year 3			**35992**	**1080**	**500**	**16980**	**1000**	**1340**	**56892**
4	AARI ACIDF ADLIDF ALIDF	Cash							
	Gov't	Cash							
		In-kind							
	Industry	Cash							
		In-kind							
Total Year 4									
5	AARI ACIDF ADLIDF ALIDF	Cash							
	Gov't	Cash							
		In-kind							
	Industry	Cash							
		In-kind							
Total Year 5									
Grand Total			**102927**	**3180**	**11500**	**55240**	**2000**	**4360**	**179207**

*Communication, Dissemination, and Linkage

6. A) Funding Contribution

Estimated Total Funds Requested for the Entire Duration of the Project

Source	Amount	Percentage of Total Project Cost
AARI ACIDF ADLIDF ALIDF	*78072	*44
Other Government sources: Cash		
Other Government sources: In-kind	84485	47
Industry : Cash	*9000	*5
Industry: In-kind	7650	4
Total Project Cost	**179207**	**100**

** See note on page 8 regarding sale of potatoes. If industry purchases the potato crop, our requirements from AARI, etc. would decrease, and our cash contribution from industry would increase significantly.*

Sources of Funding Contributions

B) Government Sources

Name (no abbreviations please)	*Amount Cash*	*Amount In-Kind*	*Confirmed (Y/N)*
AAFRD, Crop Diversification Centre South		*24785*	*Y*
AAFRD, Irrigation Branch		*59700*	*N*

C) Industry Sources

Name (no abbreviations please)	*Amount Cash*	*Amount In-Kind*	*Confirmed (Y/N)*
Southern Applied Research Association		*3000*	*N*
Potato Growers of Alberta	*9000*	*4650*	*N*

8) APPROVAL BY PRINCIPAL APPLICANT'S EMPLOYER

The undersigned declare the approval and support of their organization for the research project as described 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.

Christine Murray	Christine Murray	Director	March 8 2002
Name	Signature	Position	Date

9) 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 PGA Board.***

[signature]
Principal Cooperator Signature

March 8, 2002
Date

PGA Executive Committee Signature

Date

Effects of Soil Salinity on Potatoes

Research conducted by Shelley Woods
Crop Diversification Centre South
Alberta Agriculture Food and Rural Development

In five years, between 1997 and 2002, the Alberta potato industry expanded from 12300 to 22600 ha (30,500 to 55,800 acres). Much of this expansion took place in the irrigated region of southern Alberta, due to the opening of new processing facilities.

However, Alberta is also home to approximately 647000 ha (1,600,000 ac) of dryland salt-affected soils, with estimates that the salt affected area of soils in Alberta grows by 10% per year. Potatoes are a high input, high value crop that is known to be sensitive to soil salinity.

Because soil salinity is a possible limitation to continued growth of the potato industry in the province, it is important to quantify the potential negative impacts of salinity on yield and quality of potatoes and this was the objective of the study.

Method

Two field-scale crops of Russet Burbank potatoes were tested for the impacts of salinity on yield and specific gravity. During the 1999 growing season, a small amount of elevated salinity was noticed on a producer's field, due to leaky irrigation equipment and canal seepage. In April salinity was mapped and, at harvest, tuber samples (2.23 m^2 each) were collected at 61 sites, representing the range of soil salinity found in the field (Fig. 2a). At each tuber sample site, salinity was measured using a Geonics™ EM38 in combination with a Global Positioning Satellite (GPS) system (Fig. 1). The tubers were graded for size and specific gravity was determined for each sample.

During the 2003 growing season, a crop of potatoes was grown at the CACDI site, on soil with variable salinity. Salinity variability, at the site, was due to topography related recharge-discharge areas. In April of 2003, salinity and topography maps were made in order to determine the best locations for tuber sampling. At harvest, 20 tuber samples (0.302 m^2 each) were collected across the full range of salinity present (Fig. 2b) and salinity was also measured with an EM38. The samples were graded and analyzed for specific gravity. In addition, load cells (scales) were attached to the rollers near the end of the belt on the potato harvester and linked to GPS equipment, in order to monitor and map potato yield across the field.

Results

At the 1999 Vauxhall site, salinity was generally low, with small areas of high salinity along the southwest and southeast edges (Fig. 2a). When hand samples of tubers were collected, the area of greatest salinity (east edge) was avoided due to standing water.

Tuber samples were graded for size and deformities. The yield of medium sized tubers, as determined by the processing industry standards of 4.4-8.9 cm (1.75-3.5") in diameter, was calculated and compared to soil salinity (Fig. 3a top). As expected with field data, there is considerable scatter (r^2=0.373), however, there was a significant decline in potato yield with increasing salinity. When surface (0-0.75 m) salinity increased from 1 to 3 dS/m, yield declined by over 25%. The scatter in the data may be attributed to uncontrollable factors in the field, such as variability in soil moisture and fertility, crop disease, weeds and insects. A slight increase in tuber specific gravity was observed with increasing soil salinity (Fig. 3a bottom). Again, a low coefficient of correlation (r^2=0.142) was observed. The mean tuber weight was also determined at each sample site and there was an observed decrease with increasing soil salinity.

At the 2003 Lethbridge site, salinity exhibited a greater degree of variability, due to topography, with low salinity on the knolls and higher salinity at the lower slope discharge areas (Fig. 2b). A map of the wider area also showed slough-ring effects, with highest salinity concentrations around the edges of potholes.

No relationship between yield and salinity (Fig. 3b top) and specific gravity and salinity (Fig. 3b bottom) was observed at this site. The disappointing results from this experiment are likely a combination of factors, including an extremely early harvest date, which resulted in immature tubers. One occurrence of insufficient irrigation, which occurred in early July, would have caused areas of high topography and low salinity to be water deficient, while areas of low topography and high salinity would have maintained sufficient moisture. This situation would have temporarily counteracted the negative effects of soil salinity. In addition, only 20 hand samples were taken at this location. More samples may have served to better characterize the results.

The soil conditions, at this research site, were atypical for potato production. Clay content was higher and sand content lower than soil normally used in potato production. A combination of soil texture and moisture conditions, at harvest, led to the formation of many potato-sized clods of soil during the machine harvest. These clods constituted 0-75% of the material passing over the load cells and, as a result, the yield monitoring was unsuccessful.

Further research is necessary to determine the effects of soil salinity on yield and specific gravity of potatoes, in southern Alberta. It is recommended that a minimum of 40-50 hand-dug tuber samples be taken per field. Also, study at a more sandy-textured site will serve to increase the chances of successful yield monitoring.

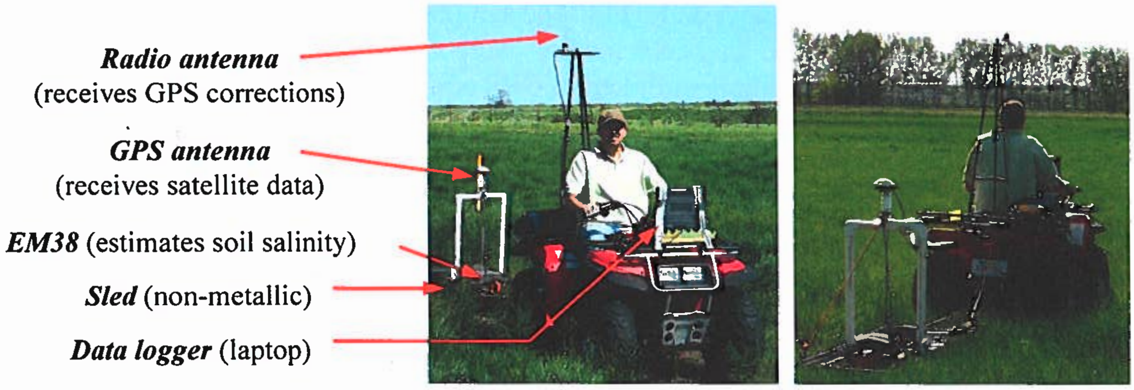

Figure 1.Salinity mapping equipment set-up.

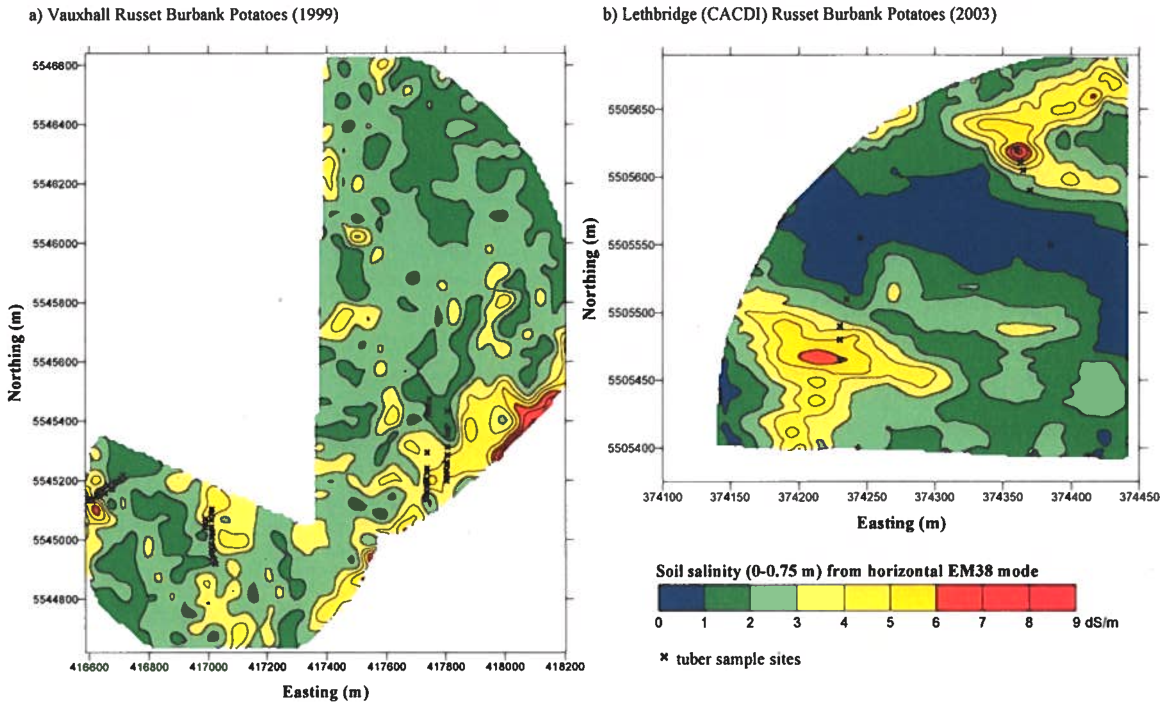

Figure 2. Soil salinity maps indicating tuber sample locations.

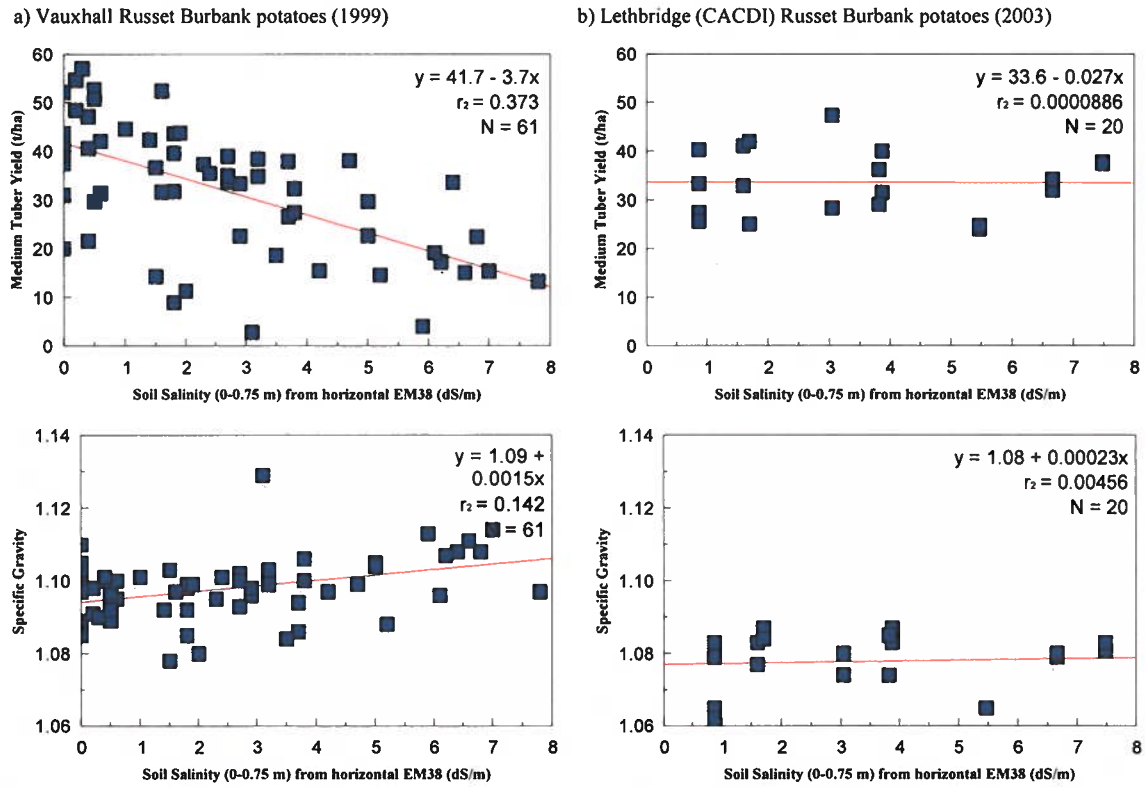

Figure 3. The response of medium tuber yield and specific gravity to increasing soil salinity.

Agriculture and Agri-Food Canada
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Mr. Vern Warkentin
Executive Director
Potato Growers of Alberta
6008-46th Avenue
Taber, Alberta
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$8,000 - Mar 12/02
Approved.
Pd Mar 21/02

March 8, 2002

Re: Funding Renewal, Irrigated Rotation Study, Vauxhall

Dear Vern:

Further to our telephone conversation, I enclose a copy of the Progress Report from the Irrigated Rotation Study at Vauxhall for the 2001 growing season.

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Sincerely,

Frank Larney

F.J. Larney
Research Scientist, Soil Conservation

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Canada

IRRIGATED CROPPING SYSTEMS FOR SUSTAINABLE MANAGEMENT

Researchers: F.J. Larney, R.E. Blackshaw, D.R. Lynch, H.H. Mündel, H.A. Carcamo, H.C. Huang, B.H. Ellert, E.G. Smith, D.C. Pearson, Agriculture and Agri-Food Canada, Lethbridge Research Centre; R.L. Conner, Agriculture and Agri-Food Canada, Morden Research Station, Manitoba; J.J. Nitschelm, Rogers Sugar Ltd., Taber; G.H. Dill, R.H. McKenzie, Alberta Agriculture Food & Rural Development, Lethbridge

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Project Duration: initiated in 2000, ongoing

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SUMMARY OF PROGRESS IN 2001

Experimental Treatments: The following crop rotations were established in spring 2000 at the Vauxhall Sub-station of Agriculture and Agri-Food Canada. The 2001 growing season represented the 2nd crop year of this study.

	Rotation	Management
1Yr	W	Cont. wheat (baseline)
3Yr	(P-B-W)c	Conventional
3Yr	(P-B-W)s	Sustainable
4Yr	(W-SB-B-P)c	Conventional
4Yr	(W-SB-B-P)s	Sustainable
5Yr	P-W-SB-W-B	Sustainable (cereal break)
6Yr	O(T)-T-T-SB-B-P	Sustainable (forage-based)

W = wheat; P = potatoes; B = beans; SB = sugar beet; O = oats, T = timothy.

Each phase of each rotation was represented resulting in 26 treatments. These were replicated four times to give 104 plots. The plot dimensions were 10 x 18.3 m with a 2.1 m interplot area between each plot.

The sustainable rotations are built around four specific management practices:
(1) direct seeding or reduced tillage where possible
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POTATOES

In 2001, potatoes (AC LR Russet Burbank) were grown on six rotations. Potatoes were seeded on April 23 and harvested on September 14, 2001. All plots received two passes of a Triple K cultivator before planting.

Potato Yield

There was no significant difference in total yield between any of the 6 potato rotation treatments in 2001 (Table 1).

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*Means followed by the same letter are not significantly different from each other. (*P* = 0.05).

Contrasts for Potato Yield:

Conventional vs. Sustainable

Conventional = 48.1 t/ha

Sustainable = 48.8 P = 0.79 *NS*

There was no negative effect of providing the full P requirement and partial N requirement of the potato crop with compost as the yield difference was non-significant. There should be some residual nutrient release from the compost for subsequent crops. Additionally, the compost added organic matter which should benefit soil tilt.

After wheat vs. after beans

After wheat = 45.1 t/ha

After beans = 50.4 P = 0.08 *NS*

Although the effect was marginally non-significant, the trend was for higher yielding potatoes after beans than after wheat. This may be due to the extra N fixed by the preceding bean crop.

Potato Agronomic and Quality Characteristics

There were no significant rotational effects on date to 50% emergence, plant vigor or stand count (Table 2). When total yield was split into marketable yield and oversize yield, there was a significant rotation effect on marketable yield. The 3 yr conventional rotation (39.1 t/ha) and the 4 yr sustainable rotation (41.6 t/ha) were significantly lower-yielding than the 4 yr conventional rotation (50.0 t/ha). Marketable yield per plant followed a similar trend as overall marketable yield.

The 4 yr sustainable rotation had significantly lower specific gravity than the other rotations (Table 2). Increased nitrogen levels can result in lower specific gravity. This may be due to the extra N fixed by the preceding bean crop. Specific gravity is a measure of dry matter content of the potato. A higher specific gravity (1.085-1.095) is desired for good texture, low oil absorption and improved production yield of french fries and chips. Rotation treatments that reduced specific gravity would be undesirable. AC LR Russet Burbank is considered to have a specific gravity suited to french fry production.

Table 2. Effect of rotation management on agronomic variables, Vauxhall, 2001.

Rotation	Julian date 50% Emergence	Vigor scale 1-5	Stand Count 36m row	Marketable Yield¶ T/ha	Oversize Yield¶¶ T/ha	Specific Gravity
3 yr Conv.	145b*	3.4a	128a	39.1b	3.0a	1.080a
3 yr Sust.	147a	3.4a	127a	44.0ab	4.2a	1.081a
4 yr Conv.	146ab	3.6a	130a	50.0a	4.2a	1.080a
4 yr Sust.	147a	3.2a	129a	41.6b	4.2a	1.071b
5 yr Sust.	146ab	3.1a	131a	45.9ab	5.4a	1.080a
6 yr Sust.	148a	2.9a	128a	44.5ab	5.6a	1.076ab

¶Marketable tubers: 48-88mm diam.; ¶¶Oversize tubers: >88mm diam.

Contrasts for Specific Gravity

Conventional vs. Sustainable

Conventional = 1.080

Sustainable = 1.077 P = 0.17 *NS*

After wheat vs. after beans

After wheat = 1.081

After beans = 1.077 P = 0.11 *NS*

When the rotations were grouped into conventional and sustainable, there was no overall significant effect of rotation on specific gravity. The sustainable rotations all received high rates of compost in the previous fall. However, the N release from the compost did not lower specific gravity compared to the conventional rotations which received N fertilizer. While the specific gravity of potatoes following beans was lower than that of potatoes following wheat, the difference was non-significant.

Potato Disease Characteristics

There were no significant rotation effects on potato disease levels (Table 3).

Table 3. Effect of rotation management on potato disease, Vauxhall, 2001.

Rotation	Marketable Deformities T/ha	Oversize Deformities T/ha	Marketable Internal Necrosis¶	Oversize Internal Necrosis¶
3 yr Conv.	0.64a*	0.40a	0.0a	1.2a
3 yr Sust.	0.39a	0.18a	0.5a	2.0a
4 yr Conv.	0.35a	0.07a	0.0a	2.7a
4 yr Sust.	0.44a	0.09a	1.0a	1.2a
5 yr Sust.	0.62a	0.36a	1.2a	1.0a
6 yr Sust.	0.93a	0.39a	0.7a	0.7a

¶Affected tubers/10 tubers sample. Means followed by the same letter are not significantly different from each other (P= 0.05).

Potato French Fry Quality

There was no significant rotation effect on any of the French fry quality parameters measured (Table 4).

Table 4. Effect of rotation on French fry characteristics, Vauxhall, 2001.

Rotation	Colour USDA Scale 1-7	Texture Scale 1-4	Colour Uniformity Scale 1-5
3 yr Conv.	4.25a	3.25a	3.25a
3 yr Sust.	4.75a	3.50a	3.25a
4 yr Conv.	4.25a	3.50a	3.50a
4 yr Sust.	4.50a	3.25a	3.50a
5 yr Sust.	5.00a	3.50a	4.00a
6 yr Sust.	4.67a	3.33a	3.67a

BEANS

Bean Yields

Black beans (UI 406) were seeded on May17/18, 2001. The 3yr and 4 yr conventional rotations were seeded at a conventional wide row spacing (60-cm). The sustainable rotations were seeded with a John Deere 1560 no-till drill in a narrow-row spacing (20 cm). Beans were harvested on September 13, 2001.

The 4-yr conventionally seeded beans were the highest yielding treatment and were significantly higher than 3 yr sustainable, the 5-yr and 6-yr rotation treatments (Table 5). Although the narrow-row beans direct-seeded into fall rye burnoff were lower-yielding (2140 kg/ha) than the wide-row beans conventionally seeded (2834 kg/ha) the effect was non-significant.

Table 5. Effect of rotation management on bean yield, Vauxhall, 2001.

Rotation	Previous Crop	Fall preparation	Spring preparation	Yield, kg/ha
3 yr Conv.	Potatoes	Cultivate + crazy harrow	Triple K	2,834 ab*
3 yr Sust.	Potatoes	Disc + crazy harrow. Fall rye cover	Direct Seed into fall rye burnoff	2,140 bc
4 yr Conv.	Sugar Beet	Cultivate + crazy harrow	Triple K	3,116 a
4 yr Sust.	Sugar Beet	Cultivate + crazy harrow	Direct seed	2,343 abc
5 yr Sust.	Wheat	Shred stubble	Direct seed into shredded stubble	1,772 c
6 yr Sust.	Sugar Beet	Cultivate + crazy harrow	Direct seed	2,043 bc

*Means followed by the same letter are not significantly different from each other. (*P* = 0.05).

Contrasts for Bean Yield:

Conventional vs. Sustainable

Conventional = 2975 kg/ha

Sustainable = 2074 P = 0.003 ** *(significant)*

Yields of the conventionally seeded (wide row) beans were significantly higher than yields of sustainably seeded (narrow row) beans. The narrow-row beans had higher weed populations than the wide-row beans which may have reduced yields.

After potatoes vs. After sugar beet

After potatoes = 2487 kg/ha

After sugar beet = 2501 kg/ha P = 0.96 *Non-significant*

There was little difference between yields after potatoes or sugar beet.

WHEAT

The soft white spring wheat variety AC Reed was seeded on April 24, 2001 at 120 lbs/ac. The 3yr and 4 yr conventional rotations were seeded after one pass with a Triple K cultivator. The sustainable rotations were direct seeded into fall worked land as set out in Table 3. The wheat was harvested on August 23, 2001.

In the 6 yr sustainable rotation wheat was substituted for 1st year timothy in 2000 and 2nd year timothy in 2001. The 6yr sustainable and 1yr continuous rotations therefore had comparable treatments. Their yields are significantly different (P = 0.05) than the rotations following non-cereal crops (Table 6). Cultivations in the fall and spring of the 6 yr and 1yr rotations produced a dry seedbed which may have resulted in poor establishment and reduced yield.

Table 6. Effect of rotation management on wheat yield, Vauxhall, 2001.

Rotation	Previous Crop	Fall preparation	Spring preparation	Yield, t/ha
3 yr Conv.	Beans	Cultivate + crazy harrow	Triple K	8.50 a*
3 yr Sust.	Beans	Disc + crazy harrow, Oat cover crop	Direct Seed into oat cover	8.77 a
4 yr Conv.	Potatoes	Cultivate + crazy harrow	Triple K	8.34 a
4 yr Sust.	Potatoes	Disc + crazy harrow, Oat cover crop	Direct seed into oat Cover	8.20 a
5 yr Sust	Potatoes	Disc + crazy harrow, Oat cover crop	Direct seed into oat cover	8.23 a
5 yr Sust.	Sugar beet	Compost, Disc + crazy harrow, Oat cover crop	Direct seed into oat cover	8.43 a
6 yr Sust	Wheat	Disc + crazy harrow	Direct seeded	5.63 b
1 yr Cont.	Wheat	Disc + crazy harrow	Direct seeded	5.42 b

*Means followed by the same letter are not significantly different from each other. (*P* = 0.05).

Contrasts for Wheat Yield:

Conventional vs. Sustainable

Conventional = 8.42 t/ha

Sustainable = 8.42 P = 0.99 *NS*

There was no significant difference in the yields between sustainable and conventional treatments. The continuous wheat and Timothy substitution wheat were not included in this contrast.

After beans vs. after potatoes

After beans = 8.63t/ha

After potatoes = 8.27 P = 0.19 *NS*

Although the effect was non-significant, the trend was for higher yielding wheat after beans than after potatoes. This may be due to the extra N fixed by the preceding bean crop.

SUGAR BEET

The sugar beets were managed by Rogers Sugar Ltd. They were seeded on April 23, 2001 and harvested on October 2-3, 2001.

All rotations had a fall preparation of shredding stubble, discing , followed by broadcast fertilizer placement worked in by a Vibrashank cultivator with packers. Spring preparation was a light harrowing prior to seeding.

There were significant rotation effects on extractable sugar with the 4 yr sustainable rotation being slightly higher (Table 7). The 6-yr rotation had a significantly lower sugar percent. These differences are not explainable as the treatments did not vary in their cropping histories at this point in the study.

Table 7. Effect of rotation management on sugar yield, and quality, Vauxhall, 2001.

Rotation	Previous Crop	Extractable Sugar Kg/acre	Extractable Sugar Kg/t	Sugar (%)	Molasses Loss (%)	Beet Yield (t/acre)	Stand (pl/100 ft)
4yr-c	Wheat	4161a*	149b	17.6ab	2.71a	28.07a	83a
4yr-s	Wheat	4390a	159a	18.3a	2.40a	27.80a	89a
5yr	Wheat	4395a	155ab	18.0a	2.51a	28.41a	85a
6yr	Wheat*	4150a	146b	17.2b	2.68a	28.66a	80a

Rotation	Previous Crop	Amino N	Na	K	Amino N	Na	K
		Meq/100g fresh wt			ppm fresh wt		
4yr-c	Wheat	1.04a	1.69a	6.76a	145a	390a	2641a
4yr-s	Wheat	0.95a	1.29a	6.29a	134a	296a	2457a
5yr	Wheat	1.10a	1.33a	6.52a	154a	307a	2548a
6yr	Wheat*	1.25a	1.74a	6.59a	174a	400a	2578a

*In the 6 yr sustainable rotation wheat was substituted for 1st year timothy in 2000 and the 2nd year timothy in 2001.Means followed by the same letter are not significantly different from each other. (*P* = 0.05).

Conventional vs. Sustainable Contrasts:

Table 8. Conventional vs sustainable contrast effects on sugar beet yield and quality.

Characteristic		Conventional	Sustainable	P value
Extractable sugar	Kg/ac	4161	4312	*0.25 NS*
	Kg/t	149	153	*0.22 NS*
Sugar, %		17.56	17.85	*0.31 NS*
MS, %		2.71	2.53	*0.20 NS*
Beet yield, t/ac		28.07	28.29	*0.78 NS*
Stand, Plants/100ft		83	85	*0.68 NS*
N, Meq/100g fresh wt		1.04	1.10	*0.73 NS*
Na, Meq/100g fresh wt		1.70	1.45	*0.41 NS*
K, Meq/100g fresh wt		6.76	6.47	*0.28 NS*
N, ppm		145	154	*0.74 NS*
Na, ppm		296	334	*0.41 NS*
K, ppm		2641	2528	*0.28 NS*

There were no significant differences in the yields between sustainable and conventional treatments (Table 8). This is not surprising since there were no differences in land preparation or previous crop for the sugar beets in 2001 or wheat in 2000. Of the four crops, sugar beets are the least likely to show treatment effects since the differences between sustainable and conventional management are least in the sugar beet phase of the rotations.

OATS AND TIMOTHY IN THE 6-YR ROTATION

On the 6-yr rotation, the oat crop yielded an average of 8.26 t/ha when harvested as green feed on July 9, 2001. These plots were direct seeded to timothy on August 28.

First cut timothy (July 3) in the first timothy phase of the 6-yr rotation yielded an average of 5.62 t/ha while second cut timothy (September 7) yielded an average of 7.45 t/ha for a total timothy yield of 13.07 t/ha in 2001. According to the Timothy Production Handbook (Canadian Hay Association, 1999) irrigated timothy is capable of producing 11-13.5 t/ha. Our yields at Vauxhall were on the upper end of that scale.

OTHER MEASUREMENTS

Insect pit-fall traps were installed in June in the 3 yr rotations to monitor ground-dwelling insects. These were emptied at 2 week intervals until the end of August. The insects will be counted and classified into groups (beneficial, non-beneficial) over the coming months and these numbers will be examined in relation to rotation treatment.

Weeds were counted on a per species basis in each plot. 15 quadrants of 1/4 sq m each were counted per plot. This was done twice: once after emergence before application of an in-crop herbicide and again 4 weeks later. Weed populations will be related to management information to examine if certain weeds build up with particular rotations.

Neutron probe access tubes (2 per plot) were installed in all plots of the 4-yr rotation (32 plots) and were read for volumetric water content during the growing season. This data was used for irrigation scheduling.

PLANS FOR 2002

Measurements of wind erosion risk will be taken on plots in March (residue cover, surface roughness, aggregate size distribution). Plots will be seeded to beans, potatoes, sugar beets, soft wheat and oats/timothy, as dictated by the rotation sequence. The plot measurements carried out in 2000 and 2001 will be repeated in 2002.

TECHNOLOGY TRANSFER, 2001

Larney, FJ. Rotation and Agronomy Research meeting with staff from AAFRD (Agronomy Unit, Edmonton) and AAFC (Lethbridge and Lacombe), December 11, 2000, Calgary, AB.

Larney, FJ. Land Management and Sustainability meeting with AAFRD staff, January 9, 2001, Lethbridge, AB.

Larney, FJ . Attended Alberta Conservation Tillage Society Board Meeting and FarmTech 2001, January 30-February 1, 2001, Red Deer, AB.

Larney, FJ. 2001. Irrigated cropping systems for sustainable management. Potato Research Network Meeting, June 18-19, 2001, Charlottetown, PEI.

Larney FJ. 2001. Low residue crops: meeting the challenge in irrigated cropping. Alberta Conservation Connection, Winter 2001. [Online], Available at http://www.agric.gov.ab.ca/sustain/acc/ (verified October 30, 2001).

Larney FJ. 2001. Blowin' in the Wind. *In* Green Matters Newsletter, Alberta Environmentally Sustainable Agriculture (AESA) Council, Issue No. 8, Summer 2001.

Larney FJ, Blackshaw RE, Dill GH and Nitschelm JJ. 2001. Irrigated cropping systems for sustainable management. P. 19 *in* Manitoba Potato Research Project Listing, October 2001, Manitoba Agriculture, Carberry, MB.

Larney, FJ. Attended Wind Erosion Meeting for AAFRD, commodity groups, producers, June 12, 2001, Taber, AB.

Larney, FJ . Conducted Irrigated Cropping Systems Plot Tour, Vauxhall, July 25, 2001.

Larney, FJ . Spoke on rotation study for Potato Growers of Alberta Field Day, Vauxhall, August 29, 2001.

Larney, FJ . Poster presentation *A new irrigated rotation study for sustainable management,* Potato Growers of Alberta, Ann. Mtg., Banff, AB, Nov. 14-16, 2001.

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After wheat = 45.1 t/ha

After beans = 50.4 P = 0.08 *NS*

Although the effect was marginally non-significant, the trend was for higher yielding potatoes after beans than after wheat. This may be due to the extra N fixed by the preceding bean crop.

Potato Agronomic and Quality Characteristics

There were no significant rotational effects on date to 50% emergence, plant vigor or stand count (Table 2). When total yield was split into marketable yield and oversize yield, there was a significant rotation effect on marketable yield. The 3 yr conventional rotation (39.1 t/ha) and the 4 yr sustainable rotation (41.6 t/ha) were significantly lower-yielding than the 4 yr conventional rotation (50.0 t/ha). Marketable yield per plant followed a similar trend as overall marketable yield.

The 4 yr sustainable rotation had significantly lower specific gravity than the other rotations (Table 2). Increased nitrogen levels can result in lower specific gravity. This may be due to the extra N fixed by the preceding bean crop. Specific gravity is a measure of dry matter content of the potato. A higher specific gravity (1.085-1.095) is desired for good texture, low oil absorption and improved production yield of french fries and chips. Rotation treatments that reduced specific gravity would be undesirable. AC LR Russet Burbank is considered to have a specific gravity suited to french fry production.

Table 2. Effect of rotation management on agronomic variables, Vauxhall, 2001.

Rotation	Julian date 50% Emergence	Vigor scale 1-5	Stand Count 36m row	Marketable Yield¶ T/ha	Oversize Yield¶¶ T/ha	Specific Gravity
3 yr Conv.	145b*	3.4a	128a	39.1b	3.0a	1.080a
3 yr Sust.	147a	3.4a	127a	44.0ab	4.2a	1.081a
4 yr Conv.	146ab	3.6a	130a	50.0a	4.2a	1.080a
4 yr Sust.	147a	3.2a	129a	41.6b	4.2a	1.071b
5 yr Sust.	146ab	3.1a	131a	45.9ab	5.4a	1.080a
6 yr Sust.	148a	2.9a	128a	44.5ab	5.6a	1.076ab

¶Marketable tubers: 48-88mm diam.; ¶¶Oversize tubers: >88mm diam.

Contrasts for Specific Gravity

Conventional vs. Sustainable

Conventional = 1.080

Sustainable = 1.077 P = 0.17 *NS*

After wheat vs. after beans

After wheat = 1.081

After beans = 1.077 P = 0.11 *NS*

When the rotations were grouped into conventional and sustainable, there was no overall significant effect of rotation on specific gravity. The sustainable rotations all received high rates of compost in the previous fall. However, the N release from the compost did not lower specific gravity compared to the conventional rotations which received N fertilizer. While the specific gravity of potatoes following beans was lower than that of potatoes following wheat, the difference was non-significant.

Potato Disease Characteristics

There were no significant rotation effects on potato disease levels (Table 3).

Table 3. Effect of rotation management on potato disease, Vauxhall, 2001.

Rotation	Marketable Deformities T/ha	Oversize Deformities T/ha	Marketable Internal Necrosis¶	Oversize Internal Necrosis¶
3 yr Conv.	0.64a*	0.40a	0.0a	1.2a
3 yr Sust.	0.39a	0.18a	0.5a	2.0a
4 yr Conv.	0.35a	0.07a	0.0a	2.7a
4 yr Sust.	0.44a	0.09a	1.0a	1.2a
5 yr Sust.	0.62a	0.36a	1.2a	1.0a
6 yr Sust.	0.93a	0.39a	0.7a	0.7a

¶Affected tubers/10 tubers sample. Means followed by the same letter are not significantly different from each other (P= 0.05).

Potato French Fry Quality

There was no significant rotation effect on any of the French fry quality parameters measured (Table 4).

Table 4. Effect of rotation on French fry characteristics, Vauxhall, 2001.

Rotation	Colour USDA Scale 1-7	Texture Scale 1-4	Colour Uniformity Scale 1-5
3 yr Conv.	4.25a	3.25a	3.25a
3 yr Sust.	4.75a	3.50a	3.25a
4 yr Conv.	4.25a	3.50a	3.50a
4 yr Sust.	4.50a	3.25a	3.50a
5 yr Sust.	5.00a	3.50a	4.00a
6 yr Sust.	4.67a	3.33a	3.67a

BEANS

Bean Yields
Black beans (UI 406) were seeded on May17/18, 2001. The 3yr and 4 yr conventional rotations were seeded at a conventional wide row spacing (60-cm). The sustainable rotations were seeded with a John Deere 1560 no-till drill in a narrow-row spacing (20 cm). Beans were harvested on September 13, 2001.

The 4-yr conventionally seeded beans were the highest yielding treatment and were significantly higher than 3 yr sustainable, the 5-yr and 6-yr rotation treatments (Table 5). Although the narrow-row beans direct-seeded into fall rye burnoff were lower-yielding (2140 kg/ha) than the wide-row beans conventionally seeded (2834 kg/ha) the effect was non-significant.

Table 5. Effect of rotation management on bean yield, Vauxhall, 2001.

Rotation	Previous Crop	Fall preparation	Spring preparation	Yield, kg/ha
3 yr Conv.	Potatoes	Cultivate + crazy harrow	Triple K	2,834 ab*
3 yr Sust.	Potatoes	Disc + crazy harrow. Fall rye cover	Direct Seed into fall rye burnoff	2,140 bc
4 yr Conv.	Sugar Beet	Cultivate + crazy harrow	Triple K	3,116 a
4 yr Sust.	Sugar Beet	Cultivate + crazy harrow	Direct seed	2,343 abc
5 yr Sust.	Wheat	Shred stubble	Direct seed into shredded stubble	1,772 c
6 yr Sust.	Sugar Beet	Cultivate + crazy harrow	Direct seed	2,043 bc

*Means followed by the same letter are not significantly different from each other. (*P* = 0.05).

Contrasts for Bean Yield:
Conventional vs. Sustainable
Conventional = 2975 kg/ha
Sustainable = 2074 P = 0.003 ** *(significant)*

Yields of the conventionally seeded (wide row) beans were significantly higher than yields of sustainably seeded (narrow row) beans. The narrow-row beans had higher weed populations than the wide-row beans which may have reduced yields.

After potatoes vs. After sugar beet
After potatoes = 2487 kg/ha
After sugar beet = 2501 kg/ha P = 0.96 *Non-significant*

There was little difference between yields after potatoes or sugar beet.

WHEAT

The soft white spring wheat variety AC Reed was seeded on April 24, 2001 at 120 lbs/ac. The 3yr and 4 yr conventional rotations were seeded after one pass with a Triple K cultivator. The sustainable rotations were direct seeded into fall worked land as set out in Table 3. The wheat was harvested on August 23, 2001.

In the 6 yr sustainable rotation wheat was substituted for 1st year timothy in 2000 and 2nd year timothy in 2001. The 6yr sustainable and 1yr continuous rotations therefore had comparable treatments. Their yields are significantly different (P = 0.05) than the rotations following non-cereal crops (Table 6). Cultivations in the fall and spring of the 6 yr and 1yr rotations produced a dry seedbed which may have resulted in poor establishment and reduced yield.

Table 6. Effect of rotation management on wheat yield, Vauxhall, 2001.

Rotation	Previous Crop	Fall preparation	Spring preparation	Yield, t/ha
3 yr Conv.	Beans	Cultivate + crazy harrow	Triple K	8.50 a*
3 yr Sust.	Beans	Disc + crazy harrow, Oat cover crop	Direct Seed into oat cover	8.77 a
4 yr Conv.	Potatoes	Cultivate + crazy harrow	Triple K	8.34 a
4 yr Sust.	Potatoes	Disc + crazy harrow, Oat cover crop	Direct seed into oat Cover	8.20 a
5 yr Sust	Potatoes	Disc + crazy harrow, Oat cover crop	Direct seed into oat cover	8.23 a
5 yr Sust.	Sugar beet	Compost, Disc + crazy harrow, Oat cover crop	Direct seed into oat cover	8.43 a
6 yr Sust	Wheat	Disc + crazy harrow	Direct seeded	5.63 b
1 yr Cont.	Wheat	Disc + crazy harrow	Direct seeded	5.42 b

*Means followed by the same letter are not significantly different from each other. (*P* = 0.05).

Contrasts for Wheat Yield:

Conventional vs. Sustainable

Conventional = 8.42 t/ha

Sustainable = 8.42 P = 0.99 *NS*

There was no significant difference in the yields between sustainable and conventional treatments. The continuous wheat and Timothy substitution wheat were not included in this contrast.

After beans vs. after potatoes

After beans = 8.63t/ha

After potatoes = 8.27 P = 0.19 *NS*

Although the effect was non-significant, the trend was for higher yielding wheat after beans than after potatoes. This may be due to the extra N fixed by the preceding bean crop.

SUGAR BEET

The sugar beets were managed by Rogers Sugar Ltd. They were seeded on April 23, 2001 and harvested on October 2-3, 2001.

All rotations had a fall preparation of shredding stubble, discing , followed by broadcast fertilizer placement worked in by a Vibrashank cultivator with packers. Spring preparation was a light harrowing prior to seeding.

There were significant rotation effects on extractable sugar with the 4 yr sustainable rotation being slightly higher (Table 7). The 6-yr rotation had a significantly lower sugar percent. These differences are not explainable as the treatments did not vary in their cropping histories at this point in the study.

Table 7. Effect of rotation management on sugar yield, and quality, Vauxhall, 2001.

Rotation	Previous Crop	Extractable Sugar Kg/acre	Extractable Sugar Kg/t	Sugar (%)	Molasses Loss (%)	Beet Yield (t/acre)	Stand (pl/100 ft)
4yr-c	Wheat	4161a*	149b	17.6ab	2.71a	28.07a	83a
4yr-s	Wheat	4390a	159a	18.3a	2.40a	27.80a	89a
5yr	Wheat	4395a	155ab	18.0a	2.51a	28.41a	85a
6yr	Wheat*	4150a	146b	17.2b	2.68a	28.66a	80a

Rotation	Previous Crop	Amino N	Na	K	Amino N	Na	K
		Meq/100g fresh wt			ppm fresh wt		
4yr-c	Wheat	1.04a	1.69a	6.76a	145a	390a	2641a
4yr-s	Wheat	0.95a	1.29a	6.29a	134a	296a	2457a
5yr	Wheat	1.10a	1.33a	6.52a	154a	307a	2548a
6yr	Wheat*	1.25a	1.74a	6.59a	174a	400a	2578a

*In the 6 yr sustainable rotation wheat was substituted for 1st year timothy in 2000 and the 2nd year timothy in 2001.Means followed by the same letter are not significantly different from each other. (P = 0.05).

Conventional vs. Sustainable Contrasts:

Table 8. Conventional vs sustainable contrast effects on sugar beet yield and quality.

Characteristic		Conventional	Sustainable	P value
Extractable sugar	Kg/ac	4161	4312	*0.25 NS*
	Kg/t	149	153	*0.22 NS*
Sugar, %		17.56	17.85	*0.31 NS*
MS, %		2.71	2.53	*0.20 NS*
Beet yield, t/ac		28.07	28.29	*0.78 NS*
Stand, Plants/100ft		83	85	*0.68 NS*
N, Meq/100g fresh wt		1.04	1.10	*0.73 NS*
Na, Meq/100g fresh wt		1.70	1.45	*0.41 NS*
K, Meq/100g fresh wt		6.76	6.47	*0.28 NS*
N, ppm		145	154	*0.74 NS*
Na, ppm		296	334	*0.41 NS*
K, ppm		2641	2528	*0.28 NS*

There were no significant differences in the yields between sustainable and conventional treatments (Table 8). This is not surprising since there were no differences in land preparation or previous crop for the sugar beets in 2001 or wheat in 2000. Of the four crops, sugar beets are the least likely to show treatment effects since the differences between sustainable and conventional management are least in the sugar beet phase of the rotations.

OATS AND TIMOTHY IN THE 6-YR ROTATION

On the 6-yr rotation, the oat crop yielded an average of 8.26 t/ha when harvested as green feed on July 9, 2001. These plots were direct seeded to timothy on August 28.

First cut timothy (July 3) in the first timothy phase of the 6-yr rotation yielded an average of 5.62 t/ha while second cut timothy (September 7) yielded an average of 7.45 t/ha for a total timothy yield of 13.07 t/ha in 2001. According to the Timothy Production Handbook (Canadian Hay Association, 1999) irrigated timothy is capable of producing 11-13.5 t/ha. Our yields at Vauxhall were on the upper end of that scale.

OTHER MEASUREMENTS

Insect pit-fall traps were installed in June in the 3 yr rotations to monitor ground-dwelling insects. These were emptied at 2 week intervals until the end of August. The insects will be counted and classified into groups (beneficial, non-beneficial) over the coming months and these numbers will be examined in relation to rotation treatment.

Weeds were counted on a per species basis in each plot. 15 quadrants of 1/4 sq m each were counted per plot. This was done twice: once after emergence before application of an in-crop herbicide and again 4 weeks later. Weed populations will be related to management information to examine if certain weeds build up with particular rotations.

Neutron probe access tubes (2 per plot) were installed in all plots of the 4-yr rotation (32 plots) and were read for volumetric water content during the growing season. This data was used for irrigation scheduling.

PLANS FOR 2002

Measurements of wind erosion risk will be taken on plots in March (residue cover, surface roughness, aggregate size distribution). Plots will be seeded to beans, potatoes, sugar beets, soft wheat and oats/timothy, as dictated by the rotation sequence. The plot measurements carried out in 2000 and 2001 will be repeated in 2002.

TECHNOLOGY TRANSFER, 2001

Larney, FJ. Rotation and Agronomy Research meeting with staff from AAFRD (Agronomy Unit, Edmonton) and AAFC (Lethbridge and Lacombe), December 11, 2000, Calgary, AB.

Larney, FJ. Land Management and Sustainability meeting with AAFRD staff, January 9, 2001, Lethbridge, AB.

Larney, FJ . Attended Alberta Conservation Tillage Society Board Meeting and FarmTech 2001, January 30-February 1, 2001, Red Deer, AB.

Larney, FJ. 2001. Irrigated cropping systems for sustainable management. Potato Research Network Meeting, June 18-19, 2001, Charlottetown, PEI.

Larney FJ. 2001. Low residue crops: meeting the challenge in irrigated cropping. Alberta Conservation Connection, Winter 2001. [Online], Available at http://www.agric.gov.ab.ca/sustain/acc/ (verified October 30, 2001).

Larney FJ. 2001. Blowin' in the Wind. *In* Green Matters Newsletter, Alberta Environmentally Sustainable Agriculture (AESA) Council, Issue No. 8, Summer 2001.

Larney FJ, Blackshaw RE, Dill GH and Nitschelm JJ. 2001. Irrigated cropping systems for sustainable management. P. 19 *in* Manitoba Potato Research Project Listing, October 2001, Manitoba Agriculture, Carberry, MB.

Larney, FJ. Attended Wind Erosion Meeting for AAFRD, commodity groups, producers, June 12, 2001, Taber, AB.

Larney, FJ . Conducted Irrigated Cropping Systems Plot Tour, Vauxhall, July 25, 2001.

Larney, FJ . Spoke on rotation study for Potato Growers of Alberta Field Day, Vauxhall, August 29, 2001.

Larney, FJ . Poster presentation *A new irrigated rotation study for sustainable management,* Potato Growers of Alberta, Ann. Mtg., Banff, AB, Nov. 14-16, 2001.

Larney, FJ . Poster presentation *A new irrigated rotation study for sustainable management,* FarmTech Conf., Red Deer, AB. January 30-February 1, 2002.

Alberta
AGRICULTURE, FOOD AND
RURAL DEVELOPMENT

RECEIVED JUN 1 9 2002

Crop Diversification Centre
South

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

Telephone 403/362-1300
Fax 403/362-1306

June 7, 2002

Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1

Attention: Vern Warkentin, Executive Director

Re: MOU for "Russet Burbank Vine Management in Southern Alberta" project

Dear Vern;

Thank you for your e-mail in March advising me that the PGA is willing to fund our project entitled "Russet Burbank Vine Management in Southern Alberta" in 2002. As a formality, we like to set up a Memorandum of Understanding (MOU) with each cooperator for externally funded projects. Please review the enclosed MOU. If the terms of the MOU are acceptable, please sign both copies and return an original to me. If you would prefer to propose alternate terms, please contact me at 403-362-1314 and we can discuss the terms further. An invoice will be issued under separate cover. Thank you.

Sincerely,

Michele Konschuh, Ph.D.
Potato Research Agronomist

Project #629015
New: Renewal: **X**

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: Russet Burbank Vine Management in Southern Alberta.

Objectives:
1. To determine how much bulking occurs in potato tubers between Reglone application(s) and harvest.
2. To compare rates of vine desiccation with Reglone applications alone or following vine rolling.
3. To determine the extent to which the method and rate of vine killing affects tuber quality (maturity, specific gravity, stem-end discoloration, and fry quality).

STATEMENT OF WORK

Alberta Agriculture, Food & Rural Development is willing to undertake this study for the PGA, who hereby agrees to contribute toward the costs of researching the information required as described in the research proposal.

PERIOD OF WORK

The research project will commence in August, 2002. A yearly report will be provided to the PGA by March 31, 2003.

BASIS OF PAYMENT

The sponsor of the project, the PGA, will provide $17,000 upon finalization of this memorandum to AAFRD, to cover the following estimated yearly costs:

Casual Manpower (on an as need basis):	$8,800
Materials & Supplies	$6,300
Overhead & GST	$1,900

The 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.

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. Michele Konschuh. She will provide all reports to AAFRD and 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 herself.

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:

Potato Growers of Alberta

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

Alberta Agriculture, Food & Rural Development:

Dr. Stanford Blade
Director, Crop Diversification Division
Crop Diversification Centre North
R.R. 6, 17507 Fort Road
Edmonton, AB T5B 4K3

Information generated from the project may be used by the Department of Agriculture, Food & Rural Development, the PGA, and other sponsors of the project.

The sponsor, the 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 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.

______________________________ Date June 7, 2002

Dr. Michele Konschuh, Project Manager

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

______________________________ Date June 10 2002

Dr. Christine Murray, Branch Head, CDCS

______________________________ Date June 12/2002

Dr. Stanford Blade, Director, CDD

______________________________ Date July 8/02

Mr. Vern Warkentin, Executive Director
Potato Growers of Alberta

Alberta
AGRICULTURE, FOOD AND
RURAL DEVELOPMENT

Crop Diversification Centre
South

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

Telephone 403/362-1300
Fax 403/362-1306

March 8, 2002

Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB   T1G 2B1

accepted

Poster Board could have been clearer!

Attention: **Board of Directors**

Re: Application for Funding
"Russet Burbank Vine Management in Southern Alberta"

Dear Board Members:

Enclosed are 10 copies of the funding application for our project entitled "Russet Burbank Vine Management in Southern Alberta". The proposal is a renewal of a project funded in 2001. The trial will be conducted in two commercial Russet Burbank fields. Conducting the treatments and harvesting in this project will require the coordination and possibly the participation of the cooperating farmers. Sampling in this project will be very labour intensive. The proposal can be adjusted if additional treatments or sampling are required. We are requesting approximately $17,000 from the PGA for 2002.

The results of this project will enable us to answer questions about the rate of tuber bulking during vine desiccation, and make recommendations about the use of vine rolling in conjunction with diquat (Reglone™) for vine killing. A second year is required to validate the first year's data and to ensure that environmental conditions did not dictate the outcome of the trial. Please contact me if you have any questions (403-362-1314).

Thank you for your consideration. I look forward to hearing from you.

Sincerely,

Michele Konschuh, Ph.D.
Potato Research Agronomist

POTATO GROWERS OF ALBERTA

FUNDING APPLICATION

(RENEWAL)

Russet Burbank Vine Management in Southern Alberta

Submitted by

Michele Konschuh, Melanie Nielsen, Darcy Driedger and Lori Delanoy

March 8, 2001

PRINCIPAL APPLICANT INFORMATION

Principal applicant's name	Phone
Michele Konschuh	403-362-1314
Research agency or company	
AAFRD, CDC South	
Mailing Address	Postal code
S.S. #4, Brooks, AB	T1R 1E6
Location of research project.(Research farm name or legal location.)	

We will require co-operators (2 per year) growing Russet Burbank potatoes in the Vauxhall and/or Taber areas.

b) Objectives

1. To determine how much bulking occurs in potato tubers between Reglone™ application(s) and harvest.
2. To compare rates of vine desiccation with Reglone™ applications alone or following vine rolling or with Liberty™ application.
3. To determine the extent to which the method and rate of vine killing affects tuber quality (maturity, specific gravity, stem-end discoloration, fry quality).

5C) Research Plan

Two fields of Russet Burbank potatoes in southern Alberta will be planted, irrigated, and managed by commercial growers. Fields will be selected in August based on petiole nitrogen levels. One field with adequate petiole nitrogen levels will be selected and one field with low petiole nitrogen levels will be selected. The trial will involve approximately 1.5 acres in each field. We will require access to the fields for soil and petiole sampling, and frequent access to the fields for the three weeks prior to harvest. No desiccant may be applied to the plots under study, although the remainder of the field may be treated at the grower's discretion. The trial should be conducted for two to three consecutive years to allow for differences in environmental conditions between years.

Seven treatments are planned, with four replicates in each field. The treatments are as follows:

1. Control - green harvest (for comparison only)
2. Instant Kill - 14 days before harvest (14 dbh)
3. Reglone 240™ - 1.2 L/ac - single application (14 dbh)
4. Reglone 240™ - 0.8 L/ac + 0.6 L/ac - split application (14 and 7 dbh)
5. Reglone 240™ - 1.2 L/ac - single application (7 dbh)
6. Rolled 1X - 14 dbh
7. Rolled 1X (14 dbh) + 1.1 L/ac Reglone 240™ - simultaneous application
8. Liberty™ - 1.2 L/ac - single application (14 to 21 dbh)

Prior to treating the plots, plots will be staked, petiole samples will be collected (four per field within the treatment area), and initial tuber samples will be collected to establish a base point for tuber bulking. Leaf material (four samples of 20 leaves within the treatment area) will be collected to establish a base line for leaf desiccation measurements. Fourteen days before harvest (14 dbh), all above ground plant material will be removed from plants in treatment #2. This will act as an instantaneous vine removal for comparative purposes. Also, treatments #3 and #4 will be sprayed with Reglone™, treatment #8 will be sprayed with Liberty™, treatments #6 and #7 will be mechanically damaged with a vine roller and treatment #7 will be sprayed with Reglone™. Every three days after the treatments begin, a tuber sample will be collected from the control plots (green harvest) to follow the rate of tuber bulking in untreated plants. Seven days before harvest (7 dbh), treatment #5 will be sprayed with Reglone™ and treatment #4 will be sprayed with the second application of Reglone™. Tubers from the center two rows of each replicate will be harvested mechanically (two rows x 50'). Tuber samples will be used to estimate yield. and. Sub-samples will be graded using the guidelines for the Western Canadian Potato Breeding Program and will be used to determine specific gravity, internal defects, and tuber quality. Another sub-sample will be stored for 4 months, then used to determine and fry quality.

5E) RELATED RESEARCH

a) At your institution

- The first year of this study was conducted in 2001 in southern Alberta. The two fields studied were managed differently and provided different insights. Results indicated that potatoes may bulk up to 2 ton/acre/week in the weeks prior to harvest. Vine rolling reduced yield in Russet Burbank unless accompanied by desiccant application. Specific gravity was affected by the method of vine killing, but tuber quality was largely unaffected (Konschuh et al., 2001).

- Studies were conducted in Brooks in 1986 and 1987 on the effect of planting date, maturity and speed of vine kill on stem-end discolouration and yield of Russet Burbank and Norchip potatoes. Results showed that potato plants sprayed with a desiccant continue to bulk and will yield significantly more than plants that have had tops mechanically removed at the same time (Schaupmeyer 1988).

b) At other institutions

- Halderson et al. (1985) conducted a study looking into the rate of vine kill (using different methods) and the effect on stem-end discolouration in tubers. They concluded that stem-end discolouration correlated well with immature vines, but not with the speed of desiccation.

- In 1989, Halderson reported that specific gravity of tubers may be affected by the method of vine kill if the vines were not allowed to mature fully before killing. Dehydration of the vines was considered complete after approximately 12 days, and harvest could proceed after that length of time. In Halderson's study, skin sets were difficult to measure and were considered somewhat unpredictable.

- Rioux (1991) compared visual assessments with metric measurements of vine desiccation on potatoes. Rioux reported that there was a linear relationship between the two methods of measurement and that it was not necessary to use both methods to assess the performance and speed of potato vine desiccants.

- Extension brochures from University of Idaho, and articles in trade journals address the topic of vine management. Few of these cite specific research on the topic and some provide conflicting information. In general, producers must consider harvest damage prevention, harvest timing, tuber size management, disease management, storage duration, vine maturity and economics when selecting a vine management strategy (Plissey 2000). The length of the growing season, vine maturity, tuber maturity and end use of the potatoes must also be considered.

- In Carberry, Manitoba (2000) a study was conducted comparing Liberty with Reglone as a desiccant for potatoes. Liberty is not registered as a desiccant on potatoes, but may eventually become an alternative to Reglone.

- There were no reports of vine management research being conducted at the Potato Association of America meetings, the University of Idaho potato school, or at the Western Potato Council meetings this year.

6) BENEFITS OF PROJECT

What are the potential economic, marketing, and quality benefits to Alberta's potato producers and to Alberta's potato industry in general. Include economic analysis of increased production potential or changed management as a result of information found in this study.

a) To Alberta's potato producers.

- Knowledge about various vine killing strategies will allow producers to make better decisions with regard to size control, harvest timing and effective vine killing.
- Vine rolling may be a cost effective approach to reduce the application rate or number of applications of diquat.
- Fry quality and storage duration may be improved through the use of appropriate vine kill strategies.

b) To Alberta's potato industry.

- The key benefit of improved vine kill strategies is that a good supply of Russet Burbank potatoes will be harvested and stored for french fry processing plants.
- Tuber size will be better controlled for economic french fry production.
- Good vine management strategies will result in less greening, good skin set, fewer internal defects, and better tuber quality going into storage.

7D) OTHER EXPENSES TO BE PAID WITH PGA/OTHER FUNDS FOR 1 YEAR

DESCRIPTION	AMOUNT
Overhead -- 5 percent.	$758.20
Other G.S.T. (7%)	$1,114.55
TOTAL OTHER EXPENSES	$1,872.75

7E) SUMMARY OF FUNDS REQUIRED FROM PGA AND OTHER SOURCES FOR 1 YEAR

DESCRIPTION	COST
Professional, technical, and casual labour	$8,800.00
Travel and accommodation	$914.00
Materials, supplies and services	$5,450.00
Other expenses	$1,872.75
TOTAL COSTS FOR WHICH FUNDING IS REQUESTED FROM ALL FUNDING SOURCES (A+B+C+D)	**$17,036.75**

7F) FUNDING SOURCE SUMMARY FOR 1 YEAR

FUNDING SOURCE	AMOUNT
Amount requested from PGA in this application	$17,000.00
Other Syngenta (Reglone) - donation	
Other Aventis (Liberty) - donation	
TOTAL FUNDS APPLIED FOR (EQUAL TO E, ABOVE)	**$17,000.00**

8) APPROVAL BY PRINCIPAL APPLICANT'S EMPLOYER

The undersigned declare the approval and support of their organization for the research project as described 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.

Christine Murray	Christine Murray	Director	March 8 2002
Name	Signature	Position	Date

9) 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 PGA Board.***

[signature]
Principal Cooperator Signature

March 8, 2002
Date

PGA Executive Committee Signature

Date

Alberta
AGRICULTURE, FOOD AND
RURAL DEVELOPMENT

Crop Diversification Centre
South

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

Telephone 403/362-1300
Fax 403/362-1306

May 22, 2003

Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1

Attention: Board of Directors

Re: Application for Funding
"Timing of Power Hilling for Russet Burbank in Southern Alberta"

Dear Board Members:

Enclosed are 10 copies of the funding application for our project entitled "Timing of Power Hilling for Russet Burbank in Southern Alberta". The trial will be conducted at CDCS in replicated plots. With spring weather being variable, hilling cannot always proceed at an optimal time. The purpose of this trial is to determine how much damage is caused by hilling later than desired. We are requesting a contribution of $3,500 from the PGA for 203. A second year of data may also be required. Please contact me if you have any questions (403-362-1314).

Thank you for your consideration. I look forward to hearing from you.

Sincerely,

Michele Konschuh, Ph.D.
Potato Research Agronomist

6.7

POTATO GROWERS OF ALBERTA

FUNDING APPLICATION

Timing of Power Hilling for Russet Burbank in Southern Alberta

Submitted by

Michele Konschuh and Simone Dalpé,

May 5, 2003

OK
approved!

POTATO GROWERS OF ALBERTA
FUNDING APPLICATION- SUMMARY PAGE

PROJECT TITLE

Timing of Power Hilling for Russet Burbank Southern Alberta

REASON FOR PROJECT (Objectives of project) (75 words)

As growers increase acreage of potatoes in southern Alberta, timing of operations throughout the year becomes more challenging. Wet conditions in the spring may also delay operations. We have had a number of questions regarding the optimal timing for power hilling as well as how much damage plants sustain when power hilling is delayed. Growers cannot experiment with timing of power hilling without risking yield reduction and plant damage, so they must use a conservative approach to power hilling. We propose to look at the effect of power hilling, under normal and more extreme circumstances.

PROJECT PLAN (What is going to be done - 50 words)

We propose to conduct the study in small plots at the Crop Diversification Centre in Brooks. Not hilling will be compared with disc hilling and power hilling up to 5 weeks after planting. Each treatment will be replicated four times. Four rows of 25 hills will be subjected to each treatment and the centre two rows will be harvested. Potatoes will be graded for total yield, marketable yield, deformities, greening and internal defects. The project should be conducted for at least two years to ensure that environmental conditions do not lead us to false conclusions.

BENEFITS TO ALBERTA'S POTATO INDUSTRY (50 words.)

Information about timing of power hilling specific to Alberta's processing potato production area may enable growers to make informed decisions about when and how to hill potatoes without sacrificing yield or grade.

DURATION OF PROJECT. The project will start (month/year) _May, 2003_ and will run until (month/year) _December, 2005_

FINANCIAL INFORMATION

	This year only	Total all years
Project cost	$7,450	$14,900
Amount requested from PGA	$4,000	$8,000
Amount from other sources	$3,450	$6,900

PRINCIPAL APPLICANT INFORMATION

Principal applicant's name	Phone
Michele Konschuh	403-362-1314
Research agency or company	
AAFRD, CDC South	
Mailing Address	**Postal code**
S.S. #4, Brooks, AB	T1R 1E6

Location of research project.(Research farm name or legal location.)

CDCS – Brooks, AB

3C) **PROJECT CONTINGENCIES**

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

Yes ____ No ____ Yes, with changes _X_

b) Modifications necessary:

We may conduct a smaller study and we would need to reduce the number of treatments and the nature of the data collected.

BACKGROUND, OBJECTIVES, AND PLAN

5A) Background to the Proposed Project

Potato acreage is expanding in southern Alberta and many growers expand operations without proportional increases in equipment or manpower. Also, spring weather is unpredictable at best, and for the past two years moisture has prevented growers from planting potatoes during an optimal timeframe. In recent years, most growers have implemented power hilling as part of their spring planting routine. In the event that there is a delay between planting and hilling, potatoes may sustain root damage and subsequent yield losses (Schaupmeyer 1992, Rowe and Secor 1993). When plants have emerged and power hilling is no longer deemed safe, some growers may rely on conventional hillers. Further, power hilling may not be suited to all soil types. There have been observations that power hillers overwork the soil and result in compaction in heavier soils.

The purpose of the proposed research is to compare not hilling with conventional and power hilling at weekly intervals for up to 5 weeks after planting. Potatoes will be graded for total yield, marketable yield, deformities, greening and internal defects

References:

Rowe, R. C. and G. A. Secor. 1993. Managing Potato Health from Emergence to Harvest. In: Potato Health Management (R. C. Rower, editor). APS Press, St. Paul, MN. Pp. 35-40.

Schaupmeyer, C. A. 1992. Potato Production Guide for Commercial Producers. Alberta Agriculture Agdex 258/20-8. pp. 20-21.

5B) Objectives

To determine how many weeks after planting potatoes can be power hilled before root pruning and yield loss occur; and

To compare conventional hilling to power hilling with respect to yield and grade of potatoes.

5C) Research Plan

Russet Burbank potatoes will be planted in 25 ft. blocks at CDCS. The plots will be irrigated and managed following the guidelines for the Western Canadian Potato Breeding Program. Each treatment will consist of our rows and only the center two rows will be harvested. Each treatment will be replicated four times. The trial should be conducted for two to three consecutive years to allow for differences in environmental conditions between years.

Ten treatments are planned as follows:

1. Control – no hilling (for comparison only)
2. Power hilling immediately after planting
3. Power hilling 1 week after planting
4. Power hilling 2 weeks after planting
5. Power hilling 3 weeks after planting
6. Power hilling 4 weeks after planting
7. Power hilling 5 weeks after planting
8. Disc hilling 3 weeks after planting
9. Disc hilling 4 weeks after planting
10. Disc hilling 5 weeks after planting

Potatoes will be planted with a two-row wheel planter. Hilling will be performed using a two-row disc hiller (disc hilling treatments) and a Stuik two-row power hiller (power hilling treatments). Observations regarding plant emergence and stage of development will be made for each treatment. Potatoes will be mechanically harvested to provide a yield estimate, and graded using the guidelines for the Western Canadian Potato Breeding Program. Greening, deformities and internal defects will also be recorded.

5D) Action Plan and Work Schedules

c) First year: 2003

May 2003	Plant potatoes and begin treatments
June 2003	Complete treatments
September 2003	Desiccate trial
	Harvest treatments
October 2003	Grade tubers
	Specific gravity, internal defects
	Data analysis
November 2003	Prepare poster for PGA annual meeting

6) BENEFITS OF PROJECT

What are the potential economic, marketing, and quality benefits to Alberta's potato producers and to Alberta's potato industry in general. Include economic analysis of increased production potential or changed management as a result of information found in this study.

a) To Alberta's potato producers.

- Knowledge about various hilling strategies will allow producers to make better decisions when weather conditions prevent optimum choices.

b) To Alberta's potato industry.

- The key benefit of the project is some actual data regarding the yield losses incurred by hilling too late with a power hiller.

7) BUDGET AND MANPOWER NEEDS **FOR 1 YEAR**

7A) MANPOWER TO BE HIRED WITH PGA/OTHER FUNDS

NAME (If known)	POSITION	TIME REQUIRED	RATE OF PAY	AMOUNT REQUIRED
Professional and Technical manpower				
Casual manpower	Field Labour	48 days	$120/day	$5,760
			TOTAL LABOUR COSTS	$5,760

7B) TRAVEL EXPENSES TO BE PAID WITH PGA/OTHER FUNDS FOR 1 YEAR

DESTINATION	PERSON(S)	PURPOSE	NUMBER OF TRIPS	TRAVEL COSTS	MEALS AND ACCOM.	TOTAL COST
PGA Conference	2	Present results	1	$280	$270.00	$550
					TOTAL TRAVEL COSTS	$550

7C) MATERIALS, SUPPLIES AND SERVICES TO BE PAID WITH PGA/OTHER FUNDS

DESCRIPTION	COST
Seed	$200
Bags, tags, stakes, etc.	$100
TOTAL COST OF MATERIALS, SUPPLIES AND SERVICES FOR 1 YEAR	$300

7D) OTHER EXPENSES TO BE PAID WITH PGA/OTHER FUNDS FOR 1 YEAR

DESCRIPTION	AMOUNT
Overhead -- 5 percent.	$330.50
Other G.S.T. (7%)	$485.84
TOTAL OTHER EXPENSES	$816.34

7E) SUMMARY OF FUNDS REQUIRED FROM PGA AND OTHER SOURCES FOR 1 YEAR

DESCRIPTION	COST
Professional, technical, and casual labour	$5,760.00
Travel and accommodation	$550.00
Materials, supplies and services	$300.00
Other expenses	$816.34
TOTAL COSTS OF PROJECT	**$7,426.34**

7F) FUNDING SOURCE SUMMARY FOR 1 YEAR

FUNDING SOURCE	AMOUNT
Amount requested from PGA in this application	$3,500.00
Other	
Other	
TOTAL FUNDS APPLIED FOR	**$3,500.00**

7G) **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	0.05	$3,110
Materials and supplies		
Travel		
Overhead (estimate)		$820
	TOTAL VALUE "IN-KIND" COSTS	**$3,930**

8) APPROVAL BY PRINCIPAL APPLICANT'S EMPLOYER

The undersigned declare the approval and support of their organization for the research project as described 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.

Christine Murray	Christine Murray	Leader CDC South	May 22/03
Name	Signature	Position	Date

9) 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 Board of the Potato Growers of Alberta.

b) Allow the Potato Growers of Alberta 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 permission of the Chairman of the PGA Board.***

[signature]

Principal Cooperator Signature

May 22, 2003

Date

PGA Executive Committee Signature

Date

Project
New: **X** Renewal:

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: Timing of Power Hilling for Russet Burbank in Southern Alberta.

Objectives:
1. To determine how many weeks after planting potatoes can be power hilled before root pruning and yield loss occur; and
2. To compare conventional hilling to power hilling with respect to yield and grade of potatoes.

STATEMENT OF WORK

Alberta Agriculture, Food & Rural Development is willing to undertake this study for the PGA, who hereby agrees to contribute toward the costs of researching the information required as described in the research proposal.

PERIOD OF WORK

The research project will commence in May, 2003. A yearly report will be provided to the PGA by December 31, 2003.

BASIS OF PAYMENT

The sponsor of the project, the PGA, will provide $4,000 upon finalization of this memorandum to AAFRD, to cover the following estimated yearly costs:

Casual Manpower (on an as need basis): $4,000

The 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.

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. Michele Konschuh. She will provide all reports to AAFRD and 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 herself.

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:

Potato Growers of Alberta	Alberta Agriculture, Food & Rural Development:
Mr. Vern Warkentin Executive Director Potato Growers of Alberta 6008 – 46th Avenue Taber, AB T1G 2B1	Dr. Christine Murray Branch Head, CDCS Crop Diversification Centre South S.S. #4 Brooks, AB T1R 1E6

Information generated from the project may be used by the Department of Agriculture, Food & Rural Development and the PGA.

The sponsor, the PGA, relinquishes ownership of any materials, supplies and assets purchased with project funds to the AAFRD 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. Michele Konschuh, Project Manager

Date July 2, 2003

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

Dr. Christine Murray, Branch Head, CDCS

Date July 2/03

Mr. Vern Warkentin, Executive Director
Potato Growers of Alberta

Date July 9/03

Alberta
AGRICULTURE, FOOD AND
RURAL DEVELOPMENT

Crop Diversification Centre
South

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

Telephone 403/362-1300
Fax 403/362-1306

July 2, 2003

Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1

Attention: Vern Warkentin, Executive Director

Re: MOU for "Timing of Power Hilling for Russet Burbank in Southern Alberta" project

Dear Vern;

Thank you for your e-mail in June advising me that the PGA is willing to fund our project entitled "Timing of Power Hilling for Russet Burbank in Southern Alberta" in 2003. As a formality, we like to set up a Memorandum of Understanding (MOU) with each cooperator for externally funded projects. Please review the enclosed MOU. If the terms of the MOU are acceptable, please sign both copies and return an original to me. If you would prefer to propose alternate terms, please contact me at 403-362-1314 and we can discuss the terms further. An invoice will be issued under separate cover. Thank you.

Sincerely,

Michele Konschuh, Ph.D.
Potato Research Agronomist

RECEIVED JUL 0 4 2003

Alberta
AGRICULTURE, FOOD AND
RURAL DEVELOPMENT

Crop Diversification Centre
South

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

Telephone 403/362-1300
Fax 403/362-1306

December 31, 2003

Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1

Attention: Board of Directors

Re: "Timing of Power Hilling for Russet Burbank in Southern Alberta" 1st Year Project Report

Dear Board Members;

Thank you for your interest in a trial looking at timing of power hilling for Russet Burbank potatoes. Enclosed are ten copies of the project report for the first year of the project. The trial was interesting to conduct and I believe we got some worthwhile information from the project. A second year of the trial is planned for 2004 and some ideas raised at the PGA general meeting may be incorporated to add to the information generated. Please review the enclosed report and let me know if you have any questions.

I am working with our Information Officer to prepare a pamphlet to summarize our findings. I would welcome an opportunity to give a short presentation on this topic and discuss future research plans. Please contact me by phone at 403-362-1314 or by e-mail at michele.konschuh@gov.ab.ca. Thank you.

Sincerely,

Michele Konschuh, Ph.D.
Potato Research Agronomist

Encl.

- this letter to the Research Binder with the copy of the report

Project Report

Timing of Power Hilling for Russet Burbank in Southern Alberta

Prepared for:

Potato Growers of Alberta
6008, 46th Avenue
Taber, AB T1G 2B1

Prepared by:

Michele Konschuh, Simone Dalpé, and Darcy Driedger
Crop Diversification Centre South / Food Processing Development Centre
S.S. #4
Brooks, AB T1R 1E6

December 31, 2003

Background

Potato acreage is expanding in southern Alberta and many growers have expanded operations without a proportional increase in equipment or manpower. In recent years, most growers have implemented power hilling as part of their spring planting routine, rather than hilling later in the spring with conventional hilling equipment. Alberta's spring weather is unpredictable at best, and for the past two years moisture has prevented growers from planting potatoes during an optimal window of time. Although damage from late hilling is anticipated, there is little information regarding the impact this damage has on yield or quality of processing potatoes. When plants have emerged and power hilling is no longer deemed safe, some growers may rely on conventional hillers.

Traditionally, commercially grown potatoes are hilled in the production cycle between emergence and canopy close (Carling and Walworth 1990, Geisel 2003). Geisel (2003) maintains that hilling is the only tillage operation necessary in the production of potatoes on the Canadian Prairies. Hilling improves drainage, minimizes tuber greening, minimizes frost damage, aids in weed control and facilitates harvesting (Carling and Walwoth 1990, Vangessel and Renner 1990, Renner 1992, Geisel 2003). Cultivation may benefit potatoes by aerating and improving the soil structure, but it may be detrimental to potato growth if soil structure is damaged, potato roots are pruned, or foliage is damaged (Carling and Walworth 1990, Renner 1992, Schaupmeyer 1992, Secor 1993).

Rotary hoes, discs, mouldboards, or power hillers equipped with a metal mould are commonly used to hill potatoes (Geisel 2003). Conventional hilling is typically conducted when plants were approximately 30 cm tall because there is little risk of covering the foliage (Carling and Walworth 1990, Vangesel and Renner 1990, Renner 1992). Vines of larger plants may, however, sustain greater damage from hilling than smaller plants, and the possibility of damaging roots and stolons increases as the plants increase in size (Carling and Walworth 1990, Rowe and Secor 1993). Geisel (2003) recommends that post-emergent hilling with conventional equipment be completed before the plants are 20 cm in height to avoid damage to roots and foliage and power hilling should be completed prior to emergence to avoid covering the plants.

The purpose of this project was to determine optimal timing of power hilling for Russet Burbank potatoes in southern Alberta and to compare not hilling with conventional and power hilling at weekly intervals for up to five weeks after planting. Potatoes were graded for total yield, marketable yield, deformities, internal defects, specific gravity and fry colour.

Objectives

1. To determine how many weeks after planting potatoes can be power hilled before root pruning and yield loss occur; and
2. To compare conventional hilling to power hilling with respect to yield and grade of potatoes.

Materials and Methods

Russet Burbank seed (E3) of the same seed lot was used for this trial. Seed pieces approximately 70 to 85 g were planted 30 cm apart in 7.5 m rows spaced 90 cm apart. Seed was treated with Maxim™ seed piece treatment (500 g/100 kg seed) prior to planting. Eptam 8E (2.0 L/ac) herbicide was incorporated prior to planting the potatoes. All treatments were planted May 27, 2003 at CDCS in Brooks, AB. Each treatment was replicated four times. Each treatment was 4 rows wide, but only the two center rows were harvested (see plot plan).

Potatoes were hilled with a power hiller or a disc hiller according to the treatment list below:

Treatments:

1. Control – no hilling (for comparison only)
2. Power hilling immediately after planting
3. Power hilling 1 week after planting
4. Power hilling 2 weeks after planting
5. Power hilling 3 weeks after planting
6. Power hilling 4 weeks after planting
7. Power hilling 5 weeks after planting
8. Disc hilling 3 weeks after planting
9. Disc hilling 4 weeks after planting
10. Disc hilling 5 weeks after planting

Lorox (0.91 – 1.82 L/ac) was applied May 29 for broadleaf weed control. The plots were irrigated throughout the season to maintain soil moisture close to 70%. Foliar fungicides were applied approximately every 2 weeks during the growing season to prevent early blight and late blight from developing (Table 1). Insecticide (Thionex, 0.6 L/ac) was applied July 9 to control Colorado Potato Beetle. Prism (24 g/ac; + surfactant) was applied July 9 to control weeds.

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

Date of Application	*Fungicide*	*Rate*
June 26	Quadris	0.250 L/ac
July 9	Ridomil Gold	1.13 L/ac
July 25	Dithane DG Rainshield	0.60 kg/ac
August 8	Bravo 500	0.75 L/ac
August 22	Bravo 500	0.75 L/ac

All treatments were harvested mechanically October 6 and 7. Tubers were weighed to obtain yield estimates and graded to remove small and deformed tubers. Marketable tubers (48 to 88 mm in diameter) were weighed to obtain estimates of marketable yield. Yield estimates have been presented in ton/acre although small plot trials do not always accurately reflect commercial yield potential. A sample of 25 marketable tubers was washed and used to determine specific gravity by the weight-in-air over weight-in-water method. Each of these tubers was then cut longitudinally to assess brown center, hollow heart and other internal defects. Also, a sample of marketable tubers was submitted to the Food Science lab at CDCS for fry quality analysis. Eight tubers were used to process fries, and 5 fry strips from each potato were used to assess fry color. Fry color was rated on a scale of 1 to 7 where 1 = very dark and 7 = very light.

Data were statistically analyzed using ANOVA and Duncan's Multiple Range Test ($p \leq 0.05$; SAS).

Results and Discussion

The trial was planted later than anticipated as a result of a cool, wet spring. Hilling treatments were planned at weekly intervals for comparison, however, the stage of growth and development of the potato plants is more informative than the time elapsed after planting. Environmental conditions affected the stage of growth and development and plants emerged rapidly after planting in 2003. The growth stages of potatoes were noted for each treatment (Table 2).

Table 2: Stages of potato growth and development at the time hilling was conducted for each treatment in 2003.

Treatment(s)	*Weeks After Planting*	*Stage of Potato Growth and Development*
1	No Hilling	N/A
2	Immediately After	Planted
3	1	Ground Crack; Growth Stage I
4	2	Emergence; Growth Stage II
5, 8	3	2 – 5" Plants; Growth Stage II
6, 9	4	7" Plants; stolon hooking; Growth Stage II
7, 10	5	12 – 15" Plants; Growth Stage III

In 2003, hilling with a power hiller any time from immediately after planting to 3 weeks after planting significantly improved gross yield of potatoes compared to not hilling (Figure 1). This corresponded to growth stages I and II (sprout development and vegetative growth). Carling and Walworth (1990) also reported that all four hilled treatments in their study yielded significantly more than the treatment that was not hilled. The highest gross yield was observed when Russet Burbank potatoes were power hilled 2 weeks after planting, when plants were just emerging from the hills.

Hilling with a disc hiller 3 to 5 weeks after planting improved yield relative to the control, but power hilling 4 and 5 weeks after planting resulted in a slight reduction in gross yield relative to the control (Figure 1). These hilling events corresponded to late stage II and early stage III (tuber initiation). Few studies have looked at the effects of the timing of hilling on potato yield and quality, and none have addressed timing of power hilling. Many of the papers dealing with timing of hilling are focused on hilling as a means of weed control, and few time frames are included. Vangessel and Renner (1990) and Renner (1992) used early hilling (ground crack) and conventional hilling (plants 12" tall) time frames in their study of weed interference in potato. In their studies, no difference in yield or marketable yield could be attributed to the time of hilling. However, in the absence of other methods of weed control, the timing of hilling impacted weed biomass, type of weed species present and yield (Renner 1992).

Rajalahti et al. (1999) used a cultivator type hiller 3 weeks after planting (late ground cracking), 4 weeks after planting (1 week after 50% potato emergence) and 5 weeks after planting (2 weeks after 50% potato emergence). Their study reported significantly greater yield in plots hilled 3 weeks after planting than those hilled 4 and 5 weeks after planting and in those hilled 4 weeks after planting compared to those hilled 5 weeks after planting, but there were no significant differences in marketable yield between timings. We also observed greater total yield in disc hilled treatments 3 weeks after planting compared to 4 or 5 weeks after planting (Figure 1), and no significant difference in marketable yield (Table 3). The difference in total yield was a result of a greater yield of small potatoes.

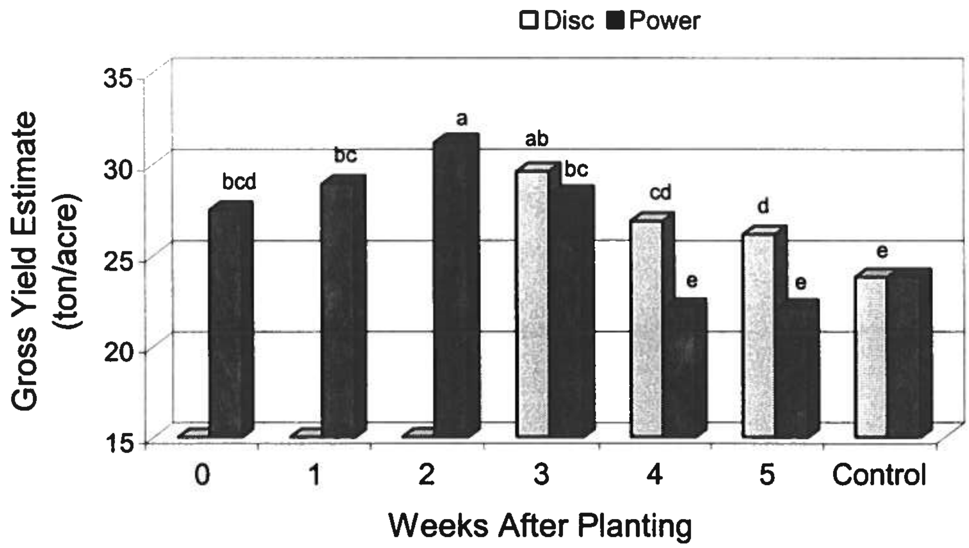

Figure 1: Gross yield estimates (ton/acre) of Russet Burbank potatoes from plants hilled with a disc hiller or a power hiller at weekly intervals from immediately after planting to 5 weeks after planting. Bars with the same letter are not significantly different at the p>0.05 level.

Harvested tubers were graded according to the Guidelines for the Western Canadian Potato Breeding Program. Potatoes with a diameter of less than 1⅞" were categorized as small tubers, tubers between 1⅞" and 3½" were classed as marketable and potatoes greater than 3½" in diameter were classed as oversized. Tubers with secondary growth, growth cracks and other deformities were reported as deformed. Results of grading from the trial are shown in Table 3. Not hilling (control) resulted in more small tubers than hilled treatments, possibly a result of hot, dry weather during tuber initiation and bulking. The greatest marketable yield was observed when Russet Burbank potatoes were power hilled two weeks after planting. In 2003, this timing corresponded with emergence of the plants from the hills. Power hilling up to three weeks after planting and disc hilling up to five weeks after planting resulted in significantly greater marketable yield than the control. Carling and Walworth hilled with a spider hiller when plants were 4 to 6" high (early treatment) or when plants were 12" high (late treatment), and reported no significant difference in total or marketable yield as a result of these treatments. Their treatments roughly correspond to our disc hilled treatments 4 and 5 weeks after planting. Power hilling 4 and 5 weeks after planting reduced marketable yield compared to power hilling up to 3 weeks after planting. Few oversized tubers were observed for any of the treatments, likely a result of planting late. No real pattern was observed for yield of deformed tubers.

Table 3: Yield estimates (ton/acre) by size category of Russet Burbank potatoes from plants power hilled or disc hilled at various times from immediately after planting to 5 weeks after planting. Bars with the same letter are not significantly different at the P>0.05 level.

Trt.	*Weeks After Planting*	*Small (<1⅞")*	*Marketable (1⅞-3½")*	*Oversize (>3½")*	*Deformed*
1	Not Hilled	12.02 a	10.77 d	0.04 ab	0.98 ab
	Power Hilled				
2	Immediately After	7.30 c	19.14 b	0.15 ab	0.89 abc
3	1	7.97 bc	19.48 b	0.33 a	1.14 a
4	**2**	**8.11 bc**	**22.36 a**	**0.68 ab**	**0.62 abcd**
5	3	9.42 b	18.38 b	0.16 ab	0.38 cd
6	4	9.60 b	11.74 cd	0.00 b	0.80 abcd
7	5	7.53 bc	14.19 c	0.04 ab	0.34 d
	Disc Hilled				
8	3	11.57 a	17.06 b	0.00 b	0.95 ab
9	4	7.83 bc	18.39 b	0.13 ab	0.52 bcd
10	5	7.85 bc	17.15 b	0.18 ab	0.97 ab

Specific gravity data is shown in Table 4. Potatoes from hilled treatments had higher specific gravity than those from the control treatment, although few of the differences were statistically significant. The highest specific gravities were observed in the samples from treatments power hilled up to three weeks after planting. No reported information was found linking specific gravity to method or timing of hilling.

Table 4: Specific Gravity of tubers harvested from plants hilled 0 to 5 weeks after planting. Specific gravity was measured using the weight in air over weight in water method.

Type of Hilling	*Weeks After Planting*					
	0	*1*	*2*	*3*	*4*	*5*
Power	1.0778 ab	1.0768 ab	1.0795 ab	1.0805 a	1.0683 ab	1.0705 ab
Disc				1.0695 ab	1.0675 b	1.0700 ab
None	1.673 b					

Fry quality data is presented in Table 5. The best fry quality was observed for tubers from treatments hilled 3 weeks after planting. Power hilling between 2 and 4 weeks after planting and disc hilling 3 and 4 weeks after planting resulted in significantly better fry color than not hilling or hilling outside of those time frames. This corresponded to Growth Stage II, vegetative growth. Hilling prior to emergence and hilling once tuber initiation had begun gave less desirable fry scores. No reported information was found linking fry colour to method or timing of hilling.

Table 5: Fry color data for tubers harvested from plants hilled 0 to 5 weeks after planting. Fry color was rated on a scale of 1 to 7 where 1 = very dark (U.S.D.A. 4 rating) and 7 = very light (U.S.D.A. 000 rating).

Type of Hilling	***Weeks After Planting***					
	0	***1***	***2***	***3***	***4***	***5***
Power	3.25 c	3.50 bc	3.75 abc	4.50 a	4.25 ab	3.00 c
Disc				4.50 a	3.75 abc	2.00 d
None	3.00 c					

Summary

Hilling with a power hiller any time from immediately after planting to 3 weeks after planting improved gross yield of Russet Burbank potatoes compared to not hilling (control). Hilling with a disc hiller up to 5 weeks after planting also improved gross yield relative to the control. All treatments, whether hilled with a disc hiller or power hiller, resulted in greater marketable yield than the control. The optimum time to hill with a power hiller appears to be at the time of plant emergence although power hilling up to stolon hooking still resulted in acceptable marketable yields. Late hilling caused a reduction in total yield, however late power hilling was more detrimental to marketable yield than late disc hilling. If power hilling has not been completed by the time plants are 2 to 5" tall, disc hilling may be better than power hilling.

Power hilling 3 weeks after planting resulted in higher specific gravity than the control, however few significant differences in specific gravity were observed between hilled treatments. The best fry quality was observed for treatments hilled 3 weeks after planting, a time when plants were 2 to 5" tall. Fry color was darker for treatments that were not hilled, or were hilled immediately after planting, or 5 weeks after planting when plants were 12 to 15" tall.

In 2003, power hilling Russet Burbank potatoes at emergence or just after emergence resulted in the best combination of marketable yield and good fry color. A second year of the trial is planned for 2004.

References

Carling, D. E. and J. L. Walworth. 1990. The effect of hilling on yield and quality of potatoes. Research Progress Report No. 16, University of Alaska, Fairbanks Agricultural and Forestry Experimental Station.

Geisel, B. 2003. Weed management. In: Guide to Commercial Potato Production on the Canadian Prairies, Western Potato Council, Portage La Prairie, MB, pp: 3.6-9 to 3.6-11.

Rajalahti, R. M., R. R. Bellinder and M. P. Hoffmann. 1999. Time of hilling and interseeding affects weed control and potato yield. Weed Science. 47: 215-225.

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Vangessel, M. J. and K. A. Renner. 1990. Effect of soil type, hilling time, and weed interference on potato (*Solanum tuberosum*) development and yield. Weed Technology. 4: 299-305.

Alberta
AGRICULTURE, FOOD AND
RURAL DEVELOPMENT

Crop Diversification Centre
South

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

Telephone 403/362-1300
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December 31, 2003

Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1

Attention: Board of Directors

Re: "Timing of Power Hilling for Russet Burbank in Southern Alberta" 1st Year Project Report

Dear Board Members;

Thank you for your interest in a trial looking at timing of power hilling for Russet Burbank potatoes. Enclosed are ten copies of the project report for the first year of the project. The trial was interesting to conduct and I believe we got some worthwhile information from the project. A second year of the trial is planned for 2004 and some ideas raised at the PGA general meeting may be incorporated to add to the information generated. Please review the enclosed report and let me know if you have any questions.

I am working with our Information Officer to prepare a pamphlet to summarize our findings. I would welcome an opportunity to give a short presentation on this topic and discuss future research plans. Please contact me by phone at 403-362-1314 or by e-mail at michele.konschuh@gov.ab.ca. Thank you.

Sincerely,

Michele Konschuh, Ph.D.
Potato Research Agronomist

Encl.

Project Report

Timing of Power Hilling for Russet Burbank in Southern Alberta

Prepared for:

Potato Growers of Alberta
6008, 46th Avenue
Taber, AB T1G 2B1

Prepared by:

Michele Konschuh, Simone Dalpé, and Darcy Driedger
Crop Diversification Centre South / Food Processing Development Centre
S.S. #4
Brooks, AB T1R 1E6

December 31, 2003

Background

Potato acreage is expanding in southern Alberta and many growers have expanded operations without a proportional increase in equipment or manpower. In recent years, most growers have implemented power hilling as part of their spring planting routine, rather than hilling later in the spring with conventional hilling equipment. Alberta's spring weather is unpredictable at best, and for the past two years moisture has prevented growers from planting potatoes during an optimal window of time. Although damage from late hilling is anticipated, there is little information regarding the impact this damage has on yield or quality of processing potatoes. When plants have emerged and power hilling is no longer deemed safe, some growers may rely on conventional hillers.

Traditionally, commercially grown potatoes are hilled in the production cycle between emergence and canopy close (Carling and Walworth 1990, Geisel 2003). Geisel (2003) maintains that hilling is the only tillage operation necessary in the production of potatoes on the Canadian Prairies. Hilling improves drainage, minimizes tuber greening, minimizes frost damage, aids in weed control and facilitates harvesting (Carling and Walwoth 1990, Vangessel and Renner 1990, Renner 1992, Geisel 2003). Cultivation may benefit potatoes by aerating and improving the soil structure, but it may be detrimental to potato growth if soil structure is damaged, potato roots are pruned, or foliage is damaged (Carling and Walworth 1990, Renner 1992, Schaupmeyer 1992, Secor 1993).

Rotary hoes, discs, mouldboards, or power hillers equipped with a metal mould are commonly used to hill potatoes (Geisel 2003). Conventional hilling is typically conducted when plants were approximately 30 cm tall because there is little risk of covering the foliage (Carling and Walworth 1990, Vangesel and Renner 1990, Renner 1992). Vines of larger plants may, however, sustain greater damage from hilling than smaller plants, and the possibility of damaging roots and stolons increases as the plants increase in size (Carling and Walworth 1990, Rowe and Secor 1993). Geisel (2003) recommends that post-emergent hilling with conventional equipment be completed before the plants are 20 cm in height to avoid damage to roots and foliage and power hilling should be completed prior to emergence to avoid covering the plants.

The purpose of this project was to determine optimal timing of power hilling for Russet Burbank potatoes in southern Alberta and to compare not hilling with conventional and power hilling at weekly intervals for up to five weeks after planting. Potatoes were graded for total yield, marketable yield, deformities, internal defects, specific gravity and fry colour.

Objectives

1. To determine how many weeks after planting potatoes can be power hilled before root pruning and yield loss occur; and
2. To compare conventional hilling to power hilling with respect to yield and grade of potatoes.

Materials and Methods

Russet Burbank seed (E3) of the same seed lot was used for this trial. Seed pieces approximately 70 to 85 g were planted 30 cm apart in 7.5 m rows spaced 90 cm apart. Seed was treated with Maxim™ seed piece treatment (500 g/100 kg seed) prior to planting. Eptam 8E (2.0 L/ac) herbicide was incorporated prior to planting the potatoes. All treatments were planted May 27, 2003 at CDCS in Brooks, AB. Each treatment was replicated four times. Each treatment was 4 rows wide, but only the two center rows were harvested (see plot plan).

Potatoes were hilled with a power hiller or a disc hiller according to the treatment list below:

Treatments:

1. Control – no hilling (for comparison only)
2. Power hilling immediately after planting
3. Power hilling 1 week after planting
4. Power hilling 2 weeks after planting
5. Power hilling 3 weeks after planting
6. Power hilling 4 weeks after planting
7. Power hilling 5 weeks after planting
8. Disc hilling 3 weeks after planting
9. Disc hilling 4 weeks after planting
10. Disc hilling 5 weeks after planting

Lorox (0.91 – 1.82 L/ac) was applied May 29 for broadleaf weed control. The plots were irrigated throughout the season to maintain soil moisture close to 70%. Foliar fungicides were applied approximately every 2 weeks during the growing season to prevent early blight and late blight from developing (Table 1). Insecticide (Thionex, 0.6 L/ac) was applied July 9 to control Colorado Potato Beetle. Prism (24 g/ac; + surfactant) was applied July 9 to control weeds.

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

Date of Application	***Fungicide***	***Rate***
June 26	Quadris	0.250 L/ac
July 9	Ridomil Gold	1.13 L/ac
July 25	Dithane DG Rainshield	0.60 kg/ac
August 8	Bravo 500	0.75 L/ac
August 22	Bravo 500	0.75 L/ac

All treatments were harvested mechanically October 6 and 7. Tubers were weighed to obtain yield estimates and graded to remove small and deformed tubers. Marketable tubers (48 to 88 mm in diameter) were weighed to obtain estimates of marketable yield. Yield estimates have been presented in ton/acre although small plot trials do not always accurately reflect commercial yield potential. A sample of 25 marketable tubers was washed and used to determine specific gravity by the weight-in-air over weight-in-water method. Each of these tubers was then cut longitudinally to assess brown center, hollow heart and other internal defects. Also, a sample of marketable tubers was submitted to the Food Science lab at CDCS for fry quality analysis. Eight tubers were used to process fries, and 5 fry strips from each potato were used to assess fry color. Fry color was rated on a scale of 1 to 7 where 1 = very dark and 7 = very light.

Data were statistically analyzed using ANOVA and Duncan's Multiple Range Test ($p \leq 0.05$; SAS).

Results and Discussion

The trial was planted later than anticipated as a result of a cool, wet spring. Hilling treatments were planned at weekly intervals for comparison, however, the stage of growth and development of the potato plants is more informative than the time elapsed after planting. Environmental conditions affected the stage of growth and development and plants emerged rapidly after planting in 2003. The growth stages of potatoes were noted for each treatment (Table 2).

Table 2: Stages of potato growth and development at the time hilling was conducted for each treatment in 2003.

Treatment(s)	*Weeks After Planting*	*Stage of Potato Growth and Development*
1	No Hilling	N/A
2	Immediately After	Planted
3	1	Ground Crack; Growth Stage I
4	2	Emergence; Growth Stage II
5, 8	3	2 – 5" Plants; Growth Stage II
6, 9	4	7" Plants; stolon hooking; Growth Stage II
7, 10	5	12 – 15" Plants; Growth Stage III

In 2003, hilling with a power hiller any time from immediately after planting to 3 weeks after planting significantly improved gross yield of potatoes compared to not hilling (Figure 1). This corresponded to growth stages I and II (sprout development and vegetative growth). Carling and Walworth (1990) also reported that all four hilled treatments in their study yielded significantly more than the treatment that was not hilled. The highest gross yield was observed when Russet Burbank potatoes were power hilled 2 weeks after planting, when plants were just emerging from the hills.

Hilling with a disc hiller 3 to 5 weeks after planting improved yield relative to the control, but power hilling 4 and 5 weeks after planting resulted in a slight reduction in gross yield relative to the control (Figure 1). These hilling events corresponded to late stage II and early stage III (tuber initiation). Few studies have looked at the effects of the timing of hilling on potato yield and quality, and none have addressed timing of power hilling. Many of the papers dealing with timing of hilling are focused on hilling as a means of weed control, and few time frames are included. Vangessel and Renner (1990) and Renner (1992) used early hilling (ground crack) and conventional hilling (plants 12" tall) time frames in their study of weed interference in potato. In their studies, no difference in yield or marketable yield could be attributed to the time of hilling. However, in the absence of other methods of weed control, the timing of hilling impacted weed biomass, type of weed species present and yield (Renner 1992).

Rajalahti et al. (1999) used a cultivator type hiller 3 weeks after planting (late ground cracking), 4 weeks after planting (1 week after 50% potato emergence) and 5 weeks after planting (2 weeks after 50% potato emergence). Their study reported significantly greater yield in plots hilled 3 weeks after planting than those hilled 4 and 5 weeks after planting and in those hilled 4 weeks after planting compared to those hilled 5 weeks after planting, but there were no significant differences in marketable yield between timings. We also observed greater total yield in disc hilled treatments 3 weeks after planting compared to 4 or 5 weeks after planting (Figure 1), and no significant difference in marketable yield (Table 3). The difference in total yield was a result of a greater yield of small potatoes.

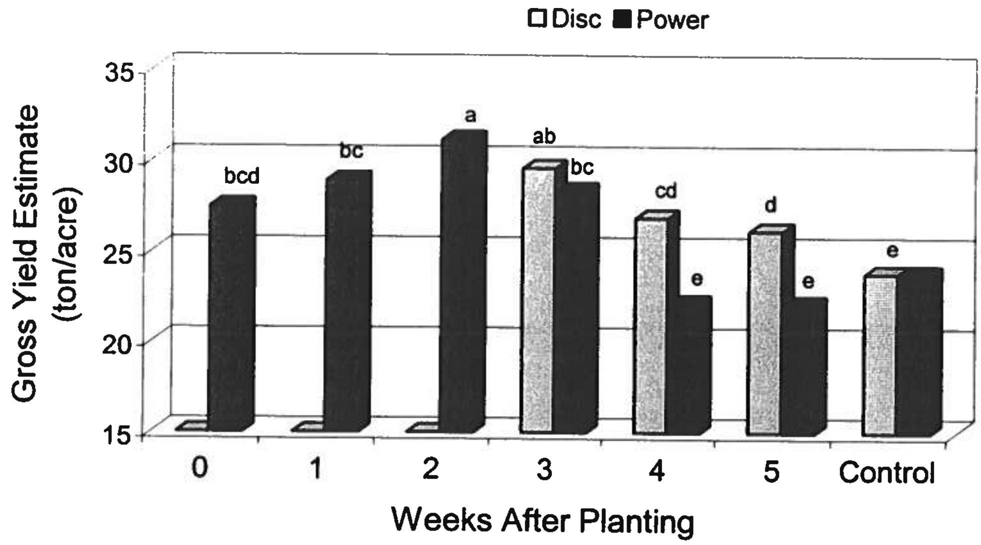

Figure 1: Gross yield estimates (ton/acre) of Russet Burbank potatoes from plants hilled with a disc hiller or a power hiller at weekly intervals from immediately after planting to 5 weeks after planting. Bars with the same letter are not significantly different at the p>0.05 level.

Harvested tubers were graded according to the Guidelines for the Western Canadian Potato Breeding Program. Potatoes with a diameter of less than 1⅞" were categorized as small tubers, tubers between 1⅞" and 3½" were classed as marketable and potatoes greater than 3½" in diameter were classed as oversized. Tubers with secondary growth, growth cracks and other deformities were reported as deformed. Results of grading from the trial are shown in Table 3. Not hilling (control) resulted in more small tubers than hilled treatments, possibly a result of hot, dry weather during tuber initiation and bulking. The greatest marketable yield was observed when Russet Burbank potatoes were power hilled two weeks after planting. In 2003, this timing corresponded with emergence of the plants from the hills. Power hilling up to three weeks after planting and disc hilling up to five weeks after planting resulted in significantly greater marketable yield than the control. Carling and Walworth hilled with a spider hiller when plants were 4 to 6" high (early treatment) or when plants were 12" high (late treatment), and reported no significant difference in total or marketable yield as a result of these treatments. Their treatments roughly correspond to our disc hilled treatments 4 and 5 weeks after planting. Power hilling 4 and 5 weeks after planting reduced marketable yield compared to power hilling up to 3 weeks after planting. Few oversized tubers were observed for any of the treatments, likely a result of planting late. No real pattern was observed for yield of deformed tubers.

Table 3: Yield estimates (ton/acre) by size category of Russet Burbank potatoes from plants power hilled or disc hilled at various times from immediately after planting to 5 weeks after planting. Bars with the same letter are not significantly different at the P>0.05 level.

Trt.	*Weeks After Planting*	*Small (<1⅞")*	*Marketable (1⅞-3½")*	*Oversize (>3½")*	*Deformed*
1	Not Hilled	12.02 a	10.77 d	0.04 ab	0.98 ab
	Power Hilled				
2	Immediately After	7.30 c	19.14 b	0.15 ab	0.89 abc
3	1	7.97 bc	19.48 b	0.33 a	1.14 a
4	**2**	**8.11 bc**	**22.36 a**	**0.68 ab**	**0.62 abcd**
5	3	9.42 b	18.38 b	0.16 ab	0.38 cd
6	4	9.60 b	11.74 cd	0.00 b	0.80 abcd
7	5	7.53 bc	14.19 c	0.04 ab	0.34 d
	Disc Hilled				
8	3	11.57 a	17.06 b	0.00 b	0.95 ab
9	4	7.83 bc	18.39 b	0.13 ab	0.52 bcd
10	5	7.85 bc	17.15 b	0.18 ab	0.97 ab

Specific gravity data is shown in Table 4. Potatoes from hilled treatments had higher specific gravity than those from the control treatment, although few of the differences were statistically significant. The highest specific gravities were observed in the samples from treatments power hilled up to three weeks after planting. No reported information was found linking specific gravity to method or timing of hilling.

Table 4: Specific Gravity of tubers harvested from plants hilled 0 to 5 weeks after planting. Specific gravity was measured using the weight in air over weight in water method.

Type of Hilling	*Weeks After Planting*					
	0	*1*	*2*	*3*	*4*	*5*
Power	1.0778 ab	1.0768 ab	1.0795 ab	1.0805 a	1.0683 ab	1.0705 ab
Disc				1.0695 ab	1.0675 b	1.0700 ab
None	1.673 b					

Fry quality data is presented in Table 5. The best fry quality was observed for tubers from treatments hilled 3 weeks after planting. Power hilling between 2 and 4 weeks after planting and disc hilling 3 and 4 weeks after planting resulted in significantly better fry color than not hilling or hilling outside of those time frames. This corresponded to Growth Stage II, vegetative growth. Hilling prior to emergence and hilling once tuber initiation had begun gave less desirable fry scores. No reported information was found linking fry colour to method or timing of hilling.

Table 5: Fry color data for tubers harvested from plants hilled 0 to 5 weeks after planting. Fry color was rated on a scale of 1 to 7 where 1 = very dark (U.S.D.A. 4 rating) and 7 = very light (U.S.D.A. 000 rating).

Type of Hilling	*Weeks After Planting*					
	0	*1*	*2*	*3*	*4*	*5*
Power	3.25 c	3.50 bc	3.75 abc	4.50 a	4.25 ab	3.00 c
Disc				4.50 a	3.75 abc	2.00 d
None	3.00 c					

Summary

Hilling with a power hiller any time from immediately after planting to 3 weeks after planting improved gross yield of Russet Burbank potatoes compared to not hilling (control). Hilling with a disc hiller up to 5 weeks after planting also improved gross yield relative to the control. All treatments, whether hilled with a disc hiller or power hiller, resulted in greater marketable yield than the control. The optimum time to hill with a power hiller appears to be at the time of plant emergence although power hilling up to stolon hooking still resulted in acceptable marketable yields. Late hilling caused a reduction in total yield, however late power hilling was more detrimental to marketable yield than late disc hilling. If power hilling has not been completed by the time plants are 2 to 5" tall, disc hilling may be better than power hilling.

Power hilling 3 weeks after planting resulted in higher specific gravity than the control, however few significant differences in specific gravity were observed between hilled treatments. The best fry quality was observed for treatments hilled 3 weeks after planting, a time when plants were 2 to 5" tall. Fry color was darker for treatments that were not hilled, or were hilled immediately after planting, or 5 weeks after planting when plants were 12 to 15" tall.

In 2003, power hilling Russet Burbank potatoes at emergence or just after emergence resulted in the best combination of marketable yield and good fry color. A second year of the trial is planned for 2004.

References

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Vangessel, M. J. and K. A. Renner. 1990. Effect of soil type, hilling time, and weed interference on potato (*Solanum tuberosum*) development and yield. Weed Technology. 4: 299-305.

Memorandum of Understanding

Between the following parties:

Potato Growers of Alberta Agriculture (PGA)

and

Southern Applied Research Association (SARA)

Project Title: Demonstration of Winter Wheat after Potatoes and Beans

Objectives:

1. To demonstrate a systems approach for both grain production and erosion control with mid to late September planted winter wheat after potato and beans in the Lethbridge, Vauxhall and Rolling Hills area and after beans in the Rolling Hills area.
2. To demonstrate the conservation and production benefits of winter wheat compared to spring wheat for diverse irrigated crop rotations in southern Alberta

Statement of Work

SARA, in cooperation with Alberta Agriculture staff at Lethbridge will complete this project as described in the attached proposal with funding support provided by PGA.

Work Period

This project will commence in September, 2004 with completion in September, 2005.

Basis of Payment

PGA will provide $2000 to SARA to be used to pay a portion of the seed and custom planting costs for the winter wheat on potato demonstrations.

If requested, SARA will provide a record of revenue and expenditure upon completion of the project or depletion of the funds. Any remaining funds following completion of the project can be used for demonstration or research at the discretion of the SARA board.

Project Manager Responsibility

The project manager is Robert Dunn with Alberta Agriculture, Food and Rural Development. He will provide project updates and reports to SARA and PGA.

Robert will be responsible to authorize expenses and submit for payment to SARA.

Amendments or Termination

This Memorandum of Understanding (MOU) may be amended by mutual consent of both parties as evidenced by exchange of letters.

Either AAFRD or the PGA may terminate this MOU by providing two weeks written notice to the other party.

Notices and Representatives

Notices for all purposes of or incidental to this MOU shall be effectively given if delivered personally, or sent by registered or certified mail to the following individuals:

PGA
Vern Warkentin
Executive Director
Potato Growers of Alberta
6008 – 46th Ave
Taber, AB T1G 2B1

SARA
Pat Pavan
Manager
100, 5401 – 1st Ave S
Lethbridge, AB T1J 4V6

The parties affirm their acceptance of the MOU terms by signing below.

Robert Dunn, Project Manager	Jan. 11, 2005 Date
Pat Pavan, SARA Manager	Jan 11, 2005 Date
Vern Warkentin, PGA Executive Director	Jan 24, 2005 Date

Alberta
AGRICULTURE, FOOD AND RURAL DEVELOPMENT

Rob Dunn, P.Ag.
Conservation Cropping Specialist
Conservation and Development Branch

Agriculture Centre
100, 5401 - 1st Avenue South
Lethbridge, Alberta, Canada T1J 4V6
Tel 403/381-5904, Fax 403/381-5765
Cell 403/308-4417
rob.dunn@gov.ab.ca

Demonstration of winter wheat after potatoes and beans

Project team:
Rob Dunn, Conservation Cropping Specialist, AAFRD
Pat Pavan, Southern Applied Research Association
Susanne Brummelhuis, Winter Cereal Agronomist, Ducks Unlimited
Don Wentz, Agrologist, Reduced Tillage Linkages
Alfonso Parra, Potato Growers Association of Alberta
Steve Wylie, Agricultural Fieldman, County of Newell

Background:
Winter wheat has been successfully grown in southern Alberta after early harvested beans or potatoes for erosion control and grain production. Optimum dates for soil conservation are mid August to early September with mid to late September planting dates often successful for grain production but not producing enough growth to hold soil through the critical mid to late winter period. Surface roughness or anchored residue is needed to further protect the soil with these later plantings. Wider row spacing hoe type air drills that leave a deep soil furrow after seeding like the Conservapak air drill will leave a fairly rough surface and further protect the soil for later planted situations. Irrigating before planting is preferred to minimize the leveling action from water application after planting. Oats are sometimes used with winter wheat to provide additional soil cover.

Yields of hard red winter wheat are typically 15 to 20% higher than spring hard red wheat with lower water, nitrogen and herbicide input costs. Radiant is a new strong strawed, milling type winter wheat developed at AAFC in Lethbridge. It is an excellent choice for irrigation with high yields, good lodging resistance and good winter hardiness. Another good variety for irrigation is CDC Falcon, a high yielding feed type with good winter hardiness and excellent lodging resistance.

Objectives:
1. To demonstrate a systems approach for both grain production and erosion control with mid to late September planted winter wheat after beans or potatoes in the Lethbridge, Vauxhall and Rolling Hills area
2. To demonstrate the conservation and production benefits of winter wheat compared to spring wheat for diverse irrigated crop rotations in southern Alberta

Methodology:
Winter wheat will be planted after potatoes and beans with a Conservapak or equivalent drill system in mid-late September at the following sites:

	Field size	Previous crop	Varieties *
Irrigation Demo Farm, Lethbridge	17 acres	Potatoes	Falcon and Radiant
AAFC Research Farm, Vauxhall	6 acres	Potatoes	Falcon and Radiant
S-Scan Farms, Rolling Hills	65 acres	Potatoes	Falcon
Harme Stikker, Rolling Hills	65 acres	Beans	Radiant
Steve Anderson, Scandia	80 acres	Beans	Radiant

* winter wheat will be seeded with and without tame oats to evaluate the effect on soil cover

Fields will be evaluated after harvest to assess the need for tillage, irrigation or herbicide burnoff prior to planting. Irrigation should be applied before seeding to minimize surface leveling after planting. Cooperators will be responsible for all other production decisions and costs after seeding, with custom seeding and some fertilizer costs being shared at several sites.

Fields will be monitored for the following:

a. stand establishment in plants/m2 in mid-October and early April
b. percent soil cover in early November and mid-March
c. field roughness in early November and mid-March
d. crop maturity and harvest dates
e. yields as reported by the cooperator with weigh wagon where appropriate

Action Plan

August

- contact and confirm sites in the Lethbridge, Vauxhall, Rolling Hills area
- line up seed and planting arrangements

September

- inspect fields prior to planting
- seed delivered and planted at sites

October

- monitor for stand establishment
- local farm tours at sites

November

- monitor for surface roughness and percent ground cover

March

- monitor for surface roughness and percent ground cover

April

- monitor for winter survival
- local farmer tours at sites

July

- tour sites as part of the field days at Lethbridge and Vauxhall

August

- evaluate and reporting

Expected Results
Demonstration of a systems approach for mid to late September seeded winter wheat as a conservation and economically viable grain crop alternative following potatoes or beans in southern Alberta.

Budget estimate

	Cost
Falcon seed (175 bu @ $8.50/bu)	$1487
Radiant seed (320 bu @ $8.50/bu)	$2720
Oat seed (40 bu @ $5.00/bu)	$200
Custom seeding (130 acres @ $15/ac)	$1950
Fertilizer (65 acres @ $30/ac)	$1950
Total costs	$8307

Contributions:	cash	in-kind
Reduced tillage linkages	$2000	
Ducks Unlimited	$1500	
AAFRD		$500 (seed transport)
County of Newell	$500	
PGA *	$2000	
Agricore United*	$2000	
SARA		$500 (admin support)
Conservapak	$500	
Total contributions	$8500	

* subject to approval

Demonstration of winter wheat after potatoes and beans

Project team:
Rob Dunn, Conservation Cropping Specialist, AAFRD
Pat Pavan, Southern Applied Research Association
Susanne Brummelhuis, Winter Cereal Agronomist, Ducks Unlimited
Don Wentz, Agrologist, Reduced Tillage Linkages
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Harme Stikker, Rolling Hills	65 acres	Beans	Radiant

* winter wheat will be seeded with and without tame oats to evaluate the effect on soil cover

Fields will be evaluated after harvest to assess the need for tillage, irrigation or herbicide burnoff prior to planting. Irrigation should be applied before seeding to minimize surface leveling after planting. Cooperators will be responsible for all other production decisions and costs after seeding, with custom seeding and some fertilizer costs being shared at several sites.

Fields will be monitored for the following:

a. stand establishment in plants/m2 in mid-October and early April
b. percent soil cover in early November and mid-March
c. field roughness in early November and mid-March
d. crop maturity and harvest dates
e. yields as reported by the cooperator with weigh wagon where appropriate

Action Plan

August

- contact and confirm sites in the Lethbridge, Vauxhall, Rolling Hills area
- line up seed and planting arrangements

September

- inspect fields prior to planting
- seed delivered and planted at sites

October

- monitor for stand establishment
- local farm tours at sites

November

- monitor for surface roughness and percent ground cover

March

- monitor for surface roughness and percent ground cover

April

- monitor for winter survival
- local farmer tours at sites

July

- tour sites as part of the field days at Lethbridge and Vauxhall

August

- evaluate and reporting

Expected Results
Demonstration of a systems approach for mid to late September seeded winter wheat as a conservation and economically viable grain crop alternative following potatoes or beans in southern Alberta.

Budget estimate

	Cost	
Falcon winter wheat seed	$1500	
Radiant winter wheat seed	$2000	
Oat seed	$50	
Custom seeding (130 acres)	$2000	
Total costs	$5550	
Contributions:	cash	in-kind
Reduced tillage linkages	$2000	
Ducks Unlimited	$1500	
AAFRD		$500 (seed transport)
County of Newell		$500 (signage and tours)
PGA *	$2000	
SARA	____	$500 (admin support)
Total contributions	$5500	$1500

Distribution of Soil Water in a Field Prepared for Potatoes by Varying the Hill-Furrow or Bed-Furrow Configuration

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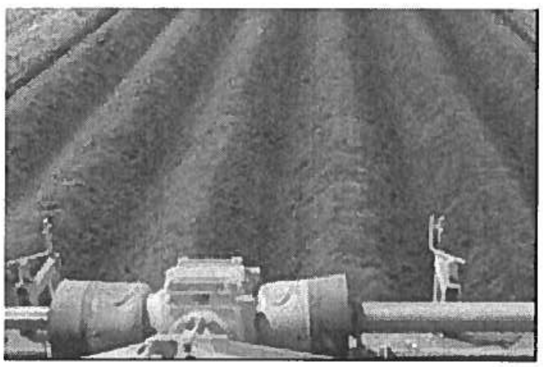
[1]. AAFRD, Irrigation Branch, Brooks AB

Executive Summary

In southern Alberta, potatoes are always hilled immediately after planting and covered with sufficient soil to prevent greening of the tubers, ensure drainage in the area of tuber formation and to facilitate mechanical harvest. The ideal shape for the potato hill, according the Manitoba Department of Agriculture (MDA), is one with fairly peaked top and gradual slope to the furrow position (ES Figure 1).



ES Figure 1. Ideal profile for a potato hill. (Courtesy of Gaia Consulting Ltd)

However with a profile described as ideal, much of the precipitation (either irrigation or rainfall) moves by gravity into the furrow position. Water ponds in the furrow position and if dammer dyked, gradually infiltrates with time. Water is believed to move from the furrow position into the hill position via soil matrix forces. Much of the precipitation accumulated in the furrow position likely percolates through the soil, below the root zone and is effectively lost to the plant.

A research project commenced in 2004 to identify the fate of precipitation (irrigation and rainfall) that infiltrates the soil in both the "ideal profile" hill and furrow position. The project continued in 2005, to determine the fate of infiltrated precipitation with altered hill shapes. The treatments included the standard or "ideal" hill profile, a modified flat-topped hill and a raised, double-row bed. Analysis included infiltration, redistribution, deep-percolation, evapotranspiration, yield and quality.

Infiltration of precipitation or increase in soil moisture after a rainfall/irrigation event was generally greatest for the double-row bed and the flat-topped hill. However, since the field was irrigated based on the standard hill shape and differential irrigation was not possible, the flat-topped hill and double row bed often lost the most amount of water

through deep percolation since they were often at or above field capacity for most of the growing season.

Evapotranspiration was similar between all treatments but soil moisture levels decreased the fastest in the standard hill profile, primarily a consequence of lower infiltration amounts for that treatment.

Modified hill profiles retain more of the applied irrigation water, thus increasing water savings within irrigated potato fields. Since it was not possible to quantify those water savings (all treatments were irrigated the same), a follow up study should be conducted to quantify water savings and to compare yield and quality data among treatments.

1. Introduction

Relative to other crops grown in southern Alberta, potato requires a very intensive irrigation management program to maximize economic returns. Potatoes have a relatively low tolerance to water stress, develop a shallow rooting system, and are typically grown on coarse-textured soils with inherently low water holding capabilities. Accordingly, growers must have an advanced knowledge of soil moisture status to maintain soil moisture at prescribed levels.

The infiltration of irrigation and rainfall into a potato hill is often assumed to be uniform. However, due to the implied topographic relief of hill-furrow tillage systems it is likely that the actual infiltration and subsequent redistribution of irrigation water is quite variable. This is supported by Saffigna et al. (1976); Stieber and Shock (1995); Bargar et al. (1999) and Robinson (1999) who all noticed that more water enters the soil through the furrow than through the ridge or hill. It is believed that between precipitation events, suction exerted by the plant's root system acts to redistribute some of the water into the hill position where it can be used by the plant. However, there is sufficient reason to believe that some of the water that collects in the furrow position will move to positions below the root zone, effectively lost for crop use.

Reservoir tillage (dammer-dyking) is commonly used in commercial potato production. In many instances it has been shown to effectively reduce runoff (Mickelsen and Schweizer, 1987; Kincaid et al., 1990). However, this practice may lead to increased movement of water beneath the furrow due to localized zones of increased infiltration. The ripping effect of the dammer-dyker's tillage shank, acts to shatter the soil, effectively increasing the ability of water to move into and through the soil. If rainfall or irrigation water ponds in the depression created by the dammer-dyker paddle, most of this water will infiltrate below the furrow position. Root density beneath the furrow is minimal and much of this water may be lost to deep percolation.

The development of the canopy of a potato crop also has a marked effect on the distribution of irrigation water. Results presented by Saffigna et al. (1976) suggest that early in the season, prior to row closure, water redistribution into the furrow was higher than after row closure. After row closure, approximately 40% of the irrigation water applied was directed toward the plant stem by the canopy. These results suggests that irrigation efficiency may actually improve throughout the growing season.

Improved irrigation efficiency may also be realized by altering standard hill shape so more of the applied irrigation water has time to infiltrate into the hill/bed before ponding in the furrow position. It is important to gain a detailed understanding of the fate of the irrigation water applied under various hill/bed configurations so the opportunity to improve irrigation efficiency is identified.

The objectives of this study are to:

1. Quantify the distribution of water within a standard hill/furrow prepared potato crop.
2. Quantify the distribution of water in altered hill/bed forms and compare with standard.
3. Quantify irrigation efficiency and identify opportunities for improvement.

2. Methodology

Year 1

The study was conducted at the Canada-Alberta Crop Development Initiative Demonstration Farm near Lethbridge, Alberta. An area of approximately 1.8 m wide x 2.0 m long, (an equivalent width of two beds and three furrow locations, extending for a distance of 2.0 m) was delineated within a field prepared and seeded to potatoes. Soil moisture was measured using 3 prong TDR sensors (Figure 1) and soil tension was measured using the granular matrix block (Watermark) sensors (Figure 2).

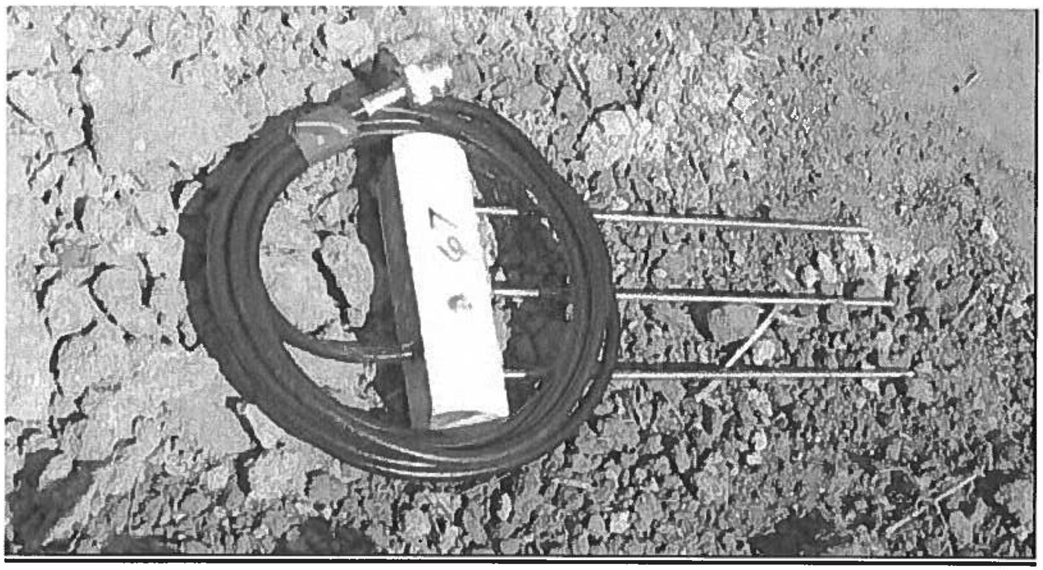


Figure 1. 3-prong TDR soil moisture probe.

Figure 2. Watermark granular matrix block soil tension probe.

A 2.1 by 0.8 m grid with 10 cm grid nodes was designed and the distribution of TDR and Watermark sensors within the soil profile for the hill-furrow configuration was determined. The TDR sensors were placed 10 cm below the surface within the hill position and 20 cm below the surface within the furrow position. Maximum vertical or horizontal distance between the probes was 10 cm within the hill position and 20 cm within the furrow (Figure 3).

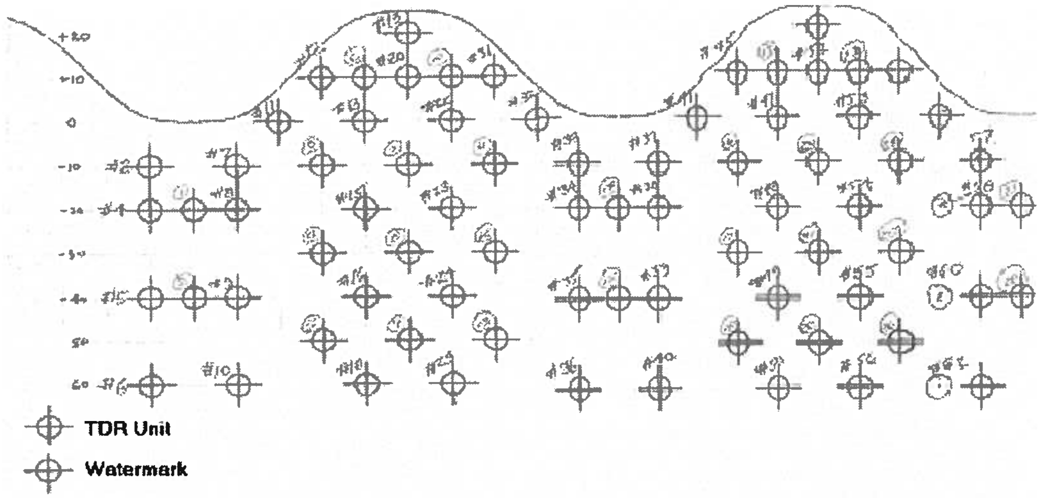


Figure 3. Schematic of soil moisture (TDR) and soil tension (Watermark) array.

A trench was excavated at one end of the plot to facilitate installation of the soil moisture and soil tension instrument array (Figure 4). A total of 50 TDR probes and 27 Watermark sensors were installed.

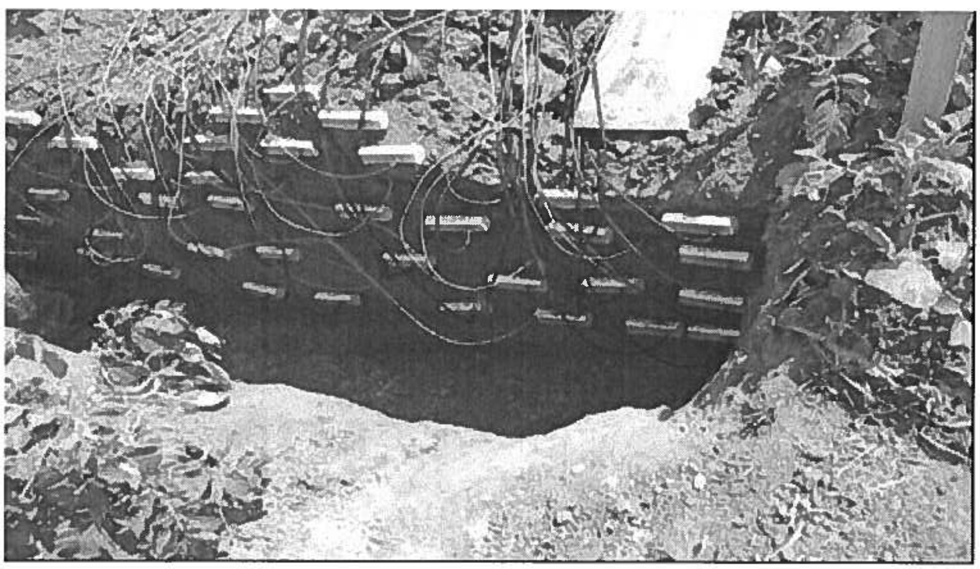


Figure 4. TDR and Watermark sensors installed in soil face.

The excavated area was hydrologically isolated from the out of plot area by installation of a 1.2 m wide by 2.4 m long by 0.23 m thick preserved wood plywood. The trench was backfilled using the excavated soil and the soil was packed in an attempt to minimize preferential infiltration into the disturbed soil (Figure 5).

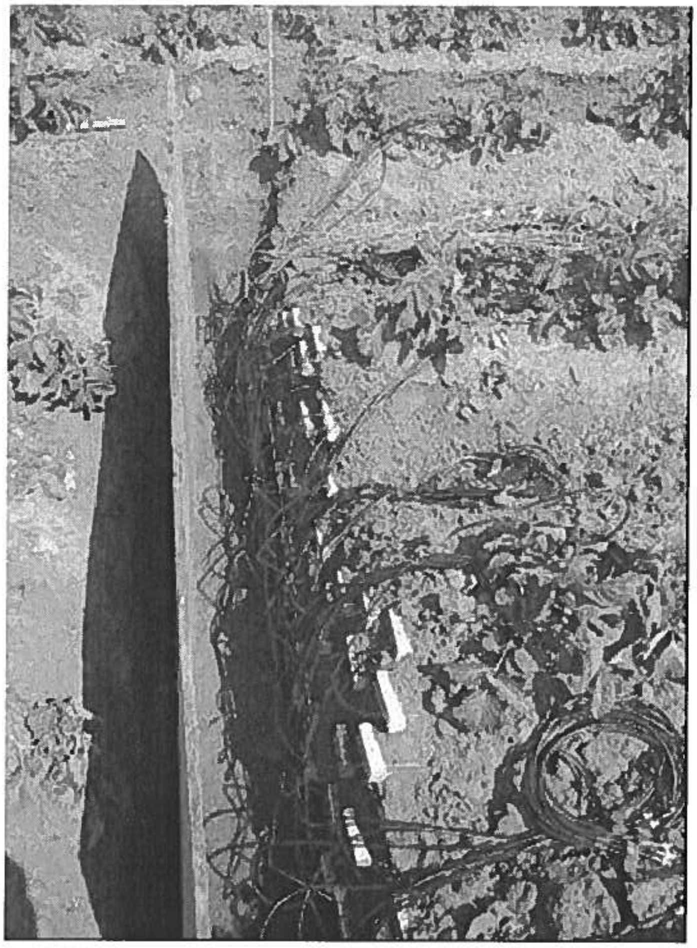


Figure 5. Plywood installed and backfill commenced.

The Watermark sensors were connected to a Campbell Scientific CR10X datalogger via a Campbell Scientific AM16/32 multiplexer (Figure 6). The TDR soil moisture probes were routed via a series of SDMX50 coax multiplexers (Figure 7) to a Tektronix 1502B TDR cable tester that was then connected to the data logger (Figure 8). Datalogger was programmed to output hourly values for soil moisture and soil tension for all the sensors.

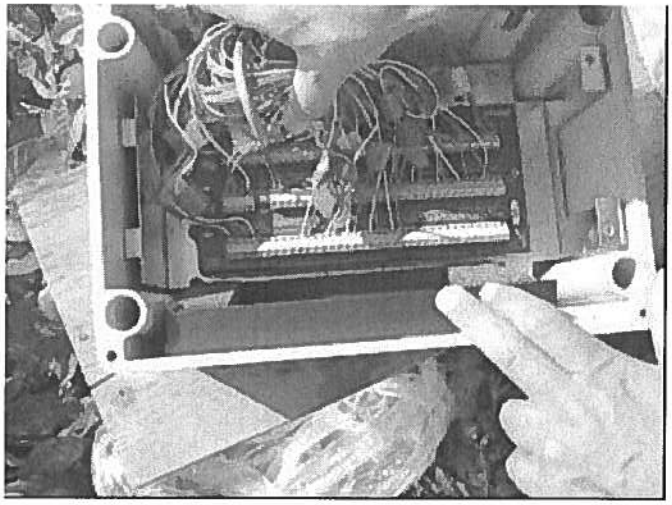


Figure 6. Watermark sensors to multiplexer.

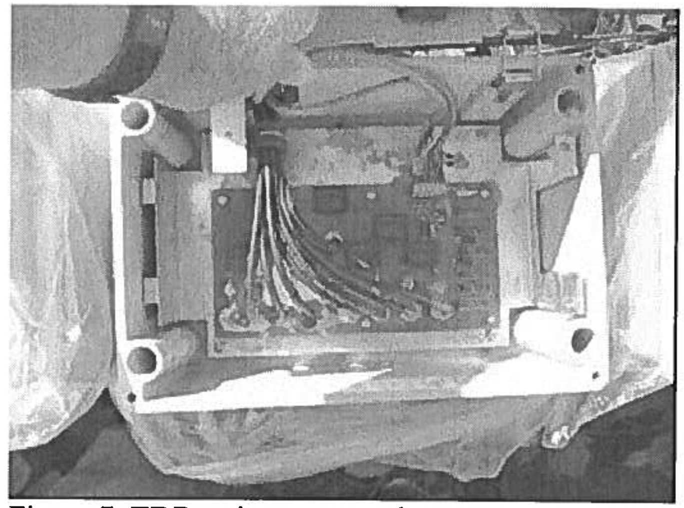


Figure 7. TDR units connected to coax multiplexer.

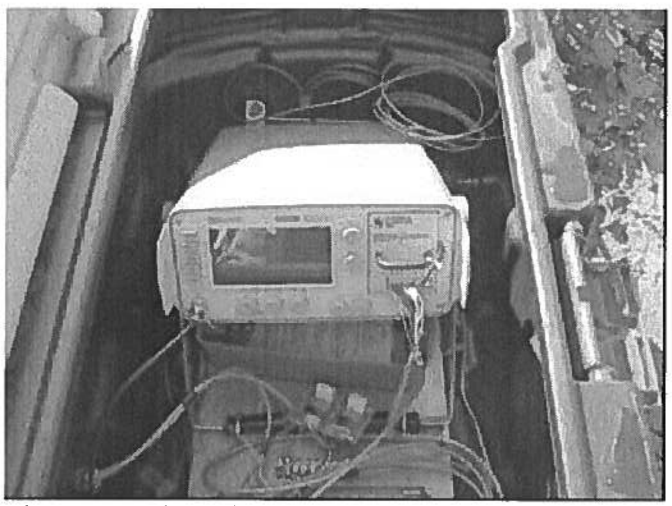


Figure 8. Tektronix 1502B cable tester.

A vadose zone fluxmeter (Figure 9) was placed 70 cm below the soil surface directly below the furrow position to record the quantity of either irrigation or rainfall that percolated below the root zone of the potato plant. The fluxmeter was also connected to the datalogger.

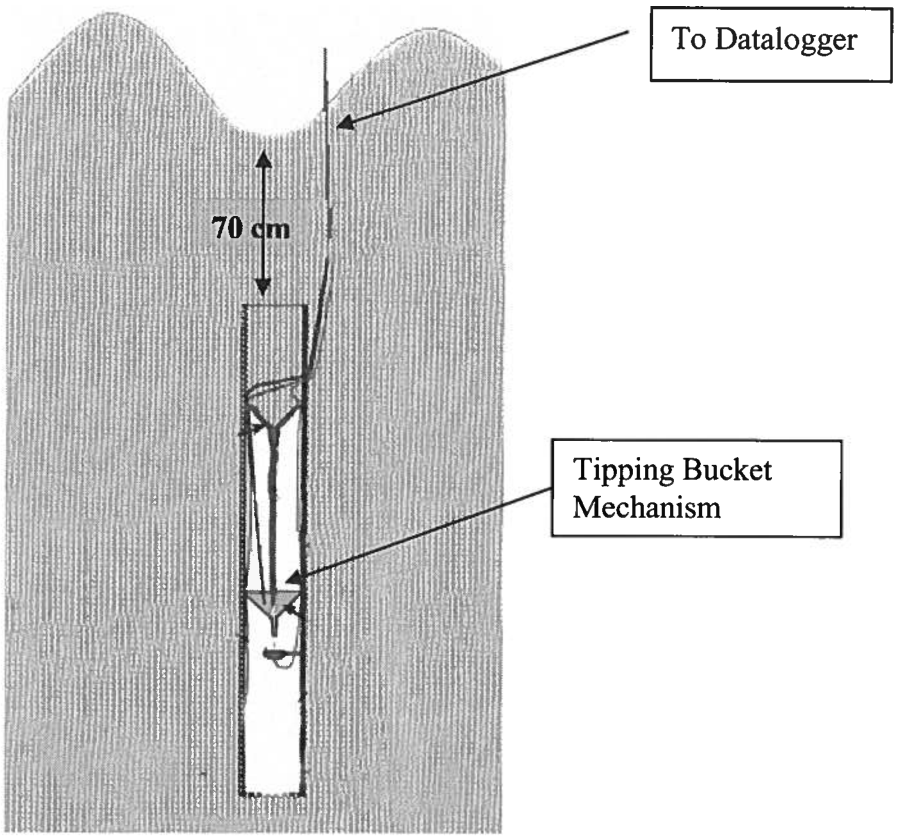


Figure 9. Flux meter installed below furrow position.

To complete the instrumentation, a tipping bucket rain gauge was installed to record rainfall or irrigation timing and amounts and two Delta T Devices, PR1-6 soil moisture probes were installed to record hourly soil moisture values within the plot. These instruments were connected to a separate datalogger.

The agronomic management practices followed were assumed to represent the majority of potato crops grown in southern Alberta and were:
- Seed Variety: Russet Burbank
-Seeded into beds spaced 0.9 m apart
-Beds constructed with power-hiller (immediately after planting operation)
-Reservoir tillage technique – ripping shank w/ dammer-dyker attachment (conducted soon after hilling)
-Irrigation method – medium pressure center pivot
-Water application – equivalent depth of 20-25 mm per application

Year 2

A total of 3 hill/bed furrow combinations were constructed on April 26, 2005, in a 12 m by 20 m area in a larger potato field irrigated with center pivot irrigation. The hill shapes were constructed with a bed former. The treatments included standard power hilled, flat topped hilled and 2 row, double cropped bed (Figure 10). The beds were seeded on April 26, 2005, with the Russet Burbank variety using a plot seeder.

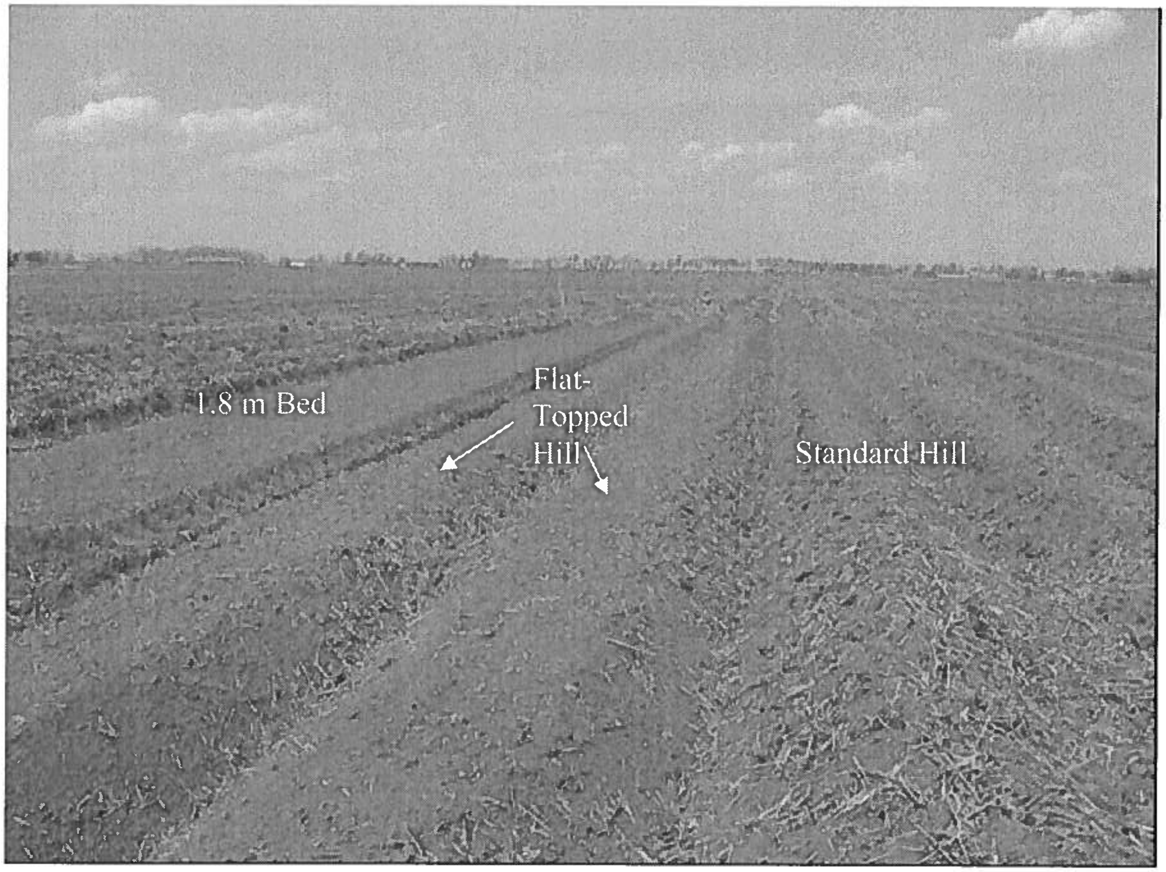


Figure 10. Bed and Hill Shape after Seeding.

Similar to Year 1, a 0.7 m deep by 0.6 m wide trench was excavated across the face of the three prepared hill shapes and an array of 32 Watermark sensors at a spacing of no greater than 20 cm either horizontally or vertically from each other were installed. All sensors were multiplexed through a Campbell Scientific AM 16/32 multiplexer and connected to a Campbell Scientific CR 10X datalogger for hourly soil tension readings. A vadose zone flux meter was installed below the furrow position near the middle of the plot at a depth of 70 cm below the soil surface.

The plot was hydrologically isolated from the upslope position with a wooden barrier. Initial rill meter readings were taken to quantify the final hill/bed shape.

Additional instrumentation included a tipping bucket rain gauge to monitor irrigation/ rainfall amount and timing, as well as an adjacent Bowen Ratio Energy Balance system to estimate potato evapotranspiration.

Analysis included infiltration into, water loss from and evapotranspiration for the various prepared bed shapes including the furrow position. Three furrows were monitored and the results were presented as an average of the three furrows.

Yield samples were taken from each plot on September 8, 2005. A three-meter section from each treatment was hand dug, the tubers were collected and analysis for potato yield and quality for the different prepared seed beds was performed.

3. Results and Discussion

Year 1

There were delays in obtaining and constructing some of the instrumentation that resulted in delays in data collection. Additional problems were experienced with programming the logger so data collection only started in early August. The soil matrix potential for August 10, 2004, is shown in Figure 11.

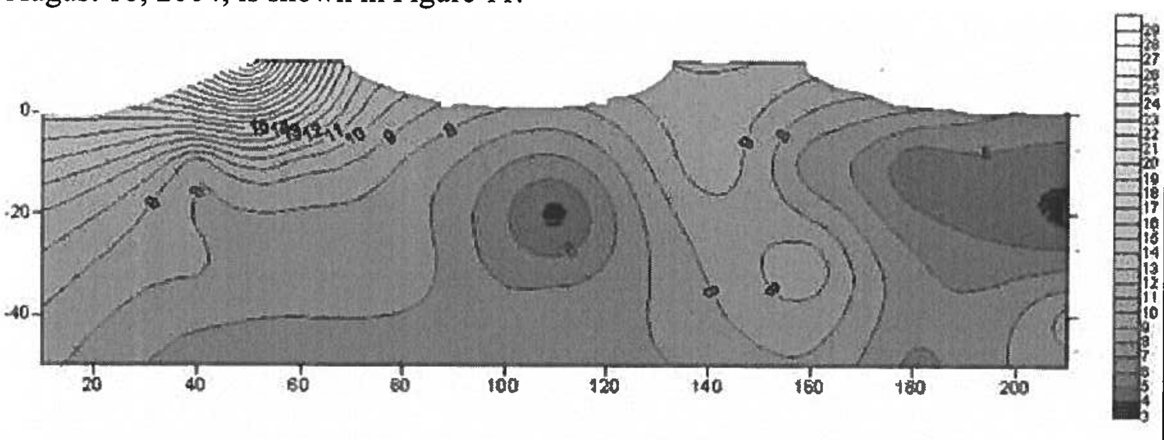


Figure 11. Soil tension profile for August 10, 2004.

Lower soil moisture content was expected in the hill versus the furrow but we found drier soil moisture conditions remained in the hill where the potato plants were actively growing, even though there was high soil moisture in the furrows. At soil moisture levels below field capacity, there appeared to be limited movement of soil moisture from the furrow into the hill. Similar soil moisture values near surface in the furrows were found at a 40 cm depth and greater in the hills.

Vadose Zone Flux Meter

There was no recorded flow through the vadose zone flux meter during the time of monitoring in August. Total rainfall and irrigation during August were 24 mm; insufficient to initiate deep percolation.

Year 2

Results were fairly consistent for infiltration of irrigation and rainfall events in that the 1.8 m bed generally gained the most moisture (an exception was when it was at or near saturation), the flat topped prepared hill gained the second most and the standard hill infiltrated the least amount of water. For many rainfall events, but not all, the furrow position had the greatest gain of soil moisture (Table 1). Since the furrow position was the average of three furrows and less water accumulated in the furrow position from the bed or the flat topped hill shape, thereby often lowering the average.

Table 1. Gain in soil moisture (mm) during rainfall/irrigation events (mm).

	June 17	June 23	June 26	June 29	July 9	July 23	July 26	August 11
Rainfall	8.6	0.0	3.6	16.4	7.0	0.6	0.0	9.2
Irrigation		14.2				28	18.2	
Bed	5.2	11.6	1.7	8.4	5.9	12.0	15.1	4.3
Flat	3.0	8.1	2.3	12.1	5.1	21.1	6.6	6.9
Standard	1.2	3.1	0.4	2.5	2.3	18.3	3.4	1.5
Furrow	7.3	17.6	7.4	2.8	15.5	14.0	9.1	2.7

However, even though the furrow position or flat-topped gained the most water during a precipitation event, since they both had consistently higher water content throughout the growing season, they also would lose, primarily through deep percolation, much of their infiltrated water. For example, a 23.0 mm rainfall event on June 17, 2005, resulted in an initial higher gain in soil moisture for both the bed and flat topped but subsequently, they lost the most to deep percolation. (Table 2). Similar results occurred for a June 27-28 rainfall of 28.2 mm.

Table 2. Infiltration and subsequent deep percolation for the various treatments.

Rainfall		Initial Gain in Soil Moisture	Subsequent Loss to Deep Percolation and Evapotranspiration
17-Jun		18-Jun	19-Jun
23.0	Bed	14.6	17.8
	Flat	6.1	8.6
	Standard	9.9	3.2
	Furrow	4.8	10.2
28-Jun		29-Jun	30-Jun
28.2	Bed	18.6	19.9
	Flat	20.8	13.0
	Standard	24.3	12.3
	Furrow	10.4	17.2

Figure 12 highlights the consistently higher soil moisture for both the bed and flat-topped hill shape compared to the standard.

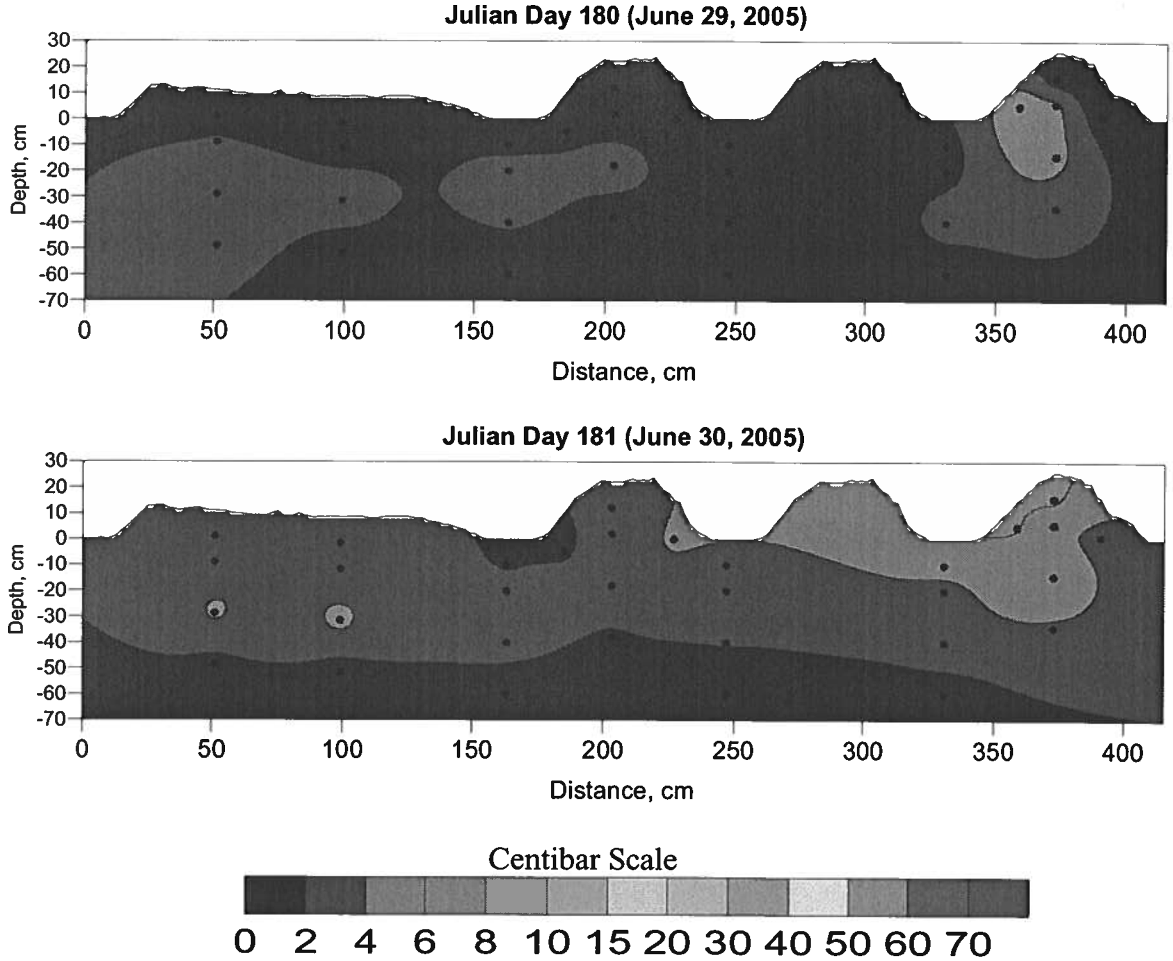


Figure 12. Drainage of profiles after saturation.

The standard-prepared hills infiltrated the least amount of water and soil moisture was depleted most rapidly within them. Figures 13 thru to 15 highlight the drying nature of the standard-prepared potato beds compared with the bed and flat-topped hill for selected times throughout the growing season. For interpretation, a soil tension reading of approximately 40-50 centibars would be the lower limit before an irrigation application.

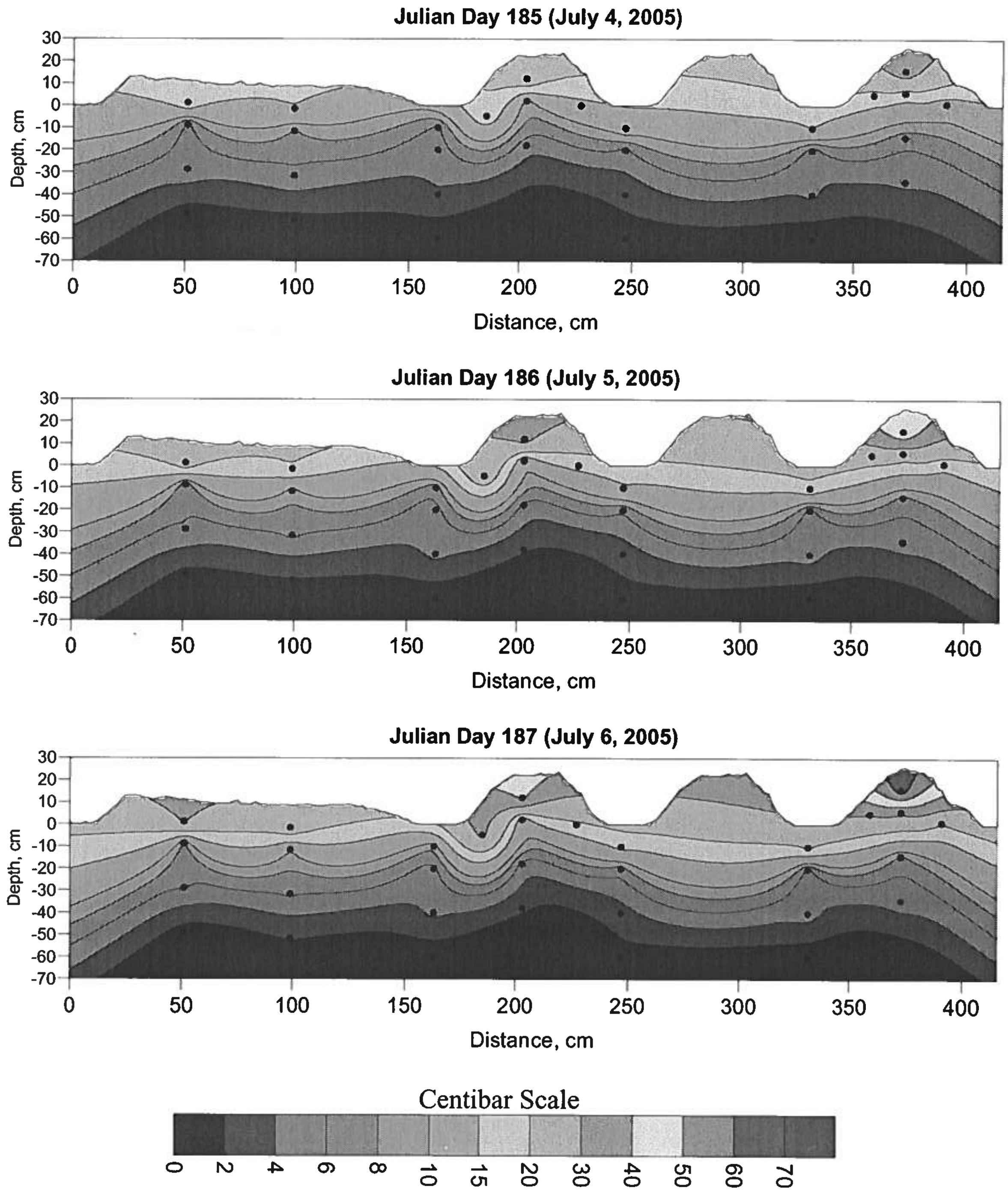


Figure 13. Soil tension readings (centibars) from July 4-6, 2005

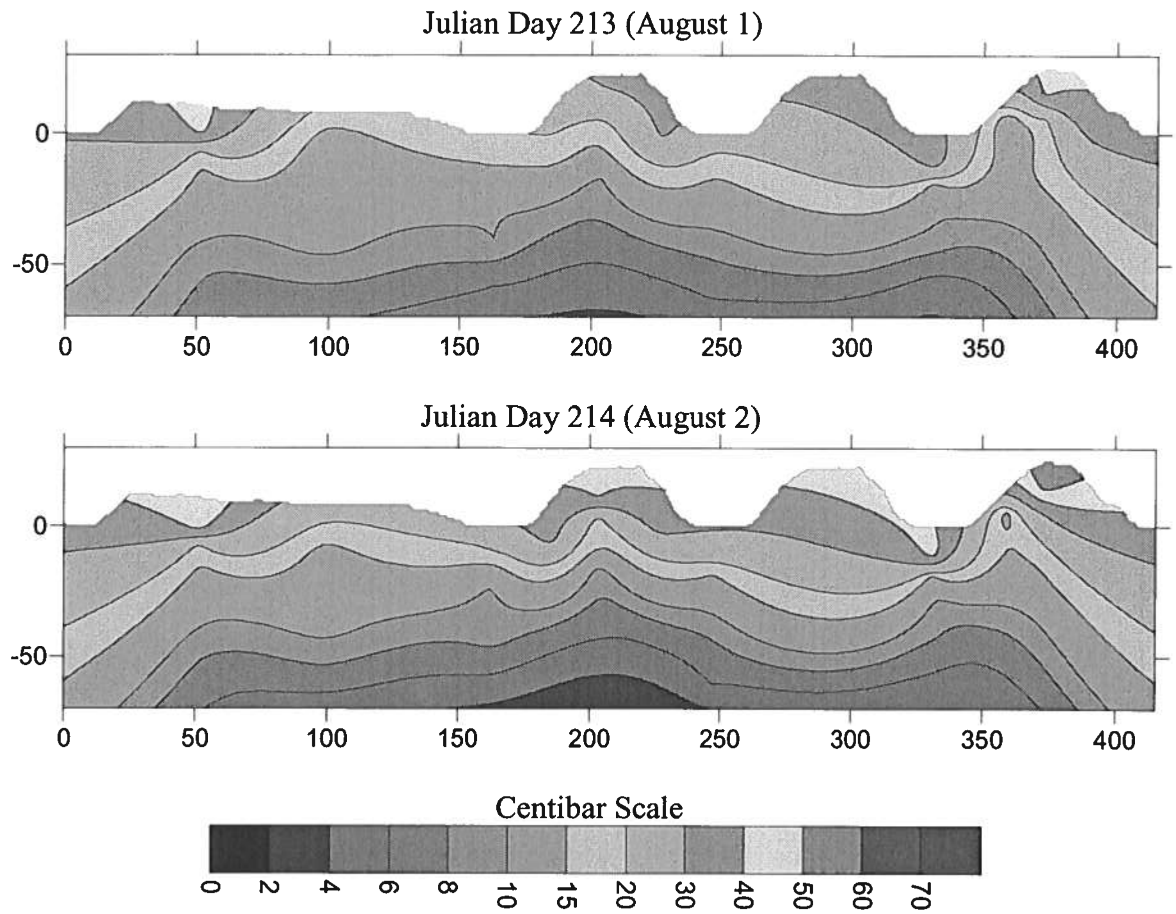


Figure 14. Soil tension readings (centibars) from August 1-2, 2005.

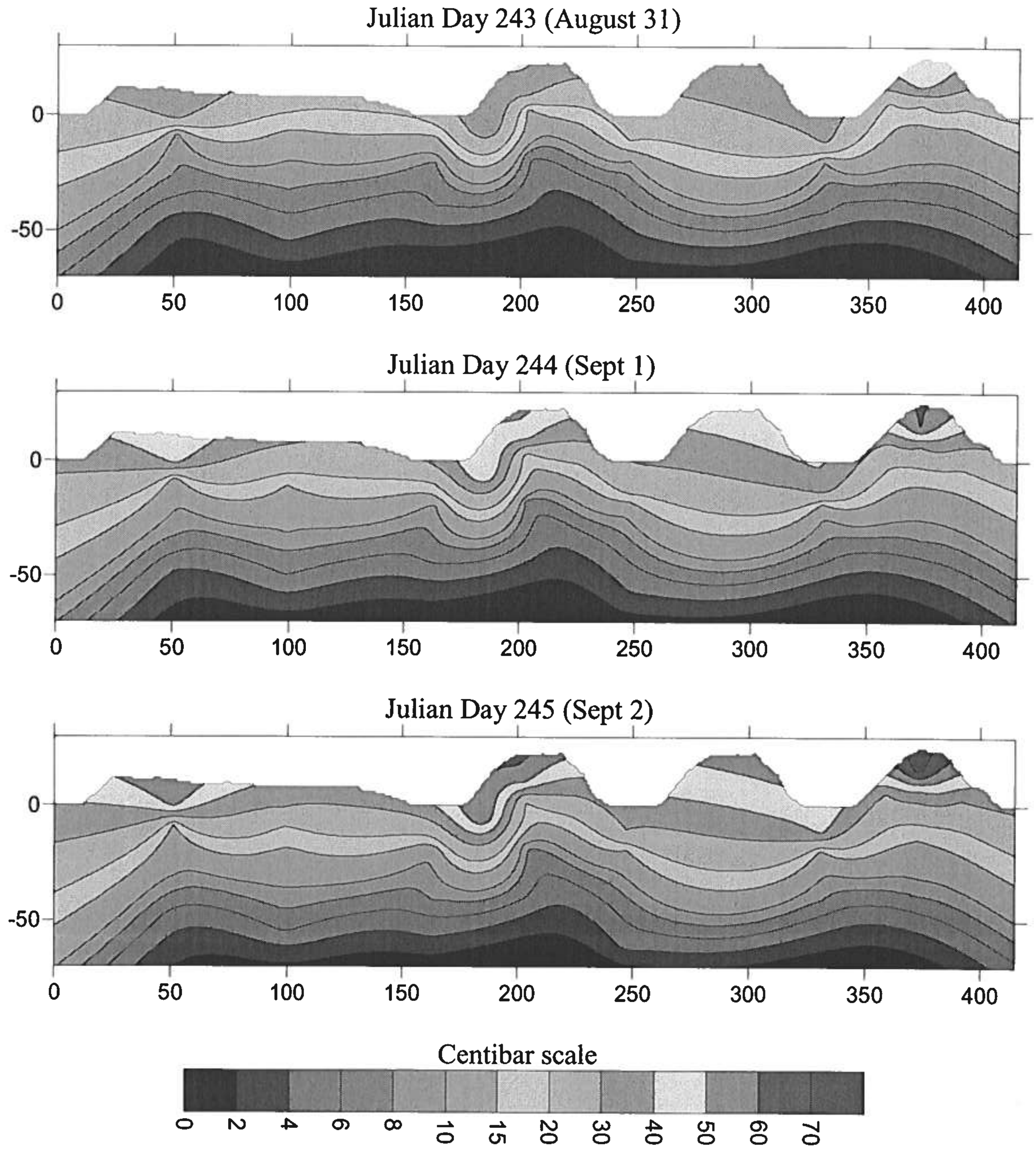


Figure 15. Soil tension readings (centibars) from August 31-Sept 2, 2005.

Evapotranspiration or potato water use was similar for all treatments throughout the growing season (Table 3) therefore differences in rate of depletion of soil moisture was primarily a result of less water infiltrating the standard-prepared hill.

Table 3. Daily evapotranspiration for the various bed/hill configurations, furrow position and theoretical potato evapotranspiration.

	21-Jun	24-Jun	1-Jul	5-Jul	11-Jul	15-Jul	22-Jul	20-Aug	22-Aug	30-Aug	31-Aug	1-Sep	2-Sep	6-Sep
Bed	4.9	2.9	5.2	5.5	3.0	2.5	1.8	7.1	7.2	3.4	7.6	1.0	2.2	3.8
Flat	4.9	2.2	6.2	4.5	2.3	2.5	5.2	8.4	6.3	2.7	6.6	0.1	1.7	3.9
Standard	4.6	3.2	5.2	3.5	1.6	3.5	4.8	7.8	5.4	2.0	5.7	0.0	2.2	5.3
Furrow	5.6	1.7	4.8	4.8	1.6	2.4	2.5	7.5	11.4	1.3	7.1	0.6	3.0	5.6
PM ET	4.8	3.5	5.5	4.9	4.6	2.7	4.8	7.5	7.1	4.3	6.7	5.0	4.5	3.6

Note: PM ET is calculated based on the FAO 56 Penman Monteith evapotranspiration equation using a locally calibrated potato crop coefficient curve.

Yield and Quality

No statistics were performed on the yield and quality data since the experiment was not a replicated trial. However, the standard and flat-topped hills were similar in number and in size categories. The double-row bed had a higher number of tubers but they were in the smaller size category. McKenzie (1998) also found that where soil moisture was consistently higher in the low-lying areas of the field, a greater number of tubers were collected but those tubers were of the smaller size category.

Table 4. Yield and quality for the three treatments.

Treatment	Graded Yield (tons/acre)	Total number of tubers	Tuber number in size categories				
			< 4 oz	< 4-6 oz	6-10 oz	>10 oz	Deformed
Double row bed	10.4	93	41 44.1%	35 37.6%	14 15.1%	1 1.1%	2
Flat Topped	9.3	63	12 19.1%	14 22.2%	25 39.7%	11 17.5%	1
Standard	10.3	73	21 28.8%	13 17.8%	29 39.7%	8 11.0%	2

4. Conclusions and Suggestions

The first year of the study identified that soil moisture/tension in the furrow position in a standard hill/furrow prepared field remained consistently wetter than the hill and that there was limited movement of soil moisture from the furrow position into the hill. Similar soil tension readings at near-surface position in the furrow occurred at a depth greater than 40 cm under the hill.

The second year of the study identified that by altering hill shape to either a 1.8 m double row bed or a flat-topped hill, more precipitation (either through irrigation applications or rainfall) infiltrated and soil moisture consistently remained higher. The design of the field plots for Year 2 did not allow differential irrigation of the various treatments. The field was irrigated for the standard-prepared hill since the plots were established within a larger field of potatoes and the entire field was irrigated using a center pivot system. This often resulted in the bed and flat-topped hill receiving an irrigation when the soil moisture was at or above field capacity. Therefore, quantifying the reduction of irrigation water required for the bed or flat-topped hill was not possible, however the qualitative data were evident.

A continuation or a follow-up study should be initiated with a replicated plot design where the arrangement of the irrigation equipment is such that each plot or group of plots could be irrigated separately from the other plots or groups of plots. Irrigation water savings could then be quantified and meaningful yield and quality comparisons may be realized.

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Russet Burbank Vine Management in Southern Alberta – 2nd Year

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Purpose

In southern Alberta, diquat (Reglone™) is typically applied as a chemical desiccant. Recently, there has been interest in using vine rollers to mechanically damage vines to enhance vine kill, improve canopy penetration of diquat, compact soil, close soil cracks and reduce tuber greening. Our goal is to determine the rate of tuber bulking following various vine kill strategies. Also, we will study the effects of various methods of vine killing on tuber quality (specific gravity, stem-end discoloration and fry quality).

Objectives

- To determine how much bulking occurs in potato tubers between Reglone™ application(s) and harvest.
- To compare rates of vine desiccation between Liberty™ application, single and split Reglone™ applications alone or following vine rolling.
- To determine the extent to which the method and rate of vine killing affects tuber quality (maturity, specific gravity, stem-end discoloration, fry quality).

Project Plan and Treatments

The study was conducted in three commercial fields of Russet Burbank potatoes in the Taber and Cranford areas. Prior to harvest, vines were killed by single and split applications of Reglone™, alone and in combination with vine rolling. These treatments were compared with complete vine removal, green harvesting and Liberty™ application to establish rates of tuber bulking and vine desiccation following vine kill. Tuber yield, grade and quality will also be assessed for each treatment.

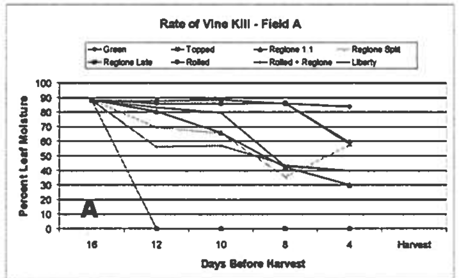
- Green Harvest - control (for determination of bulking)
- Topped - stems removed 14 days before harvest (14 dbh)
- Reglone 240™ - 1.2 L/ac - single application (14 dbh)
- Reglone 240™ - 0.8 L/ac (14 dbh) + 0.6 L/ac (7 dbh)
- Reglone 240™ - 1.2 L/ac - single application (7 dbh)
- Rolled - (14 dbh)
- Rolled + Reglone 240™ - 1.2 L/ac (14 dbh)
- Liberty™ - 1.2 L/ac (14 dbh)

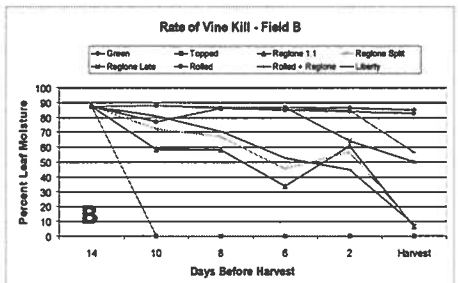
Acknowledgements

This project was supported through funding by the Potato Growers of Alberta and Alberta Agriculture, Food and Rural Development, and in-kind contributions of GBIJ Farms Ltd., Miyanaga Farms Ltd., Perry Produce Ltd., Green Power, Syngenta, and Aventis.

Note

Preliminary data from the 2001 field season was presented at the 2001 PGA Annual Meeting. We are still processing data from the 2002 field season. Specific gravity, size distribution, shrinkage and tuber quality will be assessed in the coming months. Data from at least two years will be evaluated before any general recommendations will be made.





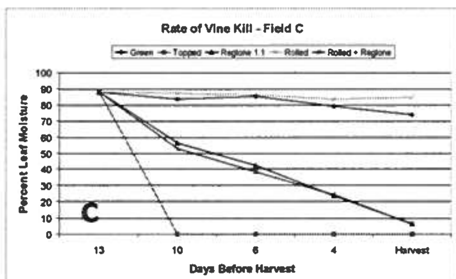


Figure 3: Moisture was determined from the fourth leaf of plants in each treatment area at intervals between application of desiccant and harvest as an indicator of the rate of vine kill.

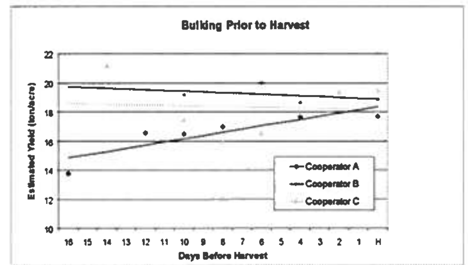
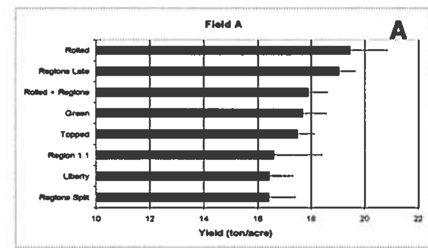
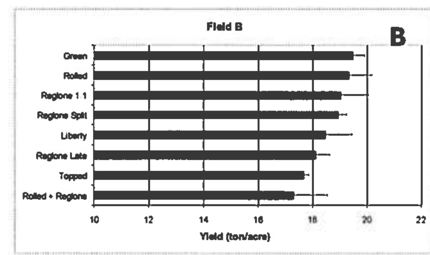


Figure 1: Yield estimates based on samples from untreated areas of each field hand-dug at intervals for two weeks prior to harvest.

Observations

- Rolling resulted in similar leaf moisture to that in the untreated area of the field. Liberty generally resulted in a slower rate of desiccation than Reglone, yet the final leaf moisture values were similar. Reglone applications with and without rolling, and split applications of Reglone resulted in the same degree of desiccation. Late application of Reglone results in only partial vine kill.
- In 2002, no bulking was observed in two cooperator fields during the two weeks before harvest, but in one cooperator's field bulking averaged 0.14 ton/ac per day in the area of the field not desiccated.
- The treatment giving the greatest yield varied with each field. In all three fields, the maximum difference in yields between treatments was only 2 ton/acre. The yield response largely depends on the status of the potato crop in each field. Yields obtained from most treatments were not significantly different from the control (green) or from one another.





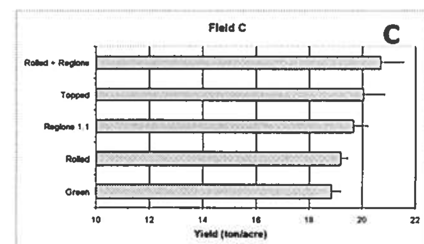


Figure 4: Yield (ton/acre) of tubers from 4 replicated 50' x 2 row samples in each treatment area at harvest.

Russet Burbank Vine Management in Southern Alberta

Michele Konschuh, Melanie Nielsen, Clive Schaupmeyer, Darcy Driedger and Lori Delanoy
Alberta Agriculture, Food and Rural Development, Crop Diversification Centre - South, S.S. #4, Brooks, AB T1R 1E6

Purpose

In southern Alberta, diquat (Reglone™) is typically applied as a chemical desiccant. Recently, there has been interest in using vine rollers to mechanically damage vines to enhance vine kill, improve canopy penetration of diquat, compact soil, close soil cracks and reduce tuber greening. Our goal is to determine the rate of tuber bulking following various vine kill strategies. Also, we will study the effects of various methods of vine killing on tuber quality (specific gravity, stem-end discoloration and fry quality).

Objectives

- To determine how much bulking occurs in potato tubers between Reglone™ application(s) and harvest.
- To compare rates of vine desiccation between Liberty™ application, single and split Reglone™ applications alone or following vine rolling.
- To determine the extent to which the method and rate of vine killing affects tuber quality (maturity, specific gravity, stem-end discoloration, fry quality).

Project Plan and Treatments

The study was conducted in two commercial fields of Russet Burbank potatoes with different maturity levels. Prior to harvest, vines were killed by single and split applications of Reglone™, alone and in combination with vine rolling. These treatments were compared with complete vine removal, green harvesting and Liberty™ application to establish rates of tuber bulking and vine desiccation following vine kill. Tuber yield, grade and quality will also be assessed for each treatment.

- Green Harvest - control (for determination of bulking)
- Topped - stems removed 14 days before harvest (14 dbh)
- Reglone 240™ - 1.2 L/ac - single application (14 dbh)
- Reglone 240™ - 0.8 L/ac (14 dbh) + 0.6 L/ac (7 dbh)
- Reglone 240™ - 1.2 L/ac - single application (7 dbh)
- Rolled - (14 dbh)
- Rolled + Reglone 240™ - 1.2 L/ac (14 dbh)
- Liberty™ - 1.2 L/ac (14 dbh)

Acknowledgements

This project was supported through funding by the Potato Growers of Alberta and Alberta Agriculture, Food and Rural Development, and in-kind contributions of GBIJ Farms Ltd., Perry Produce Ltd., Green Power, Syngenta, and Aventis.

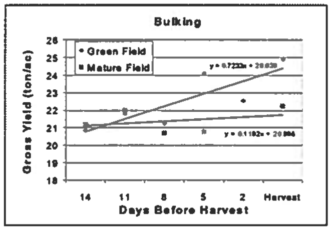


Figure 1: Estimated yield of tubers sampled from the green harvest treatment at three day intervals for two weeks prior to harvest in each field.

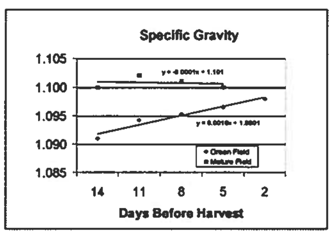
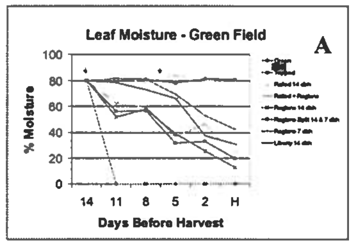


Figure 2: Specific gravity of samples collected from the green harvest treatment at three day intervals for two weeks prior to harvest in each field.



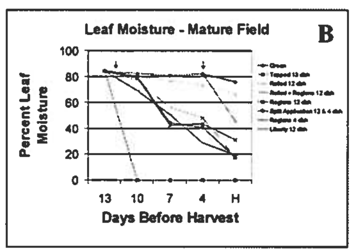
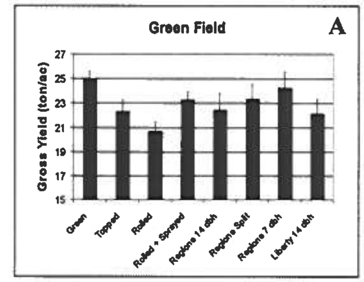


Figure 3: Moisture present in fourth leaf of plants in each treatment area between application of desiccant and harvest.
A - green field; B - mature field.

Observations

- Tubers continued to bulk in the green harvest treatment an average of 0.7 ton/ac per day in the green field, but very little bulking was observed in the mature field in the 14 days prior to harvest.
- Specific gravity remained relatively stable in the green harvest treatment in the mature field prior to harvest. Specific gravity steadily increased in the green harvest treatment in the green field in the 14 days prior to harvest.
- The rate of desiccation with Liberty was very similar to the rate of desiccation with Reglone in the mature field, however, Liberty resulted in a slower rate of desiccation than Reglone in the green field.
- In the green field, the highest yield was observed in the green harvest treatment. Spraying at 7 dbh allowed for the most bulking among the desiccated treatments, but was not significantly different from other desiccated treatments.
- In the mature field, the rolled and sprayed treatment resulted in the highest yield. Other desiccation treatments resulted in less tuber bulking.
- Rolling alone reduced tuber yield in both fields, possibly because of renewed vegetative growth in the mechanically damaged plants.



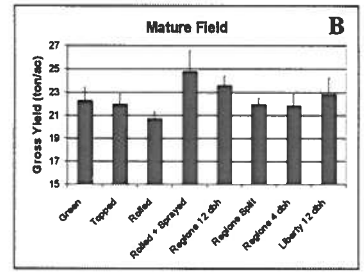


Figure 4: Yield of tubers from each treatment area at harvest.
A - green field; B - mature field.

Note

We are still processing data from the 2001 field season. Size distribution, skin set and tuber quality will be assessed in the coming months. Also, at least one more field season will be required before broad recommendations can be made.

A Comparison of Treatments for Control of Rhizoctonia on Potatoes – 2nd Year

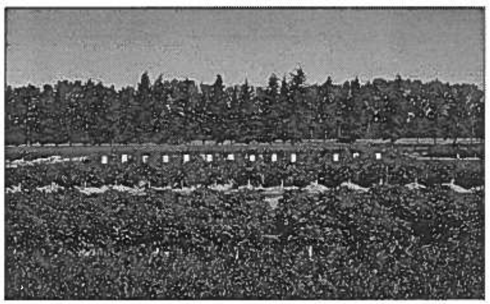
Michele Konschuh, James Calpas, Ron Howard, Sharon Lisowski and Simone Dalpe
Alberta Agriculture, Food and Rural Development, Crop Diversification Centre - South, S.S. #4, Brooks, AB T1R 1E6

Purpose

Rhizoctonia solani reduces potato yields as a result of stem and stolon cankers and reduces marketability by causing black scurf on tubers. Few commercial chemical treatments are available to Canadian growers, but a number of products are registered in the U.S. Today's consumers are more and more conscious of food safety and environmental issues, yet still expect an abundant food supply of high quality. New control products utilize natural biochemistry and beneficial microorganisms to control plant diseases. The purpose of this research project is to assess the effectiveness of several biocontrol products, including Alberta isolates of *Trichoderma*, for control of *R. solani* and to compare these with chemical control products about to enter the Canadian market place.

Objective

- To compare various biocontrol and chemical seed piece treatments for efficacy at controlling *R. solani* on fresh market potatoes.



Project Plan and Treatments

Yukon Gold and Russet Burbank potatoes with visible black scurf sclerotia were planted in six replicated blocks of 30 ft. rows at the Crop Diversification Centre in Brooks, AB. Guard rows were planted in the outside rows of each block to minimize edge effects. Each block consisted of the following treatments:

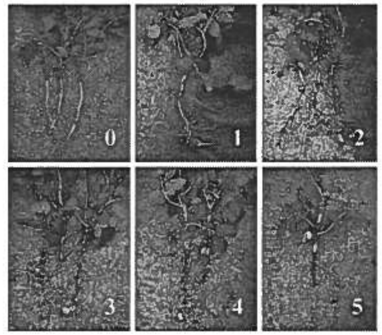
- Control - black scurf on seed, no seed treatment
- Check – no black scurf on seed
- Maxim PSP (fludioxonil) seed treatment
- Quadris (azoxystrobin) in furrow at planting
- Maxim PSP + Quadris in furrow
- *Trichoderma* in furrow at planting
- Senator (thiophanate-methyl) seed piece treatment
- ENG0500, rate 1 seed piece treatment
- ENG0500, rate 2 seed piece treatment
- L1210-A1, rate 1 seed piece treatment
- L1210-A1, rate 2 seed piece treatment
- L1049-A1 + G7050-00 seed piece treatment
- 94815A seed piece treatment
- 94815B foliar treatment
- 94815C seed piece and foliar treatments

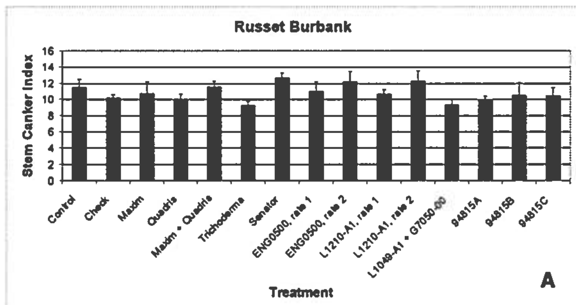
Date of emergence, stand counts and stem counts were taken during the season. At approximately 50 days after planting, 10 hills were hand dug and stem canker was assessed. The remaining potatoes were top killed in late August and harvested in September. Tubers were graded and samples of 25 marketable tubers were assessed for black scurf.

Acknowledgements

This project was supported through funding by the Potato Growers of Alberta, Alberta Agriculture, Food and Rural Development, Syngenta, Heads Up Plant Protectants, Gustafson and Engage Agro.

Figure 1: Stem canker ratings (0 = none to 5 = girdled) at 50 days after planting were used to calculate a weighted stem canker index.





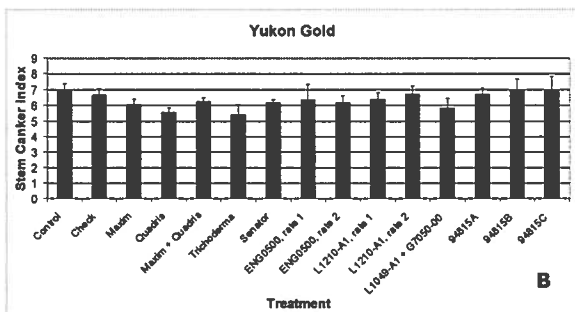


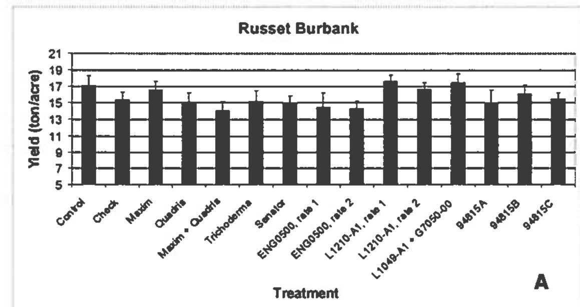
Figure 2: Stem canker index (0 = none to 100 = all girdled) for Russet Burbank (A) and Yukon Gold (B) potatoes treated with various products for control of *Rhizoctonia*.

Note

Preliminary data from the 2001 growing season were presented at the 2001 PGA Annual Meeting. We are still processing data from the 2002 field season. Data from 2001 and 2002 must be evaluated before broad recommendations can be made.

Observations - Yukon Gold

- Emergence dates were not significantly different between control plants and treatments.
- Stem canker index values were quite low in 2002. As a result, differences between treatments are not dramatic. Maxim PSP, Quadris, Trichoderma, ENG0500, L1210-A1, L1049 + G7050-00 and 94815 treatments reduced stem canker in Russet Burbank potatoes relative to the control. Most treatments reduced stem canker in Yukon Gold relative to the control.
- Total yield was not significantly different between treatments, however, the mean total yield was greatest from Russet Burbank seed treated with Maxim PSP, L1210-A1 and L1049-A1 + G7050-00 and Yukon Gold seed treated with Maxim + Quadris, Trichoderma, L1210-A1 and L1049-A1 + G7050-00 and Yukon Gold foliage treated with 94815.
- Black scurf on the potatoes will be evaluated between 1 and 3 months in storage.



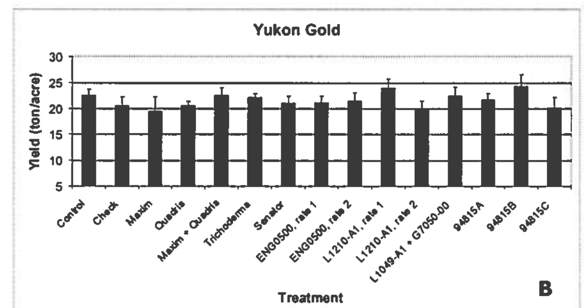
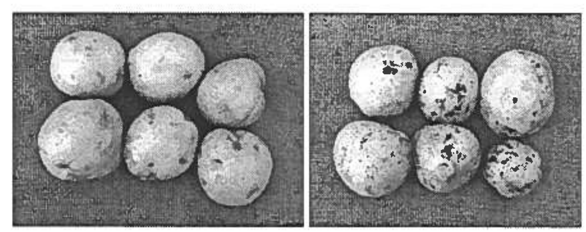


Figure 3: Total yield (ton/acre) of Russet Burbank (A) and Yukon Gold (B) potatoes from plants remaining after stem canker data was obtained. Plants were harvested at approximately 100 days after planting.



A Comparison of Biocontrol and Chemical Seed Piece Treatments for Control of Rhizoctonia on Potatoes

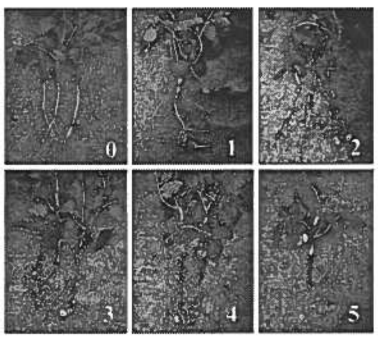
Michele Konschuh, James Calpas, Piara Bains, and Melanie Nielsen
Alberta Agriculture, Food and Rural Development, Crop Diversification Centre - South, S.S. #4, Brooks, AB T1R 1E6

Purpose

Rhizoctonia solani reduces potato yields as a result of stem and stolon cankers and reduces marketability by causing black scurf on tubers. Few commercial chemical treatments are available to Canadian growers, but a number of products are registered in the U.S. Today's consumers are more and more conscious of food safety and environmental issues, yet still expect an abundant food supply of high quality. New control products utilize natural biochemistry and beneficial microorganisms to control plant diseases. The purpose of this research project is to assess the effectiveness of several biocontrol products, including Alberta isolates of *Trichoderma*, for control of *R. solani* and to compare these with chemical control products about to enter the Canadian market place.

Objectives

- To compare various biocontrol and chemical seed piece treatments for efficacy at controlling *R. solani* on fresh market potatoes.
- To determine if *Trichoderma* spp. isolated from soils in southern Alberta are effective as biocontrol agents for *R. solani* on fresh market potatoes.



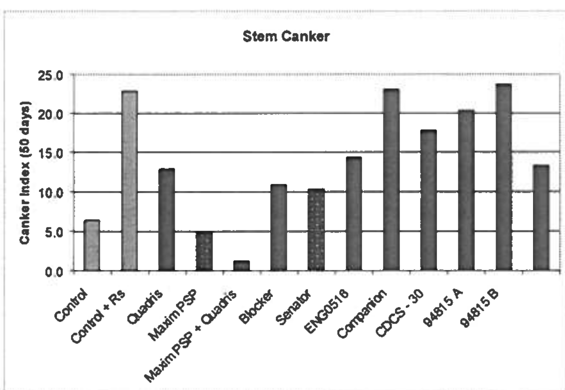


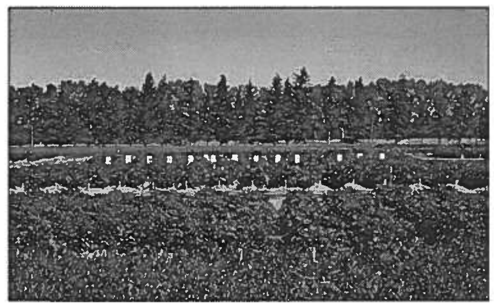
Figure 1: Stem canker ratings calculated from stem canker scores (0 = none to 5 = girdled) for individual stems of 8 Yukon Gold plants per treatment at approximately 50 days after planting.

Project Plan and Treatments

Yukon Gold, Norland, Russet Burbank and Penta potatoes were planted in four replicated blocks of 20 ft. rows at the Crop Diversification Centre in Brooks, AB. Guard rows were planted in the outside rows of each block to minimize edge effects. Each block consisted of the following treatments:

- Control - no seed treatment
- Control + *R. solani* inoculum
- Quadris (azoxystrobin) in furrow at planting + *R. solani* inoculum
- Maxim PSP (fludioxonil) seed treatment + *R. solani* inoculum
- Maxim PSP + Quadris in furrow + *R. solani* inoculum
- Blocker (pentachloronitrobenzene) in furow at planting + *R. solani* inoculum
- Sentor (thiophanate-methyl) seed piece treatment + *R. solani* inoculum
- ENG0516 (thiophanate-methyl + ??) seed piece treatment + *R. solani* inoculum
- CDCS30 (*Trichoderma*) in furrow at planting + *R. solani* inoculum
- 94815A seed piece treatment + *R. solani* inoculum
- 94815B seed piece treatment + *R. solani* inoculum
- 94815C seed piece treatment + *R. solani* inoculum

Date of emergence, stand counts and stem counts were taken during the season. At approximately 50 days after planting, 8 hills were hand dug and stem canker was assessed. The remaining potatoes were top killed in September and harvested. Tubers were graded and samples of 50 marketable tubers were assessed for black scurf.



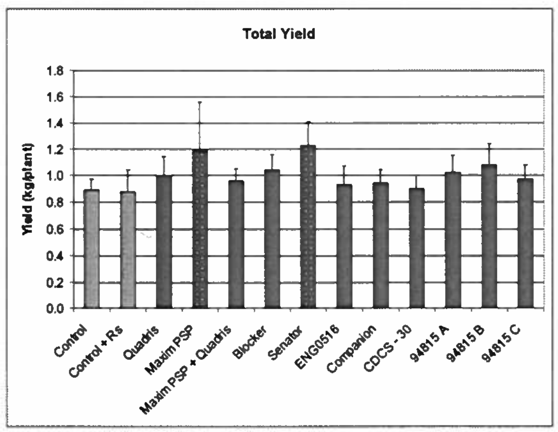
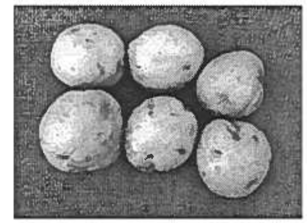


Figure 2: Total yield (kg/plant) of Yukon Gold tubers from plants remaining after stem canker data was obtained. Plants were harvested at approximately 130 days after planting.

Acknowledgements

This project was supported through funding by the Potato Growers of Alberta and Alberta Agriculture, Food and Rural Development, Syngenta, Heads Up Plant Protectants, and Engage Agro. In-kind contributions were provided by BASF, Growth Products, Soil Technologies Corp., and Bioworks, Inc.



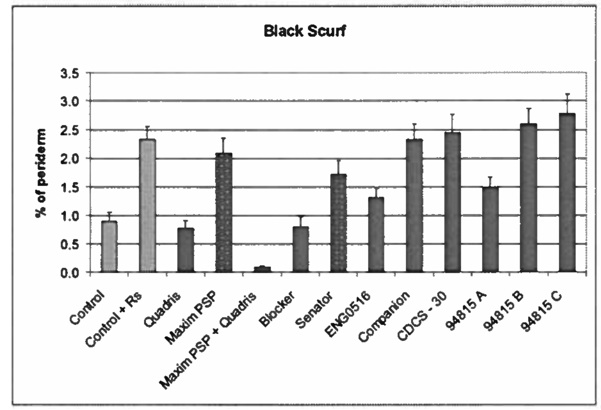


Figure 3: Average black scurf (percentage of periderm) observed on a sample of 50 marketable Yukon Gold tubers approximately one month after harvest.

Observations - Yukon Gold

- Emergence dates were not significantly different between control plants and treatments.
- All of the chemical treatments reduced the mean stem canker index relative to the inoculated control. Maxim PSP alone or in combination with Quadris in furrow resulted in the lowest stem canker index. Two biological controls, CDCS 30 and 94815C also reduced mean stem canker index relative to the inoculated control.
- Total yield was not significantly different between treatments, however, the mean total yield was greatest from seed treated with Maxim PSP or Senator.
- There were significant differences in black scurf severity between treatments. All of the chemical treatments except Maxim PSP resulted in less black scurf than the inoculated control. The least black scurf was observed on tubers treated with both Maxim PSP and Quadris in furrow. Among the biocontrol products tested, only 94815A reduced black scurf relative to the inoculated control.

Note

We are still processing data from the 2001 field season. Only data from the Yukon Gold samples are presented here. Also, at least one more field season will be required before broad recommendations can be made.

POTATO GROWERS OF ALBERTA

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Taber, Alberta T1G 2B1

Phone (403) 223-2262
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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: "Soil Moisture Distribution and Moisture Use Efficiency for Various Prepared Potato Seed Beds"

Dear Ted:

We are pleased to advise that the Board of the Potato Growers of Alberta has approved your application in the amount of $2,500.00. 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

MEMORANDUM OF UNDERSTANDING
Operation and Management

This Memorandum of Understanding Made This 9th Day of May, 2005 Between:

The Irrigation Branch of Alberta Agriculture, Food and Rural Development (AAFRD), represented by Brent Paterson

Potato Growers of Alberta represented by Vern Warkentin

Potato Growers of Alberta and Irrigation Branch of Alberta Agriculture are partners in a project entitled " Soil Moisture Distribution and Moisture Use Efficiency for Various Prepared Potato Seed Beds" for the 2005 irrigation season.

Potato Growers of Alberta have made a commitment of $2,500 for the project in 2005

Alberta Agriculture Irrigation Branch project responsibilities:

Manage the project and arrange for all field operations.
Install soil moisture arrays and instrument for continuous data gathering.
Analyze data and prepare end of season report and submit to PGA by Dec 15, 2005.
Present findings to PGA members as requested.
Ensure project is conducted as per the proposal.

Potato Growers of Alberta project responsibilities:

Provide financial assistance and industry expertise, and field selection for soil moisture demonstration for the project. The financial assistance will be used in support of labor, supply purchase and transportation costs.

AAFRD will provide the following as part of the project commitment:

1) A yearly interim progress report, which outlines the project description, site locations and initial research results.
2) Presentation of project results at a PGA breakfast meeting or grower annual meeting

The purpose of the Memorandum of Understanding is to address the operational and staffing needs of the project for the period May 1, 2005 to October 31, 2005.

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<u>Signatures</u>

Alberta Agriculture, Food and Rural Development:

Ted Harms, Project Leader
Irrigation Branch

Brent Paterson, Head
Irrigation Branch

Potato Growers of Alberta:

Vern Warkentin. Executive Director
Potato Growers of Alberta

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	
Address: CDC South SS#4	City:Brooks	Province:AB
Postal Code:T1R 1E6	E-mail :ted.harms@gov.ab.ca	
Phone Number:362-1347	Fax Number:362-1306	

Team Member:Tom O'Reilly		
Organization:AAFRD	Section/Department:Irrigation	
Address:802-6th st East	City:Bow Island	Province:AB
Postal Code:T0K 0G0	E-mail:tom.o'reilly@gov.ab.ca	
Phone Number:545-2231	Fax Number:545-6353	

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

2. Project Information

Title:Soil Moisture Distribution and Moisture Use Efficiency for Various Prepared Potato Seed Beds
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
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:Efficiency of irrigation applications in a potato crop grown in southern Alberta

Team Leader:Warren Helgason

Start Date:04/04

2.Project:

Team Leader:

Start Date:

Background.
(Max 2000 characters)

It is often assumed that the infiltration of irrigation and rainfall into a potato hill is uniform. However, due to the implied topographic relief of hill-furrow tillage systems it is likely that the actual infiltration and subsequent redistribution of irrigation water is quite variable. This is supported by Saffigna et al. 1976; Stieber and Shock, 1995; Bargar et al. 1999; and Robinson, 1999 who all noticed that more water enters the soil through the furrow than through the ridge or hill.

It is believed that suction exerted by the plant's root system acts to redistribute some of this water into the hill position over the next few days where it can be used by the plant. However, there is sufficient reason to believe that some of the water that collects in the furrow position will move to positions below the root zone, effectively lost for crop use. This is also supported by the findings of the first year of study whereby similar soil moisture values at 10 centimeters below the soil surface in the furrow position occurred at greater than 40 centimeters below the soil surface in the hill position. Thus, as an extension, excess water may be applied to maintain desirable soil moisture in the hill and as a consequence, some of the water is lost to the crop due to deep percolation in the furrow position.

Different hill shapes or combining 2 hills into one to minimize furrows within the field may improve soil moisture distribution and increase irrigation efficiency.

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

- improve soil moisture distribution of field prepared for growing potatoes.
- decrease deep percolation and improve irrigation efficiency.

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

Challenge for irrigated agriculture is to either gain more production using similar volumes of water or even gain production by using less water. This project will quantify in terms of water use efficiency, the benefit of altering field preparation to one where more of the applied water is available in the root zone of the potato plant.

This project will be used to provide initial indications if a more detailed, replicated trial is warranted. If results suggest that there are irrigation efficiency benefits to altering bed shape for potatoes, then a replicated trial (3 replicates) in varying soil textures (2 or 3) would provide sound scientific and statistical information that could then be used to encourage practice change among potato growers.

A replicated trial would be substantially more expensive and would require approaching various funding agencies for support.

Methodology Description

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

The study will be conducted at the Canada-Alberta Crop Development Initiative Demonstration Farm near Lethbridge. A total of 3 hill/bed furrow combinations will be constructed in a 4.5 m X 2.0 m area in the potato seeded 1/4 of the large pivot. They include standard power hilled, flat topped hilled and 2 row flat topped hilled.

Soil moisture will be monitored with a Watermark sensor array at a spacing of no greater than 20 cm either horizontally or vertically from each other.

All sensors will be connected to a Campbell Scientific CR 10X datalogger for hourly values.

A vadose zone flux meter will be installed below the furrow position near the middle of the plot at a depth of 70 cm below the soil surface.

The plot will be hydrologically isolated from the upslope position with a wooden barrier.

Monthly rill meter readings will be taken to quantify the integrity of the hill/beds.

Additional instrumentation will be included to monitor irrigation amount and timing, rainfall, plot soil moisture, potato ET.

End of season potato yields and quality for the different prepared seed beds will be done by the agronomy group. Potato water use, irrigation application and irrigation efficiency will be compared between the various prepared seed beds.

Technology Transfer Plan.

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

Presentation could be made to PGA sponsored conferences and/or meetings.

Year-end report will be prepared and submitted to PGA

POTATO GROWERS OF ALBERTA

3. Project Budget

		Year 1	Year 2	Year 3	Total
PGA	Cash	2500			
	In-Kind				
	Total	2500			
Other					
AAFRD	Cash	47000*			
	In-Kind	6000			
	Total	53000			
Other					
	Cash				
	In-Kind				
	Total				
Other					
	Cash				
	In-Kind				
	Total				
Other					
	Cash				
	In-Kind				
	Total				
Total		**55500**			

Project Cost Distribution	Year 1	Year 2	Year 3	Total
Personnel	3300			
Travel expenses	1000			
Capital goods	49500			
Materials	1700			
TOT				
Overhead				
Total	**55500**			

*TOT (Transference of

Technology)
Research Project Manager **Signature** **Date**

Project Report

Timing of Power Hilling for Russet Burbank in Southern Alberta

2nd Year

Prepared for:

Potato Growers of Alberta
6008, 46th Avenue
Taber, AB T1G 2B1

Prepared by:

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January 17, 2005

Background

Potato acreage has expanded in southern Alberta and many growers have expanded operations without a proportional increase in equipment or manpower. In recent years, many growers have implemented power hilling as part of their spring planting routine, rather than hilling with conventional hilling equipment. Alberta's spring weather is unpredictable at best, and in some years, moisture has prevented growers from planting and hilling potatoes during an optimal window of time. Although damage from late hilling is anticipated, there is little information regarding the impact this damage has on yield or quality of processing potatoes. When plants have emerged and power hilling is no longer deemed safe, some growers may rely on conventional hillers.

Traditionally, commercially grown potatoes are hilled in the production cycle between emergence and canopy close (Carling and Walworth 1990, Geisel 2003). Geisel (2003) maintains that hilling is the only necessary tillage operation in the production of potatoes on the Canadian Prairies. Hilling improves drainage, minimizes tuber greening, minimizes frost damage, aids in weed control and facilitates harvesting (Carling and Walwoth 1990, Vangessel and Renner 1990, Renner 1992, Geisel 2003). Cultivation may benefit potatoes by aerating and improving the soil structure, but it may be detrimental to potato growth if soil structure is damaged, potato roots are pruned, or foliage is damaged (Carling and Walworth 1990, Renner 1992, Schaupmeyer 1992, Secor 1993).

Rotary hoes, discs, mouldboards, or power hillers equipped with a metal mould are commonly used to hill potatoes (Geisel 2003). Conventional hilling is typically conducted when plants are approximately 30 cm tall because there is little risk of covering the foliage (Carling and Walworth 1990, Vangesel and Renner 1990, Renner 1992). Vines of larger plants may, however, sustain greater damage from hilling than smaller plants, and the possibility of damaging roots and stolons increases as the plants increase in size (Carling and Walworth 1990, Rowe and Secor 1993). Geisel (2003) recommends that post-emergent hilling with conventional equipment be completed before the plants are 20 cm in height to avoid damage to roots and foliage and power hilling should be completed prior to emergence to avoid covering the plants.

The purpose of this project was to determine optimal timing of power hilling for Russet Burbank potatoes in southern Alberta and to compare not hilling with conventional and power hilling at various intervals for up to ten weeks after planting. Potatoes were graded for total yield, marketable yield, deformities, internal defects, specific gravity and fry colour.

Objectives

1. To determine how many weeks after planting potatoes can be power hilled before root pruning and yield loss occur; and
2. To compare conventional hilling to power hilling with respect to yield and grade of potatoes.

Materials and Methods

The study was conducted in replicated plots at CDCS in Brooks, AB. The plots were irrigated and managed following the guidelines for the Western Canadian Potato Breeding Program. Russet Burbank seed (E3) of the same seed lot was used for this trial. Seed was cut (approximately 2½ to 3 oz. seed pieces), suberized, treated with Maxim™ seed piece treatment (500 g/100 kg seed) and planted 12" apart in 25' rows spaced 36" apart. Potatoes were planted approximately 5 to 5½" deep using a two-row wheel planter on May 4, 2004. Each treatment was replicated four times. Each treatment was 4 rows wide, but only the two center rows were harvested (see plot plan).

Potatoes were hilled with a power hiller or a disc hiller according to the treatment list below:

Treatments:

1. Control – no hilling (for comparison only)
2. Power hilling 1 week after planting (immediately after planting)
3. Power hilling 3½ weeks after planting (ground crack)
4. Power hilling 4 weeks after planting (emergence)
5. Power hilling 6½ weeks after planting (stolon hooking)
6. Power hilling 7½ weeks after planting (buds forming; plants 5 to 12" tall)
7. omitted
8. Disc hilling 4 weeks after planting (emergence)
9. Disc hilling 6½ weeks after planting (stolon hooking)
10. Disc hilling 7½ weeks after planting (buds forming; plants 5 to 12" tall)
11. omitted
12. Disc hilling 9½ weeks after planting (row close)

Potatoes were planted approximately 5 to 5½" deep using a two-row wheel planter on May 20, 2004. Each treatment was 4 rows wide, and the center two rows were harvested (see plot plan attached). Wireless temperature loggers were attached to the first seed piece in two replicates of each treatment. These data loggers were recovered just prior to harvest and daily maximum and minimum temperature data from each device were collected. The plots were irrigated to maintain soil moisture close to 70%. Eptam (2.0 L/ac) was applied pre-planting (April 15) and Prism (24 g/ac) was applied post-emergent (June 23) to control weeds. Foliar fungicides were applied approximately every 2 weeks during the growing season to prevent early blight and late blight from developing (Table 1). Insecticides were applied July 15 (Sevin, 0.5 L/ac) and July 30 (Admire, 80 ml/ac) to control Colorado Potato Beetles.

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

Date of Application	*Fungicide*	*Rate*
June 22	Quadris	0.250 L/ac
July 8	Dithane DG Rainshield	0.60 kg/ac
July 16	Ridomil Gold/Bravo	8.83 L/10 ac
July 30	Bravo 500	0.75 L/ac
August 12	Dithane DG Rainshield	0.60 kg/ac
August 27	Quadris	0.250 L/ac

All treatments were harvested mechanically September 29 and 30. Tubers were weighed to obtain yield estimates and graded to remove small and deformed tubers. Marketable tubers (1⅞ to 3½" in diameter) were weighed to obtain estimates of marketable yield. Yield estimates have been presented in ton/acre although small plot trials do not always accurately reflect commercial yield potential. A sample of 25 marketable tubers was washed and used to determine specific gravity by the weight-in-air over weight-in-water method. Each of these tubers was then cut longitudinally to assess brown center, hollow heart and other internal defects. Also, a sample of marketable tubers was submitted to the Food Science lab at CDCS for fry quality analysis. Eight tubers were used to process fries, and 5 fry strips from each potato were used to assess fry color. Fry color was rated on a scale of 1 to 7 where 1 = very dark and 7 = very light.

Data were statistically analyzed using GLM and Duncan's Multiple Range Test ($p \leq 0.05$; SAS).

Results and Discussion

The trial was planted quite early, but cool, wet weather immediately after planting delayed treatments. Hilling treatments were planned at weekly intervals for comparison, however, the stage of growth and development of the potato plants is more informative than the time elapsed after planting. Environmental conditions affected the stage of growth and development, and plants emerged later than expected in 2004. The growth stages of potatoes were noted for each treatment (Table 2).

Table 2: Stages of potato growth and development at the time hilling was conducted for each treatment in 2003.

Treatment(s)	*Weeks After Planting*	*Stage of Potato Growth and Development*
1	No Hilling	N/A
2	1	Planted
3	3½	Ground crack; Growth Stage I
4, 7	4	Emergence; Growth Stage II
5, 8	6½	Stolon hooking; Growth Stage II
6, 9	7½	5 to 12" Plants; Buds forming; Growth Stage III
10	9½	Row close; Growth Stage III

Soil temperatures ranged from 4.25°C to 28.25°C during the early part of the growing season when hilling treatments were taking place (see Appendix Figures A1 and A2). In general, climate had a greater impact on soil temperatures in potato hills than the method or timing of hilling. Carling and Walworth (1990) reported that large changes in soil temperature in potato hills were related to weather changes rather than to hilling treatment or irrigation. Timing of hilling, and method of hilling had less impact on minimum soil temperatures in the spring than on maximum soil temperatures. Maximum soil temperatures differed by as much as 4°C between treatments. Power hilling immediately after planting appeared to prevent the hills from warming up as much as the control treatments. The cooler temperatures in these hills may have delayed emergence and may account for lower yields relative to the check and to hilling at ground crack or emergence. In general, power hilling treatments had lower maximum soil temperatures and higher minimum soil temperatures in the spring compared to disc hilled treatments. This environmental buffering or insulation effect was less noticeable as the season progressed. Carling and Walworth (1990) also noted that variation in soil temperature was much less during the later part of the season, due perhaps to the shading produced by closure of the canopy. Environmental buffering was also observed in the fall (see Appendix Figures A3 and A4). Minimum temperatures were higher and maximum temperatures were lower for power hilled treatments in September compared to not hilling or to disc hilled treatments. This soil temperature buffering effect may be even more noticeable in years with greater temperature extremes. Overall, 2003 was cooler with more precipitation than 2004, especially in August.

In 2004, hilling at ground crack (3½ weeks after planting) resulted in the highest total yield, however, none of the hilling treatments resulted in statistically significant improvements in gross yield (Figure 1) compared to the control. In contrast, most hilled treatments in 2003 resulted in greater total yield than the control (not hilled). Carling and Walworth (1990) reported that all four hilled treatments in their study yielded significantly more than the treatment that was not hilled. In 2004, we experienced more regular rainfall than usual, and fewer excessively hot days. The difference in environmental conditions may explain why not hilling gave good results in 2004, but not in 2003 or other studies.

Power hilling at ground crack (3½ weeks after planting) resulted in significantly greater total yield than power hilling immediately after planting. Power hilling early in 2004, may have delayed plant emergence enough to impact yield. Hilling with a power hiller any time after stolon hooking had taken place resulted in significant yield reductions compared to not hilling. Presumably, this yield reduction is a consequence of root pruning and damage to the vegetative portions of the plant.

Hilling with a disc hiller 3½ to 7½ weeks after planting resulted in gross yield similar to the control, but disc hilling at row close (9½ weeks after planting) resulted in a significant reduction in gross yield relative to the control (Figure 1). This hilling event corresponded to stage III (tuber initiation). Few studies have looked at the effects of the timing of hilling on potato yield and quality, and none have addressed timing of power hilling. Many of the papers dealing with timing of hilling are focused on hilling as a means of weed control, and few time frames are included. Vangessel and Renner (1990) and Renner (1992) used early hilling (ground crack) and conventional hilling (plants 12" tall) time frames in their study of weed interference in potato. In their studies, no difference in yield or marketable yield could be attributed to the time of hilling. However, in the absence of other methods of weed control, the timing of hilling impacted weed biomass, type of weed species present and yield (Renner 1992). Rajalahti et al. (1999) used a cultivator type hiller 3 weeks after planting (late ground cracking), 4 weeks after planting (1 week after 50% potato emergence) and 5 weeks after planting (2 weeks after 50% potato emergence). Their study reported significantly greater yield in plots hilled 3 weeks after planting than those hilled 4 and 5 weeks after planting and in those hilled 4 weeks after planting compared to those hilled 5 weeks after planting, but there were no significant differences in marketable yield between timings.

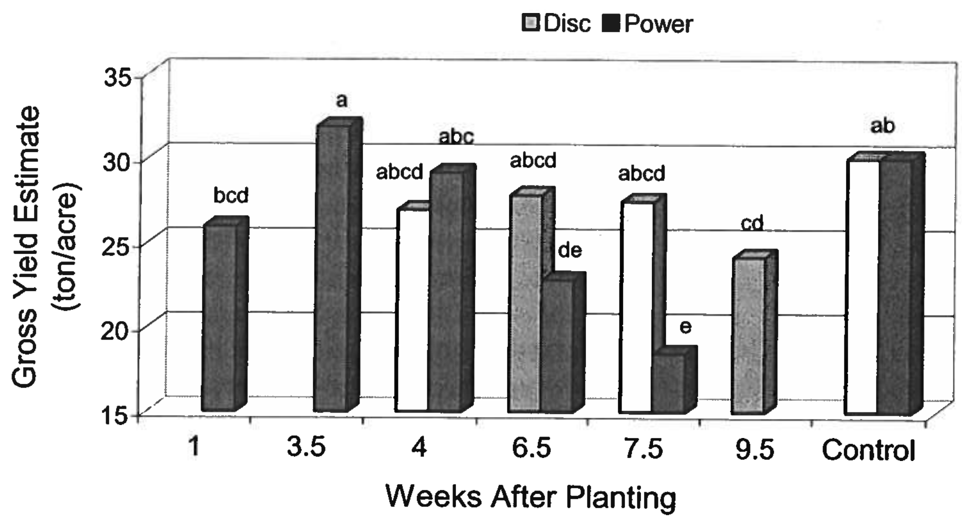

Figure 1: Gross yield estimates (ton/acre) of Russet Burbank potatoes from plants hilled with a disc hiller or a power hiller at intervals ranging from immediately after planting to 9.5 weeks after planting. Bars with the same letter are not significantly different at the $p \leq 0.05$ level.

Harvested tubers were graded according to the Guidelines for the Western Canadian Potato Breeding Program. Potatoes with a diameter of less than 1⅞" were categorized as small tubers, tubers between 1⅞" and 3½" were classed as marketable and potatoes greater than 3½" in diameter were classed as oversized. Tubers with secondary growth, growth cracks and other deformities were reported as deformed. Results of grading from the trial are shown in Table 3. None of the hilled treatments resulted in significantly different yields of undersized potatoes than the control, however there was a trend toward fewer smalls the later the plants were power hilled.

The greatest marketable yield was observed when Russet Burbank potatoes were power hilled at ground crack (3½ weeks after planting). Although not significantly different from the control, yield of marketable potatoes from plants power hilled at ground crack were significantly better than those from plants power hilled immediately after planting (1 week after planting). Power hilling after stolon hooking reduced marketable yield compared to the control. Yield of marketable tubers from disc hilled treatments were not significantly different from the control, except for treatments disc hilled at row close, which were lower. Carling and Walworth hilled with a spider hiller when plants were 4 to 6" high (early treatment) or when plants were 12" high (late treatment), and reported no significant difference in total or marketable yield as a result of these treatments. Their treatments roughly correspond to our disc hilled treatments 6½ and 7½ weeks after planting. Rajalahti et al. (1999) observed significant differences in total yields between treatments, however, no differences in marketable yield between timings of hilling events. Not hilling (control) and hilling too late resulted in more oversized and deformed tubers than other treatments, although few significant differences were observed.

Table 3: Yield estimates (ton/acre) by size category of Russet Burbank potatoes from plants power hilled or disc hilled at various times from immediately after planting to 9.5 weeks after planting. Values in columns with the same letter are not significantly different at the p ≤0.05 level..

Trt.	*Weeks After Planting*	*Small (<1⅞")*	*Marketable (1⅞-3½")*	*Oversize (>3½")*	*Deformed*
1	Not Hilled	3.94 ab	24.14 ab	0.85 ab	1.07 b
	Power Hilled				
2	1	5.47 a	20.00 bc	0.13 b	0.36 bcd
3	3½	5.83 a	24.99 a	0.37 ab	0.67 bcd
4	4	4.09 ab	23.96 ab	0.89 a	0.20 d
5	6½	3.10 b	18.66 c	0.42 ab	0.62 bcd
6	7½	3.34 b	13.69 d	0.45 ab	0.98 bc
	Disc Hilled				
8	4	4.45 ab	21.59 abc	0.60 ab	0.31 cd
9	6½	5.08 ab	21.00 abc	0.51 ab	0.53 bcd
10	7½	5.87 a	20.82 abc	0.22 ab	0.54 bcd
12	9½	4.07 ab	18.01 c	0.35 ab	1.74 a

Specific gravity data is shown in Table 4. Potatoes hilled with a power hiller after tuber formation began, or with a disc hiller at row close had lower specific gravity than those from other treatments, although few of the differences were statistically significant. The highest specific gravities were observed in the samples from treatments hilled at emergence (4 weeks after planting). No reported information was found linking specific gravity to method or timing of hilling.

Table 4: Specific gravity of tubers harvested from plants hilled 0 to 9.5 weeks after planting. Specific gravity was measured using the weight in air over weight in water method. Data in the table followed by the same letter are not significantly different at the p ≤0.05 level.

Type of Hilling	*Weeks After Planting*					
	1	*3.5*	*4*	*6.5*	*7.5*	*9.5*
Power	1.095 abc	1.087 abc	1.099 ab	1.086 bc	1.081 c	
Disc			1.101 a	1.092 abc	1.098 ab	1.087 abc
None	1.090 abc					

Fry quality data is presented in Table 5. The lightest fry colors were observed from samples of potatoes disc hilled at stolon hooking and bud formation, although there were no unacceptable fry scores from the 2004 harvest. No reported information was found linking fry color to method or timing of hilling.

Table 5: Fry color data for tubers harvested from plants hilled 0 to 9.5 weeks after planting. Fry color was rated on a scale of 1 to 7 where 1 = very dark (U.S.D.A. 4 rating) and 7 = very light (U.S.D.A. 000 rating). Data in the table followed by the same letter are not significantly different at the $p \leq 0.05$ level.

Type of Hilling	*Weeks After Planting*					
	1	*3.5*	*4*	*6.5*	*7.5*	*9.5*
Power	4.00 abc	3.50 bc	4.00 abc	3.25 c	4.25 ab	
Disc			3.75 abc	4.25 ab	4.50 a	3.75 abc
None	4.00 abc					

Tuber uniformity data is presented in Table 6. The greatest uniformity of tuber size was observed when Russet Burbank potatoes were power hilled at emergence. Tuber uniformity from this treatment was significantly better than the control and all other treatments. Poor timing of power hilling decreased the uniformity of tuber size. Carling and Walworth (1990) reported that tuber size was influenced by some hilling treatments, though not necessarily in a negative way.

Table 6: Uniformity of size for tubers harvested from plants hilled 0 to 9.5 weeks after planting. Uniformity was rated on a scale of 1 to 5 where 1 = very variable and 5 = very uniform. Data in the table followed by the same letter are not significantly different at the $p \leq 0.05$ level.

Type of Hilling	*Weeks After Planting*					
	1	*3.5*	*4*	*6.5*	*7.5*	*9.5*
Power	2.63 bcd	2.63 bcd	3.80 a	2.50 bcd	3.13 b	
Disc			2.88 bc	2.63 bcd	2.25 cde	1.75 e
None	2.13 de					

<u>Summary</u>

Power hilling at ground crack (3½ weeks after planting) resulted in the highest gross yield, the highest marketable yield and good specific gravity and fry color relative to other treatments. Gross yield and marketable yield were reduced when potatoes were power hilled after tuber initiation (6½ and 7½ weeks after planting). The optimum time to hill with a power hiller appears to be before plant emergence, although power hilling up to stolon hooking still resulted in acceptable marketable yields. Power hilling immediately after planting appeared to delay emergence and reduce yield, possibly because soil temperatures remain cool longer. Late hilling caused a reduction in total yield, however late power hilling was more detrimental to marketable yield than late disc hilling. If power hilling has not been completed by the time plants are 2 to 5" tall, disc hilling may be better than power hilling.

Power hilling at emergence resulted in the highest specific gravity, however few significant differences in specific gravity were observed between treatments. The best fry quality was observed for treatments hilled at emergence. Fry colors were very good for all treatments, regardless of timing or method of hilling.

The greatest uniformity of tuber size was observed when Russet Burbank potatoes were power hilled at emergence. Poor timing of power hilling decreased the uniformity of tuber size.

In 2004, power hilling Russet Burbank potatoes at ground crack or at emergence resulted in the best combination of marketable yield, good fry color, and uniform tuber size. A third year of the trial is planned for 2005.

References

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Appendix

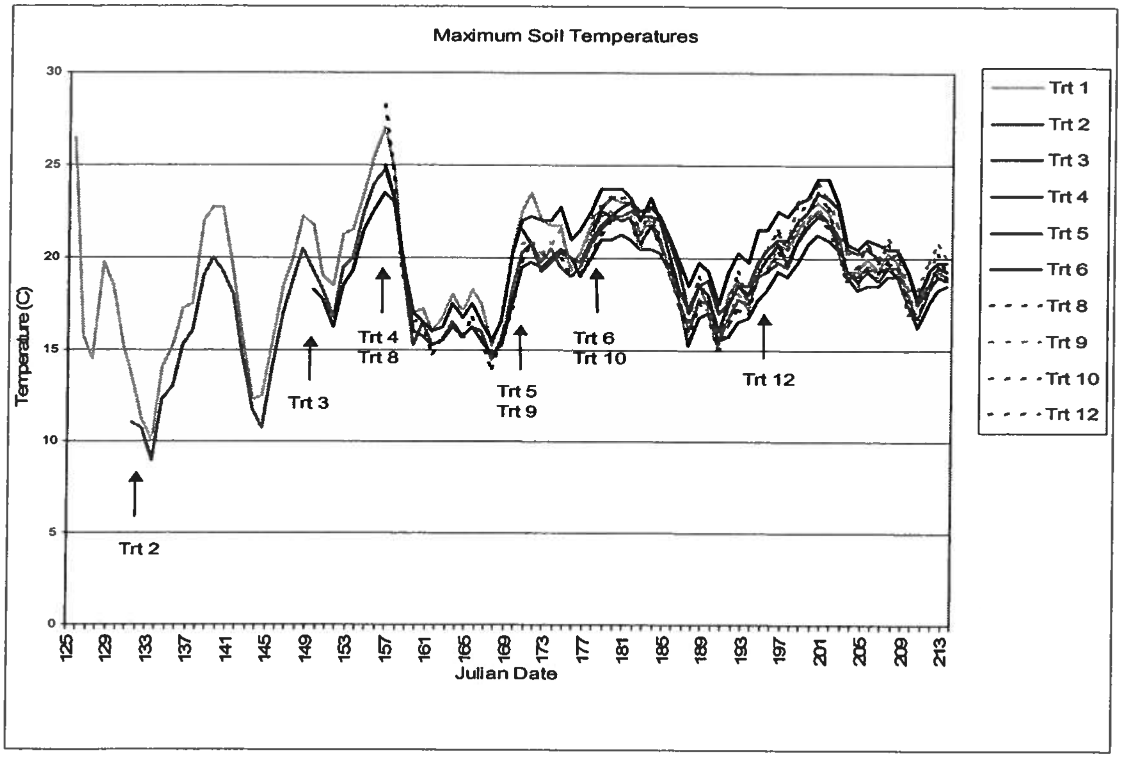

Figure A1: Maximum soil temperatures recorded in potato hills formed at different times using two types of hilling equipment (May, June and July 2004).

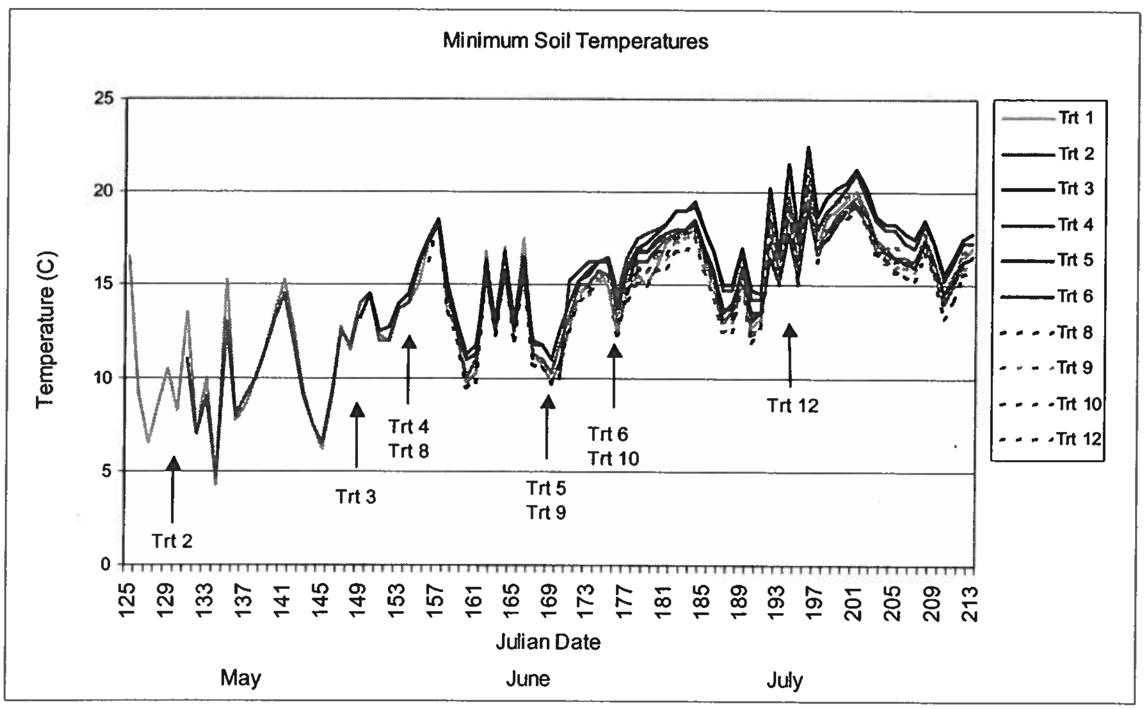

Figure A2: Minimum soil temperatures recorded in potato hills formed at different times using two types of hilling equipment (May, June and July 2004).

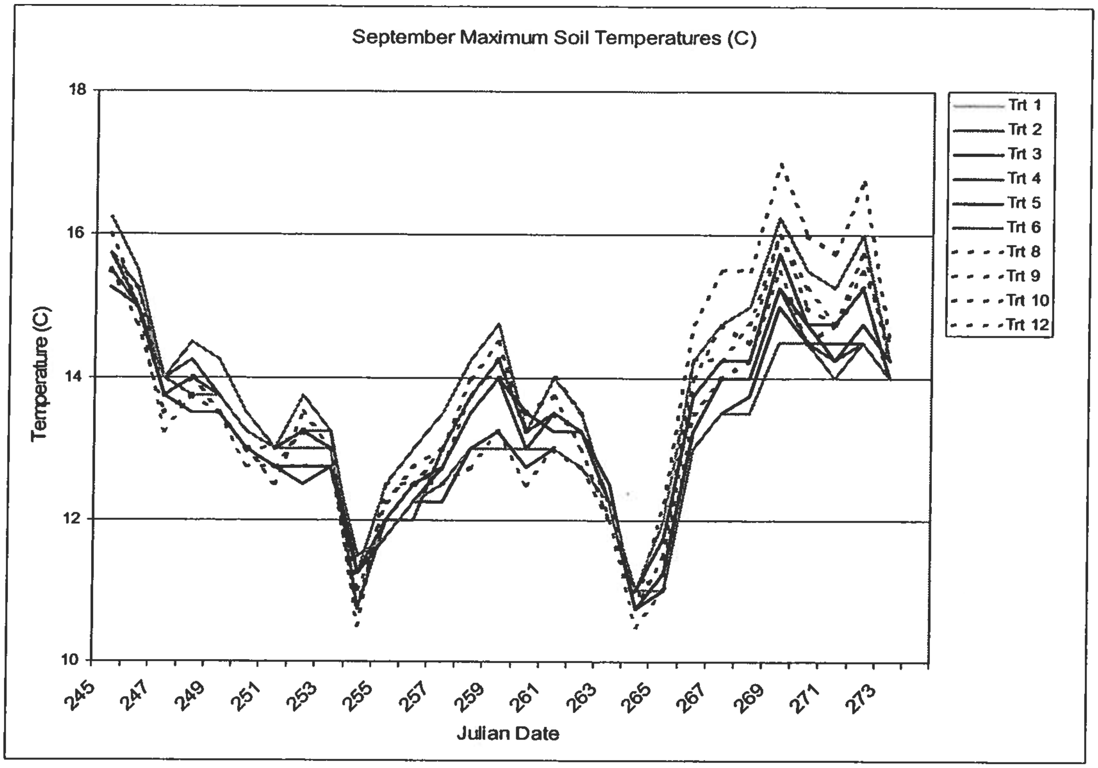

Figure A3: Maximum soil temperatures recorded in potato hills formed at different times using two types of hilling equipment (September 2004).

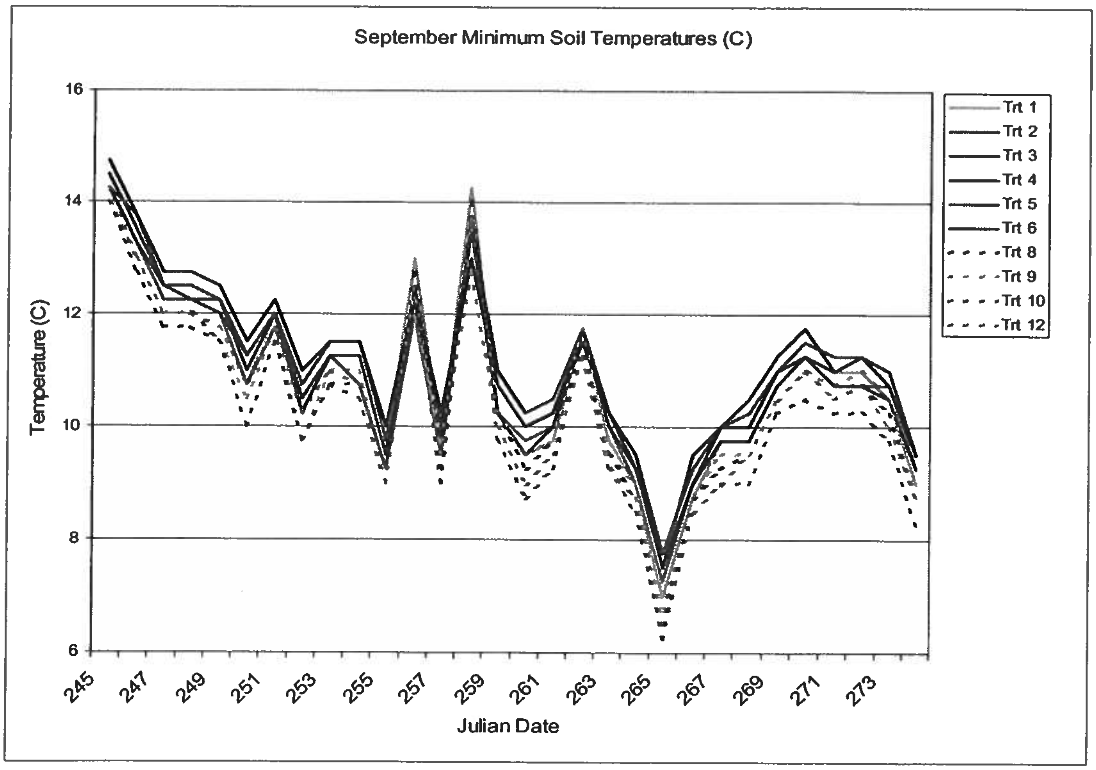

Figure A4: Minimum soil temperatures recorded in potato hills formed at different times using two types of hilling equipment (September 2004).

Plot Plan

Power Hilling Trial - 2004

Russet Burbank

N ←

7.5m | 3m | 12m | 63m

	Row	Plot	Trt	Plot	Trt	Plot	Trt	Plot	Trt	Plot	Trt
START	1	Guard		Guard		Guard		Guard		Guard	
	2	1001	2	2001	2	3001	2	4001	2	5001	2
	3	1002	2	2002	2	3002	2	4002	2	5002	2
	4	Guard		Guard		Guard		Guard		Guard	
	5	Guard		Guard		Guard		Guard		Guard	
	6	1003	10	2003	10	3003	10	4003	10	5003	10
	7	1004	10	2004	10	3004	10	4004	10	5004	10
	8	Guard		Guard		Guard		Guard		Guard	
	9	Guard		Guard		Guard		Guard		Guard	
	10	1005	11	2005	11	3005	11	4005	11	5005	11
	11	1006	11	2006	11	3006	11	4006	11	5006	11
	12	Guard		Guard		Guard		Guard		Guard	
START	13	Guard		Guard		Guard		Guard		Guard	
	14	1007	3	2007	3	3007	3	4007	3	5007	3
	15	1008	3	2008	3	3008	3	4008	3	5008	3
	16	Guard		Guard		Guard		Guard		Guard	
	17	Guard		Guard		Guard		Guard		Guard	
	18	1009	9	2009	9	3009	9	4009	9	5009	9
	19	1010	9	2010	9	3010	9	4010	9	5010	9
	20	Guard		Guard		Guard		Guard		Guard	
	21	Guard		Guard		Guard		Guard		Guard	
	22	1011	4	2011	4	3011	4	4011	4	5011	4
	23	1012	4	2012	4	3012	4	4012	4	5012	4
	24	Guard		Guard		Guard		Guard		Guard	
START	25	Guard		Guard		Guard		Guard		Guard	
	26	1013	8	2013	8	3013	8	4013	8	5013	8
	27	1014	8	2014	8	3014	8	4014	8	5014	8
	28	Guard		Guard		Guard		Guard		Guard	
	29	Guard		Guard		Guard		Guard		Guard	
	30	1015	5	2015	5	3015	5	4015	5	5015	5
	31	1016	5	2016	5	3016	5	4016	5	5016	5
	32	Guard		Guard		Guard		Guard		Guard	
	33	Guard		Guard		Guard		Guard		Guard	
	34	1017	7	2017	7	3017	7	4017	7	5017	7
	35	1018	7	2018	7	3018	7	4018	7	5018	7
	36	Guard		Guard		Guard		Guard		Guard	
START	37	Guard		Guard		Guard		Guard		Guard	
	38	1019	6	2019	6	3019	6	4019	6	5019	6
	38	1020	6	2020	6	3020	6	4020	6	5020	6
	39	Guard		Guard		Guard		Guard		Guard	
	40	Guard		Guard		Guard		Guard		Guard	
	40	1021	12	2021	12	3021	12	4021	12	5021	12
	41	1022	12	2022	12	3022	12	4022	12	5022	12
	42	Guard		Guard		Guard		Guard		Guard	
	42	Guard		Guard		Guard		Guard		Guard	
	43	1023	1	2023	1	3023	1	4023	1	5023	1
	44	1024	1	2024	1	3024	1	4024	1	5024	1
	44	Guard		Guard		Guard		Guard		Guard	

	TRT				
4-May	1	No Hilling	n/a	7	PH
10-May	2	PH 1 wk after planting	4-Jun	8	CH Emergence
28-May	3	PH 3.5 wks after planting/ground crack	18-Jun	9	CH Stolon hooking
4-Jun	4	PH Emergence	25-Jun	10	CH Buds forming/plants 5-12"
18-Jun	5	PH Stolon hooking	n/a	11	CH
25-Jun	6	PH Buds forming/plants 5-12"	14-Jul	12	CH Row Close/tubers loonie sized/plants 2

POTATO GROWERS OF ALBERTA

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April 28, 2005

Michele Konschuh
Potato Research Agronomist
Alberta Agriculture, Food and Rural Development
Crop Diversification Centre South
S.S. #4
Brooks, AB T1R 1E6

Re: "Effect of green manures on Verticillium wilt, Rhizoctonia solani, scab, root-lesion nematodes, soil fertility and yield of potatoes"

Dear Michele:

We are pleased to advise that the Board of the Potato Growers of Alberta has approved your application in the amount of $20,000.00. However, availability of the funds will be subject to the Funding Consortium commitment to this project.

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

Note:
Project started April 2004

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: Michele Konschuh		
Organization: AAFRD	Section/Department: CDCS	
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Team Member: Ron Howard		
Organization: AAFRD	Section/Department: CDCS	
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: Ross McKenzie		
Organization: AAFRD	Section/Department: CDCS	
Address: 5401-1 Ave S	City: Lethbridge	Province:AB
Postal Code:T1J 4V6	E-mail address:ross.mckenzie@gov.ab.ca	
Phone Number: 403-381-5842	Fax Number: 403-381-5765	

2. Project Information

Title:Effect of green manures on Verticillium wilt, Rhizoctonia solani, scab, root-lesion nematodes, soil fertility and yield of potatoes
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): small plots in Saskatoon and field plots near Vauxhall or Taber
Duration (Y):5 Start Date (YY/MM):05/05Ending Date (YY/MM):10/12

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

1.Project: Management of Powdery Scab
Team Leader: Ron Howard

Start Date: 2005

2.Project:
Team Leader:

Start Date:

Background.
(Max 2000 characters)

Awareness of and concern about the early dying complex of potato is building in the potato indsutry. Verticillium wilt, nematodes, weather and soil conditions may all interact to cause premature death in potatoes. Verticillium wilt can be caused by V. dahliae or V. albo-atrum. Verticillium species are soil-borne fungi and, once established, can live for long periods, even if a potato crop has not been planted for many years. Researchers from other areas are reporting a link between Verticillium wilt and soil populations of root-lesion nematodes. Preliminary nematode assessments from southern Alberta indicate that root-lesion nematodes may be a factor in early dying of potatoes.

Green manures, such as sorghum sudan grass, have been reported to suppress Verticillium wilt and increase yield and quality in subsequent potato crops. Others, such as forage pearl millet and marigold, have been shown to suppress nematodes. Green manure crops from the brassica family have been shown to reduce weed populations and reduce Rhizoctonia in subsequent potato crops. In some cases, green manure has had as much impact as soil fumigation in controlling specific potato pests.

Alberta potato growers face a short but intensive season. Processing potatoes are grown on irrigated land in increasingly tight rotations. Although green manures have been an effective tool for disease and nematode management in other potato growing areas, there is a need to establish which green manure crops could offer practical solutions in southern Alberta. Further, we have an opportunity to determine the effect of green manure crops on powdery scab from infested soil in Sakatchewan research plots and in greenhouse trials in Alberta.

Objectives (Measurable-Deliverables)

(Please use Bullets) (Max 1000 characters)

This project has three objectives:

1. To determine whether green manure crops can be used in potato rotations to suppress Verticillium wilt, nematodes, and other soil-borne potato pests.
2. To determine the effect of green manure crops on soil fertility and soil organic matter.
3. To determine the impact of using green manure crops on yield and quality in subsequent potato crops.

Economical/Environmental Benefits

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

There are potential economic benefits to using green manures in potato rotations in that fewer pesticides would be required, if green manure is successful at supressing pests, and less fertilizer would be required on land if green manure improved soil fertility. Further, there would be potential environmental benefits to improved soil organic matter and soil moisture retention, reduced soil erosion with green manure crop and / or residue on the land, and reduced inputs. There may also be an increase in beneficial organisms in the soil which would have impacts on crop and soil health overall.

Methodology Description

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

The trial would be conducted on two fields of "tired" land in potato rotations in southern Alberta as well as in a small-plot research trial in Saskatoon. Green manure crops would be planted following processing peas or a silage crop in 2005. Six to eight green manure crops would be examined against a check (no green manure). Sorghum sudan grass, forage pearl millet, radish, marigold, hairy vetch, rapeseed, and mustard are some of the green manure crops being considered. The trial would occupy between 2 and 4 acres in a cooperator field. Biomass measurement of each green manure crop will be taken, then each green manure crop will be plowed down or desiccated at the stage of growth reported to have the greatest benefit. Soil samples for fertility, soil quality and pH would be taken twice each year; prior to planting the green manure crop, and in the fall after plow down. Soil samples would be taken in summer (prior to green manure) and fall and assessed for levels of root-lesion nematodes. Baseline levels of Verticillium, Rhizoctonia, Fusarium and other soil-borne pathogens would also be established at the outset of the trial. A potato crop would be planted over the green manure plots as part of a half or full circle in 2006 (depending on cooperator). During the potato year, samples would be taken to monitor plant disease, fertility, nematodes, yield, grade and quality. We are interested in following the project through two full rotations of potato (5 year project). A sister trial in Saksatoon will be established on soil known to be contaminated with Rhizoctonia, powdery scab and common scab. This would provide valuable information about the impact of green manures on additional potato diseases. Supplemental funding will be sought for 2006 and onward.

Technology Transfer Plan.

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

The results of this trial would be made available to all sponsors through research reports and updates. Field day tours would be conducted at sites in the Taber area. The results would also be presented in poster format or through presentations to grower groups upon request.

3. Project Budget

		Year 1	Year 2	Year 3	Total
PGA	Cash	26550	27000	20000	73550
	In-Kind		3200		3200
	Total	26550	30200	20000	76750
Other					
AAFRD	Cash				
	In-Kind	5200	7000	2400	14600
	Total	5200	7000	2400	14600
Other					
U of S	Cash				
	In-Kind	3400	6000	2200	11600
	Total	3400	6000	2200	11600
Other					
Funding Consort	Cash		64210	14820	79030
	In-Kind				
	Total	0	64210	14820	79030
Other					
Cooperators	Cash				
	In-Kind	2000	5000	1000	8000
	Total	2000	5000	1000	8000
Total		**37150**	**112410**	**40420**	**189980**

Project Cost Distribution	Year 1	Year 2	Year 3	Total
Personnel	15840	80210	17350	113400
Travel expenses	1800	3100	1320	6220
Capital goods	0	0	0	0

Materials	17010	18800	18000	53810
TOT	0	500	0	500
Overhead	2500	9800	3750	16050
Total	**37150**	**112410**	**40420**	**189980**

*TOT (Transference of Technology)

Research Project Manager

Signature **Date**

PGA

Potato Growers of Alberta
Research Tracking

Title of Research Application: Effect of green manures on V.W, RS, S, R-LN, SF and yield of potatoes

Name of Researcher: Michele Konschuh

Employer: Ab. Agriculture, Food and Rural Dev.

Date application was received by PGA ____

Date application was reviewed by PGA April 3, 2006

A) approved ✓ B) declined ____

Project start date: 2006 Project finish date: 2008

Total amount requested:$ 60,000 - Amount requested per year: $20,000

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

Date completed Oct 13, 2006

Invoice received: # 102520061 Date funds advanced Nov. 2/06 Cheque# 4540 $20,000 -

Invoice received:# 011LA011601 Date funds advanced July 10/07 Cheque# 4972 $20,000 -

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: ____

Alberta
GOVERNMENT OF ALBERTA

INVOICE

COPY

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: 011LA011601
Invoice Date: June/27/2007
Customer No: C031892
Payment Terms: 30 Days
Period Covered -
Due Date: July/27/2007

AMOUNT DUE: **21,200.00 CAD**

Amount Remitted

Please cut along line and return top portion with payment

For billing questions, please call: **403-362-1302**

Invoice Number	Invoice Date	Customer Number	Payment Terms	Period Covered	Due Date
011LA011601	June/27/2007	C031892	30 Days	-	July/27/2007

Line	Description / Contract No.	Order No.	Quantity / Order Date	UOM	Unit Amt	GST Amt / PO Reference No.	Extended Amount
1			1.00	EA	20,000.00	1,200.00	20,000.00

```
Green Manure on Potato Project
8140-87925-819125.
```

Subtotal: **20,000.00**

Total (GST):
Net Amount: 20,000.00 GSTReg 6.00 % 1,200.00

AMOUNT DUE: **21,200.00**

RECEIVED JUL - 4 2007

Government of Alberta - GST Registration Number: 124072513

Original

COPY

Project #819125
New: X Renewal:

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: Use of green manure crops to reduce soil-borne pests and diseases of Alberta potato crops

Objectives:
1. To determine whether the use of green manure crops is effective for reducing soil-borne potato pests and diseases;
2. To determine which green manure crop is most effective at reducing specific potato pests and diseases;
3. To determine the impact of using green manure crops on yield and quality in subsequent potato crops, and
4. To provide economically viable alternatives to soil fumigation.

STATEMENT OF WORK

Alberta Agriculture, Food & Rural Development is willing to undertake this study for PGA, who hereby agrees to pay toward the costs of researching the information required as described in the research proposal.

PERIOD OF WORK

The research project will commence in April 2006. A final report will be provided to PGA by May 2010.

BASIS OF PAYMENT

The sponsor of the project, PGA, will provide $60,000 plus GST, one third upon finalization of this memorandum to AAFRD, one third in 2007 and one third in 2008 to cover the following estimated costs:

Casual Manpower (on an as need basis):	$55,600
Communication, Dissemination and Linkage	$1,500
Overhead	$2,900

The Budget may 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.

If requested, 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 will be used for research at the discretion of the project manager.

RESPONSIBILITY OF PROJECT MANAGER

The project manager for this study is Dr. Michele Konschuh. She will provide all reports to AAFRD and the sponsors.

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 herself.

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

Alberta Agriculture, Food & Rural Development:

Mr. Henry Najda, Branch Head
Crop Development – Food Branch
Crop Diversification Centre South
310 Horticulture Station Road East
Brooks, AB T1R 1E6

The Department of Agriculture, Food & Rural Development 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 the AAFRD 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. Michele Konschuh, Project Manager

Date Sept 25/06

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

Mr. Henry Najda, Branch Head,
Crop Development, Food Branch

Date Sept 25/06

Dr. Cornelia Kreplin, Director
Ag Research Division

Date 2006 09 27

Mr. Brian Rhiness, Assistant Deputy Minister
Industry Development Sector

Date Oct 2/2006

Mr. Vern Warkentin, Executive Director
Potato Growers of Alberta

Date Oct 13/06

Alberta FACSIMILE

AGRICULTURE & FOOD
FOOD CROPS
CDC SOUTH, 301 HORTICULTURAL STATION ROAD EAST, BROOKS, AB TIR 1E6
PHONE: (403)362-1302 – FAX: (403 362-1306

TO: PATTY – PGA

FROM: ANNA MOELLER

COMPANY:

DATE: JULY 4/07

FAX NUMBER: (403) 223 – 2268

TOTAL NO. OF PAGES INCLUDING COVER: 4

RE:

YOUR REFERENCE NUMBER:

☐ URGENT ☒ FOR REVIEW ☐ PLEASE COMMENT ☐ PLEASE REPLY ☐ FOR INFORMATION

Copy as requested.

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. Michele Konschuh
Alberta Agriculture, Food & Rural Development
301 – Horticultural Station Rd. E.
Brooks, AB T1R 1E6

Re: Green Manure Verticillium Wilt, Rizoctonia Solani, Scab, Root-lesion Nematodes, Soil Fertility & Yield of Potatoes

Dear Michele:

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 $20,000 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: Effect of green manures on V.W, RS, S, R-LN, SF and yield of potatoe

Name of Researcher: Michele Konschuh

Employer: Ab. Agriculture, Food and Rural Dev.

Date application was received by PGA ____________

Date application was reviewed by PGA April 3, 2006

A) approved ✓ B) declined ________

Project start date: 2006 Project finish date: 2008

Total amount requested:$ 60,000 - Amount requested per year: $20,000

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

Date completed Oct 13, 2006

Invoice received: # 102520061 Date funds advanced Nov. 2/06 Cheque# 4540 $20,000-

Invoice received:# 011LA011601 Date funds advanced July 10/07 Cheque# 4972 $20,000—

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

Michele Konschuh
Potato Research Agronomist
Alberta Agriculture, Food and Rural Development
Crop Diversification Centre South
S.S. #4
Brooks, AB T1R 1E6

Re: "Effect of green manures on Verticillium wilt, Rhizoctonia solani, scab, root-lesion nematodes, soil fertility and yield of potatoes"

Dear Michele:

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 three year period in the amount requested of $60,000. For the period of April 1, 2006 – March 31, 2007 the amount of $20,000 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

Alberta
AGRICULTURE, FOOD AND
RURAL DEVELOPMENT

Crop Diversification Centre
South

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

Telephone 403/362-1300
Fax 403/362-1306

October 6, 2006

Potato Growers of Alberta
6008 – 46th Avenue
Taber, AB T1G 2B1

Attention: Vern Warkentin, Executive Director

Re: MOU for "Use of green manure crops to reduce soil-borne pests and diseases of Alberta potato crops"

Dear Vern;

Thank you for your confirmation that the PGA is willing to fund our project entitled "Use of green manure crops to reduce soil-borne pests and diseases of Alberta potato crops" over the next few years. I understand that the PGA would prefer to provide their financial contribution independently of the Alberta funding consortium. As a formality, we would like to set up a Memorandum of Understanding (MOU) with the Potato Growers of Alberta before invoicing for this year's allocation. Please review the enclosed MOU. If the terms of the MOU are acceptable, please sign both copies and return an original to me. If you would prefer to propose alternate terms, please contact me at 403-362-1314 and we can discuss the terms further. An invoice for $20,000 plus GST will be issued under separate cover. Thank you.

Sincerely,

Michele Konschuh, Ph.D.
Potato Research Agronomist

Encl.

Project #819125
New: **X** Renewal:

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: Use of green manure crops to reduce soil-borne pests and diseases of Alberta potato crops

Objectives:
1. To determine whether the use of green manure crops is effective for reducing soil-borne potato pests and diseases;
2. To determine which green manure crop is most effective at reducing specific potato pests and diseases;
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4. To provide economically viable alternatives to soil fumigation.

STATEMENT OF WORK

Alberta Agriculture, Food & Rural Development is willing to undertake this study for PGA, who hereby agrees to pay toward the costs of researching the information required as described in the research proposal.

PERIOD OF WORK

The research project will commence in April 2006. A final report will be provided to PGA by May 2010.

BASIS OF PAYMENT

The sponsor of the project, PGA, will provide $60,000 plus GST, one third upon finalization of this memorandum to AAFRD, one third in 2007 and one third in 2008 to cover the following estimated costs:

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Overhead	$2,900

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RESPONSIBILITY OF PROJECT MANAGER

The project manager for this study is Dr. Michele Konschuh. She will provide all reports to AAFRD and the sponsors.

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 herself.

AMENDMENTS OR TERMINATION

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

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

Alberta Agriculture, Food & Rural Development:

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Crop Development – Food Branch
Crop Diversification Centre South
310 Horticulture Station Road East
Brooks, AB T1R 1E6

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

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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. Michele Konschuh, Project Manager

Date: Sept 25/06

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

Mr. Henry Najda, Branch Head,
Crop Development, Food Branch

Date: Sept 25/06

Dr. Cornelia Kreplin, Director
Ag Research Division

Date: 20060927

Mr. Brian Rhiness, Assistant Deputy Minister
Industry Development Sector

Date: Oct 2/2006

Mr. Vern Warkentin, Executive Director
Potato Growers of Alberta

Date: Oct 13/06

PGA POTATO GROWERS OF ALBERTA

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: Michele Konschuh		
Organization: AAFRD	Section/Department: CDCS	
Address: S.S. #4	City: Brooks	Province:AB
Postal Code:T1R 1E6	E-mail :michele.konschuh@gov.ab.ca	
Phone Number: 403-362-1314	Fax Number: 403-362-1306	

Team Member: Ron Howard		
Organization: AAFRD	Section/Department: CDCS	
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: Ross McKenzie		
Organization: AAFRD	Section/Department: CDCS	
Address: 5401-1 Ave S	City: Lethbridge	Province:AB
Postal Code:T1J 4V6	E-mail address:ross.mckenzie@gov.ab.ca	
Phone Number: 403-381-5842	Fax Number: 403-381-5765	

2. Project Information

Title:Effect of green manures on Verticillium wilt, Rhizoctonia solani, scab, root-lesion nematodes, soil fertility and yield of potatoes
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): small plots in Saskatoon and field plots near Vauxhall or Taber
Duration (Y):5 Start Date (YY/MM):05/05Ending Date (YY/MM):10/12

POTATO GROWERS OF ALBERTA

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

1.Project: Management of Powdery Scab
Team Leader: Ron Howard

Start Date: 2005

2.Project:
Team Leader:

Start Date:

Background.
(Max 2000 characters)

Awareness of and concern about the early dying complex of potato is building in the potato indsutry. Verticillium wilt, nematodes, weather and soil conditions may all interact to cause premature death in potatoes. Verticillium wilt can be caused by V. dahliae or V. albo-atrum. Verticillium species are soil-borne fungi and, once established, can live for long periods, even if a potato crop has not been planted for many years. Researchers from other areas are reporting a link between Verticillium wilt and soil populations of root-lesion nematodes. Preliminary nematode assessments from southern Alberta indicate that root-lesion nematodes may be a factor in early dying of potatoes.

Green manures, such as sorghum sudan grass, have been reported to suppress Verticillium wilt and increase yield and quality in subsequent potato crops. Others, such as forage pearl millet and marigold, have been shown to suppress nematodes. Green manure crops from the brassica family have been shown to reduce weed populations and reduce Rhizoctonia in subsequent potato crops. In some cases, green manure has had as much impact as soil fumigation in controlling specific potato pests.

Alberta potato growers face a short but intensive season. Processing potatoes are grown on irrigated land in increasingly tight rotations. Although green manures have been an effective tool for disease and nematode management in other potato growing areas, there is a need to establish which green manure crops could offer practical solutions in southern Alberta. Further, we have an opportunity to determine the effect of green manure crops on powdery scab from infested soil in Sakatchewan research plots and in greenhouse trials in Alberta.

Objectives (Measurable-Deliverables)

(Please use Bullets) (Max 1000 characters)

This project has three objectives:

1. To determine whether green manure crops can be used in potato rotations to suppress Verticillium wilt, nematodes, and other soil-borne potato pests.
2. To determine the effect of green manure crops on soil fertility and soil organic matter.
3. To determine the impact of using green manure crops on yield and quality in subsequent potato crops.

Economical/Environmental Benefits

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

There are potential economic benefits to using green manures in potato rotations in that fewer pesticides would be required, if green manure is successful at supressing pests, and less fertilizer would be required on land if green manure improved soil fertility. Further, there would be potential environmental benefits to improved soil organic matter and soil moisture retention, reduced soil erosion with green manure crop and / or residue on the land, and reduced inputs. There may also be an increase in beneficial organisms in the soil which would have impacts on crop and soil health overall.

Methodology Description

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

The trial would be conducted on two fields of "tired" land in potato rotations in southern Alberta as well as in a small-plot research trial in Saskatoon. Green manure crops would be planted following processing peas or a silage crop in 2005. Six to eight green manure crops would be examined against a check (no green manure). Sorghum sudan grass, forage pearl millet, radish, marigold, hairy vetch, rapeseed, and mustard are some of the green manure crops being considered. The trial would occupy between 2 and 4 acres in a cooperator field. Biomass measurement of each green manure crop will be taken, then each green manure crop will be plowed down or desiccated at the stage of growth reported to have the greatest benefit. Soil samples for fertility, soil quality and pH would be taken twice each year; prior to planting the green manure crop, and in the fall after plow down. Soil samples would be taken in summer (prior to green manure) and fall and assessed for levels of root-lesion nematodes. Baseline levels of Verticillium, Rhizoctonia, Fusarium and other soil-borne pathogens would also be established at the outset of the trial. A potato crop would be planted over the green manure plots as part of a half or full circle in 2006 (depending on cooperator). During the potato year, samples would be taken to monitor plant disease, fertility, nematodes, yield, grade and quality. We are interested in following the project through two full rotations of potato (5 year project). A sister trial in Saksatoon will be established on soil known to be contaminated with Rhizoctonia, powdery scab and common scab. This would provide valuable information about the impact of green manures on additional potato diseases. Supplemental funding will be sought for 2006 and onward.

Technology Transfer Plan.

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

The results of this trial would be made available to all sponsors through research reports and updates. Field day tours would be conducted at sites in the Taber area. The results would also be presented in poster format or through presentations to grower groups upon request.

3. Project Budget

		Year 1	Year 2	Year 3	**Total**
PGA	Cash	26550	27000	20000	73550
	In-Kind		3200		3200
	Total	26550	30200	20000	76750
Other					
AAFRD	Cash				
	In-Kind	5200	7000	2400	14600
	Total	5200	7000	2400	14600
Other					
U of S	Cash				
	In-Kind	3400	6000	2200	11600
	Total	3400	6000	2200	11600
Other					
Funding Consort	Cash		64210	14820	79030
	In-Kind				
	Total	0	64210	14820	79030
Other					
Cooperators	Cash				
	In-Kind	2000	5000	1000	8000
	Total	2000	5000	1000	8000
Total		**37150**	**112410**	**40420**	**189980**

Project Cost Distribution	Year 1	Year 2	Year 3	**Total**
Personnel	15840	80210	17350	113400
Travel expenses	1800	3100	1320	6220
Capital goods	0	0	0	0

Materials	17010	18800	18000	53810
TOT	0	500	0	500
Overhead	2500	9800	3750	16050
Total	**37150**	**112410**	**40420**	**189980**

*TOT (Transference of Technology)

Research Project Manager

Signature **Date**

PGA 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

0049

DATE 07102007
M M D D Y Y Y Y

PAY ******Twenty-One Thousand Two Hundred and 00/100 $**21,200.00

TO THE ORDER OF
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

MEMO Green Manure on Potato Project

PER ____________ AUTHORIZED SIGNATURE

⑈004972⑈ ⑆00139⑉010⑆ 72⑉05317⑈

POTATO GROWERS OF ALBERTA
Minister Of Finance

7/10/2007

0049

Date	Type	Reference	Original Amt.	Balance Due	Discount	Payment
07/10/2007	Bill	011LA011601	21,200.00	21,200.00		21,200.00
					Cheque Amount	21,200.00

Main Operating Accou Green Manure on Potato Project Can$21,200.00

POTATO GROWERS OF ALBERTA
Minister Of Finance

7/10/2007

0049

Date	Type	Reference	Original Amt.	Balance Due	Discount	Payment
07/10/2007	Bill	011LA011601	21,200.00	21,200.00		21,200.00
					Cheque Amount	21,200.00

Main Operating Accou Green Manure on Potato Project Can$21,200.00

PGA 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

0045

DATE 1 1 0 2 2 0 0 6
M M D D Y Y Y Y

PAY ******Twenty-One Thousand Two Hundred and 00/100 $**21,200.00

TO THE ORDER OF Minister Of Finance

POTATO GROWERS OF ALBERTA
General Account

PER ______ AUTHORIZED SIGNATURE

MEMO Use of Green Manure Crops

PER ______ AUTHORIZED SIGNATURE

⑈004540⑈ ⑆00139⑉010⑆ 72⑉05317⑈

POTATO GROWERS OF ALBERTA
Minister Of Finance 11/2/2006 0045

Date	Type	Reference	Original Amt.	Balance Due	Discount	Payment
11/02/2006	Bill	102520061	21,200.00	21,200.00		21,200.00
					Cheque Amount	21,200.00

Main Operating Accou Use of Green Manure Crops Can$21,200.00

POTATO GROWERS OF ALBERTA
Minister Of Finance 11/2/2006 0045

Date	Type	Reference	Original Amt.	Balance Due	Discount	Payment
11/02/2006	Bill	102520061	21,200.00	21,200.00		21,200.00
					Cheque Amount	21,200.00

Main Operating Accou Use of Green Manure Crops Can$21,200.00

Potato Growers of Alberta
Research Tracking

Title of Research Application: Environmental & Soil Moisture Controls on potato plant soil water use 3rd year.

Name of Researcher: Ted Harms

Employer: Ab Agriculture, Food and Rural Dev.

Date application was received by PGA____________________

Date application was reviewed by PGA April 3, 2006

A) approved ✓ B) declined________

Project start date: May 1, 2006 Project finish date: Oct. 31, 2006

Total amount requested: $ 7,200 - Amount requested per year: $ 7,200

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

Date completed ____________________

Invoice received: # 2006-17 Date funds advanced Jan 30/07 Cheque# 4706 $7,000 -

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:____________________

PGA
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 T1J 4B1

Re: "Environmental and soil moisture controls on potato plant soil water use." 3rd Year

Dear Ted:

We are pleased to advise that the Board of Directors 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 $7,200 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
Environmental and Soil Moisture Controls on Potato Plant Soil Water Use
OBJECTIVES
1)Determine the actual daily and seasonal crop water use from Russet Burbank potatoes.
2) Determine the moisture level at which the transpiration rate of potatoes is reduced.
3) Determine the environmental controls (temperature) at which the transpiration rate of potatoes is reduced.
4) Develop a crop coefficient curve for use with ET based scheduling methods.

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 $7,200 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.
Ensure data collected to satisfy objectives.
Incorporate new crop coefficient curve into AIMM, IMCIN.
Coordinate preparation and completion of year-end report.

Present findings to PGA members as requested.

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

Potato Growers of Alberta:

Vern Warkentin. Executive Director
Potato Growers of Alberta

Potato Growers of Alberta
Research Tracking

Title of Research Application: Quantification of Water Use of potatoes by altering bed-shape

Name of Researcher: Ted Harms

Employer: Ab Agriculture Food and Rural Dev.

Date application was received by PGA______________________

Date application was reviewed by PGA April 3/06

A) approved ✓   B) declined______

Project start date: May 1, 2006   Project finish date:______________

Total amount requested:$ 21,300 -   Amount committed per year: $7300 in 2006

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 Jan 30/07 Cheque# 4706 $7300 -

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 T1J 4B1

Re: "Quantification of water use of potatoes by altering bed-shapes"

Dear Ted:

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 three year period in the amount requested of $21,300. For the period of April 1, 2006 – March 31, 2007 the amount of $7,300 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
Quantification of water use of potatoes by altering bed-shape.

OBJECTIVES
1) Quantify the water-savings by altering the shape of the hill.
2) Record the frequency of irrigation applications needed for the different hill shapes.
3) Compare final potato yield and tuber quality between all treatments.

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 $7,300 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.
Prepare field with various bed shapes for seeding.
Assist agronomy unit with seeding.
Acquire all necessary soil moisture and irrigation data.
Coordinate irrigation applications.

Coordinate preparation and completion of year-end report.
Present findings to PGA members as requested.

b) AAFRD INDUSTRY DEVELOPMENT SECTOR

Field preparation, fertilizer.
Assist with bed/hill preparation.
Seed prepared beds and hills.
Assist with layout of irrigation system.
Scout trials and arrange for within season spraying of fungicide, pesticide, fertilizer.
Sample trials for yield and quality.

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. Michelle Konshuh, Agronomy,
CDC South

Potato Growers of Alberta:

Vern Warkentin. Executive Director
Potato Growers of Alberta

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:Ted Harms		
Organization:AAFRD	Section/Department:Irrigation	
Address:SS#4 CDC South	City:Brooks	Province:AB
Postal Code:T1R0E9	E-mail :ted.harms@gov.ab.ca	
Phone Number:403 362-1347	Fax Number:403 362-1306	

Team Member:Michele Konschuh		
Organization:AAFRD	Section/Department:Research	
Address:SS#4 CDC South	City:Brooks	Province:AB
Postal Code:T1R0E9	E-mail:michele.konshuh@gov.ab.ca	
Phone Number:403 362-1314	Fax Number:403 362-1306	

Team Member:		
Organization:	Section/Department:	
Address:	City:	Province:
Postal Code:	E-mail address:	
Phone Number:	Fax Number:	

2. Project Information

Title:Quantification of water use of potatoes by altering bed-shape.

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):

Duration (Y):3 Start Date (YY/MM):06/04Ending Date (YY/MM):08/10

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)

Hilling of potato rows is done in southern Alberta to prevent greening of the tubers, ensure drainage of the soil volume around the forming tubers and to facilitate mechanical harvest. However, the final contour of the typical or standard hill encourages precipitation (either rainfall or irrigation) to flow from the hill position and pond in the furrow position. Dammer-dyking of the furrow minimizes the opportunity for runoff and allows the ponded precipitation the time to infiltrate into the soil. It was believed that soil matrix forces (suction forces, negative pressure) would draw the water from the furrow position into the hill where it would be available to the potato tubers. In the previous study, it was found that a) lateral movement or water from the furrow position into the hill was minimal and b) by altering the shape of the hill, either by widening it to a double-row bed or by flattening the top of the single hill, resulted in more of the precipitation to infiltrate into the hill. Having more of the applied irrigation water infiltrating into the hill should result in a decrease in both the number of irrigation applications and the amount of irrigation water required. To quantify the savings in both the number of irrigation applications and volume of irrigation water applied, a follow-up study is proposed. The field design would be such that each hill-shape treatment could be differentially irrigated.

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

- quantify the water-savings by altering the shape of the hill
- record the frequency of irrigation applications needed for the different hill shapes.
- compare final potato yield and tuber quality between all treatments.

Economical/Environmental Benefits

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

Irrigated agriculture is coming under increased pressure to ensure that water diverted for irrigation is being used efficiently and effectively. The results of this project should be:

- less frequent irrigation applications would translate into cost savings for operation of irrigation equipment.
- more of the applied water remaining in the hill would translate into less irrigation water required.
- reduced ponding of water in the furrow position should limit the amount of deep percolation and hence nutrient flushing to areas below the root zone of the potato plant.

Methodology Description

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

The study will be conducted at CDC South in Brooks. The trial will be constructed in a randomized-complete block design with 3 treatments and 4 replications for a total of 12 plots with appropriate buffers between plots. The hill furrow combinations will include standard power hilled, flat topped hilled and 2 row flat topped hilled. Soil moisture will be monitored in each plot using a CPN503 DR soil moisture monitoring device. The access tube for soil moisture monitoring will be installed in the center of the hill/bed. Irrigation decisions (amount and timing) will be based on soil moisture values within each treatment. Treatments will be irrigated once average soil moisture drops to 65% of available in top 40 cm of soil depth. An application depth of 25 mm (1 inch) per irrigation will be applied or the profile will be brought up to 90% of available, whichever is less. Temperature will be monitored in each plot to determine moisture-temperature-tuber quality and yield relationships.

Agronomic practices for growing potatoes (fertility, disease spraying, weed control) will be based on best management practices. Comparisons for end of season potato yields and quality of tubers for the different prepared seed beds will be done. Potato water use, irrigation application and irrigation efficiency will be compared between the various prepared seed beds.

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

Talks and posters will be prepared, as requested from the PGA, for presentation to their members. A scientific paper will be prepared upon completion of the study and offered for publication in an appropriate scientific journal. Requests for interim results for publication in trade or industry magazines will be honored.

3. Project Budget

		Year 1	Year 2	Year 3	**Total**
PGA	Cash	7300	6900	7100	21300
	In-Kind				
	Total	7300	6900	7100	21300
Other					
AAFRD Irrig	Cash				
	In-Kind	12900	13000	13000	38900
	Total	12900	13000	13000	38900
Other					
AAFRD Res	Cash				
	In-Kind	15000	15000	15000	45000
	Total	15000	15000	15000	45000
Other					
	Cash				
	In-Kind				
	Total				
Other					
	Cash				
	In-Kind				
	Total				
Total		**35200**	**34900**	**35100**	**105200**

Irrigation Water Savings in Potato Production By Varying Hill-Furrow or Bed-Furrow Configurations

T.E. Harms[1] and M.N. Konschuh[2]
[1]Rural Water Branch, [2] Crop Diversification Center South
Alberta Agriculture and Rural Development
301 Hort Stn Rd East Brooks, Alberta, Canada

2008

EXECUTIVE SUMMARY

In southern Alberta, potatoes are always hilled and covered with sufficient soil to prevent tuber greening, to ensure drainage in the area of tuber formation, and to facilitate mechanical harvest. The ideal shape for the potato hill, according to Manitoba Agriculture, Food and Rural Initiatives, is one with a peaked top and gradual slope to the furrow position.

However, with a profile described as ideal, much of the precipitation (either irrigation or rainfall) moves by gravity into the furrow position. Water ponds in the furrow position and if retained, gradually infiltrates with time. Infiltrated water in the furrow position is believed to move into the hill position via soil matric forces. In coarse-textured soils, it has been shown that rainfall or irrigation water infiltrated in the furrow position percolates through the soil, moves below the root zone, and is effectively lost to the plant.

A research project was commenced in 2004 to identify the fate of precipitation (irrigation and rainfall) that infiltrated the soil in the "ideal profile" hill and the furrow position. The project continued in 2005 to determine the fate of infiltrated precipitation with altered hill shapes.

Based on the results of 2005, a new three-year project began in 2006 to quantify the potential irrigation water savings of the altered hill shapes. The three treatments (standard hill, flat-topped hill, and double-planted wide-bed hill) were arranged in a randomized strip plot design replicated four times. Soil moisture in each treatment was generally kept between 65 to 90% of available. In 2008, a fourth treatment, triple-planted wide bed was added to the project.

The irrigation requirements to maintain the treatments were 487, 442, and 449 mm for the standard hill, flat-topped hill, and double-planted bed, respectively, in 2006 and 442, 408 and 411 mm for the same treatments in 2007. This translates into approximately 10% less irrigation water required for the flat-topped hill shape compared to the standard hill shape. The flat-topped hill shape required 5.0% more irrigation than the standard hill in 2008, but the double and triple-planted wide beds required 8.0 and 9.9%, respectively, less irrigation water than the standard.

Water use efficiency was greater in all years for the altered bed shapes compared to the standard hill geometry. Greater water use efficiency can be interpreted as more of the applied water infiltrated into the hill, where the potato plant could use it for transpiration and tuber development.

Total yield was greater in 2006 for both the flat-topped hill (72.3 Mg ha^{-1}) and wide-bed hill (69.2 Mg ha^{-1}) compared to the standard hill (61.4 Mg ha^{-1}); however, the treatments were not significantly different. Significantly greater marketable yield was realized from the flat-topped hill treatment in 2006. This treatment also had a significantly greater number of marketable size tubers. In 2007, there were no significant differences in total yield; however, the standard and flat-topped treatments had a significantly greater number and yield of tubers in the 113-170 g size category. Significant differences in total yield were found in 2008. The triple-planted wide bed had significantly greater yield in the smaller size categories compared to the standard treatment and significantly greater total tuber numbers than the other treatments, but the increase was in the smaller size categories, less than 170 g (6 ounces). There were no significant differences among the treatments in yield or total number of tubers in the size categories greater than 171 g in 2008.

INTRODUCTION

In southern Alberta, potatoes are always hilled after planting and covered with sufficient soil to prevent tuber greening, to ensure drainage in the area of tuber formation, and to facilitate mechanical harvest. Final hill shape is often determined by the type and make of the hilling implement. Traditional final hill shape has been one with a fairly peaked top and side slopes ending at the furrow position. This hill shape probably evolved as a practical solution to divert excess rainfall away from the potato tubers and maintain adequate aeration within the potato hill. Chow and Rees (1994) reported that the initiation of runoff from the furrow position was sooner for hilled potatoes rather than un-hilled ones. Cooley et al. (2007) also reported that traditional hill geometry reduces infiltration into the center of the hill and promotes water drainage into the furrow position. These studies indicate that the traditional final hill shape is effective at diverting applied water into the furrow position.

However, in the irrigated areas of semi-arid southern Alberta, excess rainfall is not usually an issue. Rather than diverting excess rainfall into the furrow position, the goal for final hill shape in irrigated potato production should be a shape that maximizes the amount of applied irrigation water infiltrated into the center of the potato hill.

The infiltration of irrigation and rainfall into a potato hill is often assumed to be uniform. However, due to the topographic relief of hill-furrow tillage systems, it has been reported that the actual infiltration and subsequent redistribution of irrigation water is quite variable. Starr et al. (2005), Robinson (1999), and Saffigna et al. (1976) reported that more water enters the soil through the furrow than through the ridge or hill. It was believed that between precipitation events, increased soil matric forces due to declining soil moisture levels within the potato hill, act to redistribute some of the water into the hill position where it can be used by the plant. However, Starr et al. (2005) reported that uptake of soil moisture from the furrow position or toe of the hill was undetectable and the lowest soil moisture storage was in the center position of the potato hill.

Improved irrigation efficiency may be realized by altering the standard hill shape to one with a wider profile or a flattened top, so more of the applied irrigation water has time to infiltrate into the hill/bed before ponding in the furrow position. Starr et al. (2005) reported that infiltration of applied water did not reach the center of the hill under sprinkler irrigation. Irrigations to ensure sufficient soil moisture in the center of a standard hill shape translate into excessive runoff and ponding of the applied water in the furrow position. Deep percolation of applied water and minimal or no uptake of soil moisture by the potato plant from the furrow position results in a loss of irrigation water applied.

Mundy et al. (1999) planted three rows of potatoes in a 1.9 m wide bed to evaluate the effect on yield and quality. Although there were not always statistically significant differences, they reported the wider bed retained more moisture compared to the standard hill. Steele et al. (2006) compared yield and quality of potatoes planted within the furrow position of a modified ridge/furrow system to conventional standard-hill planted potatoes.

They found significantly greater yields and a greater yield of larger size potatoes were harvested from the furrow-planted treatments compared to the hill-planted treatments. On two sampling dates for soil moisture, they found significantly greater soil moisture in the furrow position than in the hill. Starr et al. (2005) concluded that management practices targeted at wetting the hill center under the sprinkler would likely improve water use efficiency.

Water use efficiency (WUE) has been used in many studies on irrigated crops to describe yield per unit water consumed or applied (kg/ha.mm) (Howell, 2006, Hatfield et al., 2001). Improvement in WUE has typically been interpreted as increased beneficial use of diverted water for irrigated agriculture or the “More crop per drop; same crop less drop” type concept. The whole concept of, and proper interpretation of, WUE has been criticized lately (Bessembinder et al., 2005). Some of the criticism, with the interpretation of WUE, is the high variability from year to year, even with the same regimen of agronomic practices (Tow, 1993, Musik et al., 1994, Shae et al., 1999). WUE is also influenced by other factors such as soil texture (Hatfield et al., 2001), and there are no consistent formulations for calculating WUE so comparisons between studies are difficult at best (Howell, 2006). However, improved WUE between treatments, in the same year, for the same crop, and the same variety is generally interpreted as a better utilization of soil water (Kang et al., 2004).

The objective of this study was to quantify the water savings in altered hill/bed forms compared with the standard hill and to identify the influence altered bed shapes have on tuber yield, quality and water use efficiency.

METHODS

Three treatments consisting of a standard hill, flat-topped hill and double-planted wide bed hill were arranged in a randomized strip plot design, replicated four times at the Crop Diversification Center South in Brooks, Alberta, in 2006 and 2007. A fourth replicated treatment, consisting of a triple-planted, wide-bed hill, was added to the trial in 2008. Plot sizes were 6.1 x 6.1 m with a 4 m buffer between plots. Hill forms were prepared using a Netagco power hiller/bedder. Standard and flat-topped hill treatments consisted of six rows, 0.91 m apart. The wide-bed treatments consisted of three, 1.8 m beds. Flat-topped hill preparation involved maintaining the same rotor configuration as for a standard power-hiller but setting the rear shaper blade to flatten or “drag off” the peak of the standard hill (Fig. 1). The double and triple-planted beds were prepared by setting a firm tension on the rear shaper blade (Fig. 2).

Fig. 1. Final hill shape of the flat-topped treatment.

Soils at the site are Orthic Brown Chernozem (Chin Soil Series) with soil texture ranging from loam to silt loam. Average available soil moisture (between field capacity and wilting point) in a one meter soil depth was 164 mm.

Fig. 2. Power-hiller set to form a 1.8 m wide bed.

The plots were prepared and planted with treated Russet Burbank potato pieces spaced 30 cm within the row at a depth of 15 cm on May 12, 2006; May 9, 2007; and May 8, 2008. A hand-move irrigation system, equipped with Nelson directional impact sprinklers with 4.76 mm nozzles and individual shut-off valves, was used for applying irrigation water in 2006. In 2007, Senninger mini-wobblers with 2.38 mm nozzles were used for applying the irrigation water and Hunter MP 3000 180^o directional rotators were used in 2008. The mini-wobbler was rated with an application rate of 6.2 mm h^{-1} , the impact sprinkler was rated at 10.3 mm h^{-1} and the Hunter MP 3000 rotator was rated at 9.9 mm h^{-1}.

Aluminum access tubes were installed in the hill position near the center of each plot for soil moisture determinations with a CPN® 503 soil moisture meter. Soil moisture was measured twice each week from planting until harvest. Each treatment was irrigated to field capacity once average soil moisture in the top 60 cm of soil profile for the four replicates reached 65% of available. Standard rain gauges were placed adjacent to the access tube for determining irrigation and rainfall amounts.

Individual soil temperature probes were installed in each plot. They were positioned near the seed piece within the hill or bed and were buried 0.14 m below the soil surface.

Agronomic operations.

2006

Fertilizer was broadcast on April 26 at a rate of 168 kg ha^{-1} of N and 84 kg ha^{-1} of P. Insecticides (Admire and Decis) were sprayed twice (July 5 and August 22, respectively) to control Colorado potato beetle. Dithane, Pencozeb and Ridomil Gold/Bravo were sprayed on July 16, August 3, and August 22, respectively, for early and late blight control. Plots were sprayed with the dessicant, Reglone, on September 5 and were harvested on September 13.

2007

Fertilizer was broadcast on May 5 at a rate of 150 kg ha^{-1} of N and 50 kg ha^{-1} of P. Admire was applied on July 5 to control Colorado potato beetle. Dithane, Bravo 500 and Ridomil Gold were applied on July 13, July 26 and August 20, respectively, for blight control. Reglone was applied on September 5 and the plots were harvested on September 17.

2008

Fertilizer was broadcast on May 7 at a rate of 156 kg ha^{-1} of N and 56 kg ha^{-1} of P. The insecticide Thionex EC was sprayed on July 7 to control Colorado potato beetle. Quadris, Dithane, and Ridomil Gold/Bravo were sprayed on July 7, July 23, and August 20, respectively, for early and late blight control. Plots were sprayed with Reglone on September 12 and were harvested on September 29.

All tubers from the two center rows of the standard and flat-topped treatments and the center bed were harvested and evaluated for yield, size, quality, and specific gravity.

The Tukey method was used for all multiple mean comparisons with $p < 0.05$.

RESULTS

Water use and evapotranspiration

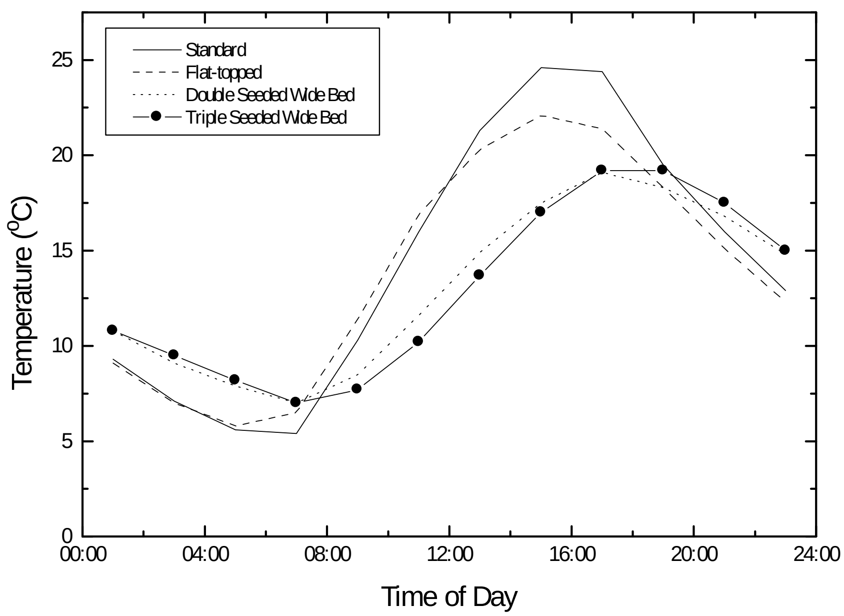
Water use efficiency (kg/ha.mm) was greater in all years for the altered hill treatments compared to the standard hill treatment (Table 1). The standard hill treatments required 7.8 and 9.2% greater irrigation amounts in 2006 and 9.9 and 10.3% in 2007 than the double-planted wide-bed and flat-topped treatments, respectively. In 2008, the wide-bed treatments, double and triple planted, required 8.0 and 9.9% less irrigation than the standard treatment; however, unlike the two previous years, the flat-topped hill treatments required 5.0% more water than the standard hill treatments.

Table 1. Irrigation demand and evapotranspiration for the hill-shape treatments.

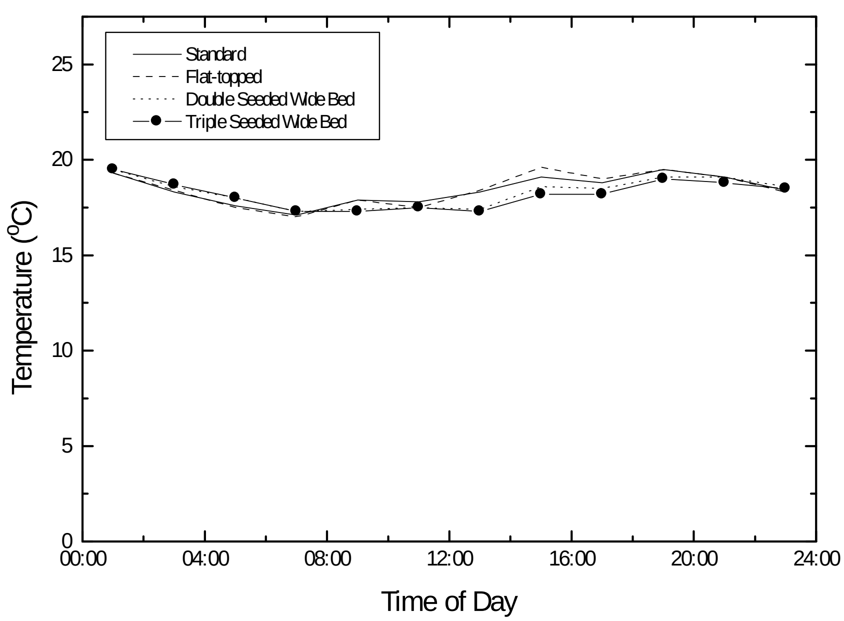
Treatment	Irrigation (mm)			Evapotranspiration (mm)			Water-Use Efficiency (kg/ha.mm)		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
Flat Topped	442	408	393	499	445	542	144.9	138.4	196.9
Wide Bed	449	411	344	488	441	511	141.8	139.9	186.7
Standard	487	442	374	500	462	533	122.8	136.6	165.4
Triple Bed			337			513			192.8

Soil Temperature

Daily maximum soil temperatures were higher, and daily minimum soil temperatures were lower in the flat-topped or standard treatments early in the season in 2007 and 2008 (Figure 4a). As soil shading due to plant growth occurred, there were no marked differences in soil temperature (Fig. 4b).



(a)



(b)

Fig. 4. Average soil temperatures for the four hill-shape treatments on (a) May 27, 2008 (at emergence) and (b) July 6, 2008 (row closure).

Tuber yield and quality

Marketable yield (171-284 g) and total number of tubers were significantly greater in the flat-topped hill compared with the double-planted bed and standard hill treatments in 2006 (Table 2). In 2007, there were no significant differences in total yield; however, the standard and flat-topped treatments had a significantly greater number and yield of tubers in the 113-170 g size category. In 2008, the flat-topped treatment had significantly greater total yield compared to the standard treatment. The triple-planted, wide-bed treatment had significantly greater yield in the smaller size categories compared to the standard treatment and significantly higher total tuber numbers than the other three treatments, but the increase was in the lower size categories, less than 170 g (6 ounces). There were no significant differences among the treatments in yield or total number of tubers in the size categories greater than 171 g in 2008.

Table 2. Yield comparisons for the hill-shape treatments.

2006										
	Yield (Mg ha^{-1})					Number of Tubers (count)				
	Size Categories (g)						Size Categories (g)			
Treatment	Total	< 113	113-170	171-284	>284	Total	<113	113-170	171-284	>284
Flat-top	72.3	15.8	19.3	22.8a	11.9	267a	118	75a	57	17
Wide-Bed	69.2	16.6	18.2	20.2ab	12.2	255b	115	71ab	52	17
Standard	61.4	13.1	15.5	17.3b	13.0	216b	94	57b	45	20
							Percentage of total yield			
							44.2	27.9	21.5	6.5
							45.2	27.7	20.3	6.8
							43.4	26.4	20.9	9.4

2007										
	Yield (Mg ha^{-1})					Number of Tubers (count)				
	Size Categories (g)						Size Categories (g)			
Treatment	Total	< 113	113-170	171-284	>284	Total	<113	113-170	171-284	>284
Flat-top	61.6	15.0	15.1b	18.1	8.9	246	119	59ab	46	13
Wide-Bed	61.7	15.6	11.6a	18.5	11.1	259	142	46a	48	16
Standard	63.1	15.4	15.1b	19.9	9.1	249	118	60b	50	13
							Percentage of total yield			
							48.4	24.0	18.7	5.3
							54.8	17.8	18.5	6.2
							47.4	24.1	20.1	5.2

2008										
	Yield (Mg ha^{-1})					Number of Tubers (count)				
	Size Categories (g)						Size Categories (g)			
Treatment	Total	< 113	113-170	171-284	>284	Total	<113	113-170	171-284	>284
Flat-top	106.7a	12.1a	15.9ab	29.2	44.2	282ac	91a	62ab	71	58
Wide-Bed	95.4ab	12.1a	14.4ab	25.7	40.1	258ab	86a	57ab	63	51
Standard	88.2b	10.7a	13.3b	25.9	36.0	238b	77a	51b	63	47
Triple Bed	98.9ab	16.4b	17.8a	26.3	35.3	304c	127b	67a	65	45
							Percentage of total yield			
							32.2	22.1	25.2	20.5
							33.3	22.3	24.5	19.9
							32.5	21.2	26.6	19.7
							41.7	22.1	21.5	14.8

Where significant hill shape effects on the potato yield were detected by analysis of variance, column means followed by the same letter are not significantly different at $p<0.05$.

DISCUSSION

The approximately 10% reduction in irrigation water applied between the standard hill and wide-bed treatments was consistent in all three years. However, the lower irrigation applications in 2006 and 2007 for the flat-topped hill were not observed in 2008. The significantly greater yield in the flat-topped treatment compared to the standard treatment likely contributed to the need for increased irrigation water in 2008.

Greater water use efficiencies with the altered hill shapes in all three years indicated better conversion of the water used for transpiration to tuber yield. Greater marketable yield, increased number of marketable tubers, and reduced tuber deformities resulted with the altered hill shapes. Greater and sustained soil moisture content with the wide-bed hill shapes reduced the frequency of irrigation applications. These yield results are consistent with the findings of Kang et al. (2004), who found that more frequent watering with drip irrigation, and not allowing the soil profile to dry prior to wetting, resulted in the greatest yield of potatoes. Similarly, Steele et al. (2006) reported that the increase in tuber quantity and size for furrow planted potatoes was most likely due to consistent seasonal soil moisture conditions.

The trial seeding 3 rows (triple-planted) on the 1.8 m wide bed was a modest success. Greater tuber numbers, even though the increase was in the smaller (less than 170 g) size category, resulted in more production per unit area. However, the expectation that an increase in total tuber weight compared to the other treatments was not realized. A possible explanation could be that extra nitrogen and phosphorus fertilizer, which would be needed for proper growth of an additional row of potatoes, was not applied. If the increased tuber numbers for the triple-seeded, wide-bed treatment had sufficient fertility for proper bulking, then a significant increase in total tuber yield for this treatment may have been realized.

Warmer daytime soil temperatures after planting for the standard or flat-topped hill should help to lessen tuber diseases. Warton et al. (2007) identified a greater incidence of rhizoctonia the longer the seed tuber remained in wet, cold soil prior to emergence. Although wet, cold soils are not typically a problem in the semi-arid region of southern Alberta, the flat-topped or standard hill have more surface area exposed, intercept more incoming solar radiation, are elevated from the surrounding soil, and thus warm faster.

CONCLUSIONS

A 10% water savings for irrigated potato production is possible in southern Alberta by modifying the standard hill shape to either a flat-topped or wide-bed hill shape. Standard hill-shape geometry adopted from other potato growing areas was not as effective at retaining irrigation and precipitation. Altering the standard hill to a flat-topped or wide-bed shape allowed more irrigation and precipitation to infiltrate. In areas where irrigation is essential for sustained potato production, an altered hill shape may improve water use efficiency and increase potato yield and quality. When pre-emergent soil moisture content is high and soil temperatures are low, and irrigation is practiced, a flat-topped hill rather than a wide-bed hill would ensure improved water use efficiency and enable maximum soil warming prior to row closure.

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Use of Green Manure Crops to Reduce Soil-Borne Pests and Diseases of Potato Crops in Alberta
Project 2006-F052R (2006-2010)

FINAL REPORT

Prepared for the
Alberta Crop Industry Development Fund
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Executive Summary

At the request of the Research Committee of the Potato Growers of Alberta, a project was initiated in 2006 to study the potential for using green manure crops in potato production systems to reduce the incidence and severity of potato early dying complex and Verticillium wilt. Initially, green manure crops were selected that had been reported to suppress Verticillium wilt in other potato production areas. Additional collaborative work was planned to evaluate the effect of the same green manure crops on other soil-borne diseases of potatoes (black scurf and scab) on research sites in Saskatchewan. Commercial fields with a potato history were selected in Alberta to study potato early dying to ensure sufficient disease pressure for the trial. Although some Brassicaceous crops (mustard, rapeseed, oilseed radish, etc.) have been successfully used as green manure crops to suppress potato diseases, all such crops were dropped from the trial in Alberta after the first field season in response to concerns about the potential for contamination of hybrid canola crops produced in potato rotations.

Green manure crops were initiated in late spring or early summer depending on the year and the availability of commercial co-operator fields. When soil moisture was adequate or the cooperating grower was willing to irrigate, good stands of green manure crops were established. Inadequate soil moisture for establishment of the green manure crop affected one site in 2006 and one in 2007. Clean fields or appropriate weed control options are required to aid in establishing green manure crops and producing sufficient green manure biomass. Weed pressure at several locations negatively affected the establishment or growth of some green manure crops. Pest control (grasshoppers, aphids and flea beetles) became an issue at some locations – especially as the crops surrounding the green manure plots matured. At most of the field sites, the green manure crops produced good biomass and that was incorporated prior to fall frosts. Hail affected the biomass production at two locations in 2008. In Saskatchewan, an oat-Austrian winter pea-vetch mixture and oriental mustard provided good biomass. In Alberta, Sorghum Sudan grass, Canadian Forage Pearl Millet, and the oat-pea-vetch mixture typically produced the most biomass. Only one year of data was collected using Oriental mustard and oilseed radish in Alberta and establishment of these crops was hampered by soil moisture issues and inadequate weed and pest control. In Saskatchewan, mustard meal was used as an amendment in place of the Brassica green manure crops in 2008.

Verticillium inoculum was measured using soil dilution assays and molecular techniques. The soil dilution assays were specific for *Verticillium dahliae* while the molecular assays picked up several Verticillium spp. In spite of selecting commercial fields for the trial, *V. dahliae* populations were not detected in all fields at the beginning of the trial. As expected, the presence of a potato crop increased the inoculum level relative to fallow areas of the field. Where *V. dahliae* was present prior to planting the green manure crops, a reduction in *V. dahliae* inoculum was measured with most green manure crops. *V dahliae* populations typically increased during the potato crop year regardless of the level of inoculum following the green manure crop year. No soil samples were collected in the year following potato production.

Although the trial was established specifically to address Verticillium wilt in potatoes, potato early dying complex can be aggravated by plant diseases other than Verticillium. In potato stem assays, the presence of Verticillium was sometimes verified, while at other sites, *Fusarium* and *Colletotrichum* were frequently identified from stem assays in moist chambers. To verify these findings, soil samples collected from some of the commercial fields were used to set up bioassays in a greenhouse using eggplants, known to be very sensitive to Verticillium wilt. Some Verticillium wilt was observed in the eggplant bioassays, especially from the two fields with higher disease pressure. Black dot (*Colletotrichum coccodes*) also affected the eggplants and could be cultured from root and stem tissue

of eggplants grown on soil from several sites. *Fusarium* spp. were also identified on eggplants grown in soil collected from green manured potato fields It is not clear whether the *Fusarium* spp. recovered are pathogenic to potatoes or perhaps antagonistic to Verticillium as has been observed in other green manure studies. *Rhizoctonia* was not very prevalent in the eggplant bioassays.

Many papers identify a link between potato early dying complex and root lesion nematode populations. Root lesion nematodes have also been shown to act synergistically with *Verticillium dahliae* to increase the incidence of wilt (Rotenberg et al. 2004). The initial proposal included nematode analyses but was dropped in the revised application to reduce trial costs. Soil samples collected to assay for Verticillium inoculum were shared with nematologists from Agriculture and Agri-Food Canada to determine the population of root lesion nematodes. The nematode analyses included in this report were provided *gratis* to complement our work on green manures. Root lesion nematodes were identified in soil samples from the commercial fields. *Pratylenchus neglectus*, rather than *Pratylenchus penetrans*, was the species present. In 2007, root lesion nematodes were found in most samples. Some crops appeared to reduce the population of root lesions nematodes in potato fields. The interaction between *P. penetrans* and *V. dahliae* has been studied, but is not thoroughly understood. Even less is known about interactions between *P. neglectus* and Verticillium or other pathogens associated with potato early dying. Additional work in this area may prove beneficial to our understanding and control of potato early dying complex.

Potatoes were grown by commercial co-operators on all but one site following the green manure year. Russet Burbank was grown on all but one site in Alberta. Fresh market varieties were used in Saskatchewan because of their greater disease susceptibility and relevance to the local industry. Regardless of the biomass produced or the effect of the green manure crop on *V. dahliae* inoculum, no yield improvements (total or marketable) were observed as a result of the incorporation of the green manure crop in Alberta. At a few sites, better yield was observed from the areas of the field not planted to green manure, but this may have been a fallow effect or a result of greater residual fertility in these areas of the field. As in Alberta, the use of green manure crops did not increase the yield in the potato crop the following year in any of the trials conducted in Saskatchewan.

In the Saskatchewan trials, a reduction in the incidence of black scurf (*Rhizoctonia solani*) on Russet Burbank was observed following Oriental mustard in 2007. Common scab and black scurf were reduced in plots where red root pigweed dominated the green manure crop. In 2009, both powdery scab and black scurf appeared to be aggravated by mustard meal amendment prior to potatoes.

As a result of this preliminary study using green manure crops in potato production systems in western Canada, we learned that potato early dying is likely a result of the interaction between several potato pathogens, but is not always caused by *Verticillium dahliae*. These pathogens may include other *Verticillium* spp., *Colletotrichum coccodes*, *Alternaria alternata*, and *Fusarium* spp. Several of the green manure crops studied can be effectively grown and incorporated in western Canada within a short growing season. These crops could be utilized as an under-seeded crop or planted following an early harvest of silage or field peas. Management of the green manure crops will influence the effectiveness of these crops to reduce disease, or increase yield. Agronomic work and pest control work may be required to establish green manure crops with sufficient biomass. We know that root lesion nematodes are present in potato production systems in western Canada, but little is known about the prevalent species, *Pratylenchus neglectus*, or its effect on potato yield. If these root lesion nematodes play a role in potato early dying in western Canada, more work is required to determine which potato pathogens are synergistically affected by the root lesion nematode populations. No consistent reduction in disease was noted as a result of incorporating green manure crops in

Saskatchewan field infested with scab and black scurf. As noted by Cherr et al. (2006), green-manure based systems may provide alternatives to current approaches to crop production; however, the use of green manures may not be economically justified without the provision of multiple services such as nutrient supply, pest and weed control, and improvement of soil characteristics for crop production.

Project Overview

Historically, the primary approach for maintaining soil fertility in intensive cropping systems around the world, green manure use in modern agricultural systems has been nearly replaced by synthetic fertilizer, weed, and pest control inputs after the post-World War II development of the agrochemical industry (Cherr et al. 2006). Work in other potato producing areas (Idaho, Minnesota, Quebec, Maine, Washington, Oregon and Ontario) indicates that green manure crops may be effective for control of nematodes and Verticillium wilt. Some work has been conducted in Atlantic Canada to show that green manures may also be effective at controlling Rhizoctonia (black scurf). A green manure crop or cover crop differs from a rotational crop in that it is not harvested, but is instead worked into the soil prior to maturity (Finnigan 2001). Benefits of green manure include: improved soil condition, increased organic matter, improved water penetration, reduction of some diseases, reduced nematode population, and increased availability of nutrients. Green manure crops can be established in spring, summer or fall, and incorporated in the fall or in the spring prior to potato planting. In some studies, multiple years of green manure were required to have significant impact, but even one season of green manure prior to potatoes has been reported as beneficial. Work in SK indicated that approximately 8 weeks were required to establish an effective biomass of many green manure crops. Consultations with potato industry contacts in AB indicated that fall incorporation would likely fit best with current industry practices.

Crop rotation is recommended in all potato growing regions to reduce pests and maintain healthy soil, but economic constraints encourage shortened rotations and the inclusion of high-value crops in the rotation rather than crops that benefit the environmental health of the cropping system. Short rotations, such as one or two years planted to non-host crops between potato crops did not provide consistent reductions in the incidence of Verticillium wilt in subsequent potato crops (Easton et al. 1992).

Root lesion nematodes (*Pratylenchus* spp.) are of concern to potato growers because they can reduce yield and make plants more susceptible to fungal and bacterial diseases (Hafez and Sundararaj 2001). There is also a positive correlation between root lesion nematodes and the incidence of Verticillium wilt (early dying) caused by the fungal pathogen *Verticillium dahliae* (Morgan et al 2002). A 3-year analysis of commercial Russet Burbank fields in Idaho revealed that infections on potato roots by *V. dahliae* accounted for over 51% of the field variability related to potato yield losses (Davis 2001). Severe early dying symptoms in potato crops can result from interactions between *V. dahliae* and root lesion nematodes (Davis et al. 2001). Early dying and Verticillium wilt have been identified in southern AB as increasingly important factors affecting the competitiveness of our processing industry.

AB potato growers face a short, but intensive growing season. Early dying and Verticillium wilt were identified in southern AB as increasingly important factors affecting the competitiveness of our processing industry. Research is required to evaluate several green manure crops to determine which green manure crops will grow in AB. We also proposed to evaluate these crops to determine which, if any, reduce Verticillium wilt infections and improve tuber yield of Russet Burbank potato.

Further, we had an opportunity to determine the effect of some of the same green manure crops on scab and black scurf from infested plots in a number of field trials conducted at the University of Saskatchewan SK.

Objectives of the Project

- **i.** To determine whether the use of green manure crops is effective in Alberta for reducing soil-borne potato pests and diseases;
- **ii.** To determine which green manure crop is most effective at reducing specific potato pests and diseases;
- **iii.** To determine the impact of using green manure crops on yield and quality in subsequent potato crops, and
- **iv.** To provide economically viable alternatives to soil fumigation.

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Literature Review / Background

In fields where potatoes have been part of the production cycle for several years, a pattern of premature vine death and declining yields often develops (Powelson et al. 1993). This syndrome, called potato early dying, limits production in many areas (Powelson et al. 1993). Potato early dying disease (PED) is complex with the root lesion nematode, *Pratylenchus penetrans*, and the wilt causing fungus, *Verticillium dahliae*, usually implicated as the causal agents (Warner 2009). Both organisms are pathogens of potato, but when present together they often interact to produce more significant yield losses than they would cause individually (Warner 2009). Co-infection of potatoes with *V. dahliae* and *P. penetrans* can result in early onset of disease symptoms and thus lower yields (Rowe and Powelson 2002). In North America, yield reduction in moderately diseased fields can easily be 10 to 15%, and in severely diseased fields it can be as high as 30 to 50% (Rowe and Powelson 2002). Tsror (Lahkim) and Haznovsky (2001) indicate that potato early dying syndrome in most potato growing regions has been associated with complexes of soil-borne parasites including *V. dahliae*, *Pratylenchus* spp., *Colletotrichum coccodes*, *Rhizoctonia solani* and *Erwinia carotovora* spp. Each year in southern Alberta, some potato fields have been observed to mature early, resulting in a loss of size and yield. Concerns about potato early dying prompted the Potato Growers of Alberta to collect plant samples in 2004 to determine whether *Verticillium* spp. were linked to the premature death of these crops. Dr. Bud Platt, Agriculture and Agri-Food Canada, tested the samples and reported that Verticillium was present in many of the samples.

Potatoes are subject to many diseases caused by soil-borne pathogens. Black scurf, caused by *Rhizoctonia solani*, and scab, both common and powdery scab, are important diseases of potato crops on the Canadian Prairies. Chemical control options are limited for many soil-borne pathogens. Two pathogens of particular significance are the soil-borne fungi, *Verticillium dahliae* and *Verticillium albo-atrum* (Rowe and Powelson, 2002). Verticillium wilt, caused by the fungus *V. dahliae* Kleb, remains one of the most important soilborne plant diseases worldwide (Lazarovits 2010). Because of their wide host range, the two species of Verticillium can maintain themselves at low populations on the roots of many symptomless crop and weed species, such as wheat and sunflower (Powelson et al. 1993). In the arid and semi-arid regions of the world, Verticillium wilt, caused by *V. dahliae* Kleb., is a common limiting factor of potato production (Davis et al. 2001). The actual dollar amount lost in production is difficult to assess and is probably greatly underestimated as infection typically reduces plant growth rather than causing death outright (Lazarovits 2010). Once established in a field, the fungus can persist in the soil for many years as microsclerotia (*V. dahliae*) or melanized hyphae (*V. albo-atrum*), either free or embedded in plant debris (Powelson et al. 1993, Ochiai et al. 2007).

The potato root is also host to the root-lesion nematode (RLN) *Pratylenchus penetrans*. Root lesion nematodes (*Pratylenchus* spp.) are of concern to potato growers because they can reduce yield and make plants more susceptible to fungal and bacterial diseases (Hafez and Sundararaj 2001). There is also a positive correlation between root lesion nematodes and the incidence of Verticillium wilt (early dying) caused by the fungal pathogen *Verticillium dahliae* (Morgan et al 2002). Soil samples tested by Growers Supply Limited revealed significant populations of root-lesion nematodes in southern Alberta potato fields, although *Pratylenchus neglectus* was the dominant species, not *P. penetrans*. While root-lesion nematodes contribute to the early dying complex, it is uncertain whether nematode control by rotation with non-host or nematode-antagonistic crops would effectively manage potato early dying (LaMondia 2006).

The two fungal pathogens alone, or in conjunction with *P. penetrans* cause a disease called potato early dying (Powelson et al. 1993, LaMondia 2006). Severe early dying symptoms in potato crops can result from interactions between *V. dahliae* and root lesion nematodes (Davis et al. 2001). Potato early dying is a vascular wilt disease characterized by a general decline of plants 4 to 6 weeks earlier than normal senescence. Although specific diagnostic symptoms are not associated with the disease, foliage show various degrees of chlorosis and necrosis, sometimes associated with wilting or dying of individual stems (Rowe and Powelson, 2002). In the early stages, individual vines may die and remain conspicuously erect in contrast to healthy plants (Rowe and Powelson, 2002). A light brown vascular discoloration in basal stem tissues is usually present in symptomatic plants. This symptom, however, is not diagnostic since vascular discoloration can result from stress factors unrelated to PED (Rowe and Powelson, 2002). In severe cases, plants across an entire field will die over a period of several weeks. A 3-year analysis of commercial Russet Burbank fields in Idaho revealed that infections on potato roots by *V. dahliae* accounted for over 51% of the field variability related to potato yield losses (Davis 2001).

In many potato producing areas of North America, soil fumigation and planting resistant cultivars remain the primary means for control of soilborne plant diseases and pests (Lazarovits 2010). Fumigation, where registered products are available, is constrained by increased costs, urbanization and its negative environmental impacts (Lazarovits 2010). The use of soil fumigants in Canada has not been widely adopted for the control of Verticillium wilt. Fumigants are non-specific, expensive and toxic to applicators and the environment. In 2005, the Research Committee of the Potato Growers of Alberta issued a call for proposals to study the effects of green manure crops on early dying of potatoes.

Crop rotation is recommended in all potato growing regions to reduce pests and maintain healthy soil. Crop rotation reduces pest problems by changing the environmental conditions in the field (McGuire 2003). In general, rotating crops that have different planting dates, different growth habits or different susceptibility to pests prevents any one pest from becoming a problem (McGuire 2003). Economic considerations favour shortened rotations and the inclusion of high-value crops in the rotation rather than crops which inherently benefit the environmental health of the cropping system.

Work in other potato producing areas (Idaho, Minnesota, Quebec, Maine, Washington, Oregon and Ontario) indicated that green manure crops may be effectively used for control of nematodes and Verticillium wilt. A green manure is a crop used primarily as a soil amendment and a nutrient source for subsequent crops (Cherr et al. 2006). A green manure crop or cover crop differs from a rotational crop in that it is not harvested, but is instead worked into the soil prior to maturity (Finnigan 2001). Benefits of green manure include: improved soil condition, increased organic matter, improved water penetration, reduction of some diseases, reduced nematode population, and increased availability of nutrients (Davis et al. 2010). The incorporation of green biomass into soils, known as green manuring, has been in use in agriculture for over 2000 years (Lazarovits 2010). Green manure approaches to crop production may improve economic viability, while reducing the environmental impacts of agriculture (Cherr et al 2006). Such approaches are complex, however, because they depend on interactions between the green manure, the environment, and management (Cherr et al 2006). Green manure crops can be established in spring, summer or fall, and incorporated in the fall or in the spring prior to potato planting.

The mechanism by which green manures may influence disease are varied and often unknown (Wiggins and Kinkel 2005). Green manures may influence pathogens directly through the breakdown of glucosinolates or by releasing fungitoxic compounds such as isothiocyanates (Wiggins and Kinkel

2005). Green manures may also affect soilborne pathogens indirectly by influencing indigenous microbial populations (Wiggins and Kinkel 2005). These changes in the microbial community may affect pathogen populations through competition, parasitism, predation or antagonism (Wiggins and Kinkel 2005).

In some studies, multiple years of green manure were required to have significant impact (Easton et al. 1992), but even one season of green manure prior to potatoes has been reported as beneficial (Davis et al. 2010). Preliminary work in SK indicated that approximately 8 weeks were required to establish an effective biomass of many green manure crops. Consultations with potato industry contacts in AB indicated that a mid-summer planting of green manure would allow producers to harvest a paying crop prior to establishing green manure crops. Fall incorporation would likely fit best with current industry practices. Davis et al (1996) reported evidence that the suppression of Verticillium wilt of potato can be achieved with green manure treatments. Compared with 3 years of a weed-free fallow, three successive green manure crops of **Sudan grass** decreased disease severity by 81% and increased marketable yield by 35%, a response equivalent to soil fumigation (Davis et al. 1996). For green manuring to be a viable approach for management of PED, a shorter time frame is required. McGuire (2003) reported that potato yields following **white mustard** (*Sinapis alba* Martigena) or **oriental mustard** (*Brassica juncea* Cutlass) green manures was not statistically different from yields of potatoes on soils fumigated with metam sodium. Some green manure crops, such as **Canadian Forage Pearl Millet Hybrid 101** (*Pennisetum glaucum* L.) have been reported to suppress root lesion nematodes in the subsequent potato crop (Ball-Coelho et al. 2003). Other crops grown as green manures, such as Austrian winter pea, canola, oats, and rye also have suppressed disease and enhanced tuber yields. Some work has been conducted in Atlantic Canada to show that green manures may also be effective at controlling Rhizoctonia (black scurf).

Duval (2003) suggested that green manures established in the year preceding a potato crop would improve nutrient cycling and soil tilth and could have an impact on certain crop pests. Beans showed an inhibiting effect against nematodes and *Rhizoctonia* (black scurf) in a subsequent potato crop while barley caused an increase in scab levels on subsequent potato crops (Duval 2003). Mustard was considered a suitable green manure crop in a potato rotation as it has shown a suppressive effect against potato scab and black scurf (Duval 2003). The biofumigation potential of Brassicaceous crops has been evaluated in Australia (Sarwar et al. 1998). *In vitro* testing of the biofumigant products from *Brassica* crops showed that *Rhizoctonia* is sensitive to the isothiocyanates produced by *Brassica* species, however it was concluded that more work was needed to determine which *Brassica* species produce substances most toxic to specific pathogens (Sarwar et al. 1998).
Over the past 15 years, numerous soil ammendments have been evaluated for their potential to suppress Verticillium wilt, including animal manures (Conn and Lazarovits 1999), composted materials (LaMonide et al 1999), industrial by-products (Lazarovits 2010) and green manures (Davis et al 1996).

Lazarovits (2010) summarized in a review that field testing of organic products and soil amendments proved to be complicated by many unknowns that included rates required, the effect of soil type, the impact of climatic conditions, factors such as soil moisture and temperature, the nature and source of the amendment, the methods and timing of application, etc. Evaluating even a few of these factors under field conditions, would require hundreds of plots to be established, even if it were possible (Lazarovits 2010).

Alberta Trials

Green Manure Crop Establishment

In 2006, green manure crops were planted in two commercial southern Alberta fields on June 27 (Field A) and July 13 (Field B) (Table 1). Planting was delayed initially to allow vetch seed to be delivered. Planting in Field B was further delayed as a result of spring rains and a low spot in the field. The trial sites were located under centre pivot irrigation in wheat fields. Cooperating growers left approximately 1 acre vacant for green manure plot establishment. Field A had only recently been used for potato rotations, while Field B had a long history of potatoes in the rotation. A randomized block design was used with four replicates of each the six treatments that were planted in 8 x 7 m plots, with 3m pathways between each plot. Green manure crops from the Brassicacea family were not planted in Field A because the producer grows hybrid seed canola in rotation with potato and contamination would be unacceptable. Two alternate green manure crops, California Bluebell and annual ryegrass, were substituted for oilseed radish and Oriental mustard as shown in Table 1).

Just prior to seeding, soil was sampled from each trial area. Four samples were collected at random per replicate at sample depths of 0-15, 15-30, 30-60 and 60-90 cm from each of the four quadrants of the plot (total of 16 samples) and the four quadrant samples were combined to give four composite samples. These samples were analysed for NO_3-N, PO_4-P, K and SO_4 by an ARD laboratory as baseline soil fertility samples for each field.

Table 1: Green manure crops planted in Alberta plots in 2006.

Field	***Crop***	***Species & Cultivar***	***Rate***
Field A	California Bluebell	*Phacelia tanacetifolia*	6 lbs/ac
	Annual ryegrass	*Lolium multiflorum*; Proven HPS Italian Ryegrass	10 lbs/ac
	Sorghum Sudan Grass	*Sorghum x drummondii*; Grazex	20 lbs/ac
	Wooly Pod Vetch	*Vicia villosa* spp. *dasycarpa*	10 lbs/ac
	Canadian Forage Pearl Millet	*Pennisetum glaucum* L.; CFPM Hybrid 101	10 lbs/ac
	Hard Red Spring Wheat	*Triticum aestivum*	120 lbs/ac
Field B	Oilseed Radish	*Raphanus sativus* var. *Oleiferus*	10 lbs/ac
	Oriental Mustard	*Brassica juncea* ; Cutlass	10 lbs/ac
	Sorghum Sudan Grass	*Sorghum x drummondii*; Grazex; Grazex	20 lbs/ac
	Wooly Pod Vetch	*Vicia villosa* spp. *dasycarpa*	10 lbs/ac
	Canadian Forage Pearl Millet	*Pennisetum glaucum* L.; CFPM Hybrid 101	10 lbs/ac
	Hard Red Spring Wheat	*Triticum aestivum*	120 lbs/ac

The seed was broadcast in a barrel spinner using seeding rates double those used in a conventional row seeder (Table 1). The seed bed was moist, and irrigation was applied to the green manure crops and the surrounding wheat crop as required to maintain conditions conducive to wheat harvest. In Field A, these conditions favoured plant establishment in the green manure plots. In Field B, some plots were too dry and others were very wet. Plot establishment in each replicate varied depending on location in the field. Plots at both sites were hand-weeded in 2006 to reduce weed-pressure on the green manure crops.

In 2007, green manure crops were planted in two commercial southern Alberta fields on July 11(Field D) and July 19 (Field C) (Table 2). Finding co-operators for the 2007-2008 year was challenging. Annual ryegrass and California bluebell were used in place of the oilseed radish and oriental mustard in both fields due to the high density of hybrid canola production in southern Alberta. An oat-pea-vetch mixture replaced the woolly pod vetch in 2007. The trial sites were located under centre pivot irrigation in commercial cereal fields. In Field C, the trial area was sprayed out with glyphosate and worked prior to planting the green manure crops. We removed standing crop and planted in stubble in Field D.

Planting green manure crops 2007.

Just prior to seeding, soil was sampled from each trial area. Four samples were collected at random per replicate at sample depths of 0-15, 15-30, 30-60 and 60-90 cm from each of the four quadrants of the plot (total of 16 samples) and the four quadrant samples were combined to give four composite samples. These samples were analysed for NO_3-N, PO_4-P, K and SO_4 by an ARD laboratory as baseline soil fertility samples for each field.

Table 2: Green manure crops planted in Alberta plots in 2007.

Field	*Crop*	*Species & Cultivar*	*Rate*
Field C	California Bluebell	*Phacelia tanacetifolia*	6 lbs/ac
	Annual ryegrass	*Lolium multiflorum*; Proven HPS Italian Ryegrass	10 lbs/ac
	Sorghum Sudan Grass	*Sorghum x drummondii*; Grazex	20 lbs/ac
	Oat-Pea-Vetch*	*Avena sativa; Pisum sativum* spp. *arvense; Vicia villosa* spp. *dasycarpa*	169 lbs/ac
	Canadian Forage Pearl Millet	*Pennisetum glaucum* L.; CFPM Hybrid 101	16 lbs/ac
	Hard Red Spring Wheat	*Triticum aestivum*	120 lbs/ac
Field D	California Bluebell	*Phacelia tanacetifolia*	6 lbs/ac
	Annual ryegrass	*Lolium multiflorum*; Proven HPS Italian Ryegrass	10 lbs/ac
	Sorghum Sudan Grass	*Sorghum x drummondii*; Grazex	20 lbs/ac
	Oat-Pea-Vetch*	*Avena sativa; Pisum sativum* spp. *arvense; Vicia villosa* spp. *dasycarpa*	169 lbs/ac
	Canadian Forage Pearl Millet	*Pennisetum glaucum* L.; CFPM Hybrid 101	16 lbs/ac
	Hard Red Spring Wheat	*Triticum aestivum*	120 lbs/ac

* Wooly Pod Vetch (30 lbs/ab) ; Austrian Winter Pea (89 lbs/ac) ; Oats (50 lbs/ac) plus inoculum

Monocot crops in plots at both sites were sprayed with Refine (12 g/ac) and MCPA (228 mL/ac) in 2007 for weed control, while others were hand-weeded. Phacelia was sprayed out in Field C because the weed pressure was very high and the crop did not catch well. Also, one replicate of the Oat-pea-vetch treatment in Field C was mis-planted and was deleted from the trial.

In 2008, green manure crops were planted in two commercial southern Alberta fields on June 18 (Fields E and F) and at CDCS in Brooks June 19 (Field G) (Table 3). Annual ryegrass and Teff were used in place of the oilseed radish and oriental mustard in all three fields due to the high density of hybrid canola production in southern Alberta. The commercial trial sites were located under centre pivot irrigation in commercial cereal fields. The cereal crop was sprayed out with glyphosate and plots were cultivated prior to planting the green manure crops.

Just prior to seeding, soil was sampled from each trial area. Four samples were collected at random per replicate at sample depths of 0-15, 15-30, 30-60 and 60-90 cm from each of the four quadrants of the plot (total of 16 samples) and the four quadrant samples were combined to give four composite samples. These samples were analysed for NO_3-N, PO_4-P, K and SO_4 by an ARD laboratory as baseline soil fertility samples for each field.

Table 3: Green manure crops planted in Alberta plots in 2008.

Field	***Crop***	***Species & Cultivar***	***Rate***
Field E	Teff	*Eragrostis tef*	8 lbs/ac
	Annual ryegrass	*Lolium multiflorum*; Proven HPS Italian Ryegrass	10 lbs/ac
	Sorghum Sudan Grass	*Sorghum x drummondii*; Grazex	20 lbs/ac
	Oat-Pea-Vetch*	*Avena sativa; Pisum sativum* spp. *arvense; Vicia villosa* spp. *dasycarpa*	169 lbs/ac
	Canadian Forage Pearl Millet	*Pennisetum glaucum* L.; CFPM Hybrid 101	16 lbs/ac
	Hard Red Spring Wheat	*Triticum aestivum*	120 lbs/ac
Field F	Teff	*Eragrostis tef*	8 lbs/ac
	Annual ryegrass	*Lolium multiflorum*; Proven HPS Italian Ryegrass	10 lbs/ac
	Sorghum Sudan Grass	*Sorghum x drummondii*; Grazex	20 lbs/ac
	Oat-Pea-Vetch*	*Avena sativa; Pisum sativum* spp. *arvense; Vicia villosa* spp. *dasycarpa*	169 lbs/ac
	Canadian Forage Pearl Millet	*Pennisetum glaucum* L.; CFPM Hybrid 101	16 lbs/ac
	Hard Red Spring Wheat	*Triticum aestivum*	120 lbs/ac
Field G	Teff**	*Eragrostis tef*	8 lbs/ac
	Annual ryegrass	*Lolium multiflorum*; Proven HPS Italian Ryegrass	10 lbs/ac
	Sorghum Sudan Grass	*Sorghum x drummondii*; Grazex	20 lbs/ac
	Oat-Pea-Vetch*	*Avena sativa; Pisum sativum* spp. *arvense; Vicia villosa* spp. *dasycarpa*	169 lbs/ac
	Canadian Forage Pearl Millet	*Pennisetum glaucum* L.; CFPM Hybrid 101	16 lbs/ac
	Hard Red Spring Wheat	*Triticum aestivum*	120 lbs/ac

* Wooly Pod Vetch (30 lbs/ab) ; Austrian Winter Pea (89 lbs/ac) ; Oats (50 lbs/ac) plus inoculum
** Teff establishment was poor at CDCS and Hairy Nightshade (*Solanum sarrachoides*) was abundant. Nightshade was allowed to grow in place of teff as a negative control at this site.

Monocot crops in plots at both sites in 2008 were sprayed with Refine (12 g/ac) and MCPA (228 mL/ac) for weed control, while others were hand-weeded.

Above-ground biomass samples were collected from all green manure plots prior to incorporation. Biomass samples were collected from Field A plots August 30, 2006 and from Field B plots September 6, 2006. Biomass samples were collected from Field D plots September 19, 2007 and from Field C September 26, 2007. Biomass samples were collected from the plots in Fields E and F September 8, 2008 and in Field G September 11, 2008. Two 0.5 x 0.5 m areas were sampled from each plot. The fresh weight of all above-ground biomass was measured in the field. To determine dry-weight, a sub-sample of up to 300g was collected, placed in a paper bag in a drying room, and dried until a constant weight was obtained.

The green manure crops in Field A were mowed and incorporated with a three-point hitch disc September 1, 2006. The green manure crops in Field B were mowed and incorporated with a three-point hitch rototiller September 6 and 7, 2006. The green manure crops in Field C were incorporated with a three-point hitch rototiller October 2, 2007. The green manure crops were incorporated in Field D with a three-point hitch rototiller October 4, 2007. The green manure crops were incorporated with a three-point hitch rototiller in late September. Field C had a touch of frost and two crops (CPFM, Sorghum Sudan grass) were killed prior to incorporation.

Photographs of the plots were taken throughout the season and prior to incorporation. Examples of some of the crops are shown in Figure 1.

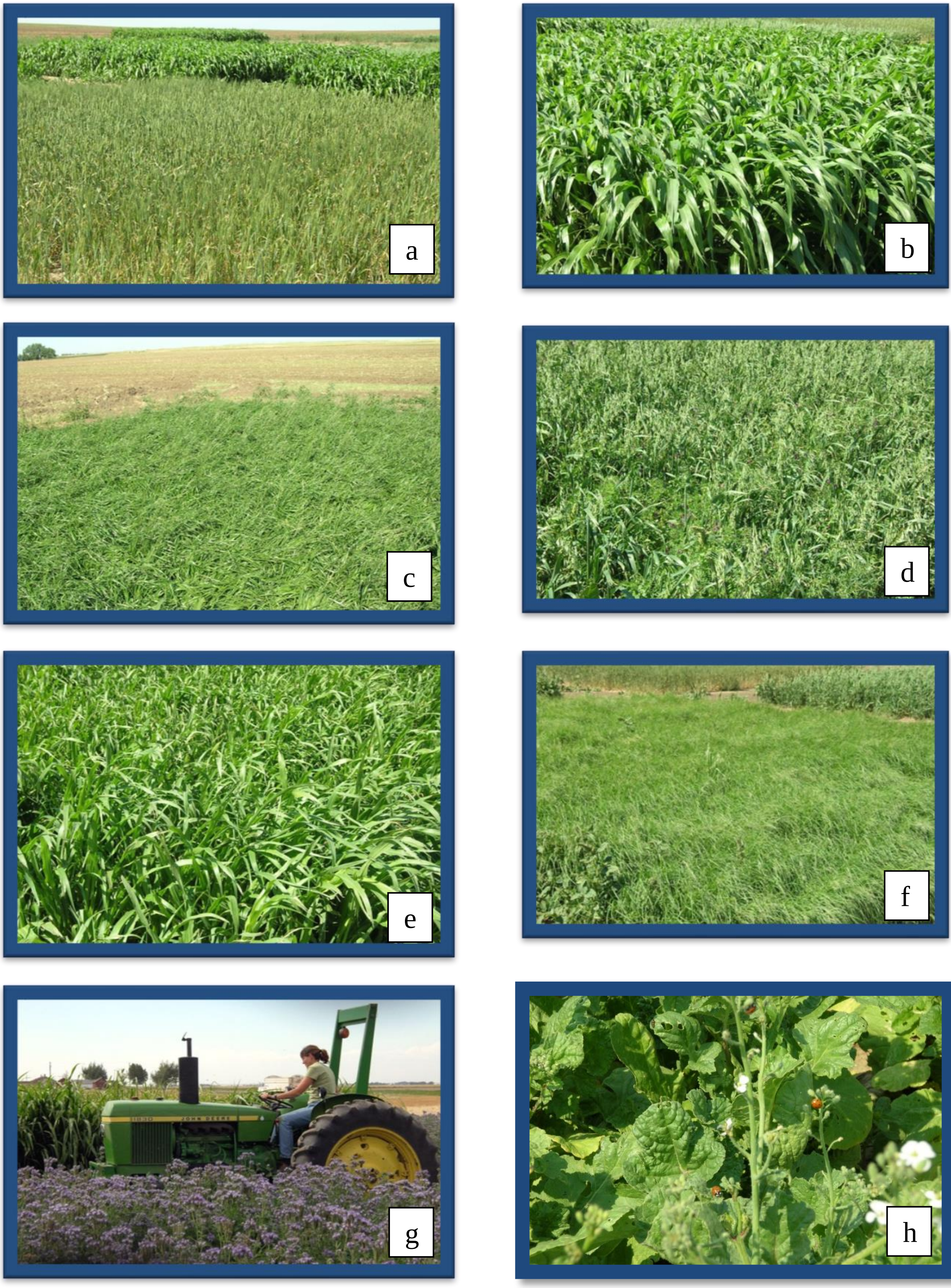


Figure 1: Green manure crops grown in potato rotations in southern Alberta: a) hard red spring wheat; b) sorghum Sudan grass; c) annual ryegrass; d) oat-pea-vetch; e) Canadian Forage Pearl Millet; f) teff; g) California bluebell; h) oilseed radish.

Green Manure Biomass

Fresh and dry weight data are presented (Table 4). Biomass production varied with each field location and by year, likely as a result of the time of year the crop was planted, the fertility at each site and the irrigation applied throughout the season. Fresh weight of each green manure crop is affected by the moisture status at the time of sampling. Dry matter produced by each green manure crop may more accurately represent the quantity of biomass produced. In Field A, Sorghum Sudan grass produced the most biomass on a dry weight basis, followed by CFPM, then Phacelia. Woolly vetch, annual ryegrass and wheat produced the least biomass in Field A. In Field B, there were no statistical differences in dry matter produced between CFPM, Sudan grass, woolly vetch, oriental mustard, and oilseed radish. Wheat again produced the least biomass, but not statistically less than woolly vetch. Much less biomass was produced in Field B than in Field A. There was variation in soil moisture between replicates and insect and weed pressure in Field B that were not observed in Field A. In Field C, there were no statistical differences in dry weight of biomass produced by the 5 green manure crops sampled. In Field D, similar quantities of biomass was recovered from all green manure crops except wheat which did not survive and annual ryegrass which produced less biomass than the other 4 crops. Fields C and D were planted in July of a hot, dry summer (2007). Irrigation was applied as required by the crop surrounding the green manure plots, but was insufficient or not timely for the green manure crop. A hail storm in August in 2008 affected the green manure crops in both Field E and Field F. The green manure crops recovered and the producer continued to irrigate the plots although the surrounding crop was written off by insurance adjusters. In Field E, Sorghum Sudan grass and CPFM produced the greatest dry weight of biomass although not significantly greater than wheat and the oat/pea/vetch mixture. Annual ryegrass produced the least biomass and teff was not significantly different from ryegrass, oat/pea/vetch or wheat. In Field F, CFPM produced a significantly greater dry weight of biomass than the other crops which were not statistically different from one another. Field G was located at a research centre and was irrigated independently of any other crop. At this location, Sorghum Sudan grass produced the greatest biomass by dry weight, followed by CFPM, the oat/pea/vetch mixture, wheat, nightshade and annual ryegrass. Nightshade overtook the teff planted as green manure and was left to determine the effect of this solanaceous weed on soil inoculum and potato yield the following year.

Ochiai et al (2007) reported that 12 Mg/ha (1,200 g/m^2) of dry biomass was required to reduce wilt severity. While not all green manure crops employed at all locations reached this threshold, CFPM 101, Sorghum Sudan Grass, the Oat Pea Vetch mixture and Teff could be expected to reach this target under good agronomic conditions fields A, E, F and G). The Brassica species, Oriental Mustard and Oilseed Radish, were only included at one site in one year of the trial and this did not give a good indication of the quantity of biomass typically expected from these crops. Annual ryegrass, Phacelia, Woolly Pod Vetch alone and wheat often did not provide sufficient biomass to have a predictable impact on wilt symptoms in subsequent crops.

Table 4: Fresh weight (g/m^2) and dry weight (g/m^2) of green manure crop biomass by field and crop. Data followed by the same letter in each row were not statistically different ($p \geq 0.05$).

Field	Wheat	CFPM 101	Sudan-grass	Vetch/OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Night-shade
Fresh Weight										
A	1317 c	6925 a	6865 a	3780 b	2770 b	5435 a				
B	1143 d	5210 a	3380 bc	1168 d				2010 cd	3828 ab	
C	2875 ab	2595 b	2445 b	2885 ab	3270 a					
D		708 bc	944 b	1455 a	517 c	1827 a				
E	4090 c	12470 a	11970 ab	9220 b	5800 c		5550 c			
F	2750 b	16950 a	4950 b	5170 b	6400 b		3550 b			
G	8110 c	14690 ab	15910 a	12130 abc	8950 c					9653 c
Dry Weight										
A	479 d	1094 b	1405 a	541 d	393 d	766 c				
B	175 b	711 a	524 a	417 ab				481 ab	626 a	
C	575 a	566 a	514 a	542 a	583 a					
D		280 a	342 a	340 a	105 b	308 a				
E	1743 ab	2329 a	2413 a	1779 ab	871 c		1516 bc			
F	1164 b	3493 a	1197 b	1306 b	980 b		1002 b			
G	3038 bc	4466 ab	5012 a	3051 bc	1564 c					2226 c

Soil Fertility

Soil Samples to Determine Available Nitrogen

After green manure crops were incorporated in 2006, soil samples were collected from Fields A and B October 12, 2006. A sub-sample of each sample was incubated moist (80% field capacity) at 25°C for 4 weeks to maximize N mineralization prior to analysis for N, NH_4-N and NO_3-N. Total N was determined using a combustion analyzer. NO_3-N and NH_4-N were determined from 10 g of soil using an equilibrium extraction with a 2.0 M KCl solution, followed by air-segmented continuous flow analysis (CFA).

After green manure crops were incorporated in 2007, soil samples were collected from Field D October 15 and from Field C October 17. Each green manure crop was sampled to a depth of 15 cm with 12 soil cores per plot. Sub-samples of 25 to 50 mg were analysed for total N, NH_4-N and NO_3-N. Total N was determined using a combustion analyzer. NO_3-N and NH_4-N were determined from 10 g of soil using an equilibrium extraction with a 2.0 M KCl solution, followed by air-segmented continuous flow analysis (CFA). Samples in 2007 were also analyzed for PO_4-P using a Modified Kelowna method. Potassium (K) concentration was determined from this same extract using a Flame Emission Photometric method. SO_4 was determined from soil using a 2:1 equilibrium extraction with a 0.01 M $CaCl_2$ solution.

After green manure crops had been incorporated in 2008, Fields E and F were sampled October 8 and Field G was sampled October 17. Sampling and lab analyses were as described in 2007.

Results of Soil Samples Prior to Planting Green Manure Crops

In order to assess overall background nutrient levels and the potential spatial variability at both sites, soil samples were collected in July 2007, just prior to seeding the green manure crops. Analytical results are given in Table 5 and summarized below.

Table 5. Summary of the soil sample analyses from plots in July 2007 prior to planting green manure crops.

	2007 Pre-Green Manure Soil Samples†							
	NO_3-N (kg/ha)		PO_4-P (kg/ha)		K (kg/ha)		SO_4 (kg/ha)	
Field C								
Depth (cm)								
0-15	29.5	a	88.5	a	12.8	a	7.75	b
15-30	16.3	b	56.0	b	6.25	b	15.0	b
30-60	16.8	b	36.5	b	13.8	a	52.3	b
60-90	16.8	b	8.75	c	11.8	a	148	a
Replicates								
1	27.3	a	44.8	a	10.3	a	73.8	a
2	16.5	a	38.5	a	11.5	a	41.3	a
3	16.3	a	44.8	a	11.3	a	48.3	a
4	19.3	a	61.5	a	11.5	a	59.3	a
Field D								
Depth (cm)								
0-15	7.00	a	58.8	a	9.50	a	10.0	a
15-30	3.75	b	57.8	a	7.00	b	7.75	a
30-60	6.50	a	31.8	b	10.3	a	99.5	a
60-90	9.25	a	15.0	c	9.75	a	210	a
Replicates								
1	8.75	a	50.5	a	9.25	a	22.0	a
2	7.75	ab	40.5	ab	9.25	a	13.8	a
3	5.25	b	32.5	b	9.25	a	131	a
4	4.75	b	39.8	ab	8.75	a	161	a
Both Sites								
Field C	19.8	a	47.4	a	11.1	a	55.6	a
Field D	6.63	b	40.8	a	9.13	b	81.9	a

† Numbers in the same undivided column, which are followed by the same letter are not significantly different at the 5% level.

At both sites, NO_3-N was least within the 15-30 cm depth range (Table 5). Overall, Field C had greater background NO_3-N levels than Field D. In Field D, there was some initial spatial variability in NO_3-N, with Rep 1 (east side of plot) being significantly greater than Reps 3 and 4 (west side of plot).

At both sites, PO_4-P was greatest at the soil surface (Table 5) and phosphate is not very mobile in soils. Overall, Field C had greater initial levels of PO_4-P, but the difference was not statistically significant. In Field D, soil PO_4-P was significantly greater in Rep 1 (east) than Rep 3), with Reps 2 and 4 being intermediate.

At both sites, K was least in the 15-30 cm depth range (Table 5). Overall K was spatially uniform. K was significantly greater in Field C than in Field D.

At both sites, SO_4 was greatest at the deepest depth range sampled (60-90 cm) (Table 5). Irrigation water naturally contains SO_4 due to the limestone minerals present in the mountain sources of southern Alberta's irrigation water. On average, 30 cm of irrigation water will add approximately 34 kg/ha of SO_4-S to the soil. Unused amounts of sulphur are very mobile and, therefore, prone to leaching through the soil profile. The large SO_4 differences between depth ranges were not statistically significant in Field D, because of the huge amount of variability in the 30-60 and 60-90 cm depth ranges. The amounts of SO_4 were greater in Reps 3 and 4 (west) due to the greater SO_4 concentrations in the 30-60 and 60-90 cm depth ranges. SO_4 was somewhat greater at Rep 1 (west) due to the greater concentration found in the 60-90 cm depth range. Overall SO_4 was greater in Field D than in Field C, mainly due to amounts in the 30-60 and 60-90 cm depth ranges. Overall, SO_4 at both sites was very similar in the surface 0-30 cm.

In 2008, soil samples were collected just prior to seeding the green manure crops in order to assess overall background nutrient levels and the potential spatial variability at all three sites. Analytical results are given in Table 6 and summarized below.

Table 6. Summary of the soil sample analyses from samples collected in July 2008.

	2008 Pre-Green Manure Soil Samples†							
	NO_3-N (kg/ha)		**PO_4-P (kg/ha)**		**K (kg/ha)**		**SO_4 (kg/ha)**	
Field E								
Depth (cm)								
0-15	80.0	b	126.3	a	34.3	a	180.5	b
15-30	116.5	b	86.8	b	19.3	b	449.3	b
30-60	219.0	a	30.8	c	12.5	b	1166.0	a
60-90	182.8	a	10.5	c	13.0	b	1025.8	a
Field F								
Depth (cm)								
0-15	22.0	b	105.0	a	26.0	a	9.0	a
15-30	33.0	b	41.5	b	11.5	b	83.8	a
30-60	143.8	a	22.3	b	13.8	b	568.8	a
60-90	114.5	a	8.5	b	14.5	b	796.3	a
Field G								
Depth (cm)								
0-15	15.3	a	73.8	a	27.3	a	5.0	b
15-30	49.3	a	45.8	b	16.3	b	43.8	b
30-60	174.8	a	24.5	c	10.8	b	830.5	a
60-90	171.3	a	37.3	bc	11.5	b	657.3	a
All Sites								
Field E	149.6	a	63.6	a	19.8	a	705.4	a
Field F	78.3	b	44.3	a	16.4	a	364.4	a
Field G	102.6	ab	45.3	a	16.4	a	384.1	a

† Numbers in the same undivided column, which are followed by the same letter, are not significantly different at the 5% level.

At all three sites, NO_3-N was lowest within the 0-15 cm depth range, followed by the 15-30 cm depth range (Table 6). NO_3-N was greatest within the 30-60 cm depth range, at all three sites. Overall, Field E had significantly greater background NO_3-N levels than Field F, in the 0-90 cm depth range. The 0-90 cm NO_3-N in Field G was intermediate and not significantly different from either of the other two sites.

At all three sites, NO_3-N was least within the 0-15 cm depth range, followed by the 15-30 cm depth range (Table 6). NO_3-N was greatest within the 30-60 cm depth range, at all three sites. Overall, Field E had significantly greater background NO_3-N levels than Field F, in the 0-90 cm depth range. The 0-90 cm NO_3-N in Field G was intermediate and not significantly different from either of the other two sites.

At all three sites, PO_4-P was greatest at the soil surface (0-15 cm depth) and decreased with increasing soil depth. Overall, Field E had greater initial levels of PO_4-P than the other two sites, in the 0-90 cm depth range, but the difference was not statistically significant.

At all three sites, K was significantly greater in the 0-15 cm depth range than all other depths sampled. In Field F, K was least in the 15-30 cm depth range and greatest in the 0-15 cm depth range (Table 6). In Field E and Field G, K was greatest in the 0-15 cm depth range and least in the 30-60 and 60-90 cm depth ranges. K was greater in Field E than at the other two sites, but the difference was not statistically significant.

In Field F, SO_4 was greatest at the deepest depth range sampled (60-90 cm) (Table 6); however, differences among the soil depths were not significant because of two extremely large values in Replicate 1, for 30-60 and 60-90 cm. In Fields E and G, SO_4 was greatest in the 30-60 cm depth range, followed by the 60-90 cm depth range. Soil SO_4 was significantly less in the two surface depth ranges (0-15 and 15-30 cm). Overall SO_4 was greater in Field E than at the other two sites, but the difference was not statistically significant. When the depth increments were analyzed separately (data not shown) soil SO_4 in Field E was significantly greater than at the other two sites for both the 0-15 and 15-30 cm depth ranges.

Results of Soil Samples After Incorporation of Green Manure Crops

In 2006, total N, which includes plant available (inorganic) N and unavailable (organic) N, was statistically the same for all green manure crops (for averages of both sites and averages within sites) (Table 7). This is as expected because N removed from the soil by the crop would have been returned to the soil during incorporation of the plant material. The only exception would be vetch, which should have theoretically added nitrogen to the soil through fixation of atmospheric N. However, no discernible benefit was reflected in the measurement of Total N. From the crops that overlapped between sites (wheat, Sorghum Sudan grass, CFPM and vetch), it was apparent that the average total soil nitrogen was greater in Field A (2661 kg/ha) than in Field B (2461 kg/ha), this difference was also statistically significant and was likely a result of different approaches to N fertilization in the surrounding wheat crop.

Table 7: Total and available N (kg/ha) in soil samples taken from green manure plots following incorporation in 2006. Numbers in the same column, which are followed by the same letter are not significantly different at the 5% level.

	Pre-Incubation											
	Total N (kg/ha)						**Available N (kg/ha)**					
Name	Field A		Field B		Overall		Field A		Field B		Overall	
Wheat	2626	a	2358	a	2492	a	33.1	ab	27.7	ab	30.4	bc
Sorghum Sudan Grass	2570	a	2470	a	2520	a	18.7	b	20.5	b	19.6	c
CFPM 101	2778	a	2526	a	2652	a	37.9	ab	35.7	ab	36.8	ab
Woolly Pod Vetch	2671	a	2492	a	2582	a	37.4	ab	44.2	a	40.8	ab
Oriental Mustard	-	-	2436	a	2436	a	-	-	29.5	ab	29.5	bc
Oilseed Radish	-	-	2447	a	2447	a	-	-	43.4	a	43.4	ab
Phacelia	2514	a	-	-	2514	a	49.5	a	-	-	49.5	a
Ryegrass	2576	a	-	-	2576	a	41.2	ab	-	-	41.2	ab

There was a greater degree of variability for available nitrogen (a sum of nitrate nitrogen and ammonium nitrogen) than for total nitrogen (Table 7). At the end of the 2006 growing season, shortly after incorporation of the green manure stand, Phacelia had the greatest amount of available N. Radish, ryegrass), woolly vetch and CFPM had the next greatest amount of available N and were not statistically different from one another or from Phacelia. The check treatment (wheat), and mustard had available N tests that were significantly less than Phacelia. Sorgum Sudan grass gave the least overall available N, significantly less than all other crops, and had a large amount of above ground biomass (Table 4). This indicates that, shortly after incorporation, much of the soil N that was immobilized by the crop remained unavailable to plants (organic form). This occurred despite thorough chopping of plant material, followed by a period of almost 40 days for potential N mineralization. Of the four green manure crop that were common to both sites (wheat, Sorghum Sudan grass, CFPM and vetch) there was no trend or significant differences between growers. Wheat and CFPM had greater available N in Field A and Sorghum Sudan grass and vetch had greater available N in Field B.

Analytical results from the 2007 green manure sites (Table 8) were taken from soil that was collected on October 15 and 17, 2007. Total N includes plant available (inorganic) N and unavailable (organic) N (Table 2). Total N was statistically the same for all crops in Field D and for the average of both sites. This is as expected because any N removed from the soil by the crop would have been returned to the soil during incorporation of the plant material. The only exception would be the oat-pea-vetch mix, which should have theoretically added nitrogen to the soil through fixation of atmospheric N. In Field D site, the oat-pea-vetch mix had the second-greatest total N. Surprising results were observed in Field C, where wheat had the greatest total N, which was significantly different from the total N in CFPM and the oat-pea-vetch mix. Total N in Field D was significantly greater than in Field C.

Table 8. Summary of the soil sample analyses from samples collected in October 2007.

	2007 Post-Green Manure Soil Samples†											
	Total N (kg/ha)						**Available N (kg/ha)**					
Name	Field C		Field D		Overall		Field C		Field D		Overall	
Wheat	2909	a	2887	a	2898	a	25.1	a	120.4	a	72.8	a
Sorgum Sudan	2611	ab	2974	a	2792	a	20.9	a	87.8	a	54.4	a
Grass	2295	b	3178	a	2736	a	25.1	a	92.2	a	58.6	a
CFPM 101	2215	b	3140	a	2743	a	20.2	a	103.9	a	68.0	a
Oat-Pea-Vetch	-	-	3033	a	3033	a	-	a	100.2	a	100.2	a
Phacelia	2380	ab	3045	a	2712	a	20.9	a	83.5	a	52.2	a
Ryegrass												
Both Sites												
Field C	2496			b			22.5			b		
Field D	3043			a			98.0			a		

† Numbers in the same column, which are followed by the same letter are not significantly different at the 5% level.

Available nitrogen is a sum of nitrate nitrogen and ammonium nitrogen. There was no statistical significance among green manure crops at either of the sample sites in 2007 (Table 8). Available N in Field D was significantly greater than in Field C. In Field D, wheat had the greatest overall available N remaining after incorporation of the green manure crop. Like available N, NO_3-N in Field D (88.9 kg/ha) was also significantly greater than in Field C (14.5 kg/ha) (results not shown). Between July and October, in Field C, NO_3-N decreased from 29.5 to 14.5 kg/ha, in the 0-15 cm depth range. In that period of time, N-mineralization would have contributed to the amount of soil NO_3-N, however uptake by the green manure crop would have immobilized N, resulting in the net decrease in NO_3-N. Between July and October 2007, in Field D, average NO_3-N increased from 7.00 to 88.9 kg/ha, in the 0-15 cm depth range. These results are surprising and suggest that the site may have received mineral N fertilizer in the intervening time, possibly through the pivot.

Analytical results from the 2008 green manure sites (Table 9) were taken from soil that was collected on October 8 and 17, 2008. Total N includes plant available (inorganic) N and unavailable (organic) N (Table 9). Total N was statistically the same for all crops at all three sites. This is as expected because any N removed from the soil by the crop would have been returned to the soil during incorporation of the plant material. The only exception would be the oat-pea-vetch mix), which could have theoretically added nitrogen to the soil through fixation of atmospheric N. The greatest total N values, in Field E, were found in the oat-pea-vetch mix), teff and ryegrass. At In Field F, the greatest total N was found for wheat and the oat-pea-vetch mix). The average total N in Field G was the same for each green manure crop (2688 kg/ha). This result occurred despite differences among the individual replicates for each crop, which ranged from 2240 to 3136 kg/ha. Field F had the greatest average total soil N in the 0-15 cm depth range, which was significantly greater than the average total N at the other two sites.

Table 9. Summary of the soil sample analyses from samples collected in October 2008.

	2008 Post-Green Manure Soil Samples†											
	Total N (kg/ha)						**Available N (kg/ha)**					
Name	Field E		Field F		Field G		Field E		Field F		Field G	
Wheat	2632	a	3080	a	2688	a	19.7	b	36.3	a	23.1	b
Sorgum Sudan	2576	a	3024	a	2688	a	22.3	b	32.4	a	19.7	b
Grass	2464	a	3248	a	2688	a	41.5	a	21.8	a	30.7	b
CFPM 101	2632	a	3864	a	2688	a	28.9	ab	39.8	a	24.6	b
Oat-Pea-Vetch	2464	a	3864	a	2688	a	25.4	b	32.9	a	27.6	b
Teff	2408	a	3752	a	2688	a	35.8	ab	52.9	a	47.0	a
Ryegrass												
All Sites												
Field E			2529	b					28.9	a		
Field F			3472	a					36.0	a		
Field G			2688	b					28.8	a		

† Numbers in the same column, which are followed by the same letter are not significantly different at the 5% level.

Available nitrogen is a sum of nitrate nitrogen and ammonium nitrogen. There was no statistical significance among green manure crops in Field F (Table 9). The greatest available N in Field F, was for ryegrass). Available N was greatest for CFPM in Field E. In Field G, ryegrass) had the greatest overall available N remaining after incorporation of the green manure crop. There was no statistical significance among the three sites for average available N.

Like available N, October NO_3-N in the 0-15 cm depth range was greatest in Field F (32.2 kg/ha), compared to Field E (25.0 kg/ha) and Field G (25.3 kg/ha). Between July and October 2008, in Field F, average NO_3-N increased from 22.2 to 32.2 kg/ha, in the 0-15 cm depth range. Between July and October 2008, in Field G, NO_3-N increased from 15.1 to 25.4 kg/ha, in the 0-15 cm depth range. In that period of time, N-mineralization could have contributed to the amount of soil NO_3-N; however, the results are surprising because it would have been expected that the growing green manure crop would have immobilized N. Between July and October 2008, in Field E, NO_3-N decreased from 80.1

to 25.0 kg/ha, in the 0-15 cm depth range. It is expected that the green manure crop would have immobilized N, resulting in the net decrease in NO_3-N.

Results of Soil Sample Incubations to Determine Mineralizable Nitrogen

The purpose of the warm/moist incubation in 2006 was to maximize mineralization of N held in organic matter within residue from the green manure crop. The available N, from this analysis, was a measure of readily mineralizable N, which includes the available N already present prior to incubation plus any N that was mineralized during incubation minus any N that might have been immobilized during the incubation period. Mould was noted on the surface of samples during the incubation process, which suggests that some immobilization may have occurred.

The total N before and after incubation should remain the same, unless nitrogen fixation, leaching or volatilization occurred during the incubation period. Leaching was prevented because containers were sealed at the bottom. Nitrogen fixation is unlikely, as no plants were growing the small soil samples used, so there were no hosts available for *Rhizobium* nodules.

Based on the recommendations developed in 2006, sub-samples were not incubated in 2007 or 2008 for mineralizable N.

Table 10: Total and available N (kg/ha) in soil samples taken in 2006 from green manure plots following incorporation and incubation to achieve maximum mineralization.

	Post-Incubation†											
	Total N (kg/ha)						**Available N (kg/ha)**					
Name	Field A		Field B		Overall		Field A		Field B		Overall	
Wheat	2722	a	2402	a	2562	a	54.3	ab	58.9	ab	56.6	b
Sorghum Sudan Grass	2537	a	2503	a	2520	a	34.0	b	44.0	b	39.0	c
CFPM 101	2811	a	2666	a	2738	a	61.0	ab	66.5	a	63.7	ab
Woolly Pod Vetch	2531	a	2582	a	2556	a	61.8	ab	78.6	a	70.2	ab
Oriental Mustard	-	-	2475	a	2475	a	-	-	66.4	a	66.4	ab
Oilseed Radish	-	-	2464	a	2464	a	-	-	76.3	a	76.3	ab
Phacelia	2498	a	-	-	2498	a	84.7	a	-	-	84.7	a
Ryegrass	2542	a	-	-	2542	a	75.7	a	-	-	75.7	ab

† Numbers in the same column, which are followed by the same letter are not significantly different at the 5% level.

Total N, after the incubation period, was statistically the same for all green manure crops (for averages of both sites and averages within sites) (Table 10). Total N values remained very similar after incubation to values determined before incubation. From the crops that overlapped between sites (wheat, Sorghum Sudan grass, CFPM and vetch), it was apparent that the average total soil nitrogen was somewhat greater in Field A (2650 kg/ha) than Field B (2538 kg/ha), this difference was not statistically significant.

The available soil N, after the incubation period, was greater than prior to incubation. This indicates that mineralization of organic N occurred during the 28 days of warm/moist conditions, as would be expected. It also indicates that the amount of mineralization exceeded any potential losses of N that may have occurred. Individual ranking of the crops, as indicated by the letters representing significant difference within columns, were very similar before and after incubation. As with the soil analysis prior to incubation, the post-incubation available N for Phacelia was greatest. After incubation, radish), ryegrass), vetch), mustard and CFPM had the next greatest amount of available N and were not statistically different from one another or from Phacelia. Wheat had post-incubation available N tests that were significantly less than Phacelia. Sorgum Sudan grass gave the least overall available N, which was significantly less than all other crops both before and after incubation of the soil samples. This suggests that much of the soil N immobilized by the crop remained unavailable, even after 28 days of warm/moist conditions. In the context of this incubation experiment, the mineralization rates of Sorghum Sudan grass residues would be the slowest of the eight green manure crops tested to supply early season N to a subsequent crop of potatoes. A different (in-field) measure of mineralization is needed to determine if this conclusion holds true under field conditions. Of the four crops that were common to both sites (wheat, Sorghum Sudan grass, CFPM and vetch) there were no trend or significant differences between fields. Wheat and CFPM had greater available N in Field A and Sorghum Sudan grass and woolly vetch had greater available N in Field B.

Differences Between Post- Incubation and Pre-Incubation N, as a Measure of Net Mineralization

The available N after the warm/moist incubation, was a measure of readily mineralizable N, which includes available N present prior to incubation plus N mineralized during incubation minus N immobilized during the incubation period. The difference, for any given sample, between the available N prior to and after incubation is an estimate for net mineralization for that period and under the imposed conditions (28 days at 25°C and 80% of field capacity).

In order to determine whether or not changes in soil N were meaningful, they were calculated as a percent of the pre-incubation N content.

Differences between pre-incubation and post-incubation total N showed no significant trend and were near zero (Table 11). Averages did not exceed ±6% of the pre-incubation total N, and therefore will not be discussed.

Table 11: Difference in total and available N (% of pre-incubation concentration) in soil samples taken from incorporated green manure plots before and after and incubation to achieve maximum mineralization.

	Difference (Post minus Pre-Incubation) †											
	Total N (% of Pre-Incubation)						**Avail. N (% of Pre-Incubation)**					
Name	Field A		Field B		Overall		Field A		Field B		Overall	
Wheat	4.0	a	2.3	a	3.1	a	76	a	112	a	94	a
Sorgum Sudan Grass	-1.4	a	1.4	a	-0.022	a	88	a	125	a	106	a
CFPM 101	1.8	a	5.8	a	3.8	a	61	a	89	a	75	a
Wooly Pod Vetch	-5.1	a	3.7	a	-.73	a	68	a	87	a	77	a
Oriental Mustard	-	-	1.1	a	1.1	a	-	-	127	a	127	a
Oilseed Radish	-	-	0.53	a	0.53	a	-	-	85	a	85	a
Phacelia	-0.29	a	-	-	-0.29	a	80	a	-	-	80	a
Ryegrass	-1.5	a	-	-	-1.5	a	128	a	-	-	128	a

Changes in available N were substantially greater than for total N, as expected. All values were positive, indicating that a net mineralization occurred, i.e. that mineralization exceeded any potential losses due to fixation or volatilization. Although there were no statistically significant differences among green manure crops, some notable trends were observed. Ryegrass showed the greatest increase in available N (128% of the pre-incubation available N). This crop, however, also had the greatest degree of variability of all the crops. The values for individual replicates were 76%, 348%, 34% and 55%, respectively. Therefore the high value may be an outlier and the true mean for this crop is considerably less. Sorghum Sudan grass and mustard also showed a slightly greater amount of N mineralized during the incubation period. Of the four crops that overlap at the two sites (wheat, Sorghum Sudan grass, CFPM and vetch), the individual ranking for each site was similar, Sorghum Sudan grass > wheat >vetch≈ CFPM in Field A and Sorghum Sudan grass > wheat > CFPM ≈vetch in Field B. Of these four crops common to both sites, the average in Field B (103%) was greater than the average for Field A (73%), however the post-incubation available N was still less in Field B (see previous section).

Recommendations for Future Sampling and Analysis

It may be preferable, in order to save costs on future soil testing and analysis, that soil samples following the green manure crop be taken just before planting of the subsequent potato crop, in order to correctly gauge the available N. The laboratory incubation process for estimating mineralizable N may give a good estimate for warm season N mineralization rates but will not be useful in estimating the amount of N that will be readily available under field conditions, where seasonal and diurnal fluctuations in temperatures and variable moisture conditions occur.

If sampling then does occur after planting, it should be decided whether cores should be taken from the hill, furrow, mid-slope or a combination.

The sampling regime used in 2006 (12 core samples per plot, 0-15 cm depth, 2 cm diameter) provided for a sufficient sample size and was ample to account for in-plot spatial variability in soil N.

Verticillium Inoculum

Green Manure Crops Root Analysis in 2006

Materials and Methods

On August 24, 2006, an initial disease evaluation of the green manure crops in both Fields A and B was conducted by digging out and bagging 5 entire plants, including all roots, from each subplot. All bags were then refrigerated at 5°C until they were processed. On Sept 22 each set of plants was individually washed under running tap water to remove the soil and crop debris, and foliage was discarded. Lower stems and roots were visually and/or microscopically examined for evidence of root rot, galls, stunting and discoloration. For each of these parameters, this disease severity (DS) rating scale was used: 0 = no root rot (or galls or stunting or discoloration) present; 1 was a slight amount of the symptom; 2 was a moderate level; and finally 3 meant that severe levels were present. Then, one feeder root/plant/subplot) ca. 2 cm long, was placed onto a glass microscope slide with a drop of lactophenol + acid fuchsin and examined microscopically for *Verticillium* spp. microsclerotia and mycelium. Results were recorded as either positive or negative for this pathogen, so no statistical analysis was performed.

Also, a composite sample of feeder roots of various sizes from each of the five root systems /subplot was sterilized in 1% sodium hypochlorite (NaOCl) for 30 sec., rinsed in sterile water, and then randomly cut into at least 20 pieces (5 mm). Five root pieces were aseptically placed onto each of four plates of agar medium/subplot as follows: two plates of CzaPEK Solution Agar amended with streptomycin (CZA-S) and acidified potato dextrose agar (PDA-A). These plates were incubated at RT for ca. 2-weeks, before microscopically examining them specifically for *Verticillium* spp. and also noting other fungal genera growing on them. As some of the cultures still had either no growth or fungal sporulation, they were rechecked at a later date after cold storage.

Results and Discussion

Data for all ratings were summarized and analyzed using the ARM 7 statistical software program (Gylling Data Management, Brookings, SD) with the DI and DS experimental means results presented as either raw or detransformed data. Duncan's Multiple Range Test (($P \leq 0.05$) was used.

Root rot and root swellings were more common in the Field B as opposed to Field A. Cereal plants in Field B were stunted as the result of a virus infection. Fungal isolations were performed on root samples to check for the presence of *Verticillium spp.*, and the plates were examined in mid-October. There was no growth of this pathogen on the agar plates after 2-3 weeks of incubation. Two pathogens that were present on the roots of some plants at both sites were *Fusarium spp.* and *Alternaria spp*.

Table 12 – Fields A and B

For Field A, crops in this location were definitely much healthier than Field B upon root evaluations. Although the root rot and gall formation results were insignificant, only Sudan grass and vetch had root rot, with very low values of < 7.5% DI and <0.1 DS. Galls only formed on the vetch crop (22.9 % DI but just 0.08 DS), Sudan grass, and wheat – both with very negligible levels. Root stunting was more prevalent, but only Sudan grass and ryegrass had significantly lower DI values of 16.3% and 25% respectively while the remaining crops were in a much higher range, from 70 % (millet) to 100% (wheat). The lowest stunting DS results (0.27 and 0.31) were found with the same crops as in the DI ratings but included millet too, in the same group (1.19 DS). Again, wheat had the highest DS rating at 2.79 out of 3. For root discoloration, the DI ratings were insignificant, although ryegrass had the lowest value at only 5% and the highest was Sudan grass at 68.8%. However for the DS rating, ryegrass was extremely low at 0.05 but was in the same statistical grouping as wheat (0.27), millet (0.25), and vetch (0.29). Sudan grass and *Phacelia* had the most root discoloration (0.8 and 1.16).

Table 12 shows the microscopic root examination from the two fields, with the DS and DI means of the four replications /crop. For Field B, all data were statistically significant ($P \leq 0.05$) and overall, mustard had the least root rot, gall formation (results of 0 DS and DI), root stunting and discoloration. For root rot, roots from the other crops had DI levels of 100%, whereas mustard was nearly half of that at 55%. Likewise, these roots had a DS severity of 0.58 (scale from 0-3 points) and Sudan grass had the next lowest level of 1.10 followed by vetch at 1.26 but these two crops were statistically higher than mustard. Wheat had the most root rot with a DS of 1.84 but was statistically similar to millet and radish. Root galls formed on 86.7 % of the vetch roots but there were none in mustard and radish. However for the DS results, wheat, mustard and radish were all ≤ 0.1 while again, vetch was the highest at 1.23 but was statistically similar to millet at 0.48. After examining each crop for stunted roots, mustard, millet and Sudan grass had significantly lower symptoms for both DI /DS (results ranged from 10% /0.01 for mustard up to 25% /0.23 for Sudan grass). Wheat had the highest rating (100% /2.36) but this was statistically similar to radish (70% /0.97). Root discoloration usually means that disease may be present, and only the mustard roots (DI = 35% and DS = 0.32) were significantly less discoloured.

<u>Table 13 - Fields A and B</u>

Table 13 shows the % of roots /crop that were infected with *Verticillium spp*. upon microscopic examination from Fields A and B. For Field A, Sudan grass roots were 100% infected with *Verticillium* but the other crops had DI levels of 0%. From this data, Sudan grass roots appeared to be highly susceptible to infection by *Verticillium spp.* For Field B, wheat was the most infested crop, with 30% of the roots showing either *Verticillium* hyphae, spores or both. This was followed by Sudan grass with 15% and then mustard and vetch crops, both showing disease incidence levels (DI) of 5%. Only radish and millet were uninfected with this pathogen.

When other root pieces were plated to CZA-S and PDA-A culture media and microscopically examined for *Verticillium spp*. (hyphae, spores or microsclerotia), in Field A showed that only roots from millet for Replicates 1 and 3 grew *V. dahliae* on a CZA-S and PDA-A plate respectively. Other fungal isolates were *Alternaria*, *Fusarium spp.*, *Cladosporium Epicoccum, Trichoderma*, *Ulocladium, Acremonium, Penicillium, Mucor* and *Rhizopus.* Fusarium grew on nearly all of the culture plates from this field. Davis et al. (2004) reported that incorporation of sudan grass and sorghum-sudangrass hybrids was closely associated with significant increases in populations of *Fusarium equiseti, F. oxysporum,* and *F. solani*. In Field B, only wheat roots from Replication 1 grew *V. dahliae*. Other fungi genera growing on plates were, *Alternaria*, *Fusarium spp., Epicoccum, Trichoderma, Ulocladium, Acremonium, Penicillium, Mucor* and *Rhizopus.* Data from these results are not on a table.

From the results obtained in Tables 12 and 13 for the green manure crops in the two fields overall, Field B had the lowest disease levels in the mustard crop whereas ryegrass was the lowest in Field A. However, these two crops were each only grown in one field.

A complicating factor in disease management through crop rotation is that roots of some non-hosts including cereals (barley, buckwheat, field corn, oats, Sudan grass, and wheat) legumes (alfalfa, Austrian winter pea, clover, and milkvetch), and brassica crops (canola, radish, and turnip) support low populations of *V. dahliae* (Rowe and Powleson 2002).

Table 12: Root evaluations performed from Fields A and B during the green manure crop year (2006).

Field	Crop	DI (%)[2,5,7]	DS (0-3)[3,6,7]	DI (%)[2,5,7]	DS (0-3)[3,6,7]	DI (%)[2,4,7]	DS (0-3)[3,5,7]	DI (%)[2,4,7]	DS (0-3)[3,5,7]
A	**Wheat**	0.0 a	0.00 a	2.3 a	0.01 a	100.0 a	2.79 a	30.0 a	0.27 bc
	Sudan Grass	2.3 a	0.01 a	2.7 a	0.02 a	16.3 b	0.27 c	68.8 a	0.80 ab
	Millet	0.0 a	0.00 a	0.0 a	0.00 a	70.0 a	1.19 bc	25.0 a	0.25 bc
	Vetch	7.2 a	0.10 a	22.9 a	0.08 a	85.0 a	1.77 ab	30.0 a	0.29 bc
	Phacelia	0.0 a	0.00 a	0.0 a	0.00 a	80.0 a	1.93 ab	66.7 a	1.16 a
	Ryegrass	0.0 a	0.00 a	0.0 a	0.00 a	25.0 b	0.31 c	5.0 a	0.05 c
Field	**Crop**	**Root rot[1]**		**Gall formation[1]**		**Stunting of roots[1]**		**Root discoloration[1]**	
		DI (%)[2,4,7]	**DS (0-3)[3,5,7]**	**DI (%)[2,4,7]**	**DS (0-3)[3,6,7]**	**DI (%)[2,4,7]**	**DS (0-3)[3,6,7]**	**DI (%)[2,4,7]**	**DS (0-3)[3,5,7]**
B	**Wheat**	100.0 a	1.84 a	30.0 bc	0.01 cd	100.0 a	2.36 a	93.8 a	1.62 a
	Sudan Grass	100.0 a	1.10 b	35.0 bc	0.33 bc	25.0 cd	0.23 cd	100.0 a	1.19 a
	Millet	100.0 a	1.44 ab	65.0 ab	0.48 ab	15.0 d	0.07 d	85.0 a	1.39 a
	Vetch	100.0 a	1.26 b	86.7 a	1.23 a	53.3 bc	0.55 bc	73.3 ab	0.86 ab
	Mustard	55.0 b	0.58 c	0.0 c	0.00 d	10.0 d	0.01d	35.0 b	0.32 b
	Radish	100.0 a	1.49 ab	5.0 c	0.01 cd	70.0 ab	0.97 b	70.0 ab	0.93 ab

[1]Results are the means of four replications.
[2]Root symptom disease incidence means (DI) are based on the percentage of roots evaluated per crop that had either root rot, gall formation, stunting of the roots and discoloration.
[3]Root symptom disease severity (DS) means are based on a 0-3 point scale, where 0 = no root rot (or galls or stunting or discoloration) present, 1 = slight symptom level, 2 = moderate symptom level and finally 4 = severe symptoms.
[4]Raw data were used for analysis.
[5]Square root-transformed data were used for analysis with detransformed means presented.
[6]Arcsine-transformed data were used for analysis with detransformed means presented.
[7]Numbers within the same undivided column followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

Table 13. Microscopic examination of the roots from each green manure crop.

Field A	Positive *Verticillium spp.* on roots (% /crop) [1,2]	Field B	Positive *Verticillium spp.* on roots (% /crop)[1,2]
Wheat	0	**Wheat**	30
Sudan Grass	100	**Sudan Grass**	15
Millet	0	**Millet**	0
Vetch	0	**Vetch**	5
Phacelia	0	**Mustard**	5
Ryegrass	0	**Radish**	0

[1]Results are the means of four replications.
[2]Root symptom disease incidence means (DI) are based on the percentage of roots evaluated per crop that had *Verticillium spp*. growing on them, including hyphae and/or spores.

Verticillium Inoculum in Soil
Materials and Methods

Soil sampling - 2006 – Fields A and B (Green manure crops)
Soil samples were collected from Fields A and B August 24-25, 2006. A composite sample was obtained using a spade. A large spade-full of soil was taken from 10 to 25 cm below soil level at five sites within each subplot to make a composite sample. Soil samples were taken from fallow areas between plots as a control. Samples were stored at 5°C until they were processed in the fall. In October, following green manure crop incorporation into the soil, post-incorporation soil samples were collected in the same manner.

During the winter months, the technologists thoroughly mixed the soil in each composite sample, taking care to break up any large lumps, remove any rocks and avoid cross-contamination between all soil samples by disinfecting the mixing trays with 85% denatured ethanol. From each sample, two 500 mL sub-samples were taken. One set of sub-samples was shipped to Dr. Guy Bélair, AAFC, Saint-Jean-sur-Richelieu, PQ, for root lesion nematode analysis. The other set of sub-samples was sent April 2007 to Dr. Larry Kawchuk, AAFC, Lethbridge, for *Verticillium* analysis using molecular methods. The remainder of the composite soil sample was retained for soil dilution plating. Also, these soil samples were used in 2008 for a bioassay using a *Verticillium*-susceptible cultivar of eggplant, carried out in a CDCS greenhouse and this methodology is described in a separate section. Soil dilution plating, the eggplant bioassay and PCR molecular analysis are compared in the main project report for their speed, accuracy and practicality, as assays for *Verticillium* species in potato soils. In April 2007, four samples from each field were sent to Dr. Bélair for a preliminary evaluation to decide on the feasibility of sending the remaining samples. He decided that after the samples had been in refrigerated storage for over half a year, the nematodes likely wouldn't have survived anyway so these samples weren't sent to him. Consequently then, soil samples for nematode analysis were always sent to the analytical laboratories shortly after obtaining them!

Soil sampling – 2007 - Fields A and B (Potatoes) and Fields C and D (Green manure crops)
Staff collected soil samples, using the same methodology as outlined above, following potato harvest (Fields A and B) and crop incorporation (Field C and D) in the fall, 2007. Baseline soil samples were also collected and composited from five areas outside each replicate in Fields C and D. In 2007 again, 500 mL sub-samples were submitted to Dr. Kawchuk and Dr. Guy Belair. The remaining soil was refrigerated (5˚C) for soil dilution plating.

Soil Sampling – 2008 - Field C (Potatoes) and Fields E, F and G (Green manure crops)
In 2008, soil samples were collected from plots areas in Field C, and from areas that had been fallow in 2007 (Outside Plot Soil). Soil samples were not collected from Field D in 2008 as potatoes were not planted following the green manure crops. Composite samples and baseline soil samples (see 2007 above) were obtained from Fields E, F and G. A smaller soil volume of >1 kg was obtained from each subplot by using a soil auger to reach a depth of ≥ 20cm in five areas within it and 10 scoops of soil (using a garden trowel) were obtained from all of them as a composite sample. A 500 mL sub-sample from each sample was shipped to Dr. Kawchuk for verticillium testing and another 250 g sub-sample was shipped to Dr. Thomas Forge for nematode testing in Agassiz, British Columbia. The remaining samples were retained at 5˚C for dilution plating and eggplant bioassays.

Soil Sampling – 2009 - Fields E, F and G (Potato crop year)
In 2009, following potato harvest, soil samples were collected as before from the centre of each subplot in Fields E, F and G. Samples were collected from between green manure plots in Fields E and F only, (Outside Plot). In Field G, potatoes were only planted into pot areas so no soil was collected from areas between plots. A 500 mL sub-sample from each sample was shipped to Dr. Kawchuk for verticillium testing and another 250 g sub-sample was shipped to Dr. Thomas Forge for nematode testing. The remaining samples were retained at 5˚C for dilution plating and eggplant bioassays.

Dilution Plating

The method of Mpofu and Hall (2003) was modified to estimate Verticillium populations in field soil samples. Two selective agar media, Soil Pectate Tergitol (SPT; Dr. Kenneth Conn, personal communication) and Sorensen's NP-10 medium (SNP-10; Dr, Fuoad Daayf, personal communication), were evaluated for recovery and identification of Verticillium spp.

Although both Verticillium dahliae and Verticillium albo-atrum were recovered from autoclaved soil samples spiked with prepared lab suspensions of each species, V. albo-atrum was indistinguishable from other light coloured fungi when field soil dilutions were evaluated. V. dahliae colonies produced sclerotia that were distinctive.

In 2008, dilution plating of the 2006-07 soil samples was used to enumerate only V dahliae on SNP-10 media, with dilutions ranging from 10^1 - 10^3dilutions /soil sample and three replicate plates /dilution. Results were calculated as colony-forming units, expressed as cfu/g of soil. Few colonies were obtained from the 10^1 and 10^2 dilutions; and for all other soil samples evaluated, only the 10^1 dilutions were required. Soil dilution plates were allowed to grow for approximately 3 weeks in the dark before colonies were counted. In 2009, oven-dried soil weights (ODW), rather than field soil weights were used to calculate the cfu/g to account for any differences in the moisture content of field soil.

Results and Discussion

Green Manure Crop Year – Fields A and B only
In the first year of the trial, samples were collected from plot areas while green manure was growing. There wasn't any verticillium inoculum in any of the soil samples collected from Field A, while green manure crops were growing. The *V. dahliae* inoculum in Field B ranged from 18.75 to 31.42 cfu/g of soil and were the highest values observed throughout the project. There were no statistical differences

between plot areas in Field A or Field B prior to green manure incorporation. In all other years of the trial, areas sampled outside of the green manure plots were used as checks.

<u>After Green Manure Crop Incorporation</u>

No verticillium inoculum was recovered from soil samples collected following the incorporation of the green manure crop in Field A, Field C and Field G. No *V. dahliae* inoculum was recovered from the areas outside of the green manure plots either, indicating that these fields were not high risk fields. The inoculum levels in Field B following the incorporation of wheat, CFPM, Sudangrass and mustard and were statistically lower than following incorporation of oilseed radish. Less inoculum was recovered from soil samples after incorporation of wheat, CFPM, Sorghum Sudangrass and the oat/pea/vetch mixture than while the green manure crops were growing. In Field D, the inoculum level in *Phacelia* plots was significantly higher those from other green manure crops. *Phacelia*, which had been introduced as a source of biomass in place of *Brasscia* relatives, was not used in subsequent years of the trial. The inoculum levels measured in Field E were extremely low and not significantly different from one another, ranging from 0 for "no green manure, wheat and teff up to 0.17 cfu/g of soil for ryegrass. Data from Field F showed significantly higher verticillium inoculum after Sorghum Sudangrass than the after incorporation of the other green manure crops.

<u>After Potato Crop Year</u>

Following potato production in Field A, verticillium inoculum levels were low but detectable, with the highest values of 1.67 and 1.68 cfu/g (Sudangrass and *Phacelia*) and the lowest for wheat, millet and ryegrass (all 0). Soil inoculum levels in the Sudangrass, *Phacelia* and Woolly Vetch plots were greater following potato than following the incorporation of the green manure crops. Soil inoculum levels in Field B were not statistically different from one another ranging from 3.42 cfu/g of soil (Sudangrass) to 7.08 (mustard). Surprisingly, these values were lower following the potato crop than following the green manure incorporation.

The soil inoculum in Field C increased following potato production from the previous year, regardless of which green manure crop was used. Although not statistically different from the inoculum in the green manured plots, soil inoculum was highest in the area where no green manure had been incorporated. Significant differences were observed between plots in Fields E and F. In Field E, inoculum values following potatoes were higher overall than following green manure incorporation. Interestingly, the plots with the highest inoculum prior to potatoes, also had the highest level of inoculum following potatoes. Soil from OPV and ryegrass (1.25 and 1.50 cfu/g of soil) had higher verticillium inoculum than teff or areas that had not been green manured. In Field F, the highest verticillium inoculum levels were observed from Sorghum Sudangrass, ryegrass and "no green manure", and the lowest inoculum levels were observed in teff plots. In Field G, verticillium inolculum was recovered from CFPM and Sudangrass soils following a potato crop, whereas this pathogen wasn't present in any of the green manured plots the previous year.

Table 14: Verticillium inoculum (cfu/g of soil) in fields in southern Alberta before and after incorporation of green manures. Data followed by the same letter in each row were not statistically different ($p \geq 0.05$).

Field	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade
Green manure crop year											
A	0	0	0	0	0	0	0				
B		30.75 a	31.42 a	30.83 a	30.00 a				18.75 a	19.83 a	
C	0	0	0	0	0	0	0				
D	0	0	0	0	0	0	0				
After green manure incorporation											
A	0	0	0	0	0	0	0				
B		14.33 b	16.17 b	15.42 b	20.0 ab				17.00 b	25.58 a	
C	0	0	0	0	0	0	n/a				
D	0.00 b	0.00 b	0.00 b	0.00 b	0.00 b	0.00 b	0.33 a				
E[2]	0.00 a	0.00 a	0.08 a	0.08 a	0.08 a	0.17 a		0.00 a			
F[2]	2.58 b	2.17 b	2.08 b	5.92 a	2.00 b	3.75 b		2.00 b			
G	0	0	0	0	0	0					0
After potato crop year											
A		0.00 a	0.00 a	1.67 a	0.83 a	0.00 a	1.68 a				
B		4.83 a	5.25 a	3.42 a	6.25 a				7.08 a	6.83 a	
C	1.00 a	0.56 a	0.33 a	0.75 a	0.56 a	0.25 a	n/a				
D[1]	0.00 b	0.00 b	0.00 b	0.00 b	0.00 b	0.00 b	0.33 a				
E[2]	0.17 c	0.75 abc	0.67 abc	0.50 abc	1.25 ab	1.50 a		0.25 c			
F[2]	5.92 a	3.75 ab	3.33 ab	5.08 ab	3.17 ab	5.00 ab		1.92 b			
G	0.00 a	0.00 a	0.33 a	0.08 a	0.00 a	0.00 a					0.00 a

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the following year.

Eggplant Bioassay

Materials and Methods

Eggplant, *Solanum melongena*,is a member of the nightshade family, and is very closely related to the potato plant (*Solanum tuberosum*). Some cultivars of eggplant are highly susceptible to verticillium wilt. A bioassay trial was conducted in a double poly hoop house, in 2008. The purpose of this bioassay experiment was to further verify *V. dahliae* inoculum in field soil samples collected from commercial potato fields. A highly susceptible eggplant variety, Black Belle II, was chosen after preliminary testing. Black Belle II eggplant seedlings were transplanted into soil samples collected from Fields A, B and C and D in 2006 and 2007, including samples taken from outside the subplots (described as “no green manure” in this report and negative controls (landscaping soil), totalling 203 soils for testing. Three to four 15 mm (6”) pots were planted, depending on the quantity of soil remaining after soil dilution plating, *Verticillium* and nematode testing.

The eggplants were watered and maintained in the hoop house from August to October, 2008, until verticillium wilt foliar symptoms developed (leaf wilting, bright yellow chlorosis along leaf veins, stunting of the plants, wilting, or death). When symptoms developed, each plant was rated for disease severity (DS) on a scale of 0-4 points: where 0 = no symptoms; 1 = single leaf wilting or half of a leaf was chlorotic; 2 = multiple leaves yellowing /wilting, leaf roll; 3 = whole plant wilts with extensive yellowing, possibly was stunted and finally; 4 = plant death. One diseased plant, (rating from 1-4 points), if any, was chosen from each replicate for root/stems fungal isolations.

The stems from each plant selected were cut off at the soil level with the foliage discarded. The root/lower stems were gently washed. The stems were surface-sterilized with 95% ETOH and allowed to air-dry. Stems were sectioned into six pieces and placed onto one half each of a plate of potato dextrose agar amended with penicillin and tetracycline (PDA-PT) and CzaPEK Solution Agar amended with streptomycin (CZA-S). Roots were washed free of adhering soil, sectioned into three pieces and directly plated onto the remaining halves of the same plates. These were incubated for at least 14 days in the dark at room temperature, and refrigerated until evaluation. The roots and stem pieces were microscopically examined for the presence of *Fusarium spp., V. dahliae, Colletotrichum coccodes (*black dot) and *R. solani* (rhizoctonia) fungal growth. Disease incidence (DI) levels for each pathogen were calculated as the percentage of stems with each of these pathogens present.

Another bioassay trial was set up in 2010, using soil samples collected from Fields E, F and G in 2009. Eggplant seedlings (variety Black Belle II) were transplanted into two replicate pots for each green manured plot in each field. During this 2010 bioassay, there was a heavy aphid infestation in the hoop house, and Safer Brand Insecticidal Soap and Pirimor were used to control the infestation. Some seedlings were replaced once the aphids were under control. Many of the plants prematurely developed severe black dot and blight (*Alternaria spp*. and *Ulocladium*) and this confounded the plant disease evaluations, as these two pathogens also cause necrosis and leaf wilting. Plants were evaluated as in 2008, and fungal isolations were also performed.

Results and Discussion

Green Manure Crop Year – Fields A and B only

Tables 15 and 16: 2006 was the only year that soil samples were obtained prior to green manure soil incorporation from all of the subplots, including areas between the replications (no green manure column in Tables 1 – 10) and the negative control soil (DS = 0.0). Field A was a very healthy field when viewed in 2006 and as expected, when eggplants were planted into these soils, they were nearly wilt-free as opposed to the plants grown in the Field B soils. In Tables 1 and 2 for the first field, all of the DS (0-4 points) and DI% levels were 0.00 with the exceptions of vetch and ryegrass, both at only 0.06 /2,7% (DS/DI) but all had statistically insignificant data ($p \geq 0.05$). There were significant differences ($p \leq 0.05$) between the eggplant DS wilt levels however, for Field B, where the negative control was significant lower than "no green manure", Sudangrass, vetch and radish (DS results for these were from 0.93 for radish to 1.24 for "no green manure). The remaining crops were statistically similar to the negative control, with relatively low DS results ranging from 0.52 to 0.66. When the percentage of the wilted eggplants were compared for this field (DI %), the crops with significantly more disease than the negative control were "no green manure", Sudangrass, vetch, mustard and radish (results ranged from50% to 68.8%). Only wheat and CFPM (millet) were similar but had DI values of 31.3% and 37.5% respectively.

Table 15: Verticillium wilt disease severity (DS)[4] in Black Belle II eggplants that were planted into field soils from southern Alberta before and after incorporation of green manures and following the subsequent potato crop. Data followed by the same letter in each row were not statistically different ($p \geq 0.05$).

GM Crop	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade	Negative Control
Field												
Green manure crop year												
A[6]	0.00 a	0.00 a	0.00 a	0.00 a	0.06 a	0.06 a	0.00 a					0.00 a
B[6]	1.24 a	0.52 ab	0.66 ab	1.00 a	1.20 a				0.64 ab	0.93 a		0.00 b
After green manure incorporation												
A[6]	0.00 a	0.00 a	0.00 a	0.00 a	0.06 a	0.06 a	0.00 a					0.00 a
B[5]	1.13 a	1.13 a	1.69 a	1.81 a	1.50 a				1.44 a	1.81 a		0.00 b
C[5]	0.88 b	0.00 a	0.00 a	0.00 a	0.00 a	0.00 a						0.00 a
D[8]	0.00	0.50	0.00	0.00	0.00	0.00	0.00					0.00
After potato crop year												
A[8]		0.00	0.00	0.00	0.00				0.00	0.00		0.00
B[5]		1.25 a	1.50 a	1.00 a	1.67 a				1.00 a	1.00 a		0.00 a
C[3]	---	---	---	---	---	----						
D[1]	---	---	---	---	---	---	---					---
E[2,5]	1.38 a	1.75 a	0.88 a	0.88 a	0.88 a	1.38 a		0.50 a				1.50 a
F[2,6]	0.56 a	0.11 a	0.11 a	0.50 a	0.20 a	0.65 a		1.56 a				1.47 a
G[5]	----[9]	0.63 a	0.50 a	0.63 a	0.50 a	0.00 a					1.75 a	1.50 a

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the following year.
[3]Insufficient soil quantities for eggplant bioassays were collected in 2008.
[4] Plant symptom disease severity (DS) means are based on a scale of 0-4 points: where 0 = no symptoms; 1 = single leaf wilting or half of leaf chlorotic; 2 = multiple leaves yellowing /wilting, leaf roll; 3 = whole plant wilts with extensive yellowing; possibly stunted and finally; 4 = plant death.
[5]Raw data were used for analysis.
[6]Square root-transformed data were used for analysis with detransformed means presented.
[7]Arcsine-transformed data were used for analysis with detransformed means presented.
[8]No statistical analysis was performed for this row because either these results were all 0s or there was only one diseased eggplant in all.
[9]There were no potatoes that were planted outside this experimental plot to obtain soil from.

Table 16: Verticillium wilt disease incidence (DI%)[4] in Black Belle II eggplants that were planted into field soils from southern Alberta before and after incorporation of green manures and year with potato crops. Data followed by the same letter in each row were not statistically different ($p \geq 0.05$).

GM Crop	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade	Negative Control
Field												
Green manure crop year												
A[6]	0.0 a	0.0 a	0.0 a	0.0 a	2.7 a	2.7 a	0.0 a					0.0 a
B[5]	68.8 a	31.3 ab	37.5 ab	66.7 a	66.7 a				50.0 a	50.0 a		0.0 b
After green manure incorporation												
A	0.0 a	0.0 a	0.0 a	0.0 a	2.7 a	2.7 a	0.0 a					0.0 a
B[5]	56.3 b	56.3 b	87.5 a	93.8 a	100.0 a				87.5 a	100.0 a		0.0 c
C[8]	---	---	---	---	---	----						---
D[1]	---	---	---	---	---	---	---					---
E[2,3]	---	---	---	---	---	---		---				
F[2,3]	---	---	---	---	---	---		---				
G[3]	---	---	---	---	---	---					---	
After potato crop year												
A[9]		0.0	0.0	0.0	0.0	0.0	0.0					0.0
B[8]		---	---	---	---				---	---		---
C[3]	---	---	---	---	---	---						
D[1]	---	---	---	---	---	---	---					---
E[2,5]	75.0 a	62.5 a	37.5 a	37.5 a	50.0 a	50.0 a		37.5 a				---[8]
F[2,5]	50.0 a	12.5 a	12.5 a	25.0 a	12.5 a	37.5 a		50.0 a				---[8]
G[5]	----[10]	25.0 a	12.5 a	25.0 a	12.5 a	0.0 a					50.0 a	---[8]

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the following year.
[3]No samples were collected prior to incorporation of green manure in 2007 and 2008 or insufficient soil quantities for eggplant bioassays were collected in 2008.
[4] Plant disease incidence means (DI) are based on the percentage of roots evaluated per crop that had verticillium wilt symptoms.
[5]Raw data were used for analysis.
[6]Square root-transformed data were used for analysis with detransformed means presented.
[7]Arcsine-transformed data were used for analysis with detransformed means presented.
[8]As there was only one plant/replication/subplot for either all or one of the crops, DI% were not performed.
[9]No statistical analysis was performed for this row either because these results were all 0s or only one plant was infected.
[10]There were no potato crops that were planted outside this experimental plot to obtain soil from.

Tables 17 – 24: For Field A, after enumerating the eggplant root /stem culture plate colonies that were positive for black dot, fusarium, *V. dahliae* and rhizoctonia (DI%), only black dot and fusarium grew on them and just from the vetch and ryegrass subplots (Tables 17-20) with all data insignificant. Black dot DI% values on these roots and stems were both 6.2%, with higher fusarium DI levels seen on the same plant parts at 20.6 and 8.7% respectively. For ryegrass, similarly low black dot results were obtained with root/stem DI levels at 4.8% and 6.2% with fusarium results at 12.5% and 6.2%. There didn't appear to be *V. dahliae* or rhizoctonia inoculum in any of the soils.

However for the Field B culture plates, statistically significant data were obtained for eggplant roots infested with black dot and fusarium. The negative control (DI = 0%) had a significantly much less black dot DI than the crops, which had very high disease levels ranging from 41.1 % for "no green manure" to 68.9% for vetch. The same pattern held for the stem results, except that millet was lowest for the crops at 35.7% and this time, the "no green manure" replication means were the highest (65.4%). Fusarium also grew at even higher levels on roots and stems from all of the soil samples (60.1% -83% on roots and 77.6% -95.7% on stems), except for the negative control (0% DI). Conversely very low, statistically insignificant *V. dahlia* levels were observed on the eggplant roots, with only the "no green manure" subplots having this pathogen at 1.95% DI but as expected, the stems had higher levels, ranging from 2.0% (radish) to 23.4% (Sudangrass). *R. solani* only grew in the stem culture plates from eggplants in Sudangrass soil (DI of 4.2%).

From these results, fusarium and black dot were the major pathogens that caused the eggplants to wilt in soils from both fields while specifically, those grown in the Sudangrass and vetch crops soil samples had higher DI% levels, but this trend wasn't statistically significant in all cases. In addition to causing tuber blemish symptoms in potato, *C. coccodes* also causes symptoms on stems and foliage, resulting in crop losses in some countries, and is implicated as a factor in the potato early dying disease complex (Lees and Hilton 2003).

Table 17: Black dot disease incidence (DI%)[4] means on eggplant root culture isolates from plants growing in the field soils from southern Alberta, before and after green manures incorporation and potato crops. Data followed by the same letter in each row were not statistically different ($p \geq 05$).

Field	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade	Negative Control
Green manure crop year												
A[6]	0.0 a	0.0 a	0.0 a	0.0 a	6.2 a	4.8 a	0.0 a					0.0 a
B[6]	41.1 a	58.0 a	58.0 a	64.8 a	68.9 a				65.4 a	66.1 a		0.00 b
After green manure incorporation												
A[6]	0.0 a	0.0 a	0.0 a	0.0 a	3.4 a	7.5 a	0.0 a					0.0 a
B[5]	75.0 a	66.7 a	62.5 a	95.8 a	66.7 a				83.3 a	87.5 a		0.0 b
C[5]	37.5 a	0.0 b	0.0 b	0.0 b	0.0 a	0.0 b						0.0 b
D[8]	0.0	4.2	0.0	0.0	0.0	0.0	0.0					0.0
E[2,3]	---	---	---	---	---	---		---				
F[2,3]	---	---	---	---	---	---		---				
G[3]	---	---	---	---	---	---					---	
After potato crop year												
A[8]		0.0	0.0	0.0	0.0	0.0	0.0					0.0
B[5]		12.5 a	37.5 a	16.7 a	72.2 a				33.3 a	16.7 a		0.0 a
C[3]	---	---	---	---	---	---						
D[1]	---	---	---	---	---	---	---					---
E[2,5]	58.3 a	79.2 a	50.0 a	45.8 a	66.7 a	62.5 a		50.0 a				79.2 a
F[2,5]	75.0 a	16.7 a	25.0 a	16.7 a	25.0 a	62.5 a		58.3 a				79.2 a
G[5]	----[9]	20.8 a	25.0 a	25.0 a	20.8 a	0.0 a					58.3 a	37.5 a

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the following year.
[3]No samples were collected prior to incorporation of green manure in 2007 and 2008 or insufficient soil quantities for eggplant bioassays were collected in 2008.
[4] Plant disease incidence means (DI) are based on the percentage of roots evaluated per crop growing on PDA-A and CZA-S agar plates with black dot.
[5]Raw data were used for analysis.
[6]Square root-transformed data were used for analysis with detransformed means presented.
[7]Arcsine-transformed data were used for analysis with detransformed means presented.
[8]No statistical analysis was performed for this row either because these results were all 0s or only one plant was infected.
[9]There were no potato crops that were planted outside this experimental plot to obtain soil from.

Table 18: Black dot disease incidence (DI%)[4] means on eggplant stem culture isolates from plants growing in the field soils from southern Alberta, before /after green manures incorporation and potato crops. Data followed by the same letter in each row were not statistically different ($p \geq 05$).

Field	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade	Negative Control
Green manure crop year												
A[6]	0.0 a	0.0 a	0.0 a	0.0 a	6.2 a	6.2 a						0.0 a
B[6]	65.4 a	55.1 a	35.7 a	42.9 a	64.5 a				39.1 a	62.3 a		0.0 b
After green manure incorporation												
A[6]	0.0 a	0.0 a	0.0 a	0.0 a	2.0 a.	6.2 a	0.0 a					0.0 a
B[7]	44.4 a	69.1 a	67.8 a	95.6 a	75.0 a				73.5 a	98.9 a		0.0 b
C[5]	41.7 a	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b						0.0 b
D[8]	0.0	4.2	0.0	0.0	0.0	0.0	0.0					0.0
E[2,3]	---	---	---	---	---	---		---				
F[2,3]	---	---	---	---	---	---		---				
G[3]	---	---	---	---	---	---					---	
After potato crop year												
A[8]		0.0	0.0	0.0	0.0				0.0	0.0		0.0
B[6]		0.0 b	37.5 ab	16.7 b	66.7 a				20.8 b	8.3 b		0.0 b
C[3]	---	---	---	---	---	---						
D[1]	---	---	---	---	---	---	---					---
E[2,5]	29.2 a	79.2 a	37.5 a	29.2 a	50.0 a	45.8 a		33.3 a				29.2 a
F[2,5]	58.3 a	0.0 a	12.5 a	0.0 a	20.8 a	29.2 a		25.0 a				29.2 a
G[5]	----[9]	25.0 a	16.7 a	20.8 a	16.7 a	0.0 a					16.7 a	37.5 a

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the following year.
[3]No samples were collected prior to incorporation of green manure in 2007 and 2008 or insufficient soil quantities for eggplant bioassays were collected in 2008.
[4] Plant disease incidence means (DI) are based on the percentage of stems evaluated per crop growing on PDA-A and CZA-S agar plates with black dot.
[5]Raw data were used for analysis.
[6]Square root-transformed data were used for analysis with detransformed means presented.
[7]Arcsine-transformed data were used for analysis with detransformed means presented.
[8]No statistical analysis was performed for this row either because these results were all 0s or only one plant was infected.
[9]There were no potato crops that were planted outside this experimental plot to obtain soil from.

After Green Manure Incorporation during Green Manure Crop Year: Fields A -D

Tables 15 and 16: For Field A, the eggplant wilt DS and DI% results were identical for soils obtained during the green manure crop growing season and were extremely low, so incorporation apparently made no difference. However, for Field B, higher results were obtained after incorporation, as opposed to before. For comparing the DS levels to each other, the negative control with DS=0 (scale 0-4), was statistically lower than the green manure crops, but now the "no green manure" and wheat means were at 1.13, with the remaining crops ranging from 1.44 (mustard) to 1.81 (Sudangrass and radish). On Table 2, again the negative control (0% DI) was the lowest, followed by "no green manure" and wheat (both 56.3%) in another Duncan's grouping but the eggplants in the millet and mustard were even more diseased (87.5%), then Sudangrass (93.8%) and finally, those in vetch and radish soils were the most wilted (100% DI%). With Field C, only the eggplants grown in the "no green manure" soils were wilted (DS of 0.88). Those from Field D were not wilted at all, and therefore, weren't cultured. Insufficient soil sample amounts were collected from Fields E, F and G for the bioassay.

Tables 17 - 24: When the culture plates were rated for Fields A and C, Field A had similarly low, statistically insignificant, black dot and fusarium DS and DI% levels calculated as" before incorporation", with these pathogens only growing on eggplant roots and stems from the vetch and ryegrass soils. For Field B however, all four of the fungi (black dot, fusarium, *V. dahliae* and *R. solani*) grew on the roots and stems (DI %), but the first two were most prevalent. Statistically significant data were obtained for black dot on roots /stems and for both fusarium and *V. dahliae* on stems only. Specifically for black dot, this fungus grew at high DI levels on the roots, from 62.5% (millet) up to 95.8% (Sudangrass), but the negative control at 0% was significantly lower. The stems had the same Duncan's groupings but this time, radish was 98.9% DI. For fusarium on roots, all of the DI% values, except for the negative control, were very high, ranging from 54.2 % (wheat) to 100% (mustard). On the stems, those from the green manure crops had significantly higher DI% levels than the negative control, with wheat (60.4 %) grouped the same as "no green manure" and millet (both 93.4%) with the remaining soils even more infested. *V. dahliae* was observed at very low, statistically insignificant levels on roots from the wheat and millet soils. However on the stems, the lowest DI% results were on the negative control, wheat (16.7%), then millet, Sudangrass and radish (ca. 35%), "no green manure" and mustard (mid-range) and finally, vetch (77.8%). *R. solani* only grew on eggplant roots from millet, Sudangrass and radish soils (2.0 - 8.4% DI) but infested stems from vetch and mustard soils (2.9 and 2.0 DI%).

Field C culture evaluations showed statistically significant, moderately high DI% levels in the "no green manure" roots /stems (black dot was 37.5% /41.7% with fusarium at 58.3% /70.8%) with the remaining crop values for the at 0%. *V.dahliae* grew just on the stems for this same crop (25% DI); significantly higher than the others. *R. solani* also was tabulated at insignificantly low levels on these same roots (4.17% DI). For this field, the green manure crops likely suppressed these pathogens, so appeared to be promising.

The Field D soil samples must have been nearly pathogen-free as very low if any, of the fungi grew on the roots and stems at insignificant DI% levels (i.e. black dot /fusarium levels were just 4.2% for the wheat soil and the rest were 0). *V. dahliae* was observed on the eggplant stems from the wheat soil at 12.5% DI and *R. solani* wasn't present at all. Although the eggplants grown in these soil samples were extremely healthy, unfortunately the farmer didn't plant this field to potatoes the following year, so no further data was obtained.

For all of the above fields, this data strongly suggests that black dot and fusarium are actually the principle pathogens causing early dying and wilt – not *V. dahliae.*

After Potato Crop Year – Fields A, B, E, F and G

Tables 15 and16: After the eggplant seedlings were transplanted into the Field A soil (2009 bioassay experiment), they all remained very healthy and therefore, were not cultured. Thus, the pathogen culture DI% results in ***Tables 21 - 24*** for this field are all 0, with no statistical analysis performed. Perhaps, these green manure crops suppressed pathogen growth, but there weren't any "no green manure" soil samples taken, as a comparison.

Field B, that was heavily disease-infested the previous year, also didn't have any "no green manure" soil samples collected but there was still the negative control soil, which grew very healthy, disease-free eggplants. Only DS values were calculated, as there was only just plant/subplot. This data were insignificant, with results from 1.0 (Sudangrass, mustard and radish) to 1.67 (vetch) and most values were only slightly decreased from the green manure crop year. For Field C, insufficient soil quantities were also collected so there wasn't enough for this bioassay and Field D was no longer available.

In the Field E 2010 bioassay, the negative control (eggplants grown in local landscaping soil) actually had wilted plants, with a DS of 1.50 (0-4 point scale), using raw data statistical analysis. This was nearly as high as for the most diseased eggplants in wheat soil (1.75) but teff was lowest (DS of 0.50) and the remaining plants had mid-range DS values. Eggplants grown in the crop soils ranged from 37.5% DI (Sudangrass and teff) to 62.5 % (wheat) and finally, 75% ("no green manure"), although this was just a trend with no statistical significance. Teff showed the most disease (DS of 1.56 /DI of 50%) in Field F, with trends only, suggesting that the lowest DS /DI ratings were for the wheat /millet soils (both 0.11 DS, 12.5% DI) followed by vetch (0.2 DS /12.5% DI).

With Field G, however, nightshade was grown rather than teff, so there is an additional column on all of the tables for this crop. As there wasn't a potato crop around this plot, it didn't have the "no green manure" treatment. Eggplants grown in the nightshade soil actually had a wilt DS rating of 1.75, which was ca. 3X higher than the remaining soil samples, ranging from 0 (ryegrass) to 0.63 (wheat and Sudangrass) but data were insignificant. Also, 50% of the plants growing in nightshade soil were wilted, whereas ryegrass had no wilting and the remaining crops were 12.5 – 25% DI.

Tables 17 – 24: For the culture plates ratings (black dot, fusarium, *V. dahliae* and rhizoctonia), a general observation was that the first two pathogens were very prevalent, agreeing with previous findings from the green manure crop year. There weren't any Field A diseased plants for dissection, because the results were all 0%. Field B showed lower DI% trends for both black dot and fusarium on the eggplant roots during the potato crop rotation, as compared to the green manure crop incorporation year, except for those in the vetch soil with slightly higher black dot levels. Although this data were statistically insignificant, it is still noteworthy that the black dot DI levels for the other soil samples were decreased, by at least 65% from before. Fusarium root disease levels were also greatly reduced on the eggplants in the mustard and radish soils, suggesting that green manure crop incorporation *may* be effective for disease prevention in potato crops. With the stem cultures, the black dot DI% data were statistically significant, with the eggplants in the vetch soil having more disease (66.7% - potato year vs. 75% green manure incorporation year) than plants in the other soil samples. Also, these same crop soils (excluding vetch) showed very dramatic DI decreases since the previous year, especially for wheat (0%), Sudangrass (16.7 %,) mustard (20.8%) and radish (8.3%). The *V. dahliae,* fusarium and *R. solani* eggplant stem DI% data were insignificant but the fusarium DI levels (except vetch), were at least 40% lower during the potato crop year. This data was then very interesting and promising, due to this contrast between the two years.

Fields E, F and G, as noted above, didn't have soil samples collected from them during the green manure incorporation year to compare with. All eggplant black dot DI data were insignificant for Field E and as the negative control values were 79.2 % (roots) and 29.2% (stems), the crop soil sample results were moderately high as well. The fusarium DI data was very high but also insignificant, with root DI % from 50% (millet and teff), 95.8% ("no green manure") and 100% (wheat). Stem DI % was 29.2% (negative control), followed by 41.7% (millet) and up to 100% ("no green manure" /wheat). However, the *V. dahliae* stem and root DI values were all statistically significant, as the negative control (roots) was unfortunately at 79.2% DI and the roots in wheat soil were 20.8% diseased with the remainder at 0%. Eggplant stems from the "no green manure", Sudangrass, vetch and teff soils were also 0%, with millet and ryegrass in the same grouping (2.0% /3.4%) but wheat and the negative control were significantly increased (21% /23.1%). *R. solani* was only present on roots from the "no green manure" soils (8.3% DI) and vetch, ryegrass and teff (4.2%), which was significantly less than the negative control (79.2%). For the stems, the negative control had a DI value of 29.2%, with significantly more diseased stems than "no green manure", Sudangrass and ryegrass (8.3%) with the rest at 0%.

After Field F black dot and fusarium DI data were analyzed, the eggplant stems and roots from all of the soil samples grew these pathogens but with insignificant results. As a trend though, the roots had more black dot than the stems, with the lowest DI demonstrated in the wheat and Sudangrass crops (16.7%), followed by millet and vetch (25%), then teff (58.3%), "no green manure" soil (75%) and finally, the negative control (79.2 DI%). The eggplant stems from wheat and Sudangrass soils had no black dot, the negative control was 29.2% with the "no green manure" soil (58.3% DI) highest of all. The fusarium DI root data showed another trend, with 70.8% to 80% of them diseased from the following soils: "no green manure", ryegrass, teff and the negative control. The stems had similar values for these three crops and the negative control was now 29.2% DI, with the remaining crops having ca. 25% DI for both roots and stems. *V. dahliae* data were statistically significant for these ratings too, showing no growth on any of roots, except for the negative control (79.2%). Similarly, the only stems that grew this pathogen were from the "no green manure", ryegrass and teff crops (extremely low DI values of 4.2%), with the negative control significantly much higher at 29.2%. *R. solani* grew on roots from the ryegrass and teff soils (4.2% /16.7%), which was significantly lower than the negative control (79.2% DI). The eggplant stems, from the "no green manure" and teff soils, showed DI levels of 16.5% and 14.8% respectively, which were statistically similar to the negative control (23.1% DI). Those from the ryegrass soil were significantly less diseased (2.0%) and were in the same Duncan's grouping as the remaining stems (0% DI).

After the Field G data evaluation, statistically insignificant data were tabulated for root /stem black dot; however, the highest DI value was on roots grown in nightshade soil (58.3%) followed by the negative control (37.5%) with the other crops at ca. 25%, except for ryegrass (0%). For the eggplant stems, the negative control was the same but the other crop soil DI values ranged from 0% (ryegrass) to 25% (wheat). Fusarium root and stem DI values were similar, although the stems had statistically significant data, where all eggplants, except for those grown in nightshade soil (70.8%), were less diseased than the negative control at 95.8% DI. Ryegrass soil (0% DI) was in the same Duncan's grouping as vetch (16.7%), wheat, millet and Sudangrass (all 25%). Neither *V. dahliae* nor *R. solani* grew on any of the eggplant roots but *V. dahliae* was observed at significant levels on the negative control stems (8.3% DI), with the remaining crops at 0% DI.

For this final potato crop year, the negative control perhaps was stored longer and became more diseased unfortunately, so it wasn't suitable to use for this study but this wasn't apparent until these evaluations were performed and results were statistically significant because of this factor. The hail storms of 2008 and 2009 also confounded some of the data for Fields E and F, so that results were likely higher for these fields due to plant damage. For the eggplant roots and stems, grown in the field soils as part of this bioassay experiment, black dot and fusarium caused the most disease on them, showing the high economic impact these pathogens may have also on potato crops.

Table 19: *Fusarium spp.* disease incidence (DI%)[4] means on eggplant root culture isolates from plants growing in the field soils from southern Alberta, before /after green manures incorporation and potato crops. Data followed by the same letter in each row were not statistically different ($p \geq .05$).

Field	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade	Negative Control
Green manure crop year												
A[5]	0.0 a	0.0 a	0.0 a	0.0 a	20.8 a	12.5 a	0.0 a					0.0 a
B[6]	60.1 a	82.8 a	78.0 a	77.6 a	76.3 a				78.0 a	74.2 a		0.0 b
After green manure incorporation												
A[6]	0.0 a	0.0 a	0.0 a	0.0 a	8.7 a	8.7 a	0.0 a					0.0 a
B[8]	83.3	54.2	62.5	95.8	77.8				100.0	75.0		0.0
C[5]	58.3 a	0.0 b	0.0 b	0.0 b	0.0 a	0.0 b						0.0 b
D[9]	0.0	0.0	0.0	0.0	0.0	0.0	0.0					0.0
E[2,3]	---	---	---	---	---	---		---				
F[2,3]	---	---	---	---	---	---		---				
G[3]	---	---	---	---	---	---					---	
After potato crop year												
A[9]		0.0	0.0	0.0	0.0				0.0	0.0		0.0
B[5]		37.5 a	54.17 a	50.0 a	66.7 a				37.5 a	25.0 a		0.0 a
C[3]	---	---	---	---	---	---						
D[1]	---	---	---	---	---	---	---					---
E[2,5]	95.8 a	100.0 a	50.0 a	70.8 a	75.0 a	75.0 a		50.0 a				79.2 a
F[2,5]	70.8 a	25.0 a	25.0 a	20.8 a	25.0 a	75.0 a		75.0 a				79.2 a
G[5]	----[10]	25.0 a	25.0 a	25.0 a	25.0 a	0.0 a					75.0 a	95.8

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the following year.
[3]No samples were collected prior to incorporation of green manure in 2007 and 2008 or insufficient soil quantities for eggplant bioassays were collected in 2008.
[4] Plant disease incidence means (DI) are based on the percentage of roots evaluated per crop growing on PDA-A and CZA-S agar plates with *Fusarium spp*. on them.
[5]Raw data were used for analysis.
[6]Square root-transformed data were used for analysis with detransformed means presented.
[7]Arcsine-transformed data were used for analysis with detransformed means presented.
[8]Raw data were used for analysis but letters are not in this row because this analysis failed the Bartlett's test for homogeneity (was significant).
[9]No statistical analysis was performed for this row because either because these results were all 0s or only one plant was infected.
[10]There were no potato crops that were planted outside this experimental plot to obtain soil from.

Table 20: *Fusarium spp.* disease incidence (DI%)[4] means on eggplant stem culture isolates from plants growing in the field soils from southern Alberta, before /after green manures incorporation and potato crops. Data followed by the same letter in each row were not statistically different ($p \geq .05$).

Field	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade	Negative Control
Green manure crop year												
A[6]	0.0 a	0.0 a	0.0 a	0.0 a	8.7 a	6.2 a	0.0 a					0.0 a
B[6]	77.6 a	88.7 a	82.9 a	91.5 a	88.2 a				82.9 a	95.7 a		0.0 b
After green manure incorporation												
A[6]	0.0 a	0.0 a	0.0 a	0.0 a	6.2 a	8.7 a	0.0 a					0.0 a
B[7]	93.4 ab	60.4 b	93.4 ab	100.0 a	100.0 a				100.0 a	98.9 a		0.0 c
C[5]	70.8 a	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b						0.0 b
D[8]	0.0	4.2	0.0	0.0	0.0	0.0	0.0					0.0
E[2,3]	---	---	---	---	---	---		---				
F[2,3]	---	---	---	---	---	---		---				
G[3]	---	---	---	---	---	---					---	
After potato crop year												
A[8]		0.0	0.0	0.0	0.0				0.0	0.0		0.0
B[5]		37.5 a	58.3 a	50.0 a	88.9 a				37.5 a	37.5 a		0.0 a
C[3]	---	---	---	---	---	---						
D[1]	---	---	---	---	---	---	---					---
E[2,5]	100.0	100.0 a	41.7 a	75.0 a	75.0 a	75.0 a		50.0 a				29.2 a
F[2,5]	75.0 a	25.0 a	25.0 a	25.0 a	25.0 a	75.0 a		75.0 a				29.2 a
G[5]	----[9]	25.0 bc	25.0 bc	25.0 bc	16.7 bc	0.0 c					70.8 ab	95.8 a

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the following year.
[3]No samples were collected prior to incorporation of green manure in 2007 and 2008 or insufficient soil quantities for eggplant bioassays were collected in 2008.
[4] Plant disease incidence means (DI) are based on the percentage of stems evaluated per crop growing on PDA-A and CZA-S agar plates with *Fusarium spp*. on them.
[5]Raw data were used for analysis.
[6]Square root-transformed data were used for analysis with detransformed means presented.
[7]Arcsine-transformed data were used for analysis with detransformed means presented.
[8]No statistical analysis was performed for this row because either because these results were all 0s or only one plant was infected.
[9]There were no potato crops that were planted outside this experimental plot to obtain soil from.

Table 21: *V. dahliae* disease incidence (DI%)[4] means on eggplant root culture isolates from plants growing in the field soils from southern Alberta, before /after green manures incorporation and potato crops. Data followed by the same letter in each row were not statistically different ($p \geq .05$).

Field	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade	Negative Control
Green manure crop year												
A[9]	0.0	0.0	0.0	0.0	0.0	0.0	0.0					0.0
B[6]	1.95 a	0.0 a	0.0 a	0.0 a	0.0 a				0.0 a	0.0 a		0.0 a
After green manure incorporation												
A[9]	0.0	0.0	0.0	0.0	0.0				0.0	0.0		0.0
B[6]	0.0 a	2.0 a	2.0 a	0.0 a	0.0 a				0.0 a	0.0 a		0.0 a
C[9]	0.0	0.0	0.0	0.0	0.0	0.0						0.0
D[9]	0.0	0.0	0.0	0.0	0.0	0.0	0.0					0.0
E[2,3]	---	---	---	---	---	---		---				
F[2,3]	---	---	---	---	---	---		---				
G[3]	---	---	---	---	---	---					---	
After potato crop year												
A[9]		0.0	0.0	0.0	0.0				0.0	0.0		0.0
B[5]		0.0 a	0.0 a	4.17 a	0.0 a				0.0 a	0.0 a		0.0 a
C[3]	---	---	---	---	---	---						
D[1]	---	---	---	---	---	---	---					---
E[2,5]	0.0 b	20.8 b	0.0 b	0.0 b	0.0 b	0.0 b		0.0 b				79.2 a
F[2,5]	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b		0.0 b				79.2 a
G[9]	----[10]	0.0	0.0	0.0	0.0	0.0					0.0	0.0

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the following year.
[3]No samples were collected prior to incorporation of green manure in 2007 and 2008 or insufficient soil quantities for eggplant bioassays were collected in 2008.
[4] Plant disease incidence means (DI) are based on the percentage of roots evaluated per crop growing on PDA-A and CZA-S agar plates with *V.dahliae on* them.
[5]Raw data were used for analysis.
[6]Square root-transformed data were used for analysis with detransformed means presented.
[7]Arcsine-transformed data were used for analysis with detransformed means presented.
[8]Raw data were used for analysis but letters are not in this row because this analysis failed the Bartlett's test for homogeneity (was significant).
[9]No statistical analysis was performed for this row because either because these results were all 0s or only one plant was infected.
[10]There were no potato crops that were planted outside this experimental plot to obtain soil from.

Table 22: *V. dahliae* disease incidence (DI%)[4] means on eggplant stem culture isolates from plants growing in the field soils from southern Alberta, before /after green manures incorporation and potato crops. Data followed by the same letter in each row were not statistically different ($p \geq .05$).

Field	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade	Negative Control
Green manure crop year												
A[8]	0.0	0.0	0.0	0.0	0.0	0.0	0.0					0.0
B[6]	9.5 a	8.5 a	20.1 a	23.4 a	8.5 a				14.4 a	2.0 a		0.00 a
After green manure incorporation												
A[8]	0.0	0.0	0.0	0.0	0.0				0.0	0.0		0.0
B[5]	50.0 ab	16.7 cd	33.3 bc	37.5 bc	77.8 a				54.2 ab	33.3 bc		0.0 d
C[5]	25.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a						0.0 a
D[8]	0.0	12.5	0.0	0.0	0.0	0.0	0.0					0.0
E[2,3]	---	---	---	---	---	---		---				
F[2,3]	---	---	---	---	---	---		---				
G[3]	---	---	---	---	---	---					---	
After potato crop year												
A[8]		0.0	0.0	0.0	0.0				0.0	0.0		0.0
B[5]		29.2 a	25.0 a	12.5 a	50.0 a				12.5 a	25.0 a		0.0 a
C[3]	---	---	---	---	---	---						
D[1]	---	---	---	---	---	---	---					---
E[2,6]	0.0 c	21.0 ab	2.0 bc	0.0 c	0.0 c	3.4 abc		0.0 c				23.1 a
F[2,5]	4.2 b	0.0 b	4.2 b	0.0 b	0.0 b	4.2 b		0.0 b				29.2 a
G[5]	----[9]	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b					0.0 b	8.3 a

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the following year.
[3]No samples were collected prior to incorporation of green manure in 2007 and 2008 or insufficient soil quantities for eggplant bioassays were collected in 2008.
[4] Plant disease incidence means (DI) are based on the percentage stems of evaluated per crop growing on PDA-A and CZA-S agar plates with *V.dahliae* on them.
[5]Raw data were used for analysis.
[6]Square root-transformed data were used for analysis with detransformed means presented.
[7]Arcsine-transformed data were used for analysis with detransformed means presented.
[8]No statistical analysis was performed for this row because either because these results were all 0s or only one plant was infected.
[9]There were no potato crops that were planted outside this experimental plot to obtain soil from.

Table 23: Rhizoctonia disease incidence (DI%)[4] means on eggplant root culture isolates from plants growing in the field soils from southern Alberta, before /after green manures incorporation and potato crops. Data followed by the same letter in each row were not statistically different ($p \geq .05$).

Field	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade	Negative Control
Green manure crop year												
A[9]	0.0	0.0	0.0	0.0	0.0	0.0	0.0					0.0
B[9]	0.0	0.0	0.0	0.0	0.0				0.0	0.0		0.0
After green manure incorporation												
A[9]	0.0	0.0	0.0	0.0	0.0				0.0	0.0		0.0
B[6]	0.0 a	0.0 a	8.4 a	2.0 a	0.0 a				0.0 a	2.0 a		0.0 a
C[5]	4.17 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a						0.0 a
D[8]	0.0	0.0	0.0	0.0	0.0	0.0	0.0					0.0
E[2,3]	---	---	---	---	---	---		---				
F[2,3]	---	---	---	---	---	---		---				
G[3]	---	---	---	---	---	---					---	
After potato crop year												
A[9]		0.0	0.0	0.0	0.0				0.0	0.0		0.0
B[5]		0.0 a	4.2 a	0.0 a	0.0 a				0.0 a	0.0 a		0.0 a
C[3]	---	---	---	---	---	---						
D[1]	---	---	---	---	---	---	---					---
E[2,5]	8.3 b	0.0 b	0.0 b	0.0 b	4.2 b	4.2 b		4.2 b				79.2 a
F[2,5]	0.0 b	8.3 b	0.0 b	0.0 b	0.0 b	4.2 b		16.7 b				79.2 a
G[,9]	----[10]	0.0	0.0	0.0	0.0	0.0					0.0	0.0

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the following year.
[3]No samples were collected prior to incorporation of green manure in 2007 and 2008 or insufficient soil quantities for eggplant bioassays were collected in 2008.
[4] Plant disease incidence means (DI) are based on the percentage of roots evaluated per crop growing on PDA-A and CZA-S agar plates with rhizoctonia on them.
[5]Raw data were used for analysis.
[6]Square root-transformed data were used for analysis with detransformed means presented.
[7]Arcsine-transformed data were used for analysis with detransformed means presented.
[8]Raw data were used for analysis but letters are not in this row because this analysis failed the Bartlett's test for homogeneity (was significant).
[9]No statistical analysis was performed for this row because either because these results were all 0s or only one plant was infected.
[10]There were no potato crops that were planted outside this experimental plot to obtain soil from.

Table 24: Rhizoctonia disease incidence (DI%)[4] means on eggplant stem culture isolates from plants growing in the field soils from southern Alberta, before /after green manures incorporation and potato crops. Data followed by the same letter in each row were not statistically different ($p \geq .05$).

Field	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade	Negative Control
Green manure crop year												
A[8]	0.0	0.0	0.0	0.0	0.0	0.0	0.0					0.0
B[5]	0.0 a	0.0 a	0.0 a	4.2 a	0.0 a				0.0 a	0.0 a		0.0 a
After green manure incorporation												
A[8]	0.0	0.0	0.0	0.0	0.0				0.0	0.0		0.0
B[6]	0.0 a	0.0 a	0.0 a	0.0 a	2.9 a				2.0 a	0.0 a		0.0 a
C[8]	0.0	0.0	0.0	0.0	0.0				0.0	0.0		0.0
D[8]	0.0	0.0	0.0	0.0	0.0	0.0	0.0					0.0
E[2,3]	---	---	---	---	---	---		---				
F[2,3]	---	---	---	---	---	---		---				
G[3]	---	---	---	---	---	---					---	
After potato crop year												
A[8]		0.0	0.0	0.0	0.0				0.0	0.0		0.0
B[5]		0.0 a	0.0 a	0.0 a	5.6 a				4.2 a	0.0 a		0.0 a
C[3]	---	---	---	---	---	---						
D[1]	---	---	---	---	---	---	---					---
E[2,5]	8.3 b	0.0 b	0.0 b	8.3 b	0.0 b	8.3 b		0.0 b				29.2 a
F[2,6]	16.5 ab	0.0 c	0.0 c	0.0 c	0.0 c	2.0 bc		14.8 ab				23.1 a
G[8]	----[9]	0.0	0.0	0.0	0.0	0.0					0.0	0.0

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the following year.
[3]No samples were collected prior to incorporation of green manure in 2007 and 2008 or insufficient soil quantities for eggplant bioassays were collected in 2008.
[4] Plant disease incidence means (DI) are based on the percentage of stems evaluated per crop growing on PDA-A and CZA-S agar plates with rhizoctonia on them.
[5]Raw data were used for analysis.
[6]Square root-transformed data were used for analysis with detransformed means presented.
[7]Arcsine-transformed data were used for analysis with detransformed means presented.
[8]No statistical analysis was performed for this row because either because these results were all 0s or only one plant was infected.
[9]There were no potato crops that were planted outside this experimental plot to obtain soil from.

Molecular Determination of Verticillium Inoculum - Alberta

Growth of fungal and plant materials for positive controls

Stock cultures of *Verticillium albo-atrum* and *V. dahliae* isolated from potato were axenically stored as a conidial suspension in aqueous glycerol at - 70 ° C. To revive stock cultures, single droplets of thawed suspension were pipetted directly onto potato dextrose agar (PDA). To obtain conidia, the resulting mycelial colonies were maintained at 22 °C in the dark and spores were harvested 4 weeks later in sterile distilled water or colonies were grown in Czapek's broth at 22 °C with shaking. Potato plants of the cultivar Shepody were grown in a growth chamber with a 12 h photoperiod. Day and night temperatures were 22 °C and 18 °C, respectively. Young rooted cuttings from cloned susceptible plants were root-dip inoculated into suspensions of 1.5 x 10^7 conidia of *V. albo-atrum* or *V. dahliae* per ml of sterile distilled water.

Potato leaves, stems and roots were collected for DNA extraction when the cuttings inoculated with *V. albo-atrum* began to develop wilt symptoms. A sample of the leaflets, as well as stem and root segments from the same plant were retained for attempted isolation of the fungi. These plant tissues were surface sterilized by dipping for 30 s in 70% ethanol, followed by 1 min in 0.5% sodium hypochlorite and 3 min of agitation in sterile distilled water. The surface sterilized segments were plated on PDA medium and the plates checked periodically for the growth of *Verticillium*.

Polymerase chain reaction

Genomic DNA from *Verticillium* and potato was extracted by the hexadecyltrimethylammonium bromide (CTAB) method. Filtered *Verticillium* hyphae from mycelial cultures or finely-cut plant pieces were ground to a coarse powder in the presence of liquid nitrogen; 1-3 g of ground tissue was suspended in extraction buffer (1.4M NaCl, 20 mm EDTA, 0.1M Tris-HCI, pH 8.0 containing 1% PVP-40 and 2 % CTAB). The suspension was extracted twice with chloroform/isoamyl alcohol and precipitated with 2 volumes of ethanol containing 2% potassium acetate.

PCR amplification was conducted in 50 µl of PCR buffer containing 0.2 mm bovine serum albumin (BSA), 0.2 mm of each deoxyribonucleotide triphosphate, 12.5 pmol of each oligonucleotide primer, 0.01-0.05 µg of DNA extract and 2g of Taq DNA polymerase (Promega, Madison, Wisconsin). The amplification was performed in a programmable heating block (Ericomp Co., San Diego, California) using 30 reaction cycles consisting of a 1m denaturation step at 94 °C, a 1minute annealing step at 60 °C and a 2 minute elongation step at 72 °C. The DNA products were precipitated with ethanol, resuspended in 25 % formamide dye and analysed on by polyacrylamide gel electrophoresis at 1000 V for 3-4 h. The gels were stained with ethidium bromide prior to photography at 300 nm on a transilluminator.

Verticillium extraction and quantitation from soil

A 10 ml beaker was used to take samples of soil from the each of the replicate samples in a particular crop field. These sub-samples were combined and mixed in a 50 ml conical tube. Approximately 3 gm of each combined sample was weighed out and DNA was extracted. Soil DNA was extracted using the Power Soil DNA Kit (MoBio Laboratories Inc., Carlsbad, CA). To enhance DNA recovery, an alternate lysis method involving incubation at high temp (65°C for 10 min) before beadbeating was performed. Isolated DNA was amplified by PCR using primers specific to the rRNA ITS region of *Verticillium* species (ITS-1F 5'tcaaacttggtcatttagaggaagtaaaagtcg3' and ST-Ve1 5'ccgttgttaaaagttttaatggttcgctaaga3'). PCR was performed for 30 cycles of 1 minute at 94°C, 1 minute at 60°C, and 1 minute at 72°C. Reaction products were run on a 1% agarose gel for 1 hour at 60V and visualized through Ethidium Bromide staining of the gel and transillumination at 300 nM. Verticillium semi-quantitation in soil samples was based on an arbitrary scale of 0-3, zero being equivalent to the negative PCR control and 3 being equivalent to the highly infected positive PCR control.

<u>Cloning and sequencing rDNA</u>

Genomic DNA was prepared from fungal and plant tissues by an adaptation of standardized procedures previously developed for *Verticillium* spp. To extract the nucleic acid, the sample was ground with liquid nitrogen before adding 2 mL of 0.15 M NaCl, 0.1M EDTA, pH 8.0. Proteinase K (Sigma Chemical Co., St. Louis, Missouri) was added (75 g/ml) and the tissues were lysed with sodium dodecylsulphate (1% final concentration) and gentle mixing at 37 °C for 3 h. The suspension was further heated at 60 °C for 30 min and extracted at room temperature with an equal volume of chloroform/isoamyl alcohol (24 :1). The nucleic acid was precipitated from the aqueous phase with ethanol, resuspended in 0.15 M NaCl, 0.1 M EDTA, pH 8.0, treated with RNAase A ribonuclease and re-extracted with chloroform/isoamyl alcohol. To construct genomic libraries, purified *Verticillium* DNA was digested with *Eco*RI endonuclease and cloned into the BlueScript II vector (Stratagene, California). The inserts from such recombinants were sequenced by the dideoxy method using T3 and T7 primers.

<u>Results and Discussion</u>

Analysis of the soil and stem samples with PCR specific for Verticillium spp. rDNA ITS have shown various levels of verticillium. *Verticillium dahliae* was the predominant species in the samples although other *Verticillium* species were detected including *Verticillium albo-atrum* and *Verticillium nigrescens.* Primers were designed for conserved sequences in the ribosomal DNA sequences to obtain the hypervariable sequences of the *Verticillium* species. Soil DNA extractions were successful using the MoBio Ultra Clean Soil DNA Isolation Kit (#12800-50). Maximum yield was obtained from 0.25 gm of soil. Soil samples spiked with verticillium species were positive with the polymerase chain reaction amplifications and greenhouse soil negative. The assay was semi-quantitative in determining the pathogen titres in soil and tissue samples (Figure 1 and Table 1).

We have also examined samples from another AAFC rotation with the developed amplification procedures and found that the levels of the verticillium wilt disease have dropped substantially in a 5-year sustainable rotation even though the pathogen levels remain virtually unchanged (Larney et al 2009). This indicates that other parameters influenced the incidence and severity of the verticillium wilt. Perhaps most interesting and surprising has been the increase in the diversity of the associated microbial populations in soil samples as detected by generic rDNA ITS amplification and sequencing. For example, the presence of a nematophagous fungus and potential biocontrol agent *Plectosphaerella cucumerina* was detected in the 5-year rotation. This likely reduces the nematode populations and severity of the early dying as the nematodes are known to play an important role in early dying disease. In addition, the increased presence of other microbes such as species of *Fusarium* in specific rotations with reduced early dying, indicates that the other microbial organisms may be out-competing the *Verticillium s*pecies and represent an important component in reducing disease levels. Diagnostics developed to assess the microbial population of soils prior to planting should assist in predicting disease levels. Furthermore, beneficial crop rotations and the promotion of beneficial soil microbes should reduce disease levels for verticillium wilt and other plant diseases.

Table 25: Molecular detection and quantification of Verticillium species in soil samples from fields in southern Alberta before and after incorporation of green manures. Data were generated from composite samples for each crop. Verticillium semi-quantitation in soil samples was based on an arbitrary scale of 0 to +++, with zero being equivalent to the negative PCR control and +++ being equivalent to the highly infected positive PCR control.

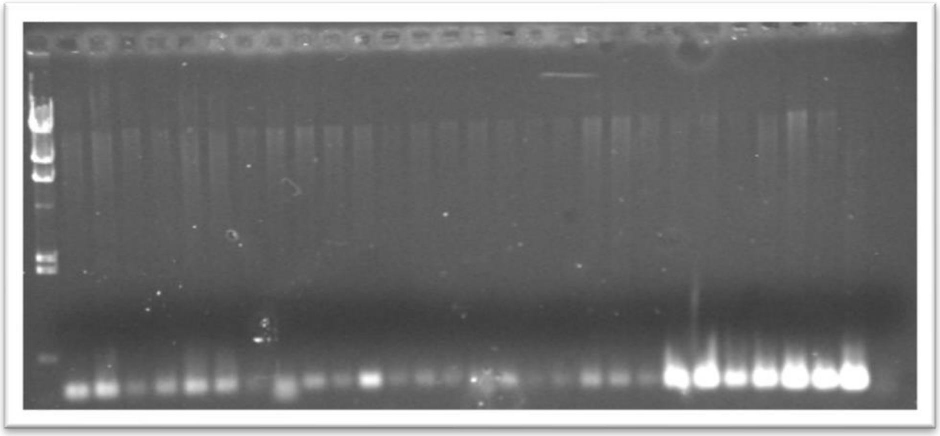
Field	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade
After green manure incorporation											
A											
B											
C	+	++	-	-	-	+	n/a				
D	+	-	-	-	-	-	-				
E[2]	+	++	+	+	+	+		+			
F[2]	+	++	+	+	++	++		++			
G	+	++	++	+	++	+					++
After potato crop year											
A	n/a	+	+	+++	+	+	+				
B	n/a	+++	+	+	-				++	-	
C	+++	+++	+++	+++	+++	+++	n/a				
D[1]	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
E[2]	+	+	+	+	-	-		-			
F[2]	+++	+++	+++	++	+++	+++		+++			
G	n/a	+	+	+	+	+					++

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the following year.

Table 26: Molecular detection and quantification of Verticillium species in potato samples collected from fields in southern Alberta the year following incorporation of green manures. Data were generated from composite samples for each crop. Verticillium semi-quantitation in stem samples was based on an arbitrary scale of - to +++, with zero being equivalent to the negative PCR control and +++ being equivalent to the highly infected positive PCR control.

Field	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade
After potato crop year											
A	n/a	-	-	-	++	-	-				
B	n/a	-	+	-	-				-	-	
C	n/a	+++	+++	+++	+++	+++	n/a				
D[1]	n/a	n/a	n/a	n/a	n/a	n/a	n/a				
E[2]	-	-	-	+	+	-		-			
F[2]	+++	++	+++	+++	+++	++		+++			
G	n/a	n/a	n/a	n/a	n/a	n/a					n/a

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the following year.



Lane 1: Lamda HindIII DNA ladder.
Lanes 2-8: Field G – OPV, CFPM, Sorghum Sudangrass, ryegrass, wheat, nightshade, no green manure.
Lanes 9-12: Field F – OPV, CFPM, Sorghum Sudangrass, ryegrass.
Lanes 13-19: Field E – OPV, CFPM, Sorghum Sudangrass, ryegrass, wheat, teff, non green manure.
Lanes 20-22: Field F – wheat, teff, no green manure
Lanes 23-28: Field C – OPV, CFPM, Sorghum Sudangrass, ryegrass, wheat, no green manure.
Lane 29: Positive control.
Lane 30: Negative control.

Figure 1. Agarose gel showing the amplified ribosomal DNA from soil and plant tissue samples.

```
1        10        20        30        40        50        60        70        80        90        100       110       120       130
                         CTCATAACCCTTTGTGAACCATATTGTTGCTTCGGCGGCTCGTTCTGCGAGCCCGCCGGTACATCAGTCTCTTTATTCATACCAACGATACTTCTGAGTGTTCTT
GCGGAGGGACATTACCGAGTATCTACTCATAACCCTTTGTGAACCATATTGTTGCTTCGGCGGCTCGTTCTGCGAGCCCGCCGGTCCATCAGTCTCTCTGTTTATACCAACGATACTTCTGAGTGTTCTT
.........................CTCATAACCCTTTGTGAACCATATTGTTGCTTCGGCGGCTCGTTCTGCGAGCCCGCCGGTaCATCAGTCTCTcTaTTcATACCAACGATACTTCTGAGTGTTCTT

131      140       150       160       170       180       190       200       210       220       230       240       250       260
AGCGAACTATTAAAACTTTTAACAACGGATCTCTTGGCTCTAGCATCGATGAAGAACGCAGCGAAACGCGATATGTAGTGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTGAACGCACATGGCGCC
AGCGAACTATTAAAACTTTTAACAACGGATCTCTTGGCTCTAGCATCGATGAAGAACGCAGCGAAACGCGATATGTAGTGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTGAACGCACATGGCGCC
AGCGAACTATTAAAACTTTTAACAACGGATCTCTTGGCTCTAGCATCGATGAAGAACGCAGCGAAACGCGATATGTAGTGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTGAACGCACATGGCGCC

261      270       280       290       300       310       320       330       340       350       360       370       380       390
TTCCAGTATCCTGGGAGGCATGCCTGTCCGAGCGTCGTTTCAACCCTCGAGCCCCAGTGGCCCGGTGTTGGGGATCTACGTCTGTAGGCCCTTAAAAGCAGTGGCGGACCCGCGTGGCCCTTCCTTGCGT
TTCCAGTATCCTGGGAGGCATGCCTGTCCGAGCGTCGTTTCAACCCTCGAGCCCCAGTGGCCCGGTGTTGGGGATCTACGTCTGTAGGCCCTTAAAAGCAGTGGCGGACCCGCGTGGCCCTTCATTGCGT
TTCCAGTATCCTGGGAGGCATGCCTGTCCGAGCGTCGTTTCAACCCTCGAGCCCCAGTGGCCCGGTGTTGGGGATCTACGTCTGTAGGCCCTTAAAAGCAGTGGCGGACCCGCGTGGCCCTTCaTTGCGT

391      400       410       420       430       440       450       460       470       480       490       500       510       520
AGTAATTACAGCTCGCATCGGAGTCCCGCAGGCACTTGCCTCTAAACCCCCTACAAGCCCGCCTCGTGCGGCAACGGTTGACCTCGG
AGTAGTTACAGCTCGCATCGGAGTCCCGCAGGCGCTTGCCTCTAAACCCCCTACAAGCCCGCCTCGTGCGGCAACGGTTGACCTCGGATCAGGTAGGAATACCCGCTGAACTTAAGCATATCAATAAGCG
AGTAaTTACAGCTCGCATCGGAGTCCCGCAGGCaCTTGCCTCTAAACCCCCTACAAGCCCGCCTCGTGCGGCAACGGTTGACCTCGG...........................................
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Figure 2. Sequences of the internal transcribed hypervariable sequence from the ribosomal RNA gene of *Verticillium albo-atrum* (top) and *Verticillium dahliae* (middle), and consensus (bottom).

Potato Crop - Alberta
Both fields where green manure plots were grown in 2006 were planted to processing potatoes in 2007 by commercial co-operators: Field A was planted to Shepody (early) potatoes; and Field B was planted to Russet Burbank (late) potatoes. Only one of the fields where green manure plots were grown in 2007 was planted to processing potatoes in 2008: Field C was planted to Russet Burbank potatoes; and Field D was planted to a different crop and no subsequent data was collected from the plots. All three fields where green manure plots were grown in 2008 were planted to potatoes in 2009: Fields E, F and G were planted to Russet Burbank potatoes. Potatoes grown in commercial fields were planted and managed throughout the growing season following each grower's usual practices. Plots were relocated within the potato crop with the help of metal detectors to find corner pins, GPS equipment and measurements from landmarks where possible. Samples were taken from the central area of each plot to ensure data was collected from the treatments area and not at the border of the treatment area.

Potato stem samples were collected from each site prior to harvest, brought back to CDCS, and evaluated for symptoms of vascular discoloration, which are typical of infection by vascular pathogens such as *Verticillium*. Tissue pieces from symptomatic stems were plated onto agar media to confirm the presence of fungal pathogens. Stem samples were also forwarded to AAFC, Lethbridge for molecular diagnosis of *Verticillium* infection.

In 2007, tubers from 6 m strips from the centre of each green-manured area were harvested August 9 from Field A and September 6 from Field B with a one-row Checci digger. Field weights were recorded, and tubers were graded into size categories.

In 2008, tubers from 6 m strips from the centre of each green-manured area were harvested September 8 from Field C with a one-row Checci digger. Field weights were recorded, and tubers were graded into size categories. No potatoes were planted in Field D, so no harvest data was available from this location in 2008.

In 2009, tubers from 6 m strips from the centre of each green-manured area were harvested September 9 from Field E and Field F with a one-row Checci digger. Field weights were recorded, and tubers were graded into size categories. Reglone (1.4 L/ac) was applied September 1 to Field G to facilitate mechanical harvest. Tubers from 6 m strips from the centre of each green-manured area were harvested September 15 from Field G with a one-row Checci digger. Tubers were evaluated at CDCS for yield, grade, specific gravity and internal defects.

Tubers were stored at 8˚C until graded. Tubers were graded into size categories (less than 4 oz., 4 – 6 oz., 6 – 10 oz., and over 10 oz. and deformed). A sample of twenty-five tubers (over 4 oz.) 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.

The data presented here have been statistically analyzed using ANOVA and Tukey's Multiple Comparison Test; (SPSS; $p \leq 0.05$). Statistical summaries are available upon request.

Results

Yield of potatoes was not significantly affected by the presence of a green manure crop in the year prior to potatoes in most site years of the study (Table 27). In Field C, the area of the field without a green manure crop resulted in greater marketable yield compared to areas of the field where green manure crops had been grown. This was likely a result of differences in fertility levels between these areas of the field. Green manure crops may have tied up N while the crops were mineralized, while N would have been more available early in the season for area of the field left fallow. Hail storms in August of 2009 affected the total and marketable yield in Fields E and F compared to yields from other site years. In Field F, total yield of potatoes following CPFM 101 was significantly greater than the total yield following Sorghum Sudan grass, however, no significant differences were observed in the marketable yield between plots.

Few significant differences were observed in specific gravity measurements from potatoes grown in green manured areas of the fields (Table 27). Where specific gravity figures were measured from potatoes grown in areas not planted to green manure, the specific gravities tended to be higher than those measured from potatoes grown in previously green-manured plots. In Field B, the Brassica green manure crops (Oriental mustard and oilseed radish) tended to reduce specific gravity relative to other green manure crops, however these crops were dropped from the study after the 2006 crop year in response to growers' concerns.

Table 27: Yield (ton/ac) and specific gravity of potatoes grown the year after green manure crops were incorporated into soil. Data followed by the same letter in each row were not statistically different ($p \geq 0.05$).

Field	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade
Total Yield											
A	n/a	17.43 a	17.40 a	16.91 a	16.72 a	17.35 a	18.36 a				
B	n/a	18.98 a	18.39 a	16.97 a	17.96 a				17.26 a	15.54 a	
C	19.11 a	15.76 a	17.14 a	16.46 a	15.82 a	17.03 a					
D[1]											
E[2]	9.34 a	8.32 a	8.32 a	8.95 b	8.04 a	7.93 a		8.33 a			
F[2]	7.05 ab	4.64 ab	9.56 a	3.43 b	5.63 ab	6.22 ab		4.81 ab			
G	n/a	33.87 a	35.14 a	35.74 a	35.30 a	36.77 a					34.19 a
Marketable Yield (> 4 oz)											
A	n/a	13.29 a	13.49 a	12.81 a	12.40 a	13.36 a	14.37 a				
B	n/a	11.80 a	11.55 a	10.86 a	11.12 a				10.79 a	9.08 a	
C	15.13 a	11.37 b	12.21 b	11.73 b	11.85 b	12.11 b					
D[1]											
E[2]	5.61 a	3.69 a	6.38 a	1.95 a	3.70 a	3.96 a		3.27 a			
F[2]	2.68 a	2.15 a	2.18 a	2.38 a	2.19 a	1.80 a		2.00 a			
G	n/a	26.91 a	27.28 a	27.26 a	28.58 a	28.47 a					26.89 a
Specific Gravity											
A	n/a	1.085 a	1.082 a	1.089 a	1.087 a	1.087 a	1.091 a				
B	n/a	1.091 a	1.091 a	1.089 ab	1.088 ab				1.086 a	1.082 a	
C	1.095 a	1.089 b	1.091 ab	1.087 b	1.092 ab	1.090 b					
D[1]											
E[2]	1.069 a	1.069 a	1.068 a	1.070 a	1.064 a	1.067 a		1.067 a			
F[2]	1.072 a	1.070 a	1.059 a	1.076 a	1.059 a	1.071 a		1.068 a			
G	n/a	1.085 a	1.085 a	1.086 a	1.084 a	1.085 a		1.085 a			

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storm in August affected yield and grade of potatoes.

Potato Disease Evaluation

Materials and Methods

Fields A and B – Potato crop year

In 2007 staff pulled five stem/roots from the outer areas on each side of a subplot for a total of 10 stems, except for Field B with only 6 stems gathered.. The tops were trimmed off with pruning shears so that each stem length was ca. 30 cm long (12"). These were then placed into labelled 15# poly bags, tied shut and placed into coolers with ice packs, prior to transporting them to CDCS. Upon arrival, they were then placed into a 5°C cooler, until disease ratings were performed. Then the stems for each subplot were washed under running tap water to remove the soil and debris, just prior to disease incidence ratings (DI %) for three pathogens. Disease severities were not rated. Each stem was scanned for rhizoctonia canker and Sclerotinia *spp*.; the presence of each disease was recorded. To perform vascular discoloration DI%, the stem top was cut to locate the vascular bundles and discoloration was noted as positive. For verification, each bundle was scraped longitudinally along the stem in three areas and any discoloration was also recorded as positive. DI% was calculated and the stems were rebagged. All stems from subplots were rated by this protocol and then stored in the 5°C cooler again, until 10 cm stem portions were prepared to send to Dr. Kawchuk, with moist chambers set up at CDCS later.

Moist chamber were prepared by using two 8# labeled plastic bags /subplot with moistened paper towels inside. Stems were trimmed to ca. 15 cm. (6") long and 5 were placed into each bag, which was then inflated, sealed and stored at RT for evaluations ca. 1 week later. Then the stems were examined under a dissecting microscope, for *Verticillium /Fusarium spp.* presence and finally, DI% was calculated for each.

Field C – Potato crop year

In 2008, approximately 2-weeks prior to the potato harvest date, the subplots were rated for early dying disease incidence in plants (DI %), early dying disease severity percentage (DS%) and finally, canopy disease severity (DS). The first rating was performed by rating 25 random potato plants /subplot as positive or negative for early dying/wilt symptoms and then calculating the DI%. Then concurrently on these same 25 plants, the number of stems on each was tabulated, with the diseased stem quantity also recorded. The percentage of infected stems was calculated and this was recorded as DS%. For the canopy DS ratings, each subplot was rated on a scale of 0-5 points where 0 = no early dying or wilt, 1 = <1% early dying or wilt, 2 = 1-10% early dying or wilt, 3 = 11-25% early dying or wilt, 4 = 26-50% early dying or wilt and finally,
5 = >50% early dying or wilt.

As before, 10 stems /subplot were then pulled, trimmed, bagged and transported to a CDCS cooler. Stem evaluations were performed the same as before, except instead of rating for sclerotinia, black dot (*Colletotrichum coccoides*) was rated instead, due to its prevalence on the stems. Also, following these ratings, 10 discs were cut /stem and placed into a labeled Petri dish moist chamber (empty dish lined with moistened filtered paper). These were sealed with Parafilm and left at RT under natural light, until rating them ca. 2-weeks later under a dissecting microscope, for *V. dahlia* presence, with DI% tabulated.

Fields E, F and G – Potato crop year

For 2009, there were no in-field examinations performed in Field F, due to extensive hail damage but Field E had all disease rating done, as per 2007, even though there was moderate hail damage there also. Field G had just canopy ratings performed (DS), as this field had been prematurely top-killed. As in 2008, 10 stems /subplot were gathered, trimmed and bagged, along with the same number from four replications in the farmer's potato field bordering Fields E and F only. Only the green manure plot stems were bagged in Field G though, because potatoes weren't planted in the surrounding field. The laboratory tasks for disease ratings were identical to 2008, with moist chambers for the stem discs set up too.

Results and Discussion

Data for all ratings were summarized and analyzed using the ARM 7 statistical software program (Gylling Data Management, Brookings, SD), with the DI and DS experimental means results presented as either raw or de-transformed data. Duncan's Multiple Range Test ($P \leq 0.05$) was used.

Table 28: Potato canopy and stem evaluations for Fields A-C and E-G
Table 29: Stem moist chamber evaluations for Fields A-C and E-G

With Fields A and B, during the potato crop year (2007), in-field ratings weren't being performed yet, so there isn't any data in the first three columns on Table 1. However, stems were still gathered and rated for both fields, with all data statistically insignificant. Field A was healthier overall than Field B, so stem vascular discoloration DI ratings were from 35% (millet) to 60% (vetch), with both *R. solani* and sclerotia having low ratings: *R. solani* ranged from 0% (millet) to 15% (wheat) and sclerotinia DI was from 7.5% (millet) to 17.5% (wheat, Sudangrass and ryegrass). However, the moist chamber readings (Table 27) showed that all of the crops had severe verticillium DI levels (≥ 88%), with moderate fusarium on the stem discs (65.6% on wheat - 85% on ryegrass). No single crop seemed to show less disease than the others.

Field B DI ratings demonstrated vascular discoloration DI levels from 79.2% (wheat) to 95.8% (radish).
R. solani DI was from 33.3% (millet) to 58.4% (Sudangrass), with sclerotinia from 25% (Sudangrass) to 41.7% (millet, vetch and mustard). The moist chambers showed wheat and Sudangrass with very high verticillium DI ratings (83.3% and 87.5%) but all stem discs from the other four crops grew this pathogen (100% DI). Fusarium developed on the discs at moderately low levels only, ranging from 4.2% (radish) up to 45.8% (Sudangrass).

All Field C ratings were statistically insignificant in 2008, which was the first year that in-field ratings were done. When it received canopy disease severity (DS) evaluations (0-5 point scale), results showed moderate disease /crop, that were from 1.60 (Sudangrass) up to 3.31 (millet). Low to moderate plant early dying /wilt DI ratings ranged from 10.6% (wheat) to 53.5% (millet) and similar levels were found on the individual plant stems during the field ratings (DS% levels were from 15.7%: wheat to 42.0%: millet). Interestingly, millet had the highest rating for both parameters, coinciding with the canopy DS evaluations. When 10 stems /subplot were evaluated in the laboratory, all were diseased with rhizoctonia and black dot, but vascular discoloration showed up in them as 71.4% (Sudangrass) up to 86.4% (wheat). The moist chambers only had verticillium DI ratings performed on them, ranging from ca. 30 – 40.8% for all of the crops. Again, as all Field C data were insignificant, no crop stood out as more beneficial than the others.

By 2009, black dots (*C. coccoides*) was very apparent as a potential cause of early dying and wilt damage in potato crops, so this was included in all stem ratings for Fields E-G. With Field E, all field data were statistically insignificant and were moderately high, likely due to the hailstorm, with the canopy DS ratings from 2.25 (millet) to 3.75 (Sudangrass and teff), plant early dying DI levels from 63% (oat-pear-vetch) to 80% (ryegrass) and the stem early dying DS (%) ranged from 40.4% (oat-pea-vetch) up to 59.4% (ryegrass). When stems lab evaluations were performed, all of the vascular discoloration DI ratings were ≥ 94.9%. Stems actually had significantly less rhizoctonia ($P \leq 0.05$) in the "no green manure" area (DI of 0%) in comparison to the other treatments, ranging from 21.4% (Sudangrass) up to 55.9% (millet). However, black dot was present at insignificant, very low levels on the stems (≤10.2 DI). Moist chamber readings were also not significant, showing stem verticillium DI from 3.6 % (wheat) to 20.8% (ryegrass) with moderate black dot, from 11% (no green manure) up to 38% (ryegrass). No trends were observed.

Field F had extensive hail storm damage, so field readings weren't performed and when the stems were evaluated in the laboratory, most ratings were very high but all were statistically insignificant. For example, the stem vascular discoloration DI values were ≥ 82.5% and black dot levels were ≥ 92.5%. However, rhizoctonia was present on the stems, ranging from 57.5% up to 92.5% DI, so wasn't as prevalent. When the moist chambers were read though, low to moderate verticillium counts were present, ranging from ca. 15% (no green manure and Sudangrass) up to 48.8% (teff), but actually, the black dot levels on the stem discs were slightly less (ca. 65% to 78% DI) than on the outside of the stems, as noted on the previous evaluation.

With Field G, all data were insignificant and only the field canopy ratings were taken, with millet at only 0.5 DS up to 1.5 DS for wheat and these values were the lowest for all of the potato fields in this experiment. This field also had nightshade rather than teff, as one of the green manure crops and also, there was not a "no green manure" potato field surrounding it as a comparison. After the stems were collected though, moderate to high DI levels were observed for vascular discoloration (52.5% to 75%), ratings for rhizoctonia were mid-range (35% to 57.5%) and finally, there were overall high levels of black dot on them (≥77.5%). For the moist chamber examinations, verticillium DI levels were extremely low, with only ryegrass and nightshade growing this fungi (0.9% /0.2%), but again, black dot was severe, with DI% levels of ≥ 88.5%.

In conclusion, although all field data were mostly insignificant, black dot was the most prevalent pathogen in Fields C, E, F and G during the potato crop year (2008 and 2009). However in 2007 for Fields A and B, verticillium was very extensive on the stems but then again, black dot wasn't specifically noted or rated that year. During the last two years for the other fields, verticillium levels were only low to moderate. *R. solani* (rhizoctonia disease) likely was a part of this disease complex, with a wide range of DI results for all fields, and at times, it was nearly as severe a pathogen as black dot. No single green manure crop stood out as potentially beneficial for reducing potato early dying complex.

Table 28: Potato canopy and stem evaluations for Fields A-C and E-G during the Potato Crop Year

Field	Crop	Field ratings[1]			Stem ratings performed in the laboratory[1]			
		Canopy DS (0-5)[3]	Plant early dying DI (%)[4]	Stem early dying DS (%)[5]	Vascular discoloration DI (%)[6]	*R. solani* DI (%)[6]	Sclerotinia DI (%)[6]	Black dot DI (%)[6]
A	Wheat	---	---	---	47.5 a[7]	15.0 a[7]	17.5 a[7]	---
	Sudan Grass	---	---	---	47.5 a	7.5 a	17.5 a	---
	Millet	---	---	---	35.0 a	0.0 a	7.5 a	---
	Vetch	---	---	---	60.0 a	7.5 a	10.0 a	---
	Phacelia	---	---	---	40.0 a	2.5 a	12.5 a	---
	Ryegrass	---	---	---	45.0 a	2.5 a	17.5 a	---
B	Wheat	---	---	---	79.2 a[7]	37.5 a[7]	33.4 a[7]	---
	Sudan Grass	---	---	---	83.3 a	58.4 a	20.8 a	---
	Millet	---	---	---	87.5 a	33.3 a	41.7 a	---
	Vetch	---	---	---	87.5 a	41.7 a	41.7 a	---
	Mustard	---	---	---	91.7 a	37.5 a	41.7 a	---
	Radish	---	---	---	95.8 a	58.3 a	25.0 a	---
C	Wheat	2.31 a[8]	10.6 a[8]	15.7 a[8]	86.4 a[8]	100.0	---	100
	Sudan Grass	1.60 a	17.8 a	23.3 a	71.4 a	100.0	---	100
	Millet	3.31 a	53.5 a	42.0 a	76.4 a	100.0	---	100
	Oat-Pea-Vetch	2.60 a	30.5 a	34.3 a	75.8 a	100.0	---	100
	Ryegrass	2.64 a	29.7 a	30.2 a	81.2 a	100.0	---	100
E[2]	Wheat	3.50 a[7]	65.0 a[7]	44.1 a[7]	97.2 a[8]	26.3 a[8]	---	10.0 a[8]
	Sudan Grass	3.75 a	75.0 a	57.0 a	100.0 a	21.4 a	---	6.0 a
	Millet	2.25 a	77.0 a	51.2 a	100.0 a	55.9 a	---	1.3 a
	Oat-Pea-Vetch	2.50 a	63.0 a	40.4 a	97.5 a	35.6 a	---	0.0 a
	Ryegrass	3.50 a	80.0 a	59.4 a	94.9 a	32.1 a	---	0.0 a
	Teff	3.75 a	79.0 a	58.0 a	100.0 a	24.5 a	---	6.3 a
	No green manure	3.00 a	69.0 a	48.2 a	100.0 a	0.0 b	---	10.2 a
F[2]	Wheat	---	---	---	95.0 a[7]	67.5 a[7]	---	92.5 a[8]
	Sudan Grass	---	---	---	97.5 a	57.5 a	---	99.4 a
	Millet	---	---	---	82.5 a	70.0 a	---	99.4 a
	Oat-Pea-Vetch	---	---	---	85.0 a	82.5 a	---	99.4 a
	Ryegrass	---	---	---	87.5 a	85.0 a	---	99.4 a
	Teff	---	---	---	92.5 a	70.0 a	---	92.5 a
	No green manure	---	---	---	97.5 a	92.5 a		100.0 a
G[9]	Wheat	1.50 a[7]	---	---	55.0 a[7]	37.5 a[7]	---	85.0 a

	Sudan Grass	1.00 a	---	---	70.0 a	35.0 a	---	77.5 a
	Millet	0.50 a	---	---	75.0 a	42.5 a	---	85.0 a
	Oat-Pea-Vetch	0.75 a	---	---	75.0 a	37.5 a	---	95.0 a
	Ryegrass	0.75 a	---	---	57.5 a	40.0 a	---	87.5 a
	Nightshade	0.75 a	---	---	52.5 a	57.5 a	---	85.0 a

[1]Results are the means of four replications. Data followed by the same letter in each row were not statistically different ($p \geq 0.05$).
2Summer hail storms (2008 & 2009) affected green manure crops/potato crop the next year; field rating may not have been done.
[3]Plant canopy early dying disease severity (DS) means are on a 0-5 point scale, where 0 = no early dying or wilt, 1 = <1% early dying or wilt, 2 = 1-10% early dying or wilt, 3 = 10-25% early dying or wilt, 4 = 10-25% early dying or wilt, 5 = >50 % early dying or wilt.
[4]Disease incidence means (DI) are the percentage of plants with early dying and/or wilt symptoms.
[5]Stem disease severity means (DS) are the percentage of stems with early dying and/or wilt symptoms
[6]Disease incidence means (DI) are the percentage of stems with vascular discoloration, *R solani*, sclerotinia or black dot.
[7]Raw data were used for analysis.
[8]Either square root or arcsine-transformed data were used for analysis with detransformed means presented.
[9]Field plant and stems ratings were not performed, as this field was top-killed, prior to this task's scheduled date.

Table 29. Potato stem disc moist chamber evaluations for Fields A-C and E-G during the Potato Crop Year[1].

Field	Crop	Stem ratings performed in the laboratory		
		Verticillium DI (%)[3]	Fusarium DI (%)[3]	Black dot DI (%)[3]
A	**Wheat**	94.4 a[5]	65.6 a[4]	---
	Sudan Grass	93.3 a	80.0 a	---
	Millet	97.3 a	67.5 a	---
	Vetch	88.1 a	77.5 a	---
	Phacelia	99.2 a	72.5 a	---
	Ryegrass	92.6 a	85.0 a	---
B	**Wheat**	83.3 a[4]	20.8 a[4]	---
	Sudan Grass	87.5 a	45.8 a	---
	Millet	100.0 a	29.2 a	---
	Vetch	100.0 a	12.5 a	---
	Mustard	100.0 a	20.8 a	---
	Radish	100.0 a	4.2 a	---
C	**Wheat**	30.0 a[5]	---	---
	Sudan Grass	40.8 a	---	---
	Millet	35.2 a	---	---
	Oat-Pea-Vetch	39.3 a	---	---
	Ryegrass	29.3 a	---	---
E[2]	**Wheat**	3.6 a[4]	---	25.1 a[4]
	Sudan Grass	16.0 a	---	33.3 a
	Millet	18.3 a	---	28.5 a
	Oat-Pea-Vetch	10.5 a	---	19.3 a
	Ryegrass	20.8 a	---	38.0 a
	Teff	6.5 a	---	15.5 a
	No green manure	6.3 a	---	11.0 a
F[2]	**Wheat**	30.5 a[4]	---	71.6 a[4]
	Sudan Grass	15.5 a	---	70.0 a
	Millet	40.5 a	---	65.8 a
	Oat-Pea-Vetch	33.3 a	---	74.5 a
	Ryegrass	42.3 a	---	77.0 a
	Teff	48.8 a	---	73.5 a
	No green manure	15.3 a	---	77.5 a
G	**Wheat**	0.0 a[5]	---	95.8 a[4]

	Sudan Grass	0.0 a	---	96.0 a
	Millet	0.0 a	---	88.5 a
	Oat-Pea-Vetch	0.0 a	---	92.0 a
	Ryegrass	0.9 a	---	96.0 a
	Nightshade	0.2 a	---	93.3 a

[1]Results are the means of four replications. Data followed by the same letter in each row were not statistically different ($p \geq 0.05$).
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the next year.
[3]Disease incidence means (DI) are the percentage of stem discs placed into moist chambers with verticillium, fusarium or black dot growing on them. For the various fields, all of these pathogens might not necessarily have been rated, depending upon the year.
[4]Raw data were used for analysis.
[5]Either square root or arcsine-transformed data were used for analysis with detransformed means presented.
[6]Field plant and stems ratings were not performed, as this field was top-killed, prior to this task’s scheduled date.

Nematode Analyses – 2007

Dr. Guy Belair analyzed soil samples collected before green manure crops were planted and after incorporation of the green manure crops in 2007. Root lesion nematode (*Pratylenchus neglectus*) populations decreased in three of the crops incorporated at one site, but no significant differences were observed at the second location. *Pratylenchus neglectus* were populations ranged from 27 to over 6500 nematodes per kg of soil. Soil samples from potatoes planted on the 2006 green manured areas were also assessed. Only samples from the oilseed radish plots showed significantly fewer nematodes than areas following other green manure crops (Table 30). To date, no funding has been secured for nematode analyses.

Table 30: Population of root lesion nematodes (*Pratylenchus neglectus*) per kg soil in 2007, 2008 and 2009. Data followed by the same letter in each row were not statistically different ($p \geq 0.05$).

Field	No Green Manure	Wheat	CFPM 101	Sorghum Sudangrass	Vetch/ OPV	Ryegrass	Phacelia	Teff	Oriental Mustard	Oilseed Radish	Nightshade
Green manure crop year											
A											
B											
C	3503 a	3851 a	5466 a	2115 a	6249 a	3267 a					
D	6538 a	760 b	5394 ab	400 b	27 c	1155 ab	1524 ab				
E[2,3]		2000 b	2752 b	2864 b	3472 b	5760 a		1408 b			
F[2,3]		944 a	1680 a	1104 a	2448 a	1568 a		480 a			
G[3]		0 a	32 a	0 a	16 a	32 a					48 a
Potato crop year											
A	n/a	4540 a	2378 a	1846 a	1613 a	3674 a	3248 a				
B	n/a	1679 ab	485 ab	2465 a	3029 a				1639 ab	177 b	
C[3]		2064 a	1825 a	2272 a	736 a	2144 a					
D[1]											
E[2,3]		320 a	160 a	448 a	336 a	416 a		432 a			
F[2,3]		256 b	160 b	960 a	96 b	208 b		176 b			
G[3]		240 a	16 a	288 a	32 a	64 a					64 a

[1]Field not planted to potatoes following green manure crop year.
[2]Hail storms in summer (2008 and 2009) affected green manure crops and potato crop in the following year.
[3]In 2008 and 2009, data was converted from number of nematodes per 50 cm^3 sample to number per kg using a bulk density of 1.25 Mg/m^3.

Nematode Analyses – 2008 - 2009

Materials and Methods:

Soil samples collected before green manure crops were planted and after incorporation of the green manure crops were evaluated for root lesion nematode populations in 2008 and 2009. Soil samples were passed through a 5 mm sieve and then 50 cm^3 subsamples were placed on Baermann pans (16 cm diameter) and incubated for 7 days for nematode extraction as described by Forge and Kimpinski (2007). After extraction, the samples were poured into gridded counting dishes, observed with an inverted microscope, and all plant-parasitic nematodes in each sample were counted. Nematodes in the genus *Pratylenchus* (root-lesion nematodes) were the only potentially damaging nematodes detected, so analyses focused on the abundance of *Pratylenchus* sp. nematodes.

Nematode count data were subjected to blocked one-way analysis of variance, with separate analyses for each site in each year. When the effect of cover crop was significant in the overall ANOVA, Fisher's protected least significant difference (LSD) was used to separate means.

Results and Discussion:

Pratylenchus population densities in samples from Fields E and F were overall considerably greater in 2008 than in 2009 (Table 30). In 2008, populations were significantly greater in the Italian ryegrass plots than under other cover crops in Field E. At both sites, the lowest population densities were under Teff, but the differences between Teff and other cover crops were not statistically significant. The observation from 2008, that teff does not support population build-up of *P. neglectus*, is promising and warrants additional research.

In 2009, population densities tended to be greatest in sudangrass plots in Fields E and F. The overall ANOVA was significant ($P = 0.02$) for Field E, and the sudangrass plots had significantly greater population densities than all other cover crops. Nematode population densities in Field G were very low in both years, and did not respond to cover crop treatments.

Based on the absence of males in the populations observed, it appears likely that the *Pratylenchus* populations at these sites were *P. neglectus*, however, a thorough species identification of the populations has not yet been conducted. *P. neglectus* can reduce growth of potato in a density dependent manner (Olthoff 1990; Umesh and Ferris 1994; Hafez et al. 1999), but there are reports of differences in pathogenicity among geographically distinct populations of *P. neglectus*. (Hafez et al. 1999).

Previous research has demonstrated that forage pearl millet can suppress population buildup of *Pratylenchus penetrans* (Belair et al. 2005). Most prior research on the relationships of root-lesion nematodes with *Verticillium* and potato early dying has been conducted with *P. penetrans* (Rowe and Powelson 2002, Rotenberg et al. 2004). *Pratylenchus neglectus* interaction with *V. dahliae* has not been studied extensively (Rowe and Powelson 2002). Research on the pathogenicity of Alberta *P. neglectus* to potato, with and without *Verticillium*, would improve understanding of the role that these nematodes may be having in Alberta potato fields. Similarly, prior research demonstrating the nematode-suppressive effects of Canadian Forage Pearl Millet (e.g. Belair et al. 2005) was conducted on *P. penetrans*. We did not observe any effects of forage pearl millet on *P. neglectus* in this study. The response of *P. neglectus* to forage pearl millet needs to be studied under more controlled conditions. *P. neglectus* has a wide host range including many small-grain crops, particularly wheat, which limits the range of crops that can be incorporated into rotations. Wheat is known to be an excellent host for *P. neglectus*, fostering buildup of *P. neglectus* population densities, and the development of high *P. neglectus* population densities under wheat preceding potato has been observed in a rotation study at Vauxhall (Forge et al. 2009). It is therefore surprising that there were no apparent effects of wheat on *P. neglectus* population densities in this study. One possible reason for the discrepancy could be the length of time between the cover crops and when soil samples were taken for analyses. Additional research, confirming the host status or suppressive effects of teff, could lead to a useful new tool for managing *P. neglectus* populations.

Saskatchewan Trial

Green Manure Crop Establishment

Materials and Methods (2006):

The trial site featured a Sutherland Series sandy loam soil (pH 8.1, E.C. <1.0 ds, with 3.8% O.M.) and has been in a three-year potato rotation for over 30 years. Animal manure is usually applied prior to growing cereals in the rotation, and potatoes were planted in the trial area in 2005. A cereal crop was initially planted in this area in 2006, but was ploughed up at the seedling stage, a month prior to planting the green manure. A randomized block design was used with four replicates of the six treatments that were planted in 8 x 8 m^2 plots, with 2 m pathways between each plot. Prior to seeding, soil was sampled from the trial area to a depth of 12 inches. Four samples were taken at random from each of the four quadrants of the plot (total of 16 samples) and the four quadrant samples were combined to give four composite sample. These samples were stored in a cold room and will be evaluated when funds are available.

The summer seeding date was used to determine if growers could grow a green manure crop following harvest of a winter cereal crop. This field used for this project (scab field) has been used for studying potato production for over 30 years. High levels of disease inoculum for a range of potato diseases are present in the soil. Black scurf (*Rhizoctonia solani*), common scab (*Streptomyces scabies*) and powdery scab (*Spongospora subterranea*) infections are common on tubers grown in this field.

Six green manure crops (Table 31) were seeded on July 11th 2006, in one of the potato field plots managed by the University of Saskatchewan. Heavy seeding rates were used to ensure a dense stand. Granular Furadan was applied to the radish and mustard plots immediately after seeding, to control flea beetles. A light rain (0.3”) occurred prior to planting and the soil was moist but workable. The plots were harrowed once each way immediately after seeding to lightly bury the seed of the green manure crops. The seed bed was moist, and irrigation was applied as necessary to maintain conditions conducive to plant establishment.

Table 31: Green manure crops planted in Saskatchewan plots in 2006.

Crop	***Species & Cultivar***	***Rate***
Oriental Mustard	Cutlass	20 lbs/ac
Oilseed Radish		20 lbs/ac
Sorghum Sudan Grass	Grazex	40 lbs/ac
Woolly Pod Vetch		20 lbs/ac
Canadian Forage Pearl Millet	CFPM Hybrid 101	20 lbs/ac
Hard Red Spring Wheat		240 lbs/ac

2007

Another set of green manure plots was planted July 11th, 2007 in the previously described Scab field. As the woolly vetch treatment had failed to establish in the 2006/2007 trial it was replaced with a green pea/oat/woolly vetch mixture. The 2007 green manure trial area was again heavily infested with pigweed, which had emerged prior to planting the green manure plots on July 11th. In an attempt to control this pigweed population the plot area was cultivated prior to seeding and harrowed again after the seed was broadcast. Despite this effort at weed control an extremely heavy pigweed infestation was present by the end of July. Buctril M (bromoxynil) was applied to the non-brassica plots in an effort to control this red root pigweed but the level of weed control achieved was not sufficient to allow for adequate establishment of the green manure crops. Consequently, all the green manure plots were ploughed down. Better weed control strategies need to be in place before planting green manure crops in weedy locations.

2008

Green manure plots were established successfully in 2008 at two locations on the University of Saskatchewan field sites to compensate for the lost crops in 2007. The green manure plots were established at two sites on the University of Saskatchewan farm, one in the Main potato field and the other in the previously described Scab field. The Main field and the Scab fields are generally similar in soil type and chemistry. However the Main field has only a limited history of potato production. Levels of soil-borne disease such as *Rhizoctonia* and scab are consequently much lower at this site than in the Scab field.

In 2008, all six green manure treatments were seeded in the Main field, in 6 m^2 plots, using a five row drill seeder at 8 inch row spacing on July 17^{th}. This promoted more uniform crop establishment and allowed for hoeing of weeds if necessary. The 5 treatments plots were seeded to pearl millet, sorghum sudan grass, or a mixture of oat/pea/vetch; allowed to develop a natural population of pigweed; or treated with a mustard meal application, watered and covered for 24 hours. The plots were 18 x 18 ft. Emergence was noted on 23^{rd} July. Weeds developed quickly and on August 5^{th} Buctril M (0.4L/acre) was applied to the millet, sorghum Sudan grass, and bare plot to be used for mustard meal application. The mixture seeded plot was hoed to remove weeds. A randomised block design replicated 4 times was used.

Mustard meal was applied to the bare plots on 15^{th} August at 2lbs meal/100 sq. ft, with a hand-held fertilizer applicator. The plots were watered with ¼' overhead irrigation before covering with clear plastic for 48hr.
The fresh weight of material and the amount of dry matter was estimated for the plots in mid September, and the plots were then flail mowed and immediately cultivated, to incorporate the green material.

The second site used was the Main potato field where there is natural inoculum of Rhizoctonia but low levels of scab inoculum. The same protocols were followed for the trial at the Main site, but the treatments were seeded as follows: 1) spring wheat/pearl millet mixture; 2) sorghum sudan grass; 3) a mixture of oat/pea/vetch; 4) oilseed radish; 5) oriental mustard; or 6) allowed to develop a natural population of pigweed. No mustard meal was applied. Buctril M and hoeing were used for weed control in plots other than treatment 6.

The green manure crops used in 2008 were oat/pea/vetch mixture, oriental mustard (cultivar Cutlass), pearl millet/ spring wheat mixture, sorghum Sudan grass, oilseed radish and an unseeded check plot. In the Scab field, the three green manure treatments tested were millet, sorghum and pea/oat/vetch mixture. No oilseed crops were sown at this site because the weed population in this field was very high, and using only monocot crops allowed the plots to be sprayed with the herbicide Buctril M. A fourth treatment used in the Scab field was an unseeded plot which was not sprayed with herbicide, and which was allowed to develop into a pigweed plot. A fifth treatment in the Scab field involved applying mustard meal to the surface of the plot. Mustard meal is being promoted as a potential herbicide but the thiocyanates present in the meal may also control certain soil-borne diseases. The mustard meal was obtained from Peacock Industries (1 Rheinland Road, Hague, Sk. S0K 1X0).

The green manure plots were seeded in mid-July 2008. Over 0.5 inch of rain fell several days after seeding – this assisted in the establishment of the plots. Seedling emergence was noted five days after seeding.

By the end of July all the green manure crops had emerged. Weed development, mainly red root pigweed, was observed in the unseeded plots, particularly in the Scab field. In early August, the millet and sudan grass plots in both fields and the unseeded plots in the Main field were sprayed with Buctril M applied at 0.4L/acre. No herbicide was applied to the unseeded plot in the Scab field, and it consequently developed a significant population of red root pigweed. Herbicide was applied to the mustard meal plot, eight days prior to the meal application. On August 15th mustard meal was applied to the surface of the unseeded plot in the Scab field at the supplier recommended rate of 2 lb/100 ft^2 (Peacock Industries, 2008 pers. comm.). The plots treated with the mustard meal were overhead irrigated with approximately ¼ inch of water and then covered with sheets of clear plastic for 48 hours. Watering "activates" the mustard meal causing it to release volatile organic compounds such as isothiocyanates which have disease control properties. Covering the treated area with a clear tarp seals in these volatiles, thereby increasing their efficacy. This treatment significantly reduced weed growth in these plots – whether this reflected toxic effects of the mustard meal or overheating due to the presence of the clear plastic cover could not be determined.

The green manure crops were incorporated into the soil in the third week in September, before any of the crops had developed mature seed, and the maximum amount of green material had been produced. Recommended timing for incorporation of Brassica green manure crops is at bolting, when flowers are beginning to form, but no seed has been produced yet. The plant material was shredded with a flail mower and then a rotovator was used to incorporate the green manure into the soil to a depth of 15 cm. In the Main field the wheat plants had begun to fill heads and the vetch was still flowering at the time of plough down. The weedy plots had well developed pigweed plants present at plough down and weeds were also present in the brassica plots. Millet and sudan grass plants had developed leaf spot disease, but this did not appreciably reduce green matter production. In the Scab field the pigweed populations were high in the non-planted "weed" plots, while in the plots treated with mustard meal only a very few, small weed plants were present. The plant material present in two 0.5 m^2 areas per plot, chosen at random, was removed and weighed in both fields, to estimate the amount of green material produced and incorporated.

Green Manure Biomass

2006

By July 20th 2006, the two *Brassica* species had emerged, the wheat seedlings were well established, the millet and sorghum were just emerging, and there was no sign of the vetch. Red root pigweed (*Amaranthus retroflexus*) became a serious weed competitor in all plots by August 4th . A tank mix of the herbicides dicamba (Banvel; 0.125 lb ai/acre) + 2,4-D amine (0.36lb ai/acre) was applied to the cereal plots on August 10th in an effort to control the red root pigweed problem. The herbicide treated pigweed started to wilt by August 15th. At the time of the herbicide treatment there was very little woolly vetch established - these plots were not treated with the herbicide, and were subsequently used as a "pigweed" check. No herbicides were available for pigweed control in the *Brassica* species, and consequently some pigweed was present in these plots. The oriental mustard was flowering by August 8th. The *Brassica* species flowered and formed pods before incorporation of the plots on September 6th. On September 6th a rototiller was used to incorporate the green manure material into the soil to a depth of 15 cm.

Scab Field 2008

The oat/pea/vetch mixture produced the most green matter at plough down in the Scab field, while the mustard meal treatments produced the least organic matter (Table 32). The presence of significant weed populations in the non-manured control treatment did result in the addition of substantial organic matter in those plots.

Table 32. Weight of plant material present in 1m^2 of green manure plots prior to incorporation in the Scab field in 2008.

Green Manure treatment in 2008	Wt. of green plant material /m^2 (kg)
Oat/pea/vetch mixture	4.0 a*
Sorghum Sudan Grass	3.1 b
CFPM 101	2.8 b
No green manure, weedy control	1.6 c
Mustard meal incorporation	0.7 d

*Means followed by the same letter are not significantly different at $p<.1$, using the Student's t-test.

The soil organic matter content of the scab field in mid-June of 2009 ranged from 3.4% in the no green manure weedy control plots to a high of 4.7% in the plots that had been green manured to pea/oat/vetch in the previous season. The relative amounts of organic matter detected in the plots in 2009 roughly corresponds to the relative amount of biomass produced by the green manure crops during the previous year (no manure lowest, oat/pea/vetch mixture highest).

Main Field 2008

The oriental mustard and pea/oat vetch green manures produced the most green manure biomass at plough down in 2008, while the oilseed radish produced the least biomass (Table 33). As a result of weed growth the control plots received a substantial amount of green biomass.

Table 33. Weight of plant material present in 1m^2 of green manure plots prior to incorporation in the Main field in 2008.

Green Manure treatment in 2008	Wt. of green plant material /m^2 (kg)
Oriental mustard	3.9 a*
Pea/oat/vetch mixture	3.7 ab
No manure, weedy control	2.8 bc
Millet	2.3 c
Sorghum	2.1 c
Oilseed radish	1.2 d

*Means followed by the same letter are not significantly different at $p<.1$, using the Student's t test.

The soil organic matter content of the Main field in mid-June of 2009 ranged from a low of 1.9% in the no manure weed control plots to a high of 2.2% in the plots previously green manured with oilseed radish and millet plots. There was no apparent correlation between the amount of biomass produced by the green manure crop and the soil organic matter content recorded in the Main field plots during the subsequent cropping season.

Potato Crop - Saskatchewan
In spring of 2007, potatoes were seeded into the green manure plots in the third week of May. Prior to seeding, additional nitrogen was applied to the trial site at 25 lbs/acre Two 6m rows of Russet Burbank (E2) and Alpha (E4) potatoes were seeded at 24 pieces per row, with a guard row between the two cultivars and on either side of each plot. The short rows (6m) helped ensure that the potatoes were only planted in a green manure area (the original green manure plots being 8m x 8m). These two cultivars were chosen because Alpha is a white-skinned potato which makes it easy to detect surface diseases such as black scurf and scab and Russet Burbank is a netted potato commonly grown by the industry.
The potato plots were managed using standard procedures for irrigation and hilling. The plots were top-killed at the beginning of September and harvested three weeks later. The harvested tubers were graded into size categories (**small** < 44 mm, **medium** 44-88 mm, **large** > 88 mm) and weights were determined in each size category. The weight of medium sized tubers was recorded as the marketable yield. The tubers were stored at 6°C until disease assessments were made on a sample of 30 washed tubers. The incidence (percentage) of tubers infected with black scurf, common and powdery scab was recorded for both cultivars. The severity of the infections (% of tubers with more than 5% of surface area infected) was also assessed. This severity threshold was based on CFIA tuber quality standards that allow 10% of tubers with light scab or *Rhizoctonia* infection to be present in a graded sample, or 5% of tubers with moderate infection.

In 2009, the green manure plots from 2008 were seeded with two potato cultivars, Alpha (E3) and Norland (E2). Norland is a popular red, table potato that is susceptible to both common and powdery scab as well black scurf. A sample of the seed potatoes planted in 2008 was evaluated for disease prior to planting. The Alpha seed had very low levels of *Rhizoctonia* (13% incidence), low levels of black dot (*Colletotrichum coccodes*) and a high incidence (69%), with low severity (2.1% of tuber surface covered with disease) of silver scurf (*Helminthosporium solani*). The Norland seed had higher levels of *Rhizoctonia* (100% incidence, 4.4% average surface area infected), slight dry rot, and very low and no levels of black dot and silver scurf respectively. The two cultivars were seeded into the green manure plots, with three 6m rows of Alpha and three rows of Norland in each plot. This resulted in 6m by 6m potato plots within the original green manure plots. Approximately 1m wide pathways separated each plot. The potatoes were planted on 12th May and were hilled approximately one month later. The 2009 potato plots were managed using standard potato growing practices for weed control and irrigation.

The soil organic matter content of the main and scab fields was tested in early June of 2009 to determine the impact of the green manure treatments on soil organic matter content during the subsequent cropping season.

Results:
The 2007 potato crop appeared healthy with no obvious problems with disease or insects. There were no visually apparent effects of the green manure treatments on the potato crop.

The green manure treatments had no significant impact on any aspect of the yields of either cultivar in 2007 (data not shown). Yields in this trial were comparable to other trials conducted by the U of S in adjacent plot areas in 2007.

In 2009, the total and marketable yield of Alpha tubers in the Scab field was highest in the plots that did not receive manure (weedy control), and was lowest in the plots where the mustard meal was applied the previous season. As root damage ratings due to *Rhizoctonia* were highest in the mustard meal plots, a depression in yield in this treatment would be expected – as damaged root systems are less capable of absorbing nutrients and water. However the Sorghum green manure plots also showed a low yield, despite having low *Rhizoctonia* root damage ratings. The Sorghum plots had the second highest levels of plant material incorporation in the Scab field so it is possible that Sorghum as a green manure had a depressant effect on potato yield in this field.

Table 34. Effect of green manure treatments on yield of Alpha tubers in the Scab field in 2009.

Green Manure Treatment	Yield (kg/6m row)	
	Total yield	Marketable yield
No manure, weedy control	22.8 a *	17.2 a
Millet	21.2 ab	15.9 ab
Pea/oat/vetch mixture	20.9 abc	14.8 abc
Sorghum	17.6 bc	12.5 bc
Mustard meal incorporation	17.4 c	11.6 c

*Means followed by the same letter are not significantly different at $p<.1$, using the Student's t test.

The green manure treatments had no significant effects on yields of either Alpha or Norland in the Main field in 2009 (data not shown).

Rhizoctonia and Scab

There were significantly lower levels of *Rhizoctonia* on the Russet Burbank tubers grown in plots following the mustard, pigweed and wheat green manure treatments in comparison with the sorghum green manure (Table 35). The overall levels of Rhizoctonia on the Russet Burbank crop were high, with all plots having at least 50% of the tubers with some black scurf infection. The levels of common scab in the Russet Burbank plots were much lower; very little scab developed in the pigweed plots, and the highest scab levels were seen in the plots previously sown to millet.

Table 35. Incidence of black scurf and common scab on Russet Burbank tubers harvested from plots previously sown to different green manure crops.

Green Manure Treatment	Incidence of Rhizoctonia (% tubers infected)	Incidence of common scab (% tubers infected)
Oriental mustard	55.0 b*	5.8 ab
Oilseed radish	66.0 ab	5.0 ab
Sorghum	88.5 a	9.0 ab
Redroot pigweed	55.0 b	0.8 b
Millet	66.5 ab	12.5 a
Wheat	60.0 b	3.3 ab
Coefficient of Variance	*22.3*	*106.2*

*values followed by the same letter are not significantly different at $P = 0.1$ using the Duncan's Multiple Range test.

The average disease levels on the Alpha tubers were lower for both black scurf and common scab than on the Russet Burbank tubers. The levels of common scab on the Alpha crop were too low for analysis of significance. This is surprising as usually disease is more obvious on the smooth-skinned white Alpha tubers than on russet type cultivars. The incidence of Rhizoctonia on the Alpha tubers was again lowest in the pigweed plots (Table 36) and highest in the millet and wheat plots. There was no significant difference in the severity of diseases on the tubers.

Table 36. Incidence black scurf on Alpha tubers harvested from plots previously sown to different green manure crops.

Green Manure Treatment	Incidence of Rhizoctonia (% tubers infected)
Oriental mustard	34.8 ab*
Oilseed radish	31.5 ab
Sorghum	43.3 ab
Redroot pigweed	12.5 b
Millet	51.5 a
Wheat	49.0 a
Coefficient of Variance	*52.6*

*values followed by the same letter are not significantly different at $P = 0.1$ using the Duncan's Multiple Range test.

At the end of August 2009, underground stems were sampled from three potato plants per row. The level of *Rhizoctonia* damage to these stems was assessed in both the Scab and Main field, using the rating scheme shown in Appendix 1. In the Scab field, powdery scab gall production on the root samples taken in late August was also assessed (rating scheme in Appendix 1). Late blight was observed in the Scab field at this time and the fields were top killed using a flail mower to prevent spread of this disease. The plots were harvested in mid-September and the total and marketable weights of tubers harvested from each 6m row were recorded as previously described. Disease ratings were made on 30 tuber samples taken at random from each bag of harvested tubers, using the previously described disease rating systems.

Statistical Analyses - All data were tested for fit to a normal distribution and if necessary data were transformed before analysis. The analysis of incidence of *Rhizoctonia* infection of Alpha tubers in the Scab field was conducted after log transformation to normalize the data.

In 2009, the incidence of powdery scab on the Alpha tubers and black scurf on the Norland tubers in the Scab field was significantly higher in the mustard meal treated plots than in the plots with no green manure treatment (Table 37). When the mustard meal was applied in 2008 there was a significant reduction in the weed density in these plots. It is possible that the increase in disease seen the next season was due to a lack of organic matter incorporation in the mustard meal treated plots, rather than any effect of the meal on the disease organisms present in the soil. There was no significant reduction in either powdery scab or black scurf when comparing incorporation of specific green manures against the disease levels seen in the non-manured plots. Although the non-manured plots had significantly less green material incorporated than the green manured plots (Table 4), there was more plant material incorporated in these "control" plots than in the mustard meal treated plots , as the mustard meal had suppressed weed growth.

Table 37 . Effect of green manure treatments on disease incidence on Alpha and Norland tubers in the Scab field in 2009.

Green Manure treatment	Alpha		Norland
	Incidence* of Powdery scab	Incidence of Black scurf	Incidence of Black scurf
Mustard meal	38.0a **	65.6 a	64.0 a
Pea/oat/vetch mixture	29.0 ab	22.7 b	39.8 ab
Millet	24.3 b	28.2 b	50.8 ab
No manure, weedy control	19.0 b	38.8 ab	36.8 b
Sorghum	16.0 b	33.0 b	57.5 ab

*incidence = % of 30 tubers infected with disease.
**Means followed by the same letter are not significantly different at *P*<.1, using the Student's t test.

There appeared to be a relationship between the incidence of black scurf on Alpha tubers in the Scab field and the amount of green plant material incorporated in the previous year (Table 38). As the amount of plant material incorporated during the previous cropping season increased the incidence of black scurf infection in the subsequent Alpha crop decreased.

Table 38. Relationship between incidence of Black scurf on Alpha tubers and weight of green material incorporated the previous year, in the Scab field.

Statistic	Measure
Linear fit	% Rhizoc = (GM wt (kg/m2) - 3.5)*-33.3
RSquare	0.22
Prob>F	0.037

The ranking of the level of *Rhizoctonia* on the stolon samples taken from the Alpha plants in the Scab field (Table 39) was roughly similar to the incidence of disease subsequently found on the tubers.

The green manure treatments had no significant effect of on powdery scab gall production on the roots sampled in August.

Table 39. Average rating of Rhizoctonia infection of roots of Alpha plants in the Scab field in 2009.

Green Manure Treatment	Average root rating
Mustard meal incorporation	1.6 a*
Pea/oat/vetch mixture	1.55 ab
No manure, weedy control	1.48 ab
Millet	1.3 bc
Sorghum	1.03 c

*Means followed by the same letter are not significantly different at p<.1, using the Student's t test.

In the Main field Alpha crop the lowest levels of black scurf were found in the non-manured plots, while significantly higher levels of black scurf were observed in the Sorghum, millet and rapeseed green manure plots. There was no correlation between the weights of green manure added in the previous season versus disease levels observed in the Alpha crop grown in the Main field (Table 40).

Table 40. Effect of green manure treatments on disease incidence on Alpha tubers in the Main field in 2009.

Green Manure Treatment	Incidence* of Black scurf
Sorghum	81.8 a**
Millet	77.6 ab
Rapeseed	75.0 ab
Pea/oat/vetch mixture	70.8 abc
Oilseed radish	66.0 bc
No manure crop	55.8 c

*incidence = % of 30 tubers infected with disease.
**Means followed by the same letter are not significantly different at $p<.1$, using the Student's t test.

The green manure treatments had little impact on disease levels in the Norland plots grown in either the Main or Scab fields. The only significant effect was on the incidence of *Rhizoctonia* infection in the Scab field, where the highest levels of infection were found in the mustard meal treated plots and the lowest in the weedy, non-manured control plots (Table 37). Both these plots had relatively little organic matter incorporated in 2008 (Table 32), so the high levels of disease in the mustard meal treated plots cannot be explained wholly by the lack of incorporation of green material in this instance. There was no effect of green manure on the levels of common or powdery scab on the Norland potatoes but there was a significant relationship between the weight of green material incorporated and the incidence of common scab (Table 41).

Table 41. Relationship between incidence of common scab on Norland tubers and weight of green material incorporated the previous year, in the Scab field.

Statistic	Measure
Linear fit	% Common scab = (Gm wt (kg/m) - 0.96)*25.0
RSquare	0.32
Prob>F	0.0099

As the amount of plant material incorporated as green manure increased so did the incidence of common scab in the next cropping season.

Discussion:

Contrary to expectations, none of the green manure treatments provided any consistent advantage to the subsequent potato crop – either in the form of yield enhancement or by providing a consistent degree of protection against soil-borne diseases such as scab or *Rhizoctonia*. In a study by Ochiai et al (2007), no green manure treatment resulted in statistically significant improvement of potato yield compared with the non-amended control. Where significant yield or disease effects of green manure treatments were observed, most commonly the non-manured weedy control treatments produced the "best" results (higher yields and/or less disease).

There are several possible explanations for these unexpected results.

The organic matter being added to the plots as a function of the green manure treatments may have exacerbated problems with soil-borne diseases such as scab and *Rhizoctonia*. The relationship between soil organic matter content and potato disease is complex (Conn and Lazarovits 1998). Soil organic matter derived from residues of previous crops or applied as animal manure may serve as an alternate food source for potentially pathogenic species like *Streptomyces* – but it may also enhance populations of microbes antagonistic to potential pathogens (Conn and Lazarovits, 1998). Soils rich in organic matter tend to better retain soil moisture – and diseases such as *Rhizoctonia* and powdery scab thrive under cool moist conditions. However, if enhanced soil organic matter increases the supply of available water to the plant this would be expected to enhance both yields and crop health. It is noteworthy that the amount of organic matter added to the soils by even the most productive green manure treatments used in this study (ca. 4 kg fresh weight/m = ca 4t/ha of dry organic matter) would have added relatively little to the total organic matter content already present in a typical sandy loam soil (ca. 2% O.M. = 45 t/ha). The soil at the Scab fields used in these trials had a long history of animal manure applications prior to its use in this potato research – and consequently this site has an unusually high level of residual soil organic matter content for a sandy loam soil type (ca 3-4%). This would have further diluted any contribution to the total soil organic matter pool made by the short-term green manure treatments used in this study.

The fact that the mustard meal treatments which supplied the least organic matter also tended to have the highest incidence of disease would suggest a potential association between disease and soil organic matter content. However this theory is contradicted by the fact that the weedy control treatment that had most frequently limited disease in the subsequent potato crop did not add as much organic matter to the soil as several of the green manure treatments – yet those green manure treatments had provided little benefit to the health of subsequent crops. This would suggest that positive effects of the weedy control treatments are working independently of any biomass contribution.

Another possibility is that the weeds present in the non-manured "control" treatments were actually serving as bio-control agents for disease. Red root pigweed (*Amaranthus retroflexus*) was the dominant weed species in the non-manured control plots in all tests. We could find no indications in the research literature of red root pigweed having any demonstrated biocontrol potential or any use as a green manure crop. Instead red root pigweed is widely considered to be a host for a number of insects, nematodes and viral diseases which may cause problems in potato crops.

While red root pigweed is widely distributed and common in cultivated fields across North America its prevalence in this trial is largely due to the manner in which the study was performed. Red root pigweed thrives in moist, nutrient rich soils and is therefore common at sites with a history of potato production. Red root pigweed requires recently disturbed soil and warm conditions to germinate. Preparing the green manure plots for seeding by rotovating in mid-summer and then irrigating after seeding would have provided the required conditions.

Management of the green manure plots in a manner that insured that only the selected green manure crop got established was problematic in this study. Red root pigweed represented a significant portion of the total biomass produced in all the green manure treatments tested – including the no green manure "control" treatment. This tended to confound and/or obscure any green manuring effects. Selection of faster growing, aggressive, green manure crops, coupled with more appropriate crop management practices, including use of selective herbicides, are required in order to achieve a vigorous and pure stand of the green manure crop. A "clean" control treatment where all weeds are controlled throughout the green manure crop period should also be included in any future studies.

A number of studies have found significant variation in the efficacy of green manures for disease control, and possible reasons for this variation have been proposed. Charron and Sams (1999) suggested that the stage of maturation of plant material of *Brassica* species and climatic factors may have an effect on the toxicity, and hence the fungicidal properties, of incorporated green manure material. Kirkegaard and Sarwar (1998) also concluded that the timing of incorporation of the green manure was important, depending on the susceptible stage of the pathogen and the need for suppression to last long enough to provide protection for the following crop. Zasada et al. (2003) concluded that consistent and reliable soilborne pest management with Brassicaceous amendments will not be achieved without a better understanding of the biological and chemical components involved. Ultimately designing pest management systems for specific target organisms will be based on integration of much information (Zasada et al. 2003).

Economics

Green manure crops were planted at rates recommended in the literature or by the supplier. At the recommended rates, the costs per acre to plant green manure crops ranged from $12 to $96. No additional fertilizer was supplied to the green manure crops. Supplemental irrigation may be required and some pest control may be necessary on all but the cleanest fields to ensure a healthy stand of biomass. Incorporation of the green manure crop was necessary. Production of the green manure crops in this study represented a significant cost – in terms of inputs (seed, fuel and labor), but most importantly it tied up high value land in a largely non-productive function for at least a portion of a cropping season. At the outset of the trial, commodity prices were low and growers were willing to entertain the idea of sacrificing a cereal crop to grow a green manure crop if the yield of the subsequent potato crop could be increased by even 1 to 2 ton per acre. As the trial progressed, commodity prices improved and the economic realities are now not conducive to adopting a green manure approach unless a consistent and significant improvement in potato yield was assured. In areas, such as the Pacific Northwest U.S.A., where soil fumigants are employed to control soil-borne potato diseases, the costs of a green manure crop are less than the costs of fumigation. In western Canada, longer crop rotations, and the inclusion of organic matter via compost or cereal crops, have proven to be more realistic approaches to reducing potato early dying (Larney et al. 2009). Davis et al. (2010) suggest several scenarios for including green manure crops in potato rotations that offer an income stream for the green manure year. These strategies include growing a forage crop and plowing in re-growth, double cropping short season crops, under-seeding an income crop to a green manure among others. Our intention was to first determine whether any of the green manure crops proposed for our area would effectively reduce potato early dying, then to develop an agronomic plan to work these crops into a potato production system. As none of the green manure crops evaluated significantly improved potato yield or reduced potato early dying, work on the logistics of the rotation are not relevant at this time. As the green manure treatments provided little obvious benefit in terms of yields or crop quality for the subsequent potato crop it is very doubtful whether this practice makes economic sense under the conditions encountered in this study. As noted by Cherr et al. (2006), green-manure based systems may provide alternatives to current approaches to crop production; however, the use of green manures may not be economically justified without the provision of multiple services such as nutrient supply, pest and weed control, and improvement of soil characteristics for crop production.

Discussion

Although an informal survey of potato fields affected by potato early dying indicated the involvement of *Verticillium* spp., the data from this report suggests that *Verticillium* is not the most significant pathogen causing premature death in Alberta potato fields. In fact, other pathogens, such as *Colletotrichum coccoides*, may play a larger role than was previously acknowledged. Davis et al. (2001) found that apical stem populations of *C. coccoides* correlated significantly with wilt severity in southeastern Idaho in one year of their study. The soil dilution assays employed during this study were specific to *V. dahliae* and did not provide information regarding other *Verticillium* spp. Several species of *Verticillum* were detected in molecular analyses and the role of these other species is not as well documented in the literature. While PED is caused primarily by *V. dahliae* in most areas of the United States, *V. albo-atrum* may be the dominant pathogen in cooler production areas of the most northern U.S. states and southern Canada, where average soil temperatures during the growing season rarely exceed 25˚C (Rowe and Powelson 2002).

Another thing that became apparent as the trial progressed, was that commercial fields with a history of potato production may not always present a risk of potato early dying as the length of crop rotations and other crops included in the rotations greatly affect both soil inoculum and infection rates in subsequent potato crops. Generally, rotation crops can reduce soil-borne pathogens by any (or all) of three different mechanisms: (i) by serving to interrupt or break the host-pathogen cycle; (ii) by altering soil physical , chemical or biological characteristics; and (iii) by indirect inhibition of pathogens (Larkin and Honeycutt 2006). In contrast, benefits of green manure include: improved soil condition, increased organic matter, improved water penetration, reduction of some diseases, reduced nematode population, and increased availability of nutrients (Davis et al. 2010). These benefits may not become apparent after a single green manure event, however, recent work reported by Davis et al (2010) reports that once a suppressive effect has been established in a soil, a single green manure treatment is sufficient to re-establish the effect.

The ultimate goal of using green manures to manage soil-borne diseases is to reduce yield losses caused by pathogens (Ochiai et al. 2007). Benefits of green manure crops often cannot always be correlated with reduced populations of *V. dahliae*, but can often be explained by reduced infections by *V. dahliae* (Davis et al. 2010). In fact, Davis et al. (1999) reported that *V dahliae* soil inoculum density was not a reliable predictor of Verticillium wilt or potato yield potential, but root colonization was highly correlated with both. In our study, we did not evaluate root colonization of potatoes by *Verticillium* spp., but further work in this area may be informative. Disease reduction has been highly correlated with changes in microbial activities as evidenced by increases in non-pathogenic *Fusarium* spp (Davis et al 1994, 1996). In Idaho, *Fusarium equiseti* (a type culture of *F. avenaceum*) populations have consistently been shown to correlate inversely with Verticillium wilt (Davis et al 2004) and may be useful as an indicator of biologically suppressive soils. In this study, *Fusarium* species were recovered from soil samples from cooperator fields, but it is not clear if these organisms contributed to the risk of early dying or if they represent suppressive soils as documented in other published studies. Wiggins and Kinkel (2005) studied soil microbial communities in green manure amended fields and indicated that green manure treatments may contribute to active management of the pathogen inhibitory activity of the Streptomycete community to achieve plant disease control for Vertilcillium wilt and potato scab. Assays for Stretomycete communities were out of scope for this study.

Although funding was not secured for root lesion nematode analyses, the efforts of two collaborating AAFC scientists contributed to our knowledge in these areas. In other studies, specific green manures, such as sorghum Sudan grass, have been shown to suppress populations of two species of root knot nematode, *Melodogyne chitwoodi* (Mojtachedi et al. 1993) and *M. hapla* (Viaene and Abawi 1998). Much of what is understood about interactions between root lesion nematodes and Verticillum wilt is based on data from regions where *P. penetrans* is the dominant and aggressive species. Root lesion nematodes in Alberta potato fields appear to be *Pratylenchus neglectus* rather than *P. penetrans*. Davis et al. reported in 2001 that studies in Idaho have not shown a relationship between *P. neglectus* and either wilt or potato yield. Amankwa et al (2006) indicated that CPFM is a poor host for *P. penetrans* compared to winter rye, but there was no mention of *P. neglectus*. In this study, no suppressive effect of sorghum Sudan grass or CFPM was observed with root lesion nematodes, however, the green manure crop, teff, did not appear to support a root lesion nematode population. Additional work with teff as a green manure or in rotation may prove beneficial.

Collaborating with researchers in Saskatchewan enabled us to determine whether the use of green manures may be beneficial in reducing the incidence or severity of *Rhizoctonia*, or common or powdery scab. While biomass of incorporated green manure has been associated with suppressive effects on some pathogens, the volume of biomass may also contribute to greater issues with common scab and black scurf. Crop rotation, rather than green manure plow down may provide better control. Larkin and Honeycutt (2006) reported that a rotation study in Maine demonstrated that incidence and severity of stem and stolon canker and black scurf of potato were reduced for most rotations, especially when potato followed canola, barley or sweet corn. No positive impact on potato yield or quality was observed as a result of green manure incorporation in the Saskatchewan fields.

Conclusions

As a result of this preliminary study using green manure crops in potato production systems in western Canada, we learned that potato early dying is likely a result of the interaction between several potato pathogens, but is not always caused by *Verticillium dahliae*. These pathogens may include other *Verticillium* spp., *Colletotrichum coccodes, Alternaria alternata*, and *Fusarium* spp. Several of the green manure crops studied can be effectively grown and incorporated in western Canada within a short growing season. These crops could be utilized as an under-seeded crop or planted following an early harvest of silage or field peas. Management of the green manure crops will influence the effectiveness of these crops to reduce disease, or increase yield. Agronomic work and pest control work may be required to establish green manure crops with sufficient biomass. We know that root lesions nematodes are present in potato production systems in western Canada, but little is known about the prevalent species, *Pratylenchus neglectus*, or its effect on potato yield. If these root lesion nematodes play a role in potato early dying in western Canada, more work is required to determine which potato pathogens are synergistically affected by the root lesion nematode populations. One green manure crop, *Erogrostis tef*, did not appear to support *P. neglectus* populations in potato fields. No consistent reduction in disease was noted as a result of incorporating green manure crops in Saskatchewan fields infested with scab and black scurf. Green-manure based systems may provide alternatives to current approaches to potato production; however, the use of green manures do not seem economically justified at this time. An integrated management approach that includes longer crop rotations will likely results in more consistent control of soil-borne pathogens at this time.

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Presentations

A field day was organized to show growers, agronomists and other potato industry personnel how the green manure plots looked August 9, 2006. Several growers indicated that they had planted green manure fields. There was some interesting discussion on the best timing and method of incorporation. Also, many individuals were speculating on how each crop might be worked in to a rotation strategy for potato production.

Posters were presented at the Annual General Meeting of the Potato Growers of Alberta in 2008, 2009 and 2010.

Acknowledgements

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Green Manure Crops for Control of Verticillium

PAA Meeting
Corvallis, OR
August 17, 2010

Michele Konschuh, Ron Howard, Ross McKenzie, Shelley Woods, Larry Kawchuk, Doug Waterer and Jill Thomson

Government of Alberta

Objectives:

- To determine:
  - whether green manure crops are effective at reducing soil-borne potato pests and diseases;
  - which green manure crop is most effective at reducing specific potato pests and diseases;
  - the impact of using green manure crops on yield and quality in subsequent potato crops, and
  - to provide economically viable alternatives to soil fumigation.

Approach Taken:

- Located in commercial potato fields in southern Alberta
- Intention was to utilize “experienced” potato land, where Verticillium had been observed or was expected
- Planted after spring rush and grew until just before main harvest
- Evaluated the potato crop in the following year

Treatments:

- Check - wheat
- Sorghum Sudan grass
- Canadian Forage Pearl Millet 101
- Hairy Vetch (2006); Oat-Pea-Vetch (2008 & 2009)
- Oilseed radish (2006, one field only)
- Oriental Mustard (2006; one field only)
- Annual Ryegrass
- Phacelia
- Teff (2009 only)
- Control – surrounding crop

Planting Green Manure Crops

Plots in Commercial Field

Wheat

Sorghum Sudan Grass

CFPM 101

Oat – Pea - Vetch

Oilseed Radish

Oriental Mustard

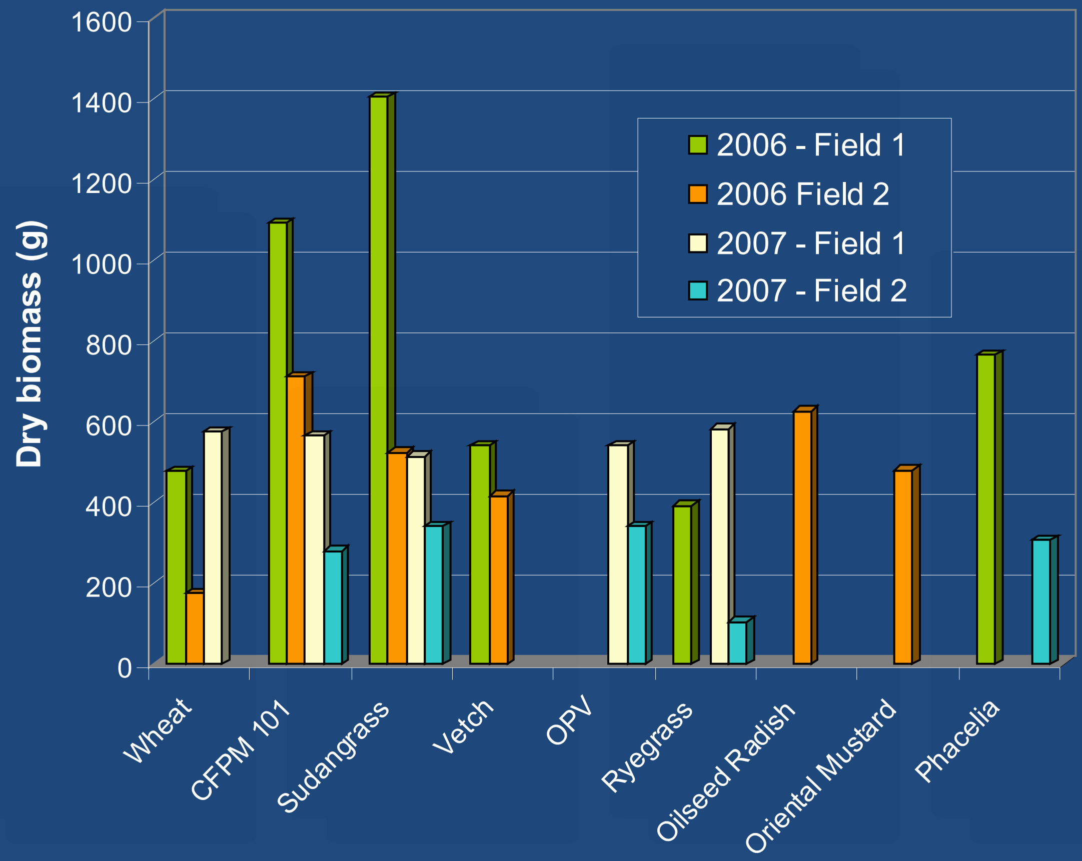
Phacelia

Annual Ryegrass

Teff

Biomass

Biomass



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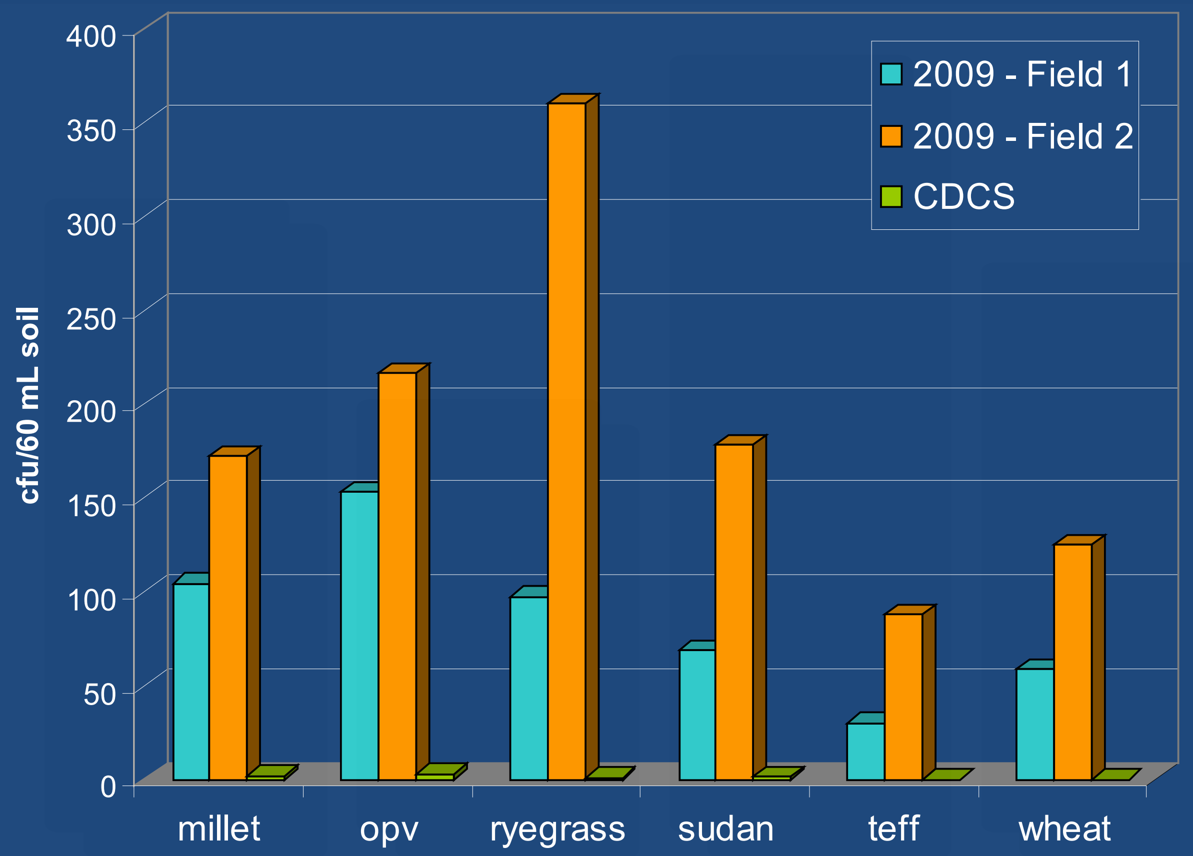
Verticillium

- Typical levels in “experienced” fields in the range of 10 cfu/g soil
- Verticillium in soil decreased after most green manure crops
- Disease incidence not always affected, but reduced in some cases
- Other species implicated in early dying

Root Lesion Nematodes



RLN Control

- In a combined analysis, teff supported significantly lower *Pratylenchus* population densities than ryegrass, millet and wheat; population densities under sudangrass and oat-pea-vetch were intermediate in value and not significantly different from either teff or ryegrass.
- These results are somewhat consistent with the 2008 cover crop results from the YPMA fields in that the oat-pea-vetch plots had low nematode population densities (teff was not evaluated in 2007).

Unexpected Findings

- Agronomics and pest control in green manure crops is critical to successfully using them in potato production systems.
- *Verticillium dahliae* may not be the primary cause of Early Dying in southern Alberta potato fields.
- *Verticillium dahliae* was not very prevalent in soil samples.
- The eggplant bioassays indicated a much higher prevalence of *Colletotrichum coccoides* than *Verticillium dahliae* in soils collected from experienced fields.
- Teff may require additional evaluation in southern Alberta for its impact on root lesion nematode population levels.

Conclusions

- Several green manure crops can be grown in southern Alberta, but more work is required on insect and pest control.
- Soil health is more complex than simply reducing inoculum of one pest.
- Rotation crops may be a better fit for southern Alberta than green manures per se.

Acknowledgements

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Agriculture and Rural Development
Food and Bio-Industrial Crops Branch
Pest Surveillance Branch

Green Manure Crops for Control of Verticillium

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Purpose

- This study was initiated to generate locally relevant information about green manure strategies and their potential impact on soil fertility, soil organic matter, potato diseases and yield of potatoes.
- Green manure plots were established the year prior to potato production for three consecutive years in commercial fields in southern Alberta.
- Use of green manure crops may make soil fumigation unnecessary, and keep costs of production competitive in the global marketplace.

Objectives

- Determine whether green manure crops are effective at reducing soil-borne potato pests and diseases;
- Determine which green manure crop is most effective at reducing specific potato pests and diseases;
- Determine the impact of using green manure crops on yield and quality in subsequent potato crops, and
- Provide economically viable alternatives to soil fumigation.

Figure 1. Green manure plots in southern Alberta

Key Findings

- Several green manure crops can be grown in southern Alberta
- Agronomics and pest control in green manure crops are essential to successfully use them in potato production systems
- *Verticillium dahliae* was not prevalent in many of the soil samples
- *Verticillium dhaliae* may not be the primary cause of Early Dying in southern Alberta potato fields
- The was a high prevalence of *Colletotrichum coccoides* in fields with Early Dying symptoms
- Soil health is much more complex than simply reducing the inoculum of one pest
- Further work may be required on Teff, Sorghum Sudan Grass, and an Oat-Pea-Vetch mixture

- Key findings from a related study indicate that crop rotation may be a more effective means of controlling Early Dying in potato crops than the use of green manures per se.

Results

- Biomass varies with the green manure crop planted, the field used and the environmental conditions each year.
- Sorghum Sudan grass and CFPM 101 (millet) typically resulted in the highest biomass per m^2, followed by Oat-Pea-Vetch, wheat and others.

- Total soil N was typically unchanged by incorporating green manure cover crops, but available N was sometimes affected. Results varied between fields and with environmental conditions.

- Soil dilutions detected *Verticillium dahliae* inoculum as high as 30 to 40 cfu/g soil in one field, but below 6 cfu/g soil in most fields in the study.
- PCR methods detected relative quantities of *Verticillium* that correlated well with Early Dying symptoms.
- Early Dying was not always observed, even when *Verticillium* could be recovered from stem samples.

- Other soil-borne pathogens, such as *Colletotrichum coccoides,* were isolated from plants exhibiting Early Dying symptoms.
- Eggplant bioassays confirmed that organisms other than *Verticillium dahliae* may be related to Early Dying in Alberta.

- Root lesion nematode populations varied with the field and the crop; some green manure crops, such as Teff, do not appear to support populations of root lesion nematodes.

- There was no significant difference in yield of potatoes from the green manure plots.

Future Considerations

- Work is needed to incorporate green manure crops into a potato production cycle.
- Agronomic and pest control recommendations for green manure crops must be developed before these crops can be widely used.
- More work is required on the prevalence of *Colletotrichum coccoides* in potato rotations.
- The potential role of Teff in reducing populations of root lesion nematodes may require further exploration.
- Further work may be required on Teff, Sorghum Sudan Grass, and an Oat-Pea-Vetch mixture

Acknowledgements

This project was supported financially by Alberta Crop Industry Development Fund Ltd., Agriculture & Food Council, Alberta Agriculture and Rural Development, Agriculture and Agri-Food Canada, and the Potato Growers of Alberta and through in-kind contributions of potato growers in southern Alberta.

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Water savings in irrigated potato production by varying hill–furrow or bed–furrow configuration

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ABSTRACT

Current agronomic practices for potato production in the irrigated areas of southern Alberta involve a hill/furrow configuration that was adopted from elsewhere, and designed to shed rainfall away from the hill and into the furrow. However, the principal intent of supplemental irrigation is to capture as much of the applied water into the hill, where the potato tubers and roots are located, and minimize water accumulating in the furrow. A three-year project began in 2006 to quantify the potential irrigation water savings of altered hill shapes for potato production. The three treatments (standard hill, flat-topped hill, and double-planted wide-bed) were arranged in a randomized strip plot design replicated four times. Soil water in each treatment was generally kept between 60 and 90% of available. A fourth treatment, triple-planted wide bed, was added to the project in 2008. The irrigation requirements to maintain the treatments were 487, 442, and 449 mm for the standard hill, flat-topped hill, and double-planted bed, respectively, in 2006 and 442, 408 and 411 mm for the same treatments in 2007. This translates into approximately 10% less irrigation water required for the flat-topped hill shape compared to the standard hill shape. The flat-topped hill shape required 5.0% more irrigation than the standard hill in 2008, but the double and triple-planted wide beds required 8.0 and 9.9%, respectively, less irrigation water than the standard. Although not always statistically significant, water use efficiency was greater in all years for the altered bed shapes compared to the standard hill geometry. Greater water use efficiency can be interpreted as more of the applied water infiltrated into the hill, where the potato plant could use it for transpiration and tuber development. Total yield was greater in 2006 for both the flat-topped hill (72.3 Mg ha^{-1}) and wide-bed hill (69.2 Mg ha^{-1}) compared to the standard hill (61.4 Mg ha^{-1}); however, the treatments were not significantly different. Significantly greater marketable yield was realized from the flat-topped hill treatment in 2006. This treatment also had a significantly greater number of marketable size tubers. In 2007, there were no significant differences in total yield; however, the standard and flat-topped treatments had a significantly greater number and yield of tubers in the 113–170 g size category. Significant differences in total yield were found in 2008. The triple-planted wide bed had significantly greater yield in the smaller size categories compared to the standard treatment and significantly greater total tuber numbers than the other treatments, but the increase was in the smaller size categories, less than 170 g. There were no significant differences among the treatments in yield or total number of tubers in the size categories greater than 171 g in 2008.

1. Introduction

In southern Alberta, potatoes are always hilled after planting and covered with sufficient soil to prevent tuber greening, to ensure drainage in the area of tuber formation, and to facilitate mechanical harvest. Final hill shape is often determined by the type and make of the hilling implement. Traditional final hill shape has been one with a fairly peaked top and side slopes ending at the furrow position. This hill shape probably evolved as a practical solution to divert excess rainfall away from the potato tubers and maintain adequate aeration within the potato hill. Chow and Rees (1994) reported that the initiation of runoff from the furrow position was sooner for hilled potatoes rather than un-hilled ones. Cooley et al. (2007) also reported that traditional hill geometry reduces infiltration into the center of the hill and promotes water drainage into the furrow position. These studies indicate that the traditional final hill shape is effective at diverting applied water into the furrow position.

However, in the irrigated areas of semi-arid southern Alberta, excess rainfall is not usually an issue. Rather than diverting excess

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Fig. 1. Final hill shape of the flat-topped treatment.

Fig. 2. Power hiller set to form a 1.8 m wide bed.

rainfall into the furrow position, the goal for final hill shape in irrigated potato production should be a hill shape that maximizes the amount of applied irrigation water infiltrated into the center of the potato hill.

The infiltration of irrigation and rainfall into a potato hill is often assumed to be uniform. However, due to the topographic relief of hill-furrow tillage systems, it has been reported that the actual infiltration and subsequent redistribution of irrigation water is quite variable. Starr et al. (2005), Robinson (1999), and Saffigna et al. (1976) reported that more water enters the soil through the furrow than through the ridge or hill. It was believed that between precipitation events, increased soil matric forces due to declining soil water levels within the potato hill, act to redistribute some of the water into the hill position where it can be used by the plant. However, Starr et al. (2005) reported that uptake of soil water from the furrow position or toe of the hill was undetectable and the lowest soil water storage was in the center position of the potato hill.

Improved irrigation efficiency may be realized by altering the standard hill shape to one with a wider profile or a flattened top, so more of the applied irrigation water has time to infiltrate into the hill/bed before ponding in the furrow position. Starr et al. (2005) reported that infiltration of applied water did not reach the center of the hill under sprinkler irrigation. Irrigations to ensure sufficient soil water in the center of a standard hill shape translate into excessive runoff and ponding of the applied water in the furrow position. Deep percolation of applied water and minimal or no uptake of soil water by the potato plant from the furrow position results in a loss of irrigation water applied.

Mundy et al. (1999) planted three rows of potatoes in a 1.9 m wide bed to evaluate the effect on yield and quality. Although there were not always statistically significant differences, they reported the wider bed retained more water compared to the standard hill. Steele et al. (2006) compared yield and quality of potatoes planted within the furrow position of a modified ridge/furrow system to conventional standard hill-planted potatoes. They found significantly greater yields and a greater yield of larger size potatoes were harvested from the furrow-planted treatments compared to the hill-planted treatments. On two sampling dates for soil water, they found significantly greater soil water in the furrow position than in the hill. Starr et al. (2005) concluded that management practices targeted at wetting the hill center under the sprinkler would likely improve water use efficiency.

Water use efficiency (WUE) has been used in many studies on irrigated crops to describe yield per unit water consumed or applied (kg/ha mm) (Howell, 2006; Hatfield et al., 2001). Improvement in WUE has typically been interpreted as increased beneficial use of diverted water for irrigated agriculture or the "More crop per drop; same crop less drop" concept. The whole concept of, and proper interpretation of, WUE has been criticized lately (Bessembinder et al., 2005). Some of the criticism with the interpretation of WUE is the high variability from year to year, even with the same regimen of agronomic practices (Tow, 1993; Musick et al., 1994; Shae et al., 1999). The WUE is also influenced by other factors such as soil texture (Hatfield et al., 2001), and there are no consistent formulations for calculating WUE so comparisons between studies are difficult at best (Howell, 2006). However, improved WUE among treatments in the same year, the same crop, and the same variety is generally interpreted as better utilization of soil water (Kang et al., 2004).

The objective of this study was to quantify the water savings in altered hill/bed forms compared with the standard hill and to identify the influence altered bed shapes have on tuber yield, quality, and water use efficiency.

2. Methods

Three treatments consisting of a standard hill, flat-topped hill, and double-planted wide bed hill were arranged in a randomized strip plot design, replicated four times at the Crop Diversification Center (CDC) South in Brooks, Alberta, in 2006 and 2007. A fourth replicated treatment, consisting of a triple-planted, wide-bed hill, was added to the trial in 2008. Plot sizes were 6.1 m × 6.1 m with a 4 m buffer between plots. Hill forms were prepared using a Netagco power hiller/bedder. Standard and flat-topped hill treatments consisted of six rows, 0.91 m apart. The wide-bed treatments consisted of three, 1.8 m beds. Flat-topped hill preparation involved maintaining the same rotor configuration as for a standard power hiller but setting the rear shaper blade to flatten or "drag off" the peak of the standard hill (Fig. 1). The double and triple-planted beds were prepared by setting a firm tension on the rear shaper blade (Fig. 2). Plots were established in different portions of CDC South each year.

Soils at the site are Orthic Brown Chernozem (Chin Soil Series) (Agriculture and Agri-Food Canada, 1998) or Aridic Haploboroll (Soil Management Support Services, 1992), with soil textures ranging from loam to silt loam. Average available soil water (between field capacity and wilting point) in a 0.8 m soil depth was 164 mm.

The plots were prepared and planted with treated Russet Burbank potato pieces spaced 30 cm within the row at a depth of 15 cm on May 12, 2006; May 9, 2007; and May 8, 2008. A hand-move irrigation system, equipped with Nelson directional impact sprinklers with 4.76 mm nozzles and individual shut-off valves,

Table 1
Monthly precipitation during growing season at Brooks in 2006, 2007 and 2008 compared with 30-year (long-term) average precipitation.

Year	Precipitation (mm)					
	May	June	July	August	September	Totals
2006	58.4	73.6	14.7	19	65.5	231.2
2007	59.5	42.9	5.1	41.5	31.4	180.4
2008	65.8	68.1	61.5	15.7	34.5	245.6
LTA^z	42.6	58.8	41.7	39.3	38.9	221.3

LTA^z = 30-year (long-term) average precipitation (Canadian Climate Normals 1971–2000, Environment Canada).

was used for applying irrigation water in 2006. In 2007, Senninger mini-wobblers with 2.38 mm nozzles were used for applying the irrigation water and Hunter MP 3000 180° directional rotators were used in 2008. The mini-wobbler was rated with an application rate of 6.2 mm h^{-1}, the impact sprinkler was rated at 10.3 mm h^{-1} and the Hunter MP 3000 rotator was rated at 9.9 mm h^{-1}.

Aluminum access tubes (1.2 m in length) were installed in the hill position near the center of each plot for soil water determinations with a CPN® 503 (Campbell Pacific Nuclear Inc., Martinez, CA) soil moisture meter, previously calibrated for a loam textured soil. Soil water was measured twice each week from planting until harvest. Each treatment was irrigated once average soil water in the top 60 cm of soil profile for the four replicates reached 60% of available. Irrigation amounts were based on the difference between available water holding capacity and average soil water depletion. Tru-check cumulating rain gauges were placed adjacent to the access tube for determining irrigation and rainfall amounts.

Evapotranspiration values for all plots were calculated using the soil water balance method based on the difference between weekly soil water readings (Eq. (1)).

$$\mathrm{ET} = \mathrm{P} + \mathrm{I} - \mathrm{R} \pm \Delta\mathrm{M} - \mathrm{D} \quad (1)$$

where ET is evapotranspiration (mm), P is rainfall (mm), I is irrigation (mm), R is runoff (mm), ΔM is water changes in soil profile between two sampling dates, and D is deep drainage (mm). Runoff was assumed to be negligible and deep percolation was calculated as irrigation or rainfall in excess of the soil water holding capacity for a 0.6-m soil depth.

Individual soil temperature probes (Watchdog, B series button logger) were installed in each plot. They were positioned near the seed piece within the hill or bed and were buried 0.14 m below the soil surface. The loggers were set to record hourly temperatures throughout the growing season.

2.1. Agronomic operations

2.1.1. 2006

Fertilizer was broadcast on April 26 at a rate of 168 kg ha^{-1} of N and 84 kg ha^{-1} of P. Insecticides (Admire and Decis) were sprayed twice (July 5 and August 22) to control Colorado potato beetle. Dithane, Pencozeb and Ridomil Gold/Bravo were sprayed on July 16, August 3, and August 22, for early and late blight control. Plots

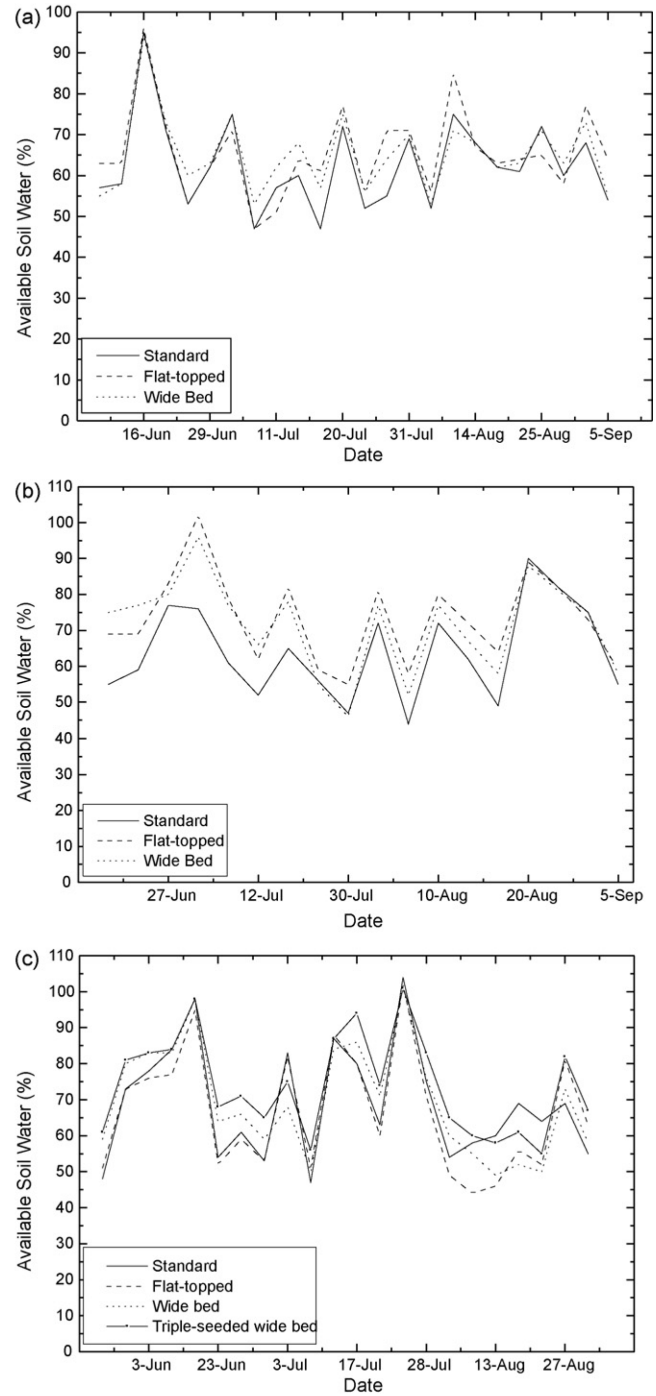

Fig. 3. Available soil water percentages in a 0.6 m soil depth for the seasons 2006 (a), 2007 (b) and 2008 (c).

Table 2
Irrigation demand and evapotranspiration for the hill-shape treatments.

Treatment	Irrigation (mm)			Evapotranspiration (mm)			Water use efficiency (kg/ha mm)		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
Standard	487	442	374	500	462	533	122.8	136.6	165.4a
Flat topped	442	408	393	499	445	542	144.9	138.4	196.9b
Wide bed	449	411	344	488	441	511	141.8	139.9	186.7b
Triple bed			337			513			192.8b

Column means followed by the same letter are not significantly different at $p < 0.05$.

were sprayed with the dessicant, Reglone, on September 5 and were harvested on September 13.

2.1.2. 2007

Fertilizer was broadcast on May 5 at a rate of 150 kg ha^{-1} of N and 50 kg ha^{-1} of P. Admire was applied on July 5 to control Colorado potato beetle. Dithane, Bravo 500 and Ridomil Gold were applied on July 13, July 26 and August 20, for blight control. Reglone was applied on September 5 and the plots were harvested on September 17.

2.1.3. 2008

Fertilizer was broadcast on May 7 at a rate of 156 kg ha^{-1} of N and 56 kg ha^{-1} of P. The insecticide Thionex EC was sprayed on July 7 to control Colorado potato beetle. Quadris, Dithane, and Ridomil Gold/Bravo were sprayed on July 7, July 23, and August 20, for early and late blight control. Plots were sprayed with Reglone on September 12 and were harvested on September 29.

All tubers from the two center rows of the standard and flat-topped treatments and the entire center bed of the wide-bed treatment were harvested and evaluated for yield, size, quality, and specific gravity.

2.2. Statistical analysis

Statistical analyses of yield, evapotranspiration, water use efficiency and temperature data included analysis of variance (ANOVA) and separation of means by the Tukey multiple mean comparison test were conducted using Sigma Stat statistical software (SPSS, Chicago, IL).

3. Results

3.1. Meteorology

Monthly and seasonal precipitation values for 2006, 2007 and 2008 are shown in Table 1. Notable is the month of July in both 2006 and 2007 with monthly precipitation values being much below average.

3.2. Water use and evapotranspiration

There were no statistically significant differences in evapotranspiration between treatments in any year. Although not always statistically significant, the trend was for improved water use efficiency (kg/ha mm) in all years for the altered hill treatments compared to the standard hill treatment (Table 2). The standard hill treatments required 7.8 and 9.2% greater irrigation amounts in 2006 and 9.9 and 10.3% in 2007 than the double-planted wide-bed and flat-topped treatments, respectively. In 2008, the wide-bed treatments, double and triple planted, required 8.0 and 9.9% less irrigation than the standard treatment; however, unlike the two previous years, the flat-topped hill treatments required 5.0% more water than the standard hill treatments.

Seasonal available soil water, for the 3 years of the study, in a 0.6 m root zone is shown in Fig. 3(a–c). The modified bed shapes, either flat-topped or wide-bed treatments, sustained soil water at a higher level than the standard hillshape throughout most of the season in 2006 and 2007. In 2008, the wide-bed treatments sustained higher soil water but the flat-topped treatment was similar to the standard treatment for water requirements.

3.3. Soil temperature

Differences between daily maximum and minimum soil temperatures were greater for the wide-bed hill-shape treatments, than they were for the flat-topped and standard hill-shaped treatments (Table 3).

Table 3
Differences between maximum and minimum daily soil temperatures for May and August 2008.

Treatment	Difference between maximum and minimum temperatures (°C)	
	May	August
Standard	11.8a	4.0a
Flat topped	12.8a	3.0a
Wide bed	18.5b	5.5b
Triple bed	19.5b	5.0b

Column means followed by the same letter are not significantly different at $p < 0.05$.

Examples of the diurnal amplitude of soil temperature early in the season, May 7, 2008 and at row closure, July 6, 2008 are shown in Fig. 4(a and b).

3.4. Tuber yield and quality

Marketable yield (171–284 g) was significantly greater in the flat-topped hill compared with the standard hill treatments in 2006 (Table 4), and the number of tubers was higher for the flat-topped treatment compared to the standard or the wide-bed treatments. In 2007, there were no significant differences in total yield; however, the standard and flat-topped treatments had a significantly greater number and yield of tubers in the 113–170 g size category. In 2008, the flat-topped treatment had significantly greater total yield compared to the standard treatment. The triple-planted,

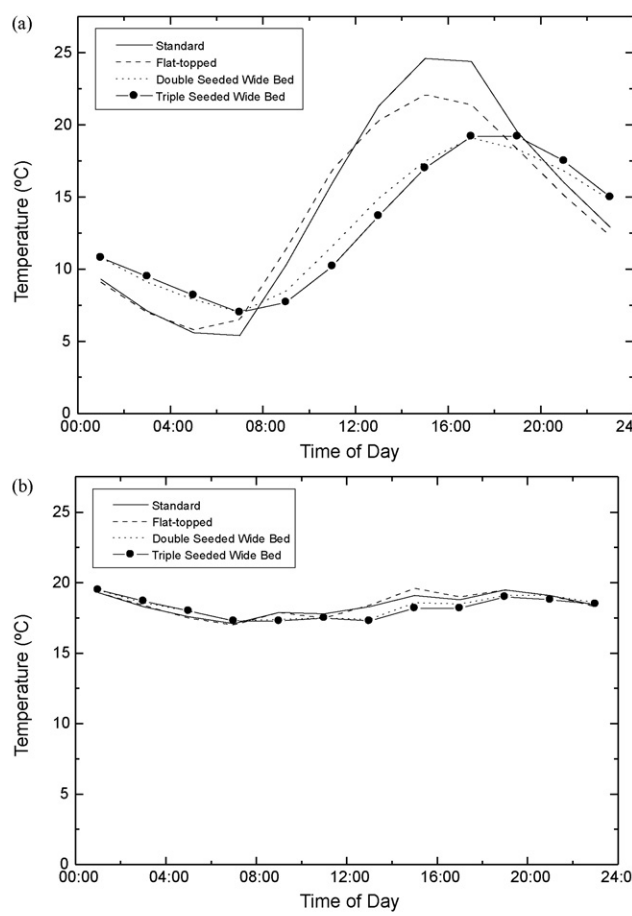

Fig. 4. Average soil temperatures for the four hill-shape treatments on (a) May 27, 2008 (at emergence) and (b) July 6, 2008 (row closure).

Table 4
Yield comparisons for the hill-shape treatments.

Yield ($Mg ha^{-1}$)						Number of tubers (count)				
		Size categories (g)					Size categories (g)			
Treatment	Total	<113	113–170	171–284	>284	Total	<113	113–170	171–284	>284
2006										
Flat-top	72.3	15.8	19.3	22.8a	11.9	267a	118	75a	57	17
Wide-bed	69.2	16.6	18.2	20.2ab	12.2	255b	115	71ab	52	17
Standard	61.4	13.1	15.5	17.3b	13.0	216b	94	57b	45	20
Percentage of total tuber count in the various size categories										
Flat-top							44.2	27.9	21.5	6.5
Wide-bed							45.2	27.7	20.3	6.8
Standard							43.4	26.4	20.9	9.4
2007										
Flat-top	61.6	15.0	15.1b	18.1	8.9	246	119	59ab	46	13
Wide-bed	61.7	15.6	11.6a	18.5	11.1	259	142	46a	48	16
Standard	63.1	15.4	15.1b	19.9	9.1	249	118	60b	50	13
Percentage of total tuber count in the various size categories										
Flat-top							48.4	24.0	18.7	5.3
Wide-bed							54.8	17.8	18.5	6.2
Standard							47.4	24.1	20.1	5.2
2008										
Flat-top	106.7a	12.1a	15.9ab	29.2	44.2	282ac	91a	62ab	71	58
Wide-bed	95.4ab	12.1a	14.4ab	25.7	40.1	258ab	86a	57ab	63	51
Standard	88.2b	10.7a	13.3b	25.9	36.0	238b	77a	51b	63	47
Triple bed	98.9ab	16.4b	17.8a	26.3	35.3	304c	127b	67a	65	45
Percentage of total tuber count in the various size categories										
Flat-top							32.2	22.1	25.2	20.5
Wide-bed							33.3	22.3	24.5	19.9
Standard							32.5	21.2	26.6	19.7
Triple bed							41.7	22.1	21.5	14.8

Column means followed by the same letter are not significantly different at $p < 0.05$.

wide-bed treatment had significantly greater yield in the smaller size categories compared to the standard treatment and significantly higher total tuber numbers than the other three treatments, but the increase was in the lower size categories, less than 170 g. There were no significant differences among the treatments in yield or total number of tubers in the size categories greater than 171 g in 2008.

4. Discussion

The approximately 10% reduction in irrigation water applied between the standard hill and wide-bed treatments was consistent in all 3 years. However, the lower irrigation applications in 2006 and 2007 for the flat-topped hill were not observed in 2008. The significantly greater yield in the flat-topped treatment compared to the standard treatment likely contributed to the need for increased irrigation water in 2008.

The trend for greater water use efficiencies with the altered hill shapes in all 3 years indicated better conversion of the water used for transpiration to tuber yield. Greater marketable yield, increased number of marketable tubers, and reduced tuber deformities resulted with the altered hill shapes. Greater and sustained soil water content with the wide-bed hill shapes reduced the frequency of irrigation applications. These yield results are consistent with the findings of Kang et al. (2004), who found that more frequent watering with drip irrigation, and not allowing the soil profile to dry prior to wetting, resulted in the greatest yield of potatoes. Similarly, Steele et al. (2006) reported that the increase in tuber quantity and size for furrow-planted potatoes was most likely due to consistent seasonal soil water conditions.

The trial seeding 3 rows (triple-planted) on the 1.8 m wide bed was a modest success. Greater tuber numbers, even though the increase was in the smaller (less than 170 g) size category, resulted in more production per unit area. However, the expectation that an increase in total tuber weight compared to the other treatments was not realized. A possible explanation could be that extra nitrogen and phosphorus fertilizer, which would be needed for proper growth of an additional row of potatoes, was not applied. If the increased tuber numbers for the triple-seeded, wide-bed treatment had sufficient fertility for proper bulking, then a significant increase in total tuber yield for this treatment may have been realized.

Warmer daytime soil temperatures after planting for the standard or flat-topped hill should help to lessen tuber diseases. Wharton et al. (2007) identified a greater incidence of rhizoctonia the longer the seed tuber remained in wet, cold soil prior to emergence. Although wet, cold soils are not typically a problem in the semi-arid region of southern Alberta, the flat-topped or standard hill have more surface area exposed, intercept more incoming solar radiation, are elevated from the surrounding soil, and thus warm faster.

5. Conclusions

A 10% water savings for irrigated potato production is possible in southern Alberta by modifying the standard hill shape to either a flat-topped or wide-bed hill shape. Standard hill-shape geometry adopted from other potato growing areas was not as effective at retaining irrigation and precipitation. Altering the standard hill to a flat-topped or wide-bed shape allowed more irrigation and precipitation to infiltrate. In areas where irrigation is essential for sustained potato production, an altered hill shape may improve water use efficiency and increase potato yield and quality. When pre-emergent soil water content is high and soil temperatures are low, and irrigation is practiced, a flat-topped hill rather than a wide-bed hill would ensure improved water use efficiency and enable maximum soil warming prior to row closure.

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