NORTHEAST POTATO TECHNOLOGY FORUM 2011

March 16-17, 2011
Fredericton, New Brunswick
Canada

CONSPECTUS

Printed courtesy of McCain Foods (Canada)

Northeast Potato Technology Forum 2011
March 16-17, 2011

Introduction

The Northeast Potato Technology Forum is an annual event that provides potato researchers and extension specialists from Atlantic Canada and Northeastern United States an opportunity to discuss potato research, exchange technical information of benefit to the potato industry, and establish lasting networks. The 2011 event in Fredericton, New Brunswick celebrates the 19th anniversary of the Northeast Potato Technology Forum.

The 2011 program is comprised of 26 oral presentations and 1 poster. The innovative and diverse potato research offered on the program promises to deliver exciting sessions and stimulating discussion. Research topics are all-encompassing: entomology, breeding, genetics, pathology, production and integrated pest management. Participating authors represent 3 universities and colleges, 3 federal and provincial government agencies, 4 agricultural companies, and 1 private researcher from 3 Canadian Provinces and 2 American States.

Many thanks are extended to the session chairs, those who provided oral and poster presentations, and to all Forum participants. Our appreciation and thanks go to McCain Foods (Canada) for the publication of this booklet; New Brunswick Department of Agriculture, Aquaculture and Fisheries for technical assistance; and Syngenta for sponsoring the evening reception. Thank you to all of our other sponsors for their support.

This conspectus booklet contains the abstract or summary of each presentation and poster from the Northeast Potato Technology Forum 2011.

Additional copies of this booklet are available from the New Brunswick Department Agriculture, Aquaculture and Fisheries, Potato Development Centre, 39 Barker Lane, Wicklow, NB E7L 3S4.

Thank you for making the 2011 Northeast Potato Technology Forum a success.

Loretta Mikitzel
Forum 2011 Chair
Telephone: 506 392 5146
Fax: 506 392 5102
Email: loretta.mikitzel@gnb.ca

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Managing Colorado Potato Beetle Resistance to Imidacloprid: from Theory to Practice

Andrei Alyokhin[1*], Megan Patterson[1], Galen Dively[2], and David Rogers[3]

[1] Department of Biological Sciences, University of Maine, 5722 Deering Hall, Orono, ME 04469
[2]Department of Entomology, University of Maryland, 4112 Plant Sciences Bldg., College Park, MD 20742
[3]Bayer CropScience, 2 TW Alexander Dr., Research Triangle Park, NC 27709

Defoliation by the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is a serious threat to potato crops in most potato-growing areas of the world. One of the major challenges in managing this pest is its remarkable ability to develop insecticide resistance to virtually every chemical that has ever been used against it (Alyokhin et al. 2008).

A neonicotinoid systemic insecticide imidacloprid is commonly used for Colorado potato beetle control, usually as a seed treatment or in-furrow application at planting. It provides excellent plant coverage and is highly persistent in potato foliage. Unfortunately, whole-field systemic applications also create strong selection pressure on insect populations towards developing resistance to this compound. The first instances of resistance to imidacloprid have been already reported from commercial potato farms in Maine, New York, Delaware, and Michigan. Imidacloprid no longer controls Colorado potato beetles on the affected farms in Southern Maine, and there is considerable cross-resistance with other neonicotinoids (Mota-Sanchez et al. 2006; Alyokhin et al. 2007). Insecticide rotation to different modes of action is one of the most commonly recommended resistance management techniques (IRAC 2005).

Laboratory, greenhouse, and small-plot experiments identified several insecticides potentially effective against the imidacloprid-resistant Southern Maine population (Alyokhin et al. 2006). The present study evaluated field performance of the management plan developed based on that information.

Colorado potato beetle abundance on the affected fields was recorded following standard protocols developed by the University of Maine Cooperative Extension (Dwyer et al. 1997). Fifty plants were randomly selected from scouted fields (the scout walked through the field in an “M” pattern and picked plants for examination along the way). Selected plants were visually examined for the presence of the Colorado potato beetle life stages. Resistance to imidacloprid was quantified between 2003-08 using a diet incorporation assay (Olson et al. 2000).

The growers were able to manage imidacloprid-resistant beetles with alternating applications of non-neonicotinoid insecticides. Beetle populations were rather stable during the second and third years of the project, either remaining below the action thresholds, or exceeding them only once during the season. The situation was more challenging during the first year, in part because of the control failure in the preceding year, and in part because of the necessity to fine-tune management techniques. There was also a shift towards using more environmentally friendly materials during the second and third years.

The levels of imidacloprid resistance declined considerably in the absence of selection pressure. This should be expected when there is resistance-related reduction in relative fitness (Denholm and Rowland 1992), which has indeed been documented for our populations (Alyokhin et al. 2006; Baker et al. 2007). However, the LC50 values remained well above that reported for the highly susceptible unexposed population (0.33 ppm) (Alyokhin et al. 2006).

Reactive approach to managing resistant populations described here was successful. However, proactive measures directed towards resistance prevention constitute a generally more sustainable approach.

Negative Effect of Phostrol on Colorado Potato Beetles

Megan Patterson

Department of Biological Sciences, University of Maine, 5722 Deering Hall, Orono, ME 04469

Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is the most important insect defoliator of potatoes. This beetle's notorious ability to develop insecticide resistance may increase the benefit gained from under-utilized indirect control methods. Field studies in 2008 and 2009 on insecticide susceptible populations demonstrated reduced beetle densities and reduced defoliation on potato foliage treated with a phosphorous acid-based fungicide Phostrol. In 2010, we conducted follow-up laboratory studies measuring the effects of Phostrol, on mortality and time of development of the Colorado potato beetle larvae. Two strains were tested: resistant strain with field-evolved resistance to multiple insecticides, and susceptible strain. The experiment consisted of five blocks organized in a complete block design with beetle strain (insecticide resistant vs. susceptible) and foliage treatment (Phostrol-dipped or water-dipped control) being the factors. Excised potato leaves from greenhouse grown 'Yukon Gold' potatoes were inserted into water filled floral picks, dipped in a 25 mL/L solution of Phostrol in distilled water or distilled water and allowed to air-dry under the fume hood. Thirty first instar larvae were introduced to leaves placed in sealable storage containers lined with fluon and paper towel. Containers were arranged following randomized complete block design inside an environmental chamber (Percival Scientific, Perry, IA) with an 18:6 (L:D) photoperiod. Developmental stage of larvae through adult emergence from pupation was recorded every other day. The primary negative effect of these treatments was the increased time required for maturation to the next life stage for later instars and pupation. Increased mortality rates of late instar larvae were also observed.

Which Aphid Species is Transmitting PVY?

Yvan Pelletier[1]*, Xianzhou Nie[1], Marie-Andrée Giguère[2], Nicola Mason[2], Upeksha Nanayakkara[1]

[1]AAFC, Potato Research Centre
[2]UNB

Potato virus Y is transmitted to potato in a non-persistent manner by many aphid species, some of which do not colonize this crop. The behavior of several aphid species on potato, a plant species that is not colonized by these aphids, was described and compared with that of the potato colonizing aphids. On the other hand, we developed a protocol to trap and determine if the aphids are carrying PVY. This allows the identification of the aphid species involved in PVY transmission in a field situation. During the summer of 2010, many samples of aphids from yellow pan traps tested positive for the presence of PVY on the stylets of the aphids. PVY positive samples were observed throughout the summer starting on June 16th. The main aphid carrying PVY in June was the Large Raspberry aphid, *Amphorophora agathonica*.

Walking Pattern of Fed and Unfed Adult Colorado Potato Beetles in Arable Land

Gui, Lian-You [1], G. Boiteau[2]*, B. G. Colpitts[3], P. MacKinley[2] and P.C. McCarthy[4]

[1]College of Agriculture, Yangtze University, Hubei 434025, China.
[2]Agriculture and Agri-Food Canada, Potato Research Centre, 850 Lincoln Road, P.O. Box 20280, Fredericton, NB, E3B 4Z7 Canada
[3]Department of Electrical and Computer Engineering, University of New Brunswick, 15 Dineen Drive, Fredericton, New Brunswick, E3B 5A3,
[4] Natural Resources Canada, Atlantic Forestry Centre, P.O. Box 4000, Fredericton, NB, E3B 5P7, Canada

Although the successful management of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), depends on preventing its dispersal between fields, its walking pattern in the farm landscape remains poorly understood and our knowledge largely anecdotal. For example, mass emigration of adult Colorado potato beetles from heavily defoliated potato fields has historically been considered a response to starvation. Colorado potato beetles would be expected to respond to food deprivation by adopting a more directed walking pattern than fed beetles. The objective of the study was to test the hypothesis under field conditions by determining the walking pattern of the different seasonal Colorado potato beetle types with and without previous access to food. The study was conducted in a fallow bare-ground field to eliminate host plant finding (silhouette, plant odours, etc) as a variable and concentrate on the intrinsic walking pattern of post-diapause, early summer and late summer adult beetles and colony beetles. Adult beetles were released in the middle of an arena and their walking pattern recorded. The use of a harmonic tracking radar made it possible to successfully track the somewhat cryptic adult beetles against the soil of the large field arena. Contrary to expectation, the walking path of all beetle types was random whether fed or unfed. Results suggest a relatively unoriented walking pattern to search arable land until host volatile or visual impulses trigger a more directed walk or flight. Results also underscore the need to account for variability in dispersal rate and step length between some seasonal types in developing management strategies.

Spore Traps – An Innovative Concept in the Fight Against Late Blight

Gilles A. Moreau [1]*, Y. Leclerc[2], L. Brodeur[3], and H. van der Heyden[3]

[1]McCain Foods (Canada), P.O. Box 11400, Grand Falls, N.B. E3Z 3E3
[2]McCain Foods (Canada), 107 Main Street, Florenceville-Bristol, N.B. E7L 1B2
[3]Phytodata Inc., Sherrington, QC J0L 2N0

Late blight, caused by *Phytophotora infestans*, remains the most important disease of potatoes. In Atlantic Canada, fungicide use represents more than 80% of the active ingredients used on the crop (17 lbs/acre/year).

Spore production, dispersal and germination on a susceptible host play a critical role in late blight epidemics. Spores can be dispersed by wind and rain from a few meters to hundreds of kilometers. Spore captors have been used to manage disease in other crops, namely botrytis leaf blight of onion. This study was conducted in the New Brunswick potato belt in 2009 and 2010. The objective was to monitor late blight spore dispersal and quantify spore load in real-time to assist with disease forecasting and fungicide scheduling.

In 2009, six stations were installed at two sites in the Florenceville area. In 2010, a network of 16 stations was strategically located across the New Brunswick potato belt. Spore traps were scheduled to run 3 days per week between 06:00 and 15:00, 10 minutes on/off. Captors were collected after each run, new captors installed and spores counted under microscope.

Over the two-year period, spore traps accurately reflected real-time spore load. Spore counts increased following infection periods with the highest spore counts recorded following periods of highest infection risk. Traps also proved useful for identification of local inoculum sources. The information generated was used to improve disease forecasting and fungicide scheduling.

Our Understanding of Confine for its Function on Late Blight Control in Potatoes

Gefu Wang-Pruski

Nova Scotia Agricultural College, Truro, NS.

Late blight is one of the most devastating diseases of potatoes in the world and has become the major concern for potato industry in Canada in recent years. Phosphonate chemicals containing phosphorous acid (PA) as an active ingredient can suppress late blight disease symptoms in field and laboratory conditions. The related fungicide Confine^{TM} has been registered in Canada for control of several diseases in potato, tomato and grapes. It has a very favorable environmental profile, therefore, has a great potential for sustainable disease management. So far, the defense mechanism of PA in plants is still not clear even several speculations have been proposed. This presentation will showcase some of our investigations at the cellular and molecular levels and our latest findings on how the Confine^{TM} works for controlling late blight disease. The outcome will be valuable for the development of new disease control strategies for potato production.

Monitoring Current Season Spread of *Potato virus Y* (*PVY*) in Seed Potato Fields of New Brunswick

Manphool S. Fageria[1], Mathuresh Singh[1] , Upeksha Nanayakkara[2], David Wattie[3], Yvan Pelletier[2] and Xianzhou Nie[2]

[1]Agricultural Certification Services Inc., Fredericton, NB, Canada
[2]Agriculture and Agri-Food Canada, Fredericton, NB, Canada
[3]NB Dept. of Agriculture and Aquaculture, Wicklow, NB, Canada

PVY can cause significant yield losses in potatoes. *PVY* incidence has increased in recent years all over North America including New Brunswick, Canada. This increase has been attributed to planting susceptible varieties that do not show good visible symptoms. Crop management practices can also impact *PVY* incidence. This study investigated *PVY* spread in New Brunswick in 11 fields with Shepody, Calwhite, Russet Burbank, Innovator, Goldrush and a private cultivar during 2009 and 2010. One hundred randomly selected plants from each field were monitored throughout the growing season. Leaf samples were collected three times at an interval of 20-25 days starting from the end of June to mid-August, and evaluated for the presence of *PVY* using ELISA and Real-time RT-PCR. Tubers were collected from each plant in August and then at the end of the growing season, after the tops were killed, in September. Tubers were tested for PVY using Real-time PCR. All cultivars had low *PVY* incidence (0-4%) in the early crop season (end of June to mid of July). *PVY* levels in the field increased rapidly between late-July and mid-August. In some of the fields, the *PVY* incidence reached to 30 %. This suggests that spread started early in season and continued spreading throughout the season in New Brunswick in both the years. Results from ELISA and Real-time PCR showed a high correlation in leaf samples of all cultivars at all sampling times in 2009 and 2010.

The Distribution of Fungicide-Resistant Strains of *Fusarium* spp. Infecting Stored Potatoes in Canada

R.D. Peters[1]*, T. Barasubiye[2], K. Lugosch[1], O. Thompson[1], K.I. Al-Mughrabi[3], K.A. Drake[1], I.K. Macdonald[1] and R. Henry[1]

[1]Agriculture and Agri-Food Canada, Crops and Livestock Research Centre, Charlottetown, PE
[2]Agriculture and Agri-Food Canada, Eastern Cereal and Oilseed Research Centre, Ottawa, ON
[3]Potato Development Centre, New Brunswick Department of Agriculture and Aquaculture, Wicklow, NB

Fusarium species are important pathogens of potato that cause yield losses at planting and in storage following harvest. Spores of the fungus are found in all soils where potatoes are grown and can survive for many years. Seed potatoes infected with *Fusarium* can rot after planting (seed-piece decay) causing “misses” in the field. Even if plants grown from infected seed do emerge, they often have reduced vigour and yield. The fungus can spread from infected to healthy seed during the cutting and handling process. After harvest, *Fusarium* spp. cause a dry rot in storage which reduces crop quality.

Potatoes infected with *Fusarium* spp. develop a spreading external decay that usually becomes shrunken and wrinkled in appearance. When diseased tubers are cut open, the brown decay can be seen spreading into the internal tissues of the tuber. The internal decay is usually marked by open cavities which contain the mycelium of the fungus. *Fusarium* spp. can only infect potatoes through wounds. Thus, infection can occur when inoculum is spread from diseased to healthy seed during seed cutting and handling. As well, inoculum in soil attached to the surface of tubers can infect potatoes through wounds made during harvest and handling operations prior to storage.

Although spores of *Fusarium* spp. can be found in all soils where potatoes are grown, our research has shown that diseased seed is the most important source of inoculum to infect daughter tubers. High levels of seed infection do not always translate into high levels of dry rot in storage, because the amount of tuber wounding at harvest is normally the biggest factor determining post-harvest dry rot. However, high levels of seed infection can lead to significant seed-piece decay with resulting yield impacts.

Our research has shown that the predominant *Fusarium* species found on seed pieces provide inoculum for infection of daughter tubers and therefore, these species are also the predominant ones found in storage. Potato seed tubers with symptoms of decay were sampled from across Canada in spring 2010. In total, 85 samples were obtained, yielding

171 individual *Fusarium* isolates. Isolates were identified to species level by microscopic examination of morphological features and DNA sequencing of the translation elongation factor 1-alpha for comparison with sequences available in GenBank and in FUSARIUM-ID (http://fusarium.cbio.psu.edu;). The seed decay pathogens *F. sambucinum, F. avenaceum* and *F. coeruleum* were the most common species recovered. Isolates of *F. oxysporum, F. cerealis, F. acuminatum* and *F. sporotrichioides* were also identified. Although mixed infections of several *Fusarium* spp. did commonly occur, one species was usually clearly predominant in a particular sample of tubers.

Isolates of the various *Fusarium* spp. collected were also been tested for their sensitivity to thiophanate-methyl (Senator ® PSPT) and fludioxonil (Maxim® PSP - common potato seed piece treatments) and thiabendazole (Mertect ® SC- a common post-harvest treatment) using a fungicide-amended agar assay. In 2010, 84% and 76% of *F. sambucinum* isolates recovered in a seed survey showed resistance to thiabendazole and fludioxonil, respectively (**Table 1**). Most isolates of *F. avenaceum* and *F. coeruleum* were sensitive to both fungicides (**Table 1**), although some fungicide-resistant isolates of these species were recovered in eastern Canada. Isolates of *Fusarium oxysporum* recovered in these surveys were always sensitive to thiabendazole and thiophanate-methyl, but resistant to fludioxonil. Therefore, species composition in a tuber lot plays a large role in determining how effective a chemical treatment will be. In British Columbia and Alberta, isolates of *F. sambucinum* were more sensitive to fludioxonil than in other parts of the country (**Table 2**).

Table 1. Results of chemical sensitivity testing of isolates of various *Fusarium* spp. isolated from potato seed pieces from Canada in 2010.*

		Fludioxonil (Maxim®PSP)		Thiabendazole (Mertect®SC)	
Species	No. of isolates	Sensitive	Resistant	Sensitive	Resistant
F. sambucinum	80	19	61	13	67
F. coeruleum	23	18	5	19	4
F. avenaceum	52	47	5	50	2
F. oxysporum	6	0	6	6	0
F. cerealis	2	1	1	2	0
F. acuminatum	1	1	0	1	0
F. sporotrichioides	7	7	0	7	0
Total	**171**	**93**	**78**	**98**	**73**

* Note: isolates resistant to thiabendazole (Mertect®SC) are also resistant to thiophanate-methyl (Senator®PSPT)

Table 2. Chemical sensitivity of isolates of *Fusarium sambucinum* isolated from potato seed pieces from various Canadian provinces in 2010.*

Province	No. of isolates	Fludioxonil (Maxim®PSP)		Thiabendazole (Mertect®SC)	
		Sensitive	Resistant	Sensitive	Resistant
PE	11	2	9	2	9
NB	18	5	13	4	14
ON	8	0	8	0	8
MB	7	1	6	0	7
SK	20	0	20	0	20
AB	9	4	5	5	4
BC	7	7	0	2	5
CANADA	**80**	**19**	**61**	**13**	**67**

* Note: isolates resistant to thiabendazole (Mertect®SC) are also resistant to thiophanate-methyl (Senator®PSPT)

Field and storage studies were conducted in Prince Edward Island to determine the impact of fungicide-resistant strains on crop loss and to define potential management strategies. In all cases, treatment of potato seed pieces with mancozeb or difenoconazole completely controlled seed-piece decay caused by a multi-class resistant isolate of *F. sambucinum*. A 3-way mixture of difenoconazole, fludioxonil and azoxystrobin was also efficacious as a post-harvest treatment as potatoes enter storage to control Fusarium dry rot in storage. Based on our research, knowing the predominant *Fusarium* spp. in a particular seedlot and their sensitivities to various chemical products would provide growers with important information to use to make disease management decisions. Thus, diagnostic testing of samples of tubers from seedlots could be a useful tool in the management of this important disease. Since fungicide resistance is a concern, alternating products from different chemical classes becomes an important strategy. In our trials, mancozeb used as a seed treatment was able to control fungicide-resistant strains. Down the road, difenoconazole and other similar products may become available for seed treatment and post-harvest application. Ultimately, the management of Fusarium dry rot and seed-piece decay depends upon an integrated approach that takes advantage of a number of control options and information generated by research studies.

In summary, the 2010 survey confirms the presence of strains of *Fusarium* in Canada resistant to thiabendazole/thiophanate-methyl and/or fludioxonil, particularly with respect to *F. sambucinum.* Fungicide resistance has limited the effectiveness of some common potato seed-piece treatments used to control seed decay and post-harvest applications used to control storage rot caused by *Fusarium* spp. in Canada. A re-evaluation of management practices for control of *Fusarium*-induced potato seed-piece decay and post-harvest rot is required.

Influence of Foliage Health on Results of Seed Treatment of Potatoes

Michel Tremblay, agr.

Dow AgroSciences, Beloeil, QC.

Following good practice recommendations when growing potatoes, using good quality potato seed pieces with less than 5% Rhizoctonia, treated with a mancozeb base seed treatment, we wanted to know if there was an influence of a regular foliage protection program against late and early blight on the evaluation results of potato black scurf caused by *Rhizoctonia solani* Kuhn.

Strategy to Deliver Bacillus Strains in the Field to Control Common Scab

Goyer, C.*, Whitney, S. and J. Zeng

Agriculture and AgriFood Canada, Potato Research Centre, Fredericton, NB.

Common scab of potato is caused by the filamentous bacterium *Streptomyces scabiei* and is responsible for important economic losses estimated at 15-17M$ each year in Canada. The pathogen is commonly found in soil and once a population is established in a field, there are few control means to reduce common scab.

With an increase in public awareness of the impact of pesticides on human health and the environment, it is important to look at alternatives traditional pesticides. The use of biological controls is an alternative avenue to control diseases. Biopesticides offer several advantages over traditional pesticides including more targeted effect on the pathogen, effective in smaller quantities, and higher rates of decomposition, thus reducing impacts on the environment and human health. The long-term aim of this project is to develop biopesticides based on soil antagonistic bacteria, *Bacillus* spp. to control common scab of potato.

Several *Bacillus* spp. isolates that could inhibit the growth of *S. scabies* in confrontation plates were obtained from different fields. From these isolates, *Bacillus* spp. BA31 and BA37, were reducing the symptoms of common scab in greenhouse trials. The two isolates were identified as *Bacillus subtilis* var *subtilis* as determined by their 16S rRNA gene sequences. The two isolates will be tested under field conditions in the summer of 2011. *Bacillus subtilis* will be delivered as a seed-piece coating in field trials. Susceptibility of *B. subtilis* to pesticides that are also applied as a seed-coating including mancozeb, imidacloprid and fludioxonil were tested. *Bacillus subtilis* was not susceptible to the pesticides except to mancozeb at high concentrations. It is important to formulate *B. subtilis* to improve stability of biopesticide during production, assist application, and protect the biopesticide from unfavorable environmental conditions. Formulations are composed of the active ingredient, i.e. microorganism and of a carrier, an inert material used to support and deliver the biopesticide. To increase the stability of the biopesticide in storage, spores of *B. subtilis* were obtained in liquid medium (10^9 spores/ml). Spores were added to five different carriers including talc, bentonite, kaolin, lactose monohydrate, and zeolite that were chosen for their capacity to coat potato seed-pieces. Testing for the viability of the *B. subtilis* stored at 4°C over several months requires time-consuming enumeration of the number of colonies on plates. A method using ATP production and luminescence was developed to increase capacity in testing appropriate ingredients for the formulation of *Bacillus subtilis*. *B. subtilis* strain BA31 spores remained relatively unchanged in the five carriers after 14 days of storage using plate counts and ATP measurement.

Genotypes of *Phytophthora infestans* Causing Late Blight in Canada in 2010

R.D. Peters[1]*, L.M. Kawchuk[2], K.I. Al-Mughrabi[3], H.W.Platt[1], B.W. Beaton[4], C. Banks[4], I. Macdonald[1] and D. Gregory[1]

[1]Agriculture and Agri-Food Canada, Crops and Livestock Research Centre, Charlottetown, PE
[2]Agriculture and Agri-Food Canada, Lethbridge Research Centre, Lethbridge, AB
[3]Potato Development Centre, New Brunswick Department of Agriculture and Aquaculture, Wicklow, NB
[4]Prince Edward Island Dept. of Agriculture, Crops and Livestock Research Centre, Charlottetown, PE

Late blight, caused by *Phytophthora infestans,* is a devastating disease of potatoes and tomatoes that occurs worldwide and causes significant crop losses annually. In recent years, late blight has been very severe in Canada, and in 2009 and 2010, both potatoes and tomatoes were severely affected. Late blight symptoms can be found on the foliage and serious epidemics can cause complete defoliation resulting in significant yield losses. Spores from infected leaves and stems can also wash into the soil during rain events to infect the tubers, leading to tuber rot in the field and in storage. Tomato fruit can also be infected resulting in significant yield loss.

Since new strains of *P. infestans* began to appear in Canada in the mid 1990s, disease control has become even more difficult. The US-8 strain of *P. infestans* which has dominated populations of the pathogen in the last decade in many growing regions of Canada is of the A2 mating type, very aggressive, can appear early in the season, and is resistant to metalaxyl-m (Ridomil Gold®), a systemic fungicide which was effective against the old A1 strain (US-1) of the pathogen which dominated pathogen populations in Canada prior to 1994. The US-8 strain was recovered from potato samples in British Columbia in 2008, however, western Canadian provinces have most often dealt with the US-11, A1 strain of the pathogen in recent years.

In the last two years, *P. infestans* populations in the northeastern United States have been comprised of unique genotypes with novel epidemiological characteristics. Some of these new strains appear to have been distributed on infected tomato transplants sold in local garden centres. Recent discoveries of tomato plants with late blight for sale at Canadian retail outlets prompted an examination of the genotypes inadvertently being distributed and causing disease in commercial production areas in Canada.

A survey was conducted in Canada in 2010 to identify strains of *P. infestans* causing disease in potato and tomato production areas. Samples of potato leaves, stems and tubers and tomato foliage and fruit showing symptoms of late blight were collected and sent to the Potato Development Centre in Wicklow, NB for isolation of pathogen strains. In total, 42 samples of diseased tissue were obtained from the provinces of Prince Edward Island (17 samples), New Brunswick (7 samples), Ontario (2 samples), Manitoba (11 samples), Saskatchewan (3 samples) and Alberta (2 samples). These samples yielded a total of 42 isolates of *P. infestans* (one isolate representing each sample) which were subsequently assessed for mating type, allozyme genotype at the glucose-6-phosphate isomerase (GPI) locus, *in vitro* sensitivity to metalaxyl-m, and restriction fragment polymorphic analysis with the multilocus RG57 sequence and *Eco*RI. Several additional isolates of *P. infestans* were recovered from plant tissue samples sourced from British Columbia and Alberta and submitted to Agriculture and Agri-Food Canada, Lethbridge Research Centre in Alberta. These isolates were also characterized using the same protocols.

All isolates of *P. infestans* from Prince Edward Island and New Brunswick were determined to be of the A2 mating type, moderately insensitive to metalaxyl-m and US-8 genotype. This is consistent with pathogen populations found in eastern Canada in recent years. By contrast, isolates from western Canada were of the A1 mating type and either of the US-23 (British Columbia, Alberta, Saskatchewan and Manitoba), US-24 (Manitoba) or US-11 (Alberta) genotypes. Isolates of the US-23 genotype predominated in western Canada and showed increased sensitivity to metalaxyl-m relative to their US-8 counterparts in eastern Canada. As well, US-23 appeared to prefer tomato as a host and although isolates were recovered from both tomato and potato, disease symptoms were often more severe on tomato. Isolates of *P. infestans* from tomato in Ontario were determined to be US-22 (A2 mating type) and displayed *in vitro* sensitivity to metalaxyl-m.

In summary, our data indicates that movement and evolution of new *P. infestans* genotypes has contributed to the increased incidence of late blight and that dissemination of the pathogen on retail plantlets may provide an additional early season source of inoculum. In addition, *P. infestans* population dynamics differ between eastern and western potato production regions of Canada (A2 in the east; A1 in the west). Although no instances occurred where both A1 and A2 strains were recovered from the same sample or province, the potential for these populations to mix resulting in the generation of new strains via sexual reproduction and the production of overwintering oospores is of concern. Continued monitoring of pathogen populations in Canada is recommended.

Efficacy of Selected Fungicides, Plant By-Products, and Soil Amendments Against Powdery Scab of Potatoes

Khalil I. Al-Mughrabi, Kithsiri Jayasuriya*, and Rene Poirier

Potato Development Centre, New Brunswick Department of Agriculture, Aquaculture and Fisheries, 39 Barker Lane, Wicklow, New Brunswick, Canada E7L 3S4

Powdery scab of potatoes caused by *Spongospora subterranea* f. sp. *subterranean* has been a significant problem to the potato industry in Canada for many decades, amid efforts to find an effective control strategy. The disease downgrades both seed and table potatoes and reduces the market value due to blemishes produced on tubers. Growers across Canada have identified powdery scab as a priority disease for which adequate control measures are currently not available. Seed lots infected with powdery scab may or may not be certified depending on the regulations of the certifying agency and the degree of infection.

Infected tubers may develop more scab lesions in storage. This can predispose the tubers to other organisms that accelerate rots. *S. subterranea* is also a vector for PMTV. The pathogen is difficult to eliminate from the field due to the longevity of the resting spores (cystosori) that are produced in the soil. Once established in the field, the inoculum levels build up during the growing season with no apparent foliar signs or symptoms of the disease. At a certain level of soil inoculums and under favorable environmental conditions, any susceptible cultivars can be confronted with sudden disease outbreaks. Presently, intensified potato production using susceptible cultivars, frequent irrigation and banning of mercury as a seed treatment, all contributed to high disease incidence. No single method can completely control powdery scab on potato, particularly when the inoculum level is high on seed or in soil. However, disease incidence in a problem area can be minimized by planting powdery scab-free seed of Russet varieties produced in disease-free areas.

Fungicides such as mancozeb, maneb, quintozene, fluazinam and flusulfamide, and high N fertilizers are known to reduce powdery scab on potatoes. Over the past decade, researchers have evaluated azoxystrobin, mancozeb, flutolanil, triphenyltin hydroxide, manganese ethylenebisdithiocarbamate, ethylendiamine tetraacetic acid and zinc sulfate as in-furrow treatments with little success and inconsistent results. Although, using resistant cultivars is the most cost-effective, cultural practices such as planting disease-free seed in well-drained soil are also preferred. Therefore, we have investigated the effect of fungicides and soil amendments on suppressing powdery scab on CalWhite (E1) in a previously powdery scab-infested field in New Brunswick. The efficacy of fungicides, soil nutrients, and plants byproducts such as mustard meal against powdery scab were also assessed.

Seed and in-furrow treatments using of fluazinam or mancozeb (1X and 2X) and single doses of fludioxonil, cyazofamid, boron, sulfur, nitrogen and mustard meal were tested. Mancozeb applied as seed treatment at the rate of 40 g/100 kg seed; mancozeb applied in-furrow at 7.5 kg or 15 kg/ha; fluazinam applied in-furrow at 2 kg or 4 Kg/ha; cyazofamid applied in-furrow at the rate of 1.86 kg/ha; and soil amendments with 2.8 kg of boron/ha, and 1064 kg of mustard meal/ha significantly reduced powdery scab incidence. Fluazinam applied as seed treatment at the rate of 25 g/100 kg seed; mancozeb applied in-furrow at the rate of 7.5 kg/ha; and mancozeb applied in-furrow at the rate of 15 kg/ha significantly reduced powdery scab by 33.2%, 59.7% and 57.1%, respectively and significantly increased marketable yield by 32.99%, 43.78% and 43.1%, respectively. Results suggest that fluazinam applied as seed treatment at the rate of 25 g/100 kg seed or mancozeb applied in-furrow at the rate of 7.5 kg/ha are the most efficacious in suppressing powdery scab in infested fields. This trial will be repeated in order to validate the data.

SolCAP – Developing SNP Markers in Elite Germplasm for Applied Potato Breeding

Walter De Jong[1]*, David Douches[2], David Francis[3], Allen Van Deynze[4], John Hamilton[2], Lukas Mueller[6], Robin Buell[7]

[1]Plant Breeding and Genetics, Cornell University, Ithaca, NY 14850-2824
[2]Crop and Soil Science Dept., Michigan State University, East Lansing,MI 48824
[3]Horticulture & Crop Science, , The Ohio State University, Wooster, OH 44691
[4]Plant Sciences, University of California-Davis, CA 95616
[5]Boyce Thompson Institute for Plant Research, Cornell University, Ithaca, New York 14853-1801
[6]Department of Plant Biology, Michigan State University, East Lansing, MI 48824-1312

The USDA-funded SolCAP project aims to provide infrastructure to link sequence variation in genes with valuable traits in potato (and tomato). Our initial efforts have focused on the identification of SNPs within cultivated potato germplasm. Normalized cDNA libraries from three elite potato cultivars (Atlantic, Snowden and Premier Russet) were prepared from callus, tuber, leaf and flower tissue. Libraries were pooled and sequenced using Illumina GAII sequencing technology. The reads, single and paired end, were assembled using Velvet generating on average 38 Mb of transcriptome sequence. Due to the high quality and depth of sequence coverage, we were able to identify more than 150,000 high quality SNPs in potato. To identify the genomic context of the assemblies and permit higher level analyses, we aligned the potato transcriptome to the draft genome sequence of *Solanum phureja* DM1-3 516R44, released by the Potato Genome Sequencing Consortium. An Infinium 10,000 SNP array will be used for potato SNP detection. We identified about 60,000 high quality SNPs that meet Infinium design specifications and are single copy in the genome. Of these, we have selected 2769 SNPs in 500-plus candidate genes, 508 SNPs in genetic markers, and 6723 SNPs distributed throughout the genome for the array. We estimate that our SNPs cover about 650Mb of genome scaffolds. These markers will be used to genotype several hundred potato varieties and advanced breeding clones as well as a reference tetraploid mapping population; all are now being evaluated for agronomic traits at several locations across the USA. We anticipate that these SNP markers will simplify and markedly accelerate future genetic mapping in elite potato germplasm. To encourage American potato breeders to use these SNPs, over the next two years the SolCAP project will be genotyping well-characterized breeding populations for free.

Genetic Diversity of *Potato Virus Y* (PVY) in Seed-lot Potatoes in New Brunswick

Upeksha Nanayakkara[1*], Mathuresh Singh[2], Yvan Pelletier[1], Gulerana Maradukhel[2] and Xianzhou Nie[1]

[1]Potato Research Centre, AAFC, Fredericton, NB, Canada E3B 4Z7
[2]Agricultural Certification Services, Fredericton, NB, Canada E3Z 3E8

Recently *Potato virus Y* (PVY) has reemerged as a major problem in seed potato production in North America including New Brunswick (NB), Canada. It has been suggested that a change in the genetic composition of PVY strains has contributed to high PVY incidences. This study investigated genetic diversity of PVY in 20 seed-lots in NB growing 11 different cultivars in 2009. Multiplex RT-PCR, serological and biological assays were used to reveal and characterize the strain identity. PVY^{O} strain (common strain) is the predominant strain in NB seed-lots. However, recombinant strains, $PVY^{N:O}$ and European (Eu or recombinant)-PVY^{NTN} are more widespread and becoming prevalent in NB. $PVY^{N:O}$ was identified in 13 of the 20 seed-lots while Eu-PVY^{NTN} was identified in 11 of the 20 seed lots. North American (NA or non-recombinant)-$PVY^{N/NTN}$ strains were conspicuously absent in these seed-lots. Mixed infections of PVY strains were found in 6 of the 20 seed-lots, with the double infection with PVY^{O} and $PVY^{N:O}$ or PVY^{O} and PVY^{NTN}. A coat protein based RT-PCR assay differentiated the dominant PVY^{O} strain into three groups: PVY^{O-}Oz/-FL/-SCRI-O type, PVY^{O}-139/-RB type, and PVY^{O}-SASA-110-like or uncharacterized PVY^{O} type. Among the PVY^{O} variant types in NB, PVY^{O}-Oz/-FL/-SCRI-O is the predominant followed by PVY^{O}-SASA-110-like/uncharacterized PVY^{O} types. Incidences of PVY^{O}-139/-RB isolates were either low or completely absent in 9 of the 20 fields. PVY^{O}-Oz/-FL/-SCRI-O variants generally produced severe symptoms in all 11 cultivars compared to other PVY^{O} types and PVY strains. Biological assays on tobacco and 'Yukon Gold' confirmed the findings from RT-PCR assays and serological assays. Other viruses such as PVX, PVS and PLRV were also found in the isolates chosen for biological assays. Results from this study clearly demonstrate the diverse nature of PVY in New Brunswick, Canada.

Examining the Impact of Biological Control Treatments on Field Cultivated Potato Plants at the Molecular Level

Ethel R. Champaco[1], Stellos Tavantzis[2], Robert P. Larkin[3], Benildo de los Reyes[2]

[1]University of Maine, Dept. of Biochemistry, Molecular Biology and Microbiology, Orono, ME
[2]University of Maine, School of Biology and Ecology, Orono, ME
[3]USDA-ARS, New England Plant, Soil and Water Lab, University of Maine, Orono, ME

Agricultural crop plants, including potato, often interact with pathogens, insect pests, biocontrol or mutualistic fungi, bacteria and viruses that elicit a variety of responses that may be beneficial or harmful to the plant. Some of the plant responses, such as induction of general resistance to pathogens and pests are at the frontier of agricultural research aimed at utilizing sustainable, inexpensive and effective ways to optimize crop production. Induced resistance, however, must be integrated within the larger context of concurrent biotic and abiotic stresses. Several studies on plant-microbe interactions at the molecular level have shown that the major signaling pathways and the resulting cellular responses often include similar or identical genes and competing physiological processes that may lead to a reduction of the effectiveness of induced resistance or have detrimental effects on plant growth and yields. Since most sustainable potato production methods involve complex interactions between the potato plant and a variety of biocontrol or mutualistic microorganisms, and pathogens and pests, it is important that we have an understanding of the costs and benefits of induced resistance in a wide array of conditions and agricultural practices. Experiments were conducted over a period of three years on one farm using conventional farming practices and another using organic farming practices. 'Yukon Gold' tubers were planted in soil amended with compost or left untreated. Additionally, the biological control agents **1)** hypovirulent *Rhizoctonia solani* (Rhs1A1), **2)** *Trichoderma virens* strain GI-21 (SoilGard™), and **3)** *Bacillus subtilis* (Kodiak™) were applied in-furrow or **4)** no biological control added. Potato leaf samples from various treatments were collected and analyzed by quantitative Real-Time Polymerase Chain Reaction. Changes in the expression levels of *StSUT4* (sucrose transporter), *ci21A/Asr1* (glucose metabolism in tuber), *PR-1* (Systemic Acquired Resistance pathway, SAR) and *Pin-II* (Induced Systemic Resistance pathway, ISR) were monitored at two time-points for each field season. Corresponding yield and potato black scurf disease assessments for each treatment were also examined.

Comparative Metabolite Profiling of *S. tuberosum* and CPB-Resistant *Solanum* Species

Kraig Worrall[1]*, Helen Tai[1], Yvan Pelletier[1], Larry Calhoun[2], and David De Koeyer[1]

[1]Agriculture and Agri-Food Canada, Potato Research Centre, P.O. Box 20280, 850 Lincoln Rd., Fredericton, N. B. E3B 4Z7
[2]Department of Chemistry, University of New Brunswick, P.O.Box 4400, Fredericton, N. B. E3B 5A3; Helen.Tai@agr.gc.ca

Colorado Potato Beetle (CPB) is a defoliator that causes serious damage to potato crops. Both adults and larvae feed on foliage of the cultivated *S. tuberosum*. A number of wild *Solanum* species closely related to *S. tuberosum* have resistance to CPB. These include *S. okadae, S. paucissectum, S. tarijense, S. chomatophilum, S. oplocense, S. piurae,* and *S. acroglossum*. In this study, LC-MS QToF was used to perform untargeted metabolite profiling of foliage extracts from wild *Solanum* and *S. tuberosum* sp. Shepody. Principle Component Analysis was used to group the species together based on metabolite profiles. *S. okadae, S. paucissectum, S. chomatophilum,* and *S. oplocense* could be placed together in one group and *S. piurae* is closely related. *S. tarijense* and *S. acroglossum* are more distant from the other wild *Solanum* and *S. tuberosum*, but show some similarity with each other. *S. tuberosum* could not be grouped with any of the other species. The mechanism of resistance to CPB shown by the wild species may be due to the production of anti-feedant compounds. Therefore, metabolite profiles for each wild *Solanum* species were compared with *S. tuberosum* using orthogonal partial least squares analysis. Compounds with higher concentration in each of the wild *Solanum* were identified. A compound with exact mass of 560.3935 was identified in both *S. paucissectum* and *S. oplocense.* Another compound of exact mass of 1046.5571 was identified *S. paucissectum, S. oplocense* and *S. chomatophilum.* Other compounds identified were enriched in a single wild *Solanum* species. Cross reference with chemical databases has identified the glycoalkaloid, dehydrocommersonine, as the compound with the mass 1046.5571.

New Tool for Quality Evaluation in Potato Breeding: Potential Application of Near Infrared Spectroscopy

B. Bizimungu[1]* & G. Kereliuk[2]

[1]Agriculture and Agri-Food Canada, Potato Research Centre, Fredericton, NB;
[2]Agriculture and Agri-Food Canada, Lethbridge, AB

Plant breeders, in seeking the most efficient means of achieving their program's objectives, need to investigate new breeding strategies and tools to use. A major focus of the Agriculture and Agri-Food Canada potato genetic enhancement program is to improve the nutritional quality and sustainability of production systems. This requires accumulating multiple disease resistances, agronomic and enhanced quality traits in elite germplasm, and involves screening large numbers of clones to identify superior selections. Rapid methods of assessing the value of a clone are highly desirable to speed up the selection process and improve breeding efficiency. We report on the feasibility of using near-infrared spectroscopy (NIRS) on small samples in the early generations of a potato breeding program. Tuber samples were scanned by NIRS and analyzed for processing and nutritional quality traits, including specific gravity, dry matter, starch content, and dietary fibre components. Calibration models were developed to establish a correlation between variation in the sample spectra and the traits of interest. Preliminary data indicate that NIRS can provide a rapid and cost-effective method for use as early generation selection tool. We are working to refine and validate calibrations.

Can Drought Tolerant Potato Clones be Selected on Irrigated Land?

B. Bizimungu

Agriculture and Agri-Food Canada, Potato Research Centre, Fredericton, NB

The specter of climate change has increased concerns about the sustainability of crops production and pressure to develop mitigation strategies. Potato production in Canada occurs in both rain-fed and irrigated environments. Constraints on water resources can be mitigated through the genetic improvement of drought stress tolerance. This study was conducted to determine whether drought tolerant germplasm can be developed as part of a conventional breeding program performed on irrigated land. A number of breeding clones were grown under irrigated and droughted conditions in replicated trials at the Vauxhall (AB) Research Sub-station of Agriculture and Agri-Food Canada. Genetic correlations between the two environments (irrigated vs. droughted) were estimated to assess 'genotype-by-environment' (GxE) interactions for important agronomic traits. The lack of 'GxE' interaction was noted for some traits associated with yield or yield components. These findings suggest that selection performed on irrigated land can lead to potato germplasm adapted to both irrigated and drought-prone environments, thus increasing resources use efficiency in breeding.

On Farm Demonstration and Validation of the New Fertilization Tables for Potatoes

Daniel Savoie[1]* and Pat Toner[2]

[1]NB Dept. Of Agriculture, Aquaculture and Fisheries, Grand-Falls, NB, E3Z 1G1
[2]NB Dept. Of Agriculture, Aquaculture and Fisheries, Fredericton, NB, E3B 5H1

This project started in the season of 2006 on two Potato Farms of the Black Brook Watershed in St-André, N-B. The Nutrient Management was part of the WEB project, a study done at the scale of the watershed of the Black Brook. Some sections of the watershed are intensively monitored.
Also the Nutrient Management of Potatoes was to evaluate at the Field scale the New Recommendation Tables for Nitrogen and especially Phosphorus, based on studies done by Zebarth and al. on Nitrogen and by Karemangingo and al. on Phosphorus in N.-B. in late 1990 beginning of 2000.

The objective of the project is to continue and expend those On Farm Demonstration Trials with other collaborators working closely with Potato Producers such as Private Consultants, Companies and Club Coordinators, etc. The purpose is to expose more people involved in the Potato Industry those New Fertility Tables to eventually adopt them. In 2006 the project was done on 2 farms (2 sites), in 2007 we increase to 5 farms (7 sites), in 2008 on 4 farms (sites), on 5 farms (sites) in 2009 and on 7 farms (sites) in 2010 with the collaboration of the Private Sector. The main cultivar and type grown are Processing Russet Burbank, cv every years; some Processing Shepody, cv; Seeds Potatoes (varieties varies) and Table Stock Potatoes (Russet Norkotah, cv and Cheiftan, cv).

The main objective is to validate at a larger scale the New Recommendation Tables and expose the industry to them (see Table 1 and 2).

Producers are doing a tremendous effort to produce a very high quality crops that meet the criteria of the market while at the same time limiting the impact on the environment. A lot of Soil Conservation works have been done in the last decades to reduce soil erosion, also crop rotation improve a little and producer are concerned about the sustainability of their farms. Works in the last 10 years on Fertilization of the Potato Crops show interesting results. Now, it is time to implement or do the Technology Transfer of those plots work to the Farm. One of the good ways of doing it is through On Farm Demonstration.

Table 1. Base values for different potato varieties

Variety	Base value kg N/ha (lb N/ac)
Russet Burbank	208 (185)
Shepody	180 (160)
Russet Norkotah*	200 (180)
Superior	190 (170)
Snowden	200 (180)
Goldrush	190 (170)
Early table	135 (120)
Other mid-season	160-180 (140-160)
Other late season	180-200 (160-180)
Other low N requirement	135-160 (120-140)

*For standard clone, reduce value for new clonal selections

Source: Nitrogen Management for Potatoes: General Fertilizer Recommendations. GHG Taking Charge Team Factsheet

Table 2. New phosphate fertilizer recommendations on hayfields, cereals and potatoes (in kg P_2O_5 ha^{-1})

Soil P ratings	Soil P levels (ppm)	Soil P saturation (%)	Potatoes		Cereals (Barley, wheat, oat, rye)	Hayfields (grass /legumes)
			Early and mid-season varieties	Late varieties		
L	≤ 38	≤ 3.00	280	335	100-120	90-120
M	39-78	3.01 - 6.00	160	210	80	80
M+	79-160	6.01 - 10.00	100	120	50	60
H	161-250	10.01 - 15.00	80	100	30	40
H+	251-350	15.01 - 22.00	60	60	20	20-30
H++	> 350	> 22.00	40	40	0	0

Source: PHOSPHORUS MANAGEMENT strategy for soils cropped to potatoes, cereals, and forage hayfields. Factsheet DAFA-02.

Over-fertilizing of some nutrients especially Nitrogen and Phosphorus can have a detrimental effect on the environment. But at the same time those nutrients are key elements in the profitability of the farm by producing a high quality crop. Well manage crops, will help the producer to achieve the market quality and at the same time limit the impact on the environment and improve the profitability of the farms. The purpose of the project is not to change completely the actual practice, but it is more to show if it is possible to reduce the amount of some nutrients when the conditions are there.

On Farm Potato Fertilization Demonstrations using the New Fertility Tables side by side with the Conventional Fertilization Practices will be compared for the years 2007 to 2010 for the major Potatoes cultivars grown in the NB Potato Belt.

Soil Phosphorus Changes Impacted by Potato Cropping Management

Zhongqi He*, Robert P. Larkin, Modesto Olanya, and John Halloran

USDA-ARS, New England Plant, Soil, & Water Laboratory, Orono, ME.

Potato crops generally require high amounts of phosphorus (P) fertilizer to reach economically acceptable yields as the low root density of potato plants makes mobilization and acquisition of phosphate a key factor in potato plant growth. In this work, we evaluated soil P changes in 10 potato fields that had subjected to three-year crop rotations with and without irrigation. As only inorganic fertilizer was applied to these fields, these management practices mainly affected the distribution of inorganic P fractions, with little significant changes in organic P fractions. Crop rotation and irrigation affected soil P distribution in two different patterns. The most labile P fraction, i.e. water extractable P, was significantly impacted by crop rotation, with the highest water extractable P found in the continuous potato and soil improving cropping managements. Irrigation had greater influence on stable and recalcitrant P fractions (i.e. NaOH and HCl extractable inorganic P). Correlation analysis suggested soil pH was the major factor contributing to the conversion of P between different fractions. More field data from short and long experimental periods are needed to confirm these observations.

Geospatial Assessments of Potato Production Systems in Maine

Sherri L. DeFauw* and Robert P. Larkin

USDA, ARS, NAA, New England Plant, Soil and Water Laboratory, University of Maine, Orono, ME 04469

Although Maine produces high quality potatoes, the average marketable yield is substantially lower than production areas in the western USA. Potential factors affecting yield include soil-water availability (timing of water stress and stress alleviation events), pest and disease control strategies, end of season crop management (ESCM) practices, crop rotation, soil quality, and soil conservation efforts. Geospatial assessments of select biophysical soil properties linked to topographic characterizations of potato production areas in Maine may reveal insightful trends and/or pattern-process relationships (at field, farmscape or sub-regional scales); these may enable improvements in adaptive management strategies and result in enhanced yield and sustainable management. The objectives of this GIS-based investigation were to: (1) quantify field, farmscape and sub-regional patterns of potato production areas using US Department of Agriculture, National Agricultural Statistics Service (NASS) 2008-2010 Cropland Data Layers (CDLs, 56m^2 resolution, raster-based map products); (2) evaluate rotational patterns; (3) relate potato field distributions to statewide classes of farmland soils and erodibility (using USDA, Natural Resources Conservation Service (NRCS), State Survey Geographic (SSURGO) soils database); and (4) begin to examine the dynamics of hydropedologic and solar radiation interactions (derived from digital elevation models or DEMs) that may impact cultivar-specific potato yields.

The Maine soil survey is 78% complete (with large tracts of Aroostook, Piscataquis and Somerset counties remaining to be mapped). Estimated statewide raster-based prime farmland (PF) and farmland of statewide importance (FSI) extents are 327,000 ha (4.1% of landbase) and 837,100 ha (10.5%), respectively. Results from geoprocessing crop and soil layers on an annual time-step indicated potato field extents for 2008-2010 occupied 26,800-29,300 ha, with an estimated 63-67% of crop totals situated on prime farmland soils. (Table 1).

Table 1. Summary of potato production areas and farmland soils use in Maine.

YEAR	Total Potato	Prime Farmland	Farmland of Statewide Importance	Not Prime Farmland
	hectares			
2008	26,800†	18,000 (67%)‡	6,700 (25%)	2,000 (7%)
2009	28,200	17,700 (63%)	7,600 (27%)	2,400 (9%)
2010	29,300	18,800 (64%)	7,800 (27%)	2,500 (9%)

†Values have been rounded to the nearest hundred hectares.

‡Conversion of soil survey maps to raster-formatted products that are, in turn, integrated with remotely-sensed cropland map images result in year-to-year variations of pixel loss due to errors in resolution of boundary complexities (therefore, estimations do not equal 100%).

Production areas in potato from year to year (coupling 2008-2009 and 2009-2010 CDL datasets) averaged 5,100 ha. Collectively (across all three years), over 1,800 ha were identified in "continuous potato" with the largest clustered tracts in Aroostook (approximately 1,600 ha), Oxford (140 ha), and Penobscot counties (20 ha). These particular sites represent opportunities to help producers improve integrated crop-soil-water-pest management practices as well as direct our attention to monitoring pest and soil-borne pathogen resistance issues. The biennial return to potato production (2-yr rotation) amounted to slightly over 14,000 ha. Merging all three years of CDL data resulted in an estimated 61,900 ha in potato production – an underestimate of true production area due to rotational complexities (Figure 1). Additional outcomes extracted from these remotely-sensed CDLs (hybrid imagery derived from multiple satellites) suggest that many farmers have diversified their operations and shifted to rotations of 3 or more years. These are positive developments worthy of commendation, because thirty years ago, sites in Aroostook County were reportedly shedding up to 190 Mg/ha of soil. Most soils classified as "prime farmland" in Maine are also designated as "potentially highly erodible"; our geospatial results indicate at least 33,400 ha merit our highest standards in soil conservation efforts.

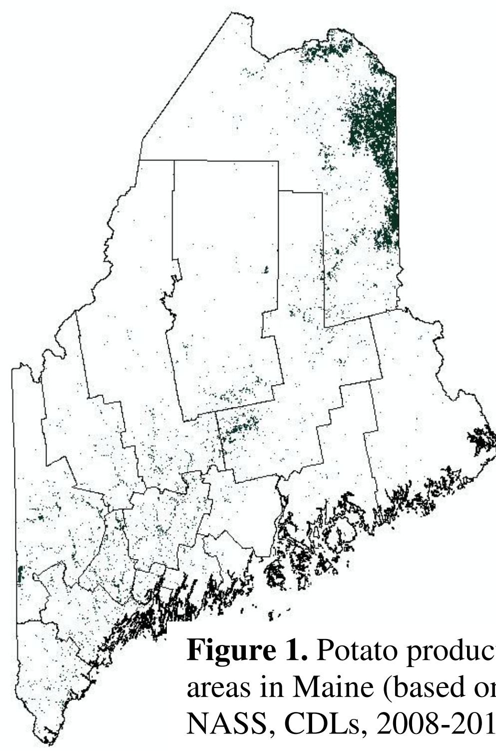


Figure 1. Potato production areas in Maine (based on NASS, CDLs, 2008-2010).

Geographic information systems (GIS) data assemblages allow us to readily track crop rotations as well as shifts in crop adjacencies and thus provide a basic framework to evaluate and model finer-scale dynamics of pest or pathogen pressures (and associated resistance issues) that may develop as a result of these configurations. In addition, geospatial applications facilitate the evaluation of topographic heterogeneity (using DEMs) as well as aid in assessments of variability in the hydropedologic conditions (soil*water) that may develop across a field or farmscape. Further explorations of site-specific factors such as quantifying aspect distributions coupled with field-scale variations in solar radiation (using geostatistics) have revealed details concerning "emplacement" interactions that may influence crop emergence, intra-field loci that may enhance late blight development (*Phytophthora infestans*) or harbor resistant soil-borne pathogens/pests (e.g., *Fusarium* spp., Colorado Potato Beetle (*Leptinotarsa decemlineata* (Say)), Potato Cyst Nematodes (*Globodera* spp.), etc.), or recurring landscape position*soil interactions that may affect tuber size profiles as well as chemical maturity and other aspects of tuber quality. Additional research (in both the field as well as GIS modeling venues) is needed along these lines of inquiry, and it is hoped that feedback from the industry will help guide future endeavors. Use of geospatial technologies helps us visualize/resolve patterns in production environments. Ground-truthing these patterns coupled with identifying site-specific details associated with agroecosystem processes will aid us in optimizing nutrient and pest management strategies and, thus, ultimately contribute to the sustainability of our diversified farm systems.

Use of Brassica and Other Disease-Suppressive Rotation Crops in Potato Production Systems

Robert P. Larkin*, O. Modesto Olanya, John M Halloran, and Zhongqi He

USDA-ARS, New England Plant, Soil, and Water Lab, University of Maine, Orono, ME 04469.

Soilborne diseases of potato can be persistent, difficult-to-control problems in potato production, and typically result in substantial losses in tuber yield and quality. Disease-suppressive rotation crops, defined as crops that actively reduce soilborne diseases through mechanisms such as altering the soil microbial environment or directly inhibiting soilborne pathogens, can be used to enhance management of multiple soilborne diseases and improve tuber yield. *Brassica* spp. and related plants, which include broccoli, cauliflower, turnip, radish, canola, rape, and various mustards, may suppress diseases through two different mechanisms, biofumigation and structural changes in soil microbial communities. These plants produce compounds called glucosinolates that break down to sulfur compounds (isothiocyanates) that are toxic to many soil organisms, and have been successfully used to reduce soilborne populations of fungal pathogens, nematodes, and weeds. Other potential disease-suppressing crops include sorghum-sudangrass hybrids, as well as other small grain and grass crops. The roles and uses of these potential disease-suppressive rotation crops in potato production systems have been evaluated for their efficacy in reducing persistent soilborne diseases and enhancing crop productivity in various field trials over the last several years in Maine.

An overview summarizing all field trials involving *Brassica* rotation crops conducted over the past several years in Maine (a total of 65 trials) indicated that, although results varied by field and year, positive effects on yield and disease reduction have been observed in the majority of trials. Yield was significantly improved in about half the trials, with increases up to 22%. Black scurf was significantly reduced in ~70% of the trials, with reductions up to 95% and an average reduction of 30% relative to typical rotation crops. Common scab was also reduced in many of the trials, with reductions up to 50%. Other diseases, such as powdery scab and Verticillium wilt were also reduced in a majority of trials where they occurred. Overall, mustard green manure worked best for reducing most soilborne diseases, but rapeseed green manure was best for black scurf. Although green manures provided the best results, production canola crops (harvested for seed) also resulted in significant disease reduction.

In a continuing long-term trial evaluating the effects of different crop management system strategies, comparing 3-yr rotations focused on Soil Conservation [SC – limited tillage, forage grass, fall mulch], Soil Improvement [SI – same as SC, but with compost amendments each year], and Disease-Suppression [DS - diverse rotation/cover crops with known disease-suppressive capability, Mustard/ rapeseed-Sudangrass/rye] with a standard 2-yr barley potato rotation [SQ – Status Quo] and a continuous potato control [PP]), the DS system has been very effective in both reducing disease and improving yield relative to the standard rotations over five full years of data collection. The DS system has averaged yield increases of 11 and 20% over all five years relative to a standard barley rotation and continuous potato, respectively (Fig.1A). Tuber diseases, such as black scurf and common scab, were also significantly lower in the DS system than all other rotations, with reductions in black scurf averaging 30 and 42%, compared to the barley and continuous potato rotations, respectively (Fig. 1B).

In order to determine how best to use these rotation crops within potato production systems, an additional trial was established evaluating potential disease-suppressive crops (mustard blend, sudangrass, and rapeseed) under different types of production management (each crop grown as a cover crop, green manure, harvested crop - residue incorporated, and harvested crop – residue not incorporated). In initial results from these trials (2 field seasons), the mustard blend has resulted in the greatest tuber yield and lowest disease levels. Regarding the management practices, crops grown as a green manure provided the greatest yield benefit, as well as the lowest tuber diseases overall.

This research demonstrated that the use of *Brassica* and other disease-suppressive rotation crops can substantially reduce soilborne disease problems, but cannot completely control or eliminate them. Good rotation strategies should be used in conjunction with other crop and soil management approaches to achieve more sustainable crop production.

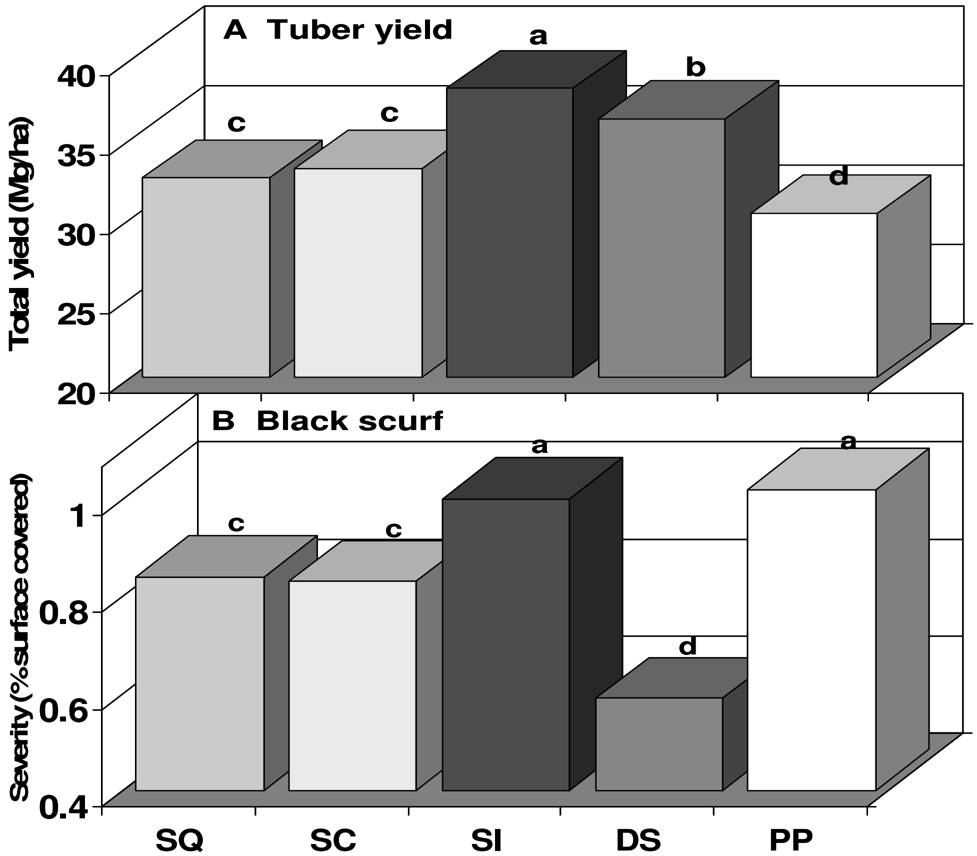


Figure 1. Effect of different cropping systems on A) severity of black scurf (caused by *Rhizoctonia solani*) and B) total potato tuber yield (Combined data from five field seasons, 2006-2010). SQ=Status Quo system, standard 2-yr rotation, (barley/clover – potato); SC= Soil Conserving system, 3-yr., limited tillage (barley/timothy – timothy – potato); SI=Soil Improving system, 3-yr, rotation same as SC, but with yearly compost amendments; DS=Disease Suppressive system, 3-yr, (Mustard blend GM/rapeseed cover crop – Sudangrass GM/ rye cover crop – potato); PP= Continuous potato, nonrotation control. Bars topped by the same letter are not significantly different from each other based on ANOVA and Fisher's protected LSD test ($p<0.05$).

Enhancing Sustainability of Potato Systems in the Northeast
Economic Implications of Alternative Potato Cropping Systems in Maine

John Halloran*, Jonathan Franz, Robert Larkin, Modesto Olanya, Micheal Rothrock, and Sherri Defauw

USDA-ARS, New England Plant, Soil, and Water Lab, University of Maine, Orono, ME 04469.

Sustainable cropping systems and management practices are needed to improve agricultural viability and rural economic vitality in Maine and the surrounding region. Research is being conducted to 1) identify the constraints to potato system sustainability and 2) develop practices and management strategies to overcome or reduce those constraints. Limitations to sustainability are being identified through interdisciplinary evaluation of cropping systems designed and managed as a) Status Quo, b) Soil Conserving, c) Soil Improving, and d) Pest Suppressive Systems under both irrigated and rainfed management. Each system will be evaluated for its impacts on soil physical, chemical, and biological properties; plant growth; plant diseases; profitability and risk; nutrient availability; and their interactions. Simultaneously, research is being conducted to increase productivity and improve economic viability. The sustainability of each system and alternative management practices and transferred to the producers

This presentation discusses the economic implications of each system with respect to producer profitability. The systems were not designed to be profitable, but rather to identify key constraints of each system. However, the results of our cropping systems do have implications with respect to the potential profitability of modified systems. Our results show that there is a wide range of potential profitability from one system to another with respect to potential profitability. With respect to economic potential we found that the crops included in a three year cycle were important and that other cultural practices, such as adding compost or irrigation affected potential profitability. There were significant differences between the systems with respect to yields. The largest effects were seen in the disease suppressive and soil improving systems.

Cavendish Farms: In Search for New and Improved Potato Varieties

Zenaida Ganga* and William Hardy

Cavendish Farms, P. O. Box 3500, Summerside, PEI C1N 5J5

Cavendish Farms is one of the leading producers of frozen potato products for retail and foodservice markets throughout Canada, the United States and around the world. The company has two state-of-the-art processing plants in PEI and another in Jamestown, ND. Cavendish Produce on the other hand, market fresh packed potatoes from both packing operations in O'Leary, PEI and Presque Isle, Maine.

The changing market demand and consumer's food preferences and the climate changes that affect potato production require new and improved varieties for processing and fresh market. In recent years, the private industry has taken the initiative and more responsibility of evaluating potato germplasms to identify varieties that meet their criteria and specific needs. The implementation of the Accelerated Release Program by the Potato Research Center of Agriculture and Agri-Food Canada has given the private sector like Cavendish Farms access to advanced generation clones; in addition to new varieties coming from the US university-based public breeding programs and also from Canadian and European private breeding programs and seed companies.

The Research Division of Cavendish Farms evaluated last 2010 cropping season more than 70 potato genotypes grouped into different sets of trials as follows: processing, fresh market whites and yellows, reds and purples and specialty type potatoes which included fingerlings and creamers. The presentation will highlight results as well as discuss selection criteria and strategy being followed to facilitate the company's search for new and improved potato varieties.

All You Wanted to Know About Lime But Were Scared to Ask

***Robert Coffin[1], J. Coffin[2], H. Tai [3], B. Zebarth[3], G. Lazarovits[4], B. Thompson[5],E. MacDonald[5], B. Beaton[5], J. MacLeaod[6], G. Swallow[7]**

[1]Potato Consulting Services Inc., North Wiltshire, PEI,COA 1Y0
[2]Privar Farm Inc., N. Wiltshire, PEI, C0A 1Y0
[3]AAFC , Fredericton, NB, E3B 4Z7
[4]A and L Biologicals, London, Ontario, N5V 3P5
[5]PEI Dept. of Agr.
[6]AAFC, Charlottetown, PEI
[7]Brookville Lime, St . John, N. B.

Objective of research project This brief report contains the highlights of a lime trial conducted in low pH soil in Green Bay, PEI in 2010. The senior author had asked different questions on the effect of liming and received a wide array of conflicting answers without supporting local data i.e. lime doesn't work for the first two years, lime works right away, Dolomitic lime may not be a reliable source of magnesium, Dolomitic lime increases scab on potato tubers but Calcitic doesn't. To generate credible local data, a trial was initiated in a field with low pH (4.5-4.7). The questions raised were:

1. How quickly does application of different types of limestone change soil pH?
2. How quickly does it affect crop growth?
3. Does it help/effect growth of some crops more than others? Indicator crops were oats, barley, soybeans, canola, crambe, table beets and several genotypes of potatoes.
4. Can Dolomitic lime supply magnesium to crops in the first year of application? 5. Does the application of lime affect the development of scab (bacterial disease) in potato tubers?
6. Do some varieties of potatoes have better tolerance to "sour" soil? Is this related to tolerance to high concentrations of manganese and/or aluminum?
7. Does lime affect utilization/efficiency of fertilizer?
8. Does application of lime affect nodulation/ nitrogen fixation on soybeans?
9. Were any nutrient deficiencies or toxicities observed and corrected in the sour soil? i.e. molybdenum, manganese, magnesium.

Introduction - Most soils in Atlantic Canada are naturally quite acidic (sour) with pH values in the 4.5-5.0 range on newly cleared soil. Ground limestone and other products containing calcium (mussel mud, wood ashes) have been used to raise the pH of soil. While some plants (blueberries, cranberries, sour sorrel weeds) can grow well in "sour" soil, some cultivated crops such as barley, canola, beets, onions and alfalfa will not grow satisfactorily when the pH is below 6.0. Some crops will grow satisfactorily on moderately low pH (5-5.5)(oats, buckwheat, oilseed radish, potatoes). Even if the soil pH has been raised by the application of limestone, the widespread use of ammonium based fertilizers results in the release of hydrogen ions, which leads to the re- acidification of the soil. As the ammonium is changed to nitrate by microbial activity (nitrification), hydrogen ions are given off.

$$\underset{\text{ammonium}}{NH4^+} \longrightarrow \underset{\text{nitrate}}{NO3^-} + \underset{\text{hydrogen ions}}{4\ H^+}$$

The pH is defined as the logoramithic measurement of hydrogen ions (H^+) in the soil. A pH of 7.0 is neutral; a pH greater than 7.0 is alkaline and a pH of less than 7.0 is acidic. The hydrogen ions are attracted to the negatively charged soil colloids. When limestone, containing calcium, is applied to the soil, some of the positively charged calcium ions (Ca^{++}) displace the hydrogen ions held on the soil colloids and the soil pH starts to rise. An excellent overview of limestone use and benefits is available in **NSA Aglime Fact Book, National Stone Association, 1986, Washington, DC, USA, 65 pages**. Some people underestimate the value of lime in obtaining high crop yields and achieving the maximum benefits of fertilizer applied to the soil. The availability of many essential nutrients decreases when the soil pH drops below pH 6.0. At low pH values i.e. < 5.0 some elements (aluminum, manganese,) are released in the soil and the large quantities released may be injurious to crop growth. Some strains of nitrogen fixing Rhizoobacteria may not effectively colonize roots of legumes such as clover and soybeans at low pH, reducing nitrogen nutrition to the growing and following crops.

Scab is a bacterial disease (*Streptomyces scabies*) and is a major problem world-wide for tuber quality. There have been observations that the severity of tuber scab sometimes increased when large quantities of lime were added to acidic soil. Some potato farmers are fearful to raise the soil pH when growing scab susceptible varieties.

Methods and materials -The land in Green Bay, PEI (Charlottetown soil series) was cleared in 2009, after clear cutting and removing mature coniferous trees. The land has good subsoil drainage and has a slight slope of 2-3%. Prior to planting the plots in late May, soil test samples were submitted to both A & L laboratories and the PEI Soil and Feed Testing Lab. Results indicated pH values 4.5-4.7 with low amounts of available P, K, Ca and Mg. Soil organic matter was relatively high (approximately 4-5%). Soil samples were collected in mid –summer (from midway between rows of crops) and again in December to assess changes in pH from the addition of lime (Table 1). The concentration of Ca and Mg were measured to verify effects of lime applications and that of P and K to verify the effect of fertilizer application.

Two types of limestone were used in the trial; Dolomitic and Calcitic, sourced from Brookville Lime Company, New Brunswick. The Calcitic lime contained 36.9 % Ca and 1.0 % Mg; whereas the Dolomitic lime contained 20.4 %Ca and 12.1 % Mg. More than 50% of lime passed through a 100 mesh screen, hence quick release would be expected. The lime was spread evenly by hand at the rate of two tons per acre in late May, 2010 and roto-tilled into the soil (5-6 inch depth). Four hundred pounds per acre of 17-17-17 fertilizer (ammonium nitrate based N) was uniformly broadcast and roto-tilled into the soil for all crops. An additional 100 pounds per acre was applied beside potato hills and covered in hilling (late June).The experiment consisted of three main blocks, two that were limed and one non-limed “check”.

To verify if adding lime increased the severity of scab, a susceptible potato variety (Shepody) was planted. One row of scab -free seed was planted in the three experimental blocks (Dolomitic, Calcitic, non-limed check plot). As well, one row of Shepody seed, severely infected with scab (numerous surface lesions) was planted to assure adequate bacterial inoculum for disease pressure on daughter tubers.

J. and R. Coffin manage a potato breeding program (Privar Farm Inc.) and have observed that some potato seedlings and varieties (Yukon Gold) grow poorly on highly acidic soil and some grow quite well. Several named varieties (Superior, Yukon Gold, Prospect) and several seedlings were planted in the three lime treatments. The seedling PR07-111 had shown excellent vigour in non-limed/ low fertility plots in 2009 and again in 2010. It was speculated that the prolific growth of some seedlings in acid soil may be due to: 1) beneficial micro-organisms growing on roots, 2) a different metabolism and larger root system and/or 3) have high tolerance to aluminum and manganese that are usually in high concentrations in acid soil.

A single row of barley (Spring variety), table beets, Canola, Crambe and two varieties of soybeans (inoculated) were planted in each of the three lime treatments.

For assessments of tuber yield, ten plants of Shepody were harvested from each block. The total weight of tubers was recorded. Tubers were rated for severity of scab. In the three hill plots of other potato varieties and seedlings, all tubers were harvested, weighed and rated for scab. Tuber samples, of some entries, were saved for laboratory analyses (mineral/nutrient analyses).

During July, 25 petioles were harvested from the first fully expanded leaves in the three Shepody plots for nutrient analyses. Ten complete plants (stalks, leaves developing pods), from each lime treatment, were collected from one variety of soybean (A) for nutrient analyses (table 2). In mid October, complete soybean plants were harvested from measured sections of row. The beans were later threshed and weighed and then submitted for nutrient analyses, including protein content – nutrient package F4.

Observations, Results and discussions- Due to space limitations for the abstract, many data tables could not be included. For extension purposes, slides of the plots and results of nutrient analyses will be made available to the collaborators. Noteworthy observations are:

1. The positive effects of lime, represented by vigorous foliage growth and improved yields of tubers(potatoes),seeds (barley, soybeans)and taproots (beets), were easily observed the first year. Some crops in the non-limed soil grew poorly and had no usable yield i.e. barley, beets and canola. Canola showed “whiptail” (molybdenum deficiency) in the non-limed treatment.

2. Both types of lime increased the soil pH during the first growing season. The initial soil pH was 4.5-4.7 and increased to 5.2-5.5 by mid -summer and increased to an average pH of 6.0 by December. The pH dropped to 4.1 in the non-limed block after addition of fertilizer. Within a week of emergence, slower growth was evident in all crops in the non-limed block, even though it had received the same application of fertilizer. Increased calcium content occurred in most plant tissues following application of both types of lime.

3. Large yield increases occurred for all crops following lime applications in the spring of the growing season. Actual yields were recorded for soybeans and potatoes. Total biological yields of Shepody potatoes increased from 160 cwt/acre in the non-limed check to 400 in Calcitic and 540 in the Dolomitic. Average yields for both soybean varieties increased from 654 lb/acre in check to 1706 in calcitic and 1639 in dolomitic. By using nutrient analyses tissue data and crop yield per unit area, the amount of nutrients removed per acre by potatoes and soybeans revealed increased total uptake of N, P, K, Ca, and Mg. Shepody potato tubers in the limed plots removed approximately 180, 27 and 169 pounds per acre of N, P and K compared to the non-limed check at 61 N, 8 P and 69 K. Applications of fertilizer alone can not guarantee high crop yields and nutrient utilization, especially if the soil has a low pH.

4. Application of Dolomitic lime to the soil greatly increased available concentrations of Mg in soil. Dolomitic lime increased the concentration of Mg in potato petiole tissues and whole plant soybean samples during the summer testing. Concentration in potato tubers and soybean seeds increased. This raises the question if application of foliar sprays of Mg or applications of “K- Mag” are required when Dolomitic lime is applied.

5. Nodulation (number, size) on roots, by N fixing bacteria, was much greater when inoculated soybeans were planted in limed soil. One variety of soybeans was more prone to visible Mg deficiency (yellow crinkled leaves).

6 .Where scab inoculum was present by planting scabby Shepody tubers, the development of scab was extensive in limed plots (equally evident in both Calcitic and Dolomitic). Negligible scab occurred in limed plots when scab- free seed was planted.

7. Soil tests revealed a higher amount of available Mn in non-limed soil. Nutrient assessment in potato tuber flesh tissues of all varieties tested revealed a 2- 3 fold in the concentration of Mn.

8. Several potato entries, notably PR 07-111, Prospect, and Superior showed good plant vigour in non-limed plots whereas Yukon Gold and Shepody showed reduced vigour and yields compared to limed plots.

9. What we do not know are the changes in soil and rhizosphere micro-flora following the application of lime and fertilizer. Techniques (G. Lazarovits and S. Hemmingsen, personal communication) are now available to assess which micro-organisms are colonizing the roots.

10. Using tissue tests alone may not be satisfactory for appraising a crop nutrition overview and applying corrective measures. The combined use of soil tests, documenting fertility and lime applications, tissue tests, visual overview of crop growth and visible

deficiencies combined with knowledge on the specific variety/cultivar of crop are required for an informed judgment on nutrient management.

Table 1. Changes in soil pH, calcium, magnesium, phosphorous and potassium following application of lime and fertilizer. Composite soil sample comprised of 12 sub-samples in each lime treatment.

Soil test values	**Non-limed Spring**	**Non-limed summer**	**Dolomitic summer**	**Calcitic summer**	**December 2010**	**Spring 2011**
pH	4.7	4.1	5.5	5.2	5.8-6.2	
calcium	200 L-	111 L-	668 L	1007 M		
magnesium	30 L	17 L	273 H	31 L		
phosphorous	70 L	239 M+	283 H	287 H		
potassium	64 L	146 H	155 H	146 H		
% organic matter	4.1-5.0	4.9	5.5	5.7		

Table 2. Whole plant analyses of soybean plants (variety A) with leaves and developing pods. Plants from non-limed plots were much smaller than in limed plots.

nutrient	**Non-limed**	**calcitic**	**dolomitic**
Calcium	0.51	1.62	1.16
Magnesium	0.28	0.32	0.68
Phosphorous	0.19	0.22	0.31
Potassium	2.06	2.17	2.17

Predicting Soil Nitrogen Supply in Potato Fields Using a Simple Kinetic Model

Bernie Zebarth[1], Jacynthe Dessureault-Rompré[1], David Burton[2], Alex Georgallas[3], Mehdi Sharifi[2], Greg Porter[4], Gilles Moreau[5], Yves Leclerc[6], Walter Arsenault[7], Lien Chow[1] and Cynthia Grant[8]

[1]Potato Research Centre, AAFC, Fredericton, NB
[2]Dept. of Environmental Science, NSAC, Truro, NS
[3]Dept. of Engineering, NSAC, Truro, NS
[4]Dept. of Plant, Soil and Environmental Science, Univ. of Maine, Orono, ME
[5]McCain Foods (Canada), Grand Falls, NB
[6]McCain Foods (Canada), Florenceville, NB
[7]Crops and Livestock Research Centre, AAFC, Charlottetown, PEI
[8]Brandon Research Centre, AAFC, Brandon, MB.

Uncertainty in the amount of N supplied by the soil to a growing crop is the greatest barrier to prediction of the optimal fertilizer N rate. Mineralization of N from soil organic matter, crop residues and organic amendments is the primary source of this N from the soil. However, it is difficult to predict how much soil N mineralization will occur on an individual field basis.

In this study, we used a simple first-order kinetic model to predict soil N mineralization over the growing season for potato fields in New Brunswick and Maine. The model was

$$N_{min} = N_0\,[1-e^{-kt}]$$

where N_{min} is the quantity of N mineralized, N_0 is potentially mineralizable N as determined from a long term aerobic incubation, k is the mineralization rate constant also determined from the incubation, and t is time. Uptake of N in the plant (vines plus tubers) plus soil mineral N in the root zone at harvest was used as a field-based measure of plant available soil N supply (PASNS).

Direct application of the kinetic model for 0-15 cm depth significantly underestimated PASNS. Modeling strategies that considered the soil mineral N (SMN) present at the start of the growing season, or included a pool of labile mineralizable N (Pool I) not normally considered in determination of N_0, performed better, but still underestimated high values of PASNS. Strategies which included a greater soil depth (0-20 or 0-30 cm depth), or which assumed that the mineralizable N pool was replenished during the growing season, overestimated PASNS. A strategy which used a higher value of k for Pool I gave the most promising results.

Results of this study suggest that it is possible to estimate growing season soil N supply using a simple kinetic model, and highlight the importance of considering both SMN and labile mineralizable N pools in predicting soil N supply. However currently, it is necessary to conduct a long term incubation to obtain the information necessary to use such a kinetic model. A practical approach is proposed whereby a simple kinetic model could be used to predict soil N supply on an individual field basis.

Communicating IPM – A Potato Industry Collaboration with McDonald's

Leigh Morrow[1]* and Yves Leclerc[2]

[1]McCain Foods USA, Easton ME; [2]McCain Foods (Canada), Florenceville, NB

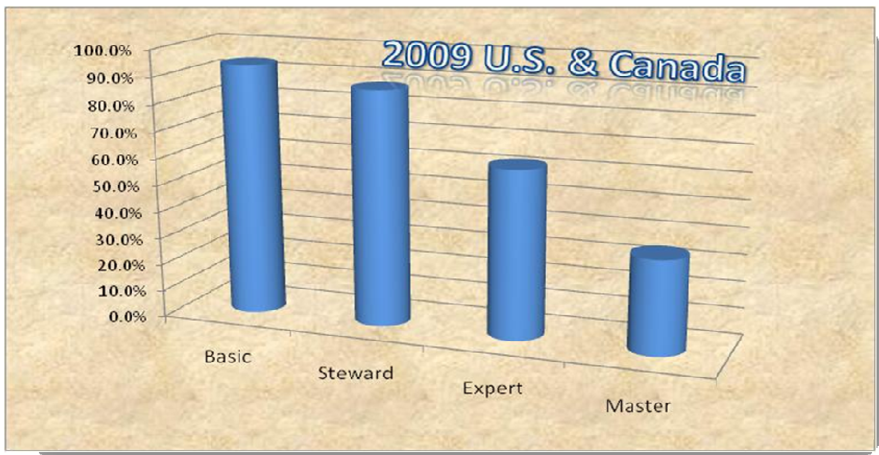
During late winter 2009, the potato processors McCain Foods, Lamb Weston, and Simplot were approached by McDonald's Corporation to participate in a response to a shareholder request to identify opportunities for pesticide use reduction in their potato supply. This shareholder activity was reported in the May 2009 issue of the *Spudman* magazine and many other news outlets. Since that time the processors, McDonald's and others have been working toward the implementation of an industry-wide Integrated Pest Management (IPM) survey to be delivered over the internet and updated annually by growers. In addition to the survey, the web site will also provide public reports, general in nature, and secure grower reports with detailed information allowing benchmarking against similar markets and regions. The web survey is expected to be functional during March 2011 and the reports activated during summer 2011.

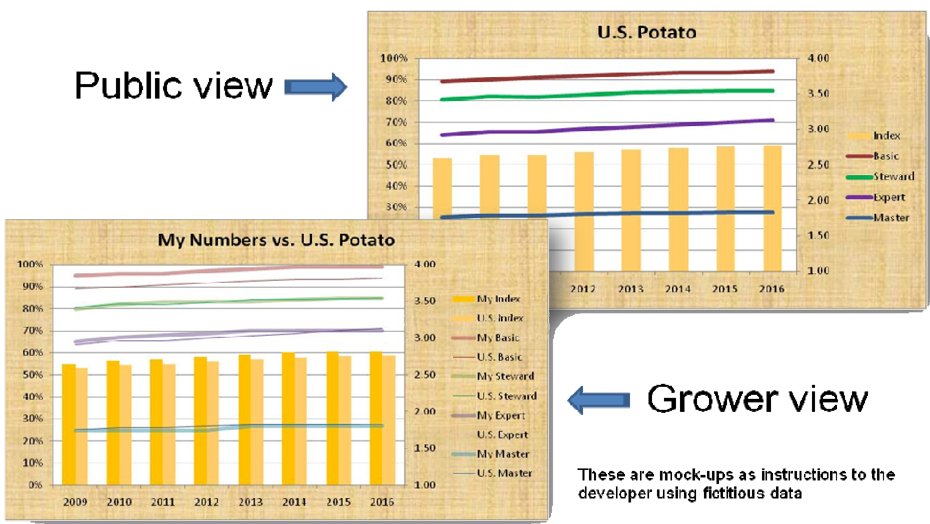
Section	# BPs	Type of practices
Management & worker protection	12	Training and management
Soil pesticide applications	7	Chemical & alternative
Seed	20	Cultural
Planting	11	Cultural
Cultivation	4	Cultural
Weed control	16	Chemical & alternative
Insect control	20	Chemical & scouting
Disease control	13	Chemical & scouting
Advanced crop & pest management	7	Monitoring & reporting
Pesticide handling & application	12	Chemical procedures
Nutrient management	16	Cultural
Irrigation water management	16	Cultural
Post-harvest	5	Chemical & cultural
Soil & water conservation	15	Cultural

Participants in this process have been the processors noted above, McDonald's, the National Potato Council (NPC), the Canadian Horticultural Council (CHC), several growers from each country, and the IPM Institute of North America. In addition, the Northeast IPM Center has granted $15,000 toward building the web site. Initially the team scoped out existing surveys, such as the Canadian Environmental Farm Plan and the NPC National IPM Protocol For Potatoes, and others to develop a comprehensive list of best practices. Through a series of deliberations and pilot testing with growers the final list of 174 best practices was established. The survey sections and number of practices in each are listed here. Any growing and resource management practice that could impact the health of the crop were considered.

Past IPM surveys have resorted to cumulative points systems to score the relative success of IPM implementation on the farm. In our survey we developed a 'tiered' approach whereby each practice belongs to one of four categories on a low-input to high-input continuum referred to as the Basic, Steward, Expert, and Master levels. During development it naturally occurred that more practices emerged for the low-input versus the high-input levels. Scoring is simply reporting the percentage of practices implemented within each level. An index can be calculated by summation of the four levels with a maximum possible of 400% or 4.0.

Examples of the web reports are shown below. The first chart shows pilot survey results and the second set of charts show examples of public and grower custom reports that will appear on the website over time. The unique features of this IPM survey are the scoring system, which should be understandable to the general public; the web delivery of survey to growers, allowing for easy updating in subsequent seasons; and the accessible public and grower reports.





Feedback from McDonald's and the shareholder interest group is that they are pleased with this approach to date. The overall objectives of this project have been to 1) communicate IPM implementation to consumers, 2) provide a benchmarking system to growers, and to 3) identify and transfer best practices.

Additional features of this web tool will be addressed during the presentation.

Effect of Strategy of Conversion to Organic on Potato Yield and Nitrogen Losses

Mehdi Sharifi[1], Derek Lynch[2], Andrew Hammermeister[2] and David Burton[1]

[1]Dept. of Environmental Science, NSAC, Truro, NS
[2]Organic Agriculture Centre of Canada, Truro, NS

The impact of green manure type and frequency with or without organic amendment or fertilizer on tuber yields, greenhouse gas emissions and overwinter N losses are being evaluated under various extended (5y) organic potato (*Solanum tuberosum* L.) rotations at NSAC. Three pre-potato sequences include: C1(oats underseeded with red clover-red clover), C3 (carrots-oats/pea/vetch mixture (OPV)) and C4 (beans followed by buckwheat-OPV). Soil fertility treatments include: non-amended potatoes (control), supplemented with P and N fertilizer (FERT), municipal food waste compost (MSW), or composted paper mill biosolids (PMB).

The highest values for potato tuber yields in 2008 and 2010 were measured in FERT treatment with average of 38 Mg ha^{-1}. The second highest yield was measured in MSW with average of 34 Mg ha^{-1}. Yields for control and PMB were not different (average 31 Mg ha^{-1}) but were significantly lower than FERT and MSW. Potato N uptake (PNU) ranged from 96 to 149 kg ha^{-1}. Greatest PNU was measured for FERT. There were no significant differences in PNU among the other fertility treatments. Rotation sequences did not affect tuber yields or PNU.

The major source of C input to the soil prior to potato planting was green manure. An average of 4.1 and 2.7 Mg C ha^{-1} were added to the soil by RC and OPV, respectively the year before the potato crop in 2008. This total organic C input was significantly greater in RC compared with OPV. When cumulative emissions during 2008 averaged across fertility treatments were compared with total organic C input to the soil in 2007, the soil C accumulation for C1 and C3 were 806 and -295 kg C ha^{-1}, respectively.

In 2008, higher soil mineral N (SMN) (125 vs. 85 kg N ha^{-1}) and mineralizable N were measured prior to potatoes in C1 compared with C3 and C4 with more than 80% of the seasonal decrease in SMN attributed to potato N uptake. About 30 kg N ha^{-1} SMN was estimated lost from the root zone (0- 30 cm) over winter (2008-2009) and was unaffected by treatments. N_2O emissions under potatoes ranged from 1.30 to 0.28 kg N_2O-N ha^{-1} for C1 and C3 sequences. In control potato sub-plots, emissions were 16% lower than under FERT treatment (0.82 vs. 0.96 kg N_2O-N ha^{-1}) but two times greater than under red clover.

Responses of Potato Cultivars to *Potato Virus Y* Strain Groups

Xianzhou Nie[1*], Bihua Nie[1,4], Mathuresh Singh[2], Andrew Sullivan[3], and Conghua Xie[4]

[1]Potato Research Centre, AAFC, Fredericton, New Brunswick E3B 4Z7, Canada;
[2]Agricultural Certification Services, Fredericton, NB E3B 8B7, Canada;
[3]NB Department of Agriculture and Aquaculture, Fredericton, NB E3B 5H1, Canada;
[4]College of Horticulture and Forestry Science, Huazhong Agricultural University, Wuhan, Hubei 430070, China

Potato virus Y (PVY, genus *Potyvirus*, family *Potyviridae*) is one of the most economically important viruses of the potato crop worldwide, causing significant yield loss and quality degradations. Multiple strains/substrains have been recognized and characterized. The ordinary (common) strain (PVY^{O}) and the tobacco veinal necrosis strain (PVY^{N}) were the basic strain groups, and from which, various recombinant strain groups including $PVY^{N:O}$ (with one recombinant event) and PVY^{NTN} (with three recombinant events) emerged. To better understand the interactions between potato cultivars and PVY strain groups, 14 common potato varieties were individually mechanically inoculated with PVY^{O}-FL (a severe PVY^{O} isolate), PVY^{O}-RB (a mild PVY^{O} isolate), $PVY^{N:O}$-Mb58, PVY^{N}-Jg or PVY^{NTN}-1 in the greenhouse. The infection was confirmed by enzyme-linked immunosorbent assay (ELISA) for PVY at three weeks post-inoculation. Foliar symptoms were monitored daily after the inoculation until harvest; and tuber symptoms, mainly potato tuber necrotic ringspot disease (PTNRD), were checked at the harvest and at two months post-harvest. The symptoms in plants varied significantly, depending on potato cultivar and virus strain. Cultivars ‘Cal White’ and ‘Red La Soda’ did not develop obvious symptoms regardless of PVY strains/isolates; and ‘Russet Burbank’ and ‘Russet Norkotah’ developed mild mosaic by PVY^{O}, $PVY^{N:O}$ or PVY^{NTN}. On the other hand, ‘Jemseg’, ‘Ranger Russet’, ‘AC Chaleur’ and ‘Yukon Gold’ developed local lesions and systemic necrosis in leaves by PVY^{O}, mild mosaic/mottle by PVY^{N}, severe mosaic by $PVY^{N:O}$, and milder but visible systemic necrosis by PVY^{NTN}. PTNRD was only observed in PVY^{NTN}-infected ‘AC Chaleur’, ‘Cherokee’, and ‘Yukon Gold’.