2017 NORTHEAST POTATO TECHNOLOGY FORUM

March 15-16, 2017

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CONSPECTUS

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New Nouveau Brunswick CANADA

2017 Northeast Potato Technology Forum

The Northeast Potato Technology Forum is an annual event that provides potato researchers and extension specialists from Atlantic Canada and Northeast United States an opportunity to discuss potato research and promote collaboration and information exchange. The 24th annual Northeast Potato Technology Forum was held March 15-16, 2017 at the Crowne Plaza Lord Beaverbrook Hotel in Fredericton, New Brunswick.

The 2017 program was comprised of 31 oral presentations and two posters. The research presented included cropping systems, crop management, diseases and disease control, herbicide drift, genomics, potato virus Y, Colorado potato beetles, soil fertility and wireworms.

Many thanks are extended to the session chairs, presenters and all participants of the Forum. Our appreciation and thanks go to Syngenta for sponsoring the evening reception; McCain Foods (Canada) for publication of this booklet, and the New Brunswick Department of Agriculture, Aquaculture and Fisheries for technical assistance. We also extend thanks and appreciation to our sponsors for their support.

This booklet contains the abstracts of the 31 oral presentations and two posters of the Forum. The research represented by these papers is integral to the growth and sustainability of the potato industry in the northeast region.

Thank you for making the 2017 Northeast Potato Technology Forum a success.

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2017 Northeast Potato Technology Forum

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Can We Minimize Nitrate Leaching by using Polymer Coated Urea in humid climates?

Athyna N. Cambouris*, Isabelle Perron, Noura Ziadi and Bernie J. Zebarth

Management strategies to reduce nitrogen (N) losses to the environment from potato (*Solanum tuberosum* L.) production while maintaining yields depend on selecting the right N source and rate. This study evaluated the efficiency of controlled release N, applied as polymer coated urea (PCU), on tuber yield and on growing season nitrate leaching on a sandy soil under rainfed and irrigated potato production in eastern Canada in two years. Two potato trials (cv. Russet Burbank; one site irrigated and one rainfed) were conducted in each of 2013, 2014, and 2015. Treatments included an unfertilized control (N0), polymer-coated urea (PCU) and a mix of PCU with granular urea in a 75–25% ratio (PCU^{+}) all applied at three rates (100, 150, and 200 kg N ha^{-1}) at-planting. A conventional mineral fertilizer treatment (CMF_N200: 100 kg N ha^{-1} at-planting as 21-0-0 plus 100 kg N ha^{-1} at-hilling as 27-0-0) was also used. Total (TY) and marketable (MY) yields were determined. Risk of N leaching was assessed using soil solution nitrate (SSN) concentration measured by suction lysimeter. The SSN was sampled biweekly from planting to harvest (nine sampling dates per year).

For the three years, no significant difference was observed between sites (rainfed and irrigated) for TY and MY. For 2013 and 2014, no significant difference was observed between sites for SSN, mainly due to wetter-than-average weather conditions (2013: 694 mm + 44 mm from irrigation; 2014: 503 mm + 66 mm from irrigation). The average SSN of PCU at a rate of 150 kg N ha^{-1} was 40% lower than the CFM_N200 in 2013 and similar to CFM_N200 in 2014. The use of PCU at 150 kg N ha^{-1} produced the greatest tuber yield. PCU may be more advantageous to reducing the risk of growing season N leaching in sandy soils compared with the conventional fertilizer practices with split application.

Nurse Crop, an Innovative Concept to Enhance the Long-Term Sustainability of the Potato Cropping System

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Tom Dixon (McCain Foods (Canada), Florenceville, NB)
Bernie Zebarth (AAFC, Fredericton, NB)
Pat Toner (NBDAAF, Fredericton, NB)

It has long been recognized that the intensive cultivation practices associated with potato production have resulted in declining soil quality. These reductions in soil quality may be expressed as changes in soil physical, chemical or biological properties, and can result in yield limitations.

Companion plantings, intercrops or nurse crops are widely used in horticulture. For example in onion and carrot, barley is commonly seeded between rows to protect onion or carrot seedlings from the effects of wind and water erosion. Small grains are commonly grown to protect an under-seeding of a slow-to-establish species such as red clover and to reduce weed competition during establishment. In potato production, the soil is bare for an extended time between planting and canopy closure. On steep slopes, extreme rain events can result in significant soil erosion. Plant roots hold soil particles in place against water erosion and increase infiltration along channels formed by growing and decaying roots.

The overall objective of this project is to evaluate the potential of the nurse crop concept in potato production to reduce soil erosion, improve water infiltration, and enhance soil water holding capacity while increasing tuber yield and quality.

Field-scale trials have been conducted during the past three years in fields under commercial potato production in New Brunswick, primarily in the Grand Falls and Florenceville areas. Seed of winter rye, barley or oats was broadcast at rates between 100 and 150 pounds per acre as the seedbed was being prepared to plant the potato crop. The nurse crop rapidly formed a thick protective mat that improved water infiltration, reduced runoff and minimized water accumulation in low lying areas. The nurse crop, either desiccated or green, was incorporated in the hill during the hilling operation.

A small 0.5-acre trial was established with the variety Shepody in 2014. In 2015, the project expanded to 450 acres at eight sites, six Russet Burbank fields and one each of Blazer Russet and Russet Norkotah. In 2016, the concept was evaluated at two sites for a total of 140 acres. At site 1, half of the nurse crop plot was hilled green, the other half was desiccated before hilling. At site 2, the nurse crop was hilled green.

In 2014, Shepody grown in the nurse crop treatment yielded more tubers per plant, had a lower incidence of hollow heart and scab, resulting in a 19 and 24 cwts per acre total and marketable yield gain. Results were not repeated using Russet varieties in 2015. In 2016, yield was increased where the nurse crop was desiccated before hilling but not at the site where it was incorporated without being desiccated.

Nurse Cropping in Potato Systems

John Jemison

Extension Professor: Soil and Water Quality

Issue

The time required for potatoes to emerge following planting is longer than any other major crop grown in Maine. During this time, the soil is subject to erosion loss. It would be beneficial to protect the soil during this time period. A nurse crop (NC) could be used to protect soils during this period, but information is needed on the following production decisions: 1) which crop species and sowing rate is optimum; 2) what is the optimum NC production period; and 3) is herbicide necessary to kill the nurse crop prior to incorporation.

Study

In the summer of 2016, a study was conducted at the Rogers Farm in Stillwater, Maine to study the effect of short-term nurse crops on potato yield and quality. The study was designed as a randomized complete block design with six replications. The study compared two sowing rates (winter rye at 100 vs. 200 lbs/ac) to 20 lbs of annual ryegrass or a check plot (no nurse crop). In addition, each of the winter rye treatments was either killed with an herbicide prior to one-pass hilling or just hilled. To address the question of how long to grow a NC, WR treatments were allowed to grow either three weeks or four weeks prior to being incorporated.

Methods

The field study was established on 18 May. The plots were established, and cereal or annual ryegrass seed was broadcast within the appropriate plot areas. A tine cultivator was run through the field to provide some seed to soil contact. Then, a potato planter was used to mark the rows, and 160 lbs/ac 10-10-10 fertilizer was banded in the row. Hand cut Snowden seed was planted by hand at 9 inch spacing, and red chieftain potatoes were planted in the four foot alleyway between plots. Admire was applied in furrow to protect against Colorado potato beetles and other insect pests as the planter was used to cover the seed pieces. Nurse crop treatments were sampled 17 days after planting (DAP) for the 21-day NC production period and at 24 DAP for the 28-day NC production period. Samples were collected using a 1ft^2 quadrat randomly placed twice within each plot. Samples of above ground biomass were cut with shears, and plants were counted prior to placing in the bag. Rimsulfuron was applied to specific nurse crop treatments at 18 DAP, and 21-day plots were incorporated at 19 DAP due to forecasted rain. Weeds were controlled with metribuzin and metolachlor at labeled rates following hilling, and plants were protected with fungicides weekly. The 28-day plots were treated similarly. Petioles were collected on 17 July and 18 August. The fourth leaflet from the top of the plant was sampled, leaves stripped off, and placed in a paper bag. Samples were ground and analyzed for nitrate. Plants were top killed 1 September 2016 and harvested three weeks later. The potatoes were washed, graded into four size categories, and sampled for skin surface and internal defect evaluation. Data were analyzed in JMP 11 – contrasts were used to separate treatment differences.

Results

Winter rye sowed at 200 lbs/ac significantly increased plant number and biomass compared to the 100 lbs/ac seeding rate (Figure 1 and Figure 2). Interestingly, the 20 lb/ac annual rye treatment had similar plant numbers but they had significantly lower biomass than either the 100 or 200 lb/ac cereal rye NC treatments. Annual ryegrass should not be recommended for this use as the plant biomass is much slower to develop compared to cereal rye. Delaying incorporation did not significantly increase dry matter production in 2016, likely due to limited soil moisture in early June. We also didn't find any difference in petiole nitrate in either sampling period. This suggests that the WR did not tap into the fertilizer banded in the potato row. It also indicates that WR does not tie up N when it breaks down following one-pass hilling. Potato yields were very low due to the lack of moisture. Delaying incorporation and not killing the nurse crop with an herbicide prior to incorporation led to lower marketable potato yields (10% level of confidence) and total yield at the 0.05% level for the 28-day growth period. The cereal rye nurse crop not killed with herbicide was not completely buried by the hiller and likely competed with the potatoes for water and nutrients, which limited yield. Rimsulfuron effectively killed WR at 27 DAP, and as such, it did not compete with potatoes for limited water.

Discussion

Nurse cropping deserves further attention as a means to protect the soil before potatoes emerge from the soil. It appears as though one can let the NC grow as long as 25 – 30 days without hurting production so long as the NC is killed with an herbicide before 30 DAP; it does not appear to interfere with soil moisture relations, potato growth and development, or tie up fertilizer N. We didn't measure soil moisture, but Gil Moreau found a slight increase in available water for several weeks after incorporation. With the risk of intense precipitation events becoming increasingly common, the time is right to explore measures that might increase cropping system resilience. Looking to next year and beyond, growers have requested that we consider trials with barley in addition to WR. Given the low commodity pricing of barley, growers could grow seed for their own NC use. While they could also grow WR, most growers are familiar with producing barley. In the summer of 2017, we look forward to comparing barley and WR at 100, 200, and 300 lbs/ac seeding rates. I also hope to find some growers interested in trying it in Central Maine production fields.

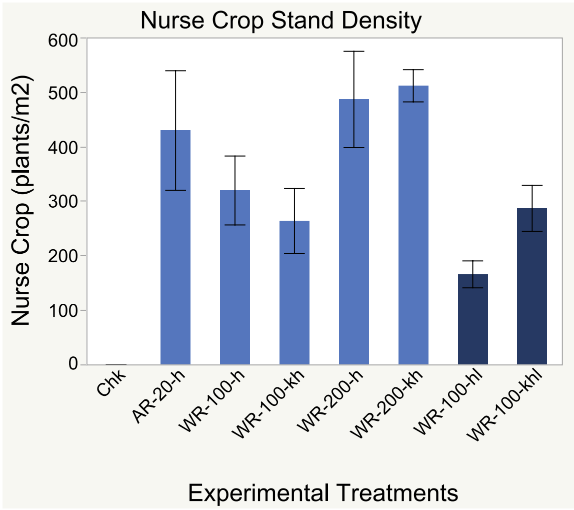

Figure 1. Nurse crop stand density

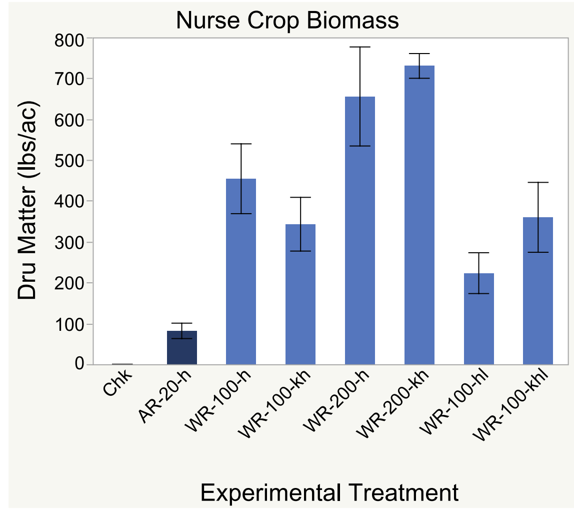

Figure 2. Nurse crop biomass at 17 DAP

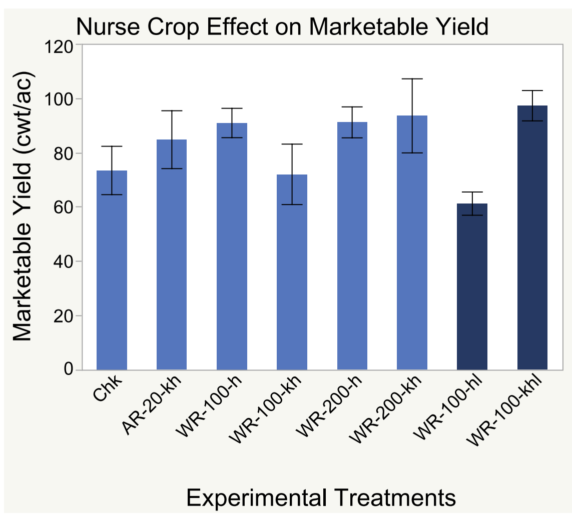

Figure 3. Marketable yield as influenced by nurse crops

Effect of Diverse Compost Products on Soil Quality and Potato Productivity

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Potato (*Solanum tuberosum* L.) is an important arable crop in New Brunswick, Canada. However, the quality of potato fields has been declining due to intensive production practices resulting in loss of soil organic matter (SOM). The addition of compost may be an effective means to rapidly increase SOM and soil quality. This study compared five compost products from a diversity of sources with a no compost control for their effects on soil quality and tuber yield. Products were fall-applied (45 Mg ha^{-1}, dry weight) to field plots in a randomized complete block design with four replicates in 2014 and 2015. Tuber yield and soil quality were assessed in 2015, after one compost application, and in 2016, after two subsequent compost applications. Compost application improved soil structure by decreasing bulk density and resistance to penetration, and increasing saturated hydraulic conductivity and gravimetric water content at field capacity. Compost application also improved soil nutrient supply, as evidenced by increased Mehlich-3 extractable soil nutrient concentrations and soil pH. All compost products significantly increased soil organic carbon concentration and increased SOM quality through increased particulate organic matter C, permanganate oxidizable C, and mineralizable C. However, there were significant differences among compost treatments. Improvements in soil properties following compost application reflected the properties of the compost product applied. In particular, the greatest soil quality improvements were observed following application of compost products with a greater C concentration. Despite improvements in soil quality, no yield effect was observed. Overall, results of this study suggest that mature compost products (e.g., C:N ratio < 30, NH_4-N:NO_3-N ratio < 3), low in ash content (*i.e.* higher in C concentration), and high in dry matter (to reduce the cost per unit of C) are most suitable for enhancing soil quality in potato production systems.

Keywords: soil quality; potato yield; compost; soil organic matter

Investigation into Causes of Yield Variability
in Prince Edward Island Potato Fields

Steve Watts, Genesis Crop Systems Inc Hampton PE

Causes of in field yield variability in potato are many and may vary from field to field. A three year study was initiated in 2013 using computer generated yield maps with the objective of identifying potential causes of yield variability in Russet Burbank processing potatoes in Prince Edward Island. Parameters under investigation include presence and level of infestation of Root Lesion Nematodes, Verticillium spp and several soil properties including soil compaction and overall soil fertility.

A summary of project results will be presented.

Development of Precision Agriculture Technologies to Improve Crop Productivity and Mitigate Environmental Risks

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Knowledge of spatial variability in soil, crop, and yield attributes can establish the basis for efficient nutrient management on an as-needed basis. Currently, crop management practices within agricultural fields are implemented uniformly with inadequate attention being given to substantial variations in soil properties, crop characterstics and yield, which not only increase cost of production but also poses a serious threat to the environemnt.

The map and sensor based precision agriculture (PA) technologies are capable of encountering these spatial variations, to allocate nutrients site-specifcally based on need. The concept of dilneating management zones (MZs) based on proper characterization and quantification of soil and crop variablity using sensors, has been proposed as a solution to more efficiently apply agricultural inputs in variable rate (VR) fashion to ensure sustainability of agricultural resources.

The geo-referenced soil and crop attributes significantly affecting the crop yield can be used to develop MZz for site-specific nutrient management. The combined approach of using sensor and map based PA technology, in conjunction with statistcal, geo-statistical and geographical information system (GIS) can aid in developing MZs without prior knowledge of productivity with the internal homogeneity and external heterogeneity. The MZs can be incorporated into the VR technology for site-specific applications to ensure economic and environmental sustainablity.

Impact of Different Forage Crops on Soil Nitrogen Cycling and on Potato Yield and Quality.

Jennifer Whittaker[1], **Judith Nyiraneza[1]**, Dave Burton[2], Bernie Zebarth[3], Vernon Rodd[1] and Yefang Jiang[1]

Charlottetown Research and Development Centre, Agricuture and Agri-Food Canada (AAFC) [1], Dalhousie University[2], Fredericton Research and Development Centre, AAFC[3]

Legumes could represent a substantial N source to the subsequent crop reducing N fertilizer requirement. When compared with legumes alone, grasses mixed with legumes could increase biomass accumulation, N acquisition and efficient N transformation. The objective of this study was to compare impacts of different forages including a legume (red clover), a grass (timothy) and a mixture of both legume and grass on subsequent potato yield and on nitrogen cycling.

The field experiment was established in 2013 at the Agriculture and Agri-Food Canada Harrington Research Farm, Prince Edward Island, Canada. The experimental design was a randomized complete block split-plot design having four replications with the main plot being three forages underseeded to barley in spring 2013.

Timothy treatment tended to be associated with lower nitrate levels in comparison with red clover or the mixture treatment and the latter treatments tended to follow a similar trend. Although lower nitrate tended to be associated with timothy treatment in comparison with red clover and the mixture of both, potato dry matter, marketable yield and total potato N uptake tended to be higher following timothy. Higher N supply than the plant N requirements can decrease potato yield and increase the residual soil N, contributing to N leaching after potato harvest. Moreover, no significant effect of N fertilization was observed on marketable potato yield implying that the soil N supply was sufficient to meet the potato N requirement without additional N fertilizer.

To meet high tuber quality and yield and to minimize nitrate leaching after potato harvest, N fertilizer rates following a legume should be adjusted to take into account legume N credit. In vulnerable agroecosystem where arable lands are connected to water bodies, including a forage grass into potato rotation could mitigate nitrate loading to groundwater while sustaining potato yield.

Biological Control of Potato Common Scab Disease by Antagonistic Strains *Bacillus* spp.

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Potato common scab (CS) is a bacterial disease caused by pathogenic *Streptomyces* spp which induce necrotic lesions on potato tubers. Tubers with more than 5% lesion coverage cannot be sold for fresh market and are difficult to use by the processing industry resulting in important economic losses to the growers. Currently, no method can efficiently control this economically important disease. The use of antagonistic bacteria has shown promises in reducing disease severity. Application of cultures of antagonistic bacteria with high cell density is important in the field to ensure their establishment and their efficacy in controlling disease. The aim of this study was to develop a biopesticide based on *Bacillus* spp that have adequate cell density, and to evaluate their capacity to inhibit pathogenic *Streptomyces* spp under field condition. Two strains of *Bacillus* spp, strains BA37 and BAQuebec, were previously shown to inhibit growth of *Streptomyces* spp in vitro and in greenhouse trials. We evaluated the growth of *Bacillus* spp strains BA37 and BAQuebec in six different media to obtain a cell density of 10^9 - 10^{10} cells/ml. Our results showed that the two strains had differences in their growth with 5.8×10^6 to 3.4×10^8cells/ml for BA37 and 1.3×10^7 to 9×10^8cells/ml for strain BAQuebec. Since we targeted a cell density of 10^9 - 10^{10} cells/ml, we further optimized the growth media by increasing the carbon source resulting in an increase of cell density to 10^{10} cells/ml for both strains. The efficacy of the *Bacillus* strains was evaluated in a naturally infested potato common scab field in the summer of 2015.The treatments included two strains of *Bacillus* spp, BA37 and BAQuebec, two different growth media, and two application strategy of the *Bacillus* spp i.e. single and multiple applications. Single application of *Bacillus* spp. was done at planting while multiple applications were done biweekly until early August. A randomized complete block design with four replicates was used. The potato cultivar Shepody was used in this trial since it is susceptible to common scab.At harvest, disease severity (percentage of lesion coverage), incidence (number of infected tubers with more than 5%) and lesion type (superficial, raised or deep-pitted) were analyzed using 40 tubers chosen randomly in each replicate at harvest time. Our field trial results suggested that both *Bacillus* strains have the ability to control common scab by decreasing the infection rate by 30-50 % under field conditions. Disease severity and incidence was not significantly different between *Bacillus* spp strains, the growth media used for the inoculum or the application strategy (single vs multiple). The same field trial was repeated in summer of 2016 using *Bacillus* spp to control potato common scab. In 2016, the efficacy of *Bacillus* spp was more variable compared to the 2015. Our results of 2016 showed that disease severity reduction was significantly different between the two *Bacillus* spp strains, the growth media used for the inoculum or the application strategy.

Analysis of QTLs for Resistance to Late Blight Disease in Canadian Potato Germplasm

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Potato late blight disease caused by oomycete pathogen *Phytophthora infestans* (Mont.) de Bary continues to be the most destructive disease in potato production worldwide. The utilization of resistant cultivars is the most desirable control measure. To decipher the genetic loci corresponding to resistance to late blight disease in the Canadian potato germplasm, an association panel of 143 lines including advanced breeding lines and commercial cultivars previously assessed for foliar (LBf) and tuber late blight (LBt) resistances was genotyped using 12K SolCAP arrays. By conducting a genome-wide association mapping, several SNPs significantly associated with the foliar late blight resistance were identified on potato chromosome 2 and 11, respectively. The significant SNPs on chromosome 2 were detected with the score of 5.74 and explained more than 14.7% phenotypic variation. The significant SNP on chromosome 11 was identified with the score of 5.82 and explained more than 5.1% phenotypic variation. The interrelationships of resistance to potato late blight with other traits such as plant vigor, maturity, specific gravity, and total yield were also deciphered by the principal component analysis (PCA). Results showed that the first four principal components (PCs) accounted for 73.7% of the observed phenotypic variation. However, LBf and LBt contributed to the PCs differently. No SNP significantly associated with LBt was identified in this association panel. Significant SNPs for LBf resistance identified in this study will be used to conduct marker-assisted selection to improve potato LBf resistance in the potato breeding program.

Genetic Interactions in Resistance to *Verticillium* Wilt

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Verticillium wilt in *Solanaceae* crops is caused by one of two fungal pathogens, *V. albo-atrum* and *V. dahliae*. Infections induce wilting and chlorosis and cause early dying that leads to reduced yields. *Verticillium* fungi are hemibiotrophic, infecting live plants through the roots and completing life cycles as a saprophyte feeding on dead plant tissue. *Verticillium* wilt disease severity was mapped to the *Ve2* resistance gene. However, *Verticillium* wilt disease severity is a complex trait and other genes are involved. Moreover, tolerance to *Verticillium* can develop where the host does not develop symptoms despite carrying high loads of pathogen. To unravel the complexities of *V. dahliae*-induced early dying, a potato diploid mapping population derived from a parent that was heterozygous for the resistance allele of the *Ve2* gene, 12120-03, and a parent that had tolerance to the pathogen and did not carry resistance alleles, 07506-01, was used to map disease severity quantitative trait loci (QTL). QTL were mapped to chromosome 5 and 9, which included loci for the *StCDF1* and *Ve2* genes, respectively. The *StCDF1* gene is involved in regulation of maturity and tuberization in potato. Genome-wide gene expression analysis was done on the foliage of the mapping population using DeepSAGE and Nanostring nCounter. The data was used for an eQTL analysis to find gene networks involved in controlling disease severity. *StSP6A* and *StSP5G* genes were found to have eQTL that were highly correlated with disease severity QTL. These genes are downstream of *StCDF1* and, *StSP6A* functions as the mobile peptide that signals maturity and tuberization, further suggesting a role for *StCDF1* in disease severity. Epistasis analysis was done and the *StCDF1* gene was found to act downstream of the *Ve2* gene. The results provide evidence that *V. dahliae* triggers natural senescence upon infection through the *StCDF1* pathway. Furthermore, it is proposed that the *Ve2* resistance gene functions to reduce activation of the *StCDF1* gene by the pathogen and that tolerance occurs when *StCDF1* carries a mutation rendering it insensitive to pathogen activation.

Identification of Potato Blackleg and Soft Rot Bacteria in Canada

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Abstract

Dickeya spp. and *Pectobacterium* spp. have caused substantial losses globally due to the emergence of new species/subspecies, and the wide spread dispersion of these pathogens which are highly virulent and pathogenic on a wide variety of hosts. Particularly in potatoes, *Dickeya* spp. and *Pectobacterium* spp. cause blackleg and blackleg-like diseases which have become increasingly problematic for seed potato production in many potato growing regions. In this report, we summarize the identification, characterization and classification of bacterial isolates of these two genera obtained from a wide range of plant hosts during the last few years. In North America, *P. atrosepticum, P.* parmentieri *(potato isolates of P. wasabiae)***,** and *P. brasiliense* were routinely detected during seed potato indexing, whereas *Dickeya* spp. were relatively rare in potato. *D. solani* has not been detected in potatoes and other plants originating in Canada. However, *Dickeya solani* was detected in hyacinth bulbs imported from overseas and is a potential threat to the local potato industry.

Research Summary

The soft rot bacteria, comprised of Dickeya spp. and *Pectobacterium* spp., are responsible for global economic losses of a wide range of crops and ornamental plants in both field and storage. While the designation, *Pectobacterium,* was originally proposed for the soft rotting enteric bacteria based on phenotypic and pathogenicity characteristics (Toth, et al 2003), it was not until the advent of genomics that the genus, *Pectobacterium*, became widely accepted based on DNA/DNA homology data (Brenner et al 1973) and 16S rRNA gene sequence analysis (Hauben et al 1998). On the other hand, Dickeya spp. (formerly *Erwinia chrysanthemi)* was initially included with the pectobacteria as *Pectobacterium chrysanthemi* (Hauben et al 1998), but its separation from other pectobacteria as a distinct 16S rRNA clade coupled with DNA/DNA hybridization data led to the proposal for a new genus, *Dickeya,* after the eminent American phytobacteriologist Robert S. Dickey, and its division into several genomic species (Samson et al 2005, Toth et al., 2011).

In our current study of dickeya/pectobacteria bacteria pathogenic to potato and other host plants in Canada, 53 bacterial isolates were identified as different *Pectobacterium* spp. using PCR with taxon-specific primers, followed by phytogenetic characterization based on selected house-keeping gene sequences. While 5 isolates were identified as *P. atrosepticum* which remained highly specific to potato, *P. brasiliense, P. parmentieri* (potato isolates of *P. wasabiae*), *P. c. carotovorum*, and *P. c. odoriferum* were isolated not only from potato, but also some other plants (Table 1). Among the 53 bacterial isolates obtained in the last three years, only two isolates from potato were identified as *D. dianthicola* and another two isolates remained unidentified. Three isolates identified as *D. solani* were isolated using an enrichment protocol from hyacinth bulbs imported from overseas. These results coincided with a previous study in that the majority of Canadian soft rot pathogens isolated from potato were *Pectobacterium* spp. while a small number were *Dickeya* spp. (De Boer et al 2012). However, importation of *Dickeya solani*-infected hyacinth bulbs from overseas remains a potential threat to the local potato industry.

Reference

1. Brenner, D. J., Fanning, G. R., Steigerwalt, A. G. 1973. Deoxyribonucleic acid relatedness among *Erwiniae* and other *Enterobacteriaceae:* the gall, wilt and dry-necrosis organisms. (Genus *Erwinia* WINSLOW et al. sensu stricto). Int. J. System. Bacteriol. 24,197-204
2. De Boer, S., Li, X., and Ward, L. J. (2012). Pectobacterium spp. associated with bacterial stem rot syndrome of potato in Canada. Phytopathology 102, 937–947.
3. Hauben, L., Moore, E.R.B., Vauterin, L., Steenackers, M. Mergaert, J., Verdonck, L., and Swings, J. 1998. Phylogenetic position of phytopathogens within the Enterobacteriaceae. System. Appl. Microbiol. 21, 384-397.
4. Nabhan, S., De Boer, S.H., Maiss, E. and Wydra, K. 2012. Taxonomic relatedness among *Pectobacterium carotovorum* subsp. *carotovorum*, *Pectobacterium carotovorum* subsp. *odoriferum* and *Pectobacterium carotovorum* subsp. *brasiliense* subsp. nov. J. Appl. Microbiol. 113: 904-913.
5. Samson, R., Legendre, J.B., Christen, R., Saux, M.F., Achouak, W., and Gardan, L. 2005. Transfer of *Pectobacterium chrysanthemi* (Burkholder *et al*. 1953) Brenner *et al*. 1973 and *Brenneria paradisiaca* to the genus *Dickeya* gen. nov. as *Dickeya chrysanthemi* comb. nov. and *Dickeya paradisiaca* comb. nov. and delineation of four novel species, *Dickeya dadantii* sp. nov., *Dickeya*

dianthicola sp. nov., *Dickeya dieffenbachiae* sp. nov. and *Dickeya zeae* sp. nov. International Journal of Systematic and Evolutionary Microbiology. 55, 1415-1427.

6. *Toth, I.K.; Bell, K.S.; Holeva, M.C.; Birch, P.R.J. 2003. Soft rot erwiniae: from genes to genomes. Molecular Plant Pathology.* ***4*** *(1): 17–30.*
7. *Toth, I.K., van der Wolf, J.M., Saddler, G., Lojkowska, E., Helias, V., Pirhonen, M., Tsror (Lahkim), L., and Elphinstone, J.G. 2011. *Dickeya* species: an emerging problem for potato production in Europe. Plant Pathology 60:385-399.

Table 1 Authentic cultures and isolates tested.

Species	Authentic Culture	Bacterial Isolates	Host Plants of the Isolates
P. atrosepticum	2	5	Potato
P. brasiliense	2	5	Potato, Leek, Zucchini
P. c. carotovorum	2	11	Potato, Rutabaga
P. wasabiae	2	0	
P. parmentieri#	2	8	Potato, Leek
P.c. odoriferum	2	2	Potato, Brussels sprouts
Undetermined Pcc##		18	Potato, Lettuce, Squash, Rutabaga
Dickeya solani	2	3	Hyacinth bulb imported from overseas
D. dianthicola	2	2	Potato
D. chrysanthemi	2	0	
D. paradisiaca	2	0	
D. zeae	1	0	
D. dadantii	3	0	
Unknown isolates		2	Potato
Total strains tested	24	53	

Potato isolates of *P. wasabiae were recently renamed Pectobacterium parmentieri .*
P. c. carotovorum and P aroiderum cannot be differentiated using the current primer set specific to P. c. carotovorum.

Field Evaluations of Pink Rot Management Using Multi Tactics

Jianjun Hao*, He Jiang, Xuemei Zhang, Nayara Marangoni, Tongling Ge.

Pink rot of potato is economically important disease in Maine. To improve the disease management, field trials were conducted at Aroostook Research Farm, Presque Isle, ME from 2014 and 2016. The studies included crop rotation, varietal screen, seed and soil treatments using biological and chemical products. Before planting in all trials, soil was infested with laboratory prepared inoculum. Three isolates of *Phytophthora erythroseptica* were incubated in mushroom spawn bags containing 6 L of vermiculite, and 3 L V8 broth for four weeks at 22°C. At planting, six liters of vermiculite inocula of P. erythroseptica were evenly hand-distributed in-furrow in each row. Fertilizer (N:P:K = 14:14:14) was applied at 1,100 lb/A. In crop rotation, two fields (A and B) were arranged. Field A was planted in the first year with potato (cv. 'Russet Norkotah') followed by rotation crops and then potato. Field B was planted in the first year with rotation crops, followed by two seasons of potato cultivation. Results showed that oat and clover were the best rotation crops for pink rot reduction, but potato rotated with either canola or alfalfa had highest yield. In variety test, cv. Snowden and Atlantic were resistant, while Dark Red Norland, Russet Norkatah, and Red Gold are more susceptible to pink rot. Some clones form breeding program also showed various levels of resistance. In soil and seed treatment, none of the biological control products showed significant reduction in pink rot when they were used alone. Presidio, Orondis were effective in reducing soil pathogen population, and Revus was effective in seed piece treatment.

A Survey of Metalaxyl-m Resistant Populations of *Phytophthora erythroseptica* in Canada and an Assessment of Pink Rot Management Strategies in Field and Storage

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Phytophthora erythroseptica is the causal agent of pink rot of potato and is ubiquitous in global potato growing regions. Pink rot is a common disease and results in a wet rot and complete tuber breakdown leading to significant yield loss under field or storage conditions. Tuber infection usually occurs via stolons, lenticels, or wounds in wet, low-lying areas prior to harvest. Superficial infections may also occur and result in pink rot development in storage or inoculate new regions via seed tubers. Traditionally, pink rot has been managed with the use of metalaxyl-m based products (Ridomil Gold®), however, in recent years metalaxyl-resistant isolates of *P. erythroseptica* have developed in the United States and Atlantic Canada signifying the need for alternative management. A national survey was established to assess the distribution of metalaxyl-resistant strains in Canada and trials were conducted to assess the efficacy of alternative fungicides to inhibit infection under field and storage conditions.

The national survey was initiated in autumn 2013 and has continued into 2016. Tubers with pink rot were collected by Canadian industry, provincial, and federal agricultural organizations and submitted to the Charlottetown Research and Development Centre. *P. erythroseptica* was isolated from the tubers and characterized for sensitivity to metalaxyl-m using V8® agar amended with 0, 1, 10, or 100 µg metalaxyl-m mL^{-1}. The isolates were rated as metalaxyl sensitive (MS), moderately metalaxyl resistant (MMR), or highly metalaxyl-resistant (MHR) based upon the concentration of chemical needed to suppress pathogen growth by 50% relative to the control. Resistant strains were recovered from Prince Edward Island, Nova Scotia, New Brunswick and for the first time in Ontario and Manitoba in 2013, and from Alberta in 2014 (Table 1).

Table 1. Summary of the total number of samples and isolates of *Phytophthora erythroseptica* collected from Canadian potato growing regions from 2013 to 2016 and the percentage of the isolates that tested sensitive or resistant to metalaxyl-m.

Province	# of Samples	# of Isolates	% Isolates MS	% Isolates MMR+MHR
Prince Edward Island	19	105	67	23
Nova Scotia	1	3	0	100
New Brunswick	22	74	51	49
Ontario	5	25	52	48
Manitoba	19	91	89	11
Alberta	17	42	95	5
British Columbia	1	3	100	0
Total	84	311	70	30

Inoculated field trials were conducted in Harrington, PEI in 2014, 2015, and 2016 to assess the ability of six fungicidal treatments to suppress infection by a metalaxyl-sensitive (PE9913) or a metalaxyl-resistant (PE1204) strain of *P. erythroseptica*. Plot rows planted with 10 seed pieces (cv. Shepody) received agar slurry inoculum applied in-furrow prior to planting. The treatments included in-furrow applications of Ridomil Gold 480SL®, Serenade SOIL®, Presidio®, Phostrol™, or Orondis®. There was also a foliar treatment of Phostrol™ (5 applications at two week intervals beginning at tuber initiation). The treatments were replicated four times and each treatment was assessed for its ability to limit infection of daughter tubers. The harvested tubers were rated for the number and mass of infected tubers and non-infected tubers for each treatment. As expected, Ridomil Gold® provided suppression of diseased caused by the sensitive strain (PE9913) but not the resistant strain (PE1204). The foliar treatment of Phostrol™ and the in-furrow treatments of Orondis® or Presidio® provided significant suppression of infection by both strains in 2014. The 2015 and 2016 growing seasons were drier than 2014, resulting in infection rates that were too low to separate treatments statistically in most instances. However, the pattern of infection remained similar to that of 2014 with higher rates of infection with treatments of Serenade SOIL and in-furrow applications of Phostrol (Figure 1).

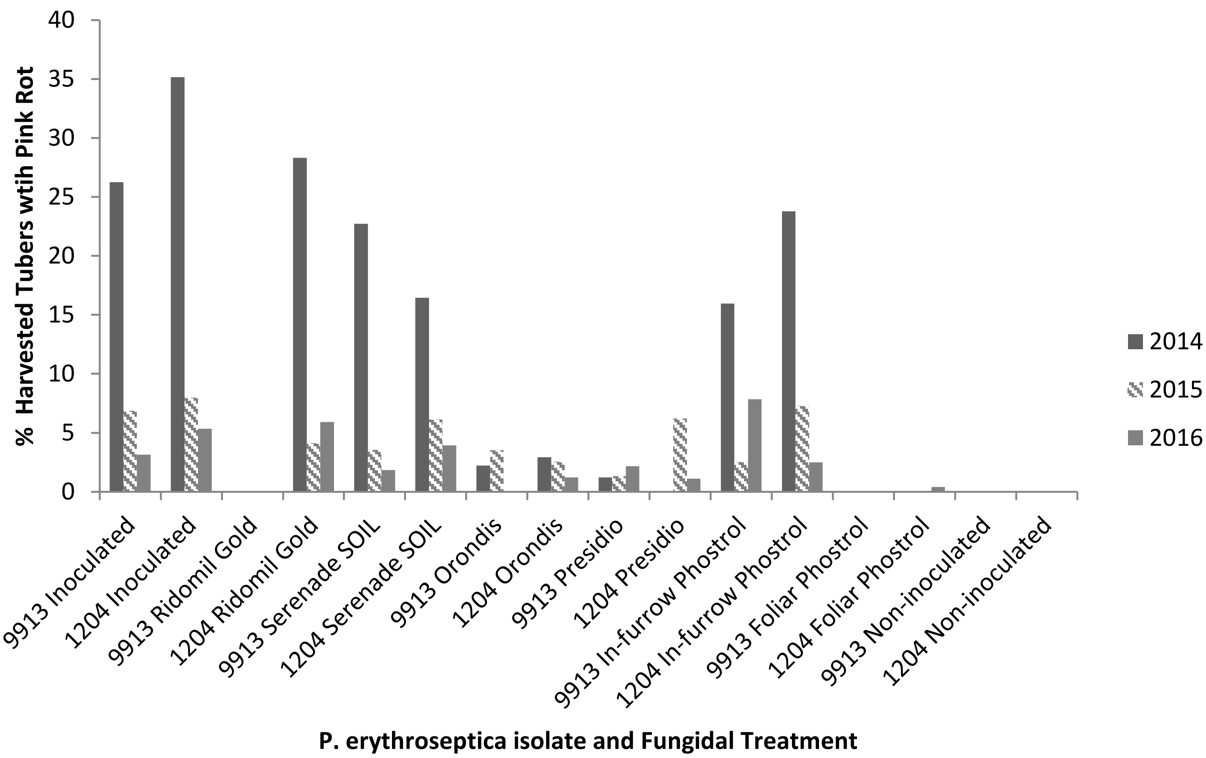

Figure 1. The percentage of daughter tubers with pink rot after inoculation at planting with a metalaxyl-m sensitive isolate (9913) or metalaxyl-m resistant isolate (1204) of *Phytophthora erythroseptica* and application of fungicidal treatments in-furrow or foliarly during the 2014 to 2016 growing seasons.

A storage trial was conducted in 2016 and 2017 to assess the ability of fungicidal treatments to prevent pink rot in storage settings, as a proof of concept only (post-harvest applications for pink rot are not currently being considered for most of these products with the exception of Phostrol™ which is already registered for such use). In each test, 10 washed Shepody tubers were inoculated with 50 mL of a *P. erythroseptica* zoospore solution (6000 spores mL^{-1}) for 1 hour and then sprayed with 8 mL of assigned chemical solution and incubated in a paper bag for 2 weeks at 18°C and 99% relative humidity. Following incubation, the tubers were rated for the number of infected tubers and the percentage of necrosis of surface and internal tissues. The treatments used in 2016 were: Phostrol™ and Serenade SOIL® applied at label rates; Orondis® and Presidio® applied at the same rate and double the rate described for the post-harvest product Stadium®. In 2017, the same treatments were used with the addition of a half rate of Orondis® and Presidio®. In the 2016 and 2017 trials, tubers treated with Orondis®, Presidio®, or Phostrol™ had significantly less infection than that of the inoculated control and were not statistically different from the non-inoculated control. In 2017, the treatment of Presidio® at the half rate had statistically more tubers infected by *P. erythroseptica* than Orondis®, Phostrol™, or the other treatments of Presidio®, but was not significantly different from Serenade SOIL®. Serenade SOIL® provided suppression of surface and internal necrosis in 2016 and 2017 as well as a reduced incidence of disease compared to the inoculated control in 2017 (Table 2).

Table 2. The percentages of the total number of inoculated tubers treated with different fungicides that developed pink rot in the 2016 and 2017 storage trials (disease incidence) and the percentage of surface and internal necrosis (disease severity) of the inoculated tubers. Means in the same column sharing the same letter are not significantly different from each other (*P < 0.05*, ANOVA and Bonferroni test, Genstat 18th Edition).

Treatment	**2016**			**2017**		
	% Tubers Infected	**Surface Necrosis %**	**Internal Necrosis %**	**% Tubers Infected**	**Surface Necrosis %**	**Internal Necrosis %**
Non-inoculated	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]
Orondis® 1/2X	*	*	*	0[a]	0[a]	0[a]
Orondis®	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]
Orondis® 2X	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]
Phostrol™	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]
Presidio® 1/2X	*	*	*	25.00[b]	9.00[ab]	8.5[ab]
Presidio®	1.25[a]	0.437[a]	0.438[a]	3.75[a]	1.44[a]	1.00[a]
Presidio® 2X	0[a]	0[a]	0[a]	10.00[a]	2.562[a]	2.38[a]
Serenade SOIL®	47.50[b]	27.437[b]	27.313[b]	26.25[b]	15.31[b]	15.56[b]
Inoculated	66.25[b]	48.5[c]	49.687[c]	82.50[c]	53.31[c]	56.00[c]

Through this research it can be concluded that metalaxyl-m resistant populations of *P. erythroseptica* are increasing in frequency and moving westward across Canadian potato growing regions. However, management of these populations and control of pink rot is possible with good cultural practices and the adoption of alternative fungicides as they become registered and available for commercial use. There is also potential to develop products for pink rot prevention in storage settings and this aspect is worth exploring further. Continued surveys to track metalaxyl-m resistance and the on-going development of new control options will aid producers with their pink rot management and help mitigate resistance development in *P. erythroseptica*.

Techniques to Reduce Common Scab in Potatoes

Gefu Wang-Pruski[1*], Robert Coffin[2], Joyce Coffin[2], Brian Beaton[3], Claudia Goyer[4]

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Researchers are looking for techniques that have limited environmental risks and can be feasibly used by potato growers to control common scab. One technique aimed at scab suppression, that is showing promise is the use of specific strains of *Bacillus* and *Pseudomonas* bacteria (biopesticides) applied in-furrow to reduce the activity of the pathogenic *Streptomyces* bacteria. Scientific research reports from Europe, along with recent reports from New Brunswick (Dr. Claudia Goyer et al., AAFC) and PEI (Dr. Robert Coffin et al., 2016) have shown encouraging results in suppression of common scab. To obtain a review of research on the use of biopesticides for suppression of common scab, please see a published abstract (Coffin et al., 2016, the use of *Bacillus* bacteria applied in furrow to reduce common scab on potatoes, Proceedings of NE Potato Tech Forum p 44-48.). Additional location-years of efficacy data is required to evaluate the performance of *Bacillus* bacteria (Microflora Pro™, Double Nickel™) to successfully become commercially available biopesticides with a label claim for control of common scab in potatoes.

The 2016 field trial was carried out at Privar Farm Inc., PEI on scab infested land. Four potato varieties with a range of susceptibility to common scab were used. They were Goldrush (resistant), Prospect (susceptible), Green Mountain (very susceptible), and Red Pontiac (very susceptible). There were two treatments in each variety, *Bacillus* bacteria (Microflora Pro) applied in furrow at 800 mL per acre and *Bacillus* bacteria (Double Nickel) applied in furrow at 800 mg/acre. Control (check plot) was included without any treatment. Four replicated plots were established with the same four varieties and treatments.

Phosphorous acid, sold as Confine, Phostrol or Rampart products is recognized as a reduced risk pesticide with a favourable environmental profile. It has been successfully used to control late blight, pink rot and silver scurf on potatoes. Dr. Gefu Wang Pruski and Dr. Rick Peters have published numerous papers on late blight control with phosphorous acid/ phosphite. The phosphorous acid treatments have two effects on the treated crop: inhibit spore germination and growth of fungal pathogens and stimulation of defence mechanisms in the potato plants. Since the products are widely used by growers in the region, its effect on common scab development on tubers of different varieties of potatoes were also investigated. The same treatments and field design were used as described above and the plots were sprayed with a phosphorous acid product 4 times during the growing season.

At harvest, tuber samples from the replicated plots were harvested and brought to Dalhousie University, Truro to assess the severity of scab development on tubers as well as perform histological assessments on development/structure of potato skins (periderm) from the different treatments. Common scab rating was achieved on every tuber by percentage of scab area, number of shallow pits, number of deep pits, and the necrotic patches (cm^2). Each variety of each treatment was subjected to suberized cell layer counting using the protocols developed in house. All data were statistically analyzed.

Cultivar differences on scab rating, shallow pits, deep pits and necrotic area are significantly different, their reactions to the treatments also showed significant variations which will be presented in details. Histological assessments on the development/structure of potato skins showed significant variations in the four varieties tested. Their changes upon each treatment is being analyzed and will be presented in details at the conference. Although there was a visible reduction of scab on tubers from the Microflora Pro and Double Nickel treatments, many of the tubers still had sufficient scab and they would not pass for premium grade table stock potatoes.

Within-row Spacing of Whole and Cut Seed Pieces for Whole Seed Production of Russet Burbank for Commercial Growing for Processing Potato

Josée Owen*, Sherry A.E. Fillmore, Sheldon Hann, Loretta Mikitzel

Processing potato is the largest horticultural export crop in Maritime Canada. Yields have been demonstrating a long-term trend of slow decline, leading to efforts to improve agronomic, environmental and economic performance of the crop. Seed management is one focus of that effort; growers are looking toward whole seed as a possibility to reduce seed bruising and fungicide use. Review of literature on whole vs cut seed production revealed a gap in knowledge about the effect of within-row spacing of Russet Burbank for whole seed production in the Canadian maritime climate. The objectives of this study were to examine four planting densities (37000, 44000, 55000 and 74000 plants ha^{-1}) of whole and cut seed on seed production agronomic traits (emergence, stems per seed, tubers per seed, tuber size distribution, prevalence of defects, specific gravity), and to subsequently store the seeds and plant them the following spring in an agronomic evaluation of their performance as planting material for commercial processing potato. Results are discussed.

Implications of Herbicide Drift to Potato Crops From Glyphosate Tolerant Soybeans and Corn

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The successful production of potato crops requires careful attention for control of weeds and numerous diseases caused by fungi, bacteria and viruses. Potato producers use a diverse range of crop protection products (pesticides) to control pests. Weed control is an essential management practice that affects the yield and profitability in all crops. The development of genetically modified (GM) varieties of soybeans, corn and canola, with tolerance to glyphosate herbicide, allows growers to spray emerged crops with glyphosate. This technology was rapidly accepted by growers and a substantial portion of these crops in North America are sprayed post emergence with Roundup^R (glyphosate) herbicide and other products containing glyphosate. Initially, this option was very effective to control numerous species of weeds in these crops. However, with the widespread and repetitive use of post emergence sprays of glyphosate herbicide, a number of weed species in some areas gradually developed resistance to the glyphosate herbicide; referred to as “super weeds”. One of the most notable was the development of glyphosate tolerant pigweed in southern USA in soybean rotations. Now, growers are very interested in new herbicide options for post emergence application to herbicide tolerant crops. Researchers are currently developing new varieties of soybeans and corn with resistance /tolerance to both glyphosate and dicamba (product name Xtend^R). Resistance/tolerance to additional herbicides such as 2,4-D have been added to varieties of soybeans, corn and cotton. Recently, modified varieties of soybeans and cotton have been developed with resistance to glyphosate, 2,4-D, and glufosinate. While the development of two way and three way tank mixes of herbicides for weed control in GM crops will help to assure good weed control, the increasing use of mixtures of post emergence herbicides, that can damage potatoes and other high value crops, is an increasing concern.

Glyphosate is a systemic herbicide. When glyphosate is applied to foliage of potato plants, it is translocated to the developing tubers. When the tubers are planted the next year, after 7-8 months of storage, the glyphosate herbicide in the tuber cells often interferes with normal cell division; hence the performance and vigour of the seed potatoes is compromised. Typical symptoms include lack of sprout growth on seed tubers, multiple stunted sprouts in each eye and stunted growth of plants. It has been confirmed in a number of studies that even minute amounts of glyphosate in potato tubers (at concentrations undetectable with normal lab assays) is enough to cause severe injury to seed potatoes. The writer has investigated a number of cases of glyphosate injury to seed, table and processing potatoes in PEI and Saskatchewan. The different situations include:

1. Western Canada - Aerial and ground spraying occurs with several herbicide products containing glyphosate to control vegetation on summer fallow land. Drift to nearby potato

fields adversely affected growth of potato plants in the same year as drift occurred; and negatively affected growth of daughter potato tubers the following year.

2. In some instances, farmers and custom pesticide applicators did not clean out sprayers (sprayer hygiene) after applying glyphosate herbicide; and then used the same sprayer to spray potatoes with other pesticides (fungicides, insecticides, herbicides).

3. Using empty Roundup^R/ Touchdown^R plastic jugs to transport water to the potato seed cutter used to cut seed tubers and apply insecticide/fungicide seed piece treatments. Even though the jugs were rinsed, there were still sufficient glyphosate residues to damage potatoes.

4. Several types of glyphosate herbicide are packed in 10 litre plastic jugs with sleeve labels or glued-on labels. Some labels became detached from the jugs and there was no permanent marking on the actual plastic jug to identify the contents. Because the jugs and the liquid contents looked similar to several insecticide products i.e. endosulfan, growers mistakenly sprayed the contents as an insecticide product. This issue was raised several times with pesticide manufacturers, with limited progress to correct the situation.

4. Spraying glyphosate tolerant corn, soybeans or canola under conditions conducive to spray drift on to nearby crops i.e. small size water droplets, excess sprayer pressure and windy conditions. Over the years extension personnel and representatives from pesticide companies stated that it was desirable to spray in calm conditions in the evening or morning. Now these so called calm conditions may not be so ideal after all. Spraying under calm conditions when the air at soil level is colder than air several feet above the crop may lead to temperature inversions, leading to movement of small spray droplets. Several excellent fact sheets on spray drift from temperature inversions are available on line from NDSU.

With substantial financial losses in potato crops due to misapplication/drift of glyphosate herbicide, different aspects of liability are being discussed by Insurance companies, pesticide manufacturing companies, government pesticide regulatory personnel and growers. Potatoes are a high value crop compared to soybeans - $300 -400 per acre for soybeans compared to $3-5,000 per acre for potatoes. Damage to fruit orchards, vineyards and blueberries, from herbicide drift, could easily exceed $10-20,000.00 per acre. One of the challenges of any investigation of glyphosate injury to potato crops is "Was it an accident or lack of due diligence "? Some custom applicators of pesticides have declined to spray glyphosate tolerant crops due to liability issues if drift occurs.

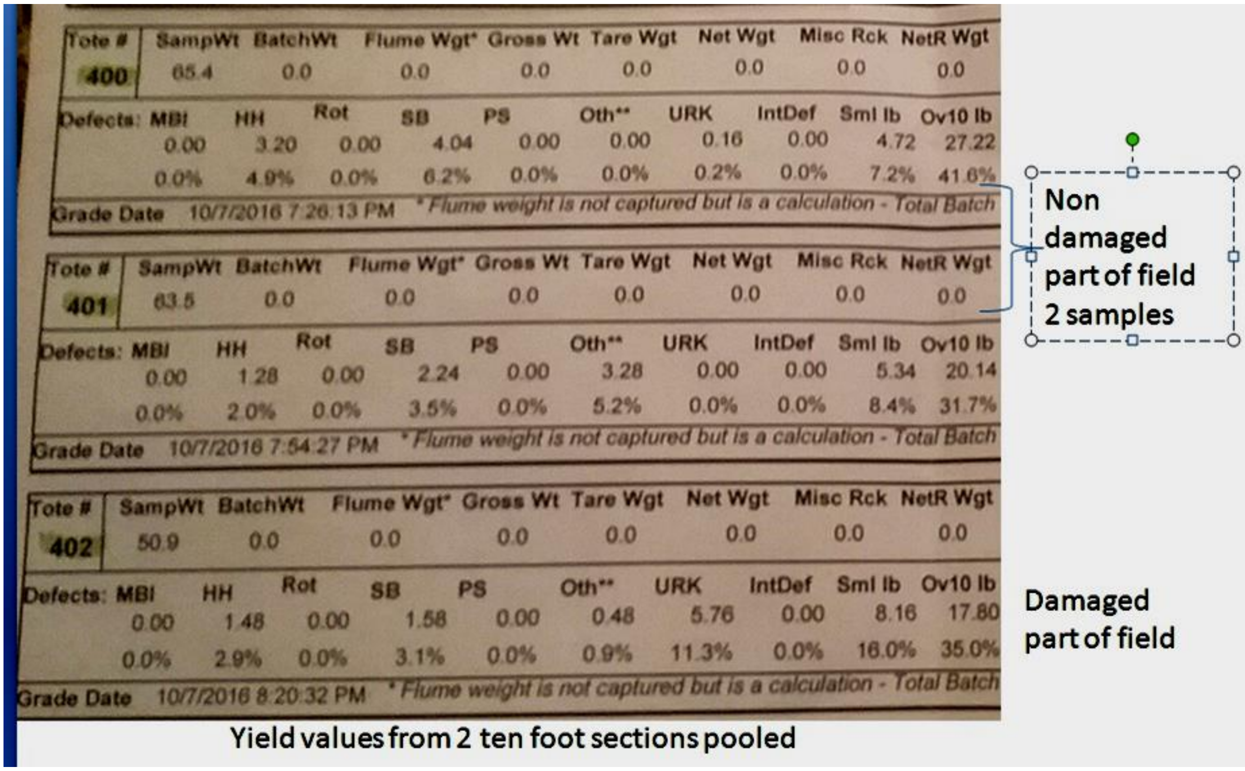
In some instances, low rates of glyphosate herbicide have drifted on to potato fields and the potato grower did not observe symptoms in potato foliage. The following year, the seed tubers were sold to different buyers. Serious complaints were received, as well as requests for compensation, due to poor growth of plants from the seed potatoes. Low rates of drift, in the same year, may only cause slight symptoms of damage (yellowing and whitening of leaf margin in younger leaves) to potato plants that may go undetected. High rates of glyphosate can severely stunt the growth of potato plants.

In cases when herbicide drift did occur, many of the symptoms on affected seed tubers the following year, were classical symptoms of glyphosate damage to potato plants and tubers; and were similar to those documented in test trials. When purchasers of non-performing seed potatoes file for financial compensation from the seed grower, who pays? In other cases, the potato grower and/or crop scouts observed symptoms of glyphosate drift on potato plants. The farmer with the herbicide damaged crop would need to verify if the damage occurred from their own farm practices or was the result of a neighbouring farmer applying glyphosate to a nearby herbicide resistant crop, under unsuitable conditions.

Many farmers purchase general farm insurance (farm liability policy) to cover a wide range of farm accidents. From investigating a number of cases of glyphosate damage to potatoes on PEI, the general pattern when glyphosate has been confirmed to have drifted on to potatoes during application to a nearby crop with glyphosate tolerance, the farmer who applied the herbicide often expects the insurance company to pay for the substantial crop loss in potatoes. If drift occurred to a potato field destined for production of seed tubers, the value of the crop could drop by 40- 50%, since the crop will need to be diverted to processing or table markets, to avoid legal issues of poor performance of the seed. Potato tubers for table or processing use often have only 50% of the value of early generation seed. At considerable cost, residue tests have been performed on tubers from affected potato crops to assure that concentrations of glyphosate in tubers did not exceed food safety standards.

In some cases, considerable drift of glyphosate occurred to potato fields, destined for processing or table use. Large losses in marketable yields occurred in the same year, due to smaller tubers, cracked tubers, mis-shaped tubers (URK –unusable rough knobs). See attached table. Weights are reported in pounds.

Note the large increase in unusable rough knobs (URK) in potatoes from the glyphosate damaged section of the field compared to non –damaged parts of the field. Also, there were more small potatoes and a lower total yield in the damaged part of the field.



Tote #	SampWt	BatchWt	Flume Wgt*	Gross Wt	Tare Wgt	Net Wgt	Misc Rck	NetR Wgt
400	65.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Defects:	MBI	HH	Rot	SB	PS	Oth**	URK	IntDef	Sml lb	Ov10 lb
	0.00	3.20	0.00	4.04	0.00	0.00	0.16	0.00	4.72	27.22
	0.0%	4.9%	0.0%	6.2%	0.0%	0.0%	0.2%	0.0%	7.2%	41.6%

Grade Date 10/7/2016 7:26:13 PM *Flume weight is not captured but is a calculation - Total Batch

Tote #	SampWt	BatchWt	Flume Wgt*	Gross Wt	Tare Wgt	Net Wgt	Misc Rck	NetR Wgt
401	63.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Defects:	MBI	HH	Rot	SB	PS	Oth**	URK	IntDef	Sml lb	Ov10 lb
	0.00	1.28	0.00	2.24	0.00	3.28	0.00	0.00	5.34	20.14
	0.0%	2.0%	0.0%	3.5%	0.0%	5.2%	0.0%	0.0%	8.4%	31.7%

Grade Date 10/7/2016 7:54:27 PM *Flume weight is not captured but is a calculation - Total Batch

Tote #	SampWt	BatchWt	Flume Wgt*	Gross Wt	Tare Wgt	Net Wgt	Misc Rck	NetR Wgt
402	50.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Defects:	MBI	HH	Rot	SB	PS	Oth**	URK	IntDef	Sml lb	Ov10 lb
	0.00	1.48	0.00	1.58	0.00	0.48	5.76	0.00	8.16	17.80
	0.0%	2.9%	0.0%	3.1%	0.0%	0.9%	11.3%	0.0%	16.0%	35.0%

Grade Date 10/7/2016 8:20:32 PM *Flume weight is not captured but is a calculation - Total Batch

Yield values from 2 ten foot sections pooled

Twenty years ago, the writer had conducted research on genetically modified (GM) potatoes, with tolerance to glyphosate. Foliar applications severely damaged and killed “regular” potato plants, but the foliage in the GM potatoes did not show any phytotoxicity symptoms. However, severe damage occurred to daughter tubers in the same year on the GM potatoes and poor growth occurred the next year when tubers were planted (glyphosate - not quite ready).

There are numerous articles on the internet addressing herbicide drift from herbicide resistant soybeans to “regular” beans; and drift of glyphosate from soybean fields to potato fields. New varieties of soybeans, with resistance to dicamba herbicide, were registered in 2016. In 2016 in southern USA, serious injury from herbicide drift occurred to thousands of acres of regular soybeans and other sensitive crops when volatile formulations of dicamba were applied to dicamba-tolerant beans. Growers had been advised to wait until less volatile formulations of dicamba became commercially available, but some growers applied regular, volatile formulations of dicamba that led to extensive drift and crop damage. Following extensive crop damage to non-target crops, investigators considered the spraying as illegal as regular dicamba was not labelled for post emergence application to soybeans. An excellent summary and photos of the situation can be found in the internet. See Eco Watch, August 2016, author Ken Rosboro**, Illegal herbicide use on GMO crops causing massive damage to fruit , vegetable and soybean farms.**

We can always learn from past experiences; and an important question is how to proceed with the use of herbicide resistant crops with minimal risk to sensitive crops and non-target vegetation. Excellent information on reducing spray drift has been presented at grower meetings, in grower magazines and on the internet. One is **Ten Dicamba Damage Takeways from Missouri** by Gil Gullickson in Successful Farming, December, 2016.   Dr. Tom Wolf spoke at the PEI Potato Technology Expo in 2016 on improving spray technology. He provided an informative guest article **The Case for Low Drift Sprays** that was published in the spring issue 2016 of PEI Potato News (publication of the PEI Potato Board). He explains the benefits of using low-drift nozzles and other practices to reduce drift of pesticides. He supports the shared value for all applicators to manage spray drift to keep unwanted pesticide products from contacting other crops and non-target aquatic, wildlife and human habitation areas. Spray drift is a concern for federal and provincial regulators, farmers and neighbouring farmers; and the general public. The following suggestions may help to reduce herbicide drift:

- Talk to neighbours about proposed cropping and spraying practices. The potato grower may decide not to grow seed potatoes in a specific field, if the soybean field next to potatoes is scheduled to be sprayed with glyphosate and/or dicamba or both herbicides.
- Use larger spray droplet size to reduce drift. Use higher volumes of water with the coarse droplets to assure weed coverage. Avoid spraying above wind speeds of 10 mph. Always check specific recommendations on the herbicide labels.
- Check with knowledgeable spray application extension specialists to obtain up-to-date information for the best type of low-drift nozzles to use and best operating pressure.
- Use low -drift spray additives to sprayer tank and low volatility forms of herbicides.
- Don't spray in dead calm due to risk of temperature inversion. See label warning.
- Under many provincial and/or state regulations, farmers who apply pesticides must take training and pass written exams. They must keep accurate written records of pesticide products applied, PCP #, rate applied, purpose, field locations and size, wind direction and speed, air temperature, starting and finishing time. This information helps in all investigations, especially when pesticide safety/regulatory personnel become involved.

Crop damage is not limited to glyphosate drift to susceptible crops. Some growers who grow herbicide tolerant varieties of crops have encountered situations where drift of post emergence herbicides and or top-killers, applied to potato fields, have drifted on to their glyphosate tolerant crops. Producers are interested in drift management options to permit different herbicide programs with minimal injury to non-target crops/areas and the natural environment.

References

Glyphosate Carryover in Seed Potato: Effects on Mother Crop and Daughter Tubers. P. J. Hutchison, J. Felix and R. Boydston. Published on line, 2014, Potato Association of America.

The Case for Low-Drift Sprays, T. Wolf, page 12-14, May-June 2016 issue of **PEI Potato News**, published on line.

The Effects of Low Levels of CIPC on Seed Potato Performance

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30 years ago, most potato growers in Maine, New Brunswick and PEI grew a small amount of seed to use on their farms. They always had one seed storage for both holding and cutting the seed prior to planting. As growers became more specialized, many converted their seed storages to processing or table storages and began using CIPC to control sprouting. Unfortunately, that left many without a specialized, CIPC-free, building where they could cut their seed. Instead, they would clean and disinfect the CIPC-treated storage before moving seed in for cutting, curing and holding the seed prior to planting. This practice has alarmed many local agronomists but, without any proof, it has been difficult to discourage the practice.

In the first two years of this study, there were visible delays of emergence and significantly lower total yields due to CIPC in the seed potatoes. In the second year the potatoes were dipped in CIPC solutions for 10 seconds then allowed to dry overnight. Rates ranged from 0 to 0.400 ppm CIPC. This year, the third of the trial, we once again dipped the potatoes in CIPC dilutions with water, at rates of 0, 0.25, 0.050, 0.100, and 0.200 ppm. All the treated potatoes were then planted on the McCain Research Farm in Greenfield, New Brunswick. We recorded emergence rates, yields, and quality. Once again emergence was delayed by CIPC, with the delay greater as the rate increased. There were also statistically significant differences in total yield, with the highest CIPC rate significantly lower than the control. In general, yield decreased as CIPC rate increased. Similar trends were seen in marketable yield, but the data has not yet been analyzed. Overall, this trial has clearly shown that even low levels of CIPC, possibly as low as 0.025 ppm or less in the tubers can reduce yield. The difference in total yield between the control and the highest CIPC rate (0.20 ppm) was 11.7% lower for Innovator and 15.9% lower for Russet Burbank.

In addition to the research trial, we also re-tested the storage that was used in the first year of the trial. After the trial the grower stopped using CIPC in the storage and steam-cleaned his storage each year before bringing seed into the building. We took the opportunity to test CIPC residue levels in the empty storage before it was filled with the processing crops. A total of nine samples were placed in three bins, with samples in the plenum and along the walls. All the samples came back below detection level. After the storage was filled we collected tuber samples from six of the bins in mid-December. Half of the samples came back with detectable CIPC, although at low levels; 0.007 – 0.011 ppm. These results suggest that steam cleaning a storage previously treated with CIPC will remove most of the CIPC from the storage. We suspect that a third year of steam cleaning will remove the final detectable traces, although this needs to be confirmed with additional testing.

Mechanical Transmission of PVY: Evidence of Virus Spread Through Field Management Activities

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Potato Virus Y (PVY) is among the most economically damaging agricultural viruses around the world, and has been a significant issue in the potato industry in New Brunswick for many years. PVY is best known to be transmitted from plant to plant by an aphid vector, or introduced to the field through contaminated seed or volunteer plants from an earlier crop season. A significant but relatively less studied route for transmission is through mechanical means. From previous research in the greenhouse setting, we have demonstrated that PVY can easily be transmitted through plant contact, specifically injury that allows transfer on infected sap from one plant to another. In 2015 and 2016, we undertook field trials to study whether mechanical transmission of PVY could actually occur in the field, and whether its extent was significant. In 2015, three commercial processing fields of variety Russet Burbank, spread widely across the potato-growing region of western New Brunswick, were selected to determine if PVY spread was greater in rows disturbed by tractor traffic compared to control rows far from tractor wheels. In both the tractor and control rows, known-PVY-infected tubers were planted at regular intervals, then PVY spread was determined by testing tubers from all plants along each row in the study area after top-kill. Averaged across all fields, tractor-rows showed 2.3 times as much PVY spread as control (low-traffic) rows, indicating a great increase in PVY spread due to management activities in the field. In 2016, we expanded the study to include more plants in each of three fields, a range of potato varieties (Goldrush, Russet Burbank and Innovator), secondary (tuber planted) PVY versus primary (artificially inoculated plants early in season) infection, and sampling in rows adjacent to those planted with infected tubers. Again, PVY transmission in tractor-rows was substantially higher than control rows, averaging nearly 5 times greater (30.6% and 6.3% respectively) in 2016. Transmission efficiency was different between the different varieties, however, with Russet Burbank showing highest transmission, perhaps due to the vining and tangled habit of growth in this variety. In both years, surprisingly, transmission of the virus was nearly equal in both directions along the rows, and not biased in the tractor travelling direction down the row as expected. One hypothesis was that the tractor traffic may be disturbing aphids and causing them to move to and infect plants in random directions. Thus, in 2016, we tested plants also in rows adjacent to the main tractor and control rows, expecting higher PVY transmission to the tractor-adjacent row if the aphid disturbance hypothesis was correct. Ultimately, however, PVY spread to adjacent rows was not significantly different in the tractor adjacent (2.7%) and control-adjacent (2.4%) rows. From our research, it is clear that tractor traffic in the field is a significant mechanism for PVY spread. Some possible techniques to minimize this mechanical spread of PVY will be discussed.

Response of Insect Pests to Potato Viruses and Mineral Oil

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Decrease in yield and quality of potato tubers caused by Colorado potato beetle defoliation and infection by aphid-transmitted Potato Virus Y (PVY) and Potato Leaf Roll Virus (PLRV) are two very important challenges encountered by commercial growers. Spraying mineral oil is a commonly used and generally effective way of decreasing virus spread within potato fields. In our studies, Colorado potato beetles chose PLRV-infected plants, which had a positive effect on beetle development, over the uninfected plants. To the contrary, PVY-infected plants, which had no detectable effect on beetle development, were less preferred compared to uninfected plants. Mineral oil had repellant and mildly insecticidal effects on the Colorado potato beetles, green peach aphids, and potato aphids. It also expedited death from infection by an entomopathogenic fungus *Beauveria bassiana* in the Colorado potato beetles.

Detection and Identification of Dickeya and Pectobacterium that Cause Blackleg and Soft Rot of Potato in Maine

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Blackleg and soft rot in potato has caused an outbread in 2015 in the Northeastern region of the U.S. To study the pathogen and its distribution, various samples were collected, including potato plant, dormant potato tubers, soil, and surface water. For isolation from plant tissues, basal stems with lesions were cut and soaked in sterile water for 5 min. The sap released from the stem were collected. For dormant tubers, stem end was cut using a cork borer and soaked in sterile water. For water samples, collected water was centrifuged for 30 min at 4,000 g, and precipitate were suspended in sterile water. The samples from different sources were plated on crystal violet pectate (CVP), and incubated at 28°C. Cavity-forming colonies were picked, transferred, and purified on tryptic soy agar (TSA). Genomic DNAs of the bacterial cultures were extracted using Mo Bio's Ultra Clean DNA purification Kit. Polymerase chain reaction was performed using species-specific primers. Representative isolates were used for pathogenicity test. For tuber inoculation, two holes were punched with a sterile pipette tip at each extremity, and filled with 20 µl of a bacterial suspension (10^8 CFU/mL). The treated tubers were incubated at 28°C for 3 days before lesion measurement. For the greenhouse assay, 4-week-old plants were punched with a syringe needle at the first node, and added with 10 µl of inoculum (10^8 CFU/mL). Both Dickeya and Pectobacterium spp. are detected from various sources. Dickeya dianthicola was the predominant species and detected frequently from symptomatic potato stems, and dormant tubers. Several samples from surface water showed positive for Dickeya spp. were pathogenic to potato, but multilocus sequence analysis showed that they were not close to any of known species of Dickeya, which needs to be further studied for taxonomy.

Genetic Mapping of Colorado Potato Beetle Resistance Metabolites in Potato

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Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is an economically important pest of cultivated potato. The adult and larvae feed voraciously on potato foliage that can significantly affect tuber yield. Applications of chemical pesticides are the common measures of CPB control, but insecticide resistant insect populations are increasing rapidly. Therefore, identification and manipulation of secondary metabolites present in potato can be developed as an alternative method of pest management. Steroidal glycoalkaloids (SGAs) are the important secondary metabolites in potato; α-solanine and α-chaconine are the most abundant SGAs in cultivated potato, while diverse kinds of SGAs have been identified in the wild relatives. SGAs have antimicrobial, antifungal and insect deterrent properties, but at higher levels they are toxic to humans and animals also. Therefore, SGAs in potato tubers for human consumption should be maintained at lower threshold (below 200 mg/ kg fresh weight) and, thus, reducing SGA levels in cultivated potato is one of the important breeding targets. Apart from abundance of SGAs, nature and composition of SGAs in potato foliage can affect CPB. For example, Leptines present in the wild species *S. chacoense* provide host resistance against CPB. Similarly, another wild species *S. oplocense* that contains dehydrocommersonine, an SGA with four sugar molecules, are less infested by CPB compared to cultivated potato. It has been found that the ratio α-solanine and dehydrocommersonine is important for CPB resistance. SGA content in potato is controlled by genetic as well as environmental factors. Thus, these compounds are metabolic phenotype for CPB resistance. We have generated potato lines by back-crossing cultivated potato (*S. tuberosum cv* shepody) with an F1 hybrid having *S. oplocense* background. Metabolic profiling of this population has been accomplished and, thus, using various SGA combinations as phenotypic data, genetic regions responsible for CPB resistance will be explored.

Development and Validation of High Resolution DNA Melting Markers Tightly Linked to Extreme Resistance to *Potato virus Y* in Tetraploid Potatoes

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Sequence analysis of the chromosome region harbouring the Ry_{sto} STS markers YES3-3A and YES3-3B in tetraploid potato cultivars 'Barbara' (*Rrrr*) and 'AC Chaleur' (*rrrr*) as well as 5 progeny selections revealed 3 sequence variants in 'Barbara' and the resistant (R) selections, and 2 variants in 'AC Chaleur' and susceptible (S) selections. Further analysis of the sequence variant ratio as well as *in-silico* PCR with YES3 primers indicates that a variant with a 21-nucleotide (nt) deletion is likely the chromosome copy harbouring the Ry_{sto}. Two primer pairs, one targeting the region containing the 21-nt deletion and the other targeting the region anchoring the YES3-3A reverse primer, were designed. As anticipated, pair one produced two visible fragments in 'Barbara'/R pool and one visible fragment in 'AC Chaleur'/S pool; pair two produced one visible fragment in all samples. When subjected to high-resolution DNA melting (HRM) analysis, two distinct melting profiles for R and S samples were observed. Analysis of 147 progenies of 'Barbara' x 'AC Chaleur' revealed 72 and 75 progenies with R and S melting profiles, respectively, which was complete consistent with YES3-3A and YES3-3B assays and phenotyping analysis. The results demonstrate the potential of HRM profiles as novel molecular markers for Ry_{sto}. The efficacy of the newly developed HRM markers for marker-assisted selection (MAS) was further validated with three populations involving 'Barbara' as the resistant parent. HRM markers offer rapid and accurate detection of potatoes carrying Ry_{sto} and can be used for high-throughput MAS in potato breeding to identify Ry_{sto}-conferred extreme resistance to *Potato virus Y*. In addition, 5 novel HRM markers linked to ER in potato clone F87084 have also been developed upon next generation sequencing analysis of a segregating population of F87084 (*Rrrr*) x F02010 (*rrrr*). The efficacy of the newly developed HRM markers for marker-assisted selection of ER to PVY is validated with different populations involving F87084.

Accumulating Evidence that Mineral Oil is Affecting the Virus – Plant Interaction

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Potato virus Y (PVY) is found worldwide and is an important concern in Canada. It is transmitted from plant to plant exclusively by aphids in a non-persistent manner and can result in important economic loss to the producers. The only reliable method known to reduce the spread of PVY in potato seed production is a weekly application of mineral oil in addition to plant “clean” tubers. While the efficacy of mineral oil was demonstrated in other countries a long time ago, mineral oil has only been available to Canadian seed potato producers for the last five years. Mineral oil is currently used to reduce the spread of PVY in seed potato fields but its mode of action is still poorly known. Improving our understanding of the mechanism of inhibition of PVY infection by mineral oil is a key component in accurately advising seed potato growers on how to efficiently use mineral oil.

To date, potato fields sprayed with mineral oil at 0 L ha^{-1} (Control), 10 L ha^{-1} (recommended dose) and 15 L ha^{-1} (variable dose) showed that mineral oil was effective in protecting potato plants against the spread of PVY without significantly affecting plant growth, canopy closure and yield. The efficacy of mineral oil was also enhanced when high doses of mineral oil were applied onto the plants. Experiments on PVY acquisition by aphids did not explain the mode of action of mineral oil. However, a strong reduction of PVY transmission by aphids as well as PVY quantity in leaves was observed under field conditions in plants that were treated with mineral oil compared to untreated plants. These results suggest that the mode of action of mineral oil is mainly linked to the effect on the interaction between PVY and the potato host plant. Therefore, we are actively investigating the impact of mineral oil on the replication and/or accumulation of the virus within plants. Using a genetically engineered virus PVY-Ros1 that induces anthocyanin accumulation to a level clearly visible to the naked eye, it seems that mineral oil reduces the number of plants that become infected. The number of leaves becoming infected is also reduced but the leaves that do become infected have a greater quantity of virus. It suggests that mineral oil is limiting virus colonization in plant by constraining the virus to few leaves.

Genomic comparison of *Pectobacterium carotovorum subsp. brasiliense* strains targeting pathogenicity related genes/loci

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Potato ranks the fourth most important human food crop. However, cultivated potatoes, like many other plants, are exposed to diverse abiotic and biotic stresses. Some of the most important bacterial pathogens of potatoes belong to the soft rot enterobacteriaceae consisting of *Dickeya* and *Pectobacterium* spp. In South Africa, *Pectobacterium carotovurum* subsp. *brasiliense* is the most widespread and aggressive soft rot enterobacterium, causing stem rot and blackleg in the field as well as tuber soft rot during postharvest storage (van der Merwe et al., 2010). As well, the global significance of *P. c. brasiliense* is growing with reports of its occurrence in countries such as Brazil, Canada, USA, New Zealand, China, and South Africa (Duarte et al., 2004; Glasner et al., 2008; van der Merwe et al., 2010; De Boer et al., 2012; Panda et al., 2012). In Canada, De Boer et al. (2012) found that Canadian isolates of *P.c*. *brasiliense* were clearly less virulent than Brazilian strains in both greenhouse and field conditions. Whether or not these differences in aggressiveness could be assigned to specific genomic differences was a major trigger for the sequencing project (Li et al. 2015).

Comparative genomics data may provide important insight into genomic differences that differentiate the highly virulent tropical strains from temperate isolates of *P. brasiliensis*. In this study, the average nucleotide identity (ANI) analysis was performed for genome-to-genome distance comparison using the method proposed by Goris et al (2007). Each pair of genomes, split into consecutive 500 bp fragments, were interegated against one another using BLASTn. For each query, the hit with the highest bit-score was selected. In total 22 available *P. brasiliense* genomes from GenBank were compared pairwise to estimate the genome-to-genome similarity. Of these 22 strains, six had higher (>98%) ANI similarity values than others (Table 1).

Table 1. Genome -to-genome distance for *P.c.brasiliense* genomes

Strains	PcbHPI01	PBR1692	LMG21371	LMG21372	BD255	ICMP19477	CFIA1001	CFIA1009	CFIA1033	YCD21	YCD29	YCD49	YCD52	YCD62	YCD64	YCD65	YCT3	YCT31	PCC21	BCD6	BCS2	YCD46	YCD60
KKH3																							
PcbHPI01	100.00%																						
PBR1692	100.00%	100.00%																					
LMG21371	100.00%	99.99%	100.00%																				
LMG21372	98.25%	98.52%	98.51%	100.00%																			
BD255	98.34%	98.37%	98.37%	98.25%	100.00%																		
ICMP19477	98.41%	98.39%	98.42%	98.54%	98.33%	100.00%																	
CFIA1001	96.01%	96.58%	96.54%	96.58%	96.01%	95.99%	100.00%																
CFIA1009	96.08%	96.68%	96.62%	96.63%	96.09%	96.08%	97.65%	100.00%															
CFIA1033	95.44%	96.07%	96.08%	96.06%	95.48%	95.43%	96.90%	96.90%	100.00%														
YCD21	96.02%	96.04%	96.56%	96.60%	95.94%	96.03%	97.57%	97.46%	96.36%	100.00%													
YCD29	95.90%	95.94%	96.47%	96.52%	95.86%	95.89%	97.61%	97.19%	96.31%	97.32%	100.00%												
YCD49	95.85%	95.88%	96.45%	96.52%	95.90%	95.82%	97.55%	97.09%	96.30%	97.24%	97.10%	100.00%											
YCD52	96.05%	96.06%	96.59%	96.60%	95.98%	96.04%	97.68%	97.66%	96.44%	97.51%	97.21%	97.17%	100.00%										
YCD62	95.99%	96.00%	96.51%	96.56%	95.89%	95.98%	97.56%	97.51%	96.37%	97.65%	97.22%	97.11%	97.51%	100.00%									
YCD64	96.05%	96.07%	96.58%	96.61%	95.99%	96.03%	97.60%	97.62%	96.43%	97.66%	97.28%	97.19%	97.61%	97.81%	100.00%								
YCD65	96.01%	96.03%	96.56%	96.60%	96.03%	95.99%	97.79%	97.36%	96.40%	97.33%	97.30%	97.20%	97.36%	97.33%	97.39%	100.00%							
YCT3	96.02%	96.06%	96.57%	96.62%	96.03%	96.02%	97.62%	97.61%	96.37%	97.58%	97.18%	97.11%	97.61%	99.07%	97.75%	97.38%	100.00%						
YCT31	95.96%	95.98%	96.51%	96.54%	95.95%	95.93%	97.57%	97.59%	96.34%	97.78%	97.22%	97.10%	97.55%	98.84%	97.79%	97.30%	98.98%	100.00%					
PCC21	95.99%	96.00%	96.55%	96.61%	95.99%	95.96%	97.72%	97.35%	96.47%	97.25%	97.16%	97.12%	97.35%	97.23%	97.33%	97.27%	97.40%	97.24%	100.00%				
BCD6	95.89%	95.85%	96.44%	96.51%	95.78%	95.83%	97.48%	97.11%	96.17%	97.13%	97.00%	97.01%	97.12%	97.10%	97.14%	97.07%	97.06%	97.05%	97.00%	100.00%			
BCS2	95.97%	95.97%	96.49%	96.55%	95.90%	95.94%	97.62%	97.26%	96.37%	97.26%	97.24%	98.08%	97.20%	97.27%	97.39%	97.34%	97.23%	97.26%	97.25%	97.11%	100.00%		
YCD46	96.02%	95.99%	96.57%	96.61%	95.96%	95.99%	97.58%	97.21%	96.35%	97.12%	97.11%	97.08%	97.20%	97.10%	97.18%	97.38%	97.12%	97.07%	97.21%	96.96%	97.13%	100.00%	
YCD60	96.09%	96.10%	96.62%	96.68%	96.09%	96.09%	97.24%	97.63%	96.38%	97.71%	97.32%	97.25%	97.54%	97.69%	97.79%	97.35%	97.71%	97.82%	97.33%	97.11%	97.31%	97.18%	100.00%

The six strains that clustered with high ANI values included known highly aggressive representatives and these also grouped together in a phylogenetic analysis based on seven concatenated loci from all pectobacterial genomes available in GenBank (Fig 1).

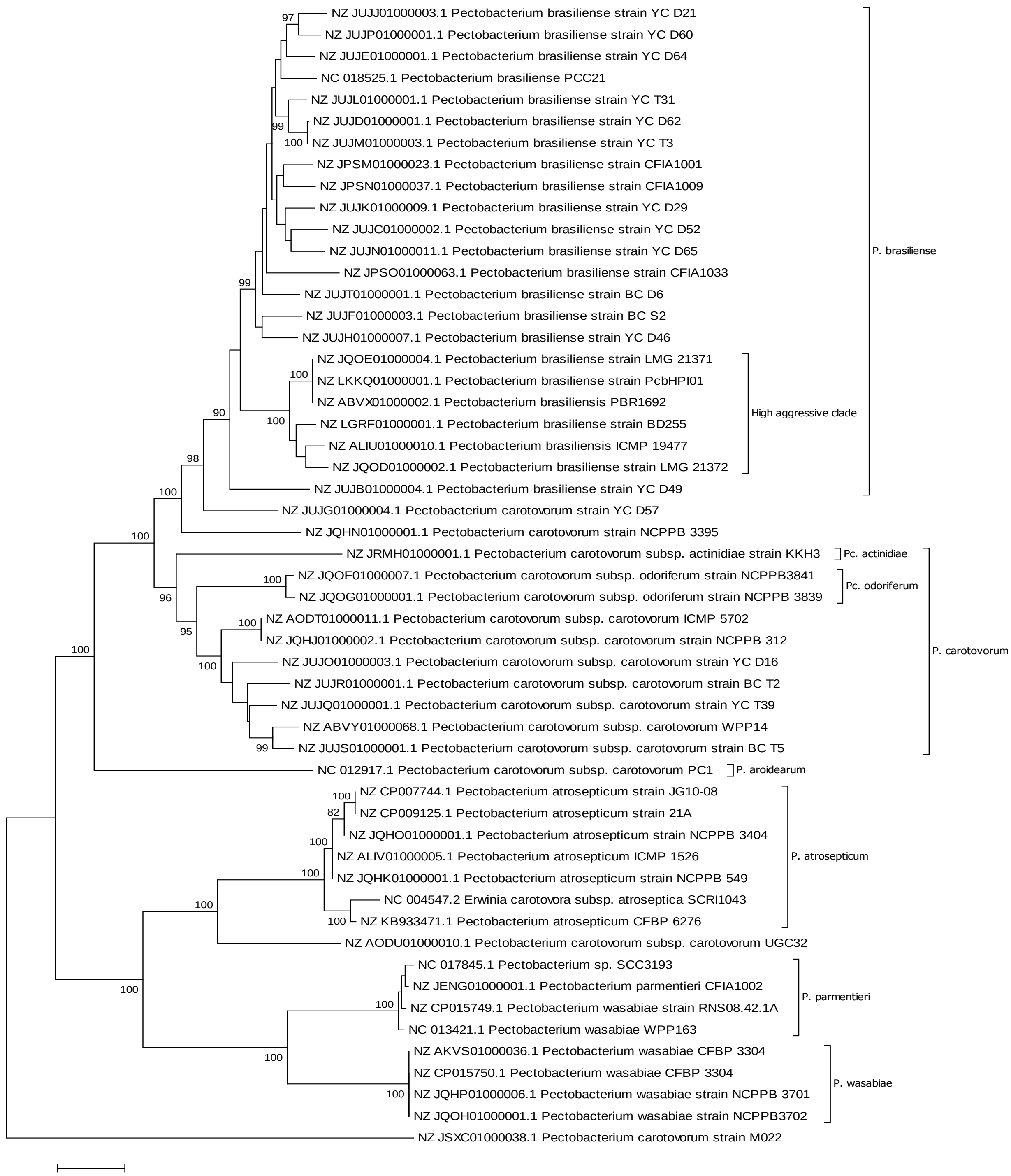

Fig 1: Phylogenetic tree of 7 concatenated loci using GRT+G model in MEGA 7.

The ANI and phylogeny analyses suggested the presence of genomic differences between the known aggressive and less aggressive strains of *P. brasiliensis*. Therefore, we compared PBR1692, a Brazilian strain representative of the highly aggressive clade, with three less virulent Canadian strains (CFIA1001, CFIA1009 and CFIA1033). Comparison was performed on function-based categories on the RAST server (Aziz et al. 2008; Overbeek et al. 2014). PBR1692 as the highly aggressive representative was used as the reference for comparison with CFIA1001, CFIA1009 and CFIA1033 to identify specific features through comparative genomic analysis. Three major deletions were identified in the three strains as shown in Fig 2.

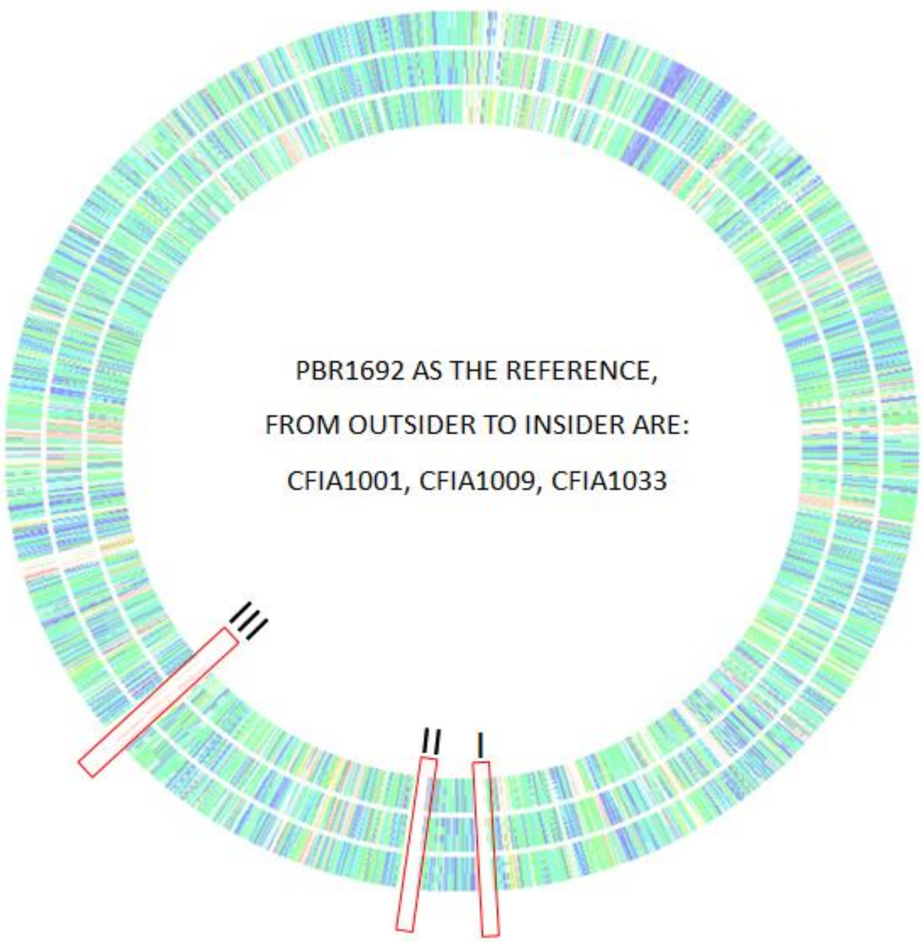

Fig 2: Function-based genomic comparison of four *P. brasilienis* genomes with PBR1692 as the reference strain. Three major deletions are highlighted in the red rectangles.

In addition to some hypothetical proteins, the three major deletions were all associated with virulence related factors. The first two identified deletions (i.e. I & II) were mainly phage-associated proteins, and the third deletion was mainly involved in other pathogenicity related mechanisms, such as the type IV secretion pathway (T4SS). As reported for *P. atrocepticum* strain Eca 1043, the T4SS appears to be more than simply an integrated conjugation machine and may function for delivery of virulence factors (Bell et al. 2004). Perhaps, the weak virulence of the three Canadian isolates of *P. brasiliense* can be directly attributed to lack of these virulence determinants in comparison with the Brazilian strain PBR1692.

References:

Aziz R.K., Bartels D., Best A.A., Dejongh M., Disz T., Edwards R.A., Formsma K., Gedes S., Glass E.M., Kubal M., Meyer F., Olsen GJ., Olson R., Osterman A.L., Overbeek R.A., Mcneil L.K., Paarmann D., Paczian T., Parrello B., Pusch G.D., Reich C., Stevens R., Vassieva O., Vonstein V., Wilke A., Zagnitko O. 2008. The RAST server: rapid annotations using subsystems technology. BMC Genomics, 9: 75.

Bell K.S., Sebaihia M., Pritchard L., Holden M.T.G., Hyman L.J., Holeva M.C., Thomson N.R., Bentley S.D., Chrucher L.J.C., Mungall K., et al. 2004. Genome sequence of the enterobacterial phytopathogen *Erwinia carotovora* subsp. *atroseptica* and characterization of virulence factors. PNAS, 101: 11105-11110.

De Boer, S., Li, X., and Ward, L. J. (2012). Pectobacterium spp. associated with bacterial stem rot syndrome of potato in Canada. Phytopathology 102, 937–947.

Duarte, V., De Boer, S. H., Ward, L. J., and Oliveira, A. M. (2004). Characterization of atypical Erwinia carotovora strains causing blackleg of potato in Brazil. J. Appl. Microbiol. 96, 535–545.

Glasner, J., Marquez-Villavicencio, M., Kim, H.-S., Jahn, C., Ma, B., Biehl, B., et al. (2008). Niche-specificity and the variable fraction of the Pectobacterium pan-genome. Mol. Plant Microbe Interact. 21, 1549–1560.

Goris J, Konstantinidis K.T, Klappenbach J.A, Coenye T, Vandamme P, Tiedje J.M. 2007. DNA-DNA hybridization values and their relationship to whole-genome sequence similarities. International Journal of Systematic and Evolutionary Microbiology, 57: 81-91.

Li X (S)., Yuan K (XL)., Cullies J., Levesque C.A., Chen W., Lewis C.T., and De Boer S.H. (2015). Draft genome sequences for Canadian isolates of *Pectobacterium carotovorum* subsp. *brasiliense* with weak virulence on potato.

Overbeek R., Olson R., Pusch G.D., Olsen G.J., Davis J.J., Disz T., Edwards R.A., Gerdes S., Parrello B., Shukla M., Vonstein V., Wattam A.R., Xia F., Stevens R.. 2014. The SEED and the rapid annotation of microbial genomes using subsystems technology (RAST). Nucleic Acids Research, 42: D206-D214.

Panda, P., Fiers, M., Armstrong, K., and Pitman, A. (2012). First report of blackleg and soft rot of potato caused by Pectobacterium carotovorum subsp. brasiliensis in New Zealand. New Dis. Rep. 26:15.

van der Merwe, J. J., Coutinho, T. A., Korsten, L., and van der Waals, J. E. (2010). Pectobacterium carotovorum subsp. brasiliensis causing blackleg on potatoes in South Africa. Eur. J. Plant Pathol. 126, 175–185.

Gene Expression Profiles for use as Bioindicators for Managing Cold-sweetening in Potato

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Cold storage (2–4 °C) used in potato production to suppress diseases and sprouting during storage can result in cold-induced sweetening (CIS), where reducing sugars accumulate in tuber issue leading to undesirable browning, production of bitter flavors, and increased levels of acrylamide with frying. Potato exhibits genetic and environmental variation in resistance to CIS. The current study profiles gene expression in post-harvest tubers before cold storage using transcriptome sequencing and identifies genes whose expression is predictive for CIS. A distance matrix for potato clones based on glucose levels after cold storage was constructed and compared to distance matrices constructed using RNA-seq gene expression data. Congruence between glucose and gene expression distance matrices was tested for each gene. Correlation between glucose and gene expression was also tested. Seventy-three genes were found that had significant p-values in the congruence and correlation tests. Twelve genes from the list of 73 genes also had a high correlation between glucose and gene expression as measured by Nanostring nCounter. The gene annotations indicated functions in protein degradation, nematode resistance, auxin transport, and gibberellin response. These 12 genes were used to build models for prediction of CIS using multiple linear regression. Nine linear models were constructed that used different combinations of the 12 genes. An F-box protein, cellulose synthase, and a putative Lax auxin transporter gene were most frequently used. The findings of this study demonstrate the utility of gene expression profiles in predictive diagnostics for severity of CIS.

1,4- SEED®: A Reversible Dormancy Enhancer and Potential Seed Production Tool

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1,4-SEED® is used as an aerosol to enhance dormancy of seed potatoes. The active ingredient is 1,4-dimethylnaphthalene (DMN) and its effects are fully reversible. It may be applied before tubers show signs of sprouting and can re-establish dormancy for seed lots that have begun peeping.

The objective of this study was to prevent seed tubers from sprouting in the spring during a 4 week pre-plant warming period.

Russet Burbank and Innovator seed tubers were treated at 7-8°C 60 days before planting with 5ppm, 10 ppm and 20 ppm DMN. The treatment barrels were sealed for 72 hours, then the vent holes on barrels were opened and the barrels were ventilated by fans inside the drums. The storage temperature was increased to 10°C 30 days before planting. Control tubers were held at 4°C (control 4C). A second control (Control 10C) was warmed to 10°C for 30 days before planting.

At planting, the tubers treated with 5 ppm DMN had very long sprouts, tubers treated with 10 ppm had sprouts that were about 2 cm long and tubers treated with 20 ppm showed no signs of sprouting, similar to the control held at 4°C.

Innovator

DMN hastened emergence somewhat and 10 ppm and 20 ppm DMN increased stem number per plant from three to five. DMN had no effect on total or marketable yield.

Yield of small tubers (<1 ⅞ inches diameter) with DMN at 20 ppm (34.8 cwt/acre) was almost twice that from the control held at 4°C (18.7 cwt/acre). DMN at 20 ppm increased the yield of tubers between 1 ⅞ inches and 8 ounces by 50.7cwt/acre. Compared with the controls, yield of >10 ounce tubers was significantly reduced with 10 and 20 ppm DMN, from 260 cwt/acre to 158 cwt/acre. Average tuber weight was reduced by 1.5 ounces with 10 and 20 ppm DMN.

Innovator produces large to very large tubers, a challenge to seed growers. DMN has the potential to reduce the yield of large tubers and shift the size profile towards more tubers of desirable seed size.

Russet Burbank

Russet Burbank responded to DMN treatment much like Innovator. DMN at 20 ppm totally stopped sprout growth before planting, increased stem number, doubled the yield of small tubers, reduced the yield of 8-10 ounce tubers and tubers greater than 10 ounces. Total and marketable yield were not affected by DMN treatment. Average tuber weight was reduced by 0.5-0.9 ounces with 20 ppm DMN treatment.

Influence of Biotic and Abiotic Factors Influencing Common Scab severity and Pathogenic *Streptomyces* spp. Populations in Agricultural Fields

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Common scab of potato was discovered more than a century ago, but there is still no reliable method to control the disease. Agricultural practices such as green manure, manure application and crop rotation to reduce common scab were evaluated in the past, however the success of these methods is highly variable from site to site. This is due to a poor understanding of the biotic (soil microbial communities) and abiotic (soil properties, macronutrients, micronutrients) factors that influence the pathogenic *Streptomyces* spp. populations. The objective of this study was to determine the biotic and abiotic factors influencing common scab severity and pathogenic *Streptomyces* spp. populations.

The experiment was carried out in 17 field sites located in 9 different locations (Quebec 2; New Brunswick 5; and Prince Edward Island 2) in Canada. Each field site consisted of three replicate plots in an area with historically relatively low severity of common scab symptoms (control) and three replicate plots in an area with historically high severity of common scab symptoms (CS infested). A common scab susceptible potato cultivar Red Pontiac was planted in each plot in May 2015. Soil samples were collected three times: at planting (May), tuberization (July) and harvest (September). Soil physico-chemical properties were measured. Field sites included sandy, loamy sand, sandy loam and loam soils. The soil texture was highly variable among sites with sand content ranging from 351 to 930 g kg $^{-1}$ and clay content ranging from 23 to 194 g kg $^{-1}$. Soil pH (1:1 water) ranged from 4.4 to 7.3.

Disease severity was assessed in potato tubers collected from experimental sites. Common scab severity varied from 7% to 70% of lesion coverage in CS infested plots while control plots had less than 5 % in lesion coverage. Soil test potassium ($r = 0.45$, $p = 0.001$), pH ($r = 0.41$, $p = 0.002$), and soil test Mg ($r = 0.41$, $p = 0.002$) were strongly positively correlated with disease severity while soil test iron ($r = - 0.40$, $p = 0.004$) and phosphorus ($r = -0.28$, $p = 0.040$) were negatively correlated with disease severity.

Diversity of soil microbial communities was evaluated by amplicon sequencing of the bacterial 16S rRNA genes and the fungal internal transcribed sequence (ITS) using the Illumina MiSeq sequencing system. Sequences were analyzed in Mothur and Qiime softwares using Ribosomal Database Project (RDP) and UNITE (Unified system for the DNA based fungal species v7) reference databases for assigning the consensus taxonomy of bacterial and fungal communities, respectively. Proteobacteria, Actinobacteria and Acidobacteria were the most dominant bacterial phyla with relative abundances of 30, 14 and 18 %, respectively, across all sites and sampling times. Low (< 10%) relative abundance was observed in other bacterial phyla including Firmicutes, Verrucomicrobia, Chloroflexi, Planctomycetes and Bacteroidetes. Bacterial alpha diversity was estimated as Shannon index. We observed that disease severity was positively significantly related to Shannon index in the CS infested plots. However, no significant relationship was observed between diversity and disease severity for control plots across sampling times. Ascomycota, Basidiomycota and Zygomycota were three dominant fungal phyla with average relative abundance of 63, 15 and 13%, respectively, when averaged among the study sites and sampling dates. Low abundance phyla were Glomeromycota (<1%) and Chytridiomycota (1.5%). Unlike bacterial diversity, fungal community diversity measured as Shannon Index was not significantly related to disease severity.

These results indicated that bacterial community diversity was correlated with common scab severity but not fungal community diversity. However further investigations will be required to determine if bacterial community diversity is a causal link explaining severity of common scab. Soil physico-chemical properties were also significantly correlated with common scab severity, which may reflect a direct effect, or an indirect effect through changes in bacterial communities.

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Soil Acidity is the Main Criterion Affecting the Critical Phosphorus Saturation in Podzolic Soils of Prince Edward Island

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In acidic soils, like those of Prince Edward Island (PEI), phosphorus (P) is highly fixed by aluminum (Al) and iron (Fe). To compensate this fixation, P fertilizers are applied in excess to the amount removed by crop. This increases the risk of P accumulation in soils and of non-point pollution. To improve P management in PEI crop productions, it is essential to develop an agri-environmental P saturation index as unifying criterion for agronomic and environmental interpretation for sustainable potato production. Our objective is to assess P environmental risk by developing an environmental model of P saturation for PEI agricultural soils using a routine laboratory Mehlich-3 (M3) soil analyses. In this study, 141 soils from various agri-pedo-climatic regions of PEI were selected. A routine soil characterization was made: organic matter, pH_{water}, pH_{SMP} and Mehlich-3 extraction (P, Al, Fe, Ca, Mg, Zn and Cu). The degree of P saturation (DPS) was determinated using the oxalate ammonium extraction procedure. A test of P desorption (P_w) using the Sissingh method was applied. Exchangeable aluminum was extracted by NH_4Cl procedure. The environmental model expressing the ratio between $[P/Al]_{M3}$ and P_w depends on the degree of soil acidity. For strong to very strong acid soils (4.5<pH<5.5), the model is expressed as follows: P_w=0.60$[P/Al]_{M3}$-1.831 (n=54; R^2=0.87; P<0.05) with an environmentally critical $[P/Al]_{M3}$ percentage of 19%, corresponding to the critical DPS value of 25% proposed in the Netherlands. For moderate acid to neutral soils (5.6<pH<7.3), the model is P_w=0.73$[P/Al]_{M3}$-0.661 (n=87; R^2=0.85; P<0.05) and the critical $[P/Al]_{M3}$ percentage is 14%.
Mehlich-3 can be used as an environmental indicator of the risk of phosphorus pollution. Soil acidity degree is a good criterion to group soils from contrasting soil types.

Incorporating Soil Health Management Practices into Viable Potato Cropping Systems

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Soil health is critical to agricultural sustainability, environmental quality, and ecosystem function, but may be degraded through agricultural production. Potato production can be particularly hard on soils due to the extensive tillage operations and intensive cropping practices used. Soil and crop management practices beneficial to soil health, such as crop rotations, cover crops and green manures, organic amendments, and reduced tillage, can help maintain or improve soil health when incorporated into potato cropping systems. Over the last several years, our lab has evaluated the effects of different management practices and cropping systems on soil health, crop productivity, and disease development, demonstrating the benefits and limitations of various strategies and practices, and how they may be implemented in potato cropping systems. A critical aspect for successful implementation and adoption is that cropping systems advancing soil health must be economically feasible and commercially viable for growers. Thus, current research is focused on how to incorporate effective soil health management practices into practical potato cropping systems.

In previous research, long-term field trials (2004-2012) featuring different potato cropping systems focused on the management goals of soil conservation, soil improvement, and disease-suppression were evaluated for their effects on crop production, soil health, and soilborne disease. These trials demonstrated the usefulness of soil health management practices in potato cropping systems, showing that a longer rotation and the use of disease-suppressive rotations, cover crops, and green manures could drastically reduce soilborne diseases and increase production, and that additions of compost could dramatically increase organic matter content, improve soil properties, fertility, and soil microbiology, and increase yield. However, these systems were designed for maximum impact of the particular management strategies, and were not necessarily designed to be the most economically practical. To follow-up and build on this research, our current cropping system study utilizes these same soil health management principles but attempts to incorporate them into existing crop production practices and develop cropping systems that maintain or improve soil health, reduce soilborne diseases, and enhance yield, but also are more practical for sustained commercial production. The modified management systems consist of: 1) Status Quo (SQ), representing a typical potato rotation in the Northeast (2-yr rotation: barley underseeded with red clover as a cover crop, followed by potato); 2) Soil Conserving (SC), with longer rotation and ryegrass as underseeded cover crop, and canola as 2nd-yr cash crop (3-yr, barley/ryegrass-canola); 3) Soil Improving (SI), with compost amendment added only once in a 3-yr period (3-yr, barley/ryegrass-canola); and 4) Disease Suppressive (DS), featuring known disease-suppressive green manures (3-yr, barley/ryegrass-mustard green manure/rapeseed cover crop). Each system was also compared to a continuous potato (non-rotation) control (PP). Study initiated in 2013, and data represents combined results from 2015 and 2016 potato seasons (after full rotation cycle).

The new modified cropping systems continued to demonstrate trends consistent with the previous trial, but with more moderate results. SI system resulted in increased potato yield (by 31% vs. SQ), higher OM (by 51%) and other nutrient contents, and higher microbial activity (represented by microbial respiration-by 42%), relative to the SQ system. The DS system also increased yield (by 15%) and increased microbial activity (by 21%) relative to SQ, and reduced black scurf by 25% and common scab by 21% relative to PP. Soil microbial community characteristics, as represented by fatty acid methyl ester (FAME) profiles were also distinctly different among the cropping systems. These results indicate that soil health management practices, such as increased rotation length, use of disease-suppressive rotation crops, cover crops, and green manures, and organic amendments, can be incorporated into potato cropping systems for improved soil properties, reduced disease, and increased yield, and that management practices can be implemented into economically viable cropping systems that may enhance sustainability, productivity, and ecosystem function. Although canola is acceptable as an additional cash crop in 3-yr rotations, there is still a need for more profitable alternative rotation crops to make the systems more economically advantageous.

Understanding the Biology of Agriotes sputator, the Dominant Wireworm Species in PEI

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Agriotes sputator, the principal insect pest species confronted by the potato and other crop industries in PEI, originated in Europe. The larval stage of this species, also known as wireworms, can cause millions of dollars of financial loss every year to the agricultural sector. Most research has focused on the development of control methods, however very little is known about the biology of this pest mainly because of its long (5 year) life cycle. To better understand the biology of this pest an intensive study was undertaken in 2016. The research results indicated that both wireworms and click beetles, the adult stage of wireworms, are phytophagous, carnivorous, and cannibalistic. Adults were found to mate multiple times and a single female can produce anywhere from 30 to 114 eggs after one mating. More than 95% eggs were produced before the beginning of the July and 90% hatch rate was recorded. A total of 5910 eggs were tracked, and the majority hatched between 17-21 days after being laid. The developmental time of newly hatched larvae indicates at least six larvae instar during the first year of development based on head capsule size. Considering the wide distribution and high adaptive capacity of this species, understanding the biology of this pest is crucial to finding control options and research in this area will continue.

Establishment of a Hydroponic System for Rapid Screening of Potato Cultivar Tolerance to Nutritional Stresses and Analysis of the Nitrogen Deficiency-induced Gene Expression in Russet Burbank Plants

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Potato cultivars vary greatly in response to nutritional stresses, such as nitrogen and phosphorus deficiencies, as indicated by variation in tuber yield or plant dry matter accumulation. Field-based screening, particularly in the case of root phenotyping, for plant tolerance to nutritional stresses can be challenging and problematic due to variation in climatic conditions and spatial heterogeneity of soil chemical and physical properties. The control of nutrients is easier in hydroponic systems compared with the field. In this study we developed a hydroponic system, and used it to investigate the varietal differences of a wide range of potato cultivars in their growth response to limited nitrogen supply.

The high-throughput recirculating hydroponic system, modified from a previous recirculating solution culture system (Sharifi et al. 2007), was built in a greenhouse at the Fredericton Research and Development Centre, Agriculture and Agri-Food Canada, Fredericton, New Brunswick, Canada. The system is consisted of 16 single channels, where each channel was 300 cm long, 5 cm high, 10 cm wide at the top and 8 cm wide at bottom. The nutrient solution was pumped from a 125-L reservoir to the inlet of the channel using a submersible pump, at a speed of 3.6 L/min. Nutrient solution drained from the opposite end of the channel, which was 2 cm lower than the inlet end of the channel, back to the reservoir. The plantlets were mounted to the hydroponic system with foam disks to support the plantlets. A 5 cm diameter plastic basket was used to hold the foam disk and was placed on the bottom of the channel. There was sufficient space below the foam disk for the plant root system to be immersed in the flowing nutrient solution. Plants grown in the same channel were provided with the same treatment solution and the concentration of the nutrient solution was maintained precisely. Potato plantlets were cultured for two weeks in a modified Hoagland's nutrient solution, with 7.5 mM nitrate as abundant nitrogen supply (Li et al. 2010) and 0.05 mM nitrate as deficient nitrogen supply (Sharifi et al. 2007; Li et al. 2010). The hydroponically-grown plants, including their roots, in this study were easy to phenotype and quantified.

We will present how plant growth of 20 cultivars responded to nitrogen deficiency. We will also describe the expression changes in expression of genes involved in regulating nitrogen uptake and metabolism in the cultivar Russet Burbank when comparing between plants grown under abundant vs deficient supply of nitrate. The knowledge learned from this study about cultivar differences in plant growth, and activity changes in nitrogen uptake and metabolic pathways in response to nitrogen deficiency can assist agronomic research, breeding, and genetic engineering to improve the nitrogen use efficiency of the potato crop.

References

Sharifi M., B.J. Zebarth, W. Coleman. 2007. Screening for Nitrogen-Use Efficiency in Potato with a Recirculating Hydroponic System. Communications in Soil Science and Plant Analysis 38:359-370

Li X.-Q., D. Sveshnikov, B.J. Zebarth, H. Tai, D. De Koeyer, P. Millard, M. Haroon, M. Singh. 2010. Detection of nitrogen sufficiency in potato plants using gene expression markers. American Journal of Potato Research 87:50-59

Identification and Functional Analyses of Heat Shock Factors of Potato in Response to Heat Stress

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Abstract Heat shock factors (Hsfs) play crucial roles in response to various stresses in living organisms. To gain insights into the mechanisms of the Hsfs adaptation to heat stress in potato, genome and transcriptome analyses of *Hsf* gene family were investigated in potato (*Solanum tuberosum*). Twenty-seven StHsf members were identified and classified into A, B and C groups via bioinformatics and phylogenetic analyses (Figure 1). The chromosomal location analysis showed that 27 *Hsfs* were located in 10 of 12 chromosomes (except chromosome 1 and chromosome 5). Expression profiles of *StHsfs* in 12 different organs and tissues uncovered distinct spatial expression patterns of these genes and their potential roles in the process of growth and development. A co-expression network between *StHsfs* and *StHsf*-co-expressed genes was generated based on the publicly-available potato transcriptomic databases and identified key candidate *StHsfs* for further functional studies.

The transcriptome analyses of potato leaves exposed to heat stress for 3 days were conducted to dissect the expression of *StHsfs* and other related genes under this relatively long-term heat stress. In total, 1421 (7%) genes showed significant differential expression. Among these genes, 771 (4%) and 649 (3%) genes were found to be over-expressed and under-expressed, respectively (Figure 2). Combined the results of transcriptome analysis and co-expression network, *Hsf003, Hsf005*, *Hsf009, sHspc*, and several *Hsp70* were selected to be the candidate genes for investigating the functional relationship between Hsfs and Hsps.

Key words heat shock transcription factors, potato, bioinformatics, heat stress, co-expression network, transcriptome analysis

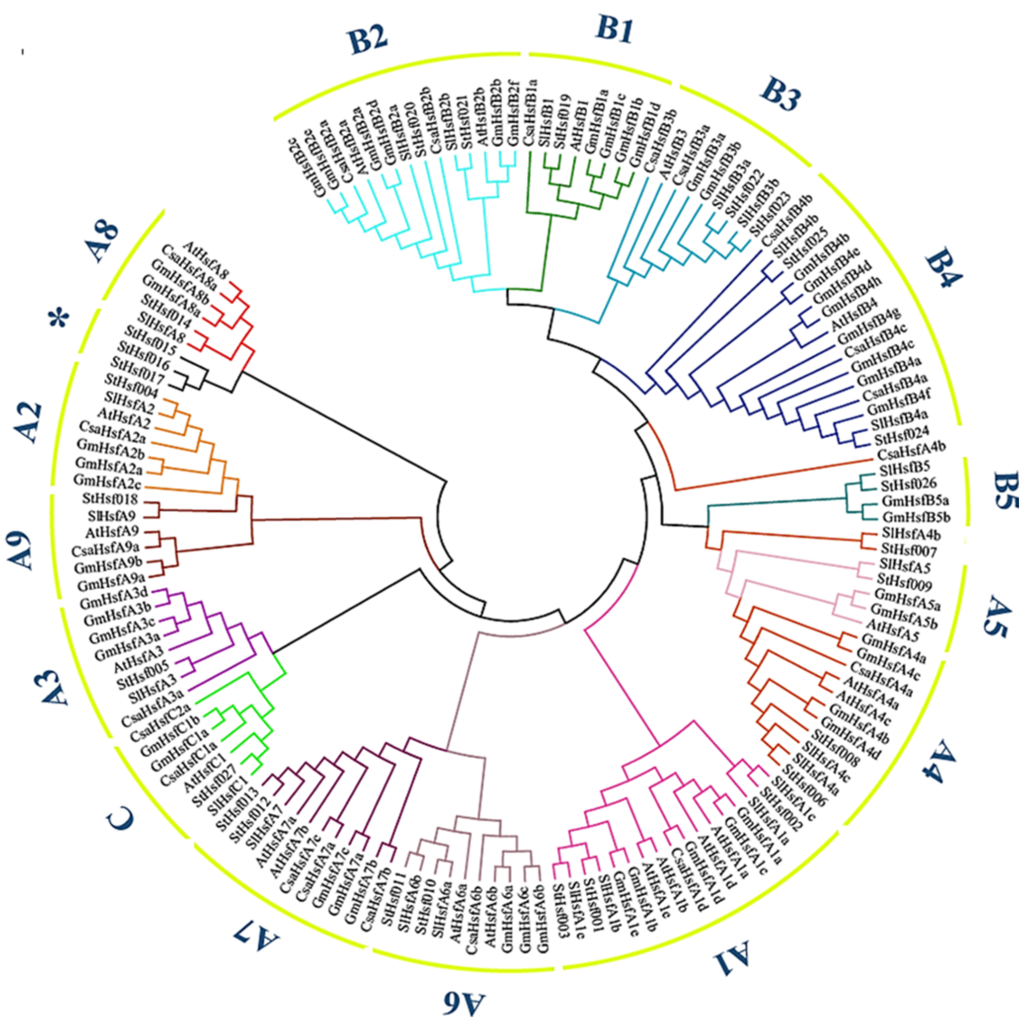

Figure 1. The Neighbor-Joining phylogenetic tree of Hsf proteins from potato, Arabidopsis, tomato, cucumber and soybean.

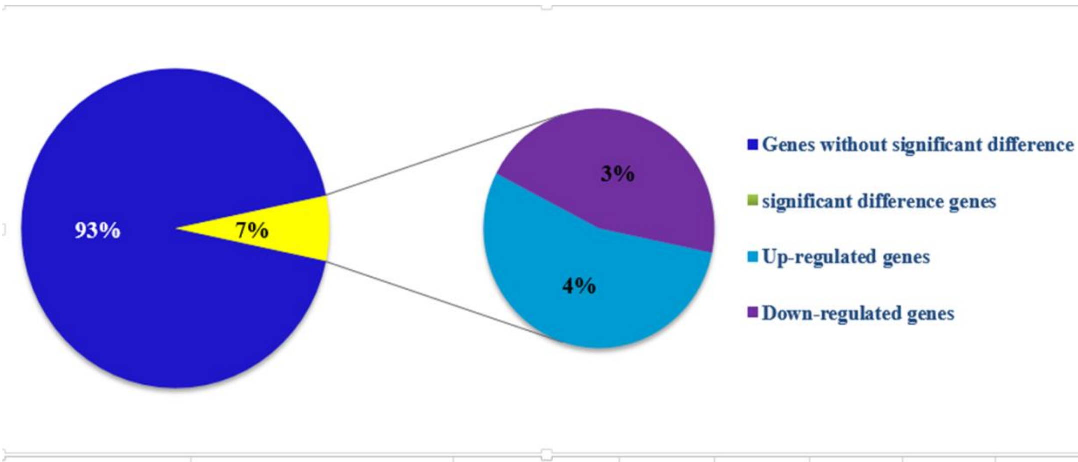

Figure 2. Percentages of up-regulated and down-regulated genes in potato leaves after three days of heat stress. Cultivar: Russet Burbank.

Comparative Analysis Between the Bud End and the Stem End of Potatoes and Between the Growing and Sprouting Stages in Dry Matter Content, Starch Granule Size, Carbohydrate Metabolic Gene Expression

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A potato tuber is a modified shoot. The bud end of the tuber corresponds to the shoot tip. Potatoes usually have the bud-end dominance in growth during tuber bulking and in tuber sprouting, using mainly the carbohydrates from the tuber stem-end. We analyzed the dry matter content, starch granule size, and carbohydrate metabolic gene expression in comparison between the bud end and the stem end and between the growing and sprouting stages of potatoes because these traits and gene activities may affect the yield, processing quality, and spout growth of tubers. Starch granule characteristics, dry matter contents, and carbohydrate metabolism at the two tuber ends may be involved in soft-end of some fries, dark-end in some fried chips, and sprout and plant early vigor of some cultivars. In this study we used potato cultivars 'Russet Burbank', 'Shepody', 'Yunshu107', and 'Yunshu505.' The tubers of 'Russet Burbank' and 'Shepody' were long, and those of 'Yunshu107' and 'Yunshu505' were round. 'Russet Burbank' and 'Shepody' tubers were analyzed at the Potato Research Centre of Agriculture and Agri-Food Canada (Fredericton, New Brunswick, Canada) and tubers of 'Yunshu107' and 'Yunshu505' were analyzed at the Gansu Agricultural University. We found the following: 1) Dry matter content was higher in the stem-end than the bud-end at both stages; 2) the bud-end starch granule size was larger in sprouting tubers than in growing tubers; 3) The bud-end of developing tubers had strong starch synthesis gene expression, which likely attracted photosynthetic sucrose; and 4) Gene expression in sprouting tubers suggested an export of carbohydrates from the stem-end to the bud-end. These changes suggest that the starch granule growth and the carbohydrate accumulation between the two ends of the tuber are not at the same speed. The gene expression for carbohydrate metabolisms was very

different between the field growing stage and the sprout growing stage of tubers despite starch accumulation at the bud-end at both stages. At the sprout emergence stage, tubers already started remobilization of resources from the stem-end to the bud-end presumably to support sprout growth. This knowledge may help develop strategies for improving tuber yield in the field, controlling sprout growth of stored potatoes, monitoring starch changes for starch-processing potatoes, and reducing stem-end darkening in fries.

References

Liu B., G. Zhang, A. Murphy, D. De Koeyer, H. Tai, B. Bizimungu, H. Si, X.-Q. Li*. 2016. Differences between the bud end and stem end of potatoes in dry matter content, starch granule size, and carbohydrate metabolic gene expression at the growing and sprouting stages. Journal of Agricultural and Food Chemistry 64:1176-1184