Northwest Potato Research Consortium
Cooperative Effort of the Potato Commissions of ID, OR, & WA

Current Projects -- Growing year 2014, Commission fiscal year 2014-15
http://nwpotatoresearch.com/

(Contact information for each scientist is listed at the end of this document.**)**

Pests and Pest Management Research

ZC/Potato Psyllid Research

Evaluation of potato insect pest management programs

Alan Schreiber (ADG, Inc.), Erik Wenninger (U of I), Silvia Rondon & Stuart Reitz (OSU), Tim Waters (WSU)

OBJECTIVES:

1. Generate efficacy data on products/programs for control of potato psyllids.
2. Examine the effects of insecticides that target potato psyllid on chemical control strategies for other insect pests.
3. Determine if potato psyllid control foments outbreaks of other insect pests.
4. Determine the effect of potato psyllid control on natural enemies.

Comparative biology of potato psyllid haplotypes and implications for Northwest potato growers

Dave Horton, Joe Munyaneza, Rodney Cooper, Kylie Swisher (USDA-ARS)

OBJECTIVES:

1. Examine overwintering biology of haplotypes.
2. Bittersweet nightshade as an alternate host.
3. Examine vector efficiency of haplotypes.
4. Develop means for visually separating haplotypes on yellow sticky cards.

Population genetics of the potato psyllid in the inland Northwest

Bill Snyder, Zhen "Daisy" Fu (WSU)

OBJECTIVES:

1. Working with the WSU core genomics facility, sequence the entire genome of a representative of a population of northwest psyllids.
2. Use the RAD-tag approach to determine relatedness among psyllids collected from potato and nightshade, across collection points in WA, OR and ID.

3. Determine whether distinct genetic groups that we have identified differ in their likelihood of carrying the zebra chip pathogen, and whether these groups exist in different parts of the inland northwest.

Quantifying effects of vector density and time of infection on ZC disease development and tuber physiology both at harvest and during storage

Erik Wenninger, Nora Olsen, Mike Thornton, Phil Nolte, Phill Wharton, Arash Rashed, Alex Karasev (U of I), Jeff Miller (Miller Research)

OBJECTIVE

Quantify effects of vector density and time of infection on ZC disease development and tuber physiology both at harvest and during storage (2014-2015).

<u>Root-Knot and other Nematode Research</u>

The impact of changes in crop rotation on nematode communities and Telone II effectiveness in potato cropping systems

Saad Hafez (U of I)

OBJECTIVES:

1. Evaluate the efficacy of onion culls and waste as a natural biofumigant for the management of root-knot nematode (2013-2016).
2. Survey nematode communities in different crop rotation systems (2013-2016)
3. Evaluate the influence of different rotation crops on the effectiveness of Telone II against Columbia root-knot nematode (2012-2016)
4. Evaluate management of Columbia root-knot, root-lesion, and stubby root nematodes using new chemistries and new numbered compounds (2013-2016)
5. Evaluate the efficacy of new green manure cultivars of mustard and oil radish for management of root-knot nematode (2013-2015)
6. Combination of green manure crops and chemical nematicides for management of root-knot nematode (2013-2016)

<u>Cyst Nematode Research</u>

Eradication strategies for *Globodera pallida*: hatching factors

Louise Marie Dandurand (U of I), Roy Navarre & Inga Zasada (USDA-ARS), Russ Ingham (OSU)

OBJECTIVES

1. Assess activity of root diffusates and partially/fully purified hatching factors (HF) from roots of potato and other non-host plants.
2. Conduct host assays of non-solanaceous plants that stimulate hatch to determine whether the plants are hosts for *G. ellingtonae* and *G. pallida*.

3. Test sources of HF (i.e. culled potatoes, waster effluent of potato) to provide commercially relevant HFs.

Functional Genomics of *Solanum sisymbriifolium* (Litchi Tomato) Immunity for PCN Eradication

Louise Marie Dandurand, Joe Kuhl (U of I), Inga Zasada & Chuck Brown (USDA-ARS)

OBJECTIVES:

1. Characterize the symptoms associated with nematode infection in litchi tomato (LT) or potato. Determine whether the defense reaction in litchi tomato is through a systemic inhibitor or through localized cell death.
2. Compare nematode gene expression in potato and litchi tomato to identify genes involved in PCN immunity in LT. Contrast gene expression in potato or litchi tomato and identify candidate genes for transfer to potato: for example genes encoding resistance proteins (R genes) and Pattern Recognition Receptor (PRR); some novel immunity genes may also be discovered.
3. Develop interspecific hybrids and production of PCN susceptible backcross progeny as a basis for identifying genes involved in resistance to *G. pallida*.

Eradication strategies for *Globodera pallida*: use of trap crops

Louise Marie Dandurand & Pam Hutchinson (U of I), Roy Navarre, Inga Zasada, Chuck Brown (USDA-ARS), Russ Ingham (OSU)

OBJECTIVES:

1. Optimize field management strategies for the PCN and Ge trap crop *S. sisymbriifolium*. Specifically, determine how to manage in-season, and kill at the termination of the growth season to prevent spread.
2. Use a recurrent selection population method to achieve a fast germinating, fast growing, slow flowering semi-sterile LT with effective pale cyst nematode eradicating properties. Select for rapid germination without gibberellic acid treatment and measure progress and heritability after one cycle of selection in an offshoot population. Determine the optimal setup for seed production with commercial bumblebee hives.
3. Quantify the effect of the selections of the potential trap crop on PCN and Ge population density.
4. Assess the efficacy of LT in infested fields.
5. Determine the relationship between G. *ellingtonae* egg density at planting and potato yield under field conditions.

Potato Virus Research

Identification of genetic determinants of tuber necrosis and virulence in recombinant PVY (PVY^{NTN})

Alex Karasev, Mohamad Chikh Ali (U of I)

OBJECTIVES:

1. Design and assemble chimeric genomes between PVY^{NTN} and genomes of other PVY isolates inducing and not inducing PTNRD, i.e. PVY^{NA-N}, PVY^{N-Wi}, PVY^{O}, and others.
2. Screen all chimeric genomes for PTNRD induction, identify genetic determinants responsible for PTNRD. Develop diagnostic tests for PTNRD determinant of PVY.
3. Screen all chimeric genomes on potato cultivars with PVY resistance genes, identify genetic determinants involved in PVY resistance. Develop diagnostic tests.

Survey of PVY strain types in PNW potato

Alex Karasev & Phil Nolte (U of I), Chris Benedict (WSU)

OBJECTIVES:

1. Collect all PVY-positive samples identified by ELISA during the winter grow-out tests, and type them to strain using our RT-PCR methodology.
2. Create a combination of maps and charts indicating distribution of PVY strains based on geography and potato cultivars, identify a pattern of distribution for ordinary strain (PVY^{O}) and necrotic strains (PVY^{NTN} and PVY^{Wi}).
3. Based on the observed patterns of PVY strain distribution, develop recommendations for the seed potato industry, focusing on elimination of recombinant PVY strains in potato cultivars.

Addressing new threats in the Northwest (PMTV)

Alex Karasev & Phil Nolte (U of I), Phil Hamm (OSU)

OBJECTIVE:

Produce PMTV-specific antisera for reliable ELISA detection of the virus in tubers.

Surveillance for PVY strain types in Washington and Oregon potato seed lot trials

Alex Karasev (U of I), Phil Hamm (OSU)

OBJECTIVES:

1. Collect all mosaic-positive samples identified during the potato seed lot trials in Washington and Oregon, and type them to strain using our ELISA and RT-PCR methodology and determine symptoms induced in tobacco since strains of PVY have been categorized in the past by the reaction on tobacco. Identify and characterize necrotic, PTNRD strains of PVY.

2. Locate origin for these necrotic PVY strains using seed lot data, and collaboratively work with certification agencies and/or specific growers to help reduce infection.

Production of virus-free potato lines and screening for PVY resistance genes in PNW cultivars

Alex Karasev & Joe Kuhl (U of I), Aymeric Goyer & Sagar Sathuvalli (OSU)

OBJECTIVES:

1. Screen the crosses between Yukon Gem X Russet Norkotah and Yukon Gem X King Edward for resistance against all five main strain groups of PVY found in Idaho (PVY^{O}, PVY^{N}, $PVY^{NA\text{-}N}$, PVY^{NTN}, $PVY^{N\text{-}Wi}$).
2. Determine the segregation ratio of HR resistance genes present in Yukon Gem on cultivar performance, when exposed to typical PNW PVY strains.
3. Identify molecular markers/genes that are associated with PVY resistance in Yukon Gem, Premier Russet, and Rio Grande that will be used by potato breeders to develop new varieties with more robust resistance to PVY for growers of the Pacific Northwest.

<u>Plant Pathology Research</u>

Managing Verticillium wilt and black dot of potato – two contributors of early dying

Dennis Johnson (WSU), Phil Hamm (OSU), Lyndon Porter (USDA-ARS), Jeff Miller (Miller Research)

OBJECTIVES:

1. Quantify infection and microsclerotia development of potato and non-potato strains of *V. dahliae* in crops potentially used in rotation with potato and of weeds associated with potato production.
2. Quantify *V. dahliae, C. coccodes* and potentially beneficial soil fungi in commercial field soil where field corn and other crop residue is and is not incorporated into soil with an Imants soil spader.
3. Determine the effects of the wild potato species, *Solanum sisymbriifolium,* and commercial sunflower on populations of *Verticillium dahliae, Colletotrichum coccodes* and the powdery scab pathogen in soil.
4. Determine the importance of cut potato seed surfaces for infection by *V. dahliae* and *C. coccodes* and the effectiveness of various soil removal and fungicide treatments in reducing the effects of *V. dahlia* infested tare dirt.
5. Evaluate the use of Vydate (oxamyl) as an alternative to metam sodium fumigation for managing Verticillium wilt and black dot.
6. Assess the efficacy of fungicides, insecticides, biologicals and nutrient treatments applied as seed treatments or in-furrow applications on the severity of Verticillium infection on Norkotah in greenhouse and field evaluations.

Managing foliar potato diseases

Jeff Miller (Miller Research)

OBJECTIVES:

1. Evaluate the efficacy of different fungicide programs against early blight, brown leaf spot, and white mold. This includes comparing the cost of the program to the economic return generated by the resulting yield and quality.
2. Determine the impact of individual fungicides and fungicide programs on the relative frequency of *Alternaria solani* (early blight) and *Alternaria alternata* (brown leaf spot).

Soil populations, aggressiveness and management of mefenoxam resistant isolates of *Pythium ultimum* causing Pythium leak in Idaho, Oregon and Washington potato production

Lyndon Porter (USDA-ARS), Phil Hamm (OSU), Phill Wharton (U of I)

OBJECTIVES:

1. Collect soil from 15 original fields in Washington, 15 fields in Oregon and 2 field in Idaho that were determined in 2006 to be infested with mefenoxam-resistant isolates of *P. ultimum*. Determine whether the population of resistant isolates has increased, decreased, remained the same or can no longer be detected. Also, collect soil from 20 new fields from Washington, Oregon and Idaho to characterize *Pythium* populations. New fields selected will include fields with known *Pythium* leak issues from 2006 to 2013. Results will be correlated with the use of mefenoxam in each field since the initial survey.
2. Assess the aggressiveness of 5 mefenoxam-resistant and 5 mefenoxam-sensitive isolates of *P. ultimum* on the five most popular potato cultivars grown in Oregon and Washington when tubers are inoculated and placed at storage temperatures of 55°F, 50°F and 45°F.
3. Determine the ability of systemic fungicides applied to manage potato late blight on the effect of these fungicides in preventing or limiting tuber infection by mefenoxam-resistant and sensitive isolates of *P. ultimum* when tubers are artificially inoculated under laboratory conditions following harvest.
4. Test and identify products with efficacy against mefenoxam-resistant *Pythium* isolates via amended agar laboratory trials.

Practical eradication of bacterial ring rot in the Pacific Northwest

Phill Wharton, Phil Nolte, Brenda Schroeder (U of I)

OBJECTIVES:

Optimization of real-time PCR assay for detection of BRR in symptomatic tuber and plant tissues, asymptomatic tuber and plant tissue and from swabs used to test surfaces for the presence of the pathogen.

Cropping Systems Research

Long term impacts of manure application on production of potato and other crops

Amber Moore (U of I)

OBJECTIVE:

Develop recommendations for optimal manure application rates and timing (annual or biennial) (few years or several years of manure application), on the basis of yield potential, tuber quality, soil quality, disease pressure, and nutrient uptake.

Breeding/Variety Development Research

Use of molecular markers to accelerate breeding of resistance to Columbia root-knot nematode

Chuck Brown (USDA-ARS)

HYPOTHESIS:

We can disrupt the connection between nematode resistance and poor tuber type by early generation of data both on resistance and horticultural performance and use these parents to produce a second and third generation of highly improved parents.

Postharvest quality of clones in the western regional potato variety development program

Rick Knowles (WSU)

OBJECTIVES:

1. Evaluate the processing quality and culinary characteristics of clones and cultivars immediately after harvest and 50 to 65 days at 44°F (7°C) and 48°F (9°C).
2. Characterize the resistance of selected clones to cold-induced sweetening by comparing reducing-sugar buildup in conjunction with fry color in non-reconditioned tubers stored at 40°F (4°C) for 50 to 65 days.
3. Assess phenotypic stability in tuber shape and storability as affected by region.
4. Quantify differences in susceptibility to blackspot bruise and soft rot.
5. Estimate differences in dormancy by evaluating the degree of sprouting in December in tubers stored at 40 and 48°F.
6. Compare the reconditioning abilities of clones from the Late Season Trials.
7. Determine the long-term (approximately 7 months) storage potential and processing. quality of clones and cultivars retained and/or advanced in the Tri-State and Regional Trials.

8. Evaluate culinary and processing attributes of red-skinned and specialty clones.

Development of molecular markers to quantify resistance gene dosage in potato

Joe Kuhl (U of I), Sagar Sathuvalli & Solomon Yilma (OSU), Rich Novy & Jonathan Whitworth (USDA-ARS)

OBJECTIVES:

The goal of this project is to develop new molecular markers for quantification of the following resistance genes, Ry^{adg}, Ry^{sto}, Ry^{-fsto}, Rx1, and Gpa2, conveying resistance to *Potato virus Y*, *Potato virus X*, and pale cyst nematode. Successful markers will determine copy number of resistance gene versions in a range of different populations.

In-field testing to identify new potato varieties and best management practices for Washington growers

Mark Pavek (WSU)

OBJECTIVES:

1. Identify and evaluate economically superior clones and cultivars for adaptability to the NW potato producing regions, particularly WA and inform the industry.
2. Conduct trials to identify best management practices for existing and recently released cultivars and inform growers.

Oregon potato breeding and variety development program

Sagar Sathuvalli, Brian Charlton, Clint Shock (OSU)

OBJECTIVES:

1. Develop efficient potato varieties for traditional fresh market, processing, chipping, and specialty enterprises.
2. Identify and incorporate genetic resistance to various production problems.
3. Develop new molecular and genome tools for use in the breeding programs.
4. Provide leadership for statewide potato breeding, genetics and genomics research and extension.

Breeding for quality, disease resistance, and yield in potato

Jeff Stark (U of I), Rich Novy & Jonathan Whitworth (USDA-ARS)

OBJECTIVES:

1. Develop multi-purpose, russeted varieties for both processing and fresh use. Other classes of varieties to be developed include single-purpose processing (e.g. solely dehydration or processing into fries), early maturing russets for fresh-pack, red-skin and yellow-flesh tablestock, and cold-sweetening resistant chippers. Characteristics of developed varieties

would include higher yield, good storage characteristics, low incidence of physiological disorders (e.g., blackspot, internal necrosis, and hollow heart), and improved genetic resistance to major pests and pathogens that negatively impact the Northwest potato industry. Enhancing the nutritional value of potato varieties is also a priority with research projects currently being conducted to increase concentrations of Vitamin C, protein, and other phytonutrients in potato.

2. Conduct associated research that will improve the efficiency of variety development. Included in this research would be: a) the use of molecular techniques, such as marker-assisted selection for PVY resistance, to speed the transfer of desirable traits to the cultivated potato, and b) the genetic analysis of traits of importance to the potato industry, such as cold-sweetening resistance and lowered acrylamide. A better understanding of the inheritance of such economically beneficial traits is critical to their rapid incorporation into a commercially acceptable variety.
3. Evaluate breeding material under typical, as well as under more severe disease conditions. Inherent in such a protocol is the continuing development of improved screening procedures for the identification of resistant individuals.
4. Investigate the nature of disease resistance, host-pathogen relationships, and various aspects of growth and reproduction of the pathogens. Improved knowledge in these critical areas hastens the identification of promising selections with genetic resistance.
5. Develop cultural management guidelines for newly released varieties to facilitate their adoption and utilization and maximize production efficiencies and profitability, along with the associated increase in sustainability.
6. Maintain seed stocks free of viruses and other pathogens for distribution to researchers and representatives of the potato industry interested in evaluating promising breeding material.

Selecting specialty potato cultivars for Idaho

Mike Thornton, Jeff Stark (U of I)

OBJECTIVES:

1. Identify and completely evaluate within Idaho growing areas Tri-state potato germplasm with specialty characteristics.
2. Cooperate with the Pacific Northwest Variety Development Program to identify specialty breeding lines with potential for release.

Nutrition/Potato Demand Research

Consumer oriented potatoes: Developing Tri-State varieties with superior appearance and nutritional value

Roy Navarre (USDA-ARS), Mike Thornton (U of I), Aymeric Goyer (OSU), Hanjo Hellmann (WSU)

OBJECTIVES:

1. Nutritional analysis of the most advanced Tri-State breeding lines, including all numbered lines that are being advanced to the market. This will include protein, vitamin C, phenolic acids, flavonols, anthocyanins, carotenoids, antioxidants, glycoalkaloids, polyphenol oxidase and potassium, iron, zinc and magnesium.
2. Determine the effect of cold storage on phytonutrients, including antioxidants, vitamin B6 and vitamin B9 in five different cultivars.
3. Determine how much variation in phytonutrients occurs in a cultivar grown at different locations.
4. Assess the effect of soil type on tuber appearance and skin color. Determine if chemical spray treatments can improve skin color and enhance phytonutrient content in select specialty potatoes.
5. Evaluate molecular and biochemical mechanisms that control tuber antioxidant content.
6. Establish dialogue with interested parties from the Northwest Potato Consortium on ways to use the tuber appearance/nutrition research for marketing and ensure the research is addressing marketing needs.

Plant Physiology Research

Effects of in-season management & stress on retention of postharvest quality

Rick Knowles (WSU)

OBJECTIVES:

1. Produce detailed growth, development and storability profiles for Teton and Owyhee Russet under four levels of in-season N, model the attainment of tuber physiological maturity (PM) and determine subsequent effects of the N levels on retention of nutritional and processing qualities during storage.
2. Screen cultivars/clones for tolerance to high temperature stress imposed during tuberization, bulking and maturation on tuber quality, postharvest physiology and storability of processing and seed potatoes (Sage, Alpine, Teton, Owyhee, Clearwater).
3. Evaluate the effects of P nutrition on retention of process quality and seed productivity (RR, RB, UR, Alpine, Sage, Teton, Alturas).

4. Characterize the effects of water stress imposed at critical periods of tuber development on postharvest physiology and retention of process quality for an array of newly released cultivars.

Storage and Tuber Physiology Research

Methods for sprout and disease suppression of potatoes in storage

Nora Olsen (U of I)

OBJECTIVES:

1. Evaluate the impact of aerosol and/or EC-CIPC applications on subsequent crop productivity of three varieties for export considerations.
2. Identify and evaluate novel chemistries as alternatives to CIPC.
3. Finalize CIPC based publications for US stewardship documentation and export negotiations.
4. Investigate early storage management temperature conditions on tuber quality response.

Storage requirements for new and "potential release" cultivars for the potato industry

Nora Olsen (U of I)

OBJECTIVES:

1. Evaluate dormancy release and sprouting characteristics for the cultivar selections at three storage temperatures.
2. Develop sugar profiles and weight loss potential for stored cultivar selections at three storage temperatures and proper sprout control.
3. Evaluate storage dry rot susceptibility of the different cultivars.
4. Observe and note overall storability of the cultivar.

Northwest Potato Research Consortium
Cooperative Effort of the Potato Commissions of ID, OR, & WA

Funded Scientists: Growing year 2014, Commission fiscal year 2014-15

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Annual Progress Report

TITLE: Evaluation of Potato Insect Pest Management Programs

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REPORTING PERIOD: July 1, 2014 – January 15, 2015 (2014 Growing Season)

ACCOMPLISHMENTS:

Our objectives for this project were the following: 1) Generate efficacy data on products/programs for control of potato psyllids. 2) Examine the effects of insecticides that target potato psyllid on chemical control strategies for other insect pests. 3) Determine if potato psyllid control foments outbreaks of other insect pests. 4) Determine the effect of potato psyllid control on natural enemies of insect pests of potato.

We evaluated nine different insecticides, each with a different mode of action, at five locations throughout the Pacific Northwest. The insects monitored and reported differed slightly among locations because of local variation in the make-up of species. During 2014, overall insect pressure at all sites was very low. Air temperatures were well above average at all of the sites during the month of July and the first part of August (Figure 1 A-E). It is likely that these high air temperatures were detrimental to significant development of several pest insects that would typically be increasing during that time period, specifically, potato psyllid. A more typical growing season would likely have resulted in higher pest insect densities to evaluate. The 2014 season did allow the Pacific Northwest Potato Entomology group an opportunity to work together on a large scale efficacy trial. This collaboration was strong, and the group was able to conduct the experiment in an efficient manner, which should be replicable in coming years if funding is procured.

RESULTS: Pasco, WA – Foliar Applications.

Tables 1 and 2 denote the seasonal means for the different pest and beneficial insects by treatment for the trial in Pasco. Seasonal means are used in an attempt to summarize and simplify the large data set that resulted from this project. Both pest and beneficial insect densities were extremely low during the season. The only species that occurred in high enough densities to evaluate and demonstrated statistically significant differences for the various treatments was

Colorado potato beetle. AgriMek (abamectin) and Exirel (cyazypyr) were the most effective treatments for Colorado potato beetle while Transform (sulfloxyfor) and Aza-Direct (azadiractin) were the least effective for the season long summaries (Table 1). During one sampling period (8/25/2014), Agri-Mek, Exirel, and Torac (Tolfenpyrad) all significantly reduced Colorado Potato beetle larvae populations compared to the other trial treatments and the untreated check (Data not shown in table).

Potato psyllid adults were significantly higher in the Sivanto (flupyradifurone)-treated plots on 9/12/2014 compared to all other treatments (Data not shown in table). The populations of potato psyllid during this sampling period were still quite low, so further experiments should be conducted to see if this trend is valid.

Table 3 lists the tuber yield and quality for the different insecticide treatments. No significant differences were detected among trial treatments. Almost all treated plots had numerically higher yields, but were not statistically significant. This is not surprising with the extremely low insect pressure that was encountered in Pasco during the 2014 growing season. In the coming season, we will continue to take yield and quality data as it is a critical component for producers to understand how insecticide efficacy can impact profitability.

RESULTS: Central Columbia Basin – Multiple application methods

At the Central Columbia Basin site (northern Franklin County), the same treatments were applied by ground (CO_2 backpack sprayer), by chemigation and by simulated aerial application (5 gallons of water by ground). Plot sizes, variety, crop maintenance and other aspects of the trial were kept as similar as possible. Treatments by method of application were kept separate, but were in close proximity to each other (all on the same six acre block) but far enough apart to prevent drift.

Simulated Aerial Applications. At the Central Columbia Basin site, applications started at the first detection of potato psyllid, which was on August 20th, as opposed to July 6th in 2013. Throughout the season, psyllid pressure was very low as it was for other potato insect pests (Table 4). This location had very high psyllid pressure the previous year. Over the course of the season, the mean number of psyllid eggs and nymphs collected per 10 leaves in the untreated check was a single egg and 1.8 nymphs. No adults were detected in the untreated check at any point during this trial. Comparably low numbers were counted for whiteflies, aphids and thrips. Practically no beneficial insects were collected during the trial, presumably due to the low numbers of pestiferous insects.

Chemigation Applications. At the Central Columbia Basin site, applications by chemigation started on August 21st. Throughout the season, psyllid pressure was very low as it was for other potato insect pests (Table 5). This location had very high psyllid pressure the previous year. Over the course of the season, the mean number of psyllid eggs and nymphs collected per 10 leaves in the untreated check was 1.8 and 1.0 nymphs. An average of 0.5 adults was collect by vacuum samples per treatment over the course of the trial. Comparably low numbers were counted for whiteflies, aphids and thrips. Practically no beneficial insects were collected during the trial, presumably due to the low numbers of pestiferous insects.

Ground Application. At the Central Columbia Basin site, applications by ground started on August 22nd. Throughout the season, psyllid pressure was very low as it was for other potato insect pests (Table 6). This location had very high psyllid pressure the previous year. Over the course of the season, the mean number of psyllid eggs and nymphs collected per 10 leaves in the untreated check was 3.0 and 0.5 nymphs. Almost no adults were collected by vacuum samples per treatment over the course of the trial. Comparably low numbers were counted for whiteflies, aphids and thrips. Practically no beneficial insects were collected during the trial, presumably due to the low numbers of pestiferous insects.

Conclusions. The combination of these three trials required a significant investment of resources and time and it is very disappointing that pressure was so uniformly low throughout the course of the trial and across the diversity of insect pest and beneficial species involved. As much as the trialists would like to draw conclusions from this set of trial, one cannot make informed decisions on comparative efficacy of products or on the comparative effectiveness of method of application due to the low pest pressure.

RESULTS: Hermiston, OR – Foliar Applications.

Few potato psyllids or other potato pests were found in the Hermiston trial. Over the course of the season, the mean number of psyllid eggs and nymphs collected per 10 leaves in the untreated check were < 0.1 per 10 leaves (Table 7). Only a seasonal mean of 0.35 adults was collected by vacuum samples per treatment. Few beneficial insects were collected during the trial, possibly because of the low numbers of pests present (Table 8).

RESULTS: Ontario, OR – Foliar Applications.

Tables 9 and 10 denote the seasonal means and analyses for the different pest and beneficial insects by treatment for the trial in Ontario, OR. Six biweekly applications were made in the trial. Few potato psyllid adults were collected in this trial, and no significant differences among numbers of adult potato psyllids were found among the treatments. However, there were significant differences among treatments in the mean numbers of potato psyllid nymphs and eggs. Brigade (bifenthrin), Sivanto (flupyradifurone), Beleaf (flonicamid), Movento (spirotetramat), and Exirel were most effective in controlling immature stages of the potato psyllid (Table 4).

However, numbers of thrips (predominantly western flower thrips) were significantly higher in the Brigade treatment than in any of the other treatments. Brigade and Sivanto tended to be detrimental to most natural enemies (Table 5). Beleaf, Exirel and Movento were not harmful to beneficials, except for lacewings.

Tubers were inspected for visual symptoms of Zebra Chip, but no symptomatic tubers were found.

RESULTS: Kimberly, ID – Foliar Applications.

Tables 11 and 12 show the seasonal means and analyses for responses of different pest and beneficial insects by treatment for the trial in Kimberly, ID. Few adult potato psyllids were found and no immature potato psyllids were found in the plots; no significant differences were observed among treatments for the adults found. Zebra chip symptoms in tubers was extremely low and did not differ among treatments. Similarly, low numbers of aphids were found across plots, and no significant differences among treatments were observed. In contrast to other pests observed, Colorado potato beetles (recorded on 23 Jul and 11 Aug) were high enough to make meaningful comparisons among treatments. Counts of larvae were lower than the untreated check in all treatments except Aza-Direct, Beleaf, and Sivanto (though counts were numerically lower than the check for all of these treatments). Adult potato beetles were significantly lower than the check for the two treatments that featured Agri-mek; no other treatments differed from the untreated check in regard to adult counts. Defoliation ratings were lower than the check for all treatments except Beleaf.

A diverse complex of natural enemies was observed across the plots; however, differences among treatments (for individual groups of beneficials or for all beneficials together) were not statistically significant.

Differences were observed among treatments in regard to tuber yield, most notably for total yield (Table 13). Yield was lowest for the check, though the yield for the Aza-Direct- and Beleaf-treated plots did not differ from the check. Yields among all other treatments did not differ among each other, though yields of the two treatments featuring Agri-mek were significantly higher than both the check and the Aza-Direct and Beleaf treatments. Differences among treatments in regard to yield appeared to mirror somewhat the differences in potato beetle infestations.

PUBLICATIONS:

No publications have resulted from this work to date. It is anticipated that these data will contribute to the PNW Insect Management Recommendations for Potatoes that are annually revised by Schreiber et al. and could be published in Arthropod Management Tests.

PRESENTATIONS:

No presentations have been made to date, but project data will be shared at several grower meetings during January and February of 2015 by Waters and Reitz.

Table 1. Seasonal means for pest insects sampled by vacuum and leaf collections for all treatments at Pasco, WA. Means with different letters are significantly different from one another (p=.05 Student-Newman-Keuls test).

Insect	Psyllid Adult	Psyllid Nymph	Wingless Aphid	Winged Aphid	Wingless Aphid	Winged Aphid	CPB larvae	CPB Larvae	CPB adult	Leafhopper nymph	Lygus nymph	Lygus nymph
Sample Type	Vacuum	Leaf	Vacuum	Vacuum	Leaf	Leaf	Vacuum	Leaf	Leaf	Vacuum	Vacuum	Leaf
Treatment												
1 UTC	0.10a	0.30a	1.50a	11.50a	3.30a	5.60a	10.40ab	5.30a	0.70a	4.20a	31.00a	0.40a
2 Abamectin & Movento	0.60a	0.10a	0.40a	8.80a	4.80a	2.00a	13.50ab	1.20a	0.10a	5.00a	32.00a	0.60a
3 Abamectin	0.10a	0.20a	1.80a	4.80a	4.50a	1.90a	4.90b	5.90a	0.10a	6.80a	23.30a	1.70a
4 Exirel	0.00a	0.00a	0.50a	7.30a	3.50a	1.50a	5.10b	3.10a	0.10a	6.50a	29.30a	0.20a
5 Transform	0.00a	0.10a	2.60a	5.50a	3.50a	3.10a	19.80a	2.60a	0.30a	5.60a	26.50a	0.80a
6 Aza-Direct	0.10a	0.40a	0.10a	3.50a	3.50a	1.80a	19.10a	0.80a	0.10a	6.50a	27.50a	2.40a
7 Beleaf	0.60a	0.20a	0.50a	8.00a	1.50a	1.80a	8.00ab	2.40a	0.30a	6.30a	25.50a	0.10a
8 Brigade	0.10a	0.10a	0.70a	6.30a	5.00a	2.90a	9.80ab	2.10a	0.00a	6.70a	23.50a	2.50a
9 Torac	0.20a	0.30a	0.10a	12.50a	3.00a	3.20a	11.80ab	1.70a	0.10a	6.80a	27.80a	0.20a
10 Sivanto	0.10a	0.40a	0.40a	10.00a	2.50a	1.00a	9.40ab	4.80a	0.00a	8.30a	27.00a	0.40a

Table 2. Seasonal means for beneficial insects sampled by vacuum and leaf for all treatments Pasco, WA. Means with different letters are significantly different from one another (p=.05 Student-Newman-Keuls test).

Insect	Big Eyed Bug	Big Eyed Bug	Nabid Bug
Sample Type	Vacuum	Leaf	Leaf
Treatment			
1 UTC	16.70a	0.70a	0.00a
2 Abamectin & Movento	19.20a	0.30a	0.00a
3 Abamectin	13.10a	0.40a	0.00a
4 Exirel	15.10a	0.00a	0.30a
5 Transform	11.90a	0.10a	0.30a
6 Aza-Direct	17.70a	1.80a	0.80a
7 Beleaf	18.90a	0.10a	0.00a
8 Brigade	15.60a	0.50a	0.30a
9 Torac	17.60a	0.90a	0.50a
10 Sivanto	18.30a	0.10a	0.80a

Table 3. Total yield, US #1 grade, and culls in tons per acre by treatment Pasco, WA. Means with different letters are significantly different from one another (p=.05 Student-Newman-Keuls test).

Treatment	Total Yield Ton/A	US #1 Ton/A	Cull Ton/A
1 UTC	25.90a	21.28a	2.30a
2 Abamectin & Movento	28.10a	23.10a	2.40a
3 Abamectin	25.40a	18.20a	2.90a
4 Exirel	33.20a	26.65a	1.90a
5 Transform	32.40a	25.13a	3.70a
6 Aza-Direct	26.10a	23.00a	1.30a
7 Beleaf	34.20a	24.50a	2.80a
8 Brigade	31.50a	26.73a	1.50a
9 Torac	31.40a	25.18a	1.90a
10 Sivanto	28.20a	20.80a	2.70a

Table 4. Seasonal means for pest insects sampled by vacuum and leaf collections for all treatments in the Central Columbia Basin, using a simulated aerial application.

Trt No.	Treatment Name	Rate	Rate Unit	# of Appl.	Psyllid Egg	Psyllid Nymph	Psyllid Adult	Whitefly Egg	Whitefly Nymph	Aphid	Thrips
1	Untreated Check				1.0 a	1.8 a	0.0 a	0.0 a	0.5 b	0.5 b	3.8 a
2	Agri-Mek	6	fl oz/a	A	0.8 a	0.8 a	0.3 a	0.8 a	14.3 a	2.3 ab	7.3 a
	Movento	5	fl oz/a	AB							
3	Agri-Mek	6	fl oz/a	ABC	1.0 a	0.3 a	0.0 a	0.8 a	5.8 ab	2.5 ab	6.5 a
4	Exirel	0.088	lb ai/a	ABC	0.0 a	0.0 a	0.0 a	0.3 a	8.5 ab	2.3 ab	2.3 a
5	Blackhawk	3.5	oz wt/a	ABC	6.5 a	0.0 a	0.0 a	1.0 a	10.3 ab	3.5 a	5.5 a
6	Aza-Direct	1.5	pt/a	ABC	2.8 a	1.5 a	0.0 a	0.3 a	5.3 ab	4.0 a	7.5 a
7	Sivanto	10.5	fl oz/a	ABC	4.5 a	0.0 a	0.0 a	0.0 a	1.5 b	0.5 b	3.8 a
8	Brigade	6.4	fl oz/a	ABC	0.3 a	0.5 a	0.0 a	0.8 a	5.5 ab	0.5 b	6.3 a
9	Torac	21	fl oz/a	ABC	2.5 a	1.5 a	0.0 a	0.0 a	3.8 ab	0.5 b	1.0 a
10	Beleaf	2.8	oz wt/a	ABC	1.8 a	0.0 a	0.0 a	0.3 a	2.3 b	0.5 b	2.8 a
Standard Deviation					4.07	1.46	0.16	0.84	7.05	1.69	4.36
Replicate F					1.726	2.099	1.000	0.660	1.099	0.605	1.280
Replicate Prob(F)					0.1853	0.1238	0.4079	0.5840	0.3667	0.6172	0.3012
Treatment F					1.019	0.941	1.000	0.801	1.452	2.635	1.075
Treatment Prob(F)					0.4501	0.5070	0.4635	0.6187	0.2160	0.0248	0.4120

Table 5. Seasonal means for pest insects sampled by vacuum and leaf collections for all treatments in the Central Columbia Basin, applied by chemigation.

Trt No.	Treatment Name	Rate	Rate Unit	# of Appl.	Psyllid Egg	Psyllid Nymph	Psyllid Adult	Whitefly Egg	Whitefly Nymph	Aphid	Thrips
1	Untreated Check				1.8 a	1.0 b	0.5 a	0.0 a	1.3 b	3.5 a	3.8 a
2	Agri-Mek	6	fl oz/a	A	1.8 a	4.5 a	0.0 a	0.0 a	0.0 b	0.5 a	6.0 a
	Movento	5	fl oz/a	AB							
3	Agri-Mek	6	fl oz/a	ABC	1.3 a	0.5 b	0.3 a	0.0 a	0.3 b	3.0 a	2.5 a
4	Exirel	0.088	lb ai/a	ABC	0.3 a	0.0 b	0.5 a	0.0 a	0.3 b	3.0 a	1.5 a
5	Blackhawk	3.5	oz wt/a	ABC	0.3 a	0.8 b	0.3 a	0.0 a	0.5 b	2.5 a	1.0 a
6	Aza-Direct	1.5	pt/a	ABC	0.0 a	0.0 b	0.0 a	0.0 a	4.0 a	1.3 a	6.0 a
7	Beleaf	2.8	oz wt/a	ABC	3.3 a	0.8 b	0.0 a	0.0 a	0.5 b	0.5 a	2.5 a
8	Brigade	6.4	fl oz/a	ABC	2.3 a	0.5 b	0.0 a	0.0 a	0.0 b	2.0 a	7.3 a
9	Torac	21	fl oz/a	ABC	1.5 a	0.8 b	0.3 a	0.0 a	0.3 b	1.3 a	8.0 a
10	Sivanto	10.5	fl oz/a	ABC	1.5 a	1.0 b	0.0 a	0.0 a	0.3 b	0.5 a	6.5 a
Standard Deviation					2.26	2.02	0.54	0.00	1.73	2.07	5.18
Replicate F					1.925	0.923	0.550	0.000	0.963	1.325	1.497
Replicate Prob(F)					0.1493	0.4431	0.6526	1.0000	0.4244	0.2869	0.2377
Treatment F					0.787	1.629	0.588	0.000	1.932	1.244	0.962
Treatment Prob(F)					0.6307	0.1568	0.7949	1.0000	0.0898	0.3108	0.4912

Table 6. Seasonal means for pest insects sampled by vacuum and leaf collections for all treatments in the Central Columbia Basin, using a ground application.

Trt No.	Treatment Name	Rate	# of Appli.	Psyllid Egg	Psyllid Nymph	Psyllid Adult	Whitefly Egg	Whitefly Nymph	Aphid	Thrips
1	Untreated Check			3.0 a	0.5 a	0.0 a	0.3 a	3.0 a	3.3 a	12.5 a
2	Agri-Mek	6 fl oz/a	A	0.3 a	0.0 a	0.0 a	0.0 a	0.3 a	0.5 b	1.8 b
	Movento	5 fl oz/a	AB							
3	Agri-Mek	6 fl oz/a	ABC	1.5 a	0.0 a	0.3 a	0.0 a	1.8 a	1.8 ab	4.0 ab
4	Exirel	0.088 lb ai/a	ABC	0.0 a	0.0 a	0.0 a	0.0 a	0.3 a	2.3 ab	1.0 b
5	Blackhawk	3.5 oz wt/a	ABC	0.5 a	3.0 a	0.0 a	0.0 a	1.0 a	1.0 ab	5.0 ab
6	Aza-Direct	1.5 pt/a	ABC	2.8 a	0.0 a	0.3 a	0.8 a	0.0 a	3.3 a	4.8 ab
7	Beleaf	2.8 oz wt/a	ABC	6.3 a	1.3 a	0.0 a	0.3 a	0.8 a	0.5 b	4.0 ab
8	Brigade	6.4 fl oz/a	ABC	0.8 a	0.0 a	0.0 a	0.0 a	0.3 a	0.3 b	5.0 ab
9	Torac	21 fl oz/a	ABC	0.5 a	0.0 a	0.0 a	0.0 a	0.0 a	1.3 ab	0.3 b
10	Sivanto	10.5 fl oz/a	ABC	5.0 a	0.3 a	0.0 a	0.3 a	2.8 a	0.5 b	5.5 ab
Standard Deviation				4.15	1.91	0.21	0.55	2.58	1.47	5.91
Replicate F				0.809	0.771	2.250	1.000	1.108	0.170	0.992
Replicate Prob(F)				0.4999	0.5205	0.1053	0.4079	0.3630	0.9160	0.4114
Treatment F				1.081	1.024	1.000	0.778	0.757	2.384	1.319
Treatment Prob(F)				0.4080	0.4462	0.4635	0.6380	0.6554	0.0392	0.2731

R-11 surfactant was used at a rate of .5% volume of product to total mix size.

Table 7. Seasonal means for pest insects sampled by vacuum and leaf collections for all treatments at Hermiston, OR. Means with different letters are significantly different from one another (p=.05 Student-Newman-Keuls test).

Insect	Psyllid Adult	Psyllids	Psyllid Eggs	Psyllid Nymphs	BLH	CPB	CPB	Aphids	Whitefly	Thrips	Thrips	Spider Mites
Sample Type	Vacuum	Leaf	Leaf	Leaf	Vacuum	Vacuum	Leaf	Vacuum	Leaf	Vacuum	Leaf	Leaf
Treatment												
1 UTC	0.35 a	0.40a	0.02 a	0.02 a	0.19 a	9.87 b	0.10 a	1.92 a	0.02 a	26.65 a	0.36 a	0.18 a
2 Abamectin & Movento	0.19 a	0.60a	0.01 a	0.03 a	0.60 a	6.93 bc	0.07 a	1.41 a	0.00 a	24.18 a	0.33 a	0.15 a
3 Abamectin	0.08 a	1.70a	0.04 a	0.05 a	0.28 a	5.70 bc	0.02 a	2.12 a	0.02 a	28.30 a	0.27 a	0.02 a
4 Exirel	0.20 a	0.20a	0.00 a	0.01 a	0.48 a	2.44 c	0.02 a	1.96 a	0.00 a	21.14 a	0.27a	0.25 a
5 Transform	0.10 a	0.80a	0.05 a	0.01 a	0.21 a	17.08 a	0.04 a	2.23 a	0.03 a	24.58 a	0.34 a	0.03 a
6 Aza-Direct	0.10 a	2.40a	0.04 a	0.04 a	0.16 a	6.11 bc	0.02 a	2.14 a	0.01 a	16.03 a	0.42 a	0.04 a
7 Beleaf	0.25 a	0.10a	0.01 a	0.01 a	0.17 a	10.50b	0.06 a	1.65 a	0.02 a	19.83 a	0.29 a	0.09 a
8 Brigade	0.12 a	2.50a	0.03 a	0.03 a	0.08 a	4.64 bc	0.01 a	1.81 a	0.00 a	31.08 a	0.38 a	1.55 a
9 Torac	0.26 a	0.20a	0.01 a	0.00 a	0.42 a	9.66 b	0.05 a	1.56 a	0.01 a	26.03 a	0.36 a	0.08 a
10 Sivanto	0.25 a	0.40a	0.09 a	0.02 a	0.56 a	5.54 bc	0.09 a	3.10 a	0.03 a	28.81 a	0.54 a	0.11 a

Table 8. Seasonal means for adults of beneficial insects sampled by vacuum and leaf for all treatments at Hermiston, OR. Means with different letters are significantly different (p=0.05 Student-Newman-Keuls test).

Insect	Damsel Bugs	Big-eyed Bugs	Pirate Bugs	Lady Beetles
Sample Type	Vacuum	Vacuum	Vacuum	Vacuum
Treatment				
1 UTC	3.64 ab	3.43 a	2.18 a	0.81 a
2 Abamectin & Movento	3.77 ab	2.56 a	2.48 a	0.98 a
3 Abamectin	4.30 a	2.82 a	2.35 a	0.91 a
4 Exirel	2.86 ab	2.72 a	1.98 a	1.05 a
5 Transform	3.27 ab	3.30 a	3.18 a	0.75 a
6 Aza-Direct	3.70 ab	3.44 a	2.39 a	0.92 a
7 Beleaf	3.23 ab	2.32 a	1.93 a	0.83 a
8 Brigade	1.35 b	2.08 a	2.92 a	1.32 a
9 Torac	3.66 ab	2.36 a	2.32 a	0.91 a
10 Sivanto	3.48 ab	3.59 a	2.52 a	0.66 a

Table 9. Seasonal means for pest insects sampled by vacuum and leaf collections for all treatments at Ontario, OR. Means with different letters are significantly different from one another.

Insect	Psyllid Adult	Psyllid Nymph	Psyllid Egg	Aphid	Adult Beet Leafhopper	Thrips	Lygus Adult
Sample Type	Vacuum	Leaf	Leaf	Vacuum	Vacuum	Vacuum	Vacuum
Treatment							
1 UTC	0.55 a	8.90 a	30.17 a	1.75 a	0.52 a	8.17 a	5.08 a
2 Abamectin & Movento	0.50 a	2.21 bc	10.39 b	0.25 a	0.43 a	16.92 a	5.71 a
3 Abamectin	0.43 a	5.43 ab	28.35 a	0.25 a	0.27 a	18.67 a	5.60 a
4 Exirel	1.29 a	1.71 bc	7.07 b	0.25 a	0.50 a	17.79 a	8.39 a
5 Transform	0.42 a	7.43 ab	28.36 a	1.75 a	0.76 a	15.76 a	6.57 a
6 Aza-Direct	0.39 a	6.82 ab	32.71 a	0.50 a	0.82 a	13.00 a	6.75 a
7 Beleaf	0.71 a	2.11 bc	8.11 b	1.50 a	0.48 a	19.87 a	3.79 a
8 Brigade	0.36 a	0.93 c	6.36 b	0.25 a	0.18 a	40.32 b	4.11 a
9 Torac	0.43 a	7.25 a	26.53 a	0.50 a	0.39 a	13.86 a	6.29 a
10 Sivanto	0.36 a	1.86 c	12.39 b	0.75 a	0.29 a	17.11 a	4.89 a

Table 10. Seasonal means for adults of beneficial insects sampled by vacuum and leaf for all treatments Ontario, OR. Means with different letters are significantly different from one another.

Insect	Pirate Bug	Big Eyed Bug	Ladybugs	Lacewings
Sample Type	Vacuum	Vacuum	Vacuum	Vacuum
Treatment				
1 UTC	2.30 ab	2.32 a	0.76 ab	4.02 a
2 Abamectin & Movento	2.61 ab	0.82 ab	0.32 ab	1.04 b
3 Abamectin	2.01 ab	1.70 ab	0.68 ab	2.50 ab
4 Exirel	3.25 ab	1.29 ab	0.82 ab	1.11 b
5 Transform	2.57 ab	0.70 ab	1.43 ab	2.13 ab
6 Aza-Direct	3.18 ab	2.39 a	0.93 ab	2.50 ab
7 Beleaf	4.30 a	1.67 ab	0.52 ab	1.05 b
8 Brigade	3.64 ab	0.46 b	0.21 b	0.82 b
9 Torac	3.00 ab	1.89 ab	0.57 ab	2.17 ab
10 Sivanto	1.75 b	1.43 ab	1.71 a	0.89 b

Table 11. Seasonal means for pest insects sampled by vacuum and leaf collections for all treatments at Kimberly, ID. Means that do not share the same letters are significantly different from one another (p=0.05).

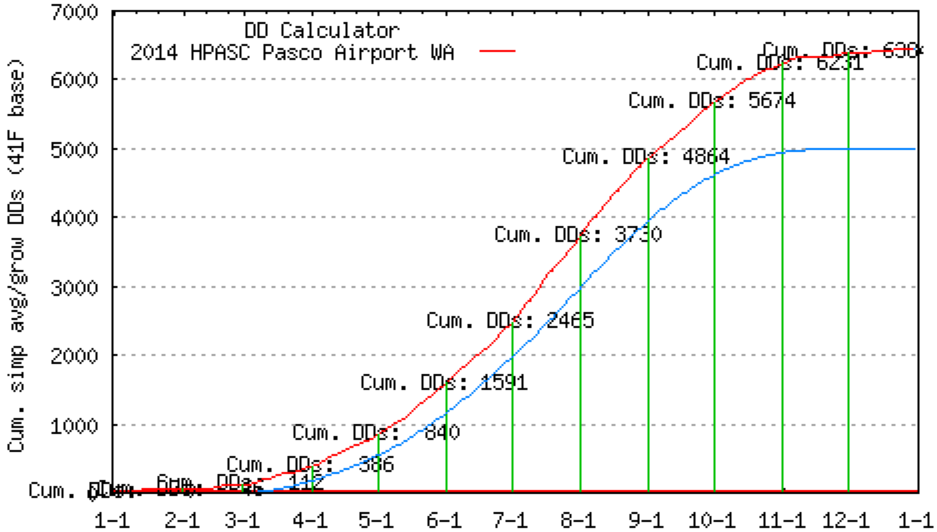
Insect	Psyllid Adult	Psyllid Nymph	Winged Aphid	Wingless Aphid	CPB eggs	CPB Larvae	CPB adult	CPB % defoliation	Zebra Chip Rating
Sample Type	Vacuum	Leaf	Vacuum	Leaf	Leaf	Leaf	Leaf	Vacuum	
Treatment									
1 UTC	0.1a	0.0a	0.0a	0.00a	0.00d	0.48a	0.91abc	62.3a	0.014a
2 Agri-mek & Movento	0.1a	0.0a	0.0a	0.04a	0.03cd	0.00c	0.09de	7.3e	0.062a
3 Agri-mek	0.0a	0.0a	0.0a	0.03a	0.09bc	0.00c	0.01e	13.7de	0.022a
4 Exirel	0.3a	0.0a	0.0a	0.04a	0.03cd	0.00c	0.22cde	7.1e	0.028a
5 Transform	0.4a	0.0a	0.0a	0.01a	0.39a	0.01bc	0.56bcd	24.9cd	0.089a
6 Aza-Direct	0.1a	0.0a	0.3a	0.05a	0.01cd	0.14ab	1.55ab	34.9bc	0.001a
7 Beleaf	0.0a	0.0a	0.0a	0.00a	0.01cd	0.31a	1.99a	49.9ab	0.059a
8 Brigade	0.1a	0.0a	0.0a	0.03a	0.30ab	0.03bc	1.46ab	17.7cde	0.003a
9 Torac	0.0a	0.0a	0.0a	0.01a	0.11bc	0.00c	0.61bcd	10.8de	0.039a
10 Sivanto	0.3a	0.0a	0.0a	0.00a	0.12abc	0.12abc	0.70bc	10.3de	0.086a

Table 12. Seasonal means for adults of beneficial insects sampled by vacuum and leaf for all treatments Kimberly, ID. Means that do not share the same letters are significantly different from one another.

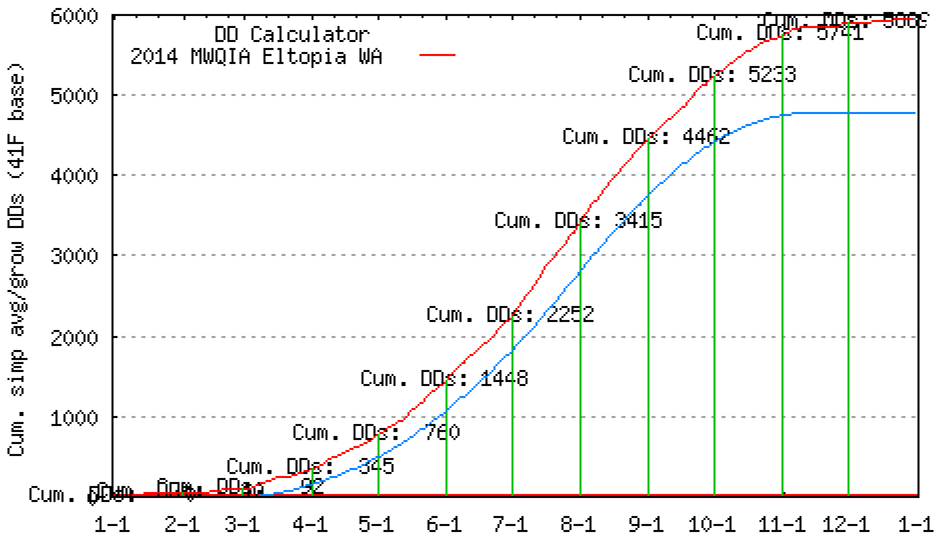
Insect	Minute Pirate Bugs	Big Eyed Bugs	Ladybugs	Lacewings	Damsel Bugs	Assassin Bugs	Flower Flies	Parasitic Wasps	chloropid Flies	Spiders	Opiliones	All Beneficials
Sample Type	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum
Treatment												
1 UTC	1.1a	3.7a	0.4a	0.5a	3.6a	0.0a	0.0a	0.1a	4.3a	1.3a	0.1a	16.2a
2 Agri-mek & Movento	0.6a	1.6a	0.4a	0.1a	1.8a	0.0a	0.0a	0.7a	5.5a	0.8a	0.1a	13.3a
3 Agri-mek	2.3a	3.5a	1.9a	0.3a	6.5a	0.3a	0.3a	0.5a	7.0a	0.8a	0.1a	27.2a
4 Exirel	1.0a	1.1a	0.4a	0.4a	2.3a	0.0a	0.0a	0.9a	2.3a	1.3a	0.1a	11.2a
5 Transform	2.4a	0.6a	1.8a	1.0a	5.0a	0.0a	0.0a	0.7a	3.8a	0.8a	0.0a	18.2a
6 Aza-Direct	1.5a	3.0a	0.3a	0.1a	3.4a	0.0a	0.0a	0.1a	3.5a	1.3a	0.1a	15.8a
7 Beleaf	0.3a	0.8a	0.7a	0.1a	0.8a	0.0a	0.3a	0.3a	2.0a	0.5a	0.0a	7.2a
8 Brigade	1.6a	0.3a	1.1a	0.0a	0.2a	0.0a	0.3a	1.2a	3.8a	0.5a	0.0a	9.1a
9 Torac	0.6a	0.3a	1.2a	0.3a	3.2a	0.0a	0.0a	0.1a	4.5a	1.5a	0.1a	14.5a
10 Sivanto	2.3a	1.0a	0.2a	0.1a	3.6a	0.0a	0.0a	0.6a	4.0a	1.3a	0.3a	15.8a

Table 13. Total yield, US #1 grade, US #2 grade, and culls in tons per acre by treatment Kimberly, ID. Means that do not share the same letters are significantly different from one another (p=0.05).

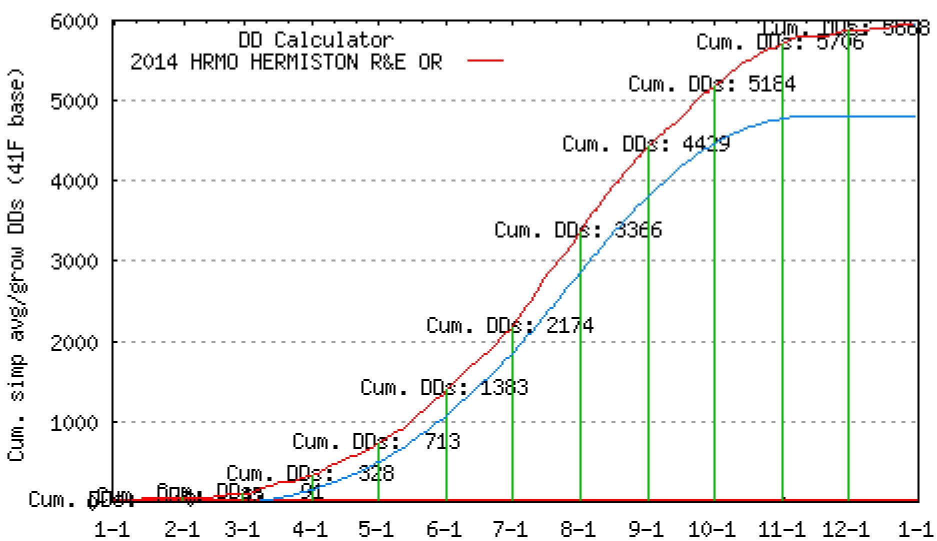
Treatment	USDA 1 Cwt/A	USDA 2 Cwt/A	Culls Cwt/A	Total Cwt/A
1 UTC	171.8a	49.8c	49.2a	270.8c
2 Agri-mek & Movento	240.1a	122.7ab	51.6a	414.3a
3 Agri-mek	238.1a	139.2a	43.4a	420.7a
4 Exirel	228.5a	116.6ab	49.0a	394.0ab
5 Transform	209.0a	102.6ab	48.9a	360.4ab
6 Aza-Direct	187.4a	97.1b	47.8a	332.2bc
7 Beleaf	164.4a	104.2ab	50.4a	319.0bc
8 Brigade	205.0a	111.2ab	46.0a	362.1ab
9 Torac	204.7a	123.2ab	43.8a	371.7ab
10 Sivanto	225.9a	114.6ab	49.1a	389.6ab



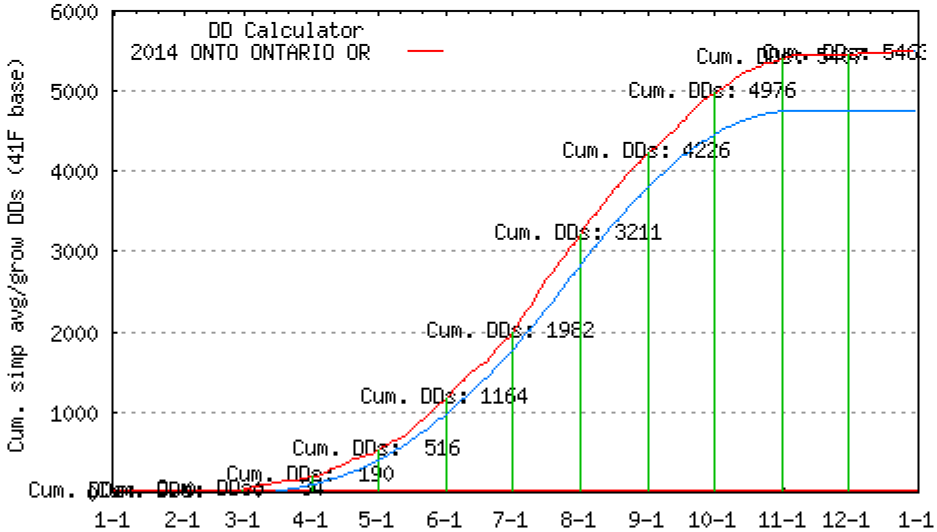
A) Pasco



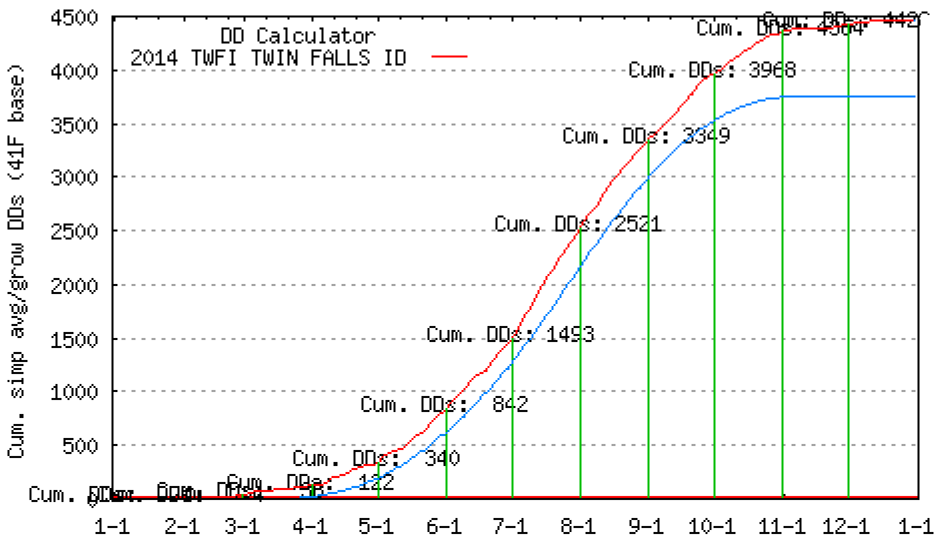
B) Central Basin (Eltopia)



C) Hermiston



D) Ontario



E) Kimberly

Figure 1. Comparison of accumulated degree growing days for 2014 (red line) versus 30 historical averages (blue line) for the five insecticide trial locations, (A) Pasco, WA, (B) Eltopia, WA, (C) Hermiston, OR, (D) Ontario, OR, and (E) Kimberly, ID. Data are from http://uspest.org/.

Annual Progress Report

TITLE: Comparative biology of potato psyllid haplotypes and implications for northwest potato growers

PERSONNEL: David Horton
Joe Munyaneza
Rodney Cooper
Kylie Swisher

REPORTING PERIOD: 1 Jan 2014 – 31 Dec 2014

ACCOMPLISHMENTS:

(1) HAPLOTYPE STUDIES

- Showed that females of the Northwestern haplotype are not interfertile with males of Central or Western haplotypes, due to absence of *Wolbachia* in NW psyllids and presence of *Wolbachia* in the other haplotypes (see **Accomplishment #3** below).
- Demonstrated differences among haplotypes in development times and fecundity.

Implications of results: Haplotype differences in fecundity and development times will cause some haplotypes to have higher population growth rates in the field. The lack of fertility between certain haplotype crosses means that population growth rates in the field could be lower for populations composed of mixtures of haplotypes than for single-haplotype populations (assuming random mating under field conditions).

(2) HOST PLANT STUDIES

- Convolvulaceae:
  - Showed that psyllids complete development on weedy, crop, and ornamental Convolvulaceae
  - Collected data suggesting that the Liberibacter pathogen can be transferred from infected psyllids to uninfected psyllids through sweet potato, despite evidence that the plant species is not a suitable host for the pathogen
- Bittersweet nightshade:
  - Showed that psyllids of the Northwestern haplotype overwinter on nightshade as nymphs and adults; new adults are found in winter during warmer intervals (due to molting of last stage nymphs); egglaying on nightshade begins in late March
- *Lycium*:
  - Determined that *Lycium barbarum* (known overwintering host in southern U.S.) is common in potato growing regions of Washington; showed that this plant hosts psyllids summer through winter, and that it may be an overwintering host for the Western haplotype (unlike bittersweet nightshade) as well as for the Northwestern haplotype
- Plant-based marker:
  - Developed a molecular assay that can be used to determine host species most recently fed upon by adult potato psyllids

Implications of results: Overwintering by psyllids on bittersweet nightshade and *Lycium* would mean that these two perennial plants could be important sources of psyllids colonizing potatoes in spring. Development of a plant-based marker will allow us to actually determine the plant source (*Lycium* vs nightshade vs potato) of psyllids arriving on potatoes in spring. Successful development of potato psyllid on common weedy, ornamental, or cultivated Convolvulaceae indicates that these hosts are potential sources of psyllids in the Pacific Northwest. Our preliminary demonstration that sweet potato may act as a "highway" through which the Liberibacter pathogen can move from infected to uninfected psyllids is evidence for a highly novel (and possibly troubling) mode of transmission of the zebra chip pathogen between psyllids.

(3) ENDOSYMBIONT STUDIES

- Showed that psyllids of different haplotypes differ in whether they carry *Wolbachia*
- Discovered that potato psyllids harbor the endosymbiont *Arsenophonus*

Implications of results: Presence or absence of *Wolbachia* among psyllid haplotypes controls whether haplotypes are interfertile; thus, the presence/absence of the endosymbiont should affect population growth rates of psyllids in fields when populations are composed of a mixture of haplotypes. The endosymbiont *Arsenophonus* is known to affect biology of insects, including causing increased defenses of infected hosts against parasitoids.

(4) VECTORING STUDIES

- Developed electrical penetration graph (EPG) methods for determining what tissues within the potato plant are accessed by feeding psyllids

Implications of results: The method was used to show that transmission of Liberibacter to potato by infected insects can occur within but a few minutes of the insect's mouthparts entering the phloem tissues of the potato host plant.

RESULTS:

(1) HAPLOTYPE STUDIES

Mating trials showed that crosses between certain haplotypes led to the production of infertile eggs. Females of the Northwestern haplotype were not interfertile with males of Central or Western haplotypes, even while the opposite crosses were entirely fertile (see Table 1). Additional studies led to the discovery that presence or absence of a bacterial endosymbiont (*Wolbachia*) governs fertility (see **(3) ENDOSYMBIONT STUDIES** below).

Percent egg hatch in each intra- and interhaplotype crosses			
	Western male	Central male	Northwestern male
Western female	90% a	83% c	81% c
Central female	86% b	85% bc	86% b
Northwestern female	0% d	0% d	85% bc

Table 1. Interhaplotype fertility trial.

Fitness assays were conducted comparing performance of each haplotype on potato and bittersweet nightshade. Figure 1 is included to show part of these results, and demonstrates large differences between haplotypes in total numbers of eggs deposited per female. Northwestern females deposited over 1,000 eggs per female in a lifetime, considerably higher numbers than deposited by either Central or Western females. Other differences between haplotypes include (data not shown): adult longevity (highest in Northwestern haplotype); development rates of nymphs (slowest in Northwestern psyllids); and total development times (longest in Northwestern psyllids). We also showed that adults of the Northwestern haplotype have larger body sizes than adults of Central or Western haplotypes.

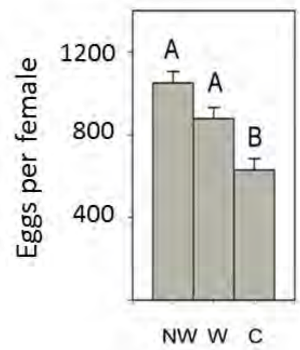


Figure 1. Fecundity of NW, W, and C haplotypes.

(2) Host Plant Studies

Convolvulaceae: We tested whether psyllids of each haplotype developed successfully on Convolvulaceae. Plant taxa included weedy species (bindweed; *Convolvulus*); agricultural species (sweet potato; *Ipomoea*); ornamental species (several types of morning glory; *Ipomoea*); and a ground cover (*Dichondra*). Figure 2 shows days from egg hatch to new adults for the Northwestern haplotype. The dashed line shows development time on potato. The psyllid developed (albeit slowly) on both ornamental and weedy Convolvulaceae, but not on the ground cover (*Dichondra*). Death of nymphs on some morning glory varieties appeared to be due to the extreme hairiness of plants, which prevented feeding by nymphs. *Lycium* was included as a potato relative, and development was excellent on this taxon (Fig. 2). *Petunia*, another potato relative, was a poor host; these plants appear to produce a sticky exudate that prevented psyllid survival. Psyllids of the Central and Western haplotypes also developed on several morning glory varieties, on sweet potato, on bindweed, and on *Lycium* (data not shown). The Central

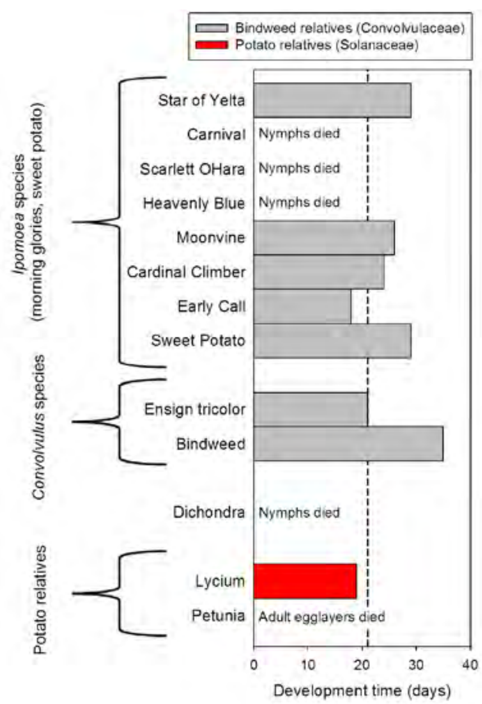


Figure 2. Development times (days) for NW haplotype on Convolvulaceae (gray bars) and Solanaceae (red). Dashed line is development time on potato.

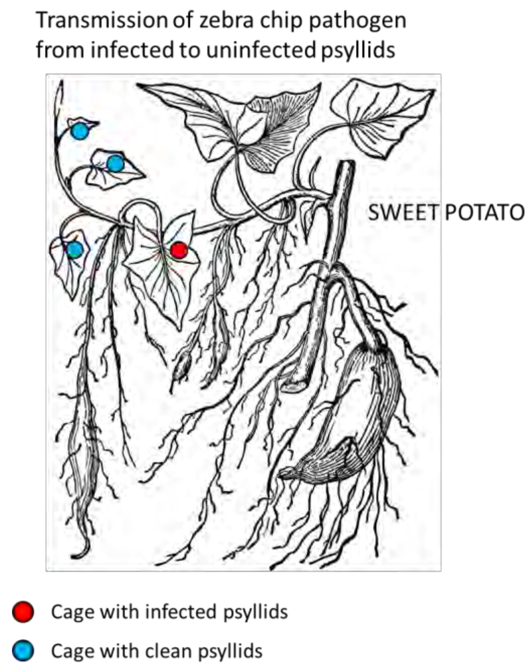


Figure 3. Diagram showing location of infected (source) and uninfected (targeted) psyllids on sweet potato plant.

haplotype appeared to be most successful of the three haplotypes at developing on the weedy and ornamental species.

We next showed that an assumed non-host of the zebra chip pathogen (sweet potato) could possibly operate as a “highway” for the pathogen moving from infected psyllids to uninfected psyllids. Small leaf cages containing infected psyllids were placed on a single leaf of a sweet potato plant (Fig. 3). Uninfected psyllids were then caged on three leaves above the treatment leaf (Fig. 3). Psyllids were allowed to feed for 1 week, removed from the plants, and then assayed (with PCR) for presence of the zebra chip pathogen. Previously uninfected psyllids were found to become infected, presumably due to movement by the pathogen through the phloem from the treatment leaf to the target leaves. A dye injected into the phloem of the treatment leaf was found to accumulate in the target leaves, supporting this interpretation. We are currently conducting additional studies to confirm these unexpected results. We have been unable to prove that the zebra chip pathogen is actually capable of surviving in sweet potato.

Bittersweet nightshade: We caged psyllids of the resident haplotype on bittersweet nightshade in summer 2012 and 2013, and monitored the plants over the duration of both subsequent winters (Fig. 4). Adults and nymphs were collected throughout winter. Females were dissected and shown to include a mixture of insects having immature ovaries and insects having a complement of mature eggs ready to be deposited (blue bubbles in Figure 4 show frequency of females containing the specified number of mature eggs; size of bubble is

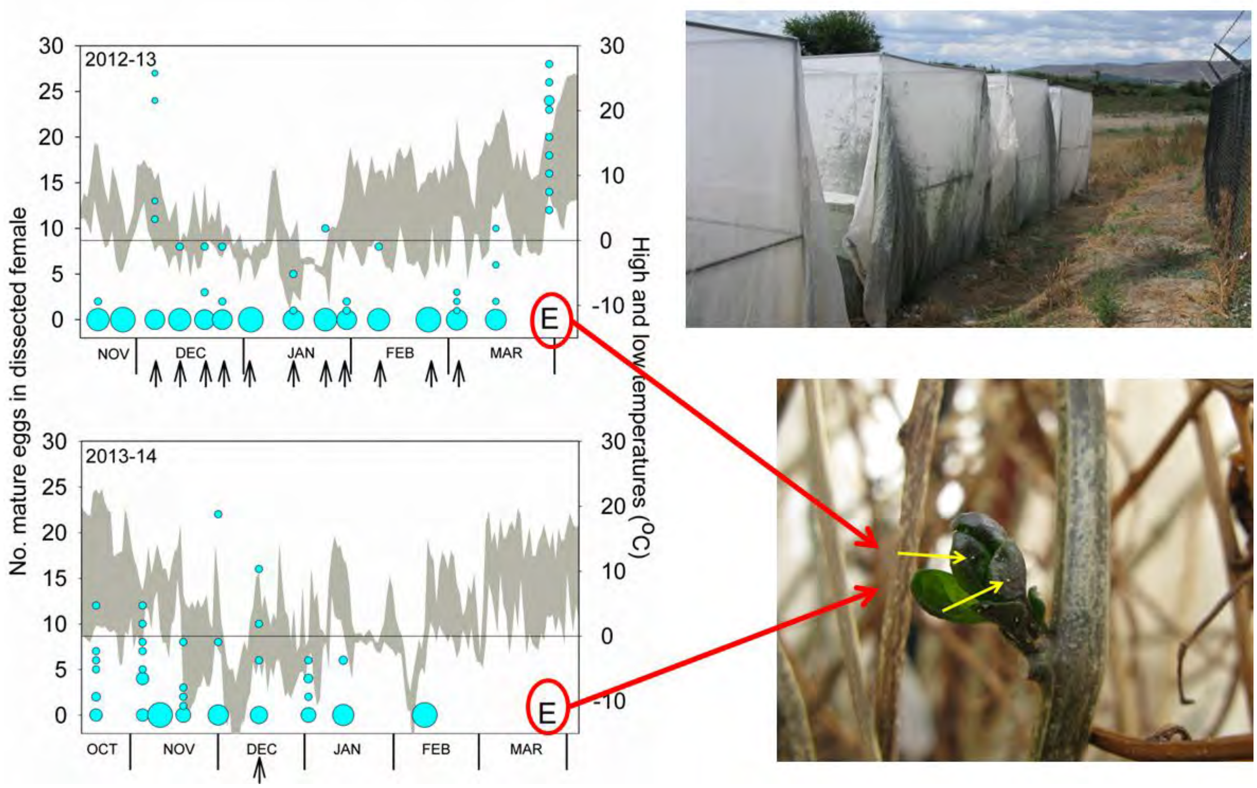


Figure 4. Wintering cage studies. Left panels: size of blue bubbles show frequency of psyllids having that number of mature eggs upon dissection. E = onset of egglaying. Black arrows: newly molted adults collected. Bottom right panel: eggs on newly flushed foliage in March.

proportional to number of females). Newly molted adults were collected following intervals of warmer temperatures both years (black arrows in Figure 4). Egglaying began on newly flushed foliage in late March both years, well before emergence of the potato crop. We believe that potato psyllid completes a full generation on bittersweet nightshade before emergence of the potato crop. Haplotyping of psyllids showed that the insects overwintering on natural stands of this nightshade are virtually 100% of the Northwestern haplotype, despite presence of the Western haplotype in large numbers on nearby potato during the growing season.

Lycium: Matrimony vine (*Lycium*) is a common overwintering host for potato psyllid in the southern U.S. We are now finding that *L. barbarum* (matrimony vine, Goji berry) is relatively widespread in the potato growing regions of Washington State (often as a backyard ornamental). Monitoring of this plant at several locations led to the discovery of potato psyllids in association during summer, autumn, and winter (Fig. 5). The insects included a mixture of the Northwestern and Western haplotypes. Previous work has shown that the Western haplotype is very uncommon overwintering on bittersweet nightshade. In contrast, *Lycium* may prove to be a winter reservoir of this haplotype, and a possible source of psyllids colonizing potato in spring.

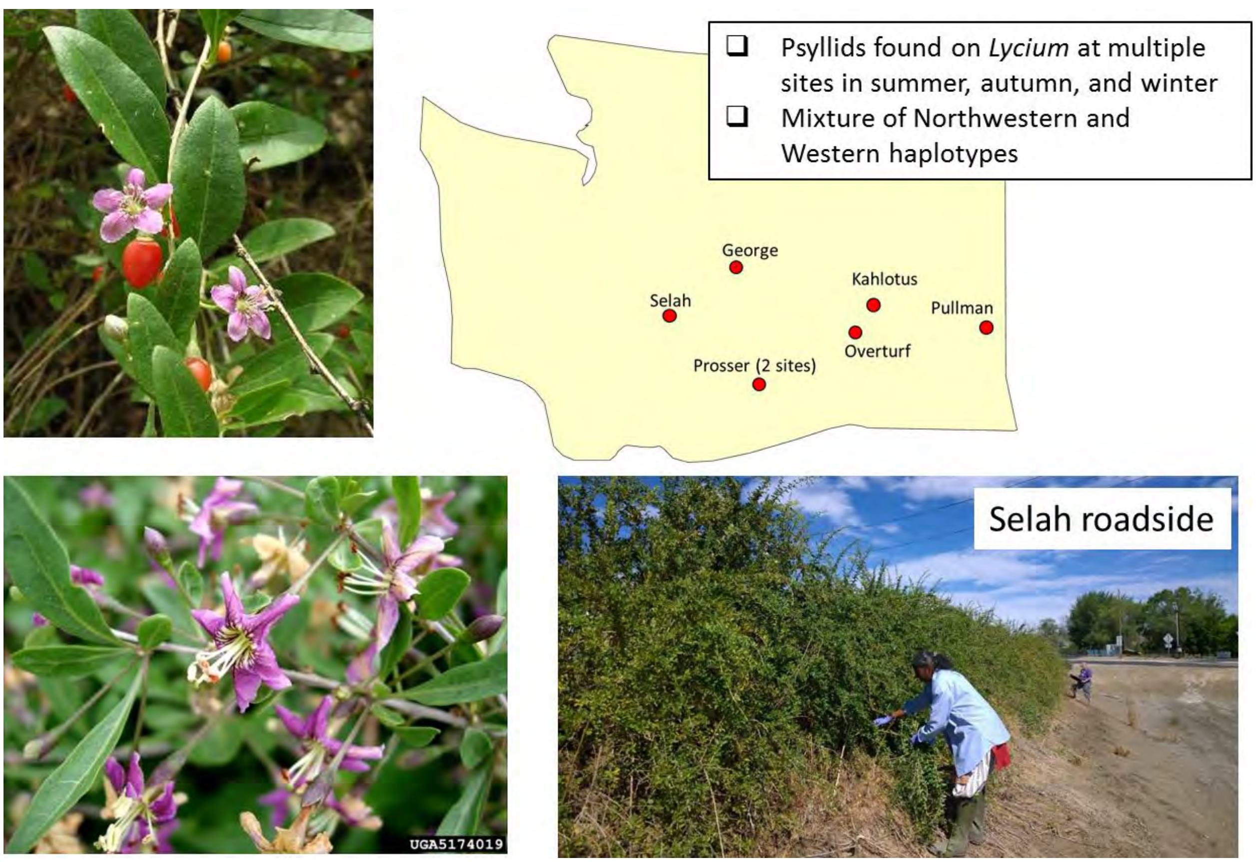


Figure 5. Photographs of *Lycium*, and location of *Lycium* stands being monitored for potato psyllid.

A plant-based marker: We showed that PCR could be used to differentiate among psyllids that had been feeding either on matrimony vine, bittersweet nightshade, or on potato (Fig. 6). The impetus for this work is the need to know what plant species are sources of psyllids colonizing potatoes in late spring. A tool which could be used to detect the plant signal in psyllids collected in spring from sticky cards placed near potato fields would allow us to make inferences about the source (matrimony vine, bittersweet nightshade, potato) of psyllids colonizing potato fields. Psyllids from the three different host cultures have different molecular signals (Fig. 6). Our next assays will be to determine whether the host plant signal is detected in psyllids removed from sticky cards, and to determine how rapidly the signal decays in the psyllids.

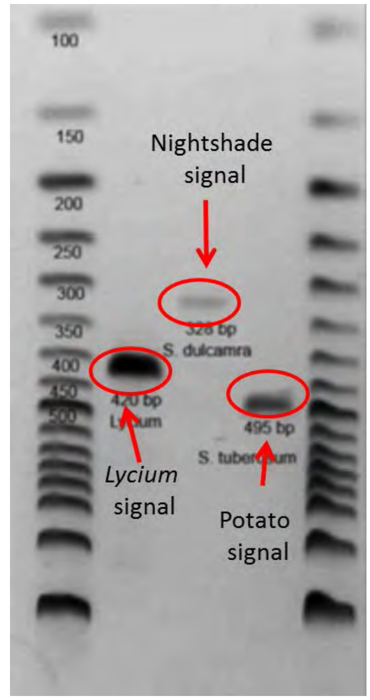


Figure 6. PCR results showing separation of psyllids based upon diet (*Lycium*, bittersweet nightshade, potato).

(3) Endosymbiont Studies

Wolbachia: DNA-sequencing revealed that two distinct strains of *Wolbachia* were present in psyllids of both the Western and Central haplotypes. *Wolbachia* was detected in 72% of psyllids of the Western haplotype and in 100% of psyllids of the Central haplotype (using PCR), but was not detected in any of the psyllids of the Northwestern or Southwestern haplotypes (Table 2, Fig. 7). The Central and Western haplotypes (both with *Wolbachia*) diverge phylogenetically from both the Northwestern and Southwestern haplotypes, in association with presence or absence of *Wolbachia*, respectively (Fig. 7). Finally, it has long been known that presence of *Wolbachia* can affect egg fertility of insects. Results of our molecular work, confirming presence of *Wolbachia* in a subset of haplotypes, are consistent with results of our interhaplotype fertility trials summarized in Table 1.

Arsenophonus: PCR revealed that potato psyllids harbor the bacterial endosymbiont *Arsenophonus*. Sequencing revealed that this is an undocumented strain of *Arsenophonus* different from that previously identified in other insects. This endosymbiont can cause a wide array of effects in insect hosts, including increased defense against parasitoids.

Haplotype	Location	Collection Dates	Wolbachia-infected/total
Western	Washington and Oregon	Sept 2009 – July 2013	13/18 (72%)
Central	Kansas, Texas, Minnesota, Wisconsin, and North Dakota	June 2009 – March 2014	17/17 (100%)
Northwestern	Washington and Oregon	Aug 2005 – July 2013	0/35 (0%)
Southwestern	New Mexico	June and July 2012	0/12 (0%)

Table 2 . Distribution of *Wolbachia* among haplotypes and geographic locations.

(4) Vectoring Studies

Electrical penetration graph methods were used to determine how rapidly feeding psyllids of each haplotype are capable of reaching the phloem tissues of the potato host plant (phloem-feeding is necessary for transmission of the zebra chip pathogen). EPG completes a simple electrical circuit between the plant and insect allowing for measurement of electrical resistance (Fig. 8). The pattern of the waveform produced with this technology provides clues into the types of tissues within the plant that are being accessed. Figure 9 shows 4 patterns for potato psyllid. The three haplotypes showed similar patterns in phloem-associated waveforms (Fig.

10). We used this technology to determine how rapidly psyllids are capable of transmitting the zebra chip pathogen once the phloem has been reached. In Figure 11 we show the most rapid transmission for each haplotype, summarizing the results for 2 psyllids per haplotype. Transmission occurs within 4-9 minutes of the psyllid having reached the phloem, reemphasizing difficulties associated with efforts to prevent transmission of the pathogen once a psyllid has colonized a potato field.

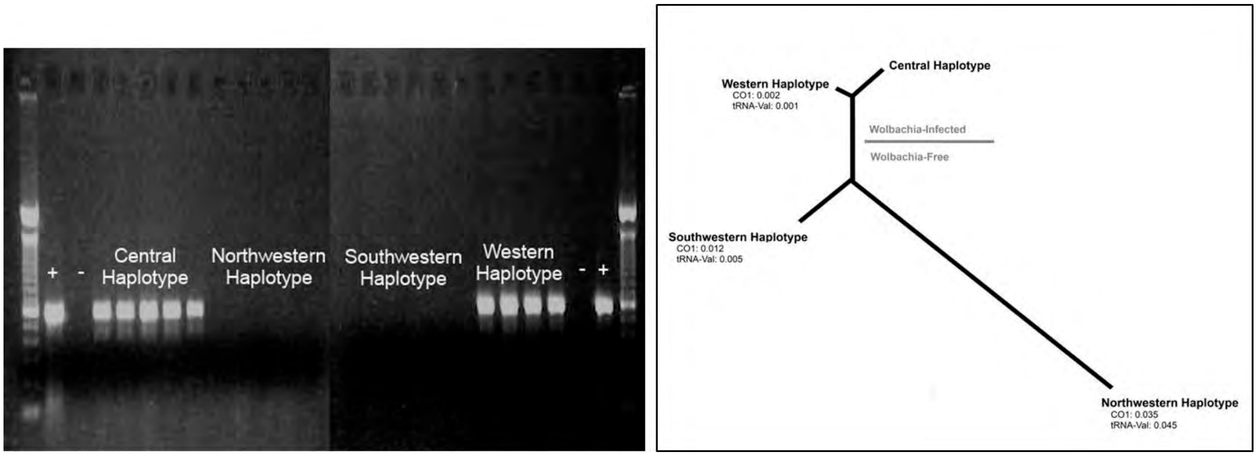


Figure 7. Gel showing presence of *Wolbachia* in Central and Western haplotypes and absence from Northwestern and Southwestern haplotypes; phylogenetic tree showing *Wolbachia* is associated with related psyllid haplotypes.

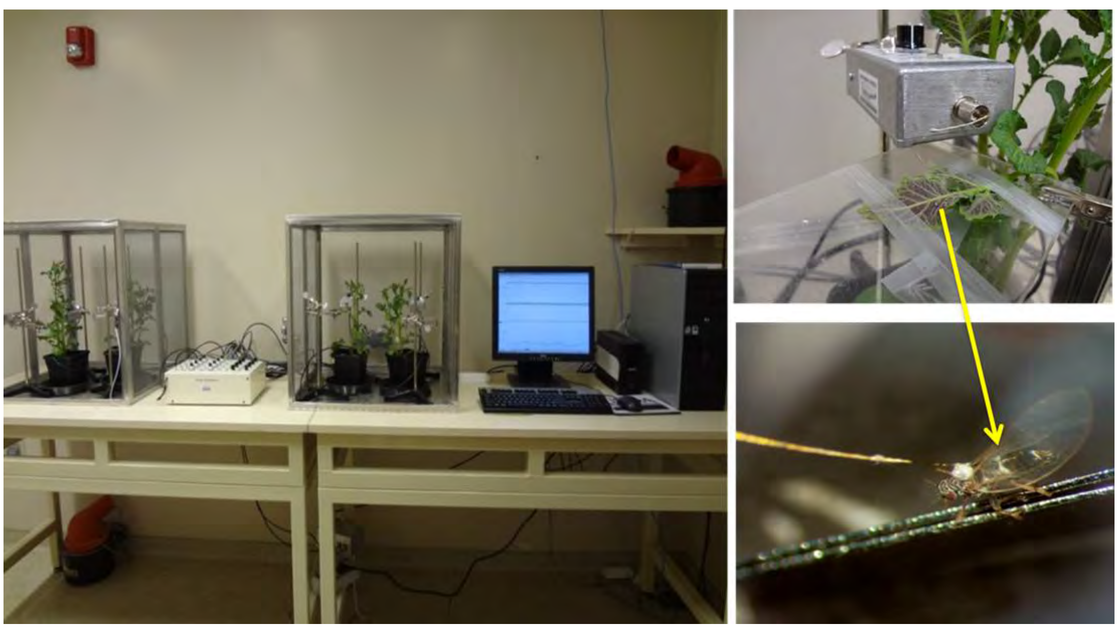


Figure 8. Electrical penetration graph set-up. Lower right panel shows psyllid with electrode attached.

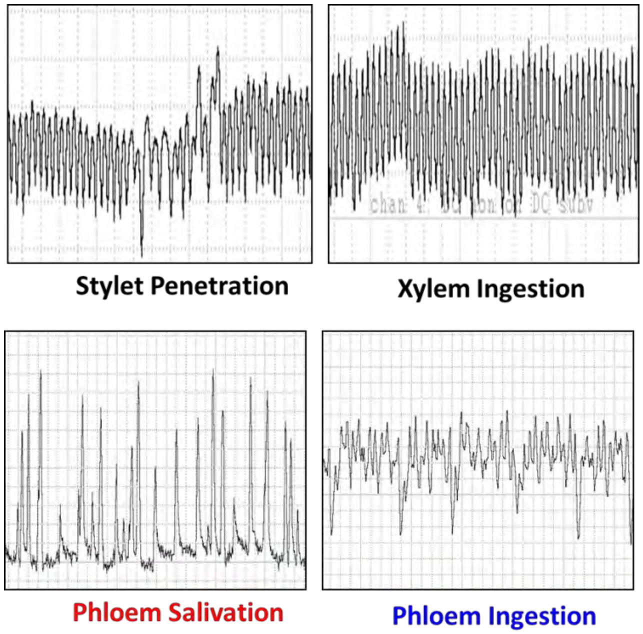


Figure 9. Waveform characteristics for different feeding activities of potato psyllid.

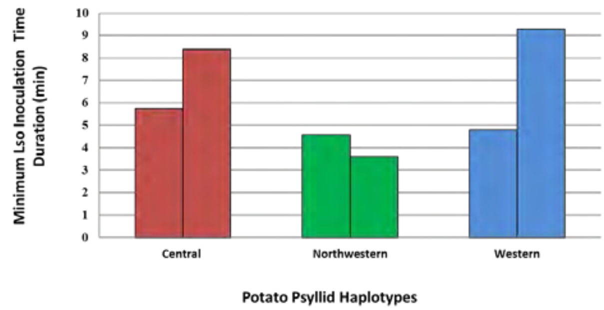


Figure 11. Minimum number of minutes following ingestion of phloem leading to transmission of the ZC pathogen. N = 2 psyllids per haplotype.

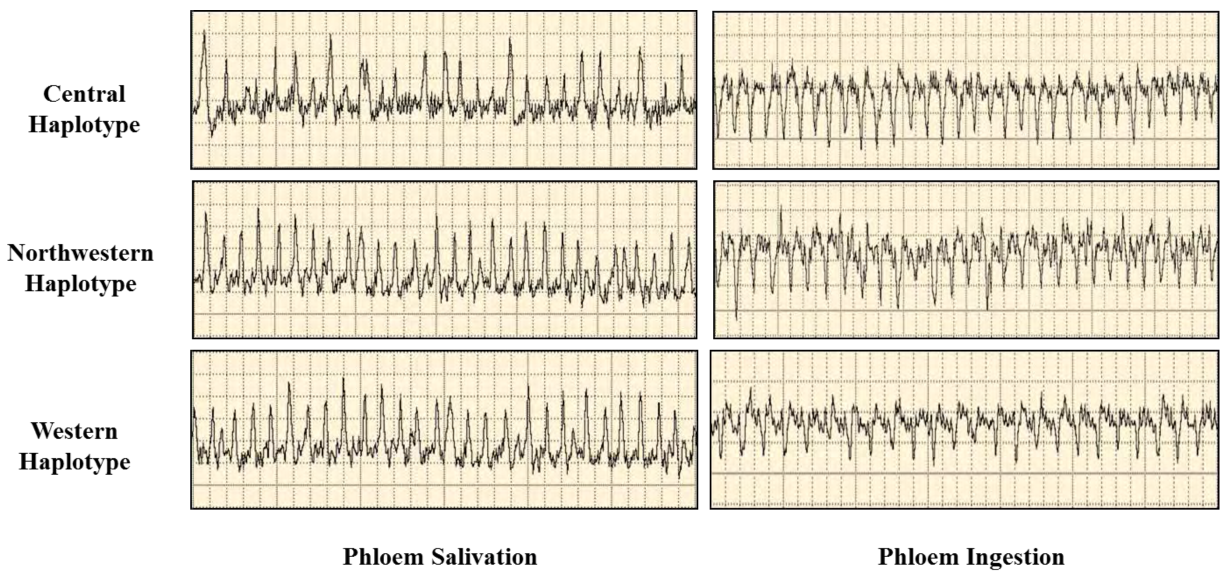


Figure 10. Waveforms associated with phloem feeding showing similarity of signals among haplotypes.

PUBLICATIONS:

Cooper, WR, KD Swisher, SF Garczynski, T Mustafa, JE Munyaneza, and DR Horton. 2015. *Wolbachia* infection differs among divergent mitochondrial haplotypes of *Bactericera cockerelli* (Hemiptera: Triozidae). *Annals of the Entomological Society of America* (in press).

Mustafa, T, DR Horton, WR Cooper, KD Swisher, RS Zack and J.E. Munyaneza. 2015. Interhaplotype fertility and effects of host plant on reproductive traits of three haplotypes of *Bactericera cockerelli* (Hemiptera: Triozidae). *Environmental Entomology* (in press).

Mustafa, T, DR Horton, KD Swisher, RS Zack and JE Munyaneza. 2015. Effects of host plant on development and body size of three haplotypes of *Bactericera cockerelli* (Hemiptera: Triozidae). *Environmental Entomology* (in press).

PRESENTATIONS & REPORTS:

Cooper, WR. Psyllids and Microbes, Friends or Foes? Natural Science Seminar Series, Central Washington University, Ellensburg, WA. 9 May 2014.

Cooper, WR, T Mustafa, KD Swisher, SF Garczynski, JM Munyaneza, and DR Horton. *Wolbachia*-infection Differs among Potato Psyllid Haplotypes. Annual Meeting of the Potato Association of America, Spokane, WA. 27-31, July 2014.

Cooper, WR. Ecological Interactions between Psyllids and Bacterial Endosymbionts. WSU Entomology Seminar, Pullman, WA. 15 October 2014.

Cooper, WR, T Mustafa, KD Swisher, SF Garczynski, JM Munyaneza, and DR Horton. *Wolbachia*-infection Differs among Potato Psyllid Haplotypes. Annual Meeting of Entomological Society of America, Portland, OR. 16-19 November 2014.

Mustafa, T, J Munyaneza, K Swisher, D Horton and R Zack. Liberibacter transmission efficiency among potato psyllid haplotypes. 2014 SCRI ZC Annual Reporting Session, Portland, OR. 9-12 November 2014.

Mustafa, T, J Munyaneza, D Horton, R. Cooper, K Swisher and R Zack. Assessing reproduction of potato psyllid haplotypes. 2014 SCRI ZC Annual Reporting Session, Portland, OR. 9-12 November 2014.

Annual Progress Report

TITLE: Population genetics of the potato psyllid in the inland Northwest

PERSONNEL: William E. Snyder and Zhen "Daisy" Fu, Department of Entomology, Washington State University, Pullman, WA 99164-6382. Tel: (509) 335-3724. wesnyder@wsu.edu; zhen.fu@wsu.edu;

REPORTING PERIOD: 2014

ACCOMPLISHMENTS:

Work out of my laboratory and others has demonstrated that potato psyllids overwinter on bittersweet nightshade, *Solanum dulcamara*. Initially, we were excited to think that we had found the source of both the northwest haplotype psyllids and of the zebra chip pathogen that eventually move to potatoes. While we often found thousands of potato psyllids in even small bittersweet nightshade patches, to date none of these psyllids, and none of the nightshade plants, have tested positive for zebra chip across our broad sampling network. At the same time, at least one 'hot' psyllid collected in a Washington potato field in the 2013 growing season was of the northwest haplotype. This suggested (1) that this infective psyllid picked up the pathogen after leaving bittersweet nightshade; (2) that the psyllids are overwintering on some other non-crop host plant that has not yet been located, but that is capable of harboring the pathogen; or (3) that there are bittersweet nightshade plants infected with zebra chip somewhere outside of our sampling network. Most recently, additional possible host plants have been identified or suggested such as goji berry (*Lycium barbarum*) or even alfalfa (*Medicago sativa*). Clearly, the source of the psyllids that are bringing zebra chip to local potatoes has remained stubbornly unclear.

While the identification of the northwest haplotype of potato psyllids has been incredibly useful, this distinction is based on genetic differences for just one gene, COI. We really still do not know if there are further genetic subpopulations at a finer level. It is possible that "all northwest psyllids are not alike", and that there are some genetic subgroups, as yet unidentified, that are the true spreaders of zebra chip. If we could identify separate breeding populations within the northwestern psyllids, this might give indirect clues as to where (and ultimately then on what host plant) these psyllids are overwintering.

We proposed to learn more about the inter-relatedness of northwestern psyllid populations, using a genomics approach. In this first year of our project, we focused on using "RAD-tags", a modern method in population genetics that looks for gene-sequence differences across an organism's entire genome. This is allowing us to determine fine-scale genetic differences among psyllids collected from nightshades, and from potatoes, across the region. Our project forms a critical step towards determining the source of the zebra chip pathogen in the interior northwest.

Our results are described in greater detail below. However, to summarize, in year 1 we have:

1. Optimized our DNA extraction protocol to allow us to extract from <u>single</u> individual psyllids sufficient DNA, of sufficient quality, to allow RAD-tag sequencing.
2. Submitted DNA extracted from 285 psyllids collected from bittersweet nightshade patches around the region, and from nearby potato fields, to our sequencing provider (Fig. 1).
3. In December the sequencing contractor returned the sequencing data to us; these data files take up over 100 gigabytes.

4. We have begun to analyze these complex data and now can begin to describe the fine-scale relatedness among potato psyllid populations from crop and non-crop host plants (Fig. 2).

Because we are at the very initial stages of examining what is a quite large and complicated dataset, our conclusions at this point are highly preliminary and subject to change as we refine our analyses. However, we can draw a few (very tentative) observations from our first look at the sequencing data:

1. **Psyllids collected from different nightshade patches seem to (sometimes) genetically differ from one another.** A key concern with our project was that frequent, long-distance movement by psyllids would break down even fine-scale genetic differences among populations. Instead, it now is clear that there are clear genetic differences between psyllid populations (Fig. 2). In some cases, psyllids collected from nearby bittersweet nightshade patches are genetically quite distinct from one another, indicating that they are not regularly interbreeding (compare for example the Caliche Lake population to the psyllids in Mesa and Pasco; Fig. 2).
2. **Psyllids collected from potato fields appear to fall into at least two genetic groups.** Visual inspection of the data in Figure 2 suggests two genetically-distinct groups of psyllids collected from Columbia Basin potato fields.
3. **Some psyllids collected in potato fields appear genetically similar to those in some nightshade patches, but others do not.** Most psyllids collected thus far from Columbia Basin potato fields seem most genetically similar to psyllids on nightshade patches near Mesa, Pasco and Colfax, WA (compare colors on the right group of bars representing potato-collected psyllids to those seen in the Mesa, Pasco and Colfax nightshade locations; Fig. 2). However, a second group of potato-collected psyllids (blue colored bars on the left side of the group of potato-collected psyllids; Fig. 2) does not seem obviously similar to the psyllids collected from any bittersweet nightshade location that we have sequenced.

While the data thus far look intriguing, it also is clear that we still have important work left to do. First, we need to continue to refine our relatedness analyses and continue to work to group psyllids found in potato fields with their closest relatives from bittersweet nightshade patches. The GIS mapping work included in our 2015 proposal, and associated predictive modeling, could allow us to develop useful forecasts about how non-crop habitats could influence the risk of zebra chip problems in nearby potato fields. It also would be useful to conduct RAD-tag sequencing on psyllids collected from goji berries, and from a larger group of psyllids collected out of potato fields across a broader area that includes Idaho and Oregon, to build greater confidence in any conclusions about psyllid movement patterns across the entire region.

RESULTS:

Refining our DNA extraction protocol:

Our first step was to define a DNA purification protocol that generates a sufficient quantity of DNA, of sufficiently high purity, from individual potato psyllids (which are relatively small animals) to allow DNA sequencing. To accomplish this, we compared three different DNA purification protocols for resulting DNA yield and purity: 1. The Qiagen DNeasy Blood & Tissue kit; 2. The Zymo Tissue & Insect DNA microPrep kit; and 3. A phenol:chloroform extraction (Chen et al. 2010). For each protocol, we extracted DNA from each of four potato psyllids collected from Columbia Basin bittersweet nightshade patches in

2013. Individual psyllids were placed into separate 1.5 ml microcentrifuge tubes with 150 µl tissue lysis buffer (either homemade SDS buffer or the buffer provided within the Zymo and Qiagen kits), and ground for 1 minute using a pestle driven by a handheld electric mixer. For the Qiagen and Zymo protocols, pysllids were processed following the manufacturers' instructions. For the phenol:chloroform extraction, samples were processed following the protocol of Chen (2010).

All extracted DNA aliquots were visualized on a 1.0 % agarose gel, with psyllid DNA revealing a light band approximately 20 kp in size. The quality and purity of the DNA were measured using the Qubit method, which is highly selective for double-stranded DNA rather than protein, salt or RNA contamination. We found that the phenol:chloroform protocol generated the highest quantity of DNA from a single psyllid; the Qiagen DNeasy blood & tissue kit generated the highest purity of DNA; and the Zymo Tissue & Insect DNA microPrep kit generated the lowest DNA yield in terms of both quantity and quality.

This led us to our final protocol for DNA extraction. Briefly, individual psyllids are placed into separate 1.5 ml microcentrifuge tubes with 150 µl tissue lysis buffer (10mM Tris, pH=8; 50mM EDTA; 200mM NaCl; 1% (w/v) SDS), and ground for 1 minute using a pestle driven by a handheld electric mixer. Then each is processed following the instructions of the Qiagen DNeasy Blood & Tissue Kit, except that 100 µl of elution buffer is used to dissolve the DNA.

RAD-tag sequencing:

Genomic DNA of 285 potato psyllids was converted into nextRAD genotyping using sequencing libraries (SNPsaurus, LLC). The psyllids were collected from various bittersweet nightshade patches around Washington and Idaho, or from 10 different potato fields in the Columbia Basin of Washington (Fig. 2). The nextRAD method uses selective PCR primers to consistently amplify genomic loci between samples. Genomic DNA (~10 ng) was first fragmented with the Nextera reagent (Illumina, Inc), which also ligates short adapter sequences to the ends of the fragments. This is implemented by incorporating an engineered transposome to simultaneously fragment and tag ("tagment") DNA; in this way, unique adapter sequences were added to both ends of fragmented DNA molecules (Fig. 1). Fragmented DNA was then amplified, with one of the primers matching the adapter and extending 9 nucleotides into the genomic DNA to capture the selective sequence. Thus, only fragments starting with a sequence that can be hybridized by the selective sequence of the primer will be effectively amplified. The resulting fragments are fixed at the selective end, and have random lengths depending on the initial Nextera fragmentation. Because of this, amplified DNA from a particular locus is present at many different sizes and careful size selection of the library is not needed.

Reads of all samples were tallied and aligned to each other to form an allelic cluster, and the read with the highest count in the population chosen as a reference read. The reads from each sample were then aligned to the reference set and the predominant haplotypes identified. Loci were discarded that (1) failed tests for presence across the population, (2) included too many samples with higher ploidy than expected, and/or (3) contained alleles with a very low frequency in the population or a low ratio to other alleles in an individual. Individual genotypes were converted to missing if the overall read level was low. Each single nucleotide polymorphism (SNP) was called from the alignments in a VCF file.

Initial analysis of sequencing data:

Next we used the software tool Admixture (Alexander et al. 2009), which clusters individuals based on multi-locus genotypes, and estimates ancestry to infer the population structure of the psyllids. For this step, we assumed a model in which there were *K* populations in all the samples. Individuals in the sample are assigned (probabilistically) to populations, or jointly to two or more populations, if genotypes indicate that they are admixed (that is, if they contain genetic information typical of more than one population). A good value of *K* exhibits a low cross-validation error compared to other *K* values. We performed 20 runs where *K* ranged from 1 to 20, and *K* = 11 demonstrated the lowest cross-validation. This means that these analyses suggest that 11 genetically-distinct psyllid populations were represented in our samples.

Figure 2 presents a (relatively) simplified summary of genetic relatedness among the psyllid populations that we examined. We sequenced psyllids from bittersweet nightshade patches located near Colfax, Mesa, Moses Lake, Pasco, and Caliche Lake in Washington, and near Twin Falls in Idaho. We also sequenced psyllids from 10 potato fields across the Columbia Basin of Washington. Samples encompassed two different years, 2012 and 2013, when multi-year samples were available from a site. Each vertical bar represents a single psyllid individual. Each color indicates that insect's genetic similarity to a particular one of the 11 distinct genetic types identified statistically as described above. In some cases individual insects belonged to just a single genetic type, and in these cases the entire vertical line is just one color. In most cases, individual psyllids exhibited genetic similarity to more than one genetic group, which implies that the insect resulted from interbreeding among populations; in these cases, that insect's vertical line includes 2 or more colors. In summary, insects, or populations of insects, that share similar colors are genetically similar (and so may be related). By comparing line colors from one site to another, we then can infer whether those psyllids are closely related.

Our initial data analyses, while quite preliminary, suggest that psyllids in some spatially-separated bittersweet nightshade patches are genetically similar to one another, while other psyllid populations on different nightshade patches are genetically quite unique. Psyllids from bittersweet nightshade patches located near Colfax, Mesa and Pasco appeared to be broadly most similar to one another (note similarly-colored bars in Figure 2). Note that these psyllid populations seem to reflect interbreeding among a broad diversity of different genetic groups. Intriguingly, most of the potato psyllids that we collected from Columbia Basin potato fields look, superficially at least, most similar to the psyllids on this first group of bittersweet nightshade patches. At the same time, there is a genetically distinct group of potato psyllids recovered from the potato fields that appears to be largely unrelated to any psyllids found on nightshades, indicated by the darker blue color in Figure 2. However, more modeling and analysis is necessary to reach solid conclusions about psyllid interrelatedness among these many different crop and non-crop sites.

In contrast, and interestingly, psyllids from bittersweet nightshade patches at Caliche Lake, WA, and from Twin Falls, ID, are genetically different from psyllids found in the other Washington nightshade patches (note distinctly-colored lines in Figure 2). The Twin Falls location is quite far from any of the Washington sites, and so it is perhaps not surprising that psyllids at this location are genetically different from those in Washington. But, it is interesting that Caliche Lake housed psyllids that were genetically distinct from those at the other Washington sites. Interestingly, the psyllids collected from nightshade at our Moses Lake site in 2012 seem genetically very different from those found at that same location in 2013 (Fig. 2). In contrast, there seemed to be relatively little year-to-year genetic change among psyllids at the Colfax and Mesa nightshade sites. Again, we note that additional analysis is needed to confirm these initial possible findings, and to interpret what they tell us about psyllid movement across the landscape.

Ultimately, we hope to be able to relate genetic variation seen in our RAD-tag data to the specific genes at which this variation occurs. This could yield insight into specifically how psyllids differ, physiologically and ecologically, from one site to another.

References:

H. Chen, M. Rangasamy, S.Y. Tan, H. Wang, and B.D. Siegfried. 2010. Evaluation of five methods for total DNA extraction from western corn rootworm beetles. PloS One 5:1-6.

D.H. Alexander, J. Novembre, and K. Lange. 2009. Fast model-based estimation of ancestry in unrelated individuals. Genome Research 19:1655–1664.

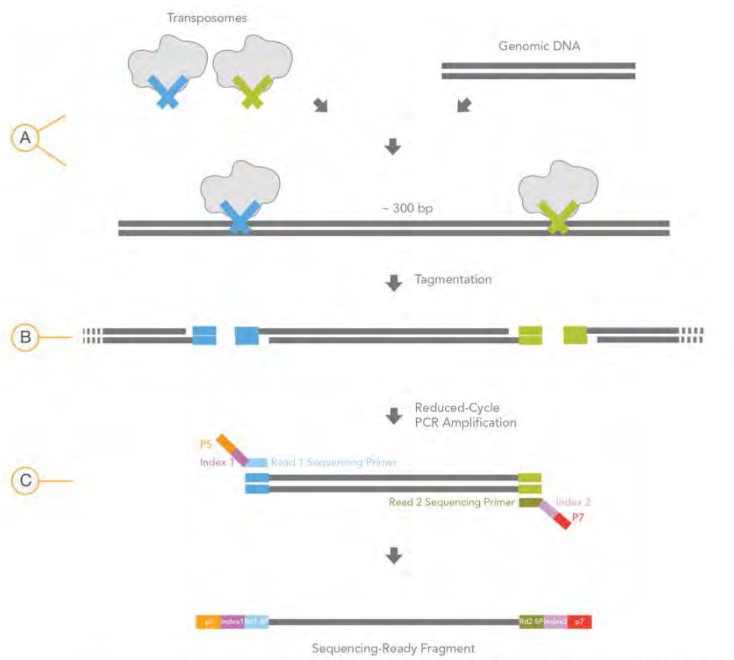
PUBLICATIONS:

Most likely, an additional year's data will be needed before we are comfortable publishing these results. Of course, our preliminary analyses will continue to be made available to Research Consortium through our progress reports and outreach presentations. We plan to present our initial data, once our preliminary analyses are finalized, in *Potato Progress*.

PRESENTATIONS & REPORTS:

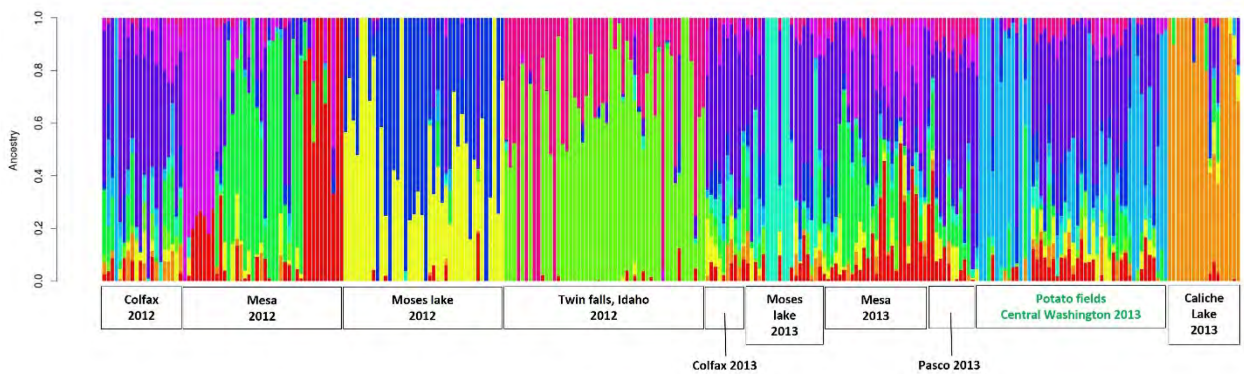
In addition to our regular progress reports to the Research Consortium, we also presented two talks at the 2014 Othello field day. We expect to expand our presentation schedule once we have the initial data in hand.

Figure 1. Graphical description of the RAD-tag sequencing approach. Source: http://support.illumina.com/sequencing/sequencing_kits/nextera_dna_kit/questions.html



A Nextera XT transposome with adapters is combined with template DNA
B Tagmentation to fragment and add adapters
C Limited cycle PCR to add sequencing primer sequences and indicies

Figure 2. Estimated individual ancestry of potato psyllids (*Bactericera cockerelli*) collected from bittersweet nightshade patches (location labeled in black text) or from potato fields (labeled in blue text; includes multiple sampling sites) in Washington and Idaho. Each vertical bar represents a psyllid individual, with a total 283 individual insects included in this figure. Similar colors indicate genetic similarity across the genome (K = 11 distinct genetic types), implying similar ancestry. Multiple colors indicate that that individual psyllid possesses genetic similarity with > 1 genetic group, suggesting interbreeding. Psyllids were collected in 2012 and 2013 as indicated in labels.



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Annual Progress Report

TITLE: Quantifying effects of vector density and time of infection on ZC disease development and tuber physiology both at harvest and during storage

PERSONNEL:

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REPORTING PERIOD: July 1, 2014 – January 15, 2015

ACCOMPLISHMENTS:
The objective of this study was to: quantify effects of vector density and time of infection on zebra chip (ZC) disease development and tuber physiology both at harvest and during storage.

Full analysis of all of the data remains to be completed (including analysis of fry color data and Lso (liberibacter) data and completion and analysis of the greenhouse study). However, the results thus far contribute substantially to our understanding of the relationship between density and timing of infection on development of ZC symptoms in tubers. A second year of data would allow us to confirm these findings and allow us to make more solid recommendations to producers. Thus far, our analyses suggest that very late-season infections may contribute little to occurrence of ZC in tubers under Idaho field conditions; however, if plants are infected earlier during the season, ZC symptoms may continue developing over time during storage.

Field study

Potatoes were planted on April 24 and individual plants were caged on May 21 as plants were starting to emerge. Eight total replicates of each of the nine treatments were established. Inoculations of 2 or 5 psyllids (from an Lso-positive greenhouse colony) were conducted 7 weeks, 3 weeks, 1 week, or 2 days before vine kill, which occurred on September 4. One set of plots served as a check and was not inoculated with psyllids. The plots that were inoculated 7 weeks and 3 weeks before vine kill were sprayed with Agri-mek ca. one week and two weeks following inoculation in order to prevent further development of psyllid populations in these plots.

Tubers from each plant were harvested on September 18 and stored at 55°F with 95% RH. Four replications of each treatment were evaluated September 26. The remaining four replications were cured for two weeks at 55°F with 95% RH; then the temperature was decreased by 0.5°F per day until reaching a final holding temperature of 45°F, at which point they were stored for 83 days before evaluation.

Tubers were evaluated as follows for ZC symptoms. Each individual tuber was cut using a Keen Kut Shoe Stringer French fry cutter and a fry plank was removed for ZC symptom rating and fry quality evaluations. Each plank was given a rating of ZC symptoms between 1 and 3 (1 = no symptoms, 2 = some visual discoloration near the stem end, 3 = ZC symptoms with discoloration throughout the tuber). The remaining tissue from each tuber—separately for each of the three rating categories—was subsampled at the stem end and the composite sample was sent to the Idaho Potato Disease lab in Aberdeen, Idaho for Lso testing (these analyses are pending).

Planks were then fried in canola oil at 375°F for 3.5 minutes. Planks were again rated for visual ZC symptoms and fry quality. Fry color was determined using a model 577 Photovolt Reflection Meter (model 577, Photovolt Instruments Inc., Minneapolis, MN). Measurements were taken on the bud and stem ends of each strip. Mean fry color reflectance was taken as an average between the bud and stem end measurements. A relationship between USDA fry color and photovolt reflectance as measured by our instrument and methodology was previously established; the lower the reflectance measurement, the darker the fry color. In addition, the incidence and severity of mottling were recorded. The severity rating scale for mottling was 1= no mottling, 2 = mild mottling (light colored, non-uniform surface browning not covering the entire fried plank, 3 = moderate mottling (light colored, non-uniform surface browning covering the entire fried plank, and 4 = severe mottling (dark colored, non-uniform surface browning covering the entire fried plank. The presence or absence of sugar end also was recorded for each plank. A plank was considered to have a sugar end if a predominant color of number 3 or darker (when compared with the USDA Munsell Color Chart for French Fried Potatoes) was seen on any 2 sides extending ½ inch or more from the end of the fried strip.

Results of from fry evaluations just after harvest (Table 1) and after storage (Table 2) are shown below. Complete analyses are pending, including analysis of fry color data and Lso data. However, analyses thus far show that density and timing of infection both factor prominently into the level of ZC symptoms found in tubers. Plants inoculated with 5 psyllids 7 weeks before vine kill exhibited much greater ZC symptoms than the other treatments, both at harvest and after storage. Plants inoculated with 2 psyllids 7 weeks before vine kill and plants inoculated with 5 psyllids 3 weeks before vine kill exhibited similar ZC symptoms just after harvest (Table 1); therefore, it appears that a low number of psyllids infecting plants earlier in the season can have a similar effect to a high number of psyllids later in the season. However, this pattern was not observed for the tubers rated after storage. Both 3 week treatments (2 or 5 psyllids) and the 7 week / 2 psyllids treatments exhibited similar levels of ZC symptoms when rated after storage (Table 2); this suggests that symptoms may continue to develop over time during storage. In addition, several tubers rated at harvest as free of ZC symptoms or only expressing mild symptoms showed clear symptoms after frying (13 of 321 tubers = 4%). However, only one tuber rated after storage (1 of 381 tubers = 0.3%) appeared clean, but fried dark. Moreover, between the harvest rating and the rating after storage, there was a 9% increase and a 6% increase in tubers exhibiting severe ZC symptoms for raw ratings and fry ratings, respectively. These observations further suggest that Lso can continue developing over time during storage. It should be noted, however, that this increase occurred in treatments in which plants were inoculated 3 or 7 weeks before vine kill. Plants inoculated within 1 week of vine kill did not show an increase in ZC symptoms after storage.

Table. 1. Mean percentage of tubers in each ZC symptom category *just after harvest* in fried samples from Russet Burbank tubers inoculated in the field with Lso-infected psyllids at different timings and densities.

Trt	Timing (before vine kill)	Number of psyllids	No symptoms		Some discoloration	Zebra chip symptoms	
1	—	—	97.5	A	0.0	2.5	CD
2	2 days	2	94.5	A	0.0	5.5	BCD
3	2 days	5	91.0	AB	2.0	6.8	BCD
4	1 week	2	97.5	A	0.0	2.5	CD
5	1 week	5	100.0	A	0.0	0.0	D
6	3 weeks	2	95.8	A	2.3	2.0	CD
7	3 weeks	5	79.5	B	12.3	18.3	BC
8	7 weeks	2	77.0	AB	2.0	21.0	B
9	7 weeks	5	8.5	C	0.0	91.5	A

Values within each column that do not share the same letter are significantly different at p≤ 0.05.

Table. 2. Mean percentage of tubers in each ZC symptom category *after storage* (88 days at 45°F) in fried samples from Russet Burbank tubers inoculated in the field with Lso-infected psyllids at different timings and densities.

Trt	Timing (before vine kill)	Number of psyllids	No symptoms		Some discoloration	Zebra chip symptoms	
1	—	—	67.3	AB	32.8	0.0	C
2	2 days	2	75.5	A	24.3	0.0	C
3	2 days	5	74.3	A	25.8	0.0	C
4	1 week	2	61.3	AB	39.0	0.0	C
5	1 week	5	78.5	A	21.5	0.0	C
6	3 weeks	2	36.5	BC	21.8	41.5	B
7	3 weeks	5	44.8	AB	21.8	33.3	B
8	7 weeks	2	48.8	AB	20.0	31.0	B
9	7 weeks	5	7.5	C	4.0	88.5	A

Values within each column that do not share the same letter are significantly different at p≤ 0.05.

Greenhouse study

Inoculations were conducted 12 and 3 weeks before vine-kill. There were three psyllid densities used in this experiment (1, 2, and 5 psyllids/plant). Each density treatment consisted of 10 plant-replicates (plus 10 uninfected controls). Plants were exposed to potato psyllids for a 48-hour period. After removing the infective psyllids, plants were maintained in the greenhouse until harvest. Weekly leaf samples have been collected and are currently being extracted for qPCR. Plant photosynthesis rates have been quantified in all plants continuously throughout the experiment until harvest. All tubers were harvested on January 8, two weeks after vine kill. Soil respiration rate was quantified for all treatments prior to harvest. A subsample of tubers was scored for ZC symptoms and sampled for Lso (to be analyzed with qPCR) on January 13 and 14. The remaining half of the harvested tubers is being stored at the University of Idaho Kimberly storage facility for post-storage evaluations. Scoring data remain to be analyzed. All psyllids used for inoculations have been extracted and will be quantified for Lso. Inoculations for the two-days-before-vine-kill treatment were conducted on January 14. Tubers for this inoculation will be harvested, scored, and sampled on January 30.

PUBLICATIONS:
No publications have resulted from this work to date. However, the results thus far are compelling enough that, following a second year of data, we should be able to generate 1-2 peer reviewed publications and an extension publication summarizing the results.

PRESENTATIONS:
No presentations have been made to date; however, some preliminary results will be presented at the Idaho Potato Conference.

Final Report FY 2015

Annual reports due: January 15th (starting with January, 2015)
Final reports due: September 30th or earlier (often submitted Jan. 15th)

PROJECT TITLE: BJKX47 **IPC Project No.:** 8873

TITLE: The impact of changes in crop rotation on nematode communities and Telone II effectiveness in potato cropping systems

PERSONNEL: Dr. Saad L. Hafez, Extension Nematologist, 208 722-6701 ext. 237; shafez@uidaho.edu; Ms. Christeena H. Sevy, Technical Aide, csevy@uidaho.edu. Address: 29603 U of I Lane, Parma, ID 83660-6699.

REPORTING PERIOD: 2014-2015

ACCOMPLISHMENTS:

Objective 1: Evaluate the efficacy of onion culls and waste as a natural biofumigant for the management of root knot nematode

Progress: Effect of culls and waste onion amendment at the rates of 2, 3 or 4 ton/A against root-knot nematode has been tested in greenhouse conditions. Results demonstrated the reduction of nematode population in treated pots as compared to untreated control. A field trial was conducted for onion culls and waste amendment against CRKN during 2014. The trial has been harvested and data was analyzed.

Results: In field conditions onion culls did not produce sufficient protection against nematode infection as compared to the untreated control and standard treatment program.

Objective 2: Survey on nematode communities in different crop rotation systems

Progress: Nematode genera from about 2,500 samples from different crop rotation systems for potato have been analyzed. After completion of nematode data entry into the spreadsheet, it will be analyzed to observe the nematode community structure under different rotational crop. Samples need to be analyzed at least for 2 to 3 consecutive years to get the impact of rotational crops on nematode community structure.

Results: Data from consecutive years is still being compiled and analyzed. This is an ongoing and continuing process to be completed in 2016.

Objective 3: Evaluate the influence of different rotation crops on the effectiveness of Telone II against Columbia root-knot nematode

Progress: The experiment on the evaluation of different rotation crops on the effectiveness of Telone II on Columbia root-knot nematode (CRKN) was started in 2012. This is year three of the program. In 2012 bean, corn and wheat were grown and crop residues were incorporated into the field. Pre- and post-plant nematode population densities were determined. Post-plant population density of nematode increase in wheat, decreased in bean but remains relatively similar in corn. In the fall 2012, each crop field was divided into three strips having five replications. Fumigation with Telone II @ 20 gal/A and Telone II @ 15 gal/A plus Vapam HL @ 30 gal/A were done in two strips of each field and one remaining strip to serve as the untreated control. The post-fumigation nematode population densities were determined in the spring of 2013 and found that the population densities had dropped down to non-detected levels in the treated plots while untreated control plots had an average CRKN larvae of 2.15 per cc of soil. Potatoes were planted in all plots in May and harvested in September 2013. Potato grading was performed and total yield and infected yield were determined.

A wheat crop rotation initially increased the population density of CRKN. Treatments of Telone II and Vapam resulted in an overall decrease in tuber infection and a slightly higher total yield as compared to the untreated control. A bean crop rotation initially decreased the population density of CRKN. Treatments of Telone II and Vapam also resulted in an overall decrease in tuber infection. A treatment of Telone II @ 15 gal/A with the addition of Vapam @ 30 gal/A significantly increased the total potato yield as compared to the bean untreated control. A corn crop rotation neither increased or decreased the population density of CRKN. Treatments of Telone II and Vapam resulted in an overall decrease of tuber infection, however, Telone @ 15 gal/A with Vapam @ 30 gal/A did not perform as well as Telone @ 20 gal/A alone in decreasing tuber infection, but did significantly increase total yield as compared to corn untreated control and Telone @ 20 gal/A.

Results: Crop rotation for a single year has little effect on nematode populations and the effect can be positive or negative. However, the addition of Telone II in program with Vapam HL or Telone II alone after crop incorporation can significantly reduce nematode population densities, increase total yield and decrease infected yield.

Objective 4: Evaluate management of Columbia root knot and root lesion nematodes using new chemistries and new number compounds

Progress: Evaluation of new compound, Nimitz (MCW-2) alone against Columbia root-knot nematode was conducted under field conditions. Efficacy of new systemic numbered compound at different rates has been tested for the management of Columbia root and root lesion nematodes on potato in field conditions. The new numbered compounds alone or in combination with Admire Pro and Absorb has also been tested against Columbia root-knot nematode in field conditions. All trials have been harvested, graded and analyzed.

MCW-2 alone provided good Columbia root-knot control applied at pre- and post-planting. However, pre-plant applications produced a slightly higher level of protection when compared to post-plant applications. On the other hand, post-plant applications of MCW-2 had a slightly higher total yield compared to pre-plant applications. XB170 plus Vydate resulted in increased total yield and increased nematode infection when compared to the untreated control, as well as XB170 alone and in combination with Mocap. SP numbered compounds alone and in combination with Admire Pro, Adsorb and along another SP compound also tended to perform well usually statistically improving nematode protection while also increasing total and marketable yield.

Field experiments to evaluate the effect of several new numbered compounds against Columbia root-knot and lesion nematodes on potato have been conducted. Three different number compounds with different combinations were tested in four different experiments against Columbia root-knot and one experiment against lesion nematode in field conditions. Potatoes were harvested in Fall 2014 and graded by hand to determine total yield, infected yield and percent infected yield. Most programs that included new numbered compounds produced positive results in significantly reducing nematode infection while also slightly increasing total yield. Treatments that had standalone new number compounds did not perform as well as incorporation into programs.

Results: New numbered compounds and new chemistries are currently producing encouraging results and are worth pursuing further trials in multi treatment programs.

Objective 5: Combination of green manure crops and chemical nematicides for management of root-knot nematode
Progress: This experiment could not be executed.

Objective 6: Evaluate the efficacy of new green manure cultivars of mustard and oil radish for management of root-knot nematode.
Progress: Varieties of mustards and oil radishes were planted this fall and incorporated. Potato may be planted spring of 2015 to evaluate the effect of new varieties on CRKN and potato yield and infection.
Results: Field constraints have caused project delays.

PUBLICATIONS:
Peer Referred Publications

Saad L. Hafez and Mahesh P. Pudasaini, 2015. Effect of Movento alone of in combinations with Vydate or Vapam for control of Columbia root-knot nematode in Potato, 2012. Plant Disease management report, Vol. 9.

Saad L. Hafez and Mahesh P. Pudasaini, 2015. Optimum timing of Movento application for control of Columbia root-knot nematode in Potato, 2010. Plant Disease management report, Vol. 9.

Peer Reviewed Publications

P. Sundararaj and Saad L. Hafez. Efficacy of chemical nematicides for the management of lesion nematodes *Pratylenchus neglectus* and *Pratylenchus thornei* on potato in Idaho, USA. Indian Nematology Conference, India, 2014.

Saad L. Hafez and P. Sundararaj. Efficacy of fumigant and non-fumigant nematicides for the management of *Meloidogyne chitwoodi* in potato. Indian Nematology Conference, India, 2014.

P. Sundararaj, T Kathiresan, and Saad L. Hafez. Effect of *Pratylenchus zeae* on β-1, 3-Glucanase and chitinase activities in resistant and susceptible sugarcane clones. Indian Nematology Conference, India, 2014.

Saad L. Hafez, Mahesh P. Rudasaini and Ransey Portenier. New chemistries, new mode of action, different formulation including see treatment and multi-target for potato, sugar beet and onion nematode management in Idaho. 6th International Congress of Nematology, Cape Town, South Africa. May 4-9, 2014

Saad L. Hafez, Mahesh P. Rudasaini and Ransey Portenier Scope of new nematicides and numbered compounds for Columbia root knot nematode management in Idaho. 6th International Congress of Nematology, Cape Town, South Africa. May 4-9, 2014

PRESENTATIONS & REPORTS:
Idaho Potato School
Simplot Fieldmen Training
Society of Nematology Meeting
Landview Fertilizer Fieldmen Training
Potato Production Class in Moscow

January 15, 2015 Annual report for NPRC

Title: Eradication Strategies: Hatching Factors

Personnel: Louise-Marie Dandurand, Roy Navarre, Inga Zasada, Russ Ingham

Objectives: Conduct hatching assays of diffusate from non-solanaceous plants that stimulate hatch to determine the potential for these crops to be valuable trap crops for both *G. ellingtonae* and *G. pallida*.

Hatching assays of *Globodera ellingtonae* were set up with equal amounts of artichoke (A1, A2, A3) or potato roots (P1, P2 and P3), and potato root diffusate and water. Artichoke roots did not stimulate hatch of G. ellingtonae (Fig1).

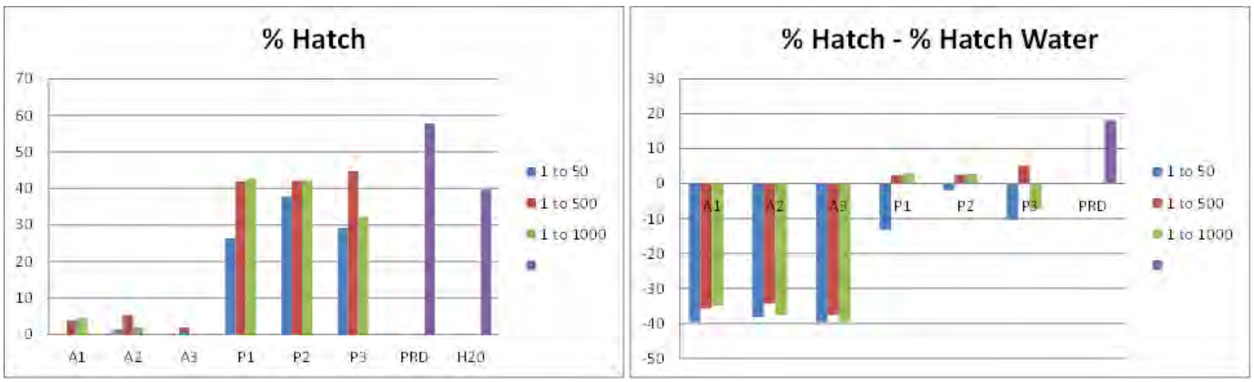


Figure 1. Hatch of *Globodera ellingtonae* to artichoke roots (A1, A2, A3), potato roots (P1, P2, P3), potato root diffusate or water

Also tested were E1AR, E1PR, E1PP and E1PL fractions. These are partially purified artichoke root extracts (AR), potato root extracts (PR), potato tuber extract (PP) and potato leaf extract (PL). The artichoke and potato root extracts are to allow determination of relative amount of HFs in artichoke versus potato roots. The tuber and leaf extracts are to determine the relative amount of HFs in tubers and leaves. Artichoke stimulated hatch as much as potato diffusate when diluted 1:500 fold (Fig. 2). Dandurand has not received these samples to test for *G. pallida*.

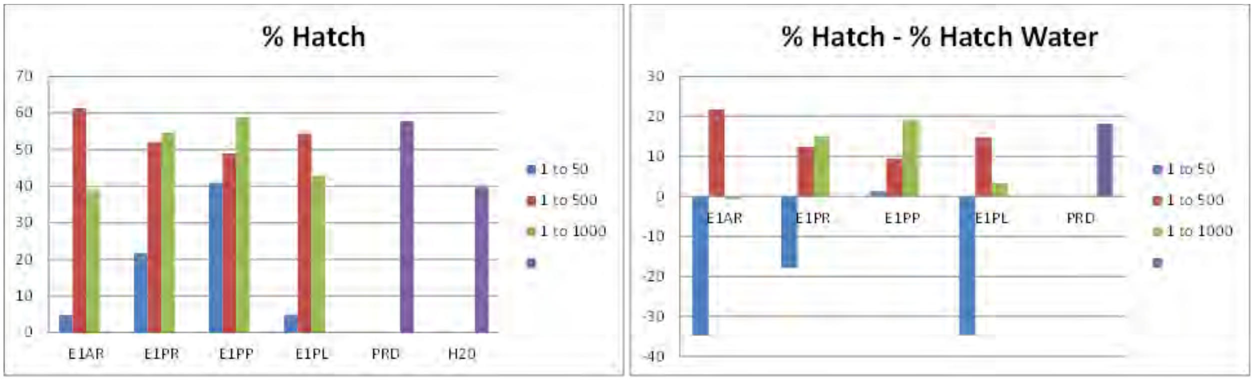


Figure 2. Hatch of *Globodera ellingtonae* to artichoke root diffusate (E1AR), or potato root (E1PR), tuber (E1PP), or leaf extracts (E1PL), potato root exudate or water at 1:50, 1:500, or 1:1000 dilutions.

Test results for *G. pallida* indicated that artichoke diffusate (Table 1) stimulates egg hatch but not as much as potato diffusate. Other materials from Roy were tested (Table 2) but these did not induce hatch. Several other commercial crop diffusate were tested (Table 3), but none showed promise as potential trap crop because of their lack of stimulatory hatch activity.

In addition, potato, artichoke, and LT was grown in small pots (included a bare soil control) and leached at 2, 4, and 6 weeks. The leachates from these pots were collected and hatching assays conducted (Table 4, Fig. 3) and repeated (Table 5). Artichoke diffusate collected at 6 weeks slightly stimulated hatch of *G. pallida* compared to the water control but not when collected earlier (2 and 4 weeks). At 6 weeks, no difference of hatch stimulation was observed when artichoke diffusate was diluted. Greatest hatch stimulus from litchi tomato diffusate (1:1) was observed when collected at 2 weeks compared to 4 and 6 weeks. Hatch was still observed at a dilution of 1:10, but when diluted more (1:100 or 1:1000) stimulatory effect of litchi tomato was lost. This indicates that the hatching factor concentration may be less in litchi tomato than in Desiree where hatch is still stimulated even at a 1:1000 dilution, although it is reduced compared to the 1:1 or 1:10 concentration. This experiment was repeated in late fall of 2014 (Table 5), but diffusates collected at 4 and 6 weeks failed to stimulate hatch, nor did hatch occur in the control potato root diffusate (PRD). As observed in previous years and as other researchers have mentioned (Lamondia, personal communication), hatching assays conducted in late fall, winter appear to be more erratic and variable than those conducted in spring or summer. This experiment will be repeated under more conducive environmental conditions.

Another study was conducted to determine if hatch stimulus was consistent over time. Hatching assays were conducted on potato diffusate collected weekly over a period of 6 weeks. Results indicate that hatch stimulus for G. pallida is greatest from diffusate collected at 5 and 6 weeks (Table 6). A comparative study will be conducted to determine if there is a similar response with litchi tomato diffusate. Additionally, dilutions of the diffusates will be made to determine how concentration of hatching factor varies over time. These data will help us optimize the management of litchi tomato for maximum benefit as a trap crop.

Dandurand is also setting up one final non-host greenhouse experiment with artichoke to include a fallow to demonstrate that decreased egg numbers under artichoke is not simply caused by natural attrition of eggs in bare soil. If similar egg numbers remain in cysts exposed to artichoke compared to those exposed to potato after 16 weeks of growth under greenhouse conditions, then it is likely that eggs were stimulated to hatch when exposed to artichoke diffusate. This experiment is scheduled to terminate at the end of January. This experiment will be completed at the end of January 2015.

Zasada conducted a greenhouse host study that included Solanaceous weeds as well as artichoke. This will be Zasada's 3rd trial with artichoke to demonstrate that it is not a host for G. ellingtonae. Data forthcoming. Dandurand has repeated host status of artichoke to *G. pallida.* No cysts were found in artichoke (Giant Roman); an average of 70 eggs/g soil was retrieved from potato (Desiree) with an average reproductive factor (final population/initial population) of 14.

Table 1. Response of *Globodera pallida* to various artichoke fractions, root diffusate from Desiree, and water.

HF Fraction	Hatch % - week 1	Hatch % - week 2
AR1	5	29
AR2	6	-
AR3	6	30
AR4	0	9
Desiree	50	50
Water	1	10

Table 2. Response of *Globodera pallida* to various fractions from Roy Navarre.

HF Fraction	Hatch % - week 1	Hatch % - week 2
S1	0	1.1
D1	0	0
S2	0	0
D2	1.6	1.6
Desiree	45.4	56
Water	1.0	9.3

Table 3. Response of *Globodera pallida* to root diffusate of lettuce, endive, and radicchio compared to Desiree and water.

HF Fraction	Hatch % - week 1	Hatch % - week 2
Lettuce	4.0	4.8
Endive	15	20.6
Radicchio	3.6	0.9
Desiree	10.7	53.6
Water	1.3	6.1

Table 4. Response of *Globodera pallida* to root diffusate of artichoke, litchi tomato and potato collected 2, 4, or 6 weeks after planting at 4 different concentrations.

		G. pallida - % hatch		
		Artichoke	Litchi Tomato	Desiree
2 weeks	1 to 1	5.1	42.8	32.7
	1 to10	13.7	17.9	27.4
	1 to 100	13.1	17.8	66.8
	1 to 1000	2.7	5.4	6
	PRD*	49.4	53.5	59.9
	water	0	0	0
4 weeks	1 to 1	5.3	17.9	50.3
	1 to10	15.7	50.3	40.8
	1 to 100	3.3	5.8	25.9
	1 to 1000	11.1	5.3	33.7
	PRD*	65.3	57.9	21.2
	water	0	11.6	57
6 weeks	1 to 1	34.2	20.4	51.3
	1 to10	32.9	16.3	89.5
	1 to 100	18.5	4.7	28.9
	1 to 1000	33.3	7.2	23.1
	PRD*	25.6	30.2	30.2
	water	19.2	0	0

*Potato root diffusate collected in February that has been shown to consistently stimulate hatch.

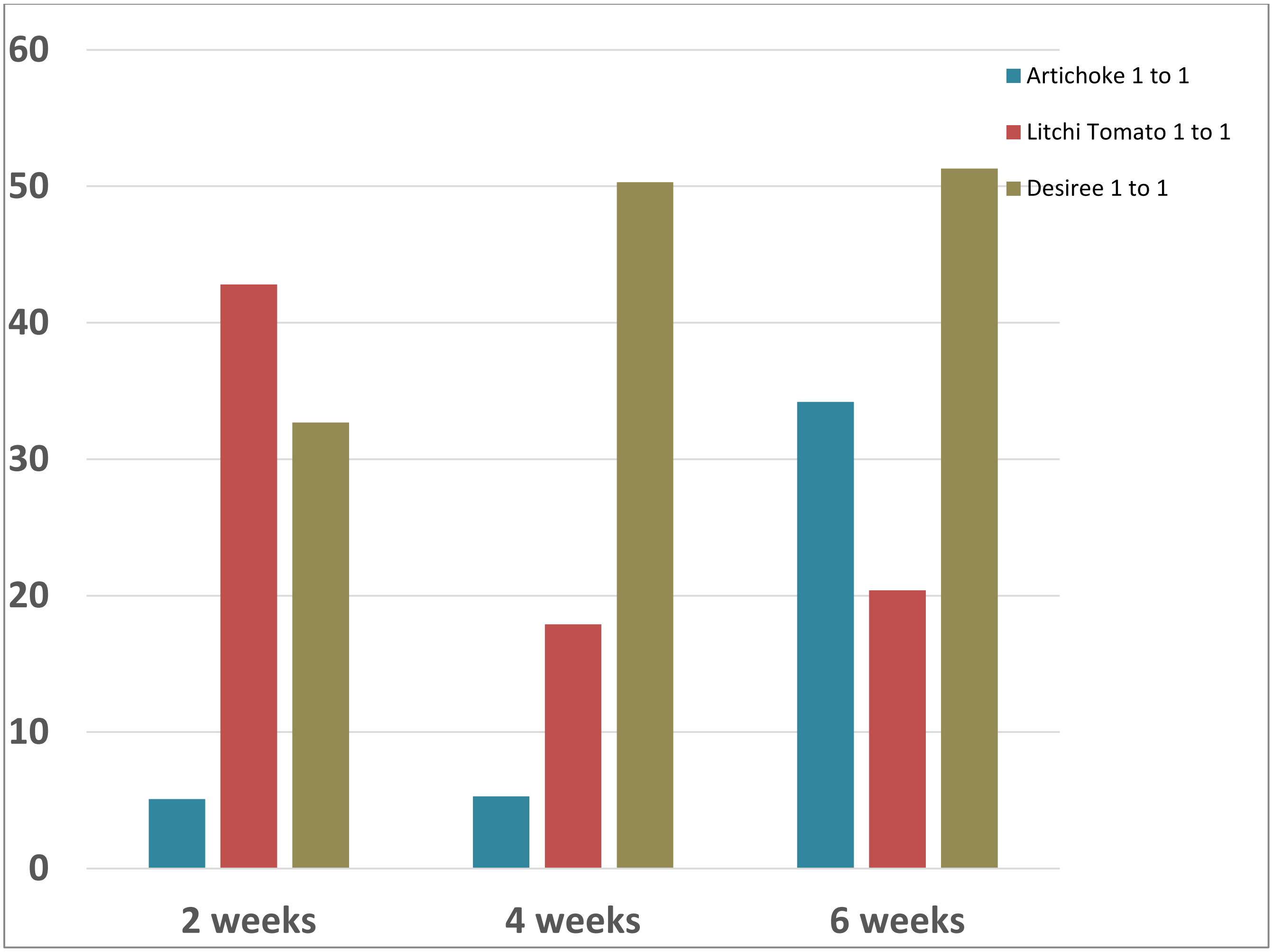


Figure 3. Hatch of *Globodera pallida* to diffusate collected from artichoke, litchi tomato, or potato 2, 4, or 6 weeks after planting.

Table 5. Repeat of experiment to study the response of *G. pallida* to root diffusate of artichoke, litchi tomato and potato collected 2, 4, or 6 weeks after planting at 4 different concentrations. The experiment was conducted in late fall when hatching is more recalcitrant and variabale.

G. pallida - % hatch

		Artichoke	Litchi Tomato	Desiree
2 weeks	1 to 1	8	30	28
	1 to10	20	19	14
	1 to 100	8	8	17
	1 to 1000	9	10	24
	PRD	30	28	28
	water	6	10	10
4 weeks	1 to 1	0	0	10
	1 to10	0	0	2
	1 to 100	0	8	0
	1 to 1000	0	10	0
	PRD	9	6	0
	water	0	12	0
6 weeks	1 to 1	0	28	17
	1 to10	0	16	53
	1 to 100	0	7	10
	1 to 1000	4	5	0
	PRD	38	20	0
	water	0	8	0

Table 6. Hatch of *Globodera pallida* to potato diffusate collected weekly for 6 weeks.

	% hatch
Week 1	16.
Week 2	22
Week 3	15
Week 4	12
Week 5	53
Week 6	52

January 15, 2015 Annual report for NPRC

Tiltle: Functional Genomics of *Solanum sisymbriifolium* (Litchi Tomato) Immunity for PCN Eradication

Personnel: Louise-Marie Dandurand, Joe Kuhl, Fangming Xiao, Allan Caplan, Inga Zasada, Chuck Brown

Currently, stable resistance or immunity against PCN does not exist in Russet potato. Because *Globodera* is a new threat to the US potato industry, novel genes that confer immunity need to be discovered and transferred to potato. Results of this research project will significantly increase our understanding of immunity to potato cyst nematodes. Our program will first establish the nature of immunity to *Solanum sisymbriifolium* (also called litchi tomato - LT) and then use this information to identify genes associated with these responses. Simultaneously, we will also work on moving the immunity response observed in LT into potato lines suitable for production in Idaho and the Northwest. These research efforts will have a positive impact on the potato industry by providing alternatives to current control efforts and will help regulators deal with current infestations and future risks.

Characterization and analysis of *S. sisymbriifolium* genome. We have completed two sets of litchi tomato cloned cDNA libraries, each set includes a primary and normalized library. The first library set involved isolating RNA from four litchi tomato tissues: leaf, stem, bud, and uninfected root. The second library set isolated RNA from infected root tissue. Both sets are high quality and both normalized libraries significantly reduced gene redundancy. Actin redundancy in the normalized compared to primary library was shown to be reduced by 25 and 30-fold for the four tissue and infected root libraries, respectively. A reference transcriptome sequence database has been initiated using RNA isolated from five tissues: leaves, stems, buds, uninfected roots, and infected roots. This database is being generated from three normalized libraries (random-primed, 3'-fragment and 5'-fragment) and utilizes two different sequencing platforms, Illumina Hiseq and Roche 454 FLX++. The final database should represent the diversity of litchi tomato transcripts and full-length gene sequences.

Determination of LT genes recognizing nematode effectors. We are currently constructing the litchi tomato expression cDNA library for yeast two-hybrid screening. Total RNA has been isolated from leaf, stem, and flower and shoot tissue of litchi tomato. mRNA has been purified from the total RNA and double-stranded cDNAs have been further generated. The last step of introduction of these cDNAs into the expression vector is in progress.

Comparison of transcript profile of different life stages of PCN under susceptible (Desiree) or immune (litchi tomato) genotype. Several experiments have been conducted to assure us that litchi tomato is indeed a non-host for G. pallida. Typically we find that roots of potato become infected with PCN as early as 2 weeks after infestation, whereas infection in litchi tomato may be delayed by as much as four weeks. In these studies, we have started with a population of eggs as opposed to hatched juvenile which means that infection may not have been synchronous. Currently, we are using the fluorescent stain PKH26 to stain hatched PCN juveniles. This allows us to follow the infection sequence in both potato and in litchi tomato (Fig. 1). Our microscopic observations indicate that when hatched juveniles are used to infect plants, there is no difference in the timing of infection between potato and litchi tomato. Invasion of infectious juveniles was observed 2 days after inoculation (dai) for both LT and potato, although fewer nematodes penetrated LT than potato. These observations may indicate that less hatching stimulus is released from LT than potato. (Hatching assays are underway to determine this.) Observations over 16 days showed continued attempts at initiating a feeding site in LT, albeit unsuccessful. Histopathological studies to document when feeding site formation is arrested in LT are in the planning stage. Cells in LT that PCN is attempting to feed on will be micro-aspirated (Figure 2) and used to compare transcript profiles from infected LT or potato.

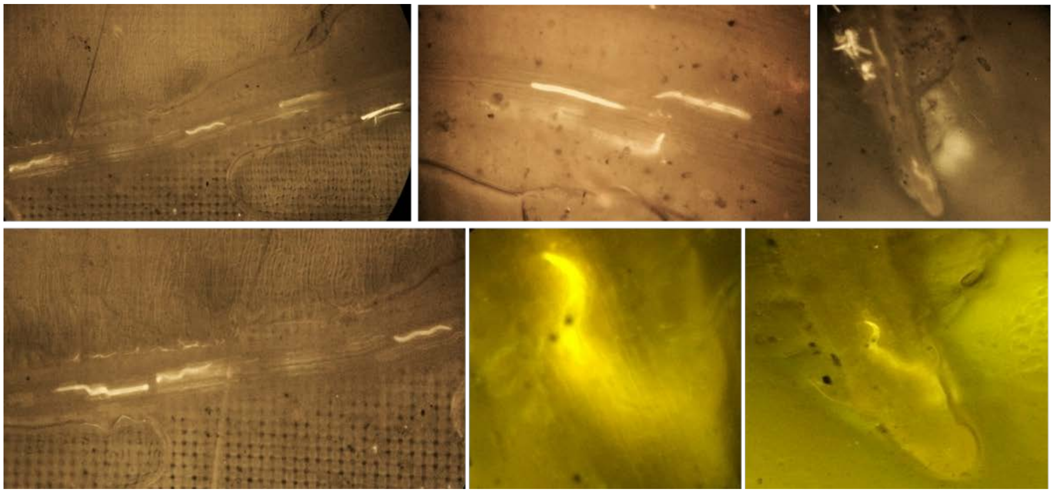


Figure 1. PKH-26 stained *G. pallida* J2 in litchi tomato roots grown in ROC 2 days post-inoculation

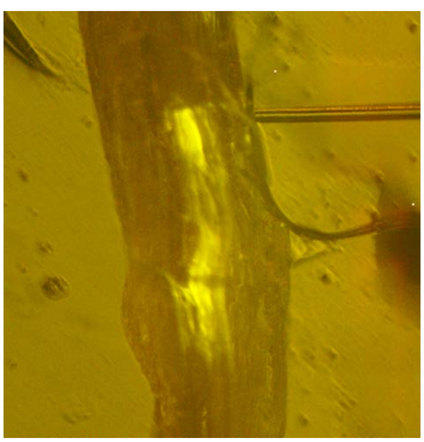


Figure 2. Micro aspiration of tissues limited to the infection area

<u>Development of protocol for *Agrobacterium tumefasciens*-mediated gene transfer to *Solanum sisymbriifolium* (LT).</u>

Purpose: We need to be able to change the expression of specific genes, either upwards or downwards, in order to determine whether those genes contribute to the defense that LT uses to halt *Globodera* infection. In the future, we will also need to transfer into potatoes some or all of the genes that pass this test to determine whether they increase their resistance to *Globodera* infection. Unfortunately, our preliminary studies have shown that both potato and LT are recalcitrant to transformation by *Agrobacterium*, at least in comparison to plants like tobacco. We therefore have to develop a procedure to introduce DNA into LT, a species which has not been investigated previously, and into potato, some of whose varieties have always been difficult to transform.

Summary of results:

Mode of infection. Most researchers use syringes to press a solution of induced agrobacteria into the interstitial spaces of tobacco leaves. In our hands, this has not worked with either LT or with 10 varieties of potato. In our hands, vacuum infiltration of induced bacteria into sterile isolated leaf discs worked well with some varieties of potato, but not with LT. We found that painting the undersurface of tobacco leaves with a soft nylon brush (to minimize wounding associated with the other methods) dipped in induced bacteria gave nearly uniform expression of GFP or GUS constructs, but similar application onto potato gave nothing. However, on LT we have had some GUS reporter gene expression which we could detect by incubating the leaves with a colorless substrate that turns blue when plant cells make GUS enzyme. This painting also reduced cell death on those plants and so will continue to be used as we explore the benefits (or lack of benefits) of the additives or plant growth conditions listed in parts that follow.

Developmental state of leaves: We are using plants derived vegetatively from a single isolate of LT in order to reduce genetic variation and variation due to developmental phase. Nevertheless, we have had inconsistent results. Based on the successes we have had, we believe that the transformation barrier can be breached. In preliminary transient expression studies, we detected patches of indigo deposition (the product of GUS activity) when bacteria were painted onto LT plants cultured hydroponically in a growth chamber. Neither plants grown in closed, sterile containers (to minimize epidermal wax accumulation), nor in greenhouse conditions gave any expression so far. We also noticed that "recently" fully expanded leaves were more likely to show GUS expression than younger leaves, or than leaves that had completed their expansion several weeks previously. In addition to confirming these results, future experiments will test whether infection is sensitive to lighting conditions as has been reported in at least one case.

Parameters for bacterial growth: The genes required for T-DNA transfer are expressed very poorly unless bacteria are treated with acetosyringone (AS) or similar plant phenolics. In nature, bacteria come in contact with this inducer around the wound sites of most dicotyledonous plants. In order to investigate whether LT infection could be improved by pre-treating cells with AS, we compared the use of agrobacteria that had been grown in rich bacterial medium without AS vs. more conventional nutrient-limited media containing AS. Both worked well when cells were painted onto tobacco, but only conventional, AS-treated cultures produced GUS-positive patches of cells on LT. Resuspending bacterial cells in medium with glucose or in autoclaved glutamine, which have improved infections of some other plants, had no benefits here. However, in one preliminary study, we found including trehalose together with the bacteria made a significant improvement in GUS expression in Ss. We will continue this study as well as determine whether it also helps infections of potatoes.

Plant signaling molecules: All, or nearly all, system wide defenses in plants are tightly controlled by a very small set of chemical regulators that are produced either in response to the introduction of pathogen-associated proteins, or to damage caused as the pathogen colonizes the host. One class of signaling molecules induced in this way are salicylic acid (SA) and jasmonic acid (JA). Each induces different sets of defense genes: SA most commonly induces genes to counter biotrophic pathogens, while JA induces genes to counter necrotrophic ones. At the same time, each signal suppresses the genes induced by the other. We reasoned that one or both might suppress the plant defense against agrobacterium so that if we applied the signal molecule together with the agrobacteria, those bacteria would survive longer on the plants leading to increased expression. In one experiment, we found that a constitutively expressed GUS gene showed better expression on LT when the bacteria were applied with SA than when they were applied with JA or without either hormone. We need to repeat this to verify this result, but it could indicate that one of the problems with infecting these plants is that they are killing the bacteria quickly. Suppressing the pathway for this defense could improve our chances to transform the plants stably.

We have also investigated whether suppressing plant cell death at the wound sites by suppressing reactive oxygen formation could protect the bacteria long enough for them to transfer genes. With this in mind, we tested whether simultaneous application of N-acetylcysteine, lipoic acid, and other antioxidants, either improved GUS expression, or reduced the hypersensitive-like response that agrobacteria seem to provoke. Initial experiments indicated that N-acetylcysteine, but none of the other chemicals, had a significant effect on GUS expression and reduced the zone of “browning” around the wound site. We will examine this further in the coming year.

Future aims:

1. We will continue to test several of the agents we have tried, especially SA, JA, and N-acetylcysteine. All tests will be done on LT and 2 representative varieties of potato, Russet Burbank (which in our hands has an extremely bad reaction against *Agrobacterium*) and Galactica, Katahdin, or Banba (which show less cell death when treated with *Agrobacterium*).
2. We will continue to test how best to grow the plants prior to agroinfection in order to improve the frequency of success.
3. We will compare transcript profile between LT and potato.
4. We will complete annotation of LT genome.
5. We will recruit a new undergraduate student to help us apply what we have learned s towards generating stably transformed plants.
6. This student will also be responsible for beginning to annotate the reference transcriptome data. (A reference transcriptome is compiled from sequences derived from a normalized cDNA

pool made from different parts of the plant. This reference transcriptome must be completed before we begin RNAseq analysis.) We hope to replace him when he leaves here this summer with a second student to continue the analysis of the sequences.

January 15, 2015 Annual report for NPRC

Title: Eradication strategies for *Globodera pallida*: Use of Trap Crops

Personnel: Louise-Marie Dandurand, Inga Zasada, Chuck Brown, Pam Hutchinson, Russ Ingham

The goal of this research is to develop and deploy trap crops as an eradicative tool for the pale cyst nematode (PCN), *Globodera pallida*. Non-host trap crops which stimulate egg hatching but do not support nematode reproduction can provide a strategy to eradicate PCN, since hatched juveniles have limited food reserves and die if they do not successfully parasitize plant roots. We have identified a trap crop species (*Solanum sisymbriifolium* or litchi tomato, LT) that stimulates suicide hatch, is a non-host and we will evaluate its efficacy in laboratory, greenhouse, and field studies. A further goal is to identify whether or not, the related cyst nematode species *Globodera ellingtonae* (Ge) is pathogenic to potato to clarify the risk of *G. ellingtonae* to the potato industry.

Objective: Quantify the effect of the selections of the potential trap crop on PCN and Ge population density.

Approach: conduct replicated greenhouse studies to determine the influence of LT on **population decline of PCN**. Assess the ability of breeding lines to cause **a suicide hatch** by exposing eggs to root diffusate in replicated hatching assays. Determine **host status** through greenhouse host assays.

RESULTS: To determine the influence of LT on **populations decline of PCN** One long-range study has been completed once and repeated. The data for these two experiments are being compiled and statically analyzed for publication. For these two experiments, we assessed the ability of LT to decrease populations of PCN under greenhouse conditions in soil infested with PCN. Potato was planted following treatments of fallow, *S.* s*isymbriifolium*, or potato, and nematode cysts were counted on the final potato crop. In both experments, LT almost entirely eliminated reproduction of the nematode population on the succeeding potato crop. Results of the second experiment are shown in Table 2.

Table 1. PCN population decline under three cropping systems under greenhouse conditions.

Crop	Cysts/pot	Eggs/cyst	Eggs/g soil
Potato after Fallow	206	155	21
Potato after LT	14	31	0.28
Potato after Potato	3,378	353	794

N=6

An additional experiment was conducted to evaluate the ability of litchi tomato to reduce PCN populations in a subsequent potato crop when initial PCN inoculum density was varied. Either potato, litchi tomato or barley were planted into soil infested with a low, medium or high PCN infestation rate (5, 20, 40 eggs/g soil) and grown under greenhouse conditions for 16 weeks. After 16 weeks (one growth cycle), one set of soil samples were taken to enumerate the number of cysts reproduced in each treatment at each infestation rate. No cysts were recovered from LT verifying that LT is a non-host for PCN. The greatest number of cysts were recovered at the highest infestation rate under potato. No reproduction was observed under barley, also a non-host. Another set of soil samples were then followed by potato so that cropping sequence was as follow: potato after potato, potato after LT, or potato after barley at all three infestation rates. For the second cycle of growth, reproduction was again highest under the potato-potato at the highest infestation rate (Table 2). Remarkably, very few cysts were found in the potato after LT at all three infestation rates. LT has the potential to serve as an effective trap crop even at high PCN infestation levels.

Table 2. Reproduction of PCN at three different infestation rates (5, 20, 40 eggs/g soil) after planting with potato, litchi tomato (LT), or barley.

Crop	**Initial PCN rate Eggs/g soil**	**PCN cyst #/pot 1st cycle***	**PCN cyst #/pot 2nd cycle***
Potato	5	436	6,972
Potato	20	1,180	9,124
Potato	40	1,885	10,048
LT	5	0	1
LT	20	0	12
LT	40	0	32
Barley	5	0	315
Barley	20	0	788
Barley	40	0	1,885

*Average of six replicates

Nine selections were tested to determine their ability to cause a suicide hatch and the host status to *G. pallida*. None of the selections tested were found to be hosts for *G. pallida* (Table 3). The experiment has been repeated, and samples are in our extraction queu. In addition, a hatching assay of diffusate from all 9 lines and a University of Idaho potato root diffusate control from 6-week-old Desiree was conducted (Table 4). Hatching of eggs from diffusate of the selection called LT syn II was as effective as the potato root diffusate provided by Chuck Brown (Desiree).

Table 3. Host assay for 9 selections of *Solanum sisymbriifolium* (litchi tomato -LT), wild type (wt), selections (syn) or crosses (x) as a trap crop for G. pallida compared to Desiree potato.

Accession or selection	*# of Juveniles (2,3)*	Average # of cysts/plant
Wt 331140	1.5	0
Wt 353311	0	0
Wt 357597	1.8	0
Wt 381291	0	0
LT syn I	0	0
LT syn II	0.16	0
LT syn III	0	0
Mut 1 x Roy 1	0	0
Mut 1 x Elite	0	0
Desiree	4.1	237

Average of 6 replicates grown under greenhouse conditions for 12 weeks.

Table 4. Hatching assay for 9 selections of *Solanum sisymbriifolium* (litchi tomato - LT), wild type (wt), selections (syn) or crosses (x) as a trap crop for *G. pallida* compared to Desiree potato.

Accession or selection of litchi tomato	% Hatch
Wt 331140	6.8
Wt 353311	39.5
Wt 357597	13.3
Wt 381291	42.1
LT syn I	11.9
LT syn II	38.7
LT syn III	16.6
Mut 1 x Roy 1	11.6
Mut 1 x Elite	15.8
Desiree	39.9
UI PRD Control	50.8

Average of 4 replicates.

Objective: To assess the efficacy of LT in infested fields against both *G. pallida* and *G. ellingtonae*.

Approach: conduct replicated field trials in Idaho Falls (*G. pallida*) and Powell Butte (*G. ellingtonae*) to determine the efficacy of trap crops in reducing cyst nematode densities by evaluating viability of cysts periodically through the growing season by use of Meldola's blue, hatching assays and greenhouse bioassay.

Field efficacy of LT in Idaho against *G. pallida*: After receiving permission from the owner, the operator, APHIS, and ISDA, litchi tomato (LT) plants were transplanted into a replicated field trial in an infested field located in Idaho Falls, ID on July 9, 2014. The 9-wk-old plantlets were planted in a square grid pattern (6 inches apart) and contained as per the containment plan on file with the ISDA. The treatments were: 1) fallow; 2) *S. sisymbriifolium* (litchi tomato - LT); and 3) wheat. Plots were sampled every two weeks for 10 weeks. Final take down of the field trial was done on September 17, 2014 (Fig. 1-3). For each sampling time, soil (approximately 5 lbs) was sampled from each plot and cysts will be extracted from soil for enumeration of egg numbers/cyst, and viability (%). Hatching assays and a bioassay to measure reproductive ability will be conducted with cysts from the first sampling (7/9/14) and the last sampling (9/17/14). At take down measurements of biomass (height and weight of tops) of LT was also taken. Two LT plants (with root balls) were removed from each plot and transplanted to pots for further studies under greenhouse conditions. At each sampling time, one root ball with attached rhizosphere soil was removed for assessment of PCN juvenile presence in soil and/or in roots.

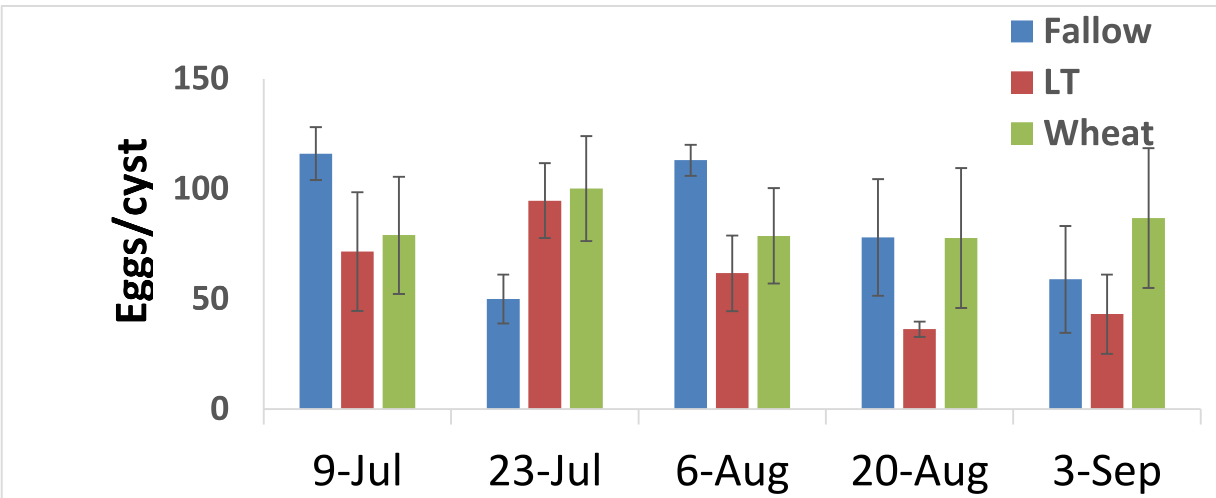
At the end of the experiment, LT containment cages were brought to the edge of the field to be pressure washed and steam cleaned by APHIS and entire root balls of each LT plant was removed. All remaining equipment/items were brought to the edge of the field and either bleached on site, or placed into autoclave bags to be sterilized.

Figure 1 and Figure 2. Litchi tomato after 10 weeks of growth in a PCN infested field in Idaho Falls; measuring growth of tops and photograph of root system.

Figure 3. UI and APHIS personnel sampling soil in field trial at take down on September 2014.

Cysts were collected at set-up and every two weeks thereafter for 10 weeks. Table 5 shows the average number of eggs/cyst under fallow, wheat or LT treatments. Data are currently being analyzed, however we observed a very high variability in egg numbers/cyst as evidenced by the standard error as shown in Table 5. A bioassay of the remaining cysts is being conducted to evaluate there viability.

Table 5. Field trial in Idaho Falls to determine effect of litchi tomato, wheat, or fallow on egg numbers/cyst at initiation, 2, 4, 6 and 8 weeks after establishing the field trial.



Field Trails and Pathogenicity tests for *G. ellingtonae* -

1. *Globodera ellingtonae* developmental biology: As part of the trial to investigate *G. ellingtonae* development a set of bags was prepared to enable us to track juvenile hatch under potato and in bare soil over the course of the growing season. To date, we have found that hatching is highest in weeks 3-6 under potato, with egg numbers in cysts reduced from 311 eggs/cyst to 26 eggs/cyst. In bare soil, hatch occurs at low levels continuously through the growing season. Samples are still being processed and data analyzed.

2. *Globodera ellingtonae* pathogenic effects on potato

Final Report: To evaluate the pathogenic effects of *G. ellingtonae* on potato, five field trials over a three-year period were conducted. In three trials, potato Russet Burbank was inoculated with increasing initial densities (Pi) of *G. ellingtonae* ranging from 0 to 80 eggs/g soil; a similar trial was conducted with potato Désireé. In another trial, potato varieties varying in maturity lengths were either inoculated (80 eggs/g soil) or not with *G. ellingtonae*. In all of the trials G. ellingtonae successfully invaded and reproduced on all of the potato varieties (Figure 1, Table 2). Only one of the trials conducted with increasing levels of Pi, resulted in a significant negative correlation between Pi and yield of Russet Burbank. Combining data from the three years of Russet Burbank trials in a multiple linear regression model indicated a significant effect of Pi on tuber yield (Figure 2). Based on the linear regression model of tuber yield on log(Pi) with a single slope for the three Russet Burbank trials, 11.3 to 17.0% yield loss is predicted at a Pi of 40 eggs/g soil and 13.5 to 20.2% yield loss is predicted at a Pi of 80 eggs/g soil when tuber yields at Pi of 0 eggs/g soil are 1,829 to 2,744 g/plant. None of the potato varieties inoculated with 80 *G. ellingtonae* eggs/g soil had significantly reduced yields compared to non-inoculated plants (Figure 3). Care should be taken in extrapolating the results from this single field site to probable effects of *G. ellingtonae* on potato in other environments.

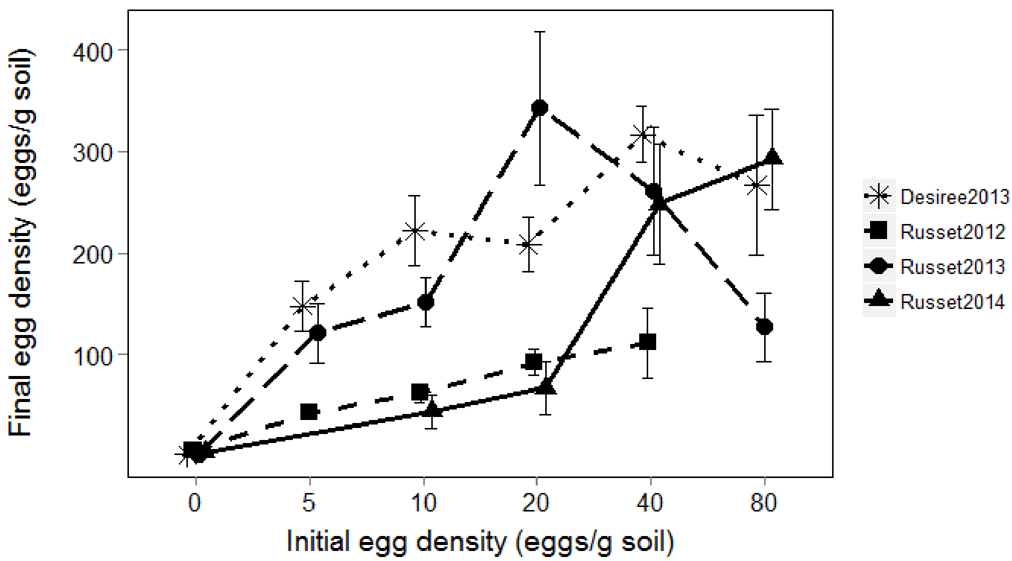


Figure 1. *Globodera ellingtonae* final egg density (P_f, eggs/g soil) at different initial *G. ellingtonae* egg density (P_i, eggs/ g soil) over three years of field experiments on potato (*Solanum tuberosum*) Russet Burbank and Désireé.

Objective: Optimize field management strategies for litchi tomato. Specifically, determine how to establish the trap crop, manage in-season, and kill at the termination of the growth season to prevent spread.

Approach: conduct replicated field trials to determine which, if any, standard potato herbicides and other weed management practices will control the trap crop. Trap crop will be planted at

100 seeds/m^2 to assess production and viability at various locations (Prosser, Aberdeen, Shelley, and Powell Butte).

Optimize field management strategies.

Herbicide management: Weed control in *S. sisymbriifolium* (litchi tomato) is needed not only for production reasons, but also to control weedy PCN-hosts, such as hairy nightshade (*Solanum sarrachoides*). In addition, it is possible that an introduced crop such as this one has the potential to become a weed. Field trials were established at the Aberdeen R&E Enter for preemergence (PRE) and postemergence (POST) treatments of herbicides labeled for use in other crops by seeding litchi tomato at 100 per sq m with denatured mustard seed. PRE treatments were applied 2 weeks after seeding and approximately 2 weeks before emergence. Litchi tomato growth at the Aberdeen R&E Center in 2014 was relatively slow and POST treatments were not applied until early September. Frost soon after application prevented control ratings and desiccation treatments planned for the end of the season.

At 2 and 3 months after PRE herbicide application, Litchi tomato was controlled 100% by metribuzin 75 DF and Chateau (flumioxazin) applied at 2/3 lb and 1.5 oz/A, respectively, while Prowl H2O at 2.1 pt/A provided 80 to 85% control (Figure 1). Litchi tomato was not injured by Matrix (1.5 oz/A) or Sonalan 3EC (2.5 pt/A) at either rating time. Linex 4L at 1.5 pt/A and Eptam at 4.5 pt/A caused 0 to 10 and 10 to 20% injury, respectively, consisting of slight stunting. Otherwise, Dual Magnum or Outlook at 1.4 pt or 16 fl oz/A. respectively, caused early injury and Reflex at 1 pt/A injured/stunted the Litchi tomato up to 40% by the September rating. As mentioned in previous reports, European recommendations for weed control in Litchi tomato includes Prowl H2O which was not safe to the trap crop in our trials.

Herbicide PRE, POST, and season-end kill trials should be conducted in 2015 especially since Litchi tomato growth was slow and the POST and desiccation treatments were either applied too close to frost or not applied due to the late growth of the trap crop.

<u>Flower/Berry Prevention</u>: In the 2013 POST applied herbicide trial, flowering was seemingly prevented by some of the growth regulator herbicides. Stunting also resulted from these treatments applied at the typical use rates. Therefore, a field trial including low rates of these herbicides was planned for 2014 to determine flower/berry production prevention. The trial are was seeded, however, since plant growth was slow, only a few flowers developed. Litchi tomato will be grown in the greenhouse during the winter to flowering stage and low rates of growth regulator herbicides will be applied via greenhouse sprayer.

<u>Agronomic performance</u>: The optimum Litchi tomato seeding rate determined in SW Idaho as 100 per sq m may not be optimum for growing conditions in E Idaho. In 2014, a seeding rate study was planted at the Aberdeen R&E Center rather than in a grower field near PCN regulated areas due to challenges finding an appropriate field. Litchi tomato was drilled at 50, 100, 150, 200, or 300 seeds per sq m. Aboveground biomass fresh wt g/sq m was 1341.9, 1610.3, 1644.3, 2597.4, 2291.3, respectively. Dry wt was415.8, 550, 572.7, 861.8, and 793.8, respectively (Figure 2). These results are a possible indication that 200 seeds per sq m planting rate would be more appropriate for SE Idaho growing conditions in order to produce ideal aboveground biomass. This trial should be repeated for a better understanding of seeding rate needed.

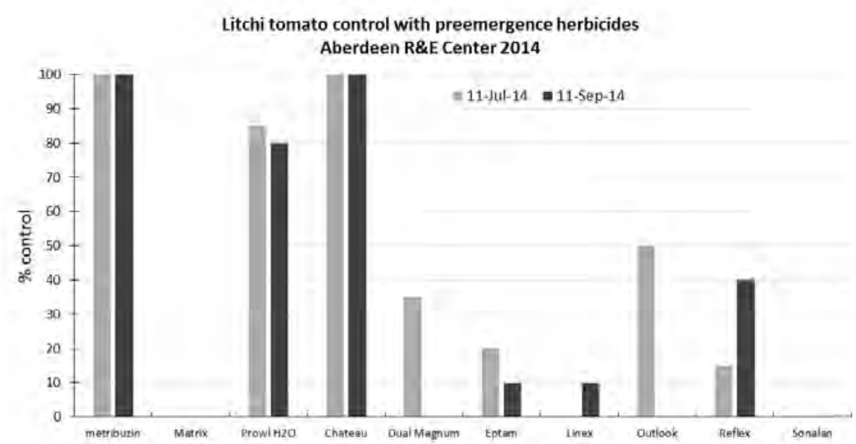


Figure 1. Litchi tomato control with preemergence-applied herbicides in 2014 at the Aberdeen R&E Center.

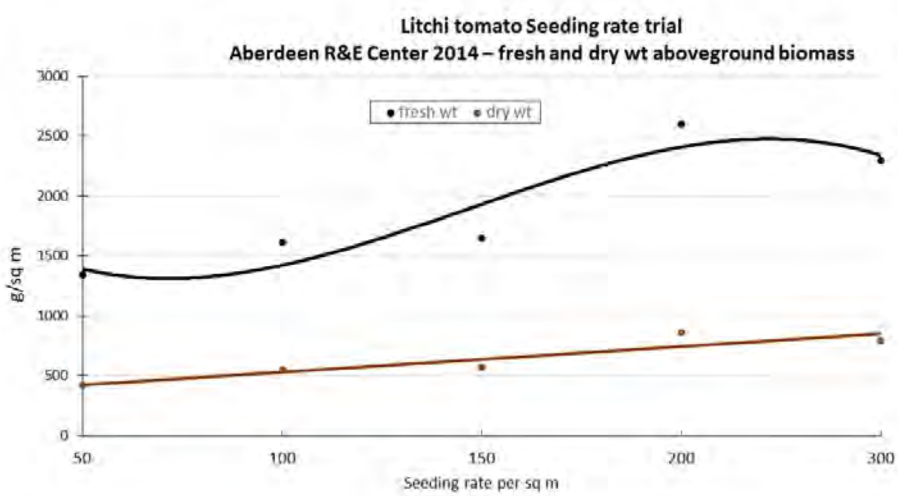


Figure 2. Litchi tomato aboveground biomass (fresh and dry wt) in a 2014 seeding rate trial at the Aberdeen R&E Center.

Objective: Breed LT for desirable characteristics such as reduced prickles, rapid germination and rapid growth, reduced flowering and berry set, greater root mass and higher production of hatching factor.

Approach: select plants with desired characteristics under greenhouse and field conditions. Intercross selected individuals in the greenhouse. Establish field populations for the next cycle of selection.

Breeding and development of Litchi tomato

We began sowing seed in March in order to commence field transplanting on May 9. On August 22 we started berry harvest. We have 100 rows of 230 transplants each. We purchased a grape crusher and a so-called Millett Wet Vegetable seed separator that specializess in crushing fruits with tomato sized seed and separates fruit debris from seed. We will try these out and examine the utility of an array of seed drying equiipment being loaned on site by Nunhems Seed Company in Parma.

Two-year old seed has largely lost its dormancy. Germination at 30 degrees C accelerates date of germination onset and termination. Starting imbibition at such a temperature may be practical. In a farm setting.

We purchased bumblebee hives but have no good control treatment to assess if this increases seed production. Our irrigation was by solid set and moving lateral move. Solid set seemed to be necessary initially to charge the root zone, this combined with dammer diking to impede run-off.

This would depend on soil type and history of cultivation. Our experience in 2014 was that soil was resistant to water penetration. This made us rather relaxed, with a droughth tolerant species like Litchi Tomato, when we should have been probing constantly.

Quarterly Report – January 2015

TITLE: Identification of genetic determinants of tuber necrosis and virulence in recombinant PVY (PVY^{NTN})

PERSONNEL: Alexander Karasev, Mohamad Chikh Ali

REPORTING PERIOD: Quarterly, January 2015

ACCOMPLISHMENTS/RESULTS:

Objectives:

1. Design and assemble chimeric genomes between PVY^{NTN} and genomes of other PVY isolates inducing and not inducing PTNRD, i.e. PVY^{NA-N}, PVY^{N-Wi}, PVY^{O}, and others.
2. Screen all chimeric genomes for PTNRD induction, identify genetic determinants responsible for PTNRD. Develop diagnostic tests for PTNRD determinant of PVY.
3. Screen all chimeric genomes on potato cultivars with PVY resistance genes, identify genetic determinants involved in PVY resistance. Develop diagnostic tests.

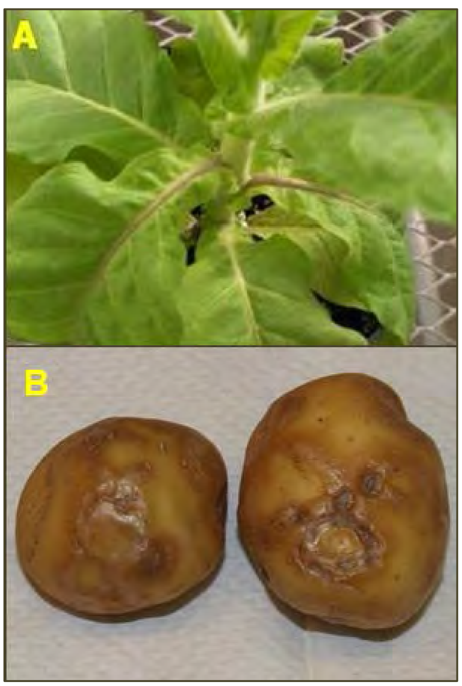


Fig. 1. (A) Vein necrosis induced in tobacco by pBIN-2-8C3-IV2 construct, 4 weeks post-inoculation. (B) PTNRD induced by pBIN-2-8C3-IV2 in potato cv. Yukon Gold, visible immediately after tuber harvest.

PROCEDURES:

We have developed a manipulatable genetic system based on a full-length, infectious clone of PVY. This infectious PVY clone represents a PVY^{NTN} isolate inducing PTNRD in susceptible cultivars, like Yukon Gold, and is adapted for delivery to a plant through agroinfection. We have shown that this infectious clone induces typical virus symptoms in all tested host plants, including potato and tobacco, and provides an ideal model to study virus-host interactions in potato (Fig. 1). We have an extensive collection of PVY isolates from the U.S. displaying wide range of symptoms in potato cultivars, and we also have a large set of potato cultivars with defined genetic background that ideally suit these molecular genetic experiments. Genetic exchanges will be performed between different PVY strains displaying various foliar and tuber symptoms, with subsequent screening of the phenotypes exhibited by chimeric PVY constructs in potato. Our approach will integrate the latest techniques in molecular genetics, molecular biology, and bioinformatics to identify genetic determinants of PVY involved in symptom development in potato, and will help in creation of new diagnostic tools. Point mutations in virus genes will be used to narrow down the identified areas of the genome involved in PTNRD and HR induction. This site-directed mutagenesis will be based on bioinformatics data that we generated through a large-scale PVY sequencing project.

POGRESS TO DATE (January 2015):

- Seven chimeric constructs were designed with N-sections in the NTN genome replaced with progressively larger segments of O-sequences (from isolate MON). These were confirmed by sequencing and inoculated into tobacco to confirm infectivity. The infectious constructs have been inoculated into potato indicators, Maris Bard and Desiree, to evaluate the HR induction due to the presence of the *Nz* gene, and into Yukon Gold plants to evaluate for the PTNRD induction (see Fig 2).
- Our preliminary mapping placed the PTNRD-inducing determinant of the NTN recombinant close to the VPg cistron. We are identifying individual amino acids that differ between NTN and O sequences, to start mutagenesis for final confirmation of the PTNRD genetic determinant (see Fig. 3).

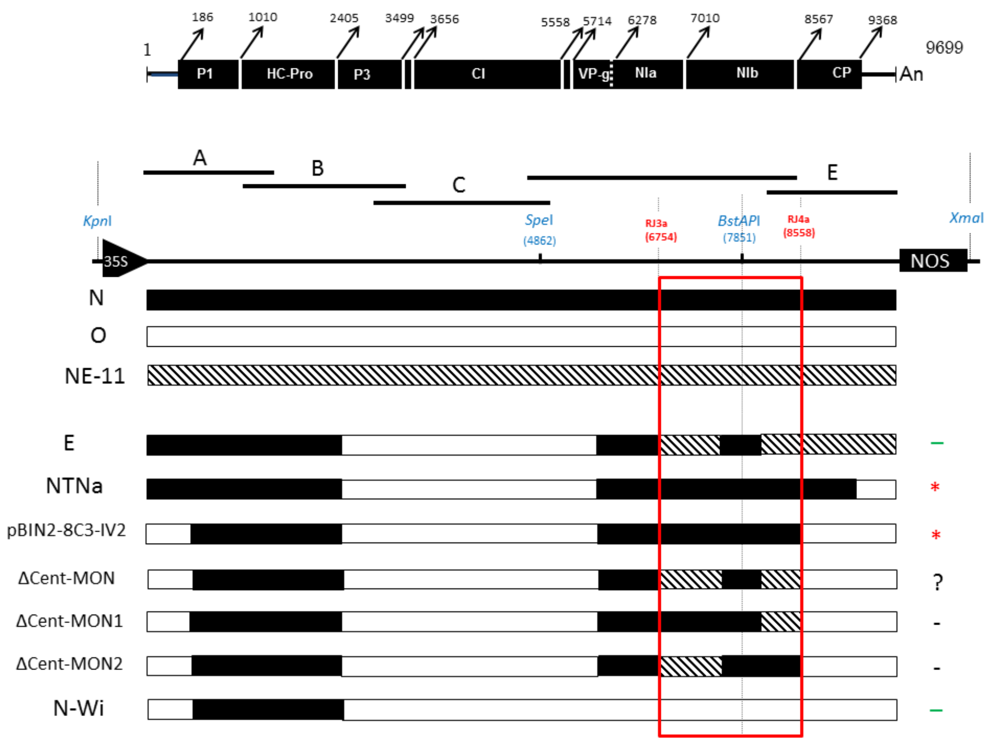


Fig. 2. Schematic representation of PVY constructs used to map the genetic determinant involved in triggering the *Nz* resistance gene.

Work is progressing well on this project and we are on schedule in meeting our objectives. Genetic exchanges between our infectious PVY^{NTN} clone and PVY^{O} and PVY^{E} sequences from our isolate collection have been made producing 7 chimeric clones. These seven clones are being tested on potato indicators for foliar hypersensitive resistance (HR) induction (cvs Maris Bard and Yukon Gold) and for potato tuber necrotic ringspot disease (PTNRD) induction (cv Yukon Gold). The goal is to identify genetic determinants of PVY involved in HR and PTNRD induction in potato.

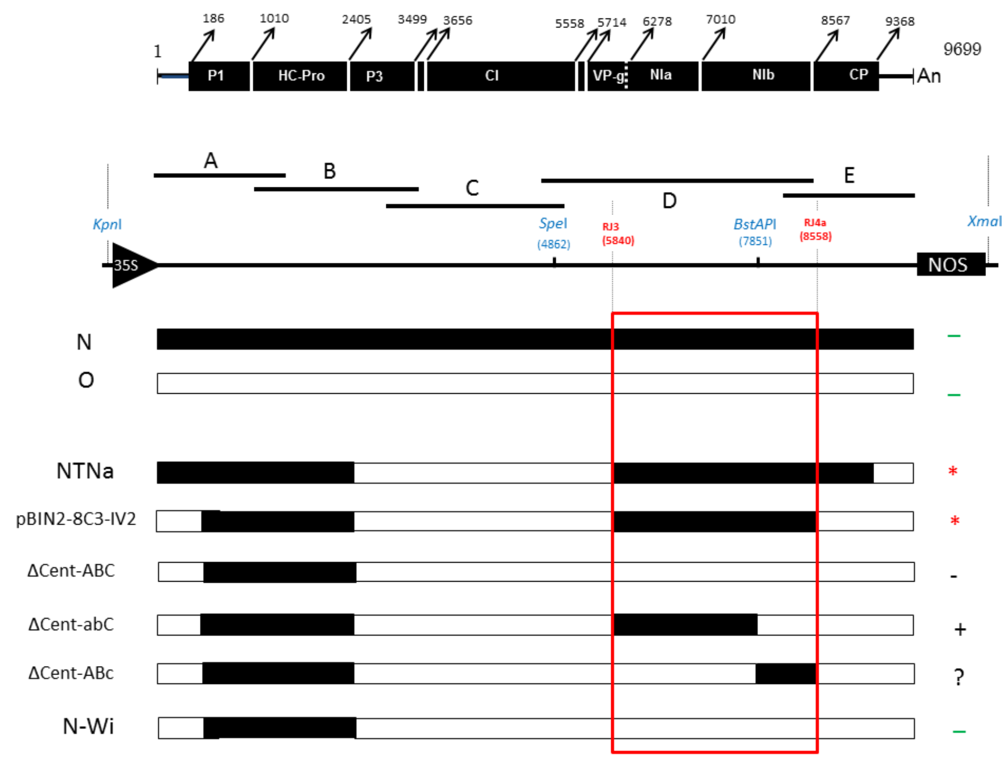


Fig. 2. Schematic representation of PVY constructs used to map the genetic determinant involved in triggering the PTNRD in Yukon Gold.

<u>PUBLICATIONS</u>:

1. Chikh-Ali, M., Rowley, J.S., Kuhl, J.C., Gray, S.M., and Karasev, A.V. (2014) Evidence of a monogenic nature of the *Nz* gene conferring resistance against *Potato virus Y* strain Z (PVY^Z) in potato. *American Journal of Potato Research* **91:** 649-654. <u>An image related to this paper has been selected for the free image page of the December issue of *AMERICAN JOURNAL OF POTATO RESEARCH*</u>
2. Rowley, J.S., Gray, S.M., and Karasev, A.V. (2015) Screening potato cultivars for new sources of resistance to *Potato virus Y*. *American Journal of Potato Research* **93**: in press; published on-line July 24, 2014 (DOI 10.1007/s12230-014-9409-5).
3. Quintero-Ferrer, A., Robles-Hernandez, L., Gonzalez-Franco A.C., Kerlan, C., and Karasev, A.V. (2014) Molecular and biological characterization of a recombinant isolate of *Potato virus Y* from Mexico. *Archives of Virology* **159**: 1781-1785.

<u>PRESENTATIONS & REPORTS</u>:

Karasev, A.V. (2014) *Potato virus Y*: a new problem in potato. Abstracts of the European Association of Potato Research, Pathology Section Meeting, November 17-21, 2013, Jerusalem, Israel. *Potato Research* 57: 164-165.

Nikolaeva, O.V. and Karasev, A.V. (2014) Antigenic structure of *Potato virus Y*. Abstracts of the European Association of Potato Research, Pathology Section Meeting, November 17-21, 2013, Jerusalem, Israel. *Potato Research* 57: 165.

Chikh-Ali, M., Gray, S.M., and Karasev, A.V. (2014) A multiplex RT-PCR assay for the detection and accurate identification of the complex strains and recombinants of *Potato virus Y*. Abstracts of the Annual Meeting of the Pacific Division of the American Phytopathological Society, July 9-11, 2014; Bozeman, MT. *Phytopathology* 104 (Suppl. 3): S3.180.

Karasev, A.V. (2014) Recombinant strains of *Potato virus Y* – a new problem in potato. Abstracts of the Annual Meeting of the Pacific Division of the American Phytopathological Society, July 9-11, 2014; Bozeman, MT. *Phytopathology* 104 (Suppl. 3): S3.182.

Quintero-Ferrer, A., Evans, K.J., and Karasev, A.V. (2014) Genetic diversity of the NE-11 strain of *Potato virus Y*. Abstracts of the Annual Meeting of the Pacific Division of the American Phytopathological Society, July 9-11, 2014; Bozeman, MT. *Phytopathology* 104 (Suppl. 3): S3.183.

Benedict, C., Inglis, D., McMoran, D., and Karasev, A.V. (2014) Tuber symptoms associated with recombinant strains of *Potato virus Y* in specialty potatoes under Western Washington growing conditions. Abstracts of the Annual Meeting of the Potato Association of America, July 27-31, 2014; Spokane, WA.

Chikh-Ali, M., Gray, S.M., and Karasev, A.V. (2014) A multiplex IC-RT-PCR assay distinguishes fourteen recombinant structures of *Potato virus Y*. Abstracts of the Annual Meeting of the Potato Association of America, July 27-31, 2014; Spokane, WA.

Chikh-Ali, M., Rowley, J.S., Kuhl, J.C., Gray, S.M., and Karasev, A.V. (2014) Evidence of a monogenic, dominant nature of the *Nz* gene conferring resistance against *Potato virus Y* strain Z (PVY^Z) in potato. Abstracts of the Annual Meeting of the Potato Association of America, July 27-31, 2014; Spokane, WA.

Evans, K.J., and Karasev, A.V. (2014) Genetic diversity and evolution of recombinants of *Potato virus Y*. Abstracts of the Annual Meeting of the Potato Association of America, July 27-31, 2014; Spokane, WA.

Karasev, A.V., Hamm, P.B., Eggers, J.E., and Crosslin, J.L. (2014) Typing strains of *Potato virus Y* circulating in the Pacific Northwest in potato seed lot trials, 2011 to 2013. Abstracts of the Annual Meeting of the Potato Association of America, July 27-31, 2014; Spokane, WA.

Quintero-Ferrer, A., Evans, K.J., and Karasev, A.V. (2014) Genetic diversity of the NE-11 strain of *Potato virus Y*. Abstracts of the Annual Meeting of the Potato Association of America, July 27-31, 2014; Spokane, WA.

Lin, Y.H., Evans, K., Karasev, A.V., and Gray, S.M. (2014) The phenotypic and genetic diversities of the ordinary strain of *Potato virus Y* (PVY^O). Abstracts of the Annual Meeting of

the American Phytopathological Society, August 9-13, 2014; Minneapolis, MN; 81-P. *Phytopathology* 104 (Suppl. 3): S3.70.

Quarterly Report – January 2015

TITLE: Survey of PVY strain types in PNW potato

PERSONNEL: Alexander Karasev (UI), Phil Nolte (UI), Chris Benedict (WSU Extension)

REPORTING PERIOD: Quarterly, January 2015

ACCOMPLISHMENTS/RESULTS:
This is a new project initiated on July 1, 2014. Previous typing efforts (prior to July 1, 2014) were smaller in scale and were funded partially through the SCRI project.

In the fall 2014, we received a dozen leaf samples from D. Inglis, collected in Western Washington, to determine the presence of the virus and identify the strain; several positives were all typed as N-Wi.

More than 750 samples were collected in the Idaho winter grow-out conducted in Hawaii. The expression of the symptoms was great, and only mosaic samples were collected. Preliminary typing showed that of the 751 samples tested, 75% had O-serotype, 20% had N-serotype, 3% had mixed O/N serotype (likely mixed infection), and only 13 samples were found negative for PVY. The more advanced, RT-PCR based strain typing is underway right now. Initial data may be available by the time of the WA Potato Conference. The project is on schedule.

PUBLICATIONS:
N/A.

PRESENTATIONS & REPORTS:
N/A.

Annual Progress Report / Final Report

TITLE: Management of potato viruses in the Pacific Northwest: Surveys of Seed Potato Fields in western Washington.

PERSONNEL: Chris Benedict, Alexander Karasev

REPORTING PERIOD: 2014-2015

ACCOMPLISHMENTS:
What are the main accomplishments of the project and their significance in terms of the problem solved or impact on the Northwest potato the industry?

Field surveys were conducted to monitor for presence of PVY in Washington seed potato fields. The main accomplishment of this work has been assisting seed potato growers with managing PVY in their seed lots, assistance with plant diagnosis, and tracking of asymptomatic strain presence. The survey and outreach work has resulted in a significant reduction in PVY incidence in western Washington seed lots. We are preparing to sample the winter greenhouse grow out that was initiated in December 2014 and we plan to sample throughout January of 2015.

What has been contributed to science and/or to the industry?
Through our work we have been able document the first widespread survey of PVY strain in this region. This has also allowed us to develop best management practices for seed growers in collaboration with other ongoing research projects.

RESULTS:
During the summer of 2014, eight different potato cultivars in 21 seed lot fields were evaluated for PVY presence by taking samples from symptomatic, suspect (plant potentially showing signs), and asymptomatic plants. Based on initial field testing the distribution of PVY positive plants across the three categories included: symptomatic (53%), suspect (6%), and asymptomatic (20%). Strain results from laboratory testing have not been confirmed yet.

PUBLICATIONS:
List the publications, technical reports, and articles in trade magazines that have resulted from this project. **Please note that the Consortium requests a copy of all journal articles resulting from Consortium-funded research.**

Benedict, C. A., D. W. McMoran, D. A. Inglis, and A. V. Karasev. 2014. Tuber Symptoms Associated with Recombinant Strains of Potato virus Y in Specialty Potatoes Under Northwestern Washington Growing Conditions. American Journal of Potato Research. Under Review.

PRESENTATIONS & REPORTS:
List all reports and presentations to the potato industry in the Northwest.
Benedict, C., D. McMoran, D. Inglis, A. Karasev. 2012-2014. *PVY Monitoring in western Washington*. Western Washington Potato Conference. Mt. Vernon, WA.

Quarterly Report – January 2015

TITLE: Addressing new threats in the Pacific Northwest (PMTV)

PERSONNEL: Alexander Karasev (UI), Phil Nolte (UI), Phil Hamm (OSU)

REPORTING PERIOD: Quarterly, January 2015

ACCOMPLISHMENTS/RESULTS:
This is a new project initiated on July 1, 2014.

The CP gene of the PMTV was expressed in bacteria using the pMAL system, the resulting fusion protein was affinity-purified using column chromatography, and submitted for antisera production to an external vendor. We have received initial bleedings for testing. Concomitantly, we have collected symptomatic tubers from various storage locations in Idaho, and confirmed their PMTV-positive status using RT-PCR; these are being used for testing of our PMTV-specific antisera in TAS-ELISA. We are testing initial bleedings of the antisera produced against our PMTV recombinant CP. The ELISA tests are run in parallel with the control commercial antibody from SASA. The project is on schedule.

PUBLICATIONS:
N/A.

PRESENTATIONS & REPORTS:
N/A.

Quarterly Report – January 2015

TITLE: Surveillance for PVY strain types in Washington and Oregon potato seed lot trials

PERSONNEL: Alexander Karasev (UI), Phil Hamm (OSU)

REPORTING PERIOD: Quarterly, January 2015

ACCOMPLISHMENTS/RESULTS:
We are modifying our more advanced primer set, the so-called MCA primer set, to make one of the more difficult bands to show up more reliably. The modified set is being tested on the PVY isolates from our collection, more than 100 isolates. The project is on schedule, we are making preparations for the summer testing in Othello and Hermiston.

PUBLICATIONS:
N/A.

PRESENTATIONS & REPORTS:
N/A.

Quarterly Report – January 2015

TITLE: Production of virus-free potato lines and screening for PVY resistance genes

PERSONNEL: Alexander Karasev (UI), Joseph Kuhl (UI), Aymeric Goyer (OSU), Vidiasagar Sathuvalli (OSU)

REPORTING PERIOD: Quarterly, January 2015

ACCOMPLISHMENTS/RESULTS:
This is a new project, started on July 1, 2014

We have completed the first experiment testing progeny of the Yukon Gem x Norkotah cross for phenotype expression against infection with the PVYN-Wi challenge. We observed an initial 1:1 ratio for the HR phenotype, suggesting the presence of a single dominant *N* gene in Yukon Gem. 30 progenies of YGxRN cross have been established in tissue culture, and the next experiment is underway, utilizing these tissue culture material. The project is on schedule.

PUBLICATIONS:
N/A.

PRESENTATIONS & REPORTS:
N/A.

Annual Progress Report

TITLE: Management of Potato Viruses in Pacific Northwest
Subproject 4: **S**creening for PVY resistance population (RioGrande Russet x Premier Russet).

PERSONNEL: Sagar Sathuvalli
REPORTING PERIOD: 2014-2015
ACCOMPLISHMENTS:
Evaluation of potato clones for resistance to Potato Virus Y

A greenhouse study was conducted to evaluate 49 clones, each with three replications for resistance to Potato virus Y O strain. For this, potato tubers from previous season were selected as seed and planted in 2 gallon pots and arranged in a completely randomized design on June 7, 2014. Three weeks old plants were inoculated (on August 4, 2014) with PVY. For this, PVY infected leaves were broken into small pieces, ground with mortar and pestle, added with 0.03 M potassium phosphate buffer (pH 8) while gradually grinding and made into slurry (1:10 w/v). In each plant two leaves were selected and lightly sprinkled with carborundum powder. Smooth paint brush was dipped in the inoculum and applied on top of the selected leaves using gentle pressure while supporting the leaves from underneath, with a folded paper towel. Following inoculation, leaves were marked by punching a small hole one inch from the tip. Within two weeks (August 21, 2014) a second inoculation was performed. Ten days and one month after second inoculation, plants were evaluated for symptoms using 0-10 scale (below).

0- No symptoms
1- 10% leaf area covered with symptoms
2- 20% leaf area covered with symptoms
3- 30% leaf area covered with symptoms
4- 40% leaf area covered with symptoms
5- 50% leaf area covered with symptoms
6- 60% leaf area covered with symptoms
7- 70% leaf area covered with symptoms
8- 80% leaf area covered with symptoms
9- 90% leaf area covered with symptoms
10- 100% leaf area covered with symptoms

Enzyme linked immune sorbent assay (ELISA) was also performed on leaf samples collected on September 8, 2014 and September 24, 2014. For this, from each plant one leaf from middle and one leaf from the top were collected and tested by ELISA procedure (Agdia Inc., Elkhart, IN) for PVY presence using Agdia Inc. PVY reagent set. ELISA plates were read on plate reader at 405 nm. PVY inoculum was used as positive control. General extraction buffer was used as negative control. 17 out of 49 samples exhibited the symptoms of leaf chlorosis, necrosis and mosaic. In five clones (A05141-44, A05141-76, A05141-91, A05141-119 and Rio Grande Russet) foliage symptoms were more extensive (>80%) compared to others. 26 (apart from 17 that showed symptoms, 9 asymptotic plants) out of 49 samples tested positive with ELISA on both sampling dates. Thus, PVY infection of plants doesn't always be reflected as symptoms. Here below is the summary of clones tested positive and negative with ELISA.

S. No	CLONES TESTED	ELISA TEST
1	A05141-5	-
2	A05141-10	-
3	A05141-19	-
4	A05141-39	-
5	A05141-40	-
6	A05141-46	-
7	A05141-47	-
8	A05141-50	-
9	A05141-51	-
10	A05141-52	-
11	A05141-61	-
12	A05141-65	-
13	A05141-67	-
14	A05141-68	-
15	A05141-69	-
16	A05141-75	-
17	A05141-101	-
18	A05141-102	-
19	A05141-105	-
20	A05141-106	-
21	A05141-107	-
22	A05141-109	-
23	A05141-116	-
Res. Parent	Premier Russet	-

S. No	CLONES TESTED	ELISA TEST
1	A05141-11	+
2	A05141-29	+
3	A05141-30	+
4	A05141-34	+
5	A05141-35	+
6	A05141-42	+
7	A05141-44	+
8	A05141-48	+
9	A05141-54	+
10	A05141-76	+
11	A05141-80	+
12	A05141-82	+
13	A05141-91	+
14	A05141-95	+
15	A05141-99	+
16	A05141-100	+
17	A05141-110	+
18	A05141-111	+
19	A05141-118	+
20	A05141-119	+
21	A05141-121	+
22	A05141-123	+
23	A05141-125	+
24	A05379-69VR	+
Susc. Parent	Riogrande Russet	+

Results: 23 of 47 segregating clones are resistant and remaining 24 clones are susceptible of

PVY O strain. Genotyping information if available from Solcap will be used further to identify Single Nucleotide Polymorphism markers that correlate to resistance.

PUBLICATIONS:

We are waiting to obtain Solcap genotyping data to add to this project for publication

PRESENTATIONS & REPORTS:

No publications or presentations were made from this research.

Northwest Potato research Consortium Report

TITLE: Managing Verticillium wilt and Black dot of Potato –Two Contributors of Early dying

PERSONNEL: Project Leaders: **Dennis A. Johnson**, Plant Pathologist, (509) 335 3753, dajohn@wsu.edu, WSU Plant Pathology, Pullman, WA 99164-6430
Jeffrey S. Miller, (208) 431-4420, jeff@millerresearch.com, 426 E 200 N, Rupert, ID 83350
Lyndon Porter, (509) 786-9237) lyndon.porter@ars.usda.gov, 24106 N. Bunn Rd., Prosser, WA, 99350; **Philip Hamm**, (541) 561-4724, philip.b.hamm@oregonstate.edu; 2121 S. First Street, Hermiston, OR 97838, Fax (541) 567-2240
Support Personnel: Tom Cummings, Senior Scientific Assistant, tfc@wsu.edu
David Wheeler and Zack Frederick, Graduate Research Assistants
Sarah Light, Ph. 415-577-9012, Email sarah.light@oregonstate.edu; Trent Taysom, Research Scientist, trent@millerresearch.com

REPORTING PERIOD: 2014

ACCOMPLISHMENTS:

White mustard, two brown mustards, arugula, Austrian winter pea, sweetcorn, sudangrass, spring wheat, and spring barley were asymptomatically infected by at least one, but not all of eight isolates of *Verticillium dahliae* (Verticillium wilt).

A rotation crop species by *V. dahliae* isolate interaction occurred in that quantities of *V. dahliae* differed among crop species and isolate of *V. dahliae*. Plant infection and soil densities of *V. dahliae* depended on previous rotation crop and *V. dahliae* isolate. Crop biomass of rotation crops and growth rate of *V. dahliae* were affected after infection of specific rotation crops.

Plant collections of white and brown mustard, arugula, pea, bean, dill, buckwheat, sunflower, wheat, barley, oats, sweetcorn, timothy, and proso millet from commercial fields validated the finding that rotation crops were asymptomatically and differentially infected with isolates of *V. dahliae*

Fresh cut tuber surfaces of potato seed tubers were susceptible to infection by *V. dahliae* and *Colletotrichum coccodes* (black dot). Plant stems from seed pieces inoculated with infested tare dirt at a cut surface became infected with each of the two pathogens. Increased control of both pathogens will likely result from eliminating infested tare dirt was an inoculum source with a seed piece fungicide.

Incidence of plants infected with *V. dahliae* and *C. coccodes* from infested tare dirt was reduced by fungicidal seed treatments.

Planting of *Solanum sisymbriifolium* for management of the Pale Cyst Nematode does not appear to have the potential to substantially increase populations of *V. dahliae* and *C. coccodes* in field soil.

RESULTS:

Quantities of *Verticillium dahliae* isolates in rotation crops of potato

Methods: Two experiments, each composed of two trials, were completed to quantify isolates of *V. dahliae* from rotation crops of potato. In the first experiment, white mustard 'Martigena' (*Sinapis alba*.), brown mustards 'Pacific Gold' and ISCI 99 (*Brassica juncea*.), sweetcorn 'Marvel' (*Zea mays*.), wheat 'Alpowa' (*Triticum aestivum*.), sudangrass 'Piper'

(*Sorghum sudanense*), potato ‘Norkotah’ (*Solanum tuberosum*), native mint (*Mentha spicata*), and peppermint ‘Black Mitchum’ (*M. x piperita*) were planted in potting media infested and not infested with two isolates of *V. dahliae*. Isolates of *V. dahliae* aggressive to potato and mint were selected for this experiment (Table 1). The concentration of inoculum was 30 colony-forming units (CFU) per gram of mix. Plants were arranged in a randomized complete block design with 3 replicates under greenhouse conditions. Plants were grown to maturity, harvested and assayed for *V. dahliae*.

In the second experiment, Austrian winter pea (*Pisum sativum* subsp. *arvense*), arugula ‘Nemat’ (*Eruca sativa*), sweetcorn ‘Marvel’, Barley ‘Baroness’ (*Hordeum vulgare*), sudangrass, potato and peppermint were planted in potting media infested and not infested with one of eight isolates of *V. dahliae*. Regionally representative isolates of *V. dahliae* differing in host of origin, vegetative compatibility group (VCG), multilocus haplotype, and mating type were selected for the present study (Table 1). Plants were arranged in a greenhouse in a randomized complete block design with five replicates. Plants were grown until maturity under greenhouse conditions, evaluated for disease symptoms, and harvested. *V. dahliae* was quantified from stems, roots and potting media with *in-vitro* assays.

Results: One of two isolates of *V. dahliae* was detected from the stems of mustards and spring wheat during the first experiment (Fig. 1a). Potato and mint isolates of *V. dahliae* were detected in bioassay crops, potato and peppermint grown in soils where potato and the mustards were grown. Incidence of infected stems ranged from 0.5 to 33% among infected bioassay plants (Fig.1d).

All rotation crops tested were asymptomatically infected in the second experiment. At least one of eight isolates was detected from the stems (Fig. 2a), roots (Fig. 2b) and soil (Fig. 2c) of each rotation crop. A rotation crop species by *V. dahliae* isolate interaction ($P < 0.0001$) occurred and different quantities of *V. dahliae* were detected among isolates within each rotation crop. More quantities ($P < 0.05$) of *V. dahliae* (CFU/g of stem) were detected from stems of arugula infected with isolate 155 and Austrian winter pea infected with isolates 381and VMD-4 than from potato infected with the same isolates (Fig. 2a). Similar quantities of *V. dahliae* (CFU/g of stem) were detected between Austrian winter pea and potato grown in soil infested with isolate155. Fewer quantities ($P < 0.05$) of *V. dahliae* (CFU/g of stem) were detected from arugula and Austrian winter pea than potato grown in soil infested with isolates 111, 653, VD5 VSP699, 49.B.2010, and 461. Fewer quantities ($P < 0.05$) of *V. dahliae* (CFU/g of stem) were detected from sweetcorn, barley, and sudangrass than potato grown in soil infested with all isolates (Fig. 2a). Fewer quantities ($P < 0.05$) of *V. dahliae* (CFU/g of stem) were detected from sweetcorn, barley and sudangrass than arugula and Austrian winter pea grown in soil infested with all eight isolates (Fig. 2a).

More quantities ($P < 0.05$) of *V. dahliae* (CFU/g of root) were detected from roots of arugula than from potato grown in soil infested with 7 of 8 isolates (isolates 111, 653, 155, VD5 VSP699, 49.B.2010, 461, and VMD-4 (Fig. 2b). More quantities ($P < 0.05$) of *V. dahliae* (CFU/g of root) were detected from roots of Austrian winter pea than from potato grown in soil infested with isolates 111, 653, 381, and 461. Similar quantities ($P < 0.05$) of *V. dahliae* (CFU/g) in soil were detected among crops in the first trial (Fig. 2c). Stem and seed biomass of Austrian winter pea decreased ($P < 0.05$) while height of sweetcorn increased after infection by one isolate of *V. dahliae.* Growth rate, as indicated by radial growth, of one isolate of *V. dahliae* was less ($P < 0.05$) after infection of barley than the same isolate after infection of potato.

Prevalence of asymptomatic infections of specific rotation crops in the Columbia Basin, WA.

Methods: Stems of white mustard, brown mustard 'ISCI 99', arugula, pea (*Pisum sativum*), bean (*Phaeolus vulgaris*), dill (*Athenum graveolens*), buckwheat (*Fagopyrum esculentum*), sunflower (*Helianthus annuus*), corn, wheat, barley, and proso millet (*Panicum miliaceum*) were collected from 21 commercial fields with histories of Verticillium wilt of potato or mint in the Columbia Basin, WA. Stems sections were excised, surface sterilized, and plated on semi-selective media to select for *V. dahliae*. Plated material was incubated at 21^{o} C for 10 to 14 days. Incidence of infected stems was calculated.

Results: *V. dahliae* was detected from stems of rotation crops from 8 of 21 fields (38%). Mean incidence of infected stems within each field was 0% for arugula, buckwheat, dill, pea, beans, corn, oat, timothy, 1% for corn, 2% for millet and wheat, 8% for buckwheat, 10% for barley, 24% for sunflower, and 6 to 63% for brown mustard (Table 2). All infected plants were asymptomatic under field conditions.

Infection of potato stems via infested cut tuber seed surface

Methods: Cut seed tuber surfaces were inoculated with sand artificially infested with *V. dahliae* (50 CFU/g sand) and *C. coccodes* (50 CFU/g of sand). The infested sand was designed to simulate infested tare dirt. Seed tubers were planted in potting media and arranged in a randomized complete block design with 10 replicates under greenhouse conditions. Necrosis, yield, incidence of stems and progeny tubers, and soil population densities of *V. dahliae* and *C. coccodes* were recorded. The trial was repeated.

Results: Stems of three of 10 plants were infected with *V. dahliae* and one of 10 with *C. coccodes* in the first trial. Incidence of stems per plant infected with *V. dahliae* ranged from 16 to 66% and incidence of stems infected with *C. coccodes* was 20%. Mean incidence of stems infected with *V. dahliae* was 76%. Stems of nine of 10 plants were infected with *V. dahliae* and six of 10 with *C. coccodes* in the second trial. Incidence of stems per plant infected with *V. dahliae* ranged from 9 to 48% and incidence of stems infected with *C. coccodes* ranged from 2 to 20%. Mean incidence of stems infected with *V. dahliae* was 14% and mean incidence of stems infected with *C. coccodes* was 23%. Additionally, *V. dahliae* was detected from 80% of potting media after potatoes were harvested.

***Solanum sisymbriifolium* as a potential host for *Verticillium dahliae* (Verticillium wilt) and *Colletotrichum coccodes* (black dot)**

Methods: *Solanum sisymbriifolium* is an annual herb from South American that has been shown to reduce populations of the Pale Cyst Nematode. The objective was to determine if *S. sisymbriifolium* is a host for *V. dahliae* and *C. coccodes*. Alturas, Ranger Russet, Russet Norkotah and *S. sisymbriifolium* were grown in soil infested with two pathotypes of *V. dahliae* (30 CFU/g sand) and one strain of *C. coccodes* (30 CFU/g sand) in two experiments in the greenhouse. These plants were planted in soilless potting media and arranged in a completely randomized design with 5 replicates. Ranger and *S. sisymbriifolium* were also grown in field plots at Othello, WA. Plants were grown to maturity and then assessed for both pathogens. These plants were replicated five times within a single row.

Results: Greater quantities of the potato pathotype (VCG 4A) of *V. dahliae* and *C. coccodes* were usually obtained from Alturas, Norkotah, and Ranger than the non-inoculated control; whereas, greater quantities of *V. dahliae* VCG 4A and *C. coccodes* were not obtained from *S. sisymbriifolium* than the non-inoculated control in both experiments in the greenhouse (Tables 3 and 4). Greater quantities of *V. dahliae* VCG 4A and *C. coccodes* were obtained from the three potato cultivars than *S. sisymbriifolium*. Greater quantities of *V. dahliae* VCG 4A were usually obtained than the mint pathotype VCG 2B from the three potato cultivars. Quantities of *V. dahliae* VCG 4A and VCG 2B did not differ for *S. sisymbriifolium* (Tables 3 and 4). Greater quantities of *V. dahliae* and *C. coccodes* were detected in stems and roots of Ranger Russet than *S. sisymbriifolium* when plants were grown in the field at Othello (Table 5).

Quantify *V. dahliae* populations in commercial field soil where dried crop residue was and was not incorporated into soil by a soil spader.

Methods. Experimental treatments were implemented with the help of cooperators in Grant County, WA. Treatments consisted of four fields where crop residues were incorporated into field soil with a soil spader (Imants, Reusel, Netherlands) and two fields where no soil spader was used, giving a total of six fields. Four of the six fields were fumigated with metam sodium (Fig. 3). GPS coordinates were recorded for plots with a handheld Garmin Etrex 20 (Garmin, Olathe, KS) with a deviation of 3.05 meters. To compensate for the deviation, soil and plant collection sites were sighted along a line between a fixed object, such as a nearby building, to the center pivot of the field. Collections were taken in a straight line between these two points as informed by GPS coordinates. Sample sites were 4.5 meters apart to ensure sampling sites were spatially discrete despite variability associated with GPS coordinates. Soil samples (10 soil cores/field) were collected up to 12 inches beneath the soil surface from each site 4 times throughout the production season on 18 March, 5 June, 22 August and 29 September. Crop samples were collected on 5 June and 22 August.

Results. Number of *V. dahliae* colonies varied among individual fields (Fig. 3). The number of *V. dahliae* colonies obtained from soil increased and then decreased over the growing season (Fig. 3). The number of *V. dahliae* colonies from soil over the four sample dates was lowest for fields where alfalfa was incorporated with fumigation (field 1), where wheat was incorporated without fumigation (field 2) and where alfalfa was not incorporated but fumigated (field 5). Three of the four fields (Fields 1,2,3 vs. field 4) where crop residue was incorporated with the soil spader had low levels of *V. dahliae* colonies (Fig. 3).

Mean number of *V. dahliae* colonies were significantly less for fields where crop residue was incorporated into soil but not fumigated then for fields where alfalfa was not incorporated and fumigated for the third collection period in August (Fig. 4). Field subjected to both incorporation of crop residues and fumigation showed fewer *V. dahliae* colonies than fumigated fields at the first and second collection periods (Fig. 4).

Impact of seed treatments on potato grown from seed encrusted with *Verticillium dahliae* and *Colletotrichum coccodes*-infested soil

Methods. Seed lots encrusted with *V. dahliae* and *C. coccodes*-infested soil were treated with physical or fungicidal seed treatments. Physical treatments included water wash and physical removal of the tare dirt from seed tubers by scrapping. Fungicidal seed treatments included Mancozeb, Topsin M, Mertect 340, Banrot WP, and Mertect 340 after water wash. After seed treatment application seed tubers were planted in soilless media and arranged in a randomized complete block design with 12 replicates under greenhouse conditions. Emergence, senescence, yield, and incidence of stems infected with *V. dahliae* and *C. coccodes* were recorded.

Results. Potato emergence, area under senescence progress curve (AUSPC), yield, and incidence of plants infected with *V. dahliae* and *C. coccodes* data are presented separately for each year and trial since a significant seed lot by seed treatment interaction ($P < 0.05$) was detected (Tables 6 and 7). Emergence was reduced ($P < 0.05$) by soil removal compared to the control + soil and water wash treatments in two seed lots. AUSPC was reduced ($P < 0.05$) by soil removal and mancozeb treatments compared to the control and control + soil treatments in two seed lots, respectively. Yield was reduced or increased ($P < 0.05$) by soil removal and water wash treatments depending on the seed lot. Incidence of plants infected with *V. dahliae* was generally reduced by fungicidal seed treatments compared to the control and or control + infested soil treatments. Incidence of plants infected with *C. coccodes* was generally reduced by fungicidal and water wash seed treatments compared to the control + infested soil treatment (Tables 6 and 7).

2014 Field (Lyndon Porter):

In 2014 the field selected for testing the efficacy of 22 treatments in managing Verticillium wilt did not develop high levels of Verticillium. Low soil inoculum levels resulted in sporadic infection throughout the field based on stem assays. Consequently, data collected in year two was inconclusive with regards to the efficacy of the treatments in managing Verticillium wilt. In our 2013 field trial, four treatments (Calcium chloride, Banrot, Phosphorus 10-34 and Phosphorus 11-52) significantly reduced or delayed the emergence of plants in the spring when applied in close contact with the seed. In the 2014 field trials, these products did not significantly reduce emergence compared to the non-treated control when these treatments were applied so they were not in direct contact with the seed.

2014 Greenhouse (Lyndon Porter):

The same 22 treatments evaluated in the field trial were also evaluated in a greenhouse trial. Unfortunately there was an issue with an unidentified soilborne fungus (Fig. 5) that caused a stem rot in the majority of the treatments. The soil was pasteurized prior to use, but this does not guarantee a complete control of soilborne fungi in the soil or possible seed infestation.

Objective 5: Use of Vydate (Oxamyl) as an Alternative to Metam Sodium Fumigation

A field trial was established at Acequia, ID comparing metam sodium (Vapam) to Vydate and Vydate + Vapam for effects on yield, grade, and economic return. A full report detailing all the methods and results is attached at the end of this document.

Results Summary. Vydate was not effective as an alternative to Vapam. Combining a reduced rate of Vapam with Vydate was effective in reducing all nematodes present and slightly improving plant vigor, yield and grade was not positively affected. The only treatments to provide a positive net economic return was Vapam at 40 gallons/acre and Vapam at 20 gallons/acre + two applications of Vydate (in-furrow and at 12” tall plants).

Conclusions

All rotation crops tested were asymptomatically infected with at least one, but not all of eight isolates of *Verticillium dahliae*. A rotation crop species by isolate interaction occurred and isolates of *V. dahliae* were detected in different quantities among rotation crops. Quantities of *V. dahliae* detected from plant tissues depended on the rotation crop and isolate combination. More quantities of *V. dahliae* (CFU/g of stem) were generally detected from potato than the rotation crops; however, similar quantities were detected from Austrian winter pea and potato grown in soil infested with isolate 155. Additionally, more quantities of *V. dahliae* (CFU/g of stem) were detected from stems of arugula infected with isolate 155 and Austrian winter pea infected with isolates 381 and VMD-4 than from stems of potato infected with the same isolates. Differences in quantities of *V. dahliae* detected from specific crops may be explained by adaptation of specific isolates to host species. Additional research is needed to determine the mechanism. Rotation crop biomass varied in infected plants and indicated that, although infections are asymptomatic, plant biomass was affected by infection. Growth rate of *V. dahliae* decreased after infection of barley relative to potato. Previous cropping history affected incidence of potato and peppermint stems infected with *V. dahliae* isolates as indicated from the bioassay tests.

Asymptomatic infection of rotation crops was validated when *V. dahliae* was isolated from rotation crops from commercial fields in the Columbia Basin. Incidence of infected stems varied among rotation crops and was generally less in grasses than mustards.

Transmission of *V. dahliae* and *C. coccodes* from seed to stems was observed when cut seed tuber surfaces were inoculated with artificially infested tare dirt. Increased control of both pathogens will likely result from eliminating infested tare dirt as a source of inoculum with a seed piece fungicide.

Planting of *S. sisymbriifolium* for management of the Pale Cyst Nematode does not appear to have the potential to substantially increase populations of *V. dahliae* and *C. coccodes* in field soil.

Incidence of plants infected with *V. dahliae* and *C. coccodes* from infested tare dirt was reduced by fungicidal seed treatments.

Incorporating high levels of organic matter over many seasons will likely increase soil health and promote Verticillium-suppressive soil.

Replacing Vapam with Vydate was not effective in improving yield, grade and net economic return in 2014.

Table 1. Eight *Verticillium dahliae* isolates from various hosts, vegetative compatibility groups (VCG), multilocus haplotypes, and mating types used in experimental inoculations (from Dung et al. 2013).

V. dahliae isolate	Host	VCG	Multilocus haplotype	Mating type	Source
111	Peppermint	2B	H02	*MAT1-2*	D. Johnson
653	Potato	4A	H04	*MAT1-2*	R. Rowe
155	Peppermint	4A	H04	*MAT1-2*	D. Johnson
VD5 VSP699	Spinach	2B/4B	H07	*MAT1-2*	L. du Toit
49.B.2010	Potato	4B	H07	*MAT1-2*	J. Dung
381	Watermelon	2A/B	H24	*MAT1-2*	S. Miller
461	Tomato	2	H37	*MAT1-1*	R. Rowe
VMD-4	Tomato	2A/B	H38	*MAT1-2*	M. Lacy

Table 2. Incidence of rotation crop stems infected with *Verticillium dahliae* collected from 21 fields with histories of Verticillium wilt of potato or mint in the Columbia Basin, WA.

Rotation crops sampled	Cropping history	County	# of stems sampled	Incidence (%)
Arugula 'Nemat'	Potato, peppermint	Grant	50	0
Arugula 'Nemat'	Potato, peppermint	Grant	50	0
Brown mustard ISCI 99, millet	Potato	Grant	150, 50	63, 2
Brown mustard ISCI 99, wheat	Potato	Grant	50, 50	14, 2
White mustard 'Martigena'	Potato	Grant	50	6
Sunflower	Potato	Grant	25	24
Pea	Potato	Grant	100	0
Pea	Potato	Adams	100	0
Bean	Potato	Grant	100	0
Buckwheat	Potato	Grant	100	7
Buckwheat	Potato	Grant	100	9
Buckwheat	Potato	Grant	100	0
Dill	Native mint	Yakima	100	0
Corn	Potato	Franklin	100	1
Corn	Potato	Grant	100	0
Corn	Potato	Adams	100	0
Corn	Potato	Grant	100	0
Oat	Potato	Grant	100	0
Oat	Potato	Grant	100	0
Barley	Potato	Grant	100	10
Timothy	Peppermint	Adams	100	0

Table 3. Quantity of two pathotypes of *Verticillium dahliae* and *Colletotrichum coccodes* in stems of three potato cultivars and *Solanum sisymbriifolium* when grown in infested soil in the 2013 greenhouse trial.

	V. dahliae			*Colletotrichum coccodes*	
	Non-inoculated Control	Infested soil VCG2B	Infested soil VCG 4A	Non-Inoculated Control	Infested soil
Alturas	5	46 xz	97 xyz	0	41 xz
Norkotah	29	21 z	108 xyz	0	20 z
Ranger	0.2	4.5	72 xyz	0	20 z
Solanum sisymbriifolium	0.6	0.8	11	0	3

x = Significantly different than non-inoculated control at $P = 0.05$ (across rows)
y = Significantly different than *V. dahliae* VCG2B at $P = 0.05$ (across rows)
z = Significantly different than *S. sisymbriifolium* at $P = 0.05$ (down columns)

Table 4. Quantity of two pathotypes of *Verticillium dahliae* and *Colletotrichum coccodes* in stems and roots of three potato cultivars and *Solanum sisymbriifolium* when grown in infested soil in the 2014 greenhouse trial.

	Stem					Root				
	Verticilium dahliae			*C. coccodes*		*Verticilium dahliae*			*C.coccodes*	
	Con-trol	VCG2B	VCG4A	Con-trol	isolate	Con-trol	VCG2B	VCG4A	Con-trol	isola te
Alturas	2.3	23 xz	41 xz	0	56 xz	2.3	32 x	58 xy	0	56 x
Norkotah	2.0	20 x	88 xz	0	77 xz	0.3	18 x	87 xyz	0	79 x
Ranger	0.6	6.2	25 xyz	0	29 x	1.4	3.6	30 xy	0	33 x
S. sisym-briifolium	1.1	12 x	6.1 x	0	15 x	1.9	22	21 x	0	46 x

x = Significantly different than non-inoculated control at $P = 0.05$ (across rows)
y = Significantly different than *V. dahliae* VCG2B at $P = 0.05$ (across rows)
z = Significantly different than *S. sisymbriifolium* at $P = 0.05$ (down columns)

Table 5. Quantity of *Verticillium dahliae* and *Colletotrichum coccodes* detected in Ranger Russet and *Solanum sisymbriifolium* grown in replicated field plots and Othello.

	Stem		Root	
	Verticillium dahliae	*C. coccodes*	*Verticillium dahliae*	*C. coccodes*
Ranger	22 z	19 z	17 z	23 z
S. sisym-briifolium	1	0	1.1	0

z = Significantly different than *S. sisymbriifolium* at $P = 0.05$

Table 6. Emergence, AUSPC, yield, and incidence of plants infected with *Verticillium dahliae* and *Colletotrichum coccodes* when seed pieces were grown in tare soil with various seed treatments in 2013.

2013: Russet Burbank 1[a]	Emergence (%)	AUSPC	Yield (g)	Inc. of plants with *V. dahliae* (%)	Inc. of plants with *C. coccodes* (%)
Control	83 ab	1215 a	418 abc	20 ab	30 ab
Control + soil	100 a	1058 ab	325 bc	50 a	50 a
Water wash	83 ab	790 ab	392 abc	20 ab	10 b
Soil removed	67 b	760 b	317 c	13 b	50 a
Mancozeb	100 a	795 ab	416 abc	8 b	17 ab
Topsin	100 a	1034 ab	436 ab	8 b	0 b
Mertect	100 a	884 ab	454 a	17 b	33 ab
Wash + Mertect	100 a	817 ab	458 a	0 b	25 ab
Banrot	100 a	968 ab	473 a	0 b	9 b

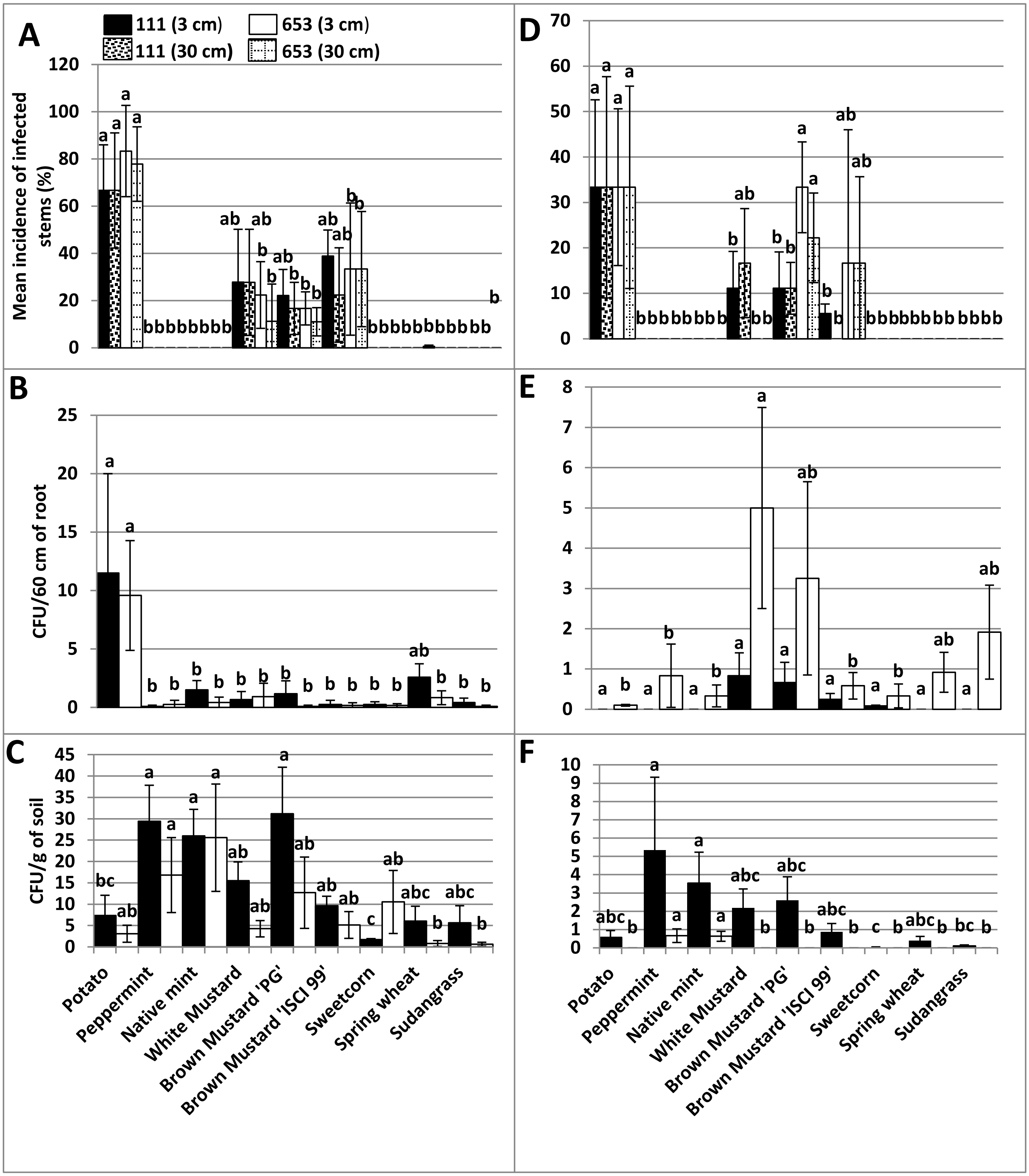
[a] 200 CFU/g of *V. dahliae* and 26 CFU/g of *C. coccodes* were detected from seed lot.

Table 7. Emergence, AUSPC, yield, and incidence of plants infected with Verticillium dahliae and Colletotrichum coccodes when seed pieces were grown in tare soil with various seed treatments in 2014.

2014: Russet Burbank 60 [a]	Emergence (%)	AUSPC	Yield (g)	Inc. of plants with *V. dahliae* (%)	Inc. of plants with *C. coccodes* (%)
Control	100	1532	265	0	50
Control + soil	100	1488	264	8	41
Soil removed	100	1543	296	8	58
Banrot	92	1217	311	0	27
2014: Russet Burbank 70 [b]					
Control	100	1287 ab	283	8 b	33 ab
Control + soil	100	1312 a	285	33 a	41 a
Water wash	100	1179 ab	315	0 b	0 b
Soil removed	100	1256 ab	288	0 b	25 ab
Mancozeb	100	1038 b	331	0 b	8 ab
Mertect	100	1178 ab	280	0 b	18 ab
Banrot	100	1204 ab	310	0 b	16 ab
2014: Russet Norkotah 38 [c]					
Control	92	1847	275	9	18 ab
Control + soil	92	1869	245	9	45 a
Banrot	92	1859	259	0	9b
2014: Russet Norkotah 47 [d]					
Control	83 ab	1220	284 a	10	10
Control + soil	83 ab	1189	251 ab	10	40
Water wash	100 a	1598	298 a	16	16
Soil removed	66 b	1285	176 b	0	25
Mancozeb	83 ab	1125	270 a	0	40
Mertect	66 b	1832	235 ab	0	37
Banrot	83 ab	1306	244 ab	0	10
2014: Alturas [e]					
Control	100 a	1376 b	256 a	0 b	91 a
Control + soil	100 a	1689 ab	214 ab	25 a	66 ab
Water wash	100 a	1872 a	171 b	0 b	66 ab
Soil removed	92 b	1573 ab	228 a	0 b	72 ab
Mancozeb	100 a	1443 b	222 a	0 b	66 ab
Topsin	100 a	1644 ab	219 ab	0 b	41 b
Mertect	100 a	1513 ab	236 a	0 b	41 b
Wash + Mertect	100 a	1660 ab	250 a	0 b	58 ab
Banrot	100 a	1533 ab	252 a	8 b	58 ab

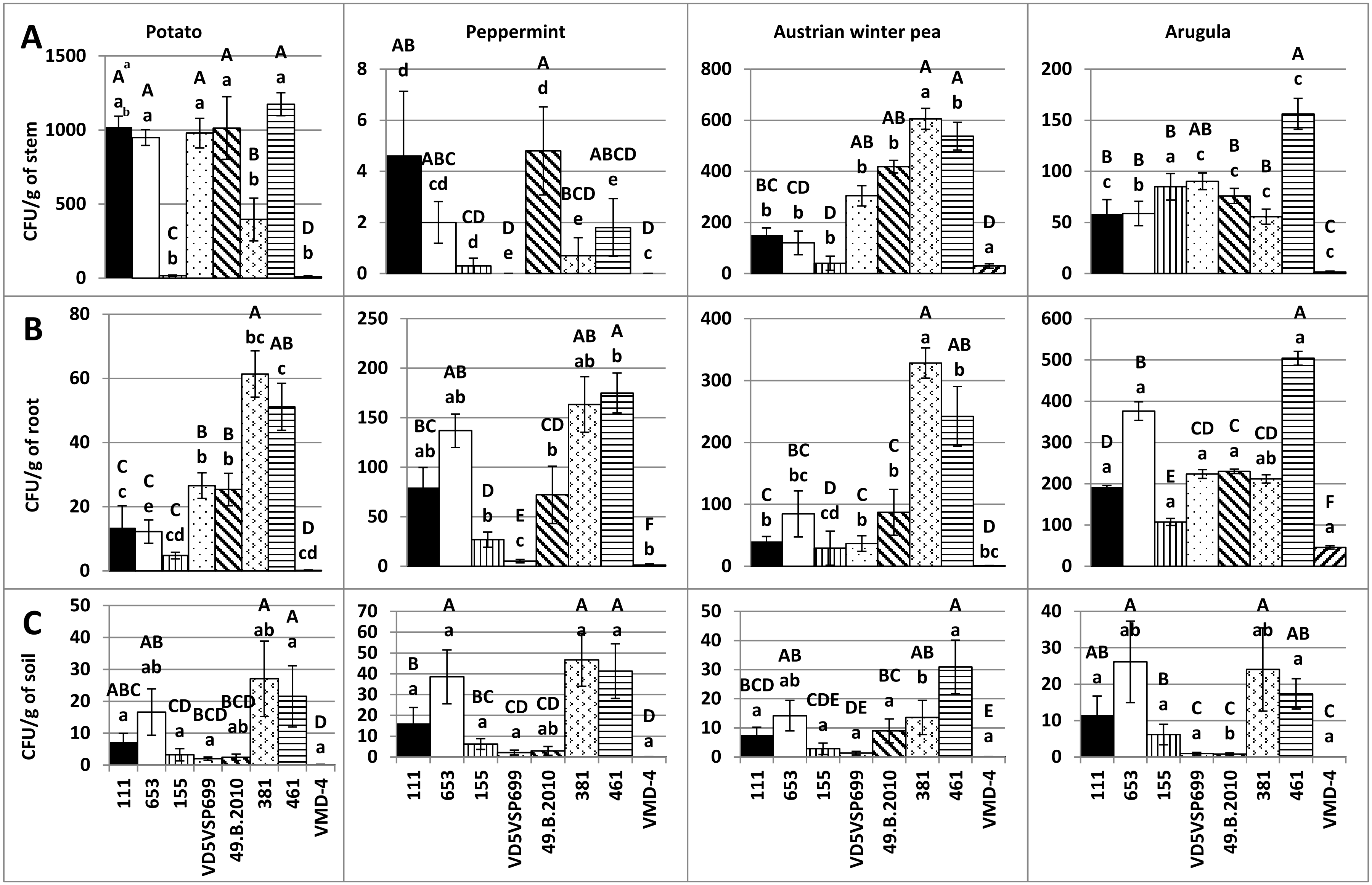
[a] 82 CFU/g of *V. dahliae* and 18 CFU/g of *C. coccodes* were detected from seed lot.
[b] 338 CFU/g of *V. dahliae* and 10 CFU/g of *C. coccodes* were detected from seed lot.
[c] 34 CFU/g of *V. dahliae* and 20 CFU/g of *C. coccodes* were detected from seed lot.
[d] 134 CFU/g of *V. dahliae* and 46 CFU/g of *C. coccodes* were detected from seed lot.
[e] 53 CFU/g of *V. dahliae* and 0 CFU/g of *C. coccodes* were detected from seed lot

Figure 1. Mean incidence of infected stems from 3- and 30cm above the soil , CFU/ 60 cm of root and CFU/g of soil detected from plants of rotation crops (A,B,C) and bioassay crops (D,E,F) grown in soil infested with two isolates of *V. dahliae*.



[a] Mean separation letters were assigned with Tukey's honest significant difference (H.S.D). Means that share the same letter across rotation crops and within an isolate are not significantly different ($P < 0.05$).

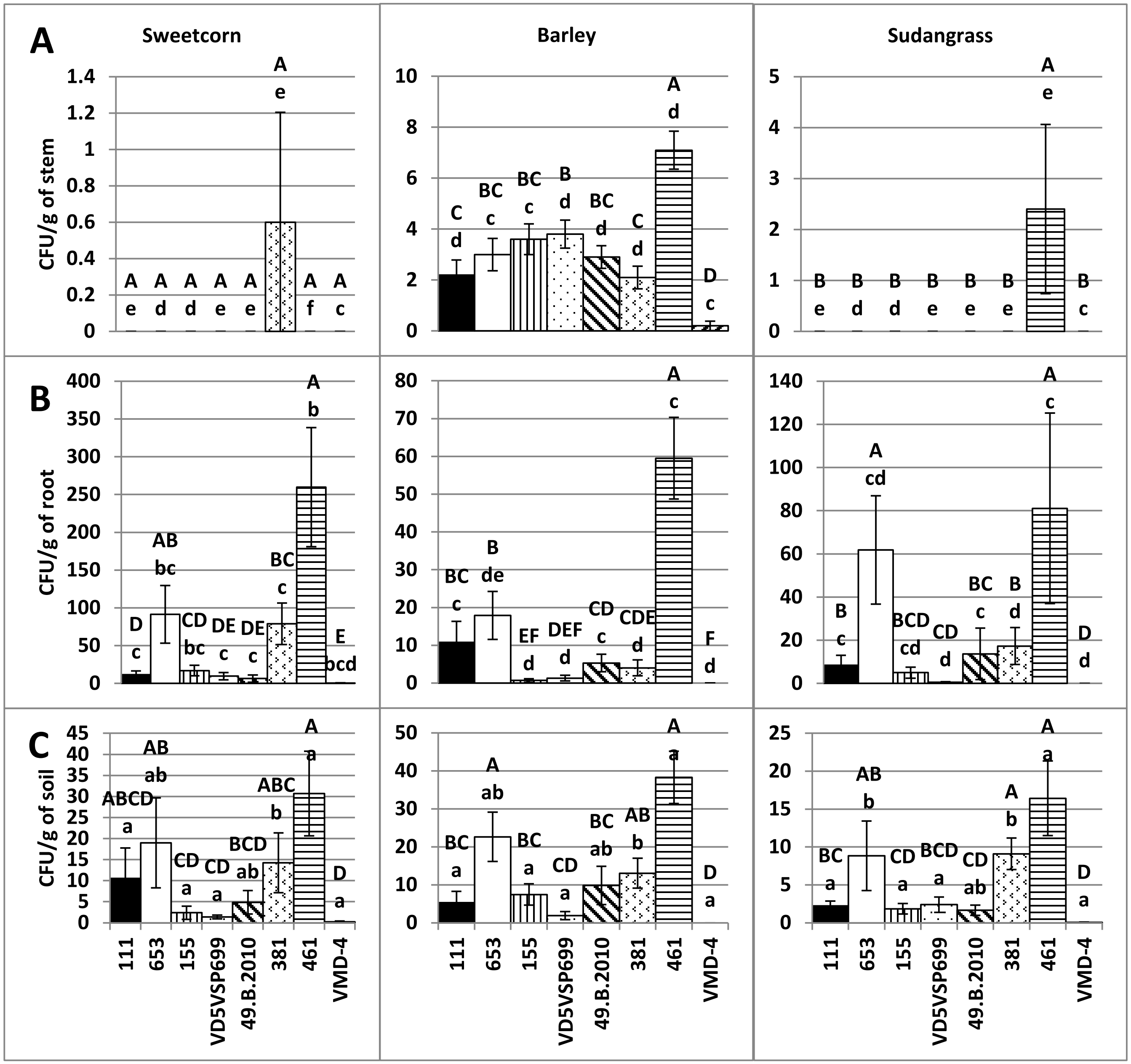
Figure 2. *Verticillium dahliae* CFU/g of stem (A), root (B), and soil (C) detected from plants and soil of rotation crops grown in infested



[a] Mean separation letters from log-transformed data were assigned to raw stem (CFU/g) data with Tukey's honest significant difference (H.S.D) test. Means that share the same letter are not significantly different ($P < 0.05$). Uppercase letters indicate significant differences among isolates within a crop while lowercase letters indicate significant differences across rotation rotation crops within an isolate.

[b] Error bars represent the standard error of each mean.

Figure 2 (cont.).*Verticillium dahliae* CFU/g of stem (A), root (B), and soil (C) detected from plants and soil of rotation crops



[a] Mean separation letters from log-transformed data were assigned to raw stem (CFU/g) data with Tukey's honest significant difference (H.S.D) test. Means that share the same letter are not significantly different ($P < 0.05$). Uppercase letters indicate significant differences among isolates within a crop while lowercase letters indicate significant differences across rotation rotation crops within an isolate.

[b] Error bars represent the standard error of each mean.

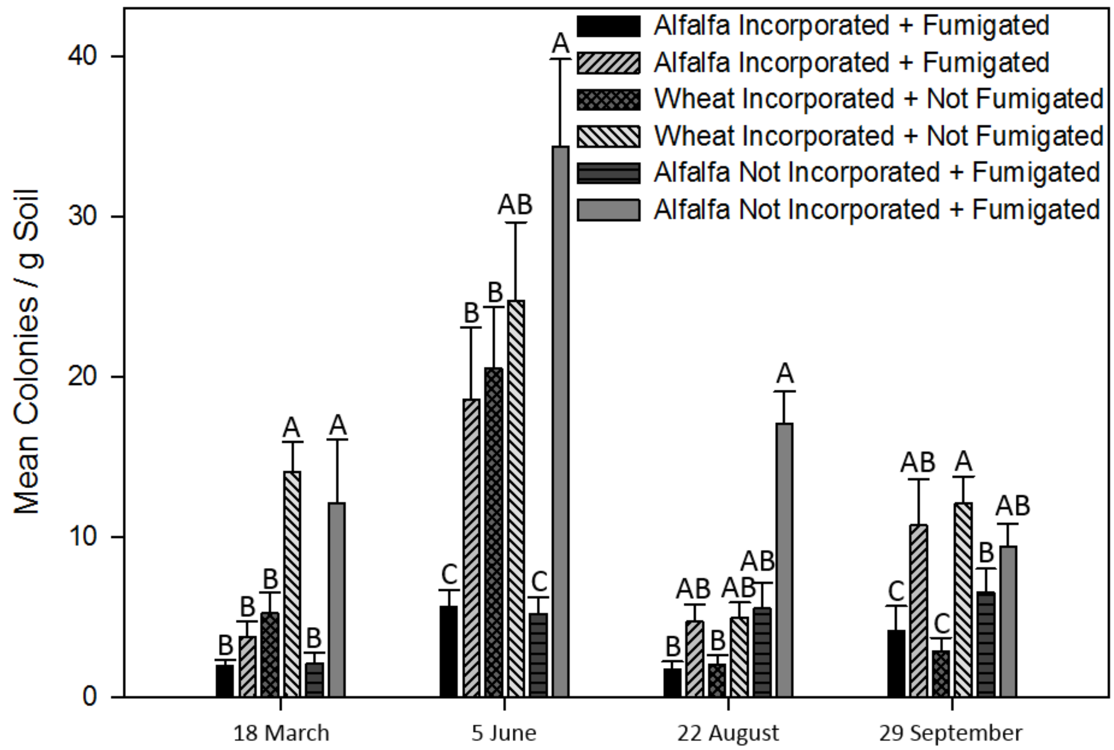


Figure 3. Number of *V. dahliae* colonies from soil for six individual fields over four collection dates where crop residue was incorporated with a soil spader.

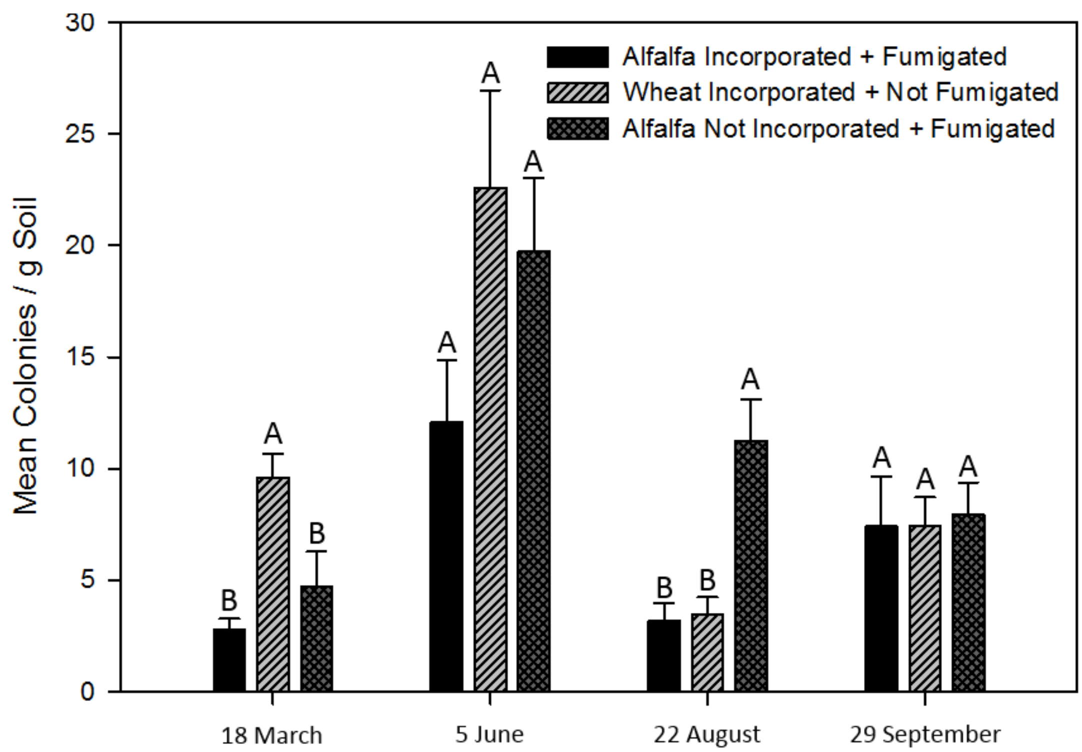


Figure 4. Mean number of *V. dahliae* colonies from soil for six fields over four collection dates where crop residue was incorporated with a soil spader.

Figure 5. Unidentified fungus causing a stem rot at the base of the majority of the plants in the Verticilliuim wilt greenhouse trial. The infections were so widespread among the potted plants that the experiment had to be terminated.

Publications:
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Objective 5: Use of Vydate (Oxamyl) as an Alternative to Metam Sodium Fumigation
Sponsored by the Northwest Potato Research Consortium

The purpose of this trial was to evaluate if Vydate could be used as an alternative to metam sodium fumigation. Results from a trial sponsored by DuPont in 2013 indicated that this was possible. However, the results from this trial conducted in 2014 were not supportive. A secondary goal was to determine how many applications of Vydate were necessary to obtain a yield or quality benefit from Vydate. In this trial none of the Vydate treatments provided an economic benefit over using metam sodium (Vapam). A reduced rate of Vapam combined with Vydate was an effective way to manage nematodes at this location, but nematode populations were not at a high enough level to cause economic damage. At this point in time, we are not ready to recommend the use of a Vydate program as a replacement for metam sodium.

If Vydate could be used to reduce the amount of metam sodium, a significant reduction in the amount of pesticide active ingredient would be realized. Vapam at 40 gallons/acre results in 170 lb of active ingredient applied to the crop. Six applications of Vydate without Vapam results in about 6 lb of active ingredient. A combination of Vapam at 20 gallons and six applications of Vydate results in about 89 lb of active ingredient. If the Vapam/Vydate combination could work, a substantial reduction in pesticide active ingredient would be realized.

The trial needs to be performed again to see if 2013 or 2014 results are more typical.

Answers to questions asked at the outset of this project:

1. <u>Does Vydate need to be applied by chemigation, or can it also be applied as a foliar application?</u>

This question cannot be satisfactorily answered based on this year's data. Vydate was not effective regardless of the application method used. Additional trials have been planned for 2015 to make another effort to answer this question.

2. <u>Are 6 applications needed to get yields similar to metam sodium? Could the same result occur with fewer applications?</u>

The six application program worked in 2013, but not in 2014. It appeared that four or more total applications resulted in slightly longer canopy life, but the differences between the two application program and the four and six application programs were slight. None of the Vydate programs resulted in the yield and economic return comparable to the metam sodium program.

3. <u>Could a reduced rate of metam sodium shanked in the soil (i.e. 20 gal/acre) be combined with Vydate to produce a more economical approach to controlling potato early die?</u>

The reduced metam sodium combined with Vydate program was effective in 2013 but not in 2014. The reasons for the year to year difference are not known. We propose to conduct the trial another year to see if we can repeat the results of 2013.

INTRODUCTION

This trial was established to evaluate the use of Vydate (oxamyl) as an alternative to metam sodium for managing Verticillium wilt and black dot. Research from 2013 showed that 6 applications of Vydate (one in-furrow and 5 chemigation applications) produced yields similar to those produced with metam sodium applied at 40 gallons/acre (580 cwt/acre for the Vydate program, 575 cwt/acre for metam sodium). Combining both metam sodium and Vydate together produced even greater yields (612 cwt/acre). Several questions remain about the use of Vydate, however:

1. Does Vydate need to be applied by chemigation, or can it also be applied as a foliar application?
2. Are 6 applications needed to get yields similar to metam sodium? Could the same result occur with fewer applications?
3. Could a reduced rate of metam sodium shanked in the soil (i.e. 20 gal/acre) be combined with Vydate to produce a more economical approach to controlling Verticillium wilt?

Treatments

	Fall 2013	In-furrow	Foliar*
1.	Untreated	Untreated	Untreated
2.	Vapam (40 gal)		
3.		Vydate CLV (2.1 pt)	Vydate CLV (2.1 pt) 1X, chemigated
4.	Vapam (20 gal)	Vydate CLV (2.1 pt)	Vydate CLV (2.1 pt) 1X, chemigated
5.		Vydate CLV (2.1 pt)	Vydate CLV (2.1 pt) 3X, chemigated
6.	Vapam (20 gal)	Vydate CLV (2.1 pt)	Vydate CLV (2.1 pt) 3X, chemigated
7.		Vydate CLV (2.1 pt)	Vydate CLV (2.1 pt) 5X, chemigated
8.	Vapam (20 gal)	Vydate CLV (2.1 pt)	Vydate CLV (2.1 pt) 5X, chemigated
9.		Vydate CLV (2.1 pt)	Vydate CLV (2.1 pt) 3X, simulated aerial
10.		Vydate CLV (2.1 pt)	Vydate CLV (2.1 pt) 5X, simulated aerial

***** First application made at the first sign of trash on the ground. Repeated applications are scheduled on 14-day intervals.

MATERIALS AND METHODS

Trial Establishment

The field portion of the trial was established at the Miller Research Experimental Farm near Acequia, ID. The previous crops were dry beans (2013), sugarbeet (2012), and potato (2011.

Dry fertilizer was spread on October 25, 2013. MAP (11-52-0) was applied at 144 lb/acre and KCl (0-00-60) was applied at 167 lb/acre for an application of 16 units N, 75 units P_2O_5, and 100 units K_2O (Appendix 1).

Metam Sodium Application

The trial area was tilled using a disk-ripper (custom DMI machine) to a depth of 12 inches on October 29, 2013. Metam sodium fumigant (Vapam HL, 42% active) was injected 9 inches deep on the ripper shanks for the plot areas for treatments 2, 4, 6, and 8 (Figure 1). At the time of application the soil moisture was about 75% field capacity and the soil temperature was between 47-54°F. The soil surface was packed to help seal the fumigant in the soil as part of the tillage operation.

Planting and Maintenance

Certified disease-free seed (cv. Russet Burbank) for this trial was purchased from a commercial potato grower. Seed was cut to an average weight of 2.42 oz/seed piece and treated with 6% MZ dust applied at a rate of 1 lb/cwt. The seed was planted with a modified four-row Acme commercial cup type potato planter on April 23. Potato rows were 36 inches apart and seed was planted 12 inches apart within the row to a depth of 7 inches. This translated to an approximate planting rate of 2196 lb of seed per acre. Plots were four rows wide and 29 feet long with a 7-foot border between plots. The border was established by driving perpendicular to the planting direction with a roto-tiller pulled by a tractor using GPS sub-inch guidance. Borders were tilled multiple times to keep the borders free from volunteer potato plants and weeds. Two rows were established on the west and east border of the trial and between each replication. Treatments were established according to a randomized complete block design with four replications (Figure 2).

Standard liquid fertilizers were applied at planting two inches to the side and just below where the seed piece was dropped in the furrow. Additional dry fertilizer was applied prior to hilling, and potato rows were hilled the same day (May 12) with a Lilliston cultivator. Herbicides were applied May 13 and incorporated with about 0.55” irrigation. Liquid N in the form of urea (32-0-0) was applied through the irrigation system during the season as needed. Petiole sampling was done outside the trial area to determine the fertility requirements of the growing crop.

Specific details on trial initiation and maintenance are provided in Appendix 1.

Figure 1. Equipment used to inject metam sodium in the soil on October 29, 2013.

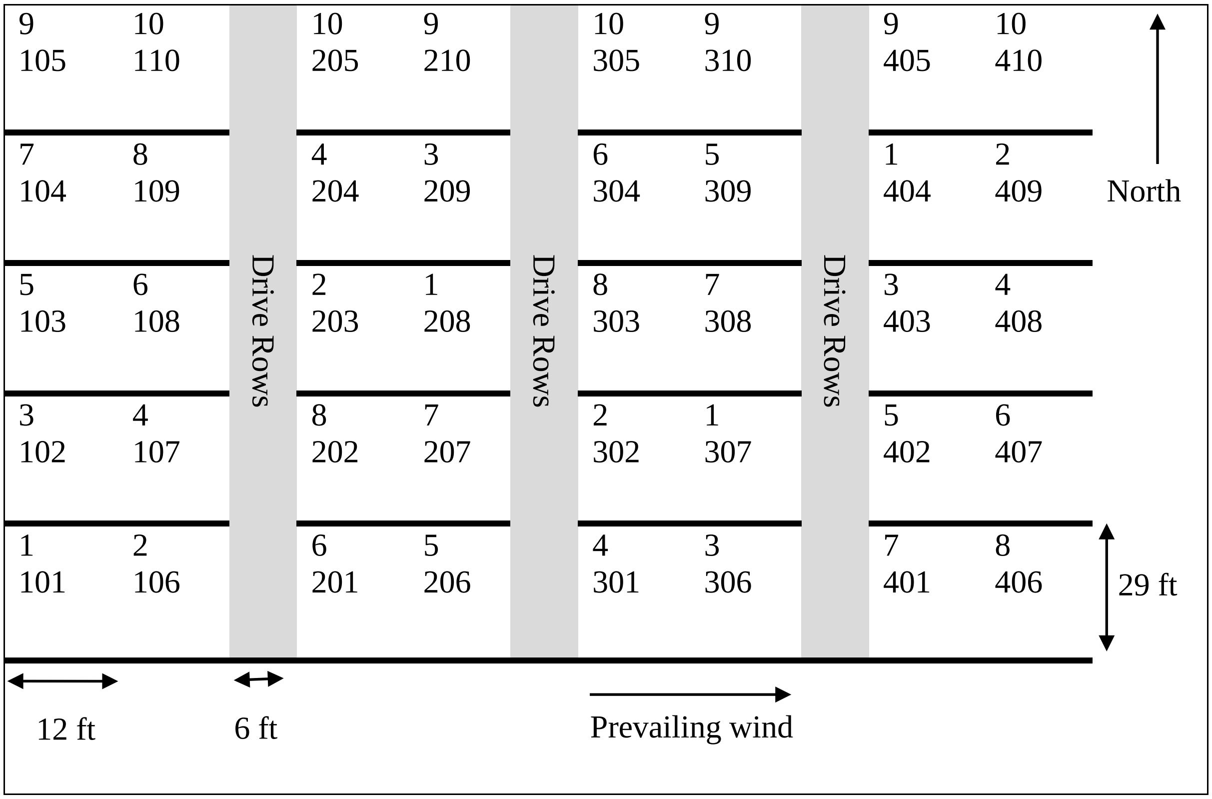


Figure 2. Trial map for the Northwest Potato Research Consortium trial evaluating the use of Vydate as an alternative to metam sodium for Verticillium wilt control in potato.

In-Furrow Applications

Products for in-furrow applications were mixed in three-gallon stainless steel tanks. A Teflon-coated laboratory magnet was placed inside the tank and the tanks were placed on a spray rack on the planter. A second magnet located on the spray rack under the tank was turned with a hydraulic motor. This caused the magnet inside the tank to turn creating constant agitation of the test products during application. Each spray tank was individually pressurized with compressed air and protected with a one-way valve to prevent intermixing of products during application.

The in-furrow application was made at planting on April 23. The spray mixtures were applied with TeeJet flat fan 8002E nozzles mounted on the potato planter. The spray volume was 17 gallons of spray mix per acre. Red Ball flow indicators were used to monitor the output for each nozzle and help ensure accurate and uniform spray delivery for each row in each plot. Nozzles (one per row) were positioned 8 inches above the opened furrow and tilted so that the spray was applied to the soil as it was turned over and around the seed piece.

Chemigation Applications

Chemigation applications were made utilizing the Miller Research portable chemigation system (Figure 3). The system is configured to apply products in large water volumes in a short period of time (e.g. 71 gallons/plot in approximately 8 minutes). Twelve mini-I-wobblers (0.125” core) were suspended over the center of each plot, aligned parallel with the rows. Each mini-I-wobbler was attached to a 10 psi regulator to ensure even volume flow for all units. Tarps were suspended between plots to prevent overspray from one plot reaching a neighboring plot.

The amount of spray mixture applied to each plot was determined based on the area being treated. The distribution of water was evaluated by Senninger Irrigation, Inc. Senninger determined that 26% of the water being applied through the wobblers landed outside the 12×30 treated plot area. As a result, the amount of test substance mixed was adjusted by a factor of 1.26 to account for the overspray.

For each plot, the spray mixture was mixed in a plastic bottle with 500 ml of water. The pH of the water was adjusted to 6.0-6.2 with the use of the adjuvant Indicate 5 (Brandt Agricultural Products) prior to adding the test products. Water was supplied to the chemigation system and the flow was measured with a GPI Electronic Water Meter (Great Plains Industries, Inc.; Wichita, KS). As soon as the wobblers were observed to be operating properly, the bottle with the test substance was pressurized (65 psi), and then the test substance was injected into the water stream being applied to the plot. Approximately 0.25 inches of water was used to chemigate the test product (71 gallons per plot, accounting for overspray).

Chemigation application of Vydate was first done on June 11 when plants were about 12 inches tall. Additional applications were made July 1, 14, 29, and August 12. Details on application including environmental conditions, crop conditions, and application equipment are provided in Appendix 2.

Figure 3. Equipment used to simulate chemigation applications.

Simulated Aerial Applications

Simulated aerial applications were made the same day as the chemigation applications using the Miller Research ground plot sprayer (a small self-propelled tractor with a hydrostatic drive). Water was added to a three-gallon capacity stainless steel tank and the pH of the water was adjusted to 6.0-6.2 as mentioned above. Vydate was then added. A Teflon-coated laboratory magnet was placed inside the tank. Tanks were loaded on a sprayer rack on the tractor. A second magnet on the sprayer rack located under the tank was turned with a hydraulic motor which caused the magnet inside the tank to turn. This created constant agitation of the spray mixture during application. The spray tank was pressurized with compressed air. The spray boom consisted of eight TeeJet XR 11002 VS flat fan nozzles spaced 18 inches apart. Sprayer speed was measured at 6.4 mph and this resulted in a spray volume of 7.2 gallons per acre.

Plant Stand

Plant emergence was measured in the center two rows of the four row plots. A plant was counted as emerged when any portion of a potato plant was visible. Five ratings were taken during the period of emergence from May 19 to June 28. Counts were converted to a percentage of plants emerged based on the estimated number of planted seed pieces per row.

Row Closure

Plant vigor was evaluated on June 19 by visually estimating the percentage of row closure. A value of 100% represented complete row closure (no soil visible when looking between rows).

Late Season Crop Vigor

Plants were rated for general vigor on August 13, 19, 27, and September 5. The health of the plants was visually estimated using a 0-100 scale where 0 represents dead plants and 100 represents completely healthy plants. Ratings were made by two individuals and averaged to obtain the final rating. Photographs were taken of each plot in replication 1 on August 14 and 26.

Nematode Sampling

Soil was sampled for the presence of plant parasitic nematodes on August 20. Eight soil cores were collected from each plot from between plants in row three (third row from the west). Soil samples were sent to Dr. Saad Hafez at the University of Idaho in Parma for evaluation.

Tuber Yield

Tubers from the center two plot rows were harvested using a specially modified two-row Lockwood 4620 harvester on October 6. Tubers were lifted and cleaned by the harvester and crew riding on the machine, and then dropped into a basket hanging from the end of the delivery boom. The basket was suspended by an electronic load cell scale which weighed all tubers harvested from the two center rows. A fresh-pack cardboard box (50 lb capacity) was placed in the hanging basket in order to obtain a sample (45-50 lb) for determining tuber grade. The weight in pounds was converted to cwt/acre.

Tuber Grade and Quality

USDA standards were used in grading the tuber samples collected at harvest. Tubers were separated into US#1, US#2, cull, and undersize categories and then individually weighed on November 10-11. Weights from the sample were used to determine the percentage of yield in the following grade categories: < 4 oz, 4-6 oz. US#1, 6-10 oz. US#1, 10-14 oz. US#1, >14 oz. US#1, 4-10 oz. US#2, >10 oz. US#2, and culls. The percentage of tubers in various fresh-pack carton sizes was also determined as described below in "Economic Return."

Economic Return

The gross economic value of each plot was estimated using mock processing and fresh pack contracts. For processing, the marketable yield (all US#1 tubers greater than 4 oz and all US#2 tubers) was determined. Incentives were then estimated based on the percentage of US#1 tubers and the percentage of all tubers >10 oz. For US#1 tubers, an incentive of $0.01/cwt was awarded for each percentage point over 65% with a cap set at 85%. A disincentive of -$0.01/cwt was deducted for each percentage point below 65%. Incentives (and disincentives) for the percentage of tubers > 10 oz were awarded based on the following table:

%>10 oz	Incentive	%>10 oz	Incentive	%>10 oz	Incentive	%>10 oz	Incentive
>45%	$0.44	34%	$0.26	22%	$0.02	10%	-$0.22
45%	$0.44	33%	$0.24	21%	$0.00	9%	-$0.24
44%	$0.43	32%	$0.22	20%	-$0.02	8%	-$0.26
43%	$0.42	31%	$0.20	19%	-$0.04	7%	-$0.28
42%	$0.41	30%	$0.18	18%	-$0.06	6%	-$0.30
41%	$0.40	29%	$0.16	17%	-$0.08	5%	-$0.32
40%	$0.38	28%	$0.14	16%	-$0.10	4%	-$0.34
39%	$0.36	27%	$0.12	15%	-$0.12	3%	-$0.36
38%	$0.34	26%	$0.10	14%	-$0.14	2%	-$0.38
37%	$0.32	25%	$0.08	13%	-$0.16	1%	-$0.40
36%	$0.30	24%	$0.06	12%	-$0.18	0%	-$0.42
35%	$0.28	23%	$0.04	11%	-$0.20		

Incentives or disincentives were added to or deducted from a base contract price of $8.00/cwt of marketable tubers (all US#1 tubers > 4 oz and all US#2 tubers).

For fresh pack, the economic value of each sample was determined using values from the National Potato and Onion Report issued on Friday, October 10, 2014 by the USDA Agricultural Marketing Service Fruit and Vegetable Program (Volume XCVI Number 197). Dollar values were assigned to the grade sample based on the following table:

Item	Tuber Category	Value/cwt		Item	Tuber Category	Value/cwt
10# Film	5.0-6.4 oz., US1	$7.00		80 ct	9.5-10.7 oz., US1	$17.00
40 ct	18-22 oz., US1	$17.50		90 ct	8.5-9.5 oz. , US1	$15.00
50 ct	14.7-18 oz., US1	$17.50		100 ct	6.4-8.5 oz. , US1	$14.00
60 ct	12.4-14.7 oz., US1	$17.50		US#2	6-10 oz	$13.00
70 ct	10.7-12.4 oz., US1	$17.50		US#2	>10 oz	$15.00

The percentage of tubers in each Tuber Category was multiplied by the price (Value/cwt column) and the resulting values were totaled to obtain a dollar value per cwt. These values were then multiplied by the marketable yield in hundredweight per acre to obtain the dollar value per acre. The fresh pack contract values did not take into account the packer margin or shipping costs which can be highly variable and will reduce the amount paid to the grower substantially.

Rhizoctonia Black Scurf

Fifteen US#1 tubers were randomly selected during the grading process and then evaluated for black scurf on November 12. Tubers were washed for approximately five minutes in a circulating water bath. The severity of black scurf was evaluated using a 0-4 scale based on the photograph below.

0 1 2 3 4

A severity index was calculated using the following formula:

$$\text{Severity} = \frac{(x_1) + (x_2 \times 2) + (x_3 \times 3) + (x_4 \times 4)}{\sum_1^4 x} \times 100$$

This formula is simply a weighted average of the severity scores, expressed as a value between 0 and 100. For example, if every tuber was rated as a 4, then the severity index would be 100.

Verticillium/Black Dot

Soil was sampled for the presence of *Verticillium dahliae* and *Colletotrichum coccodes* on August 20. Samples were collected from an area immediately adjacent to the trial which had not been treated with either Vydate or Vapam (similar to the check). Eight soil cores were collected and composited to form a single sample. Four different samples were collected for evaluation and sent to the diagnostic laboratory at Oregon State University in Hermiston.

The degree of infection by *Verticillium dahliae* (cause of Verticillium wilt) and *Colletotrichum coccodes* (cause of black dot) was estimated by sample tuber stem ends. Fifteen slices of potato peel about 1 mm thick and 1 cm in diameter were cut from the stem end of 15 tubers. Peel slices were air dried for several weeks, ground with a Wiley mill, and then plated on NPX media with an Anderson sampler (Davis et al. 1983). For each sample, 10 mg of tissue were spread per plate and 5 plates were used per sample. <u>These tests are still on-going and results are not yet available.</u>

Soil Nematode Populations

Eight soil cores were collected from row two of each plot to estimate the populations of plant parasitic nematodes. Soil samples for were sent to Dr. Saad Hafez at the University of Idaho in Parma to be evaluated for Columbia root knot (*Meloidogyne chitwoodi*), root lesion (*Pratylenchus neglectus* and *P. penetrans*), stubby root (*Paratrichodorus* spp. and *Trichodorus* spp.), and pin (*Paratylenchus* spp.) nematodes.

Statistical Analysis

All data were analyzed by analysis of variance (ANOVA) using Agricultural Research Manager (ARM) version 9. When the treatment effect was significant ($P<0.10$; see "Treatment Prob (F)" at the bottom of each data column in the tables), mean separation was performed using Fisher's protected LSD. Means followed by the same lowercase letter are not statistically different when compared to each other. If the treatment variances were not homogeneous as determined by Bartlett's test for homogeneity, means were transformed prior to analysis. Back-transformed data are listed in the results.

RESULTS AND DISCUSSION

General Comments

We intended to compare three and five simulated aerial applications of Vydate (treatments 9 and 10, respectively) to the same number of chemigated Vydate applications. However, as the season progressed it became apparent that treatment 10 had also received 20 gallons of Vapam. Additionally, a pivot track crossed these plots. We were not able to fit these treatments in any other place. We felt that we would still be able to get accurate evaluation of plant health with these plots, but realized that yield and grade would be compromised.

As a result, the comparisons between simulated aerial application and chemigation could not be made as planned for yield. However, we have included the results for rough comparison purposes only.

Stand

Significant differences were observed among treatments at the earliest plant stand observation (Table 1). Treatments 2 and 4 had plant stand greater than the untreated check. Both of these treatments had received fall fumigation with Vapam. However, treatments 6, 8, and 10 were also fumigated with Vapam and these treatments were similar to the check. This indicates that the emergence difference on May 19 was likely random and not related to the Vapam application. Regardless, the stand for all treatments was similar on all subsequent evaluation dates.

Table 1. Effect of Vapam and Vydate on the percentage of plants emerged (cv. Russet Burbank; Acequia, ID; 2014).

Description				% Plant Stand				
Rating Date				19 May	21 May	23 May	26 May	28 May
Days after Planting				26	28	30	33	35
Trt	Treatment	Rate	Unit					
1	Check			23 c	60 a	85 a	90 a	91 a
2	Vapam	40	gal	34 a	69 a	84 a	87 a	88 a
3	Vydate IF + Chem	2.1	pt	24 c	59 a	85 a	90 a	91 a
4	Vapam Vydate IF + Chem	20 2.1	gal pt	32 ab	65 a	83 a	88 a	88 a
5	Vydate IF + Chem 3X	2.1	pt	27 abc	62 a	83 a	88 a	89 a
6	Vapam Vydate IF + Chem 3X	20 2.1	gal pt	22 c	57 a	82 a	88 a	89 a
7	Vydate IF + Chem 5X	2.1	pt	21 c	60 a	81 a	86 a	88 a
8	Vapam Vydate IF + Chem 5X	20 2.1	gal pt	22 c	64 a	80 a	86 a	86 a
9	Vydate IF + Air 3X	2.1	pt	19 c	53 a	78 a	85 a	87 a
10	Vapam Vydate IF + Air 5X	20 2.1	gal pt	26 bc	56 a	77 a	85 a	87 a
LSD (P=.10)				7.79	8.76	5.21	4.17	2.97t
Standard Deviation				6.47	7.28	4.33	3.47	2.46t
CV				25.84	12.05	5.3	3.97	3.52
Grand Mean				25.04	60.39	81.72	87.28	70.01t
Treatment Prob (F)				**0.0490**	0.1197	0.1093	0.3280	0.2741

Means followed by same letter do not significantly differ (P=0.10, LSD). Mean comparisons performed only when ANOVA Treatment Prob (F) is significant at the pre-determined mean comparison level (<0.10). Significant values are bolded. t=Mean descriptions are reported in transformed data units, and are not de-transformed. Data were transformed using the arcsine square root transformation. Back transformed means are given in the table.

Row Closure

Row closure is one way to measure early season plant vigor. More vigorous treatments may show a greater degree of row closure. All treatments showed a similar degree of row closure on June 19 (Table 2) indicating similar vigor early season. As of June 19, only two Vydate applications had been made to treatments 3-10. These early season Vydate applications did not result in improved plant vigor.

Table 2. Effect of Vapam and Vydate on plot row closure (cv. Russet Burbank; Acequia, ID; 2014).

Description Rating Date				% Row Closure 19 Jun
Trt	Treatment	Rate	Unit	
1	Check			84 a
2	Vapam	40	gal	91 a
3	Vydate IF + Chem	2.1	pt	88 a
4	Vapam Vydate IF + Chem	20 2.1	gal pt	90 a
5	Vydate IF + Chem 3X	2.1	pt	88 a
6	Vapam Vydate IF + Chem 3X	20 2.1	gal pt	88 a
7	Vydate IF + Chem 5X	2.1	pt	88 a
8	Vapam Vydate IF + Chem 5X	20 2.1	gal pt	88 a
9	Vydate IF + Air 3X	2.1	pt	86 a
10	Vapam Vydate IF + Air 5X	20 2.1	gal pt	88 a
LSD (P=.10)				5.03
Standard Deviation				4.17
CV				4.75
Grand Mean				87.95
Treatment Prob (F)				0.5629

Means followed by same letter do not significantly differ (P=0.10, LSD). Mean comparisons performed only when ANOVA Treatment Prob (F) is significant at the pre-determined mean comparison level (<0.10). Significant values are bolded.

Plant Vigor

The last foliar nitrogen application was made on August 10 (Appendix 1). After that, the vines began to decline quickly. By August 13, the check (no Vapam and no Vydate) was only showing 41% vigor compared to 88-91% for all treatments receiving Vapam (Table 3, Figure 4). The Vydate treatments (treatments 3, 5, 7, and 9) ranged from 73 to 79% vigor. The number of Vydate applications did not have an effect on vigor. For the treatments receiving Vydate by chemigation, this trend continued for two weeks through August 27 (Figure 5). By September 5, the check was completely dead and very little life was left in the Vydate only treatments. Three foliar Vydate applications by chemigation was slightly more effective than three foliar applications by simulated aerial application (compare treatments 5 and 9).

Differences were not observed among any of the treatments receiving Vapam. Based on 2013 results and space constraints, we decided not to include Vapam at 20 gallons by itself in the 2014 trial. In hindsight we should have included that treatment. It is not possible to determine if the increase in vigor for treatments 4, 6, 8, and 10 (compared to the check) is due to the combination of Vapam and Vydate, or the result of Vapam alone.

Two total Vydate applications (treatment 3) were not as effective as four or six total applications based on vigor on September 5. However, the differences observed on this date were small and did not translate to differences in yield (see Yield and Grade section below).

Table 3. Effect of Vapam and Vydate on plant vigor (cv. Russet Burbank; Acequia, ID; 2014).

Description				Vigor (1-100)			
Rating Date				13 Aug	19 Aug	27 Aug	5 Sep
Trt	Treatment	Rate	Unit				
1	Check			41 c	15 d	3 c	0 d
2	Vapam	40	gal	90 a	83 a	63 a	19 a
3	Vydate IF + Chem	2.1	pt	73 b	50 b	15 b	2 c
4	Vapam Vydate IF + Chem	20 2.1	gal pt	88 a	75 a	54 a	15 a
5	Vydate IF + Chem 3X	2.1	pt	79 b	59 b	23 b	5 b
6	Vapam Vydate IF + Chem 3X	20 2.1	gal pt	90 a	81 a	55 a	16 a
7	Vydate IF + Chem 5X	2.1	pt	78 b	58 b	20 b	6 b
8	Vapam Vydate IF + Chem 5X	20 2.1	gal pt	91 a	78 a	51 a	15 a
9	Vydate IF + Air 3X	2.1	pt	75 b	34 c	14 b	3 c
10	Vapam Vydate IF + Air 5X	20 2.1	gal pt	91 a	76 a	59 a	20 a
LSD (P=.10)				5.9t	6.7t	8.1t	0.2t
Standard Deviation				4.9t	5.5t	6.7t	0.2t
CV				7.67	10.72	19.08	17.6
Grand Mean				64.26t	51.54t	35.25t	0.9t
Treatment Prob(F)				**0.0001**	**0.0001**	**0.0001**	**0.0001**

Means followed by same letter do not significantly differ (P=0.10, LSD). Mean comparisons performed only when ANOVA Treatment Prob (F) is significant at the pre-determined mean comparison level (<0.10). Significant values are bolded. t=Mean descriptions are reported in transformed data units, and are not de-transformed. Data were transformed using the arcsine square root transformation (August ratings) and the log (X+1) transformation (September 5 rating). Back transformed means are given in the table.

Figure 4. Photographs taken on August 14, 2014 of replication 1. All photos were taken facing north with the center rows in the middle of the photo.

101, Trt 1: Check

102, Trt 3: Vydate IF + Chem

103, Trt 5: Vydate IF + Chem 3X

104, Trt 7: Vydate IF + Chem 5X

105, Trt 9: Vydate IF + Air 3X

106, Trt 2: Vapam 40 gpa


107, Trt 4: Vapam 20 gpa, Vydate IF + Chem


108, Trt 6: Vapam 20 gpa, Vydate IF + Chem 3X


109, Trt 8: Vapam 20 gpa, Vydate IF + Chem 5X


110, Trt 10: Vydate IF + Air 5X

Figure 5. Photographs taken on August 26, 2014 or replication 1. All photos were taken facing north with the center rows in the middle of the photo.

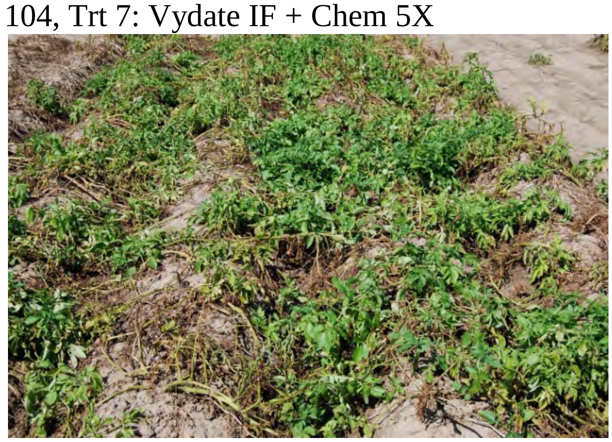

101, Trt 1: Check


102, Trt 3: Vydate IF + Chem


103, Trt 5: Vydate IF + Chem 3X


104, Trt 7: Vydate IF + Chem 5X


105, Trt 9: Vydate IF + Air 3X


106, Trt 2: Vapam 40 gpa


107, Trt 4: Vapam 20 gpa, Vydate IF + Chem


108, Trt 6: Vapam 20 gpa, Vydate IF + Chem 3X


109, Trt 8: Vapam 20 gpa, Vydate IF + Chem 5X


110, Trt 10: Vydate IF + Air 5X

Nematode Sampling

Treatments had a significant effect on nematode populations (Table 4). Vapam either at 40 or 20 gallons was effective in reducing Columbia root knot from 520 organisms/500 cc soil to almost none. Vydate by simulated aerial application also resulted in a reduction in root knot counts, but applications by chemigation did not.

Stubby root numbers were very low. It appeared that Vapam at 40 gallons significantly increased the populations. Most other treatments were similar to the check.

Similar to root knot, pin nematodes were reduced by Vapam at either rate. Vydate also reduced pin counts, but was not as effective as Vapam.

The combination Vydate/Vapam treatments were effective in reducing all three nematodes species. Root lesion nematodes were present in some plots, but at very low levels (e.g. 20 in plot 210). The root knot numbers here are lower than what would be expected to cause damage in the sandy soils of the Magic Valley (Dr. Saad Hafez, personal communication). Also, the sampling time for stubby root nematode was later than optimal. For a more accurate estimate, samples should have been collected in April or May.

Table 4. Effect of Vapam and Vydate on plant parasitic nematodes collected from soil on August 20, 2014.

				# Nematodes/500 cc Soil		
Description				Columbia Root Knot	Stubby Root	Pin
Trt	Treatment	Rate	Unit			
1	Check			520 a	11 bcd	2939 a
2	Vapam	40	gal	1.1 c	311 a	29 c
3	Vydate IF + Chem	2.1	pt	278 a	15 bc	955 b
4	Vapam	20	gal	1.1 c	23 b	67 c
	Vydate IF + Chem	2.1	pt			
5	Vydate IF + Chem 3X	2.1	pt	364 a	1.1 cde	1056 b
6	Vapam	20	gal	0 c	3 b-e	23 c
	Vydate IF + Chem 3X	2.1	pt			
7	Vydate IF + Chem 5X	2.1	pt	117 ab	0.8 de	1379 b
8	Vapam	20	gal	0 c	3 b-e	60 c
	Vydate IF + Chem 5X	2.1	pt			
9	Vydate IF + Air 3X	2.1	pt	32 b	7 bcd	937 b
10	Vapam	20	gal	0 c	0 e	17 c
	Vydate IF + Air 5X	2.1	pt			
LSD (P=.10)				0.78t	0.92t	12.71t
Standard Deviation				0.64t	0.77t	10.55t
CV				53.79	86.72	48.9
Grand Mean				1.2t	0.88t	21.58t
Treatment Prob (F)				**0.0001**	**0.0055**	**0.0001**

Means followed by same letter do not significantly differ (P=0.10, LSD). Mean comparisons performed only when ANOVA Treatment Prob (F) is significant at the pre-determined mean comparison level (<0.10). Significant values are bolded. t=Mean descriptions are reported in transformed data units, and are not de-transformed. Data were transformed using the log (X+1) transformation (Columbia root knot and stubby root) and the square root (X+0.5) transformation (Pin). Back transformed means are given in the table.

Soil Pathogen Enumeration

All four samples for soil receiving no Vydate and no Vapam showed very low levels of *Verticillium dahliae* (cause of Verticillium wilt) and *Colletotrichum coccodes* (cause of black dot) (Table 5). However, plants showed symptoms of Verticillium wilt shortly after we stopped applying nitrogen in early August. Symptoms of black dot were also present on the crop late in the season as plants senesced.

Table 5. Number of colony forming units per gram of soil for *Verticillium dahliae* (cause of Verticillium wilt) and *Colletotrichum coccodes* (cause of black dot) from soil collected in the root zone of check (non-Vydate, non-Vapam) on August 20, 2014.

Sample #	*V. dahliae*	*C. coccodes*
1	2	6
2	2	2
3	0	2
4	2	8

Yield and Grade

As pointed out in the beginning of this section, the yield and quality data from treatments 9 and 10 should be interpreted with caution. These two treatments were added late in the planning stage of the trial. We had already situated treatments 1-8. We tried to squeeze 9 and 10 in on the north end of the trial (Figure 2) which was at the end of the field. Those plots did have a pivot track running through them so we knew the yield and quality would be compromised. We did not realize how detrimental this would be. As a result, we are disregarding the yield and grade data from these treatments.

The highest total and marketable yield was obtained with Vapam at 40 gallons (Table 6). Total yield somewhat followed the trend observed for vigor in that all of the Vapam treatments (except treatment 10) were higher than the check. One purpose of this trial was to see if Vydate could be used alone or with a reduced rate of Vapam to maintain potato yield. While total yields were always greater with the Vapam combined with Vydate treatments, the marketable yields were mostly similar (compare treatment 1 to treatments 6 and 7). Vydate alone appeared to be detrimental to marketable yield (compare treatment 1 to treatments 3, 5, and 7).

The quality was relatively poor in this trial with the overall average of US#1 tubers at 49% (Table 6). In 2012 and 2013 the percentage of US#1 tubers was 79% and 81%, respectively at our Acequia research farm. The lower percentage of US#1 tubers (cv. Russet Burbank) was common among commercial growers in 2014 as well. From a sample of 35 Burbank fields from four commercial growers, spread over a 1,000 square mile area of south-central Idaho, and grown in a variety of different soil types (from sandy loams to silt loams), the percentage of US#1 tubers averaged only about 68%. The range of variability fell between a low of 52% and a high of 84% (Miller Research, LLC, unpublished data). This was likely due to challenging growing conditions. Spring growing conditions were ideal, leading to heavy tuber sets, but tubers were not able to bulk and get good shape because of growth interruptions caused by cool and wet weather later in the season.

In the 2014 trial, Vapam at 40 gallons resulted in the highest percentage of US#1 tubers. The Vydate combined with Vapam treatments were all significantly lower. The lowest values were observed in the two treatments receiving six total Vydate applications. Differences were not observed among treatments for US#2 or tubers over 10 oz. The highest percentage of tubers over 10 oz was observed with Vapam at 40 gallons. Average tuber weight trended similar to US#1 tubers with the highest value resulting from Vapam at 40 gallons. Compared to the check, the Vydate treatments alone or with 20 gallons of Vapam did not improve tuber quality.

Significant differences were observed among treatments for some grade categories (6-10 oz US#1 and > 14 oz US#1). None of the treatments significantly improved the percentage of US#1 tubers compared to the check (Table 7). Treatments receiving Vapam generally had a higher percentage of > 14 oz US#1 tubers (treatments 2, 4, and 8 were at 2.9% or higher). Treatment differences were not observed for other measures of grade. The percentage of undersize tubers (< 4 oz) was relatively high (24% average) and this was the largest component of the non-US#1 tubers. US#2 and cull tubers averaged 19% and 10%, respectively.

Black Scurf

Treatments did not have an effect on Rhizoctonia black scurf (data not shown). Incidence and severity were similar across all treatments.

Table 6. Effect of Vapam and Vydate on yield and quality (cv. Russet Burbank; Acequia, ID; 2014).

Description				Yield (cwt/acre)		Total %			Avg. Tuber
Rating Unit				Total	Market	US#1	US#2	> 10 oz	Wt. (oz)
Trt	Treatment	Rate	Unit						
1	Check			581 c	414 c	55 ab	16 a	17 a	5.1 ab
2	Vapam	40	gal	672 a	519 a	59 a	19 a	30 a	5.6 a
3	Vydate IF + Chem	2.1	pt	575 c	372 d	48 bc	17 a	18 a	4.6 bc
4	Vapam Vydate IF + Chem	20 2.1	gal pt	661 ab	457 b	50 bc	20 a	24 a	5.1 ab
5	Vydate IF + Chem 3X	2.1	pt	588 c	366 d	48 bc	15 a	16 a	4.4 c
6	Vapam Vydate IF + Chem 3X	20 2.1	gal pt	635 b	412 c	47 bc	18 a	18 a	4.9 bc
7	Vydate IF + Chem 5X	2.1	pt	580 c	384 cd	41 c	25 a	20 a	4.7 bc
8	Vapam Vydate IF + Chem 5X	20 2.1	gal pt	647 ab	417 c	44 c	21 a	18 a	4.6 bc
9	Vydate IF + Air 3X	2.1	pt	513	318	41	21	14	4.6
10	Vapam Vydate IF + Air 5X	20 2.1	gal pt	591	332	33	24	19	4.6
LSD (P=.10)				28.9	39.7	9.02	8.11	8.95	0.58
Standard Deviation				23.8	32.6	7.41	6.66	7.36	0.47
CV				3.85	7.8	15.19	35.69	36.91	9.75
Grand Mean				617.18	417.7	48.82	18.67	19.94	4.87
Treatment Prob(F)				**0.0001**	**0.0001**	**0.0519**	0.5077	0.2322	**0.0414**

Means followed by same letter do not significantly differ (P=0.10, LSD). Mean comparisons performed only when ANOVA Treatment Prob (F) is significant at the pre-determined mean comparison level (<0.10). Significant values are bolded.

Table 7. Effect of Vapam and Vydate on tuber grade (cv. Russet Burbank; Acequia, ID; 2014).

Description				% US#1				% US#2		%Unmarketable	
Rating Unit				4-6 oz	6-10 oz	10-14 oz	>14 oz	4-10 oz	>10 oz	< 4 oz	Culls
Trt	Treatment	Rate	Unit								
1	Untreated check			21 a	25 a	8 a	1.2 bcd	8 a	7 a	20 a	8 a
2	Vapam	40	gal	17 a	24 ab	11 a	4.4 a	7 a	10 a	18 a	4 a
3	Vydate IF + Chem	2.1	pt	22 a	16 cde	8 a	1.0 cd	8 a	8 a	26 a	9 a
4	Vapam	20	gal	17 a	21 a-d	7 a	3.7 ab	8 a	11 a	22 a	9 a
	Vydate IF + Chem	2.1	pt								
5	Vydate IF + Chem 3X	2.1	pt	20 a	19 b-e	8 a	1.1 cd	8 a	6 a	28 a	9 a
6	Vapam	20	gal	17 a	22 abc	6 a	1.3 bcd	8 a	9 a	23 a	12 a
	Vydate IF + Chem 3X	2.1	pt								
7	Vydate IF + Chem 5X	2.1	pt	19 a	17 cde	4 a	0.3 d	9 a	14 a	25 a	10 a
8	Vapam	20	gal	16 a	19 a-d	6 a	2.9 abc	11 a	9 a	26 a	9 a
	Vydate IF + Chem 5X	2.1	pt								
9	Vydate IF + Air 3X	2.1	pt	20 a	15 de	5 a	1.0 cd	13 a	7 a	27 a	11 a
10	Vapam	20	gal	14 a	12 e	6 a	0.7 d	12 a	10 a	27 a	16 a
	Vydate IF + Air 5X	2.1	pt								
LSD (P=.10)				5.28	6.26	4.31	0.34t	0.94t	0.24t	6.87	6.37
Standard Deviation				4.38	5.20	3.58	0.28t	0.78t	0.20t	5.70	5.29
CV				24.24	27.23	51.81	71.91	25.26	20.37	23.46	53.95
Grand Mean				18.08	19.09	6.92	0.4t	3.07t	0.99t	24.32	9.81
Treatment Prob(F)				0.2326	**0.0423**	0.3678	**0.0817**	0.7646	0.5275	0.2422	0.3339

Means followed by same letter do not significantly differ (P=0.10, LSD). Mean comparisons performed only when ANOVA Treatment Prob (F) is significant at the pre-determined mean comparison level (<0.10). Significant values are bolded. t=Mean descriptions are reported in transformed data units, and are not de-transformed. Data were transformed using the log (X+1) transformation (> 14 oz US#1 and > 10 oz US#2) and the square root (X+0.5) transformation (4-10 oz US#2). Back transformed means are given in the table.

Economic Return

With respect to the check, only the Vapam at 40 gallons resulted in a significant increase in dollar return (Table 8). Most treatments were statistically similar to the check. Even though the Vydate and Vapam combinations had increased vigor, this did not translate to a significant increase in marketable yield, and subsequently in dollar return per cwt or acre.

The cost of the Vydate and/or Vapam component of each treatment was estimated based on prices available to Miller Research from local retailers (Table 9). These costs can be variable and should not be considered absolutes. Our cost was $4.65/gallon for Vapam and $83.12/gallon for Vydate. The only programs to results in a positive net dollar return were the Vapam at 40 gallons and the Vapam at 20 gallons with two Vydate applications (Table 9, Figure 6). All other programs resulted in a net loss compared to the non-Vapam, non-Vydate check.

While it is tempting to discard the four and six Vydate application programs based on these results, a different result was observed in 2013. In 2013 the six application Vydate program provided a substantial net increase over the check and was more profitable than a spring application of Vapam at 40 gallons.

Table 8. Effect of Vapam and Vydate on economic return (cv. Russet Burbank; Acequia, ID; 2014).

Description				Processing		Fresh	
Rating Unit				$/cwt	$/acre	$/cwt	$/acre
Trt	Treatment	Rate	Unit				
1	Check			7.88 bc	3270 bc	8.47 bc	3580 bc
2	Vapam	40	gal	8.16 a	4242 a	10.05 a	5233 a
3	Vydate IF + Chem	2.1	pt	7.81 bcd	2909 cde	7.50 bcd	2822 cde
4	Vapam Vydate IF + Chem	20 2.1	gal pt	7.95 b	3627 b	8.68 ab	3960 b
5	Vydate IF + Chem 3X	2.1	pt	7.78 bcd	2848 def	7.17 cd	2625 de
6	Vapam Vydate IF + Chem 3X	20 2.1	gal pt	7.81 bcd	3218 bcd	7.68 bcd	3170 bcd
7	Vydate IF + Chem 5X	2.1	pt	7.78 bcd	2999 cd	7.59 bcd	2968 cde
8	Vapam Vydate IF + Chem 5X	20 2.1	gal pt	7.78 bcd	3248 bcd	7.71 bcd	3248 bcd
9	Vydate IF + Air 3X	2.1	pt	7.66 d	2448 f	6.90 d	2291 e
10	Vapam Vydate IF + Air 5X	20 2.1	gal pt	7.69 cd	2561 ef	6.69 d	2247 e
LSD (P=.10)				0.211	413.4	1.383	825.3
Standard Deviation				0.175	343.3	1.149	685.3
CV				2.24	10.94	14.64	21.32
Grand Mean				7.83	3137.15	7.84	3214.25
Treatment Prob(F)				**0.0268**	**0.0001**	**0.0134**	**0.0001**

Means followed by same letter do not significantly differ (P=0.10, LSD). Mean comparisons performed only when ANOVA Treatment Prob (F) is significant at the pre-determined mean comparison level (<0.10). Significant values are bolded.

Table 9. Net economic gain for Vapam and Vydate programs (cv. Russet Burbank; Acequia, ID; 2014).

Description Rating Unit				Program Cost*	Net Dollar Gain over Check	
					Process	Fresh
Trt	Treatment	Rate	Unit			
1	Check			0	--	--
2	Vapam	40	gal	186	786	1467
3	Vydate IF + Chem	2.1	pt	87	-448	-845
4	Vapam Vydate IF + Chem	20 2.1	gal pt	180	177	200
5	Vydate IF + Chem 3X	2.1	pt	175	-597	-1130
6	Vapam Vydate IF + Chem 3X	20 2.1	gal pt	268	-320	-678
7	Vydate IF + Chem 5X	2.1	pt	262	-533	-874
8	Vapam Vydate IF + Chem 5X	20 2.1	gal pt	355	-377	-687
9	Vydate IF + Air 3X	2.1	pt	175	-997	-1464
10	Vapam Vydate IF + Air 5X	20 2.1	gal pt	355	-1064	-1688

*Cost of only the Vapam or Vydate applications. The cost of maintenance products is not included. Vapam cost was $4.64/gallon and Vydate cost was $83.12/gallon.

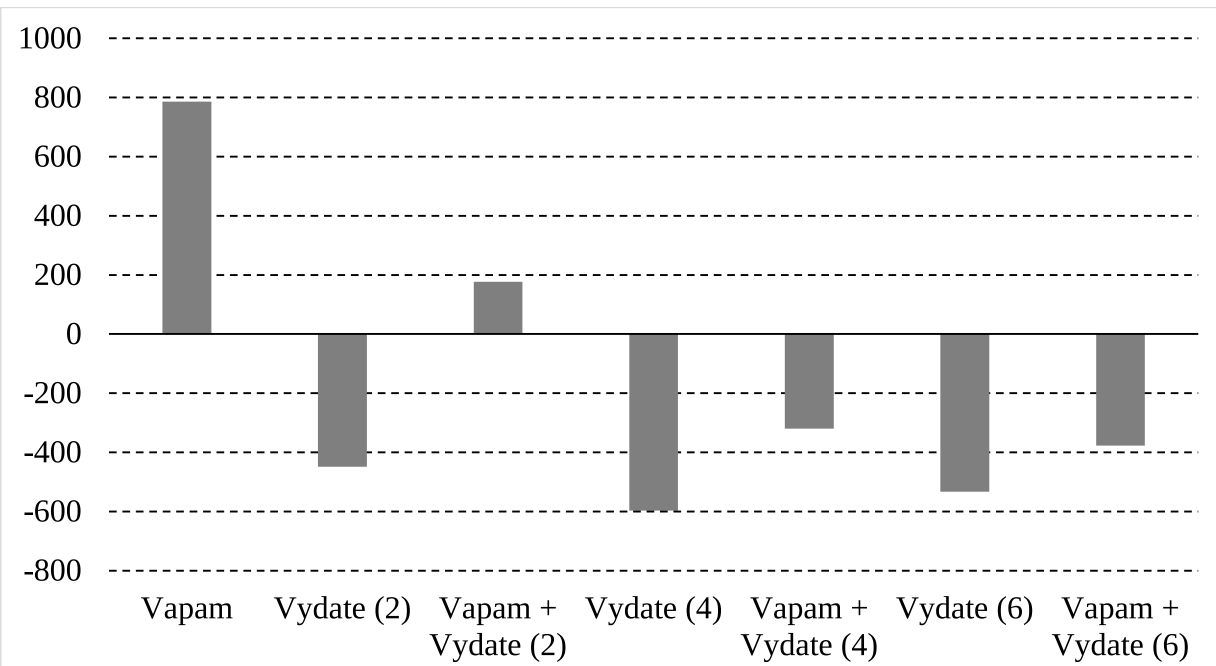


Figure 6. Net dollar return based on a mock processing contract for Vapam and Vydate programs.

Summary

The purpose of this trial was to evaluate if Vydate could be used as an alternative to metam sodium fumigation. Results from a trial sponsored by DuPont in 2013 indicated that this was possible. However, the results from this trial conducted in 2014 were not supportive. A secondary goal was to determine how many applications of Vydate were necessary to obtain a yield or quality benefit from Vydate. In this trial none of the Vydate treatments provided an economic benefit over using metam sodium (Vapam). A reduced rate of Vapam combined with Vydate was an effective way to manage nematodes at this location, but nematode populations were not at a high enough level to cause economic damage. At this point in time, we are not ready to recommend the use of a Vydate program as a replacement for metam sodium.

If Vydate could be used to reduce the amount of metam sodium, a significant reduction in the amount of pesticide active ingredient would be realized. Vapam at 40 gallons/acre results in 170 lb of active ingredient applied to the crop. Six applications of Vydate without Vapam results in about 6 lb of active ingredient. A combination of Vapam at 20 gallons and six applications of Vydate results in about 89 lb of active ingredient. If the Vapam/Vydate combination could work, a substantial reduction in pesticide active ingredient would be realized.

The trial needs to be performed again to see if 2013 or 2014 results are more typical.

Answers to questions asked at the outset of this project:

4. <u>Does Vydate need to be applied by chemigation, or can it also be applied as a foliar application?</u>

This question cannot be satisfactorily answered based on this year's data. Vydate was not effective regardless of the application method used. Additional trials have been planned for 2015 to make another effort to answer this question.

5. <u>Are 6 applications needed to get yields similar to metam sodium? Could the same result occur with fewer applications?</u>

The six application program worked in 2013, but not in 2014. It appeared that four or more total applications resulted in slightly longer canopy life, but the differences between the two application program and the four and six application programs were slight. None of the Vydate programs resulted in the yield and economic return comparable to the metam sodium program.

6. <u>Could a reduced rate of metam sodium shanked in the soil (i.e. 20 gal/acre) be combined with Vydate to produce a more economical approach to controlling potato early die?</u>

The reduced metam sodium combined with Vydate program was effective in 2013 but not in 2014. The reasons for the year to year difference are not known. We propose to conduct the trial another year to see if we can repeat the results of 2013.

References

Davis JR, Pavek JJ, and Corsini DL. 1983. A sensitive method for quantifying *Verticillium dahliae* colonization in plant tissue and evaluating resistance among potato genotypes. Phytopathology 73(7):1009-1014.

Appendix 1. Site Description

Trial Location

City:	Rupert	Latitude of LL Corner °:	42.65503 N
State:	ID	Longitude of LL Corner °:	113.58840 W
Postal Code:	83350	Altitude of LL Corner, Unit:	4170 FT
Country:	USA	Angle y-axis to North °:	0

Crop Description

Solanum tuberosum		Potato	
Variety:	Russet Burbank	Planting Date:	23 April 2014
Planting Depth:	7 in	Rate (12”):	2196 lb/a
Row Spacing:	36 in	Rate (15”):	1757 lb/a
Avg. Seed Size:	2.42 oz	Emergence:	21 May 2014

Site and Design

Plot Width:	12 ft	Site Type:	Field
Plot Length:	29 ft	Experimental Unit:	1 Plot
Plot Area:	348 ft^2	Tillage Type:	Conventional-till
Replications:	6	Study Design:	Randomized Complete Block (RCB)
% Slope:	0.0	Untreated Arrangement:	Single control randomized in each block

Previous Crop

Year	Crop	Pesticides
2013	Dry bean	Sonalan, Outlook
2012	Sugarbeet	Roundup PowerMax, Chlorpyrifos, Mustang Max
2011	Potato	Metribuzin, Outlook, Prowl H2O, MetaStar, Endura, Bravo, Endigo, Echo

Soil Description

% Sand:	77	% OM:	0.7	Texture:	Sandy loam
% Silt:	14	pH:	6.9	Soil Name:	Tindahay
% Clay:	9	CEC:	11.8	Fert. Level:	Good
				Soil Drainage:	Excellent

Analyzed By: Agvise Laboratories; 604 Highway 15 West; PO Box 510; Northwood, ND 58267

Cultural Practices

Cultivation-Ripper/Fumigation with DMI, 29 October 2013
Row mark-out with potato bedder (36” rows), 26 November 2013
Hilling with Lilliston cultivator, 12 May 2014

Initial Soil Fertility (16 October 2013)

Salts (mmhos/cm)	0.7	Organic N (lb/acre)	40	Calcium (meq/100 g)	3.9
Chlorides (ppm)	41	Ammonium-N (ppm)	4.8	Magnesium (meq/100g)	1.8
Sodium (meq/100g)	0.3	Nitrate-N (ppm)	9	Sulfate-S (ppm)	14
Excess Lime (%)	0.2	Phosphorus (ppm)	23	Zinc (ppm)	1.6
		Potassium (ppm)	110	Iron (ppm)	10.6
				Manganese (ppm)	4.2
				Copper (ppm)	0.7
				Boron (ppm)	0.70

Analyzed by Stukenholtz Laboratory; 2924 Addison Ave. E., PO Box 353; Twin Falls, ID 83303-0353

Fertilizers Applied (at-plant shaded in gray)

Fertilizer	Composition	Rate	Units Applied	Date Applied
MAP	11-52-0	144 lb/acre	16 N, 75 P	25 Oct 13
KCl	0-0-60	167 lb/acre	100 K	25 Oct 13
Ammonium Phosphate	10-34-0	25 gal/acre	29 N, 100 P	24 Apr 14
Boron	0-0-0-10 B	0.5 gal/acre	0.55 B	24 Apr 14
Manganese	0-0-0-5 Mn	0.5 gal/acre	0.28 Mn	24 Apr 14
Zinc	0-0-0-10 Zn	1.0 gal/acre	1.2 Zn	24 Apr 14
Humus	(NA, humic acid)	1.0 gal/acre	--	24 Apr 14
Urea (dry)	46-0-0	174 lb/acre	80 N	12 May 14
K_2SO_4	0-0-50-18 S	170 lb/acre	85 K, 31 S	12 May 14
UAN	32-0-0	4.2 gal/acre	15 N	30 May 14
UAN	32-0-0	5.4 gal/acre	19 N	03 Jun 14
UAN	32-0-0	5.4 gal/acre	19 N	09 Jun 14
UAN	32-0-0	8.5 gal/acre	30 N	17 Jun 14
K_2SO_4	0-0-50-18 S	150 lb/acre	75 K, 27 S	24 Jun 14
UAN	32-0-0	9.3 gal/acre	33 N	25 Jun 14
UAN	32-0-0	4.2 gal/acre	15 N	27 Jun 14
UAN	32-0-0	7.9 gal/acre	28 N	01 Jul 14
UAN	32-0-0	3.1 gal/acre	11 N	03 Jul 14
UAN	32-0-0	4.0 gal/acre	14 N	05 Jul 14
UAN	32-0-0	4.8 gal/acre	17 N	08 Jul 14
UAN	32-0-0	4.8 gal/acre	17 N	12 Jul 14
UAN	32-0-0	4.5 gal/acre	16 N	17 Jul 14
UAN	32-0-0	4.5 gal/acre	16 N	20 Jul 14
UAN	32-0-0	5.1 gal/acre	18 N	27 Jul 14
UAN	32-0-0	4.5 gal/acre	16 N	03 Aug 14
UAN	32-0-0	4.5 gal/acre	16 N	10 Aug 14

Total units: 425 N, 175 P, 260 K, 58 S, 0.55 B, 0.28 Mn, 1.2 Zn (Full program)
80% at plant program: 419 N, 155 P, 260 K, 58 S, 0.44 B, 0.22 Mn, 0.96 Zn (Reduced program)

Maintenance Pesticides

Product	Active Ingredient	Rate/acre	Target	Date
Tricor 4F	metribuzin	0.75 pt	Weeds	13 May 14
Outlook	dimethenamid-p	15 fl oz	Weeds	13 May 14
Prowl H_2O	pendimethalin	1.5 pt	Weeds	13 May 14
Ultra Flourish	mefenoxam	6.4 fl oz	Pink rot	11 Jun 14
Ultra Flourish	mefenoxam	6.4 fl oz	Pink rot	25 Jun 14
Leverage 360	imidicloprid, β-cyfluthrin	2.8 fl oz	Insects	25 Jun 14
Luna Tranquility	fluopyram, pyrimethanil	11.2 fl oz	Early blight, white mold	25 Jun 14
Bravo WS	chlorothalonil	1 pt	Early blight, late blight	25 Jun 14
Luna Tranquility	fluopyram, pyrimethanil	11.2 fl oz	Early blight, white mold	12 Jul 14
Bravo WS	chlorothalonil	1 pt	Early blight, late blight	12 Jul 14

Appendix 2. Application Data

Application Data

	A	B	C	D	E	F
Application Date:	30 Oct 13	23 Apr 14	11 Jun 14	11 Jun 14	01 Jul 14	01 Jul 14
Appl. Start Time:	9:00 AM	1:30 PM	6:00 PM	7:45 AM	6:30 AM	9:00 AM
Appl. Stop Time:	9:35 AM	2:30 PM	7:30 PM	8:00 AM	7:30 AM	9:15 AM
Application Method:	Spray	Spray	Chemigation	Spray	Chemigation	Spray
Application Timing:	Pre-plant	At Plant	12” Plant	12” Plant	First trash	First trash
Application Placement:	Soil-incorp.	In-furrow	Foliar	Foliar	Foliar	Foliar
Applied By:	(Custom)	J. Miller	J. Miller	J. Miller	J. Miller	J. Miller
Air Temperature (F):	40	56	75	75	50	68
% Relative Humidity:	82	42	42	42	68	50
Wind Velocity (mph):	4	15	2	2	1	5
Wind Direction:	SW	SW	WSW	WSW	E	E
Dew Presence:	No	No	No	No	No	No
Soil Temperature (F):	50	48	74	74	56	58
Soil Moisture:	75FC	80FC	75FC	75FC	75FC	75FC
% Cloud Cover:	80	50	0	0	0	0
Next Moisture:		25 Apr 14	11 Jun 14	11 Jun 14	01 Jul 14	01 Jul 14

	G	H	I	J	K	L
Application Date:	14 Jul 14	14 Jul 14	29 Jul 14	29 Jul 14	12 Aug 14	12 Aug 14
Appl. Start Time:	5:00 PM	9:30 PM	9:00 AM	11:46 AM	8:50 AM	11:30 AM
Appl. Stop Time:	6:00 AM	9:40 PM	9:40 AM	11:51 AM	9:30 AM	11:35 AM
Application Method:	Chemigation	Spray	Chemigation	Spray	Chemigation	Spray
Application Timing:	E + 14 days	F + 14 days	G + 14 days	H + 14 days	I + 14 days	J + 14 days
Application Placement:	Foliar	Foliar	Foliar	Foliar	Foliar	Foliar
Applied By:	J. Miller	J. Miller	J. Miller	T. Taysom	J. Miller	J. Miller
Air Temperature (F):	86	75	71	75	68	80
% Relative Humidity:	50	54	63	53	85	41
Wind Velocity (mph):	3	2	2	2	2	6
Wind Direction:	E	SSW	E	ENE	E	E
Dew Presence:	No	No	No	No	Yes	No
Soil Temperature (F):	78	70	(NM)	68	65	66
Soil Moisture:	75FC	75FC	80FC	80FC	90FC	85FC
% Cloud Cover:	50	10	100	95	90	60
Next Moisture:	15 Jul 14	15 Jul 14	31 Jul 14	31 Jul 14	12 Aug 14	12 Aug 14

(NM) = Not measured

Crop Stage at Application

	A	B	CD	EF	GH	IJ	KL
Description	Pre-plant	Seed	Late rosette	First trash	Bulking	Bulking	Bulking
Diameter(in):	NA	0	14	36	36	36	36
Height (in):	NA	0	14	28	20	18	18
Height Min., Max:	NA	0, 0	11, 16	22, 32	13, 26	14, 22	14, 21
Crop coverage (%):	NA	0	40	100	100	100	100

Application Equipment

	A	B	CEGIK	DFHJL
Appl. Equipment:	Custom DMI	MR Unit Planter	ChemigationM	MR Sprayer 1
Equipment Type:	Disk-ripper	Planter-mounted	MR Chemigator	Tractor-mounted
Operation Pressure (psi):	20	20	65	20
Nozzle Type:	TJK Floodjet	Flat fan	Mini-wobbler	Flat fan
Nozzle Size:	#5	8002E	0.125	XR 11002VS
Nozzle Spacing (in):	15	36 in	30	18
Nozzles/Row:	2	1	NA	2
% Coverage:	100	17	100	100
Boom ID:	CE-DMI	MR-Bulk-IF	ChemMan	1A
Boom Length:	12 ft	12 ft	30 ft	12
Boom Height:	9 in (in soil)	8 in	30 in	20
Ground Speed:	5 mph	1.4 mph	NA	6.4 mph
Carrier:	NA	Water	Water	Water
Water Hardness (ppm CaCO3):	NA	250	Not measured	250
Spray Volume:	40 or 20 gal/acre	17.7 gal/acre	0.25 acre inch	7.2 gal/acre
Mix Size:	NA	2 gal	71 gallons	1.5 gal
Spray pH:	NA	7.8	6.0-6.2	6.0-6.2
Propellant:	Pump (hydraulic)	Compressed air	Compressed air	Compressed air
Tank Mix:	No	No	No	No

Appendix 3. Monthly weather data for the Northwest Potato Research Consortium Vapam/Vydate trial conducted in Acequia, Idaho; 2014. Precipitation data were collected using an ECH$_2$O ECRN rain gauge (Decagon Devices, Inc.) located in the trial area; air temperature and relative humidity were collected using a WatchDog 2800 weather station (Spectrum Technologies, Inc.) located near the Miller Research Main Office, Acequia, ID.

Monthly Weather Data – Acequia West Pivot

			Air Temperature (F)						
	Precip	Irrigation	Max		Min			% RH	
	(in)	(in)	Absolute	Average	Absolute	Average	Average	Max	Min
April	0.96	0	75	60	22	34	47	100	6
May	1.17	2.04	87	71	33	43	57	100	6
June	0.48	7.64	90	77	40	48	63	100	7
July	0	10.52	100	90	45	58	74	97	10
August	2.72	4.05	95	82	46	55	67	100	19
September	0.48	1.33	95	80	33	47	62	100	7
October	0	0.36	83	72	32	36	53	100	9
Total	5.85	25.94							

Annual Progress Report / Final Report

Annual reports due: January 15th (starting with January, 2015)

Final reports due: September 30th or earlier (often submitted Jan. 15th)

TITLE: Managing Foliar Potato Diseases

PERSONNEL: Jeff Miller and Trent Taysom, Miller Research

REPORTING PERIOD: January 2015 (Final Report)

ACCOMPLISHMENTS:

Managing early blight and white mold can with fungicides can be done by following the recommended program outlined below. Our evaluation shows that the recommended program controls both early blight and white mold (the two most common foliar diseases in southern Idaho). The improvement in disease control more than pays for the cost of the products. Following the recommended program should also help avoid the development of fungicide resistance.

RESULTS:

Summary Points

1. The standard fungicide program was Endura (5.5 oz) + Bravo WS (1 pt) at row closure and 14 days later, followed by Bravo WS (1.5 pt) 14 and 28 days after that for four total applications. This provided 47% early blight control and controlled white mold.
2. Adding another application of a protectant fungicide (Bravo WS) to the end of the standard program improved early blight control to 65%.
3. Adding an early Headline application (14" tall plants) to the standard program did not improve early blight control.
4. Increasing the rate of Endura to 7 or 8 oz did not improve early blight control.
5. Early blight control was improved by adding Revus Top at the third and fourth application.
6. Programs based on Luna Tranquility were the most effective against both early blight and white mold.
7. In-furrow fungicides did not improve early blight control.
8. Quadris Top was highly effective against early blight and relatively inexpensive, but did was not effective against white mold.
9. Quash appeared to improve yield in one of the two treatments where it was used. Quash alone was effective against early blight, but not white mold.
10. Bravo WS alone was inexpensive and highly effective against early blight. However, it increased white mold incidence.
11. Late blight and gray mold were not present in the trial.

Our recommended standard program for 2015 will be:

1. Luna Tranquility (11 fl oz) + Bravo WS (1 pt) just prior to row closure

2. Luna Tranquility (11 fl oz) + Bravo WS (1 pt) 14 days later
3. Bravo WS (1.5 pt) 14 days later
4. Bravo WS (1.5 pt) 14 days later

Any chlorothalonil or EBDC-based protectant could be used in place of Bravo WS. For areas requiring additional applications (i.e. longer growers seasons), Revus Top or Quadris Top should be placed at applications 3 and 4 and protectants could be used to finish the season.

This recommendation does not take into account the presence of late blight. If late blight were to occur, the recommended program could still be used, but additional products would need to be added and applications would need to be made more frequently.

PUBLICATIONS:

1. Miller, J.S., Miller, T.D., Taysom, T.W., and Anderson, D.A. 2014. Potential for foliar applications of chlorothalonil and mancozeb to increase incidence of white mold of potato. *Am. J. Potato Res*. 91:57.

PRESENTATIONS & REPORTS:

Presentations:

1. Potential for Foliar Applications of Protectant Fungicides to Increase Incidence of White Mold of Potato. Poster presented at the 2014 Potato Expo in San Antonio, TX on January 8-10, 2014.
2. Managing Potato Diseases. Presentation given to Simplot Grower Solutions agronomists at Idaho Falls, ID on January 17, 2014.
3. Managing Foliar Potato Diseases: Keeping the Leaves Clean. Presentation given at the Malheur County Plant Disease Short Course at Ontario, OR on February 18, 2014. 110 attendees.
4. Potato Diseases: Foliar. Workshop presented at the University of Idaho 46th Annual Potato Conference at Pocatello, ID on January 22, 2014.
5. Managing Potato Diseases. Presentation given at the Simplot Grower Solutions grower meeting in Idaho Falls, ID on February 26, 2014.
6. Fungicides for Potato Disease Control. Presentation given at Landview Fertilizer at Acequia, ID on February 11, 2014.
7. Managing Potato Diseases. Presentation given at the Simplot Grower Solutions grower meeting in Ashton, ID on February 26, 2014.
8. Managing Potato Diseases. Presentation given at the Simplot Grower Solutions grower meeting in St. Anthony, ID on February 27, 2014.
9. Efficient Management of Early Blight. Presentation given at the 2014 Ontario Potato Conference at Guelph, Ontario, Canada on March 6, 2014.

Foliar Potato Disease Management by Fungicides
Sponsored by the Northwest Potato Research Consortium
Trial ID: 14P-IPC-02

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This recommendation does not take into account the presence of late blight. If late blight were to occur, the recommended program could still be used, but additional products would need to be added and applications would need to be made more frequently.

Miller Research

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INTRODUCTION

Early blight (caused by *Alternaria solani*) and brown leaf spot (caused by *Alternaria alternata*) are the primary causes of leaf spot diseases in potatoes in southern Idaho. Gray mold (caused by *Botrytis cinnerea*) and black dot (caused by *Colletotrichum coccodes*) are diseases which can be damaging in certain circumstances but are typically of little consequence. White mold (caused by *Sclerotinia sclerotiorum*) can cause significant damage to potato canopies. Potato growers must construct a fungicide program each year to manage all of these diseases. Many fungicides are available, and the choice as to which fungicide should be used at which time can be confusing.

Endura has been the industry standard for controlling early blight, brown leaf spot, and white mold in southern Idaho for many years. However, product efficacy has begun to decrease the last few years. Traditionally, programs that consisted of at least two applications of Endura rarely showed any early blight, brown leaf spot, or white mold. Recently resistance to boscalid (Endura) in the early blight pathogen population (*Alternaria solani*) has been reported in Idaho[1] and *A. solani* isolates collected from our research farm have been confirmed to be resistant to boscalid[2]. Research sponsored by the Idaho Potato Commission in previous years has shown a decline in efficacy of Endura for controlling early blight.

The goal of this research is to develop cost-effective fungicide programs that will allow growers to control early blight, brown leaf spot, and white mold with an integrated program. Information on the fungicide treatments used in this trial are provided in Table 1.

MATERIALS AND METHODS

Trial Establishment and Maintenance

This trial was established at the Miller Research Experimental Farm near Acequia, ID. The previous crops were dry beans (2013), sugarbeet (2012), and potato (2011).

Dry fertilizer was spread on October 25, 2013. MAP (11-52-0) was applied at 144 lb/acre and KCl (0-00-60) was applied at 167 lb/acre for an application of 16 units N, 75 units P_2O_5, and 100 units K_2O.

The trial area was tilled using a disk-ripper (custom DMI machine) to a depth of 12 inches on October 29, 2013. Metam sodium fumigant (Vapam HL, 42% active) was injected 9 inches deep on the ripper shanks at a rate of 40 gallons per acre. At the time of application the soil moisture was about 75% field capacity and the soil temperature was between 47-54°F. The soil surface was packed to help seal the fumigant in the soil as part of the tillage operation.

Certified disease-free seed (cv. Russet Burbank) for this trial was purchased from a commercial potato grower. Seed was treated with 6% MZ dust applied at a rate of 1 lb/cwt. Average seed weight was 2.42 oz. The seed was planted with a modified four-row Acme commercial cup type potato planter on April 21. Potato rows were 36 inches apart and seed was planted 12 inches apart within the row to a depth of 7 inches. This translated to a planting rate of 2196 lb seed/acre.

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[1] Gudmestad, N.C., Arabiat, S., Pasche, J.S., and Miller, J.S. 2013. Prevalence and impact of SDHI fungicide resistance in *Alternaria solani*. Plant Disease 97:952-960.
[2] Fairchild, K.L., Miles, T.D., and Wharton, P.S. 2013. Assessing fungicide resistance in populations of *Alternaria* in Idaho potato fields. Crop Protection 49:31-39.

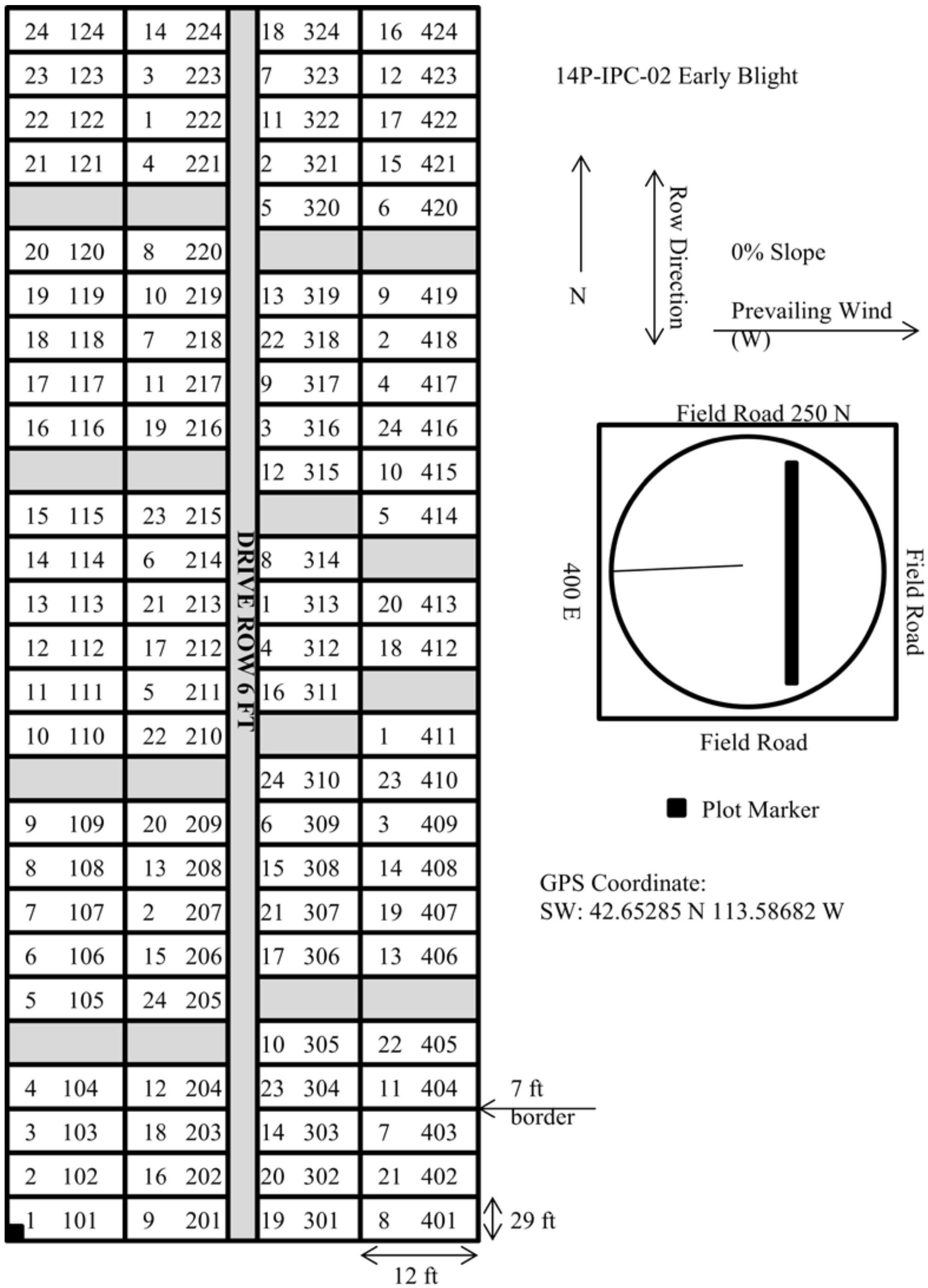

Figure 1. Trial map of the foliar disease efficacy trial sponsored by the Northwest Potato Research Consortium. The number on the left-hand side of the cell represents the treatment number and the number on the right-hand side represents the plot number. Plots in replication 1 are labeled in the 100's, replication 2 in the 200's, etc.

Plots were four rows wide and 29 feet long with a 7-foot border between plots. The trial was established as shown in Figure 1. Two rows were established on the west and east border of the trial and between replications 2 and 3 as drive rows allowing for tractor travel in the trial area without damaging plots. Areas where the pivot traveled through the trial were not used for plots and these are represented as gray areas in Figure 1. Treatments were established according to a randomized complete block design with four replications.

Standard liquid fertilizers were applied at planting two inches to the side and just below where the seed piece was dropped in the furrow. Additional dry fertilizer was applied May 12 and incorporated with a Lilliston cultivator the same day (hilling operation). Herbicides were applied May 13 and incorporated with 0.55" irrigation. Liquid N in the form of urea (32-0-0) was applied through the irrigation system during the season as needed. Petiole sampling was done outside the trial area to determine the fertility requirements of the growing crop. Additional details on crop establishment and maintenance are provided in Appendix 1 at the end of the report.

In-Furrow Applications

Two treatments were established to evaluate the potential impact of in-furrow fungicides on early blight control. On occasion in the past, we have observed that in-furrow applications of Quadris have reduced foliar early blight severity. However, this observation could not be repeated consistently.

Products for in-furrow application were mixed in three-gallon stainless steel tanks. A Teflon-coated laboratory magnet was placed inside the tank. Tanks were placed on a mixing rack mounted to an ACME 4-row potato planter. A second magnet located on the bottom of the mixing rack was turned with a hydraulic motor. This caused the magnet inside the tank to turn creating constant agitation of the test products during application. The spray tanks were pressurized with compressed air. Each tank was individually pressurized and protected with a one-way valve to prevent intermixing of products during application.

In-furrow application was made at planting on April 21. Products were applied with TeeJet flat fan 8002E nozzles mounted on the potato planter. Nozzles (one per row) were positioned 8 inches above the opened furrow and were positioned to spray the soil as it was being turned into the furrow. Products were applied using 18.8 gallons of spray mix per acre. Red Ball flow indicators were used to monitor the output for each nozzle and help ensure accurate and uniform spray delivery for each row in each plot. The spray lines were flushed between each plot. Additional details on application including equipment, crop stage, and conditions at application are provided in Appendix 2.

Table 1. Fungicide programs evaluated for foliar disease control (cv. Russet Burbank; Acequia, ID; 2014).

	A,B	C – June 21	E – July 8	G – July 22	I – August 6	K - August 20
1.	UTC	UTC	UTC	UTC	UTC	UTC
2.		Endura (5.5) + Bravo (1)	Endura (5.5) + Bravo (1)	Bravo (1.5)	Bravo (1.5)	
3.		Endura (5.5) + Bravo (1)	Endura (5.5) + Bravo (1)	Bravo (1.5)	Bravo (1.5)	Bravo WS (1.5)
4.	Headline (9) + Bravo (1) - B	Endura (5.5) + Bravo (1)	Endura (5.5) + Bravo (1)	Bravo (1.5)	Bravo (1.5)	
5.		Endura (5.5) + Scala (7)	Endura (5.5) + Scala (7)	Bravo (1.5)	Bravo (1.5)	
6.		Endura (5.5) + Revus Top (5.5)	Endura (5.5) + Revus Top (5.5)	Bravo (1.5)	Bravo (1.5)	
7.		Endura (5.5) + Bravo (1)	Endura (5.5) + Bravo (1)	Revus Top (5.5) + Bravo (1)	Revus Top (5.5) + Bravo (1)	
8.		Endura (5.5) + Revus Top (5.5)	Endura (5.5) + Revus Top (5.5)	Scala (7) + Bravo (1)	Scala (7) + Bravo (1)	
9.		Endura (5.5) + Bravo (1)	Endura (5.5) + Bravo (1)	Super Tin (3.75)	Super Tin (3.75)	
10.	Luna Privilege (6.84) - A	Luna Tranquility (11.2)[1,2]	Luna Tranquility (11.2)[1,2]	Bravo WS (1.5)[2]	Bravo WS (1.5)[2]	
11.		Luna Tranquility (11.2)[1,2]	Luna Tranquility (11.2)[1,2]	Bravo WS (1.5)[2]	Bravo WS (1.5)[2]	
12.		Luna Tranquility (11.2)[1,3]	Luna Tranquility (11.2)[1,3]	Bravo WS (1.5)[3]	Bravo WS (1.5)[3]	
13.		Luna Tranquility (11.2)[1,2]	Luna Tranquility (11.2)[1,2]	Bravo WS (1.5)[2]	Scala (7)[1,2]	
14.		Luna Tranquility (11.2)[1,2] + Quash (4)	Luna Tranquility (11.2)[1,2] + Quash (4)	Bravo WS (1.5)[2]	Bravo WS (1.5)[2]	
15.		Luna Tranquility (11.2)[1,2] + Aproach (12)	Luna Tranquility (11.2)[1,2] + Aproach (12)	Bravo WS (1.5)[2]	Bravo WS (1.5)[2]	
16.	Quadris (8.7) - A	Endura (8)[1] + Bravo (1)	Endura (8)[1] + Bravo (1)	Bravo WS (1.5)	Bravo WS (1.5)	
17.		Quadris Top (8)[1]	Quadris Top (8)[1]	Bravo WS (1.5)	Bravo WS (1.5)	Bravo WS (1.5)
18.		Quadris Top (10)[1]	Quadris Top (10)[1]	Bravo WS (1.5)	Bravo WS (1.5)	Bravo WS (1.5)
19.		Quadris Top (10)[1]	Bravo WS (1.5)	Bravo WS (1.5)	Revus Top (7)[1]	Bravo WS (1.5)
20.		Endura (7)[1] + Inspire (7)	Endura (7)[1] + Inspire (7)	Headline (6)[1]	Bravo WS (1.5)	
21.		Endura (7)[1] + Inspire (7)	Endura (7)[1] + Inspire (7)	Super Tin (3.75)[1] Scala (7)	Bravo WS (1.5)	
22.		Quash (2.5)[1]	Quash (2.5)[1]	Bravo WS (1.5)	Bravo WS (1.5)[4]	
23.		Bravo WS (1.5), weekly for 9 total applications.				
24.		Bravo WS (1.5), weekly for 6 total applications.				

A = In-furrow at planting on April 21, B = Pre-row closure on June 11.

[1] Tank-mixed with Preference at a rate of 0.25% v/v.

[2] The pH of the mix water was 7.7. Treatment was buffered to a pH of 6.5 prior to application.

[3] The pH of the mix water was 7.7. Treatment was buffered to a pH of 5.0 prior to application.

[4] Due to a scheduling error, Bravo was applied on July 14 and 22 instead of July 22 and August 6.

All applications were made with a spray volume of 18.8 (in-furrow) or 12.3 (foliar) gallons/acre.

Fungicide Applications

Fungicide applications were made using the Miller Research ground plot sprayer (a small self-propelled tractor with a hydrostatic drive).

Products were mixed in 3-gallon capacity stainless steel tanks. A Teflon-coated laboratory magnet was placed inside the tank. The tanks were loaded onto the sprayer. A second magnet located under the tank was turned with a hydraulic motor which caused the magnet inside the tank to turn. This allowed for constant agitation of the spray mixture during application. Spray tanks were pressurized with compressed air and connected to the spray manifold with one-way valves to prevent an intermixing of spray solutions.

The spray boom consisted of eight TeeJet XR 11002 VS flat fan nozzles spaced 18 inches apart. Sprayer speed was measured at 3.75 mph which resulted in a spray volume of 12.3 gallons per acre. The boom was positioned approximately 18-20 inches above the canopy.

The first foliar fungicide application for treatment 4 was made on June 11, which we estimated to be two to three weeks prior to row closure. This has been postulated as an effective timing for the control of black dot. The first application for the majority of treatments began just prior to row closure on June 21. For most treatments, applications were planned on a two-week schedule. Treatments 23 and 24 received applications weekly for 9 and 6 total applications total, respectively.

Rhizoctonia Disease Severity

Evaluations for Rhizoctonia stem canker (caused by *Rhizoctonia solani*) were taken on August 6 at 107 days after planting (DAP). The percentage of the underground roots, stems, and stolons with disease symptoms was estimated from 10 plants and then averaged. Any plant with a girdled stolen automatically received a minimum 10% rating regardless of the stem infection level. The percentage of plants with severe Rhizoctonia canker (i.e. greater than 40% of root area affected) was also determined. The number of stems per plant was also recorded.

Early Blight/Brown Leaf Spot

Each plot was visually assessed for the percentage of foliage with early blight and brown spot leaf symptoms on August 13, 26 and September 2. Assessments were made by two people and the ratings were averaged.

Alternaria solani Determination

Leaves with lesions typical of early blight were selected from healthy plants near the end of the season from selected treatments. A total of 20 lesions were chosen for isolation on water agar from an untreated area. A section of each lesion (approximately 0.5 cm^2) was cut from the leaf and placed on water agar. Isolations were allowed to incubate for at least two weeks and then evaluated for the presence of conidia typical of *Alternaria solani* or *Alternaria alternata*.

Alternaria solani conidium

Alternaria alternata conidia

White Mold

White mold (caused by *Sclerotinia sclerotiorum*) was evaluated on October 8 just prior to harvest. Each stem in the center two rows of each plot was visually inspected for white mold lesions. The number of lesions was counted.

Stem lesions affected with black dot and gray mold can sometimes appear similar to white mold. The presence of sclerotia in lesions (noted by the white arrow in the accompanying photo) was used to verify that lesions were caused by *S. sclerotiorum*.

Program Cost

The cost of each fungicide program was estimated using values obtained by Miller Research personnel from local pesticide retailers. Pesticide costs can range significantly from retailer to retailer, and manufacturers may provide incentives to growers. As a result, the prices listed here may not be the same as those available to all growers. These costs represent what it would have cost us to purchase these products in our area in 2014.

Product	Cost/Unit	Product	Cost/Unit	Product	Cost/Unit
Aproach	$240/gal	Luna Privilege	--*	Quash	$115/lb
Bravo WS	$25/gal	Luna Tranquility	$310/gal	Revus Top	$228/gal
Endura	$3/oz	Preference	$13/gal	Scala	$180/gal
Headline	$280/gal	Quadris	$195/gal	Super Tin	$19/lb
Inspire	$303/gal	Quadris Top	$226/gal		

*Cost has not been decided upon at this point in time.

Tuber Yield

Tubers were harvested using a specially modified two-row Lockwood 4620 harvester on October 8. Tubers from the center two rows of each four-row plot were lifted and cleaned by the harvester and crew riding on the machine. The tubers were dropped into a basket hanging from the end of the delivery boom. The basket was suspended by an electronic load cell scale which weighed all tubers harvested from the plot. The weight in pounds was converted to cwt/acre. A fresh-pack cardboard box (50 lb capacity) was placed in the hanging basket in order to obtain a sample (45-50 lb) for determining potato grade distribution.

Tuber Grade and Quality

USDA standards were used in grading the tuber samples collected at harvest. Tubers were separated into US#1, US#2, cull, and undersize categories and then individually weighed from November 13-14, 21, and 24-25. Weights were then used to determine the percentage of yield in the following grade categories: < 4 oz, 4-6 oz. US#1, 6-10 oz. US#1, 10-14 oz. US#1, >14 oz. US#1, culls, 4-10 oz. US#2, and >10 oz. US#2. The percentage of tubers in various fresh-pack carton sizes was also determined as described below in "Economic Return."

Economic Return

The gross economic value of each plot was estimated using mock processing and fresh pack contracts. For processing, the marketable yield (all US#1 tubers greater than 4 oz and all US#2 tubers) and process cull yield (<4 oz tubers) was determined. Incentives were determined based on the percentage of US#1 tubers and the percentage of all tubers >10 oz. For US#1 tubers, an incentive of $0.01/cwt was awarded for each percentage point over 65% with a cap set at 85%. A disincentive of -$0.01/cwt is deducted for each percentage point below 65%. Incentives (and disincentives) for the percentage of tubers > 10 oz were awarded based on the following table:

%>10 oz	Incentive	%>10 oz	Incentive	%>10 oz	Incentive	%>10 oz	Incentive
>45%	$0.44	34%	$0.26	22%	$0.02	10%	-$0.22
45%	$0.44	33%	$0.24	21%	$0.00	9%	-$0.24
44%	$0.43	32%	$0.22	20%	-$0.02	8%	-$0.26
43%	$0.42	31%	$0.20	19%	-$0.04	7%	-$0.28
42%	$0.41	30%	$0.18	18%	-$0.06	6%	-$0.30
41%	$0.40	29%	$0.16	17%	-$0.08	5%	-$0.32
40%	$0.38	28%	$0.14	16%	-$0.10	4%	-$0.34
39%	$0.36	27%	$0.12	15%	-$0.12	3%	-$0.36
38%	$0.34	26%	$0.10	14%	-$0.14	2%	-$0.38
37%	$0.32	25%	$0.08	13%	-$0.16	1%	-$0.40
36%	$0.30	24%	$0.06	12%	-$0.18	0%	-$0.42
35%	$0.28	23%	$0.04	11%	-$0.20		

Incentives or disincentives were added to or deducted from a base contract price of $8.00/cwt of marketable tubers (all US#1 tubers > 4 oz and all US#2 tubers). Processing culls were estimated as 75% of the tubers in the undersize (< 4 oz) and cull category and were given a value of $2.50/cwt.

For fresh pack, the price for each sample was determined using values from the National Potato and Onion Report issued on Friday, October 10, 2014 by the USDA Agricultural Marketing Service Fruit and Vegetable Program (Volume XCVI Number 197). Dollar values were assigned to the grade sample based on the following table:

Item	Tuber Category	Value/cwt		Item	Tuber Category	Value/cwt
10# Film	5.0-6.4 oz., US1	$7.00		80 ct	9.5-10.7 oz., US1	$17.00
40 ct	18-22 oz., US1	$17.50		90 ct	8.5-9.5 oz. , US1	$15.00

50 ct	14.7-18 oz., US1	$17.50		100 ct	6.4-8.5 oz. , US1	$14.00
60 ct	12.4-14.7 oz., US1	$17.50		US#2	6-10 oz	$13.00
70 ct	10.7-12.4 oz., US1	$17.50		US#2	>10 oz	$15.00

The percentage of tubers in each Tuber Category was multiplied by the price (Value/cwt column) and the resulting values were totaled to obtain a dollar value per cwt. This values was then multiplied by the marketable yield in hundredweight per acre to obtain the dollar value per acre. The fresh pack contract values do NOT take into account the packer margin or shipping costs which can be highly variable and will reduce the amount paid to the grower substantially.

Statistical Evaluation

All data were analyzed by analysis of variance (ANOVA) using Agricultural Research Manager (ARM) version 9. The data were analyzed according to a randomized complete block design with four replications. When the treatment effect was significant mean separation was performed using Fisher's protected LSD. Lowercase letters were placed after the averages in the table to help demonstrate when one average was statistically different from another. It is possible for two averages to be numerically different (e.g. show a difference of 20 cwt/acre), but not represent a true biological difference due to the variability in the individual plot values that were used to generate the average.

RESULTS AND DISCUSSION

In 2012 we conducted an early blight trial under pivot irrigation where we evaluated 26 different treatments. This high number of treatments was used so that all treatments could be compared together. We anticipated that yields would be too variable over such a large area, but that disease severity would be uniform enough to draw conclusions on program performance. We were surprised to see that we had relatively low variability for yield (coefficient of variation = 4.7, LSD = 31.0 cwt/acre). The average yield over the entire trial was 573 cwt/acre.

This year we were under a pivot again and decided to take the same approach in evaluating 24 treatments. The coefficient of variation was the same (4.7), but the overall average yield was much higher at 724 cwt/acre. The treatment effect was not considered significant for yield when all treatments were evaluated together. Differences were observed when specific subsets of treatments were compared. The entire data tables are shown in this report, but the results from some specific subset analyses are referenced occasionally.

Alternaria solani was isolated from 20 out of 20 lesions that were taken from the untreated check. *Alternaria alternata* was isolated from 19 of those lesions. This indicates that both pathogens were present in the field and were recovered with similar frequency. For convenience sake, the foliar disease will be referred to as early blight even though both early blight and brown leaf spot were present.

Phytotoxicity was not observed with any of the treatments in the trial (data not shown). We did experience some difficulty applying Super Tin on August 6 (application I). This may have been due to using relatively older product. The Super Tin had come from a bag that was opened in 2013. When a new bag was opened we did not experience mixing problems.

Early blight developed late. Disease severity was only 22% by August 26, but increased to 35% by September 2 (Table 1). All treatments significantly reduced early blight. Some programs were more effective than others. Most programs were effective against white mold.

White mold pressure was very light, however, and we only observed an average of 4.4 lesions per plot in the untreated check.

Yield and quality were statistically similar for all treatments in 2014 (Tables 3 and 4). That is normal for grade, but somewhat surprising and disappointing for yield. In 2012 we had a large trial and we were able to show significant yield differences when the means differed by 32 cwt/acre. This year the LSD (value to show true differences was 40 cwt/acre, but the treatment effect was deemed insignificant based on random variation within the trial. As a result, it is difficult to draw solid conclusions using apparent yield differences from this trial. Evaluation of trends needs to be done in relation to results from previous trials.

Treatment 2 (Endura + Bravo WS twice, followed by Bravo WS twice) has been our standard program for many years. We used this program as the comparison for all other treatments. This program only provided 47% control at the end of the season. In previous years we have had disease control greater than 90% with programs similar to this.

Additional Protectant Fungicide

Adding another application of Bravo WS (3 solo Bravo WS applications, 5 total applications; treatment 3) significantly increased control to 65%. Surprisingly, the yield was lower in treatment 3 than 2. In reviewing the replicated plot data, we could see nothing that would compromise the performance of treatment 3 in any of the replications. Plot 316 had the lowest yield (676 cwt) and it also had the lowest early blight control (52%). However, there was no reason to suspect that this plot had been compromised in any way. This difference is likely the result of random field variation. We have never observed a drop in yield resulting from Bravo applications in the past.

Early Season Strobilurins

Adding an application of Headline to the standard program when the plants were 12-16 inches tall (treatment 4) did not improve early blight control compared to the standard. Resistance to strobilurin fungicides (such as Headline) has already been demonstrated in the early blight pathogen populations of southern Idaho.[3] This early strobilurin application has been speculated to improve black dot control. While we have observed visual decreases in black dot severity with this approach, we have not been able to show an associated improvement in yield or quality. In this trial, the yield of treatment 4 was virtually the same as that of treatment 2. We did not observe any benefit from an early application of Headline.

Changing Endura's Tank-Mix Partner

In treatments 5 and 6, the Bravo WS tank mix partner with Endura for the first two applications (treatment 2) was replaced with Scala and Revus Top, respectively. With all data analyzed, disease control was slightly, but not significantly improved.

The addition of Revus Top to a program does improve late blight control. This may not be important every year, but this should be kept in mind when considering the overall merits of this product.

Two treatments in the trial evaluated higher rates of Endura (7 oz instead of 5.5 oz) tank mixed with Inspire (difenoconazole) for applications 1 and 2 (treatments 20 and 21). Treatment 20 utilized Headline instead of Bravo WS at application 3 and treatment 21 used Super Tin +

[3] Fairchild, K.L., Miles, T.D., and Wharton, P.S. 2013. Assessing fungicide resistance in populations of *Alternaria* in Idaho potato fields. Crop Protection 49:31-39.

Scala instead of Bravo for application 3. Treatment 20 resulted in more effective disease control than the standard, but treatment 21 did not. Increasing the rate of Endura and replacing Bravo with Inspire did not improve disease control. However, adding Headline to the program instead of Bravo for the third application increased disease control.

Tank Mixing Late Season

Our previous research has shown that the systemic products should be applied earlier in the season. But would tank-mixing them with a protectant late season improve control? Revus Top and Scala were tank-mixed with Bravo WS for the last two applications in treatments 7 and 8, respectively. As with tank-mixing early, disease control was improved slightly, but not significantly. The cost of tank mixing Revus Top and Scala late was slightly higher than tank mixing early. When these were mixed early, Revus Top and Scala replaced Bravo WS. However, when the products were used late, the replacement does not occur.

As mentioned above, one benefit of using Revus Top late is that Revus Top provides additional late blight protection. Historically, late blight has not appeared until late in the season. Late applications of Revus Top would provide increased protection against late blight and potentially improve early blight control.

When a subset of treatments (treatments 1-9) was analyzed, the increase in disease control with Revus Top late was significantly greater than the standard program (data not shown).

Super Tin

Super Tin has been reported to improve control of early and late blight in the past. Substituting Super Tin for Bravo WS the last two applications did result in a slight but not significant improvement in early blight control. Super Tin does have the liabilities of toxicity (signal word = poison), the difficulty in use, and the potential for phytotoxicity. Switching from a standard protectant to Super Tin late in the season would not provide enough benefit to outweigh non-monetary costs from an early blight standpoint.

Super Tin has been used as a tank-mix partner with protectants to improve late blight control. Applying Super Tin to the soil late season as a spore barrier against late blight has been shown to be effective.[4] However, the standard protectants Polyram and Penncozeb were more effective and do not have some of the same handling issues.

Luna Tranquility

Luna Tranquility has been labeled for a few years, but growers in the Pacific Northwest have not been able to utilize this product due to MRL (maximum residue limits) issues associated with potatoes exported to Pacific Rim countries. Treatments 10-15 evaluated different approaches to using Luna in place of Endura. For all of these programs, the pH of the water was adjusted prior to mixing the chemical according the recommendations by Bayer Cropscience.

Five of the six program resulted in significantly greater control than the standard program. Treatment 11 is likely the most comparable Luna Tranquility counterpart to the standard Endura program. For treatment 12, the pH of the spray solution was adjusted down to 5.0. This did not improve product performance. Replacing the final Bravo spray with Scala did

[4] Porter, L.D., Cumming, T.F., and Johnson, D.A. 2006. Effects of Soil-Applied Late Blight Foliar Fungicides on Infection of Potato Tubers by *Phytophthora infestans*. Plant Disease 90:964-968.

result in a significant drop in efficacy compared to treatment 11. Combining Quash or Aproach with Luna Tranquility did not significantly increase control. However, combing Quash with Luna Tranquility did result in an increase in yield over Luna Tranquility alone. (When all the treatments were analyzed together, the treatment factor is not statistically significant. However, when treatments 1, 2, and 10-15 are analyzed, significant differences are observed for yield.)

For the past three years we have observed an increase in yield with applications of Quash. The results of this trial and others show that this yield increase is not due to additional disease control. In this trial, the yield increase was not associated with a similar increase in economic return. The marketable yield was not increased in a similar manner. The Luna Tranquility/Quash program was the most expensive ($122.05). In the last two years the correlation between total yield and economic return was stronger, justifying the added cost. Unfortunately, MRL's have not been established for Quash for all Pacific Rim countries at this time (January 14, 2015). As a result, it is not likely to be allowed for use by any grower who has their product go to a processor or dehydrator.

<u>In-Furrow Fungicides</u>

Treatments 10 and 16 were used to evaluate the impact of Luna Privilege (fluopyram only) and Quadris, respectively, applied in-furrow for early blight control. Adding an in-furrow Luna Tranquility application to a foliar Luna program (treatment 10) did not improve disease control compared to the foliar program along (treatment 11). Additionally, adding Quadris to a foliar Endura program (treatment 16) did not improve early blight control of the Endura foliar program alone (treatment 2).

The use of these in-furrow fungicides did increase the program cost without any additional benefit for early blight. However, many growers may choose to use an in-furrow fungicide for the primary purpose of managing Rhizoctonia. Any other benefits would be considered secondary.

One important difference between treatments 2 and 16 is that Endura was applied at 5.5 oz in treatment 2 and 8 oz in treatment 16. In essence, treatment 16 has an increased rate of Endura and Quadris in-furrow in addition to what was done in treatment 2 without any increase in disease control. This substantiates 2013 results showing that increasing the rate of Endura does not improve early blight control.

Quadris was effective in reducing Rhizoctonia canker (Table 6). Luna Privilege was intermediate being similar to both Quadris and the untreated check. Quadris continues to rank at the top of in-furrow fungicides for control of Rhizoctonia.

<u>Quadris Top</u>

Treatments 17-19 evaluated Quadris Top as a replacement to the Endura + Bravo applications early in the season. Two applications of Quadris Top at 8 fl oz (instead of Endura) + Bravo resulted in more effective early blight control (compare treatments 2 and 17). Surprisingly, the 10 fl oz rate of Quadris Top was not as effective as the 8 fl oz rate. In 2013 these two treatments performed similarly. Based on our past experience, we assume this difference is a random result influence by the large number of treatments. Using Quadris Top for the first application and Revus Top for the last was also effective. This program was also relatively inexpensive ($45.94/acre).

The one problem with the Quadris Top programs is that they were not effective in reducing white mold. If a grower knows potatoes will be in a field with a history of white mold, then additional treatment would be necessary. In this trial the white mold pressure was low enough that the disease did not have an effect on yield.

Quash

Programs with Quash tended to have the highest yield. This has been observed in at least eight separate, independent tests from 2012-2014 not counting this trial. As mentioned above in the section on Luna Tranquility, the trend for higher yield was also observed in treatment 14. Treatment 22 evaluated Quash alone in place of Endura + Bravo. The Quash program exhibited greater early blight control and was similar for cost. Unlike treatment 14, however, there was no indication of increased yield and Quash alone is not as strong on white mold.

Protectant Only

A couple of years ago we were able to demonstrate good efficacy of protectant fungicides alone against early blight. This year programs utilizing only Bravo WS showed disease control similar to the standard. More applications were used (9 in treatment 23 and 6 in treatment 24), but the program cost was relatively inexpensive. Six applications of Bravo resulted in early blight control similar to the standard at about half the cost. Nine applications improved early blight control over the standard program and still cost less than the standard.

The drawback to this approach is that white mold is flared with repeated protectant use in potatoes.[5] In this trial white mold incidence was almost double with nine Bravo applications compared to the untreated check.

Summary

The results from our current standard (treatment 2) were somewhat anomalous this year. Treatment 3 was simply adding another application to treatment 2. We have done this before and observed both treatments to perform similarly. This year, treatment 2 produced a relatively high yield, but treatment 3 did not. At face value a person might say adding another application of Bravo was detrimental. However, we feel very confident that is not what happened. It is more likely that treatment 3 is more reflective of how treatment 2 would normally perform. Evidence for this is obtained from our Idaho Potato Commission reports from 2012 and 2103.

Going forward, our new standard program will be something similar to this:

1. Luna Tranquility (11 fl oz) + Bravo WS (1 pt) just prior to row closure
2. Luna Tranquility (11 fl oz) + Bravo WS (1 pt) 14 days later
3. Bravo WS (1.5 pt) 14 days later
4. Bravo WS (1.5 pt) 14 days later

This exact program was not tested in 2014. Treatments 11 and 12 did not have a protectant fungicide at applications 1 and 2. However, we feel that is a useful addition to help with late blight protection. The two components of Luna Tranquility (fluopyram and pyrimethanil) are not active against late blight. Additionally, the addition of a protectant such as Bravo should help with fungicide resistance management. The results from this trial demonstrate the pyrimethanil (Scala) is not as effective as fluopyram. Our experience is that other chlorothalonil or EBDC-based protectants can be used.

We feel that programs should begin just prior to row closure and then continue on an approximate 14-day interval. Four applications may not be enough in western Idaho or other

[5] Miller, J.S., Miller, T.D., Taysom, T.W., and Anderson, D.A. 2014. Potential for foliar applications of chlorothalonil and mancozeb to increase incidence of white mold of potato. Am. J. Potato Res. 91:57.

areas with a longer growing season. Using Revus Top later in the program appears to add extra disease control. Adding Revus Top for applications 3 and 4 utilizes a different mode of action (difenoconazole) and provides added late blight protection and this program variation will be tested in 2015.

Table 2. Effect of fungicide programs for foliar disease and total yield (cv. Russet Burbank; Acequia, ID; 2014).

		Early Blight Severity			White Mold	% Control	Program
	Abbreviated treatment description	Aug 13	Aug 26	Sep 2	Oct 8	vs. UTC	Cost
1.	UTC	5.5 a	21.8 a	34.7 a	4.4 abc	0 k	
2.	Endura/Bravo(2), Bravo(2)	1.2 b-f	3.7 cde	17.7 bc	0.6 ef	47 ij	$50.36
3.	Endura/Bravo(2), Bravo(3)	1.3 b-e	2.1 g-k	11.7 ef	0.4 f	65 def	$55.05
4.	Headline/Bravo early, Endura/Bravo(2), Bravo(2)	0.9 c-g	4.2 bcd	17.7 bc	0.4 f	47 ij	$73.17
5.	Endura/Scala(2), Bravo(2)	1.6 bcd	3.9 b-e	15.4 b-e	0.6 ef	53 g-j	$63.80
6.	Endura/RevusTop(2), Bravo(2)	1.8 bc	2.8 d-h	14.9 b-e	0.4 f	55 f-i	$69.05
7.	Endura/Bravo(2), RevusTop/Bravo(2)	0.9 c-g	2.2 g-k	13.5 de	0.6 ef	60 fgh	$66.83
8.	Endura/Bravo(2), Scala/Bravo(2)	0.9 c-g	5.0 bc	16.9 bcd	0.6 ef	50 hij	$66.92
9.	Endura/Bravo(2), SuperTin(2)	1.9 b	3.9 b-e	14.8 cde	0.6 ef	56 f-i	$49.89
10.	LunaP IF, LunaT(2, pH=6.5), Bravo(2)	1.0 b-g	1.4 kl	5.8 hi	0.0 f	83 abc	$65.46*
11.	LunaT(2, pH=6.5), Bravo(2)	1.3 b-e	1.9 h-l	6.6 hi	0.0 f	81 abc	$65.55
12.	LunaT(2, pH=5.0), Bravo(2)	0.4 g	1.9 h-l	8.1 gh	0.3 f	74 bcd	$65.87
13.	LunaT(2, pH=6.5), Bravo, Scala	1.0 b-g	3.0 d-h	14.1 cde	0.2 f	58 f-i	$70.71
14.	LunaT/Quash(2, pH=6.5), Bravo(2)	1.2 b-f	1.6 jkl	5.4 hi	1.1 def	84 ab	$122.05
15.	LunaT/Aproach(2, pH=6.5), Bravo(2)	0.7 d-g	1.2 l	4.2 i	0.0 f	87 a	$110.55
16.	QuadrisIF, Endura8/Bravo(2), Bravo(2)	1.4 b-e	5.8 b	19.3 b	0.3 f	42 j	$78.61
17.	QuadrisTop8(2), Bravo(2)	2.1 b	4.2 bcd	9.7 fg	4.9 abc	72 cde	$44.05
18.	QuadrisTop10(2), Bravo(2)	1.7 bc	3.5 c-f	15.1 b-e	2.9 bcd	54 f-j	$51.11
19.	QuadrisTop10, Bravo(2), RevusTop	1.2 b-f	3.7 cde	12.7 ef	9.8 a	63 d-g	$45.94
20.	Endura/Inspire(2), Headline, Bravo	0.6 efg	2.7 e-i	12.4 ef	0.2 f	62 efg	$95.56
21.	Endura/Inspire(2), SuperTin/Scala, Bravo	2.0 b	3.7 cde	16.9 bcd	0.0 f	49 hij	$96.70
22.	Quash(2), Bravo(2)	1.2 b-f	2.3 f-j	11.6 ef	2.3 cde	65 def	$47.05
23.	Bravo(9)	0.5 fg	1.7 i-l	6.8 gh	8.4 a	80 abc	$42.19
24.	Bravo(6)	0.7 d-g	3.2 d-g	14.3 cde	6.9 ab	55 f-i	$28.13
	LSD (P=.10)	2.630t	0.14t	0.53t	0.34t	12.1	
	Standard Deviation	2.225t	0.12t	0.45t	0.29t	10.2	
	CV	34.52	19.42	12.34	89.81	17.04	
	Grand Mean	6.45t	0.62t	3.63t	0.32t	60.04	
	Treatment Prob(F)	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	*Partial cost.

Table 3. Effect of fungicide programs on yield and grade (cv. Russet Burbank; Acequia, ID; 2014).

Description	Yield (cwt/acre)		Total %			Avg. Tuber
	Total	Market	US#1	US#2	> 10 oz	Wt. (oz)
Trt Abbreviated treatment description						
1 UTC	669 a	480 a	57 a	15 a	29 a	5.5 a
2 Endura/Bravo(2), Bravo(2)	740 a	598 a	65 a	16 a	29 a	5.7 a
3 Endura/Bravo(2), Bravo(3)	704 a	531 a	56 a	19 a	30 a	5.8 a
4 Headline/Bravo early, Endura/Bravo(2), Bravo(2)	733 a	543 a	58 a	16 a	32 a	5.6 a
5 Endura/Scala(2), Bravo(2)	718 a	529 a	62 a	11 a	27 a	5.7 a
6 Endura/RevusTop(2), Bravo(2)	723 a	512 a	52 a	19 a	32 a	6.1 a
7 Endura/Bravo(2), RevusTop/Bravo(2)	742 a	542 a	56 a	17 a	28 a	5.6 a
8 Endura/Bravo(2), Scala/Bravo(2)	700 a	508 a	52 a	21 a	36 a	5.7 a
9 Endura/Bravo(2), SuperTin(2)	725 a	519 a	59 a	13 a	30 a	5.9 a
10 LunaP IF, LunaT(2, pH=6.5), Bravo(2)	708 a	496 a	50 a	20 a	27 a	6.0 a
11 LunaT(2, pH=6.5), Bravo(2)	735 a	546 a	58 a	16 a	32 a	6.0 a
12 LunaT(2, pH=5.0), Bravo(2)	742 a	516 a	59 a	10 a	23 a	5.2 a
13 LunaT(2, pH=6.5), Bravo, Scala	722 a	478 a	57 a	10 a	23 a	5.6 a
14 LunaT/Quash(2, pH=6.5), Bravo(2)	760 a	549 a	55 a	17 a	30 a	5.9 a
15 LunaT/Aproach(2, pH=6.5), Bravo(2)	744 a	547 a	55 a	18 a	31 a	5.6 a
16 QuadrisIF, Endura8/Bravo(2), Bravo(2)	742 a	525 a	53 a	18 a	34 a	5.7 a
17 QuadrisTop8(2), Bravo(2)	719 a	538 a	59 a	16 a	32 a	6.0 a
18 QuadrisTop10(2), Bravo(2)	717 a	555 a	57 a	20 a	36 a	6.3 a
19 QuadrisTop10, Bravo(2), RevusTop	731 a	549 a	62 a	13 a	32 a	6.0 a
20 Endura/Inspire(2), Headline, Bravo	723 a	536 a	55 a	19 a	27 a	5.4 a
21 Endura/Inspire(2), SuperTin/Scala, Bravo	728 a	581 a	62 a	17 a	28 a	5.6 a
22 Quash(2), Bravo(2)	747 a	531 a	56 a	15 a	37 a	6.3 a
23 Bravo(9)	702 a	508 a	56 a	17 a	27 a	5.6 a
24 Bravo(6)	708 a	491 a	55 a	14 a	24 a	5.4 a
LSD (P=.10)	40.2	63.1	10.87	8.48	9.00	0.63
Standard Deviation	34.0	53.4	9.20	7.18	7.62	0.54
CV	4.7	10.08	16.14	44.54	25.58	9.34
Grand Mean	724.33	529.61	56.98	16.12	29.78	5.76
Treatment Prob(F)	0.1836	0.3158	0.9027	0.8209	0.4853	0.3677

Table 4. Effect of fungicide programs on grade categories (cv. Russet Burbank; Acequia, ID; 2014).

Description		% US#1				% US#2		% Unmarketable	
Rating Unit		4-6 oz	6-10 oz	10-14 oz	>14 oz	4-10 oz	>10 oz	< 4 oz	Culls
Trt	Abbreviated treatment description								
1	UTC	15 a	24 a	12 a	5 a	4 a	10 a	20 a	8 a
2	Endura/Bravo(2), Bravo(2)	18 a	28 a	12 a	7 a	6 a	9 a	15 a	4 a
3	Endura/Bravo(2), Bravo(3)	17 a	22 a	9 a	7 a	6 a	13 a	17 a	8 a
4	Headline/Bravo early, Endura/Bravo(2), Bravo(2)	17 a	20 a	11 a	9 a	4 a	12 a	18 a	8 a
5	Endura/Scala(2), Bravo(2)	16 a	28 a	14 a	4 a	4 a	7 a	17 a	9 a
6	Endura/RevusTop(2), Bravo(2)	14 a	20 a	14 a	3 a	5 a	14 a	15 a	12 a
7	Endura/Bravo(2), RevusTop/Bravo(2)	17 a	22 a	12 a	4 a	6 a	11 a	16 a	10 a
8	Endura/Bravo(2), Scala/Bravo(2)	14 a	16 a	14 a	6 a	7 a	13 a	18 a	8 a
9	Endura/Bravo(2), SuperTin(2)	14 a	21 a	16 a	8 a	6 a	6 a	18 a	9 a
10	LunaP IF, LunaT(2, pH=6.5), Bravo(2)	14 a	21 a	11 a	3 a	8 a	12 a	16 a	13 a
11	LunaT(2, pH=6.5), Bravo(2)	12 a	25 a	15 a	4 a	4 a	11 a	17 a	9 a
12	LunaT(2, pH=5.0), Bravo(2)	16 a	25 a	12 a	5 a	4 a	5 a	22 a	7 a
13	LunaT(2, pH=6.5), Bravo, Scala	13 a	24 a	14 a	6 a	5 a	3 a	18 a	15 a
14	LunaT/Quash(2, pH=6.5), Bravo(2)	17 a	19 a	10 a	8 a	6 a	12 a	18 a	10 a
15	LunaT/Aproach(2, pH=6.5), Bravo(2)	17 a	20 a	12 a	6 a	6 a	12 a	20 a	6 a
16	QuadrisIF, Endura8/Bravo(2), Bravo(2)	15 a	18 a	10 a	8 a	4 a	14 a	19 a	8 a
17	QuadrisTop8(2), Bravo(2)	18 a	20 a	14 a	7 a	4 a	11 a	15 a	9 a
18	QuadrisTop10(2), Bravo(2)	14 a	22 a	12 a	8 a	5 a	15 a	16 a	7 a
19	QuadrisTop10, Bravo(2), RevusTop	14 a	24 a	15 a	8 a	5 a	7 a	18 a	7 a
20	Endura/Inspire(2), Headline, Bravo	14 a	24 a	12 a	4 a	8 a	10 a	18 a	7 a
21	Endura/Inspire(2), SuperTin/Scala, Bravo	17 a	28 a	10 a	6 a	6 a	11 a	16 a	4 a
22	Quash(2), Bravo(2)	13 a	17 a	16 a	10 a	4 a	11 a	15 a	14 a
23	Bravo(9)	16 a	22 a	10 a	5 a	7 a	9 a	18 a	10 a
24	Bravo(6)	19 a	21 a	9 a	5 a	4 a	10 a	19 a	11 a
LSD (P=.10)		4.37	6.42	0.70t	1.14t	0.78t	7.04	4.05	1.08t
Standard Deviation		3.70	5.43	0.60t	0.97t	0.66t	5.95	3.43	0.92t
CV		23.93	24.61	16.7	38.22	27.44	57.43	19.74	30.24
Grand Mean		15.47	22.08	3.57t	2.53t	2.42t	10.37	17.38	3.03t
Treatment Prob(F)		0.4982	0.1081	0.5452	0.8671	0.9378	0.5957	0.3778	0.4696

Table 5. Effect of fungicide programs on gross economic return (cv. Russet Burbank; Acequia, ID; 2014).

Description		Processing		Fresh	
Rating Unit		$/cwt	$/acre	$/cwt	$/acre
Trt	Abbreviated treatment description				
1	UTC	8.13 a	3903 a	9.51 a	4571 a
2	Endura/Bravo(2), Bravo(2)	8.21 a	4912 a	10.55 a	6326 a
3	Endura/Bravo(2), Bravo(3)	8.15 a	4342 a	9.79 a	5264 a
4	Headline/Bravo early, Endura/Bravo(2), Bravo(2)	8.21 a	4457 a	9.86 a	5362 a
5	Endura/Scala(2), Bravo(2)	8.14 a	4310 a	9.61 a	5103 a
6	Endura/RevusTop(2), Bravo(2)	8.13 a	4162 a	9.47 a	4869 a
7	Endura/Bravo(2), RevusTop/Bravo(2)	8.09 a	4385 a	9.41 a	5190 a
8	Endura/Bravo(2), Scala/Bravo(2)	8.17 a	4162 a	9.73 a	5013 a
9	Endura/Bravo(2), SuperTin(2)	8.18 a	4258 a	9.69 a	5109 a
10	LunaP IF, LunaT(2, pH=6.5), Bravo(2)	8.02 a	3993 a	9.02 a	4581 a
11	LunaT(2, pH=6.5), Bravo(2)	8.21 a	4488 a	10.25 a	5643 a
12	LunaT(2, pH=5.0), Bravo(2)	8.03 a	4149 a	8.93 a	4660 a
13	LunaT(2, pH=6.5), Bravo, Scala	8.01 a	3834 a	8.70 a	4197 a
14	LunaT/Quash(2, pH=6.5), Bravo(2)	8.14 a	4465 a	9.39 a	5175 a
15	LunaT/Aproach(2, pH=6.5), Bravo(2)	8.15 a	4457 a	9.49 a	5196 a
16	QuadrisIF, Endura8/Bravo(2), Bravo(2)	8.18 a	4291 a	9.49 a	4995 a
17	QuadrisTop8(2), Bravo(2)	8.22 a	4428 a	9.89 a	5358 a
18	QuadrisTop10(2), Bravo(2)	8.25 a	4581 a	10.52 a	5897 a
19	QuadrisTop10, Bravo(2), RevusTop	8.23 a	4521 a	10.28 a	5649 a
20	Endura/Inspire(2), Headline, Bravo	8.08 a	4331 a	9.59 a	5153 a
21	Endura/Inspire(2), SuperTin/Scala, Bravo	8.16 a	4737 a	10.35 a	6013 a
22	Quash(2), Bravo(2)	8.26 a	4393 a	9.87 a	5269 a
23	Bravo(9)	8.08 a	4115 a	9.23 a	4728 a
24	Bravo(6)	8.02 a	3945 a	8.68 a	4314 a
LSD (P=.10)		0.207	580.4	1.245	1177.3
Standard Deviation		0.175	491.2	1.054	996.4
CV		2.15	11.38	10.93	19.34
Grand Mean		8.14	4317.44	9.64	5151.41
Treatment Prob(F)		0.8011	0.3688	0.5141	0.3994

Table 6. Effect of selected fungicide programs on Rhizoctonia canker and stem number (cv. Russet Burbank; Acequia, ID; 2014).

Description				Rhizoctonia Canker			
				% Incidence	% Severity	% Severe	Stem Number
Trt	Treatment	Rate	Unit				
1	Untreated check			100 a	52 a	54 a	4.2 a
10	Luna Privilege	6.84	oz/a	100 a	40 ab	42 a	4.3 a
	Luna Tranquility	11.2	oz/a				
	Preference	0.25	% v/v				
	Bravo WS	1.5	pt/a				
16	Quadris	8.7	oz/a	100 a	26 b	21 a	3.7 a
	Endura	8	oz/a				
	Bravo WS	1	pt/a				
	Preference	0.25	% v/v				
	Bravo WS	1.5	pt/a				
LSD (P=.10)				0.00	17.30	37.18	0.98
Standard Deviation				0.00	12.59	27.06	0.72
CV				0.0	32.2	69.57	17.67
Grand Mean				100.0	39.09	38.9	4.05
Treatment Prob(F)				1.0000	**0.0737**	0.2871	0.5074

Appendix 1. Site Description

Trial Location

City:	Rupert	Latitude of LL Corner °:	42.65286 N
State:	ID	Longitude of LL Corner °:	113.58682 W
Postal Code:	83350	Altitude of LL Corner, Unit:	4175 FT
Country:	USA	Angle y-axis to North °:	0

Travel northeast from Rupert, Idaho on state Highway 24 for 2.8 miles. Turn east (right) on 200 North and travel just over two miles to the Miller Research Office located at 426 East 200 North. The trial is located in the northeast corner of the field which is approximately 0.5 miles to the north of the office.

Crop Description

	Solanum tuberosum		Potato
Variety:	Russet Burbank	Planting Date:	21 April 2014
Planting Depth:	7 in	Rate:	2196 lb/a
Row Spacing:	36 in	Emergence:	13 May 2014

Site and Design

Plot Width:	12 ft	Site Type:	Field
Plot Length:	29 ft	Experimental Unit:	1 Plot
Plot Area:	348 ft^2	Tillage Type:	Conventional-till
Replications:	4	Study Design:	Randomized Complete Block (RCB)
% Slope:	0.0	Untreated Arrangement:	Single control randomized in each block

Previous Crop

Year	Crop	Pesticides
2013	Dry bean	Sonalan, Outlook
2012	Sugarbeet	Roundup PowerMax, Chlorpyrifos, Mustang Max
2011	Potato	Metribuzin, Outlook, Prowl H2O, MetaStar, Endura, Bravo, Endigo, Echo

Soil Description

% Sand:	77	% OM:	0.7	Texture:	Sandy loam
% Silt:	14	pH:	6.9	Soil Name:	Tindahay
% Clay:	9	CEC:	11.8	Fert. Level:	Good
				Soil Drainage:	Excellent

Analyzed By: Agvise Laboratories; 604 Highway 15 West; PO Box 510; Northwood, ND 58267

Cultural Practices

Cultivation-Ripper/Fumigation with DMI, 29 October 2013
Row mark-out with potato bedder (36” rows), 26 November 2013
Hilling with Lilliston cultivator, 12 May 2014

Initial Soil Fertility (16 October 2013)

Salts (mmhos/cm)	0.7	Organic N (lb/acre)	40	Calcium (meq/100 g)	3.9
Chlorides (ppm)	41	Ammonium-N (ppm)	4.8	Magnesium (meq/100g)	1.8
Sodium (meq/100g)	0.3	Nitrate-N (ppm)	9	Sulfate-S (ppm)	14
Excess Lime (%)	0.2	Phosphorus (ppm)	23	Zinc (ppm)	1.6
		Potassium (ppm)	110	Iron (ppm)	10.6
				Manganese (ppm)	4.2
				Copper (ppm)	0.7
				Boron (ppm)	0.70

Analyzed by Stukenholtz Laboratory; 2924 Addison Ave. E., PO Box 353; Twin Falls, ID 83303-0353

Fertilizers Applied

Fertilizer	Composition	Rate	Units Applied	Date Applied
MAP	11-52-0	144 lb/acre	16 N, 75 P	25 Oct 13
KCl	0-0-60	167 lb/acre	100 K	25 Oct 13
Ammonium Phosphate	10-34-0	25 gal/acre	29 N, 100 P	21 Apr 14
Boron	0-0-0-10 B	0.5 gal/acre	0.55 B	21 Apr 14
Manganese	0-0-0-5 Mn	0.5 gal/acre	0.28 Mn	21 Apr 14
Zinc	0-0-0-10 Zn	1.0 gal/acre	1.2 Zn	21 Apr 14
Humus	(NA, humic acid)	1.0 gal/acre	--	21 Apr 14
Urea (dry)	46-0-0	174 lb/acre	80 N	12 May 14
K_2SO_4	0-0-50-18 S	170 lb/acre	85 K, 31 S	12 May 14
UAN	32-0-0	4.2 gal/acre	15 N	31 May 14
UAN	32-0-0	5.4 gal/acre	19 N	05 Jun 14
UAN	32-0-0	5.4 gal/acre	19 N	10 Jun 14
UAN	32-0-0	8.5 gal/acre	30 N	18 Jun 14
K_2SO_4	0-0-50-18 S	150 lb/acre	75 K, 27 S	24 Jun 14
UAN	32-0-0	9.3 gal/acre	33 N	26 Jun 14
UAN	32-0-0	4.2 gal/acre	15 N	28 Jun 14
UAN	32-0-0	7.9 gal/acre	28 N	02 Jul 14
UAN	32-0-0	3.1 gal/acre	11 N	04 Jul 14
UAN	32-0-0	4.0 gal/acre	14 N	07 Jul 14
UAN	32-0-0	4.8 gal/acre	17 N	09 Jul 14
UAN	32-0-0	4.8 gal/acre	17 N	14 Jul 14
UAN	32-0-0	4.5 gal/acre	16 N	19 Jul 14
UAN	32-0-0	4.5 gal/acre	16 N	22 Jul 14
UAN	32-0-0	5.1 gal/acre	18 N	29 Jul 14
UAN	32-0-0	4.5 gal/acre	16 N	05 Aug 14
UAN	32-0-0	4.5 gal/acre	16 N	12 Aug 14

Maintenance Pesticides

Product	Active Ingredient	Rate/acre	Target	Date
Vapam HL	sodium methyldithiocarbamate	40 gal	Verticillium, weeds	29 Oct 13
Tricor 4F	metribuzin	0.75 pt	Weeds	13 May 14
Outlook	dimethenamid-p	15 fl oz	Weeds	13 May 14
Prowl H_2O	pendimethalin	1.5 pt	Weeds	13 May 14
Ultra Flourish	mefenoxam	6.4 fl oz	Pink rot	11 Jun 14
Ultra Flourish	mefenoxam	6.4 fl oz	Pink rot	25 Jun 14
Leverage 360	imidicloprid, β-cyfluthrin	2.8 fl oz	Insects	25 Jun 14

Appendix 2. Application Information

Application data

	A	B	C	D	E	F
Application Date:	Apr 21 2014	Jun 11 2014	Jun 21 2014	Jun 30 2014	Jul 8 2014	Jul 14 2014
Appl. Start Time:	5:30 PM	10:20 AM	6:05 PM	11:30 AM	12:52 PM	11:00 AM
Appl. Stop Time:	6:20 PM	10:30 AM	7:05 PM	11:45 AM	2:08 PM	11:17 AM
Application Method:	Spray	Spray	Spray	Spray	Spray	Spray
Application Timing:	At Planting	Pre RC	Row Closure	C + 7	C + 14	E + 7
Application Placement:	In-furrow	Broadcast	Broadcast	Broadcast	Broadcast	Broadcast
Applied By:	Miller, J.	Miller, J.	Miller, J.	Miller, J.	Miller, J.	Taysom, T.
Air Temperature (F):	73	61	80	68	87	89
% Relative Humidity:	24	41	29	42	35	31
Wind Velocity (mph):	7	4	2	4	3	5
Wind Direction:	S	W	SW	SW	WSW	E
Dew Presence:	No	No	No	No	No	Yes
Soil Temperature (F):	67	58	70	61	NM	NM
Soil Moisture:	80FC	75FC	80FC	75FC	75FC	85FC
% Cloud Cover:	60	0	20	0	30	5
Next Moisture:	Apr 22 2014	Jun 13 2014	Jun 22 2014	Jul 2 2014	Jul 9 2014	Jul 14 2014

NM = Not measured

	G	H	I	J	K
Application Date:	Jul 22 2014	Jul 29 2014	Aug 6 2014	Aug 12 2014	Aug 20 2014
Appl. Start Time:	4:48 PM	12:36 PM	1:06 PM	11:55 am	12:45 PM
Appl. Stop Time:	5:19 PM	12:47 PM	2:06 PM	12:00 AM	1:05 PM
Application Method:	Spray	Spray	Spray	Spray	Spray
Application Timing:	E + 14	G + 7	G + 14	I + 7	I + 14
Application Placement:	Broadcast	Broadcast	Broadcast	Broadcast	Broadcast
Applied By:	Taysom, T.	Taysom, T.	Miller, J.	Miller, J.	Miller, J.
Air Temperature (F):	89	78	65	80	78
% Relative Humidity:	31	49	85	41	38
Wind Velocity (mph):	5	5	4	6	2
Wind Direction:	NNW	NE	WSW	E	S
Dew Presence:	No	No	Yes	No	No
Soil Temperature (F):	NM	68	NM	66	NM
Soil Moisture:	90FC	90FC	90FC	85FC	NM
% Cloud Cover:	15	80	100	60	40
Next Moisture:	Jul 24 2014	Aug 1 2014	Aug 12 2014	Aug 12 2014	Aug 20 2014

Crop Stage at Application

	A	B	C	D	E	F	G	H	I	J	K
BBCH Majority:	02	31	39	41	42	43	44	45	46	47	48
Diameter (in):	0	20	30	36	36	36	36	36	36	36	36
Height (in):	0	14	23	26	26	16	16	15	16	16	NM
Height Min, Max:	0, 0	12, 16	21, 25	25, 27	24, 30	13, 17	11, 22	14, 16	11, 22	11, 22	NM
Crop coverage (%):	0	70	95	100	100	100	100	100	100	100	90

NM = Not measured

Application Equipment

	A	DEFGHIJK
Appl. Equipment:	Bulk Potato Planter	MR Sprayer 01
Equipment Type:	Planter-mounted sprayer	Tractor-mounted sprayer
Operation Pressure (psi):	20	20
Nozzle Type:	Flat fan even	Flat fan
Nozzle Size:	8002E	XR 11002VS
Nozzle Spacing (in):	36	18
Nozzles/Row:	1	2
Band Width (in):	6	NA
% Coverage:	17	100
Boom ID:	BulkPlanter	SP1_8_02 1A
Boom Length (ft):	12	12
Boom Height (in):	8	About 20” above canopy
Ground Speed (mph):	1.4	3.75
Carrier:	Water	Water
Water Hardness (ppm CaCO3):	250	250
Spray Volume:	18.8 gal/acre	12.3 gal/acre
Mix Size (gallons):	2	1.5
Spray pH:	7.8	7.8 unless specified
Propellant:	Compressed air	Compressed air

MR Sprayer 1

Appendix 3. Monthly weather data for the NPRC early blight trial conducted in Acequia, Idaho; 2014. Precipitation data were collected using an ECH_2O ECRN rain gauge (Decagon Devices, Inc.) located in the trial area; air temperature and relative humidity were collected using a WatchDog 2800 weather station (Spectrum Technologies, Inc.) located near the Miller Research Main Office, Acequia, ID.

			Air Temperature (F)						
	Precip	Irrigation	Max		Min		% RH		
Month	(in)	(in)	Abs	Avg	Abs	Avg	Avg	Max	Min
April	0.96	0.00	75	60	22	34	47	100	6
May	1.17	2.24	87	71	33	43	57	100	6
June	0.48	7.16	90	77	40	48	63	100	7
July	0.00	9.92	100	90	45	58	74	97	10
August	2.92	5.08	95	82	46	55	67	100	19
September	0.48	1.44	95	80	33	47	62	100	7
October	0.00	0.36	83	72	32	36	0	100	9
Total	6.01	26.20							

Appendix 4. Daily weather data. All irrigation was supplied by a center pivot system and water was obtained from a surface canal system.

April	Precip	Irrigation	Air Temperature (F)			% RH	
Date	(in)	(in)	Max	Min	Avg	Max	Min
1-Apr	0.11	0	39	31	35	100	69
2-Apr	0.03	0	43	29	35	100	60
3-Apr	0.01	0	51	32	40	100	36
4-Apr	0.01	0	55	32	43	93	28
5-Apr	0	0	53	30	42	100	29
6-Apr	0	0	57	39	47	86	31
7-Apr	0	0	65	33	49	89	27
8-Apr	0	0	74	32	54	93	11
9-Apr	0	0	70	39	56	85	25
10-Apr	0	0	65	41	53	78	10
11-Apr	0	0	71	34	54	89	11
12-Apr	0	0	64	44	54	60	8
13-Apr	0.08	0	52	33	42	100	29
14-Apr	0	0	61	22	42	72	6
15-Apr	0	0	61	34	48	60	11
16-Apr	0	0	58	33	45	62	8
17-Apr	0	0	73	29	53	75	11
18-Apr	0.10	0	60	41	51	97	11
19-Apr	0	0	73	30	52	95	8
20-Apr	0	0	63	44	53	56	6
21-Apr	0	0	75	30	55	77	7
22-Apr	0.11	0	64	38	51	99	28
23-Apr	0.01	0	51	33	42	94	32
24-Apr	0	0	60	32	46	93	35
25-Apr	0.49	0	55	41	46	100	61
26-Apr	0	0	51	36	42	100	32
27-Apr	0.01	0	51	32	41	91	38
28-Apr	0	0	51	31	41	97	19
29-Apr	0	0	61	29	45	77	6
30-Apr	0	0	66	29	49	91	9
Absolute	0.96	0	75	22		100	6
Average			60	34	47	87	23

May	Precip	Irrigation	Air Temperature (F)			% RH	
Date	(in)	(in)	Max	Min	Avg	Max	Min
1-May	0	0	75	33	55	88	9
2-May	0	0	78	39	59	89	11
3-May	0	0	81	45	64	79	6
4-May	0	0	73	47	61	66	9
5-May	0	0	64	49	54	70	30
6-May	0.88	0	49	35	44	100	57
7-May	0.20	0	53	39	45	100	67
8-May	0	0	63	37	51	100	29
9-May	0.09	0	57	45	50	98	39
10-May	0	0	53	40	46	97	30
11-May	0	0	60	38	48	91	26
12-May	0	0	60	41	50	62	11
13-May	0	0	67	34	51	66	8
14-May	0	0.56	74	37	58	82	13
15-May	0	0	78	44	62	88	14
16-May	0	0	80	52	66	78	16
17-May	0	0	79	44	62	97	9
18-May	0	0	68	47	56	87	30
19-May	0	0	66	42	54	84	28
20-May	0	0	72	42	55	91	21
21-May	0	0	76	43	58	99	25
22-May	0	0	80	41	60	98	19
23-May	0	0	82	45	64	92	14
24-May	0	0	75	56	63	68	27
25-May	0	0	78	48	64	71	19
26-May	0	0	83	47	66	87	18
27-May	0	0.76	87	49	68	89	9
28-May	0	0	80	53	64	69	11
29-May	0	0	68	44	55	56	9
30-May	0	0	78	41	61	86	19
31-May	0	0.92	79	50	63	75	14
Absolute	1.17	2.24	87	33		100	6
Average			71	43	57	84	21

June	Precip	Irrigation	Air Temperature (F)			% RH	
Date	(in)	(in)	Max	Min	Avg	Max	Min
1-Jun	0	0	75	49	63	61	10
2-Jun	0	0	87	43	66	83	9
3-Jun	0	0	80	51	66	77	19
4-Jun	0	0	78	47	64	88	7
5-Jun	0	0.88	81	45	66	67	8
6-Jun	0	0	78	45	64	81	13
7-Jun	0	0	76	45	63	82	21
8-Jun	0	0	78	48	65	93	19
9-Jun	0	0	84	47	67	88	11
10-Jun	0	0.92	78	52	65	76	9
11-Jun	0	0	78	45	63	80	9
12-Jun	0	0	90	48	70	71	9
13-Jun	0	0.92	72	51	62	62	26
14-Jun	0	0	67	46	55	82	28
15-Jun	0	0.76	76	41	60	90	19
16-Jun	0.24	0	64	45	53	98	48
17-Jun	0	0	59	43	50	98	30
18-Jun	0.24	1.04	56	41	47	95	66
19-Jun	0	0	81	40	61	100	19
20-Jun	0	0.48	85	51	69	80	19
21-Jun	0		84	53	67	78	19
22-Jun	0	0.72	82	52	68	80	19
23-Jun	0	0	84	52	68	82	19
24-Jun	0	0	85	53	69	85	27
25-Jun	0	0	84	57	70	74	26
26-Jun	0	1.00	72	56	63	89	46
27-Jun	0	0	71	54	62	88	41
28-Jun	0	0.44	74	48	61	98	36
29-Jun	0	0	78	48	64	93	27
30-Jun	0	0	80	48	63	78	19
Absolute	0.48	7.16	90	40		100	7
Average			77	48	63	83	23

July	Precip	Irrigation	Air Temperature (F)			% RH	
Date	(in)	(in)	Max	Min	Avg	Max	Min
1-Jul	0	0	86	45	68	83	16
2-Jul	0	0.68	95	56	75	72	12
3-Jul	0	0	89	56	73	80	27
4-Jul	0	0.92	97	57	78	80	10
5-Jul	0	0	89	60	74	79	28
6-Jul	0	0	97	51	76	92	12
7-Jul	0	0.72	94	59	76	64	19
8-Jul	0	0	91	53	73	88	28
9-Jul	0	0.80	89	57	74	84	29
10-Jul	0	0	91	67	77	64	19
11-Jul	0	0.80	97	64	77	80	18
12-Jul	0	0	94	63	78	82	19
13-Jul	0	0	98	63	79	87	19
14-Jul	0	0.76	100	66	80	62	19
15-Jul	0	0	87	63	76	72	26
16-Jul	0	0.88	90	62	75	72	19
17-Jul	0	0	90	58	74	88	19
18-Jul	0	0	86	56	72	92	28
19-Jul	0	0.80	86	59	72	55	25
20-Jul	0	0	87	59	75	70	29
21-Jul	0	0	85	60	72	86	38
22-Jul	0	0.80	92	57	75	97	19
23-Jul	0	0	93	60	75	73	27
24-Jul	0	1.04	73	54	66	66	34
25-Jul	0	0	80	48	64	81	29
26-Jul	0	0.84	91	48	71	84	10
27-Jul	0	0	97	54	75	86	10
28-Jul	0	0	88	60	73	81	31
29-Jul	0	0.88	81	62	71	87	43
30-Jul	0	0	90	56	72	96	19
31-Jul	0	0	88	60	73	81	25
Absolute	0	9.92	100	45		97	10
Average			90	58	74	79	23

August	Precip	Irrigation	Air Temperature (F)			% RH	
Date	(in)	(in)	Max	Min	Avg	Max	Min
1-Aug	0	0.72	91	56	74	88	19
2-Aug	0	0.48	93	59	75	86	19
3-Aug	0	0	95	58	77	88	19
4-Aug	0.12	0	74	62	68	96	52
5-Aug	0.52	0.76	72	62	66	100	73
6-Aug	0.48	0	68	59	62	100	82
7-Aug	0	0	76	55	65	100	51
8-Aug	0	0	85	54	67	100	29
9-Aug	0	0	86	56	69	95	27
10-Aug	0	0	93	55	73	92	19
11-Aug	0	0	92	53	73	92	19
12-Aug	0	0.96	93	61	73	87	26
13-Aug	0.28	0.36	86	60	68	95	39
14-Aug	0.24	0	81	61	70	97	38
15-Aug	0	0	81	58	69	97	40
16-Aug	0	0	83	52	68	99	33
17-Aug	0	0	92	52	72	98	19
18-Aug	0	0	89	56	70	92	19
19-Aug	0	0.92	88	59	72	82	29
20-Aug	0.16	0	87	56	67	92	27
21-Aug	0.4	0	80	57	65	98	35
22-Aug	0.6	0	68	51	59	98	71
23-Aug	0.08	0	67	46	56	99	48
24-Aug	0	0	75	51	61	96	33
25-Aug	0.04	0	70	53	59	92	55
26-Aug	0	0	78	49	63	100	35
27-Aug	0	0	82	49	65	100	32
28-Aug	0	0	88	50	68	98	19
29-Aug	0	0	89	52	70	95	19
30-Aug	0	0.88	75	52	64	93	35
31-Aug	0	0	71	51	60	89	29
Absolute	2.92	5.08	95	46		100	19
Average			82	55	67	95	35

September	Precip	Irrigation	Air Temperature (F)			% RH	
Date	(in)	(in)	Max	Min	Avg	Max	Min
1-Sep	0	0	75	47	60	90	27
2-Sep	0	0	85	43	63	99	23
3-Sep	0	0	69	49	59	94	13
4-Sep	0	0	78	38	57	88	10
5-Sep	0	0.8	84	36	58	96	8
6-Sep	0	0	90	42	64	91	16
7-Sep	0	0	89	49	68	84	16
8-Sep	0	0	85	47	65	93	19
9-Sep	0	0.2	75	52	65	84	19
10-Sep	0	0	71	50	60	57	24
11-Sep	0	0	69	42	54	83	25
12-Sep	0	0	78	33	52	71	7
13-Sep	0	0	88	40	61	84	9
14-Sep	0	0	87	41	63	96	10
15-Sep	0	0	91	45	66	89	11
16-Sep	0	0.24	95	52	70	75	12
17-Sep	0	0.08	94	53	72	85	13
18-Sep	0	0	81	55	68	88	37
19-Sep	0	0	79	51	63	97	32
20-Sep	0	0	87	44	64	99	14
21-Sep	0.12	0	75	49	60	100	39
22-Sep	0	0	75	52	62	100	43
23-Sep	0	0	89	47	66	100	25
24-Sep	0	0	93	53	70	88	19
25-Sep	0	0.12	87	50	69	83	17
26-Sep	0	0	76	52	61	95	28
27-Sep	0.28	0	59	50	55	97	76
28-Sep	0	0	66	50	58	96	61
29-Sep	0.04	0	60	41	50	100	73
30-Sep	0.04	0	59	47	52	100	52
Absolute	0.48	1.44	95	33		100	7
Average			80	47	62	90	26

October Date	Precip (in)	Irrigation (in)	Air Temperature (F) Max	Min	Avg	% RH Max	Min
1-Oct	0	0	59	41	48	97	34
2-Oct	0	0.12	66	33	50	97	22
3-Oct	0	0	68	32	50	95	27
4-Oct	0	0	73	33	52	100	27
5-Oct	0	0	75	37	56	93	26
6-Oct	0	0	77	39	58	95	27
7-Oct	0	0.12	79	39	57	99	25
8-Oct	0	0.12	83	38	52	96	9
Absolute	0	0.36	83	32		100	9
Average			72	36	53	97	25

Annual Progress Report

TITLE: Soil Populations, Aggressiveness and Management of Mefenoxam-resistant Isolates of *Pythium ultimum* Causing Pythium Leak in Idaho, Oregon and Washington Potato Production

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Only those individuals whose names are **bolded** will be receiving money.

REPORTING PERIOD: January 2014 to January 2015

ACCOMPLISHMENTS:

1. Soil was collected from 92 potato fields across Idaho (22), Oregon (35) and Washington (35) to be assessed for metalaxyl-resistant *Pythium*. The majority of the soils from Oregon have been assessed and those from Idaho and Washington will be assessed within the next month.

2. Presence of metalaxyl-resistant *Pythium* can be loss or reduced to non-detectable levels in previously infected fields since 18 of 23 Oregon potato fields that tested positive for metalaxyl-resistant *Pythium* in 2003-2004 tested negative for metalaxyl-resistant *Pythium* in 2014 (Table 1).

3. Potato fields in Oregon are still developing metalaxyl-resistant Pythium since 9 of 46 Oregon fields that were negative for metalaxyl-resistant Pythium in 2003-2004 were positive for metalaxyl-resistant Pythium in 2014 (Table 1). Management practices will be analyzed from these fields to try to determine practices that favor development of resistance within these fields.

4. Development of metalaxyl resistant *Pythium* in potato fields continues to still be a problem since one out of five new fields assessed in Oregon was positive for metalaxyl-resistant *Pythium* (Table 1; there are three replications of each field listed as not being surveyed in 2003 or 2004). Additional fields are still being assessed.

5. Resist57 at 10 pints/A and Oxathiapropilin at 4.8 fl. oz/A were the most effective products in reducing tuber rot based on weight of rotted tubers in a field trial in Aberdeen, Idaho. Both products significantly reduced the amount of tuber rot compared to the non-treated control (Figure 1).

6. Foliar applications of Resist57, Omega 500F, HeadsUp, Ridomil Gold Bravo SC and Oxithiapropilin did not significantly differ from the non-treated control in reducing the incidence of infection of Ranger Russet tubers that were harvested from a field trial in Aberdeen, ID and challenge inoculated after superficial wounding of the tubers. However, Resist57 and HeadsUp were the most effective products in significantly reducing the disease severity compared to the non-treated control (Figure 1).

7. Tubers of Ranger Russet, Russet Burbank and Umatilla Russet grown in fields located in Paterson, WA and Hermiston OR that were treated with foliar applications of Ridomil Gold Bravo SC, Oxithiapiprolin, HeadsUp, Phostrol, and wound –inoculated with *Pythium ultimum* did not significantly reduce the % incidence of infection or the disease severity compared to the non-treated controls (Tables 2 and 3). Wound inoculation may be too severe for these products to be successful.

8. Two late season applications (applied four and two weeks prior to vine kill) of Ridomil Gold Bravo SC at 2.5 pints/A and Phostrol at 10 pints/A were successful in reducing the incidence of late blight tuber rot of Russet Burbank, Ranger Russet, and Umatilla Russet tubers compared to the non-treated controls (Tables 4).

RESULTS:

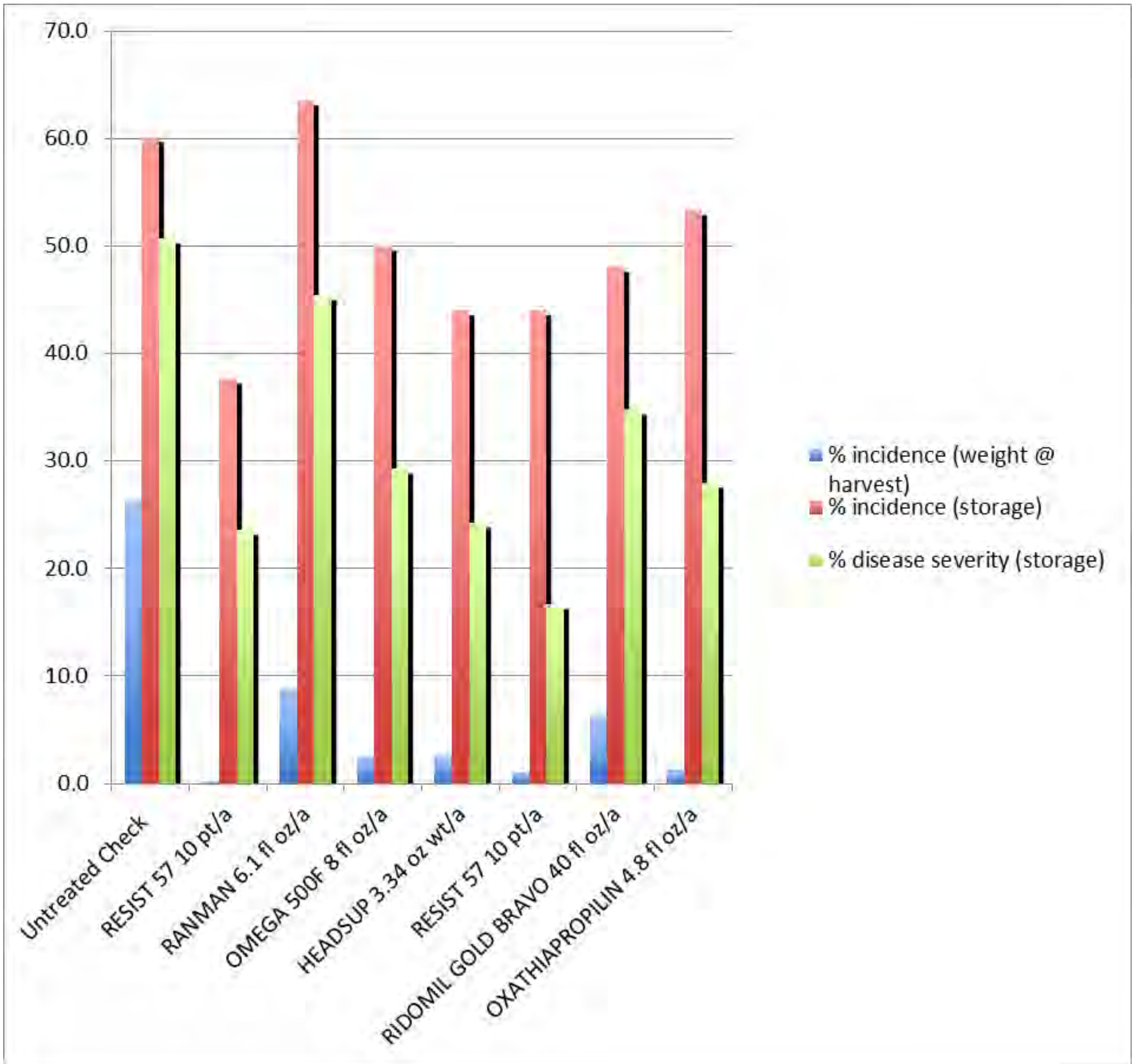


Figure 1. Percent incidence of rotted tubers in the field, and incidence and disease severity of challenge-inoculated tubers under storage conditions, when potatoes were sprayed with two or three foliar applications of products in a field trial in Aberdeen, ID and tubers were harvested and inoculated with *Pythium ultimum*, causal agent of Pythium leak.

Table 1. Potato fields sampled for metalaxyl-resistant *Pythium* in Oregon in 2014 that were previously sampled for resistance in either 2003, 2004 or not previously surveyed.

Field Description	Mean # of total *Pythium*, 2014	Mean # of metalaxyl-resistant *Pythium*, 2014	Mean # of metalaxyl-resistant *Pythium*, 2003/2004
RC4-1	104.9	0.0	16.0
RC4-2	75.9	0.0	0.0
RC4-3	130.4	0.0	48.0
RC4-4	103.2	0.0	59.0
RC4-5	15.9	0.0	5.0
RC4-6	133.6	0.0	148.0
RC4-7	102.6	0.0	5.0
RC4-8	5.4	0.0	90.0
RC4-9	338.6	0.0	27.0
RC5-1	33.3	0.0	0.0
RC5-2	5.5	0.0	0.0
RC5-3	22.0	0.0	0.0
RC5-4	16.7	0.0	0.0
RC5-5	11.0	0.0	0.0
RC5-6	49.3	0.0	0.0
RC5-7	5.5	0.0	0.0
RC5-8	0.0	0.0	0.0
RC5-9	16.5	0.0	0.0
RC5-10	16.4	0.0	0.0
RC10-1	104.0	0.0	11.0
RC10-2	145.1	0.0	0.0
RC10-3	96.0	0.0	11.0
RC10-4	188.0	5.5	0.0
RC10-5	93.3	0.0	5.0
RC10-6	60.3	0.0	27.0
RC10-7	116.8	0.0	21.0
RC10-8	178.9	0.0	0.0
RC10-9	138.6	5.3	0.0
RC10-10	207.1	0.0	5.0
RC12-1	43.6	0.0	0.0
RC12-2	159.7	0.0	0.0
RC12-3	27.0	0.0	16.0
RC12-4	142.2	0.0	5.0
RC20-1	137.4	0.0	0.0
RC20-2	217.0	0.0	0.0
RC20-3	214.8	0.0	0.0
RC20-4	258.4	0.0	0.0
RC20-5	154.0	0.0	0.0

RC20-6	218.5	0.0	0.0
RC20-7	167.8	0.0	0.0
RC20-8	236.8	0.0	0.0
RC20-9	280.1	0.0	0.0
RC20-10	244.2	0.0	0.0
RC 9-1	146.4	5.6	84.0
RC 9-2	151.0	5.6	11.0
RC 9-3	158.6	22.7	48.0
RC 9-4	147.1	5.4	0.0
RC 9-5	184.6	16.8	118.0
RC 9-6	185.6	22.5	0.0
RC 9-7	174.4	0.0	32.0
RC 9-8	177.6	11.1	21.0
RC 9-9	238.7	34.1	0.0
Field 19-1	34.0	0.0	missing
Field 19-2	166.8	17.3	0.0
Field 19-3	152.9	0.0	0.0
Field 19-4	139.1	17.4	0.0
Field 19-5	78.8	0.0	0.0
Field 19-6	21.4	0.0	0.0
Field 19-7	164.5	5.7	0.0
Field 19-8	91.4	11.4	0.0
Field 19-9	170.5	0.0	0.0
Field 19-10	79.6	0.0	11.0
Field 303-1	0.0	0.0	not surveyed
Field 303-2	22.6	0.0	not surveyed
Field 303-3	5.6	0.0	not surveyed
Field 306-1	191.8	0.0	not surveyed
Field 306-2	227.1	0.0	not surveyed
Field 306-3	210.7	0.0	not surveyed
Field 308-1	66.6	5.6	not surveyed
Field 308-2	143.4	0.0	not surveyed
Field 308-3	99.4	0.0	not surveyed
Field 309-1	89.0	0.0	not surveyed
Field 309-2	140.3	0.0	not surveyed
Field 309-3	118.6	0.0	not surveyed
Field 311-1	422.0	0.0	not surveyed
Field 311-2	366.5	0.0	not surveyed
Field 311-3	345.7	0.0	not surveyed
Field 1-1	37.7	0.0	0.0
Field 1-2	59.8	0.0	0.0
Field 1-3	32.6	0.0	0.0
Field 10-1	26.9	0.0	0.0
Field 10-2	82.0	0.0	0.0
Field 10-3	385.4	0.0	0.0

Field 22-1	114.2	0.0	0.0
Field 22-2	73.5	0.0	0.0

Table 2. Percent incidence of infection and percent infection of internal tuber tissue when two late season foliar applications of five products were sprayed at two week intervals and the harvested tubers were challenge inoculated with *Pythium ultimum*, causal agent of Pythium leak. Field trial conducted in Hermiston, OR.

Treatment	Cultivar	% Infection of internal tuber tissue	% Incidence
Non-treated Control	Russet Burbank	52.3±11.3	100
Non-treated Control	Ranger Russet	51.5±10.4	100
Non-treated Control	Umatilla	45.0±12.1	100
Ridomil Gold Bravo 2.5 pints/A	Russet Burbank	45.5±8.7	100
Ridomil Gold Bravo 2.5 pints/A	Ranger Russet	47.5±7.9	100
Ridomil Gold Bravo 2.5 pints/A	Umatilla	51.3±12.2	100
Phostrol 10 pints/A	Russet Burbank	52.0±7.0	100
Phostrol 10 pints/A	Ranger Russet	52.0±12.8	100
Phostrol 10 pints/A	Umatilla	47.3±14.2	100
Ranman 6.1 fl oz./A	Russet Burbank	49.8±10.8	100
Ranman 6.1 fl oz./A	Ranger Russet	49.5±10.0	100
Ranman 6.1 fl oz./A	Umatilla	49.8±13.3	100
HeadsUp 3.34 oz wt/A	Russet Burbank	53.8±10.0	100
HeadsUp 3.34 oz wt/A	Ranger Russet	48.5±10.4	100
HeadsUp 3.34 oz wt/A	Umatilla	45.0±7.9	100
Oxathiapropilin 4.8 fl. oz./A	Russet Burbank	54.3±8.2	100
Oxathiapropilin 4.8 fl. oz./A	Ranger Russet	47.0±12.6	100
Oxathiapropilin 4.8 fl. oz./A	Umatilla	45.8±12.3	100

Twenty tubers were inoculated for each treatment/cultivar combination.

Foliar applications applied at two week intervals. Last application applied two weeks prior to vine kill.

Table 3. Percent incidence of infection and percent infection of internal tuber tissue when two late season foliar applications of five products were sprayed at two week intervals beginning at flowering and the harvested tubers were challenge inoculated with *Pythium ultimum*, causal agent of Pythium leak. Field trial conducted in Paterson, WA.

Treatment	% Infection of internal tuber tissue	% incidence of Infection
Non-treated Control	50.5±8.4	100
Resist57 10 pints/A (2x)	48.5±11.1	100
Resist57 10 pints/A (3x)	53.3±8.0	100
Resist Foliar Nutrient 10 pints/A (2x)	47.3±12.5	100
Oxathiapropilin 4.8 fl. oz./A (2x)	50.3±12.0	100
Ranman 6.1 fl. oz./A (2x)	48.5±9.5	100
Omega 500 F 8.0 fl. oz./A (2x)	52.8±10.4	100
HeadsUp 3.34 oz wt/A (2x)	47.5±9.7	100
Ridomil Gold Bravo SC 2.5 pints/A (2x)	47.3±10.2	100
Phostrol 10 pints/Acre	49.5±8.1	100

Table 4. Percent incidence of infection and percent infection of internal tuber tissue when two late season foliar applications of five products were sprayed at two week intervals beginning at flowering and the harvested tubers were challenge inoculated with *Phytophthora infestans*, causal agent of late blight. Field trial was conducted in Hermiston, OR.

Treatment	Cultivar	% Infection of internal tuber tissue	% incidence of Infection
Non-treated Control	Russet Burbank	60.4±35.0	84.0
Non-treated Control	Ranger Russet	80.1±26.7	95.0
Non-treated Control	Umatilla	70.7±34.5	85.0
Ridomil Gold Bravo 2.5 pints/A	Russet Burbank	13.2±27.2 (-47.2)[1]	35.0 (-49)
Ridomil Gold Bravo 2.5 pints./A	Ranger Russet	24.3±25.2 (-55.8)	65.0 (-30)
Ridomil Gold Bravo 2.5 pints/A	Umatilla	12.6±29.4 (-58.1)	20.0 (-65)
Phostrol 10 pints/Acre	Russet Burbank	41.3±39.1 (-19.1)	60.0 (-24)
Phostrol 10 pints/Acre	Ranger Russet	66.3±40.0 (-13.8)	84.2 (-10.8)
Phostrol 10 pints/Acre	Umatilla	41.8±45.6 (-28.9)	50.0 (-35)
Ranman 6.1 fl oz./A	Russet Burbank	64.9±34.4 (+4.5)	85.0 (+1)
Ranman 6.1 fl oz./A	Ranger Russet	84.3±25.3 (+4.2)	95.0 (0)
Ranman 6.1 fl oz./A	Umatilla	58.3±42.5 (-12.4)	70.0 (-15)
HeadsUp 3.34 oz wt/A	Russet Burbank	66.7±30.8 (+6.3)	90.0 (+6)
HeadsUp 3.34 oz wt/A	Ranger Russet	83.5±30.5 (+3.4)	90.0 (-5)

HeadsUp 3.34 oz wt/A	Umatilla	67.8±37.0 (-2.9)	85.0 (0)
Oxathiapropilin 4.8 fl. oz./A	Russet Burbank	62.8±31.3 (+2.4)	85.0 (+1)
Oxathiapropilin 4.8 fl. oz./A	Ranger Russet	72.5±34.2 (-7.6)	85.0 (-10)
Oxathiapropilin 4.8 fl. oz./A	Umatilla	49.1±42.1 (-21.6)	68.4 (-16.6)

[1]Numbers in parenthesis are the percent reduction (-) or increase (+) in % infection or percent incidence compared to the non-treated controls.

Twenty tubers inoculated for each treatment/cultivar combination.

Methods for field trial in Aberdeen, ID:

Evaluation of in-furrow and foliar treatments for the control of Pythium leak, 2014.

Ranger Russet potato seed was hand cut on 7 May 2014 and planted on 14 May into 2-row x 20 ft-long plots (ca. 12 in. between plants to give a target population of 40 plants at 36 in. row spacing) replicated four times in a randomized complete block design. Treatment rows were separated by 5 ft-long blank plots. Fertilizer (220 units P_2O_5 + 10 units Zn + 5 units Mn + 110 units N) was drilled into plots before planting, formulated according to the results of soil tests. Additional nitrogen (10-34 at 40lbs/A) was applied to the growing crop with irrigation based on the results of petiole sampling which was carried out periodically during the growing season. Insecticide (Admire, 16.9 oz/A) was applied at hilling on 10 June. Weeds were controlled with herbicide (1.5 oz/A Matrix + 0.67 lb/A Sencor) which was applied post planting on 18 June. Emergence was first observed on 9 June and full emergence was observed on 23 June. Emergence was rated as the number of plants breaking the soil surface or fully emerged after planting. Applications were made at flowering (1 August), and then on a 14-day interval after that on 15 and 29 August with an ATV rear-mounted R&D spray boom calibrated to deliver 25 gal/A (40 p.s.i.) using two XR8003VS nozzles per row. Plots were inoculated with Pythium shortly before hilling with heavily Pythium infected seed pieces. Infected seed pieces were placed between rows at about 1 seed piece per 2 plants and were incorporated into the soil at hilling. To encourage disease, Pythium plots were always kept wetter than normal, almost waterlogged. Plots were further inoculated with Pythium on 25 July and 5 September as follows. Liquid cultures of the Pythium leak pathogen (*Pythium ultimum*) were grown in Potato Dextrose Broth for 7 days prior to inoculation. On the day of inoculation, plots were irrigated heavily for 8 hrs so that standing water was visible in the furrows and the soil was thoroughly waterlogged. Concurrently, the Pythium cultures were blended to break up mycelia and oospores. The suspension was passed through cheese cloth and collected in 4 L conical flasks. The concentration of oospores in the resulting suspension was counted using a hemacytometer and adjusted to ca. 1 x 10^4 oospores ml^{-1}. Each 4L flask of suspension was then added to a 3 gallon spray canister and adjusted to 3 gallons. One 3 gallon spray canister was then used to inoculated each treatment replicate (equivalent to 540ft per row) resulting in 12 gallons of inoculum being applied to all treatment plots. The inoculum was applied using the ATV rear mounted R&D spray boom after irrigation was completed in the late afternoon. Vines were killed with Reglone 2EC (1.0 pt/A on 12 September). Tubers were harvested on 10 October and graded from 20-22

October. At grading disease tubers were segregated and weighed. Samples of 25 healthy looking US No.1 6-10 oz. tubers/plot were also retained and placed in storage at 50 °F. On 2 December, these tubers were placed in onion sacks and inoculated with Pythium by immersion in a Pythium suspension at 72 °F. Tubers were left in the Pythium suspension for 24 h before being removed and placed in storage at 50°F. Tubers were incubated for 2 weeks and rated on 16 December for Pythium incidence and severity. Severity was calculated as the volume of diseased tissue per tuber which was estimated visually by cutting open the tuber.

PUBLICATIONS:

No publications have yet been submitted for this research work since it is in its first year.

PRESENTATIONS & REPORTS:

No presentations or reports have yet been submitted on this research

Annual Progress Report / Final Report
Annual reports due: January 15th (starting with January, 2015)
Final reports due: September 30th or earlier (often submitted Jan. 15th)

TITLE: Practical Eradication of Bacterial Ring Rot in the Pacific Northwest

PERSONNEL:
Phillip Wharton, Katie Fairchild, James Woodhall

REPORTING PERIOD: January 15th

ACCOMPLISHMENTS:

A greenhouse trial was established at Parma R&E Center at the end of June 2014 to study disease progress of Clavibacter michiganensis (CMS) in different potato cultivars over the growing season and to determine the earliest time that the bacteria can be detecting in non-symptomatic tissue. Potatoes of three different varieties (Umatilla and Ranger Russet, and Russett Burbank) were studied. The bacterium was not found in any of the tissue samples that were collected over the course of the study. Testing of original CMS cultures that were provided to us for the experiment showed that the cultures were not in fact CMS. In September, plant material from a USDA BRR trial at Kimberly R&E center was tested using the BRR qPCR primers. Stem, petiole and leaf samples from inoculated and non-inoculated plants were all tested separately. Results showed that the qPCR primers do work as CMS was detected in positive controls, and stem and petiole samples from inoculated plants, but not leaf samples (Fig 1). Only 50% of the plants tested that were positive for CMS showed visible symptoms of the disease. The overall levels of disease in this trial which was established using inoculated seed pieces was low. These two separate studies illustrate the difficulties in working with this slow growing bacterial pathogen. However, it also illustrates that the pathogen can be reliably detected in asymptomatic tissue using real-time PCR.

RESULTS:

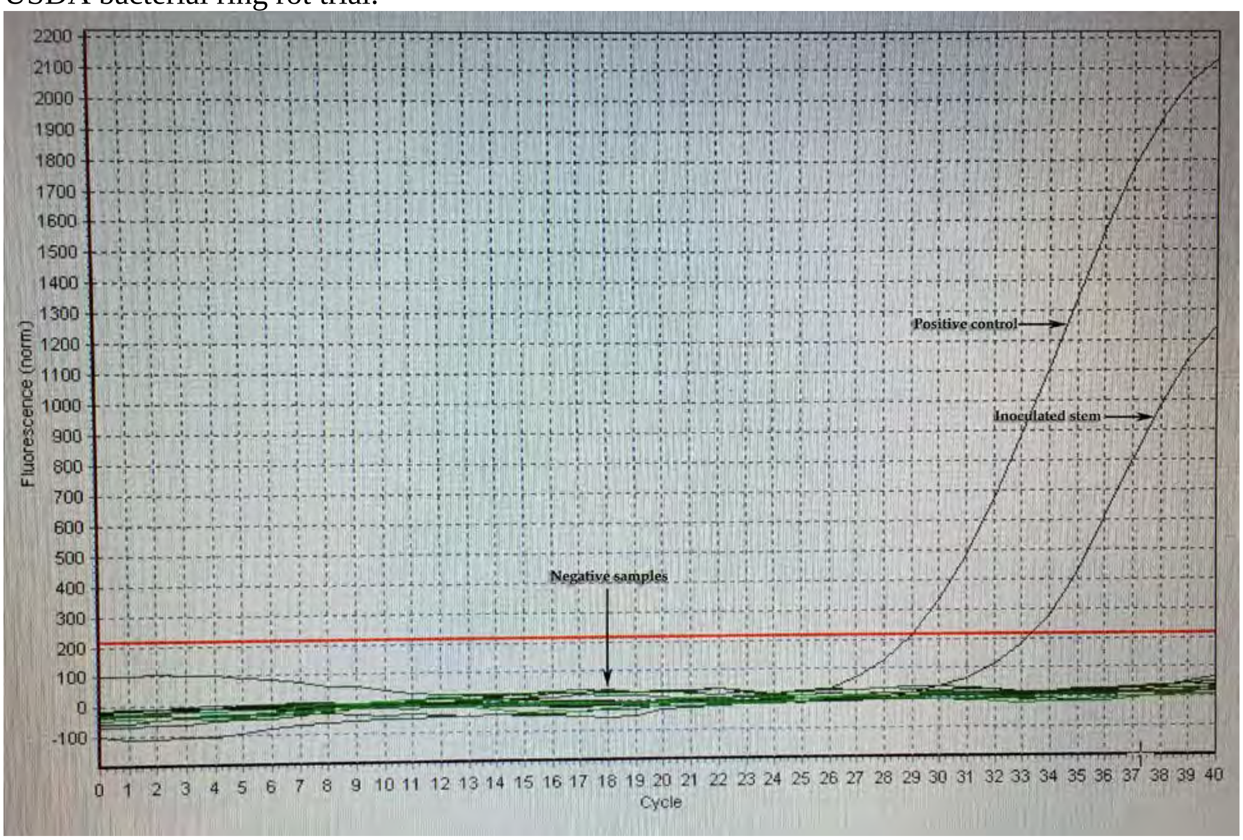
A greenhouse trial was established at Parma R&E Center at the end of June 2014. Potatoes of three different varieties (Umatilla and Ranger Russet, and Russett Burbank) were planted in June and inoculated with Clavibacter michiganensis. Plants were inoculated by injecting 0.5 ml of a bacterial suspension containing 1×10^6 bacteria /ml into the base of the stems after the plants had emerged. Plant samples were collected every two weeks, from two weeks after emergence until golf-ball sized tubers were formed (beginning of July until the first week of September). Three stems were collected per plant at each timing and the stems were separated into stem sections, petioles and leaves. DNA was extracted from stems, petioles and leaf samples and all were tested for the presence of the bacteria separately using real-time PCR. All PCR analysis was done at the same time in September after all the samples had been collected and processed.

Real-time PCR results showed that all plant samples were not infected with the bacterium. Further analysis of DNA from bacterial cultures that were used for inoculations revealed that the cultures were not Clavibacter michiganensis. However, positive controls run during all PCR reactions did show results indicating that the real time PCR primers that we developed were working. In September, the opportunity arose to test the primers against inoculated plants from a USDA trial being carried out at Kimberly R&E center. Stem, petiole and leaf samples from inoculated and non-inoculated plants were all tested separately. Results showed that the qPCR primers do work as CMS was detected in positive controls, and stem and petiole samples from inoculated plants, but not leaf samples (Fig 1). Only 50% of the plants tested that were positive for CMS showed visible symptoms of the disease.

PUBLICATIONS: None

PRESENTATIONS & REPORTS:
Idaho Association of Plant Protection annual meeting, Jerome, ID November 5th, 2014. Presentation: “Rapid detection of potato pathogens using real-time PCR and LAMP”.

Figure 1. Real-time PCR results from testing of inoculated and non-inoculated plants in the USDA bacterial ring rot trial.



TITLE: Long-Term Impacts of Manure Application on Production of Potato and Other Crops

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REPORTING PERIOD: 2014-2015

ACCOMPLISHMENTS:

In 2014, we completed our first season of potato production in this eight-year study. Our main accomplishment was the collection of a diverse and robust dataset from an Idaho potato production field receiving multiple dairy manure applications. We are confident that findings from the 2014 growing season will be useful for helping potato growers understand how potatoes respond to manure applications, and how to adjust their practices to determine the most ideal management method for this byproduct on their own operation. The unique information generated from this research will have a significant contribution to the scientific knowledge of interactions between dairy manure applications and potato production.

RESULTS:

Soil Salt Accumulations and Germination

Preplant soil salt accumulations was the most noticeable in plots receiving annual manure applications. Plots receiving 20, 40, and 60 ton manure/acre annually had electrical conductivity (aka EC or soluble salts) levels of 1.8, 2.9, and 3.5 dS/m, respectively (table 2). In comparison, plots receiving 20, 40, and 60 ton manure/acre biennially had EC levels of only 0.9, 1.0, and 1.3 dS/m, respectively (table 2). Potatoes are a salt sensitive crop, with EC threshold levels reported to be only 1.7 dS/m (Maas and Hoffman, 1977). This finding suggests that applying manure biennially instead of annually could be beneficial to salt sensitive crops like potatoes.

It should be mentioned that there is clear evidence that the soil salts are leaching down into the second foot soil depth, with soil EC levels increasing significantly with increasing manure application rate and frequency (table 3). This encouraging, illustrating that soil salt issues related to manure applications may be quickly remediated on a well-drained soil, especially if the grower can practice biennial manure application instead of annual.

Sodicity (salt issues related to sodium) does not yet appear to be an issue, with sodium adsorption ratios (SAR) remaining below the sodicity threshold of 13.0 at both the first and second foot soil depths (tables 2 and 3).

It should also be mentioned that germination rates for the 60 ton/acre annual treatment were significantly lower than the 20 ton/acre annual, 20 ton/acre biennial, and 40 ton/acre biennial manure application treatments at 24 and 27 days after planting (table 1). While the cause for this is not known, we suspect that the soil salt levels may be contributing to slow germination on the plots receiving heavy annual manure applications.

Table 1. Germination rates for Russet Burbank potatoes planted on April 29, 2014 on a Portneuf silt loam in Kimberly, Idaho.

Dairy manure rate (wet ton/acre)	**Frequency of Applications**	**Percent Germination**		
		5/23	**5/26**	**6/6**
Control	NA	4.3c	53.5bc	86.7abc
Fertilizer	NA	5.8bc	56.6abc	83.3c
20 ton/acre	Every other fall before grain*	8.1b	57ab	86.4bc
40 ton/acre		7.1bc	53.9bc	85.2bc
60 ton/acre		11.4a	62.7a	86.2bc
20 ton/acre	Every fall**	8.1b	63.3a	90.6a
40 ton/acre		5.4bc	53.9bc	88.1ab
60 ton/acre		4.6c	49.4c	85.8bc
	p-value	0.0033	0.0153	0.0505

*One manure application in Fall 2012.

**Manure applications in Fall 2012 and Fall 2013.

Soil Nutrients

Increasing accumulations of total nitrogen, nitrate, phosphorus, potassium, sulfate, boron, copper, manganese, and zinc with increasing manure rate and/or frequency were significant on 2014 preplant soil analysis at the 0-12 inch depth (tables 2 and 4). Accumulations of these nutrients offer opportunities for potato growers to rely on manure applications as a nutrient source for their potato crop. However, continued trends of accumulation for nitrate, phosphorus, potassium on the 40 and 60 ton/acre annual applications could become issues in terms of nitrate leaching, phosphate runoff, and milk fever (caused by over-consumption of potassium-rich plants).

Decreasing accumulations iron with increasing manure rate and/or frequency were significant on 2014 preplant soil analysis at the 0-12 inch depth (table 4). The cause for this decrease in iron concentration is not yet known. Soil pH also decreased significantly with increasing manure applications. Soil acidification of our alkaline soils with manure applications can help to increase the availability of phosphorus and micronutrient availability to plants.

2014 preplant soil tests also showed a lack of a significant difference in soil nitrate concentrations in the second foot soil depth, regardless of manure application rate or frequency of applications up to 60 ton manure/acre (table 3). This finding is encouraging, suggesting that the preceding wheat crop (and possibly the following volunteer wheat crop) was able to take up enough N from the manure applications to mitigate negative nitrate leaching effects. This finding differed from the neighboring barley crop that received similar manure and N fertilizer applications, where soil test nitrate levels did increase significantly at the second foot soil depth for the annual 60 ton manure/acre application treatment (26 ppm nitrate compared to 3-11 ppm nitrate for all other treatments). These results suggest that wheat may be a more favorable crop for mitigating nitrate leaching issues related to heavy manure in comparison to barley.

Potassium and sulfate both leached into the second foot soil depth (table 3). Both potassium and sulfate are highly mobile nutrients and susceptible to leaching. In contrast to nitrate, potassium and sulfate concentrations were in excess of what could be used by the wheat or potato crops, and therefore susceptible to leaching. Neither potassium or sulfate are considered to be major pollutants, and are therefore not regulated in leachate in the way that nitrates are regulated.

Table 2. Preplant soil nutrient and chemical characteristics of a Portneuf silt loam in Kimberly, Idaho receiving various rates and frequencies of dairy manure applications. Soils were sampled on March 18th, 2014 to a depth of 0-12 inches.

Dairy manure rate (wet ton/acre)	Frequency of Applications	Total N (ppm)	% o.m.	Nitrate-N (ppm)	Ammonium-N (ppm)	Olsen P (ppm)	Olsen K (ppm)	Sulfate-S (ppm)	EC (dS/m)	pH	B (ppm)	SAR (Sodium Adsorption Ratio)
Control	NA	990cde	1.42cd	8.9d	3.4a	11.9d	122e	9.3e	0.8e	7.80ab	0.47d	1.0e
Fertilizer	NA	910e	1.40d	7.9d	3.1ab	12.7d	127e	8.6e	0.7e	7.85a	0.47d	1.0e
20 ton/acre	Every other fall before grain*	1,060bcd	1.45bcd	10.4cd	2.5abc	14.7cd	175e	10e	0.9de	7.70bc	0.51d	1.1d
40 ton/acre		930de	1.65bc	14.0bcd	1.8c	24.7b	320d	11de	1.0de	7.82a	0.67bc	1.2d
60 ton/acre		1,100abc	1.67b	17.5b	1.5c	28.2b	442c	16cd	1.3d	7.80ab	0.66c	1.6c
20 ton/acre	Every fall**	1,050cd	1.62bcd	15.6bc	2.2bc	22.2bc	305d	22c	1.8c	7.70bc	0.60cd	1.6c
40 ton/acre		1,200ab	1.95a	28.7a	2.5abc	39.5a	557b	31b	2.9b	7.65c	0.80ab	2.2b
60 ton/acre		1,220a	1.97a	31.7a	2.0c	45.5a	727a	39a	3.5a	7.65c	0.88a	2.5a
	p-value	0.0008	0.0001	<0.0001	0.0122	<0.0001	<0.0001	<0.0001	<0.0001	0.0080	<0.0001	<0.0001

*One manure application in Fall 2012.

**Manure applications in Fall 2012 and Fall 2013.

Table 3. Preplant soil nutrient and chemical characteristics of a Portneuf silt loam in Kimberly, Idaho receiving various rates and frequencies of dairy manure applications. Soils were sampled on March 18th, 2014 to a depth of 12-24 inches.

Dairy manure rate (wet ton/acre)	**Frequency of Applications**	**Total N (ppm)**	**% o.m.**	**Nitrate-N (ppm)**	**Ammonium-N (ppm)**	**Olsen P (ppm)**	**Olsen K (ppm)**	**Sulfate-S (ppm)**	**EC (dS/m)**	**pH**	**B (ppm)**	**SAR (Sodium Adsorption Ratio)**
Control	NA	550	0.82	4.9	2.2abc	2.2	99b	17b	0.8b	7.82ab	0.37	0.88c
Fertilizer	NA	700	0.93	5.1	2.4ab	3.4	111b	16b	0.8b	7.85a	0.38	0.89bc
20 ton/acre	Every other fall before grain*	610	0.83	11.9	2.2abc	2.3	100b	28a	1.4a	7.75abc	0.37	1.10ab
40 ton/acre		630	0.84	6.7	2.0bc	3.7	107b	28a	1.5a	7.70bc	0.38	1.15a
60 ton/acre		640	0.84	9.3	1.9c	4.5	125ab	28a	1.8a	7.70bc	0.37	1.24a
20 ton/acre	Every fall**	640	0.83	5.6	2.6a	3.2	104b	28a	1.4a	7.67c	0.31	1.06abc
40 ton/acre		590	0.88	7.1	2.0bc	5.5	125ab	30a	1.8a	7.65c	0.39	1.15a
60 ton/acre		730	0.94	8.3	1.8c	6.0	140a	30a	1.8a	7.62c	0.44	1.27a
	p-value	0.3531	0.6959	0.5751	0.0333	0.1805	0.0319	0.0376	0.0027	0.0151	0.3295	0.0079

*One manure application in Fall 2012.

**Manure applications in Fall 2012 and Fall 2013.

Table 4. Preplant soil nutrient and chemical characteristics of a Portneuf silt loam in Kimberly, Idaho receiving various rates and frequencies of dairy manure applications. Soils were sampled on March 18th, 2014 to a depth of 0-12 inches.

Dairy manure rate (wet ton/acre)	**Frequency of Applications**	**Lime%**	**Cu (ppm)**	**Fe (ppm)**	**Mn (ppm)**	**Zn (ppm)**	**Ext Ca (meq/100g)**	**Ext Mg (meq/100g)**	**Ext Na (meq/100g)**	**Cd (ppm)**	**Ext Cl (meq/100g)**
Control	NA	4.9	1.01b	10.7a	4.9c	3.0c	28.2a	4.7b	0.18c	0.16abc	14d
Fertilizer	NA	5.0	1.03b	9.6bc	4.8c	2.9c	27.5ab	4.7b	0.21c	0.16abc	18d
20 ton/acre	Every other fall before grain*	5.1	1.02b	9.2bc	5.6c	2.9c	27.2abc	4.7b	0.30bc	0.16bc	22d
40 ton/acre		4.6	1.00b	9.1bc	6.0bc	3.1c	26.5bcd	4.8b	0.32bc	0.15c	23d
60 ton/acre		5.1	1.06ab	10.0ab	6.3bc	3.2bc	26.2cd	4.7b	0.39b	0.15c	33d
20 ton/acre	Every fall**	4.9	1.07ab	9.6bc	8.0ab	3.0c	27.5ab	4.8ab	0.37b	0.16ab	113c
40 ton/acre		4.6	1.15a	8.8c	9.6a	3.5ab	26.7bcd	5.0a	0.65a	0.17a	200b
60 ton/acre		4.9	1.12a	8.9c	8.4a	3.8a	26.0d	4.9ab	0.71a	0.17ab	242a
	p-value	0.9289	0.0125	0.0269	0.0001	0.0004	0.0122	<0.0001	<0.0001	0.0303	<0.0001

*One manure application in Fall 2012.

**Manure applications in Fall 2012 and Fall 2013.

Table 5. Preplant soil nutrient and chemical characteristics of a Portneuf silt loam in Kimberly, Idaho receiving various rates and frequencies of dairy manure applications. Soils were sampled on March 18th, 2014 to a depth of 12-24 inches.

Dairy manure rate (wet ton/acre)	**Frequency of Applications**	**Lime%**	**Cu (ppm)**	**Fe (ppm)**	**Mn (ppm)**	**Zn (ppm)**	**Ext Ca (meq/100g)**	**Ext Mg (meq/100g)**	**Ext Na (meq/100g)**	**Cd (ppm)**	**Ext Cl (meq/100g)**
Control	NA	6.2	1.2	9.1	3.0	0.6	28.2	4.7	0.23	0.00	27c
Fertilizer	NA	4.5	1.2	10.6	3.6	1.0	27.2	4.6	0.21	0.06	25c
20 ton/acre	Every other fall before grain*	7.1	1.2	8.5	3.0	0.6	28.5	4.4	0.33	0.02	69bc
40 ton/acre		7.3	1.1	8.4	3.0	0.7	27.7	4.5	0.32	0.02	85ab
60 ton/acre		7.6	1.3	9.0	3.1	0.7	27.2	4.6	0.31	0.03	132a
20 ton/acre	Every fall**	4.7	1.2	9.4	3.6	0.6	28.2	4.5	0.25	0.05	92ab
40 ton/acre		8.4	1.1	8.9	3.4	0.7	28.0	4.5	0.26	0.05	127a
60 ton/acre		4.5	1.2	8.9	3.6	1.0	27.2	4.6	0.33	0.08	130a
	p-value	0.7615	0.6258	0.0708	0.3331	0.6327	0.9256	0.9354	0.3360	0.3825	0.0004

*One manure application in Fall 2012.

**Manure applications in Fall 2012 and Fall 2013.

Soil Health

Soil organic matter is a major contributor to soil health, with benefits including improved soil moisture retention, improved infiltration, increased microbial and biological activity, and improved soil structure. Soil organic matter in the first foot increased significantly from 1.4% (fertilizer-only treatment) to 1.7% for biennial applications at 40 and 60 ton manure/acre, and increased to 2.0% for annual applications at 40 and 60 ton manure/acre (table 2). It is encouraging to see that soil organic matter levels remained elevated in biennial treatments, suggesting that soil organic matter levels can still be increased when applying manure only before the grain crop in a grain-potato-grain-sugar beet rotation.

Improved soil moisture retention is also an important quality of soil health. Soil moisture content information was collected from select treatments by April Leytem's program over the 2014 growing season (Figure 1). While the soil moisture information has not yet been statistically analyzed, it appears that the heaviest manure treatment (green line) had consistently greater soil moisture retention than the other treatments from mid-May to early July. However, this trend appears to reverse in late August and early September, with the heaviest manure plots appearing to have the least moisture. One cause for this may be the fact that the heavy manure plots had the most evidence of continued growth later in the season compared to the other treatments, therefore the plants were likely taking up more water than plants in other plots. We noticed a similar soil moisture trend in 2013, with volunteer wheat on heavily manure plots taking up more soil moisture than on other plots in late August and September.

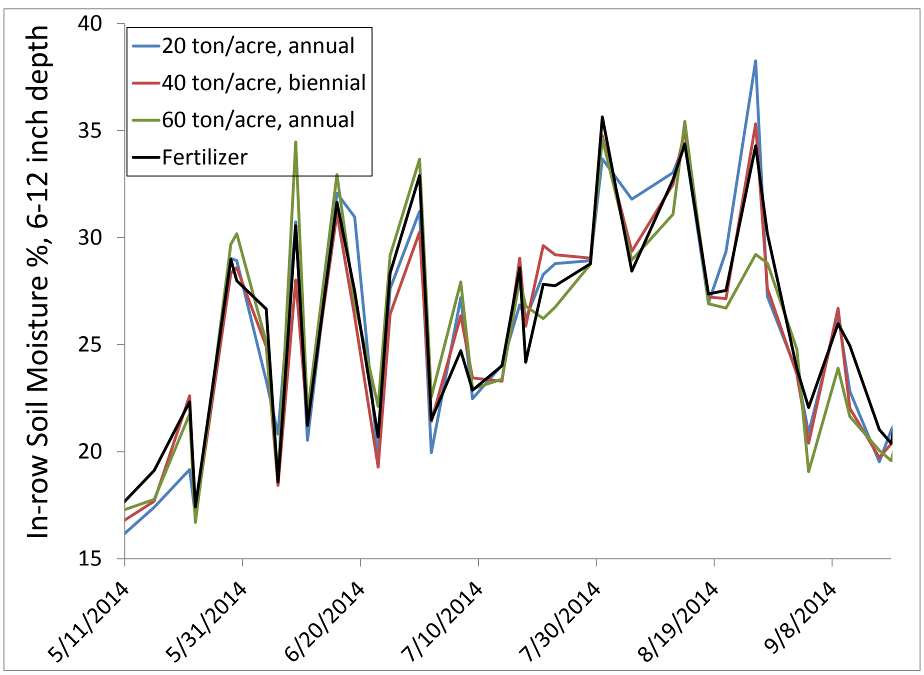

Figure 1. In-row soil moisture content in a potato production field in Kimberly, Idaho, receiving fertilizer or dairy manure applications at various application rates and frequencies. Application rates are on a wet ton/acre basis.

Decreases in soil pH can also improve the health of an alkaline soil. Soil pH decreases significantly with increasing manure rate and frequency at both the first and second foot soil depths (tables 2 and 3). Soil acidification could be a major benefit of manure applications, and needs to be investigated further.

Petiole Nutrients

Petiole nutrient concentrations were followed during tuber set, bulking, and maturation periods for specific petiole nutrients (figures 2-12). While we have not statistically analyzed petiole nutrient concentrations at this time, there does appear to several interesting trends. For example, petiole nitrate levels tend to be lower for annual applications than biennial during tuber set and bulking (figure 2). One cause for this may interactions between soil nitrates and chlorides, as chlorides have been attributed to reduce nitrate uptake in plants. In contrast, petiole nitrate levels at tuber maturation more closely reflected mid-June soil nitrate test concentrations (data not shown). This may be illustrating that salts have leached out the system, allowing plants to take up more nitrates.

Other trends worth mentioning include potential luxury consumption of P with increase manure P soil concentrations, possible cation competition between K (over-consumption) and Mg and Ca (under-consumption), and reduced uptake of S, B, Fe, and Cu with increasing manure application rate and frequency (figures 3-12). It should also be mentioned that, in most cases, petiole nutrient levels rarely decreased below sufficiency levels recommended by the University of Idaho.

Petiole nutrient results will be further studied along with total nutrient uptake results collected in potato plant tubers and tops prior to senescence (nutrient uptake data not shown).

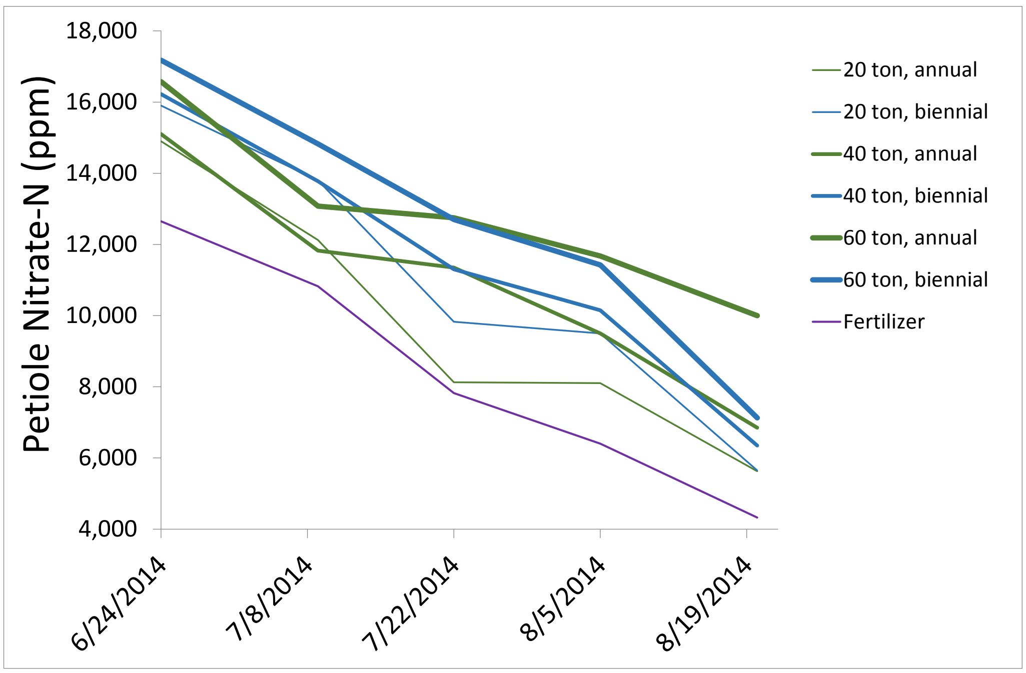

Figure 2. Petiole nitrate-N for Russet Burbank potatoes planted on a Portneuf silt loam in Kimberly, Idaho, receiving fertilizer or dairy manure applications at various application rates and frequencies. As a reference, the University of Idaho recommends that petiole concentrations are sufficient above 20,000 ppm nitrate-N during tuber bulking.

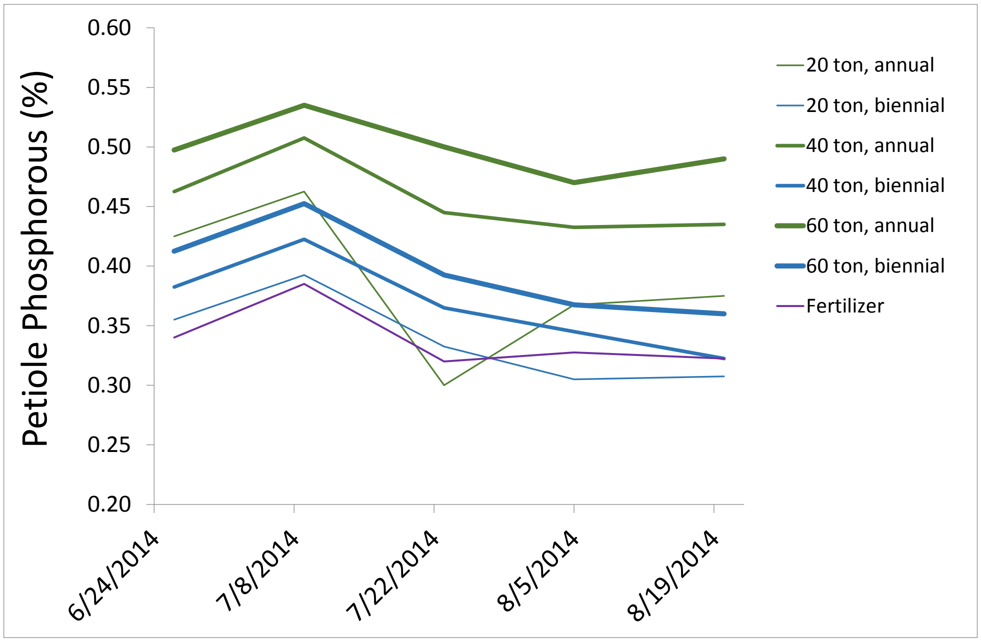

Figure 3. Petiole phosphorus (P) for Russet Burbank potatoes planted on a Portneuf silt loam in Kimberly, Idaho, receiving fertilizer or dairy manure applications at various application rates and frequencies. As a reference, the University of Idaho recommends that petiole concentrations are sufficient above 0.22 % P during tuber bulking.

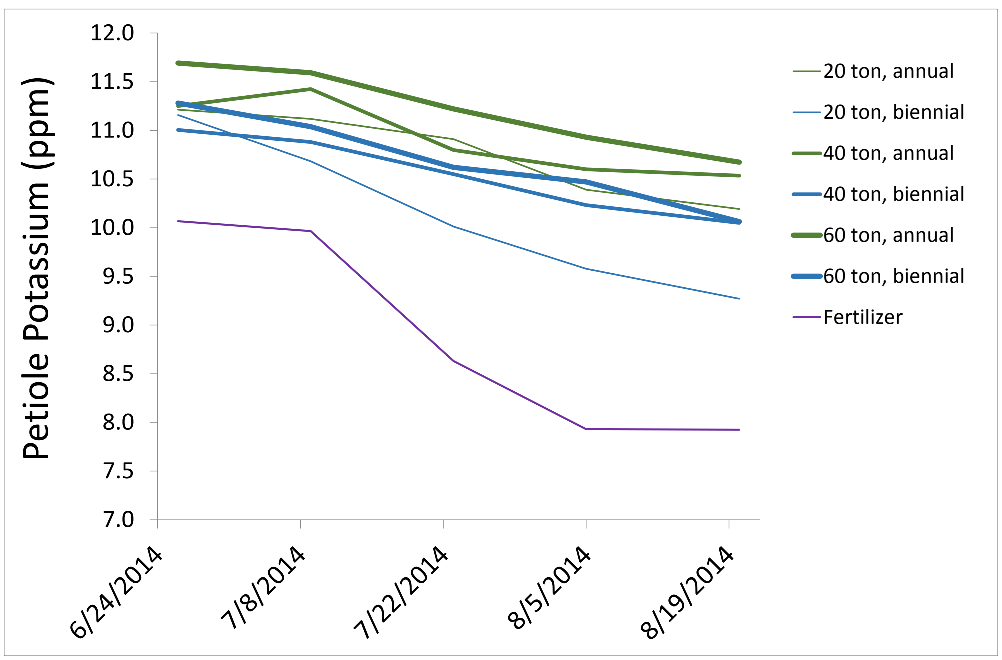

Figure 4. Petiole potassium (K) for Russet Burbank potatoes planted on a Portneuf silt loam in Kimberly, Idaho, receiving fertilizer or dairy manure applications at various application rates and frequencies. As a reference, the University of Idaho recommends that petiole concentrations are sufficient above 8% K during tuber bulking.

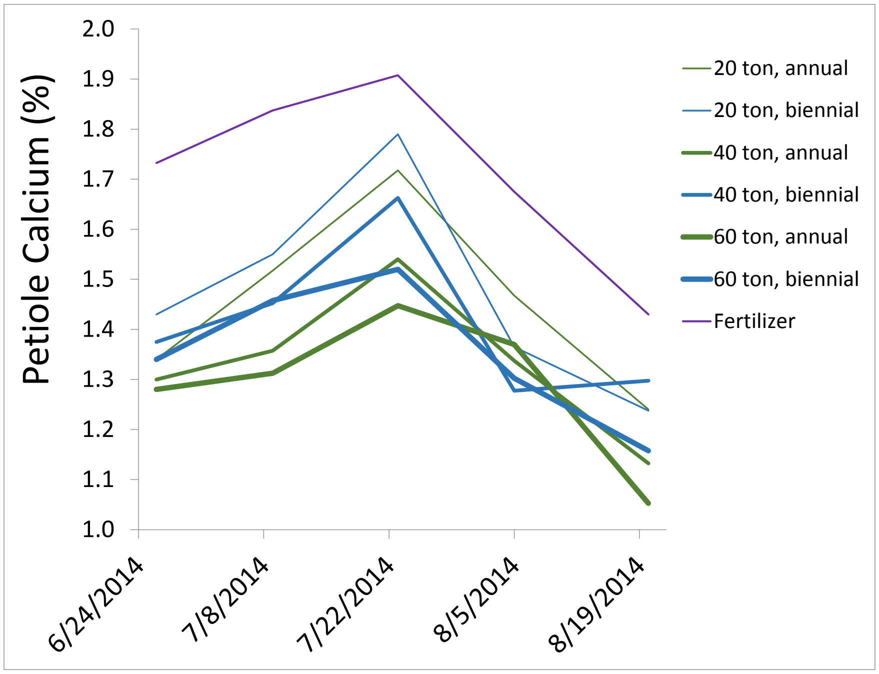

Figure 5. Petiole calcium (Ca) for Russet Burbank potatoes planted on a Portneuf silt loam in Kimberly, Idaho, receiving fertilizer or dairy manure applications at various application rates and frequencies. As a reference, the University of Idaho recommends that petiole concentrations are sufficient above 0.6% Ca during tuber bulking.

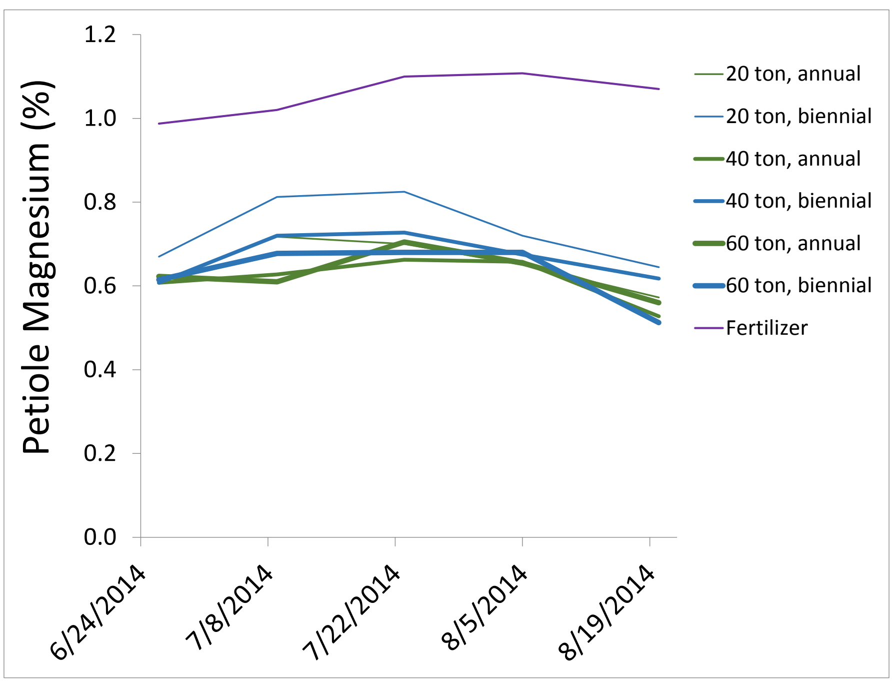

Figure 6. Petiole magnesium (Mg) for Russet Burbank potatoes planted on a Portneuf silt loam in Kimberly, Idaho, receiving fertilizer or dairy manure applications at various application rates and frequencies. As a reference, the University of Idaho recommends that petiole concentrations are sufficient above 0.3% Mg during tuber bulking.

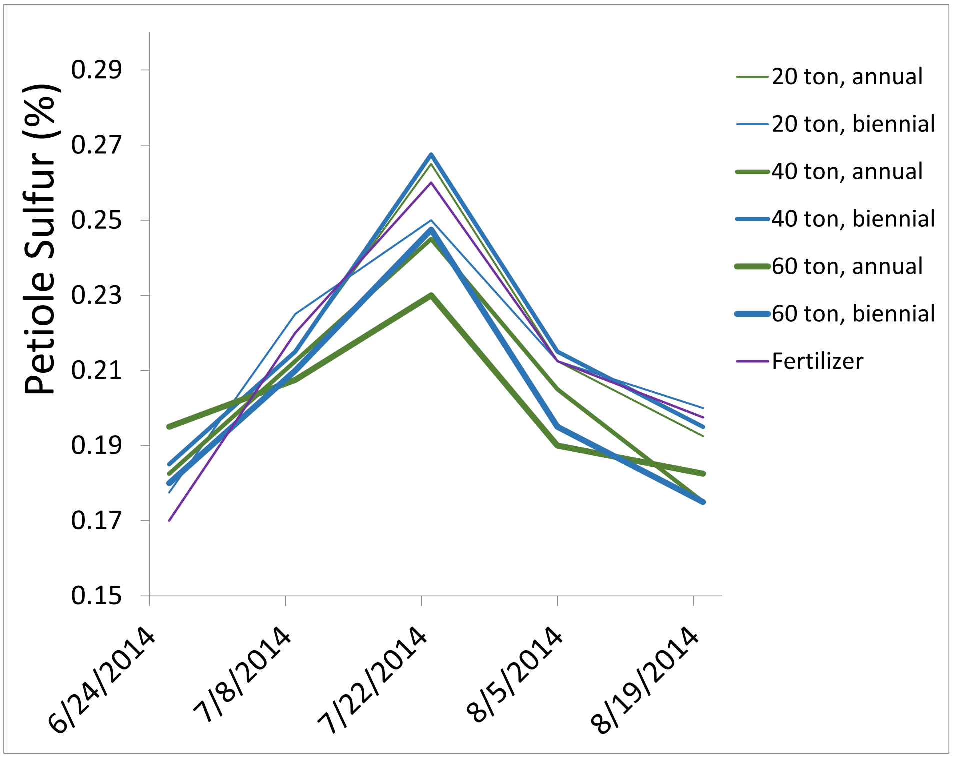

Figure 7. Petiole sulfur (S) for Russet Burbank potatoes planted on a Portneuf silt loam in Kimberly, Idaho, receiving fertilizer or dairy manure applications at various application rates and frequencies. As a reference, the University of Idaho recommends that petiole concentrations are sufficient above 0.20 % sulfur during tuber bulking.

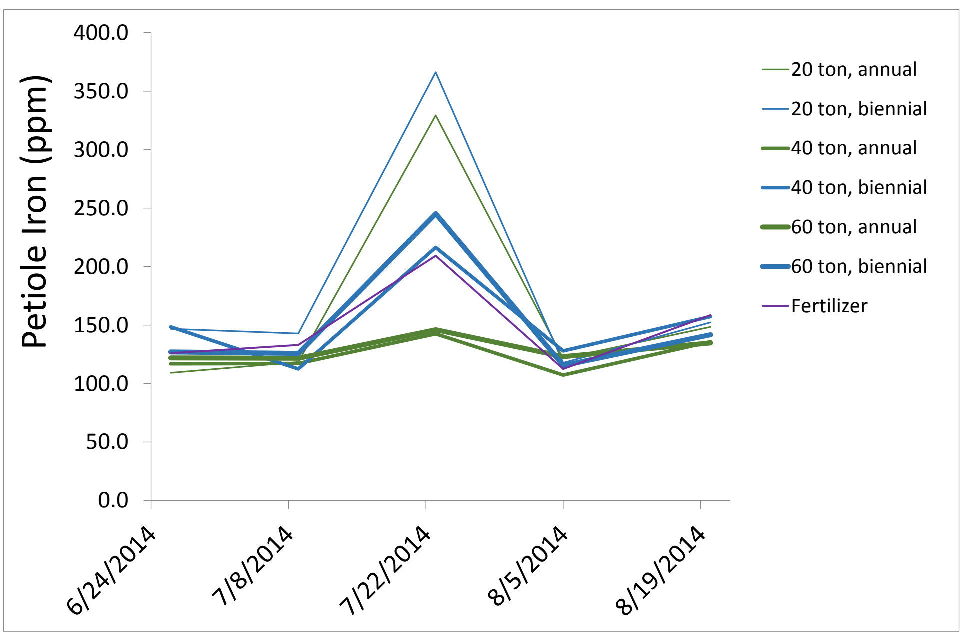

Figure 8. Petiole iron (Fe) for Russet Burbank potatoes planted on a Portneuf silt loam in Kimberly, Idaho, receiving fertilizer or dairy manure applications at various application rates and frequencies. As a reference, the University of Idaho recommends that petiole concentrations are sufficient above 50 ppm Fe during tuber bulking.

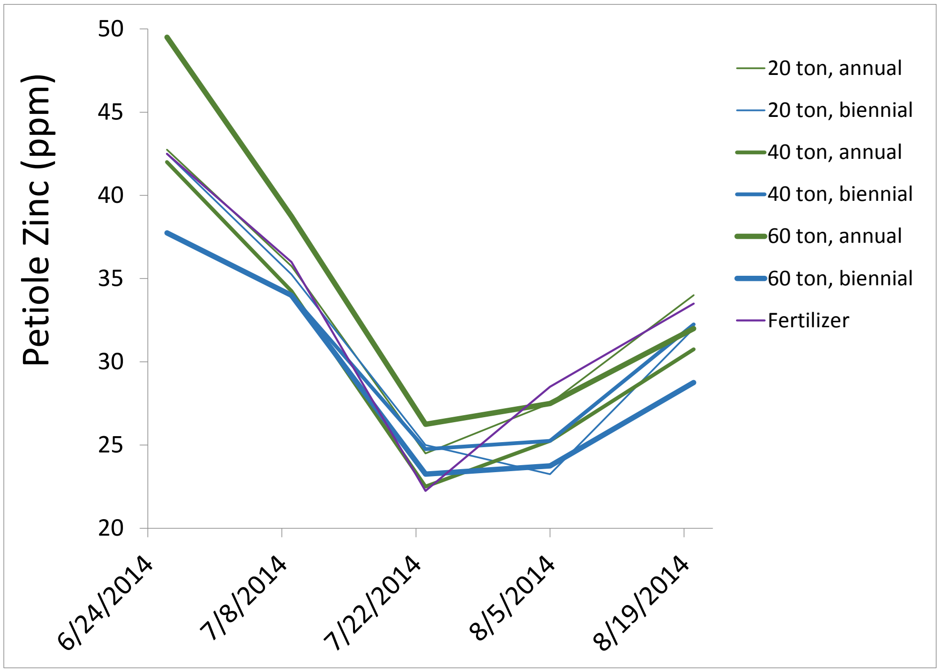

Figure 9. Petiole zinc (Zn) for Russet Burbank potatoes planted on a Portneuf silt loam in Kimberly, Idaho, receiving fertilizer or dairy manure applications at various application rates and frequencies. As a reference, the University of Idaho recommends that petiole concentrations are sufficient above 25 ppm Zn during tuber bulking.

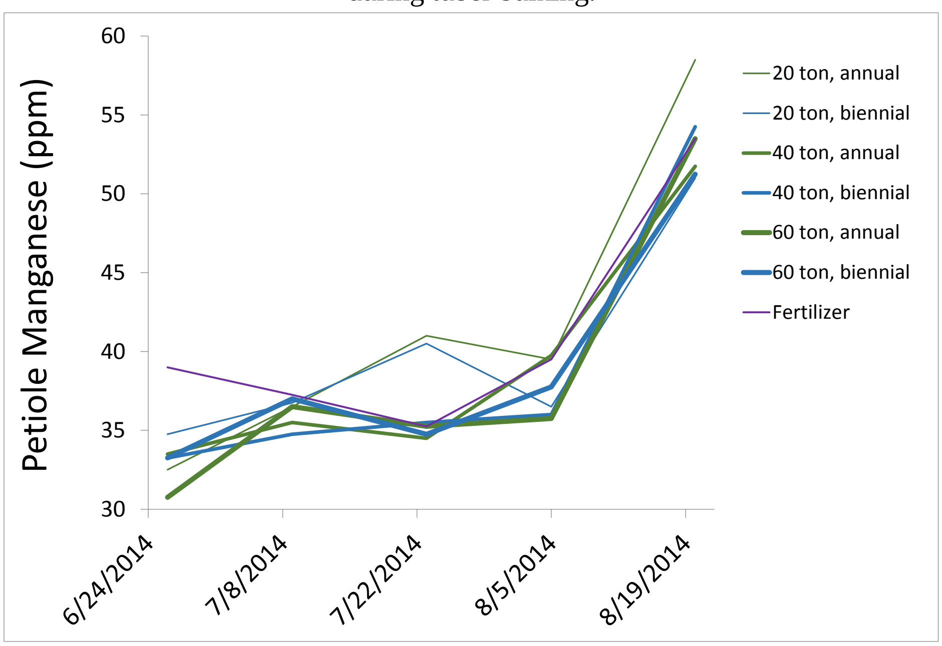

Figure 10. Petiole manganese (Mn) for Russet Burbank potatoes planted on a Portneuf silt loam in Kimberly, Idaho, receiving fertilizer or dairy manure applications at various application rates and frequencies. As a reference, the University of Idaho recommends that petiole concentrations are sufficient above 40 ppm Mn during tuber bulking.

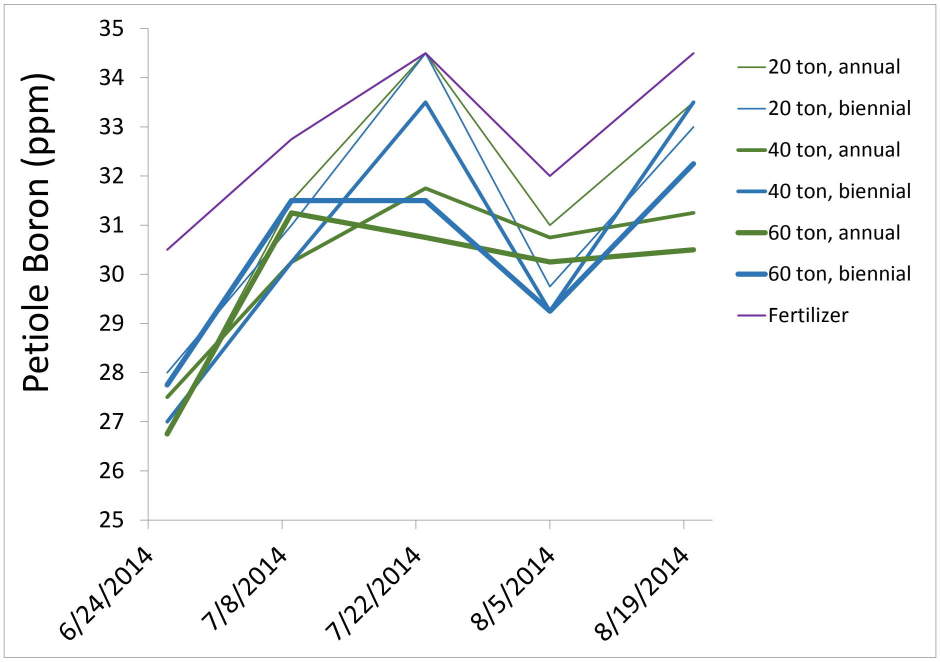

Figure 11. Petiole boron (B) for Russet Burbank potatoes planted on a Portneuf silt loam in Kimberly, Idaho, receiving fertilizer or dairy manure applications at various application rates and frequencies. As a reference, the University of Idaho recommends that petiole concentrations are sufficient above 20 ppm B during tuber bulking.

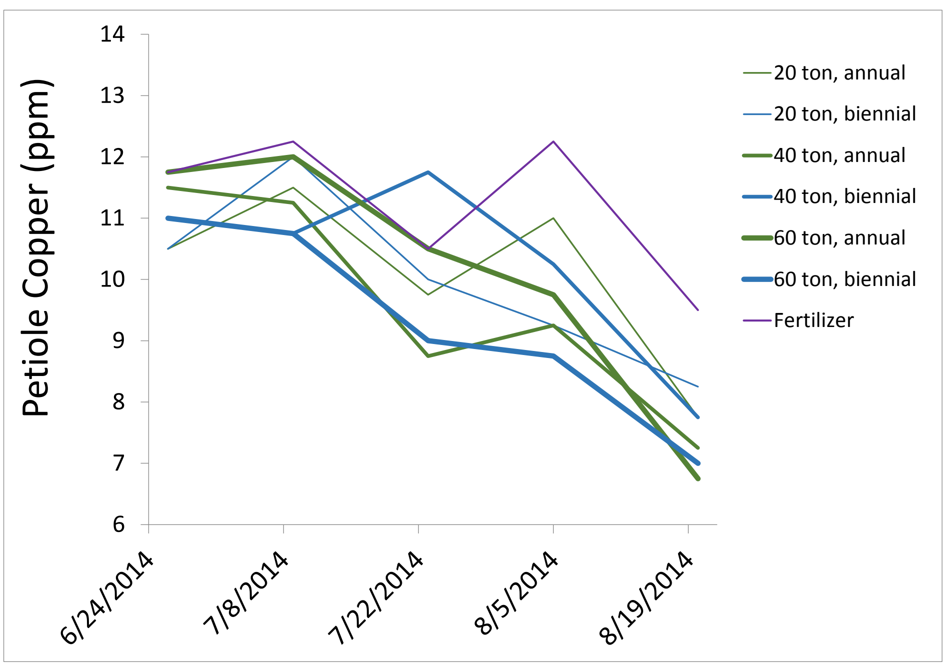

Figure 12. Petiole copper (Cu) for Russet Burbank potatoes planted on a Portneuf silt loam in Kimberly, Idaho, receiving fertilizer or dairy manure applications at various application rates and frequencies. As a reference, the University of Idaho recommends that petiole concentrations are sufficient above 4 ppm Cu during tuber bulking.

Potato Yield

Potato yields and quality were significantly impacted by manure application treatments (table 6). Annual applications of 60 ton manure/acre significantly decreased tuber yields to 452 cwt/acre in comparison to biennial applications of 60 ton manure/acre (527 cwt/acre) and annual applications of 20 ton manure/acre (521 cwt/acre). It appears that yield gains for biennial manure treatments were cause by a larger proportion of very large potatoes (>12 oz.) (see table 6). We also observed that manure treated plots still had some green foliage at harvest, while fertilizer treatments were yellow from natural defoliation, suggesting that the manure treated potatoes continued to bulk, assuming that tuber bulking was not hindered by high salt levels.

We speculate that the tuber yield loss in the highest annual manure plots is related to salinity issues. Electrical conductivity (EC or soluble salt) levels in the high manure plots reached 3.5 dS/m, which would like compromise potato plant growth.

Potato Quality

Potato quality was evaluated by Nora Olsen's program. Specific gravity also decreased significantly with increasing manure applications, with the most notable decrease occurring in the annual manure applications (table 6). Specific gravity is known to decrease at high soil test potassium (K) levels, due to osmotic effects related to increased potassium levels in the tuber. Soil test (Olsen) K levels reached 727 ppm in the heavy manure plots, compared to 127 ppm in the fertilizer plots. A link between K, manure rates, and specific gravity is likely. These results indicate the risk in diminished quality for process potatoes when manure is applied annually and at higher biennial rates. There was no significant difference in bud end fry color, but the control had significantly darker stem end and a higher percentage of sugar ends. The 40 and 60 ton/acre annual treatments also showed darker stem end fry color. This may indicate the higher rates of annual manure may impact processing quality. Additional management for specific gravity would need to be incorporated into programs that include manure applications.

Table 6. Impact of fall dairy manure applications on Russet Burbank potatoes grown in Kimberly, Idaho in 2014, following a spring hard red wheat crop.

Dairy manure rate (wet ton/acre)	**Frequency of Applications**	**Total Yield (cwt/acre)**	**US No. 1 (cwt/acre)**	**US No. 2 (cwt/acre)**	**Rot cwt/acre**	**< 4 oz cwt/acre**	**4-6 oz cwt/acre**	**6-12 oz cwt/acre**	**>12 oz cwt/acre**	**% Fresh Weight Glucose**	**% Fresh Weight Sucrose**	**Specific Gravity**
Control	NA	378c	318d	51c	9	45	70	184	79d	0.148a	0.148	1.0817a
Fertilizer	NA	514ab	417ab	92ab	5	49	74	223	167abc	0.058b	0.120	1.0815a
20 ton/acre	Every other fall before grain*	493ab	415ab	75bc	3	42	62	202	186ab	0.050b	0.120	1.0790ab
40 ton/acre		511ab	407ab	97ab	7	43	66	209	192ab	0.048b	0.118	1.0757bcd
60 ton/acre		527a	430ab	93ab	4	48	70	208	201a	0.040b	0.115	1.0775bc
20 ton/acre	Every fall**	521a	437a	82ab	2	49	72	228	171abc	0.045b	0.130	1.0742cd
40 ton/acre		491ab	378bc	104ab	9	56	72	210	152c	0.068b	0.128	1.0732d
60 ton/acre		452b	337cd	110a	5	54	68	199	131c	0.060b	0.130	1.0670e
	p-value	0.0009	0.0012	0.0151	0.2239	0.0908	0.6933	0.3774	0.0001	<0.0001	0.1102	<0.0001

*One manure application in Fall 2012.

**Manure applications in Fall 2012 and Fall 2013.

Pest Pressure

Manure treatments did have a significant effect on rhizoctonia severity rating taken by Phill Wharton's program on July 17th, 2014. The 60 ton/acre annual manure treatment had the lowest rhizoctonia in-season visual rating (26.0), and was significantly lower than the control (59.1), 40 ton/acre annual (58.9), 20 ton/acre biennial (56.4), 60 ton /acre biennial (55.7), and fertilizer (49.2). Preplant soil, in-season soil, in-season stems, and at-harvest tubers are currently being analyzed by Phill Wharton's program for black dot and rhizoctonia diseases using real-time PCR.

Intensive manure applications also had a suppressive effect on early season lambsquarter populations. Lambsquarter populations on May 18th, 2014 were only 0.06 plants per square foot on the 60 ton/acre annual manure treatment, which was significantly smaller than the control (3.0 plants per square foot) and the 20 ton/acre biennial treatment (1.7 plants per square foot). The heavy manure treatment lambsquarter population mean was smaller than all other treatments, but statistically similar to fertilizer and the remaining manure treatments. Manure applications had no significant effect on the other weeds that were present (kochia, hairy nightshade, volunteer dry beans, volunteer wheat, green foxtail, or Russian thistle).

Manure treatments had no significant effect on nematode populations that were evaluated by Saad Hafez's program (Root Lesion, Spiral, Pin, Northern Root Knot, Columbia Root Knot, and Stem). Treatments also had no significant effect on wireworm scarring incidence, per evaluation under Erik Wenninger's program.

PROJECTIONS:

Results from these studies will allow us to develop clear recommendations for Idaho potato growers on how to get the most out of their manure application without compromising crop production or soil quality.

PUBLICATIONS

Three articles have been published in the Magic Valley Times News in 2014, with one article specifically focused on cereal grower response to our 2013 findings. One abstract was published in the 2014 ASA-SSSA-CSA proceedings, entitled "Should dairy manure be applied to high value crops?".

PROGRESS REPORT 2013-2014
TITLE: Use of Molecular Markers to Accelerate Breeding of Resistance to Columbia Root-Knot Nematode

YEAR INITIATED: 2013-2014. **CURRENT YEAR:** 2014-2015. **TERMINATING YEAR 2015-2016**.

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REPORTING PERIOD 2014-2015

ACCOMPLISHMENTS:

1. Determination that the difficulty of selecting commercially viable root-knot nematode clones is due the low frequency of good tuber type in general.
2. Demonstration of feasibility of early selection simultaneously for good tuber type, yield, and double resistance in the first seedling year.
3. Identification of six doubly resistant parents that have been converted to coupling phase from repulsion phase. Estimation of linkage distance between the R_{Mc1} and $Ry_{.}$ of four centimorgans (i.e.4 % recombination). This is the first time that the linkage and chromosome configuration has been determined for two resistance genes introduced from exotic sources, in a tetraploid potato.
4. Examination of seedling population of 231 individual clones in a nematode infested field for selectibility in reference to molecular marker genotype. Determination that there is no statistically significant difference between doubly resistant and doubly susceptible clones.

Introduction:

The Columbia Root-Knot Nematode is a major pest in the Pacific Northwest. It is more serious in the State of Washington but has a presence in all the Western States other than Montana. Fumigation has been used successfully for decades, but the increasing regulation and probable ban of certain fumigants make the search for non-chemical control more urgent. Host resistance research has yielded a good option, a resistance controlled by a single gene derived from a Mexican wild species. It has been discovered that this gene and a gene encoding PVY resistance are associated with poor tuber type and appearance and reduced frequency of russeted skin. In Washington about 60 % of the fields are infested with CRKN. The dependence on fumigation at the present time argues strongly for the concerted effort to select a commercially viable long russet processing variety. The purpose of this proposal is to examine several schemes to select parents that are highly improved in their capacity to confer resistance combined with good horticultural traits to sexual progeny by determining their molecular marker composition early in the selection process. The main innovation is to carefully preselect the families on the basis of tuber type and plant them in the field with multiple tubers of each seedling. Selection will be accompanied by early determination of molecular marker status of R_{Mc1} and Ry_{adg} resistance genes. If successful this will provide the key components for the selection of commercially viable cultivars with Columbia Root-Knot Nematode resistance.

RESULTS

Figure 1 provides a review diagram of the origin of the materials that we are working with. Initially, the only goal of the breeding program was to incorporate root knot nematode resistance into a new variety. With emergence of a more serious presence of Corky Ringspot after the decline of usage of Temik, we identified sources of resistance and produced breeding lines with combined resistance. It became apparent more than a decade ago that it would be impossible to breed without resistance to Potato Virus Y. Breeding lines became infected at an alarming rate, decimating the best selections. With the incorporation of the Ry_{adg} gene, this has ceased to be an issue, and also allows us to select from the beginning in Prosser, in a nematode infested field.

In Table 1 the mean selectibility for a sample of the field grown seedlings from 2014 growing are shown. They assorted in ascending order within the doubly susceptible and resistant groups. Each seedling is represented by three replications with two plants in each replication. This a deviation from the standard practice of selecting among seedlings where the seedling is only one plant. The overall mean of selectibility is virtually identical and not statistically different between the two groups. We think this shows that we have been able through early selection to break the linkage between resistance and poor selectibility. However, early examination of seedlings reveals that an overriding problem is that the frequency of superior tuber type is too low regardless of consideration of resistance. This means that we must pre-select tuber families with an eye to long shape and russet skin and discard families that do not present a high frequency of this combination. This is graphically depicted in in Figure 2, which shows the sorted arrangement of double resistant and doubly susceptible. Inside the rectangle on this figure we see that in the first field grow-out we are selecting for resistance and tuber type.

One of the most important goals of this project was to examine the genetic behavior of the two resistance genes introduced from exotic sources. In mapping studies it was determined that both genes mapped to the upper arm of chromosome 11. Although these genes have never before been together in any potato plant our breeding efforts placed them together. At first the two genes would have been located on different chromosomes. This would have meant that combined resistance would occur in about one quarter of the progenies in a cross from this so-called repulsion phase. However, in future generations we have selected a high frequency of coupling phase individuals that show a high frequency of combined or double resistance progeny. This frequency is close to one-half of the progenies. From the frequency of recombinants (i.e. the progenies that differ from the parental types due chromosome crossovers) we estimate that the genetic map distance is 4 centiMorgans. For our purposes this is quite close and a highly desirable result. It has been the desire of plant geneticists to be able to pyramid resistance genes in breeding lines. Unfortunately, most of this research has involved gene transfer after assembling multiple genes in an *Agrobacterium* Ti plasmid. This research has succeeded in pyramiding in close linkage two very important genes by non-GMO techniques.

Figure 3 shows the raw results of the gene markers on a gel. The PCR markers are easily processed in one step. No further manipulation is required after performing PCR. In cooperation with the alfalfa breeding program we have assembled the equipment to partially automate the DNA extraction process. We have a "shaker" that will handle 200 samples by taking leaf pieces and macerating them with beads which serve as the tissue disrupters during a high frequency shaking. Upon finishing the shaking the 200 samples are subjected to mass centrifugation, without transfer and the reagents are added to the wells. The next step is to place the plates, again, these are the original plates that we placed the fresh or frozen leaves into, for DNA amplification on the thermocycler. Upon completion we have a choice of using a capillary genetic analyzer which reveals the presence of amplified DNA by size separation and UV detection. Alternatively we can use gel separation. We have preferred the latter, because it is easier to trouble shoot. The gel separates DNA by size. It can be seen that the markers are very clear on the gel free of ghost bands or weak amplification.

Relevant Literature Published by the Project Leader.

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Presentations

1. Presentation to Variety Discussion Group Washington-Oregon State Potato Conference, 2014, entitled "Resistance to PMTV." Kennewick, WA.
2. Presentation at Idaho Potato Conference "Breeding Litchi Tomato to counter Pale Cyst Nematode in Idaho" Pocatello, ID. 2014
3. Roundtable meeting with USDA/APHIS and Idaho Potato growers "Litchi tomato as a trap crop to counter Pale cyst nematode in Idaho.
4. Presentation "Resistance to various viruses, 2014. WSU Warden Field Day.
5. Presentation "Resistance to Soil-borne pests and diseases." Paterson Field Day.
6. Presentation to Conagra, Kennewick, WA "Resistance to PMTV." 2014.

7. Presentations at PAA annual meeting Spokane, WA, “Stability of performance of high phytonutrient potatoes,.” “Use of molecular markers to select combined resistance to PVY and Columbia Root-Knot Nematode.” 2014

Awards Received

Honorary Lifetime Member of the Potato Association of America, 2014

Introduction of nematode resistance from *Solanum bulbocastanum*

BC_1

BC_2

BC_3

Introduction of resistance to Corky Ringspot

BC_4

BC_5 x PVY resistance

BC_6

BC_7

Introduction of Molecular Markers

Figure 1. A diagram showing the breeding of resistance to Columbia Root-Knot Nematode Resistance extracted from a Mexican wild species. A series of backcrosses improved overall plant and tuber type. Resistance to Corky ringspot was introduced early in the process. The PV Y resistance was introduced because it was impossible to keep good breeding selections as they became infected with PVY. Molecular markers were developed for nematode and PVY resistances

Table 1. The selectibility ratings and molecular marker genotypes of a sample of the 231 seedlings evaluated in the nematode infested field. The results are the means of three reps, each rep consisting of two hills. Selectibility is the mean of four independent raters.

id	AVERAGE	SE	Genotypes
POR14NCKY6-54	3.33	0.27	S_{MC} S_{PVY}
POR14NCKY6-2	3.25	0.75	S_{MC} S_{PVY}
POR14NCKY4-43	2.94	0.52	S_{MC} S_{PVY}
POR14NCKY4-8	2.78	0.42	S_{MC} S_{PVY}
POR14NCKY6-82	2.75	0.25	S_{MC} S_{PVY}
POR14NCKY6-57	2.72	0.61	S_{MC} S_{PVY}
POR14NCKY6-21	2.67	0.24	S_{MC} S_{PVY}
POR14NCKY6-73	2.61	0.64	S_{MC} S_{PVY}
POR14NCKY6-94	2.61	0.93	S_{MC} S_{PVY}
POR14NCKY4-12	2.50	0.68	S_{MC} S_{PVY}
POR14NCKY4-82	2.44	0.16	S_{MC} S_{PVY}
POR14NCKY4-66	2.44	0.31	S_{MC} S_{PVY}
POR14NCKY6-78	2.33	0.94	S_{MC} S_{PVY}
POR14NCKY4-85	2.22	0.87	S_{MC} S_{PVY}
POR14NCKY6-93	2.17	0.24	S_{MC} S_{PVY}
POR14NCKY4-35	2.11	0.96	S_{MC} S_{PVY}
POR14NCKY4-46	2.00	0.00	S_{MC} S_{PVY}
POR14NCKY6-8	2.00	0.00	S_{MC} S_{PVY}
POR14NCKY6-23	2.00	0.00	S_{MC} S_{PVY}
POR14NCKY6-85	2.00	0.82	S_{MC} S_{PVY}
POR14NCKY6-9	1.94	0.48	S_{MC} S_{PVY}
POR14NCKY4-74	1.89	0.42	S_{MC} S_{PVY}
POR14NCKY4-89	1.89	0.42	S_{MC} S_{PVY}
POR14NCKY6-19	1.89	0.68	S_{MC} S_{PVY}
POR14NCKY6-46	1.78	0.57	S_{MC} S_{PVY}
POR14NCKY6-84	1.75	0.75	S_{MC} S_{PVY}
POR14NCKY6-95	1.67	0.00	S_{MC} S_{PVY}
POR14NCKY6-48	1.67	0.33	S_{MC} S_{PVY}
POR14NCKY4-52	1.50	0.41	S_{MC} S_{PVY}
POR14NCKY4-62	1.22	0.31	S_{MC} S_{PVY}
POR14NCKY6-27	1.78	0.57	S_{MC} R_{PVY}
POR14NCKY6-42	2.33	0.27	S_{MC} R_{PVY}
POR14NCKY4-6	3.56	0.31	R_{MC} R_{PVY}
POR14NCKY4-68	3.56	0.31	R_{MC} R_{PVY}
POR14NCKY4-91	3.33	0.72	R_{MC} R_{PVY}
POR14NCKY6-55	3.22	0.57	R_{MC} R_{PVY}
POR14NCKY6-65	3.22	0.57	R_{MC} R_{PVY}
POR14NCKY6-44	3.00	0.00	R_{MC} R_{PVY}

POR14NCKY6-67	2.94	0.48	R_{MC} R_{PVY}
POR14NCKY6-29	2.89	0.68	R_{MC} R_{PVY}
POR14NCKY6-64	2.67	0.33	R_{MC} R_{PVY}
POR14NCKY4-11	2.56	0.31	R_{MC} R_{PVY}
POR14NCKY6-72	2.50	1.08	R_{MC} R_{PVY}
POR14NCKY4-88	2.44	0.16	R_{MC} R_{PVY}
POR14NCKY6-59	2.33	1.03	R_{MC} R_{PVY}
POR14NCKY4-5	2.22	0.68	R_{MC} R_{PVY}
POR14NCKY6-31	2.22	0.57	R_{MC} R_{PVY}
POR14NCKY4-4	2.22	0.31	R_{MC} R_{PVY}
POR14NCKY6-91	2.22	0.31	R_{MC} R_{PVY}
POR14NCKY4-7	2.11	0.87	R_{MC} R_{PVY}
POR14NCKY4-10	2.11	1.13	R_{MC} R_{PVY}
POR14NCKY4-31	2.11	0.79	R_{MC} R_{PVY}
POR14NCKY4-55	2.11	0.16	R_{MC} R_{PVY}
POR14NCKY4-69	2.00	0.82	R_{MC} R_{PVY}
POR14NCKY6-13	2.00	0.41	R_{MC} R_{PVY}
POR14NCKY6-14	1.83	0.62	R_{MC} R_{PVY}
POR14NCKY6-77	1.83	0.24	R_{MC} R_{PVY}
POR14NCKY4-1	1.78	0.57	R_{MC} R_{PVY}
POR14NCKY4-39	1.78	0.68	R_{MC} R_{PVY}
POR14NCKY4-15	1.72	0.61	R_{MC} R_{PVY}
POR14NCKY6-6	1.72	0.70	R_{MC} R_{PVY}
POR14NCKY4-64	1.67	0.47	R_{MC} R_{PVY}
POR14NCKY4-67	1.67	0.00	R_{MC} R_{PVY}
POR14NCKY4-30	1.00	0.00	R_{MC} R_{PVY}

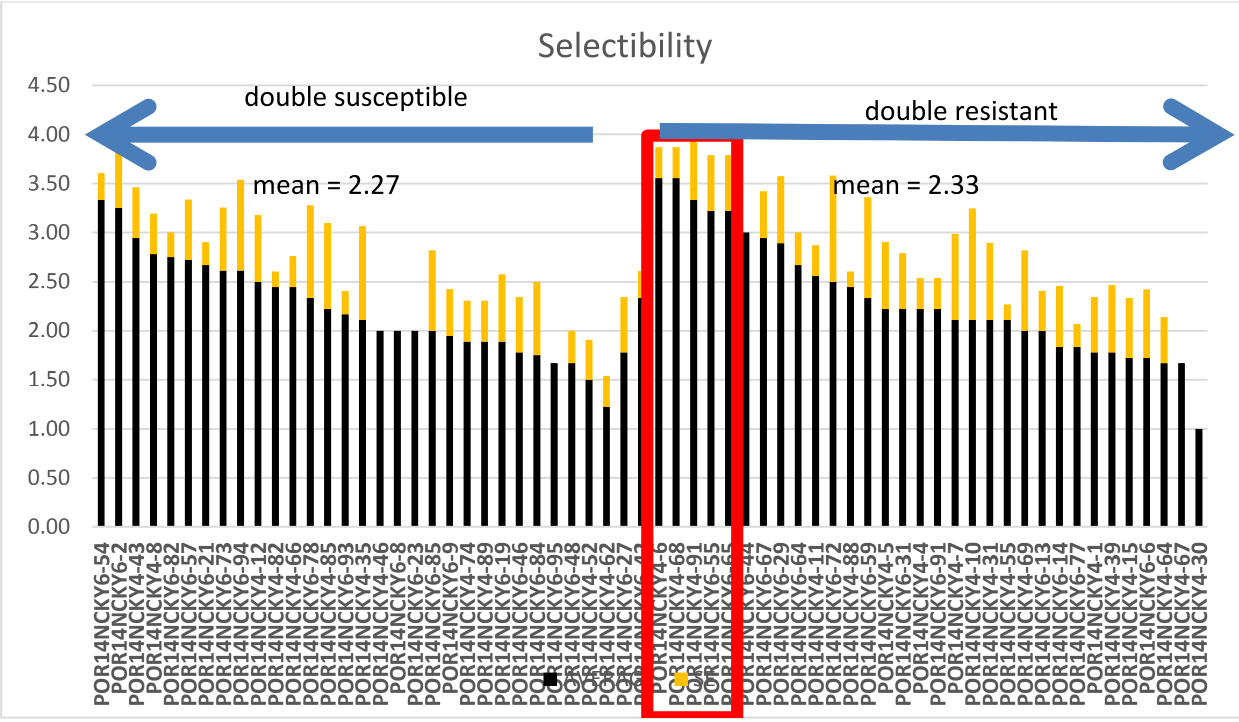
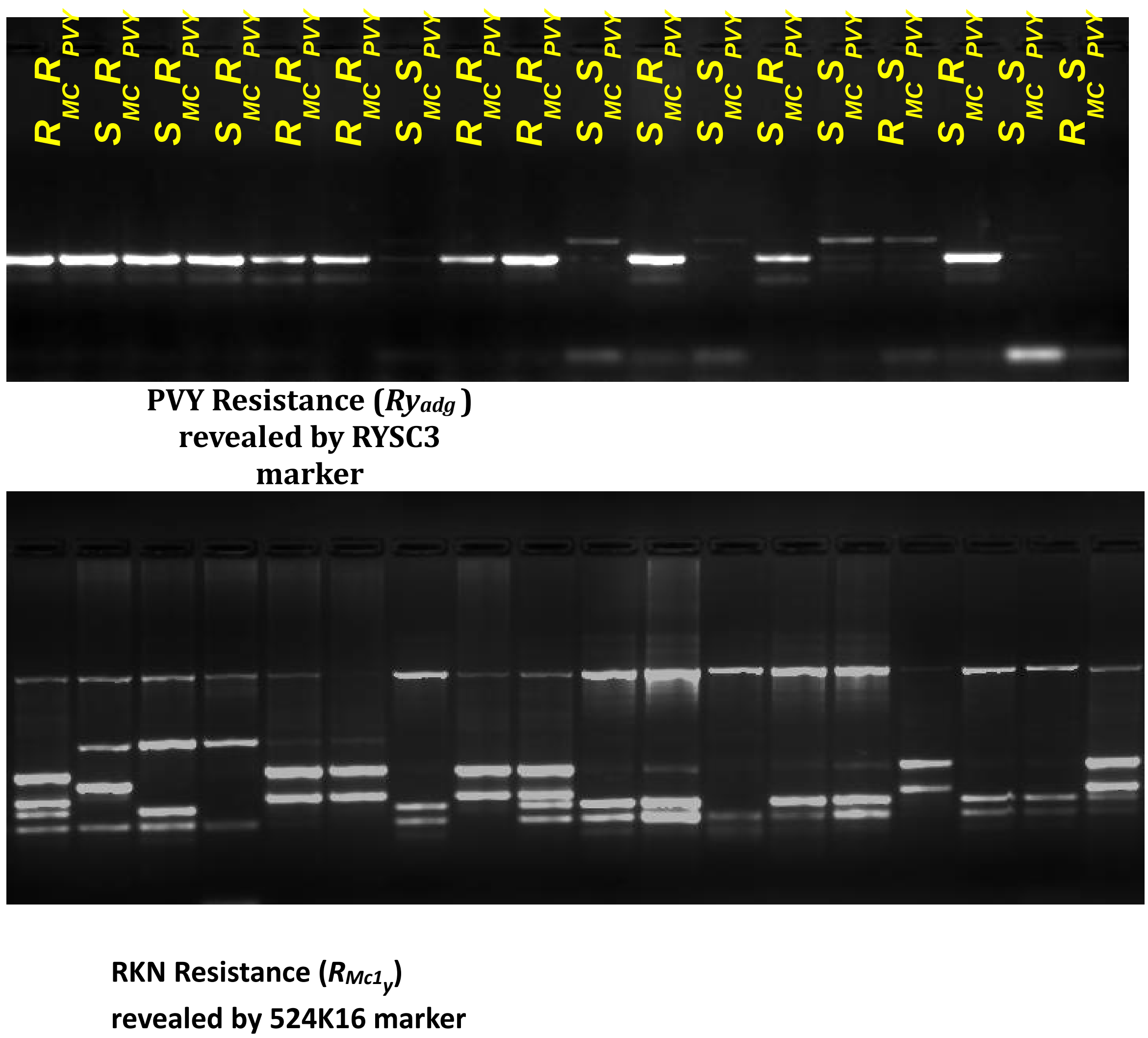


Figure 2. A graphic presentation of the data in Table 1. At harvest, keeping in mind this was the first seedling year. We are able to select with greater knowledge the seedlings inside the rectangle. They are doubly resistant with superior tuber type. Note that the means for of the double susceptible and double resistant groups are virtually identical.

Table 2. Tabulation of segregation of the two resistance markers and determination of linkage distance between them on chromosome 11. It is remarkable that all of these parental clones proved to be in coupling phase. This condition will make the transfer of the both resistance genes to progeny an efficient process. The recombinant fraction is 4 % which translates to 4 centiMorgans in genetic map terms.

	Cross	Number of progenies	$R_{Mc1(blb)}Ry_{(adg)}$	$R_{Mc1(blb)}Sy_{(adg)}$	$S_{Mc1(blb)}Ry_{(adg)}$	$S_{Mc1(blb)}Sy_{(adg)}$
Pop. 1	POR14NCKY1 (PA10NCKY4-10x37-2)	100	44	4	5	47
Pop. 2	POR14NCKY2 (PA10NCKY4-11x57-2)	104	50	3	3	48
Pop. 3	POR14NCKY3 (PA10NCKY5-1xPG1-3)	32	21	1	1	9
Pop. 4	POR14NCKY4 (PA10NCKY6-13x57-2)	96	44	1	4	47
Pop. 5	POR14NCKY5 (PA10NCKY8-12xPG3Y)	96	45	3	1	47
Pop. 6	POR14NCKY6 (PA10NCKY5-1x37-2)	96	45	1	3	47
	Sum	524	249	13	17	245
	Recombinant fraction = 4% or 4 cM					

Figure 3. Sequence Tagged Site (STS) markers linked to the resistance genes R_{Mc1} and Ry_{adg}.



PROGRESS REPORT

PROJECT NO: 13C-3055-4346

TITLE: Post Harvest Quality of New Clones and Cultivars

PERSONNEL: N. Richard Knowles (Project Leader)
Mark J. Pavek
Nora Fuller
L.O. Knowles

REPORTING PERIOD: 2014

INTRODUCTION:

The postharvest evaluations identify clones from the Tri-State and Western Regional Cultivar Improvement Trials that are best suited for the Pacific Northwest potato industry. Tubers grown as part of the Washington, Idaho and Oregon field adaptation portions of these trials are evaluated for processing quality and storability at the potato Postharvest Research Laboratory, WSU, Pullman. Red-skinned and specialty clones and cultivars were also evaluated as part of the Tri-State trials this year. Industry input has helped to create the current rating systems, which are continually being revised based on evolving needs and priorities.

Processing ability and storage potential of the clones were evaluated by comparing the physicochemical characteristics and culinary properties of processed French fries, assessing bruise potential and susceptibility to rot, measuring sprout development after different intervals of storage, comparing specific gravities, and determining the resistance to low temperature-induced sweetening over a range of storage temperatures. Reconditioning abilities were also assessed. Estimates of fry yields based on tuber length-to-width ratios for 8- to 10-oz tubers and evaluations of the variability in tuber shape and thus fry yield across growing sites were also included. The methods used in these evaluations are summarized below (see Procedures).

ACCOMPLISHMENTS:

Clones from the Late Tri-State and Regional Variety Programs were evaluated for postharvest quality and storage potential, with a focus on identifying varieties for the 'directly out-of-field' and 'after-storage' processing windows. Process quality of clones from the Red-Skin and Specialty Trials were also assessed. To-date we have completed postharvest processing evaluations of approximately 163 clones across 13 trials. Complete details of the postharvest performance of these clones are available in the WSU Potato Cultivar Yield and Postharvest Quality annual report (2014). Copies of this report will be available at the Washington State Potato Conference and Trade Show.

Overall ratings of the postharvest performance of clones in the Tri-State and Regional Trials are presented in this report. Estimates of the stability of tuber shape across production sites and of the effects of growing region on the ability of tubers to maintain processing quality during storage are provided. The clones have been ranked according to their abilities to retain process quality in response to storage temperature and location of production. For a particular clone, low variation in tuber shape and retention of processing quality is desirable for production in the Pacific Northwest.

Summary of Objectives Accomplished:

1.) Completed postharvest processing, culinary and storage evaluations for 163 clones and cultivars across 13 trials. Depending on the trial, clones and cultivars were assessed immediately after harvest and/or after approximately 60 days of storage at 40, 44 and 48°F.

2.) Evaluated differences in susceptibility of the clones to bruise and bacterial soft rot.

3.) Tuber length to width (L/W) ratios were used to predict the yield of French fries for 8- to 10-oz tubers of each clone grown in WA, ID and OR. This facilitated the relative ranking of clones based on their tendency to change shape (and thus yield of processed product) when grown at various sites across the Tri-State region.

4.) Determined the extent to which clone and production region affected the ability of tubers to resist low temperature-induced sweetening (LTS) and thus maintain at-harvest French fry process quality during storage.

5.) Evaluated reconditioning abilities and ranked the clones accordingly.

6.) Conducted taste panel evaluations and rated physical characteristics of boiled, baked and microwaved samples of clones in the Red and Specialty Trial. Chipping and French fry quality evaluations were also completed for those clones.

Procedures

Early Harvest

Culinary and quality characteristics of clones from the Red and Specialty Trials were evaluated after oven-baking, microwaving, boiling, chipping, and French frying. Four- to six-ounce tubers were selected for the cooking protocols described below. After cooking, each tuber was halved from stem to bud end. One half was immediately evaluated on a scale from 1 to 5 (5 is best) for texture, flavor, tuber center and skin. The remaining half was set aside for 30 minutes and after-cooking-darkening was then graded on a 1 to 5 scale based on a color chart we developed for white- and yellow-fleshed clones (1 = excessive graying, 5 = no discoloration).

Cooking Protocols

- Oven Baking - Tubers were pierced twice with a fork on each side and baked at 400°F for 1 h.
- Boiling - Tubers were cooked in a sieved double-boiler for 1 hour after coming to a boil.
- Microwave - Tubers were pierced twice with a fork on each side and cooked for 10 minutes at the outer edge of a microwave oven (high setting). The tubers were then turned and moved to the center of the microwave where they were cooked for an additional 10 minutes. Four tubers each of two clones (8 tubers total) were cooked simultaneously.
- Chipping – Tubers were cut longitudinally from stem to bud end. French fries were cut from one of the halves as described below. Two, 0.05-inch-thin slices were taken from the cut face of the other half. The first slice was discarded to insure uniform thickness of the second slice, which was processed as a chip. The chips (12-tuber samples) were rinsed and fried in 375°F vegetable oil for 2 minutes. The chips were drained and color was rated using the Potato Chip Snack Food Association (SFA) color chart (1=light to 5=dark).

Late Harvest

Testing of clones in the late harvest trials involved the following postharvest quality evaluations. As soon as possible after harvest, tuber specific gravity and fry color (Photovolt readings) were measured on 12 tubers from each clone. Clones designated as fresh processing were French-fried and Photovolt readings compared at harvest only. Additional tubers of each clone were placed in storage at 40, 44 and 48°F. Tubers stored at 48°F were evaluated for bruise potential, soft rot susceptibility, consumer acceptance of French fries, and cooking time in October and November. Reducing sugar content and

French fry color were assessed in early December. The extent of sprouting was recorded in late December. Tubers stored at 44°F were also evaluated for sugar accumulation in December. Storage of tubers at 40°F until mid December was done to determine the "cold-frying" potential of clones. Fry color and reducing sugar content were assessed in these tubers but the results are not reflected in the final numerical rating for each clone (see below).

EVALUATIONS OF RATED CHARACTERISTICS

Specific gravity was measured on a 12-tuber sample from each clone prior to storage by the weight-in-air/weight-in-water method and values were transformed into a 5-point scale as shown below. These same tubers were then used for French fry quality evaluation.

5= 1.083 – 1.088
4= 1.081 – 1.082 and 1.089 – 1.091
3= 1.080 and 1.092 – 1.093
2= 1.078 – 1.079 and 1.094 – 1.095
1= 1.076 – 1.077 and 1.096 or higher
0= 1.075 or lower

French fries were processed by frying tuber slices (3/8" x 1 1/8") in 375°F oil for 3.5 minutes. Fry color was measured with a Photovolt reflectance meter within 3 minutes of frying. A Photovolt reading of 19 or less was considered unacceptably dark. The stem- and bud-end Photovolt readings were reported along with the USDA color class (see below). The absolute difference between the bud- and stem-end Photovolt readings was calculated and a difference of 9 Photovolt units or more constitutes non-uniform fry color. A point was either added or subtracted from the total score, based on the uniformity of fry color. A (+) or (-) symbol included with the Photovolt rating indicates that a point was either added or subtracted during tabulation of the total score. The USDA color classes assigned to French fries are based upon the Photovolt readings of the darkest ends (usually the stem end) and are for information only; they are not used in determining the final rating for each clone.

Photovolt reading	USDA color
> 31	0
25-30	1
20-24	2
15-19	3
< 14	4

Rating		Av. Photovolt reading
5	=	41 or higher
4	=	36 thru 40
3	=	31 thru 35
2	=	25 thru 30
1	=	20 thru 24
0	=	19 or less

Taste panels were used to determine the consumer acceptance of French fries from each clone. Slices (3/8" x 3/8") from tubers stored at 48°F were fried in 375°F oil for 4.5 minutes. Approximately twenty untrained panelists rated the fries on a 1 to 5 (5=best) scale for taste, texture, internal flesh color and weak units (limpness). The average rating of the four fry characteristics is reported and was used in calculating the total rating score for each clone.

Reducing sugar content of the stem and bud ends of tubers was estimated on a percent dry weight basis in tubers stored at 40, 44 and 48°F and the values were transformed into a 5-point scale (5 = 0.9% or lower, 4 = 1.0 through 1.49%, 3 = 1.5 through 1.9%, 2 = 2.0 through 2.49%, 1 = 2.5% or higher). With the exception of tubers stored at 40°F that were not rated, sugar scores contributed to the final rating of each clone.

EVALUATIONS OF NON-RATED CHARACTERISTICS

Bruise potential and severity – For each clone, 12 tubers were warmed to room temperature for one day. Each tuber was then held under a device that dropped a 4-oz weight from a height of 23 inches. Each tuber received four such impacts, two on the stem end and two on the bud end. After 24 hours, the tubers were peeled and the percentage of impacts resulting in a blackspot or shatter bruise was calculated. Blackspot bruise severity ratings ranged from 1 to 5 (max. severity) and was based on color intensity and percentage of impacted area showing color (1= no bruise, 2= white knot bruise, 3= less than 50% of impacted area with color, 4= >50% of impact area darkened or whole area light brown, 5= full impact area dark).

Soft rot index - Bacterial soft rot susceptibility was determined by wounding the stem and bud ends of room-temperature tubers, inoculating the wounds with *Pectobacterium carotovorum* subsp. *carotovorum*, and incubating the tubers (six tubers per clone) for 24 hours at 72°F in a mist chamber. The percent by fresh weight of tissue lost due to rot is reported.

Tuber shape characteristics - The lengths and widths of up to twenty-five 8- to 10-ounce tubers from each clone were measured and length to width (L/W) ratios reported. This was done to reveal the effects (if any) of growing location on tuber shape and to estimate the yield (% by number) of ≥3-inch-long fries for each clone. Fry yields were calculated based on algorithms relating tuber shape (L/W) to the number and weight of usable fries. The equations are as follows:

Visual Shape*	Tuber L/W Ratio	Percentage French Fries ≥ 3 Inches in Length (by weight)	(by number)
Round	1.00	53.9	35.2
	1.25	70.3	51.6
Blocky	1.50	82.6	64.1
	1.75	90.8	72.8
	2.00	95.0	77.6
Elongated	2.25	95.1	78.5

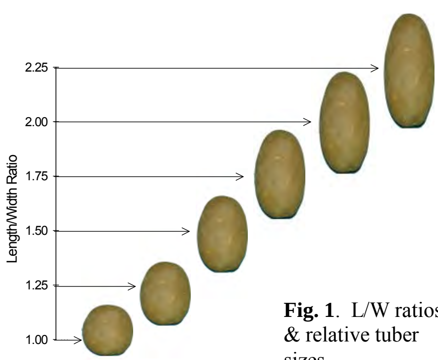


Fig. 1. L/W ratios & relative tuber sizes.

Percent fries by no. = $-68.9 + 135(L/W) - 30.9(L/W)^2$
$r = 0.80$ ($P \leq 0.001$)

Percent fries by wt = $-52.3 + 139(L/W) - 32.5(L/W)^2$
$r = 0.81$ ($P \leq 0.001$)

Percent fries by no. = $120 - 2.51(\%\text{ by wt}) + 0.022(\%\text{ by wt})^2$
$r = 0.96$ ($P \leq 0.001$)

The data and schematic in Figure 1 reflect these relationships. A L/W ratio close to one indicates a round tuber not ideally suited for French fry production. A ratio in the 1.5 to 1.75 range represents a more oblong, blocky tuber (e.g. Russet Burbank) that is desirable for processing. A typical L/W ratio for Russet Burbank is 1.80. Blocky tubers result in high French fry yield with less waste. Because of the curvilinear relationships between fry yield and L/W ratio, greater differences are required at higher L/W ratios to significantly affect fry yield. Schematics illustrating how relative tuber shape changes with L/W ratio (Fig. 1) are included with L/W and fry yield data in the WSU Potato Cultivar Yield and Postharvest annual report.

Sprouting - The degree of sprout development in tubers stored at 40 and 48°F was assessed after all other tests had been completed (usually late December). The percentage of tubers that sprouted and the average sprout length per tuber were recorded for 15 tubers of each clone.

LONG-TERM STORAGE CHARACTERISTICS OF CLONES IN THE 2013 TRI-STATE AND REGIONAL VARIETY TRIALS

For evaluation of long-term storability, tubers were held at 48°F until December 21, 2013 and then transferred to 44°F. The tubers were processed into French fries and reducing sugars were estimated following ca. 7 months of storage for Tri-State and Regional trials (April 28-May 1, 2014). Tubers were not reconditioned prior to frying.

RESULTS:

AT-HARVEST AND AFTER-STORAGE EVALUATIONS OF CLONES IN THE 2014 TRI-STATE AND REGIONAL VARIETY TRIALS

2014 Late Harvest Tri-State Trial

Samples were obtained from the Washington, Idaho and Oregon field adaptation trials for analysis in Pullman. Seventeen numbered entries and two cultivars were tested from ID, WA and OR. Overall ratings of the clones compared with Russet Burbank appear in Table 1. Details are summarized below. An "*" in the summary below indicates similar performance and/or ranking in trials from previous years.

- **Overall Postharvest Rating (Table 1)**
  Highest scoring clones: A03141-6*, A0073-2, A06020-8, AOR06070-1KF*, OR08014-4
  Lowest scoring clones: RB, A08014-11TE, A07103-1T, A06096-2
- **Low Temperature Sweetening (Figs. 2 & 3)**
  Most resistant: A03141-6, A0073-2, A06020-8, OR08014-4
  Most susceptible: RB, A08014-11TE, A07103-1T
- **Taste Panel** (see WSU 2014 Potato Cultivar Evaluation book)
  Highest rated: A03141-6*, A07008-4T, OR08014-4, A06914-3CR
  Lowest rated: RR, A06014-14TE, A06862-18VR
- **Blackspot Bruise Susceptibility** (see WSU 2014 Potato Cultivar Evaluation book)
  Most resistant: A07103-1T, AO03123-6, A03141-6
  Most susceptible: RR*, A06862-18VR, OR08014-4, A0073-2
- **Variability in Tuber Shape & Fry Yield (8- to 10-oz tubers) (Figs. 6 & 7)**
  Lowest L/W: A06408-99LB, A08014-9TE, A06862-18VR, COA05149-2, A07103-1T
  Highest L/W: RR*, A07008-4T, RB, AO03123-2
  Least variable: A0073-2, RR, A07008-4T, AO3123-2, RB
  Most variable: A06914-3CR, A06408-99LB, A06014-14TE, A06862-18VR

Details

- Averaged across states, all entries received higher postharvest scores than Russet Burbank (Table 1).
- A03141-6*, A0073-2, A06020-8, AOR06070-1KF* and OR08014-4 were the highest rated entries, scoring 33.4, 32.4, 31.1, 29.4 and 29.2 out of 38 points, respectively (Table 1).
- A03141-6, A0073-2, A06020-8 and OR08014-4 were resistance to low temperature sweetening (Figs. 2 & 3), with samples from all states producing highly acceptable light colored fries (USDA 0-1 after 60 d at 44°F; USDA 0-2 at 40°F; average of stem ends). However, A03141-6, A06020-8, and OR08014-4 had non-uniform fry color after storage at 44 and 40°F, particularly from WA and OR. Retention of fry color (60 days at 44°F) for RB, A06914-3CR and A03141-6 was minimally affected

by growing location (Fig. 4). In contrast, retention of fry color in A06408-99LB, AOR06070-1KF and AO03123-2 was highly variable across the three production sites.

- RB, A08014-11TE, A07103-1T and A06096-2 received the lowest overall postharvest scores (14.2, 19.8, 22.7 and 22.7 out of 38, respectively) (Table 1).
- Average (across states) gravities of COA05149-2 and A08014-9TE were 1.070 and 1.072, respectively; too low for frozen processing contracts. In contrast, average gravities of 12 of 19 entries ranged from 1.082-1.089, which is ideal for most contracts.
- A03141-6*, A07008-4T, OR08014-4 and A06914-3CR were the favorites in the taste panels, scoring 3.7, 3.7, 3.5 and 3.5, respectively, across growing locations (5 is best). RR, A06014-14TE and A06862-18VR received the lowest taste panel scores (avg = 3.0).
- In addition to rating overall bruise susceptibility, blackspot bruise severity was rated from 1 to 5 (max. bruise) based on color intensity and percentage of the impacted area showing color (1= no bruise, 2= white knot bruise, 3= less than 50% of impact area with color, 4= >50% of impact area darkened or whole area light brown, 5= full impact area dark). RR*, A06862-18VR, OR08014-4, A0073-2 were the most susceptible, scoring 90, 72, 69 and 69% bruise (stem end), respectively, in the controlled impact study. These clones also had the highest bruise severity, averaging 3.1/5. A07103-1T, AO03123-6 and A03141-6 were the most resistant, averaging 9.4% bruise (stem end) and 1.2/5 severity rating.
- The 8- to 10-oz tubers of A06408-99LB, A08014-9TE, A06862-18VR, COA05149-2 and A07103-1T had low length to width ratios (avg. L/W=1.49), resulting in yields of 3-inch or longer fries averaging only 63% by number (Fig. 6). A06914-3CR, A06408-99LB, A06014-14TE and A06862-18VR had the greatest variation in L/W ratio (Fig. 7); usable fry yields ranged from 58 to 77%, depending on production area. RR*, A07008-4T, RB and AO03123-2 had the highest L/W ratios (Fig. 6) across all states, resulting in an average of 75% yield of French fries by number.
- Reconditioning (60^{o}F, 21 days) tubers of COA05149-2, AO03123-2, OR08014-4, A08014-11TE and A06862-18VR that had been stored at 40^{o}F for 60 days resulted in the greatest improvement in stem end fry color compared with the other clones (Fig. 5). In contrast, fry color of A03141-6, A06408-99LB and A0073-2 changed little in response to reconditioning. AO6191-1 and A08014-9TE appeared more susceptible to sugar end development based on attenuated reconditioning of the stem versus bud end of tubers following storage at 40^{o}F.
- On average, 99% of tubers of A06096-2, A08014-9TE, A06862-18VR, COA05149-2 and A06408-99LB had 1.2-inch sprouts after 60 days storage at 48^{o}F compared with 89% of RR tubers (avg sprout length = 0.75 inches). In contrast, tubers of A03141-6 and A08014-11TE had no sprouts compared with 9% sprouting of RB. The remaining entries sprouted 50% on average, with sprouts averaging 0.37 inches, indicating dormancy intermediate between RB and RR.

Table 1. Accumulated total postharvest ratings of 2014 Tri-State Trial clones (ranked on total score).

Clone	WA Rating Total §	WA Discard §§	ID Rating Total §	ID Discard §§	OR Rating Total §	OR Discard §§	3 State av. Rating Total
4 A03141-6	32.6		34.9		32.6		33.4
3 A0073-2	33.3		27.6		36.3		32.4
6 A06020-8	31.1		31.4		30.7	Sp. Gr.	31.1
17 AOR06070-1KF	28.6		30.2		29.4		29.4
19 OR08014-4	30.5		29.6		27.6		29.2
10 A06914-3CR	30.4		33.5		21.5	Sp. Gr.	28.5
11 A07008-4T	29.9		30.5		24.6		28.3
8 A06408-99LB	31.0		23.2		24.3	Sp. Gr.	27.7
9 A06862-18VR	28.2		26.8		25.1		26.7
5 A06014-14TE	26.3		29.9		22.8	Sp. Gr.	26.3
15 AO03123-2	26.4		23.9		26.4		25.6
18 COA05149-2	25.8	Sp. Gr.	27.1	Sp. Gr.	21.8	Sp. Gr.	24.9
14 A08014-9TE	24.0		27.5		20.0	Sp. Gr.	23.8
16 AO06191-1	23.4		22.6		25.1		23.7
1 Ranger Russet	20.8		21.6		28.3		23.6
7 A06096-2	25.5		26.9		15.8		22.7
12 A07103-1T	21.0		26.4		20.6		22.7
13 A08014-11TE	20.3		24.0		15.0	Sp. Gr.	19.8
2 Russet Burbank	15.3		13.9	Sp. Gr.	13.3	Sp. Gr.	14.2
Average	26.5		26.9		24.3		26.0

§ maximum rating possible = 38

§§ Values for the indicated evaluation are lower than the rejection level.

Table 2. Effect of production site on ability to retain at-harvest French fry processing color (stem end) in 2014 Tri-State clones stored at 48 and 44^{o}F for 60 days. Mean separation by LSD (P≤0.01).

State	At Harvest Photovolt	Storage Temp 48^{o}F	Storage Temp 44^{o}F
		(% at-harvest photovolt)	
WA	37b	84	83
ID	39a	81	84
OR	36b	91	79

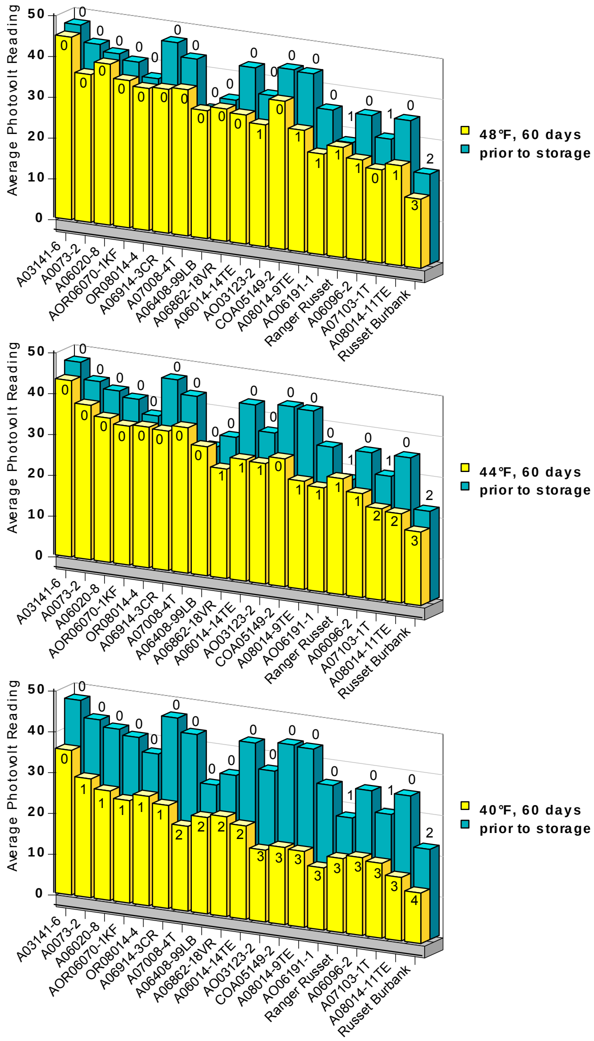


Fig. 2. Comparison of before-storage (dark bars) and after-storage (light bars) colors of the stem ends of French fries for Tri-State clones (3-state average). Tubers were stored for 60 days at 48, 44 and 40°F. High reflectance values indicate light colored fries. Clones are ranked from highest (left) to lowest (right) postharvest merit. USDA fry colors are shown.

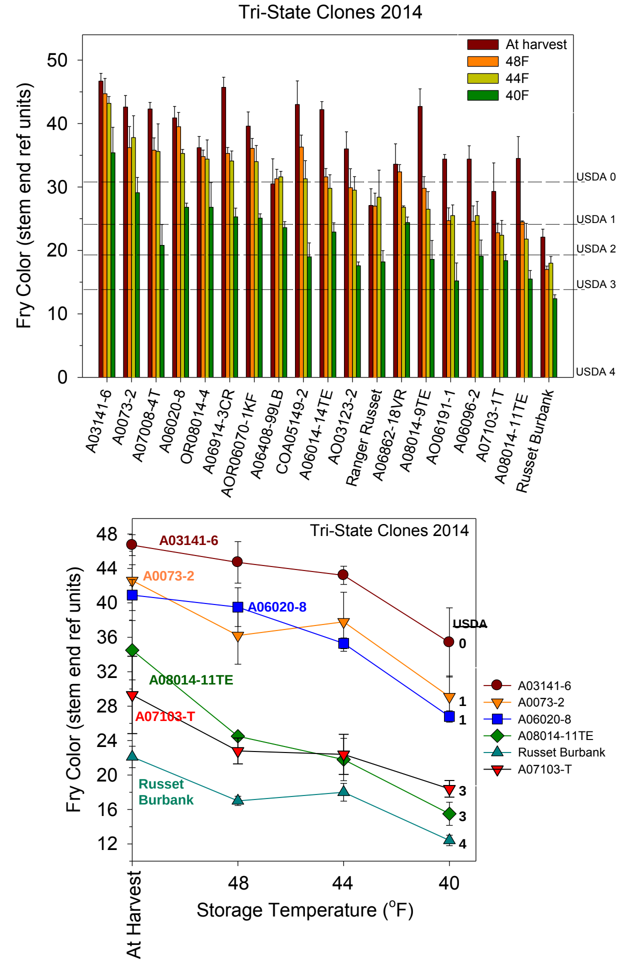


Fig. 3. Top: At-harvest and after-storage French fry colors (stem end) of clones in the Tri-State Trial. Tubers were stored for 60 days at 48, 44 and 40°F. The clones are ranked from best to worst based on fry color of the 44°F-stored tubers. High reflectance values indicate light colored fries. **Bottom:** Effects of storage temperature on changes in stem end fry color for some of the best and worst performing clones.

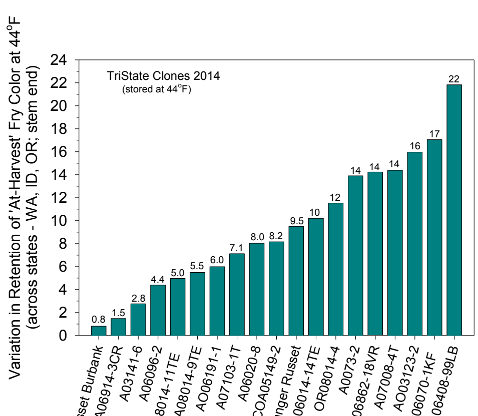


Fig. 4. Variability in retention of fry color (stem end) following storage for 60 days at 44°F. Variability is expressed as the standard deviation for percent of at-harvest fry color for tubers processed out of 44°F storage calculated across WA, ID, & OR production sites.

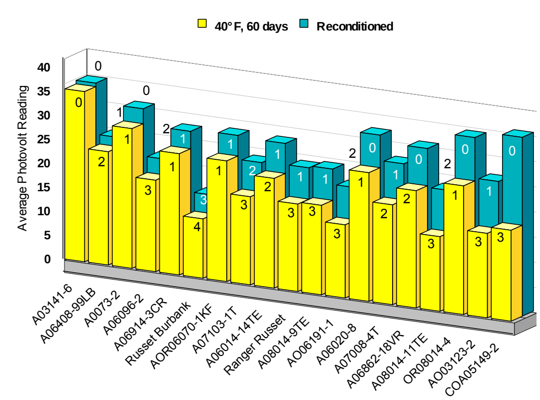


Fig. 5. Reconditioning ability of clones in the Late Season Tri-State Trial. Tubers were reconditioned at 60°F for 21 days following storage for 60 days at 40°F. Fry color is plotted as photovolt reflectance (stem end) averaged across states. High values indicate lighter fries. Clones are ranked from least to greatest difference in fry color with reconditioning. Numbers in bars are USDA values for the darkest (usually stem) end of the French fries.

Table 3. Tuber Length to width ratios and estimated yields of French fries for 8- to 10-oz tubers from clones and cultivars produced in the 2014 Tri-State Trial. Data was averaged over nineteen clones to reveal the significant (*P*≤0.01) main effect of growing region on tuber shape.

State	Tuber Length/Width	Yield of French Fries (≥3") By number	Yield of French Fries (≥3") By fresh wt.
WA	1.60c	66.0	75.5
ID	1.94a	73.4	90.3
OR	1.73b	69.3	87.5

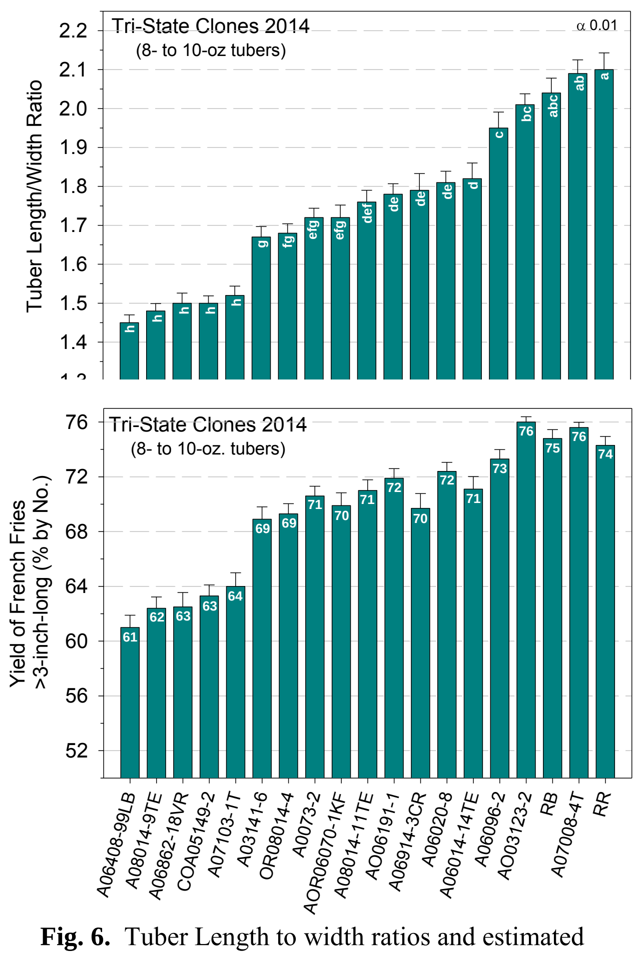


Fig. 6. Tuber Length to width ratios and estimated yields of French fries for clones and cultivars in the 2014 Tri-State Trial. Data were averaged over WA, ID and OR to reveal the significant (*P*≤0.01) main effect of clone.

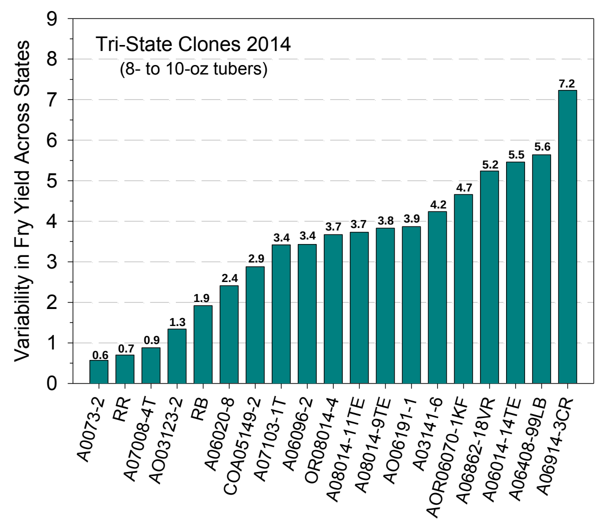


Fig. 7. Relative ranking of clones in the Late Season Tri-State Trial for variability in yield of French fries prepared from 8- to 10-oz tubers. Variability is expressed as the standard deviation calculated across production sites for the yield of fries ≥3 inches in length (% by number). High values reflect more variation in tuber shape and thus fry yield from state to state.

2014 Late Harvest Regional Trial

The 2014 trial evaluated twelve numbered clones along with Ranger Russet and Russet Burbank as check cultivars from each growing location. When averaged across states, all entries received higher overall postharvest scores than Russet Burbank (RB) (Table 4). An "*" in the summary below indicates similar performance and/or ranking in trials from previous years.

- **Overall Postharvest Rating (Table 4)**
  Highest scoring: A02507-2LB*, CO05068-1RU, A03921-2, A06084-1TE
  Lowest scoring: RB, A03158-2TE*, A06021-1T
- **Low Temperature Sweetening (Figs. 8 & 9)**
  Most resistant: A02507-2LB*, A03921-2, A06084-1TE, CO05068-1RU, POR06V12-3*, OR05039-4
  Most susceptible: RB, A03158-2TE, RR
- **Taste Panel** (see WSU 2014 Potato Cultivar Evaluation book)
  Highest rated: A02507-2LB*, POR06V12-3, A06084-1TE, A03921-2
  Lowest rated: RB*, A03158-2TE
- **Blackspot Bruise Susceptibility** (see WSU 2014 Potato Cultivar Evaluation book)
  Most resistant: OR05039-4, POR06V12-3*, AO02060-3, A03158-2TE, AO01114-4
  Most susceptible: RR*, A03921-2, CO05068-1RU, A02424-83LB*
- **Variability in Tuber Shape & Fry Yield (8- to 10-oz tubers) (Figs. 12 & 13)**
  Lowest L/W: A02507-2LB* and CO05068-1RU
  Highest L/W: RR, RB, OR05039-4*, CO05175-1RU and A06084-1TE
  Least variable: AO02060-3, OR05039-4*
  Most variable: CO05068-1RU, A03921-2, A03158-2TE* A02507-2LB*

Details

- A02507-2LB*, CO05068-1RU, A03921-2 and A06084-1TE were the highest rated entries, accumulating an average of 34.3, 29.5, 27.8 and 27.6 of 38 possible points, respectively (Table 4).
- A02507-2LB*, A03921-2, A06084-1TE, CO05068-1RU, POR06V12-3* and OR05039-4 were resistant to low temperature sweetening (LTS), producing USDA 0 or 1 fries (stem end) when stored for 60 days at 40^{o}F averaged across locations (Fig. 9). RB, A03158-2TE and RR were susceptible to LTS, producing USDA 3-4 fries after 60 days at 40^{o}F.
- A02507-2LB, AO02060-3 and A03158-2TE contained 30% and 33% lower concentrations ($P<0.05$) of asparagine (acrylamide precursor) than RB in 2012 and 2013, respectively. A02424-83LB and POR06V12-3 contained 38% and 49% less asparagine than RB in 2013. These entries are undergoing further evaluations in the 2014 National Fry Processing Trials and/or the Advanced Agronomic Trials for development of low acrylamide varieties (USDA SCRI funded).
- RB, A03158-2TE* and A06021-1T scored the lowest on overall postharvest performance with 12.9, 20.0 and 22.8 out of 38 possible points, respectively (Table 4).
- The specific gravities of RB, A06084-1TE and A03158-2TE averaged 1.074, 1.073 and 1.072, respectively; too low for processing contracts. In contrast, gravities of RR, A02424-83LB*, AO01114-4*, and A02507-2LB* ranged from 1.084-1.087, which is ideal for most contracts.
- A02507-2LB*, POR06V12-3*, A06084-1TE and A03921-2 were the favorites in the taste panels, averaging 3.6/5 across growing locations (5 is best). RB was the lowest scoring clone (2.9/5). The

narrow range of taste panel scores (3.0-3.7) across numbered entries indicates that all were rated favorably for French fry culinary quality.

- On average, tubers grown in ID produced the lightest fry colors at harvest (Table 5). The Regional entries retained 89% and 84% of their at-harvest processing quality (stem end fry color) when stored at 48 and 44°F for 60 days, respectively.
- At harvest, 12/14, 1/14 and 13/14 entries had non-uniform fry color from WA, ID and OR, respectively. The majority of clones had non-uniform fry color regardless of production site after 60 days storage at 48 and 44°F. CO05175-1RU, A02424-83LB*, A02507-2LB, AO01114-4, RR* and A03921-2 varied the most in ability to retain process quality during storage for 60 days at 44°F across production sites (Fig. 10).
- AO02060-3*, AO01114-4*, RR* and A06084-1TE, and CO05175-1RU showed the greatest improvement in stem end fry color when reconditioned at 60°F following storage for 60 days at 40°F (Fig. 11). Reconditioning A02507-2LB*, A03158-2TE*, A06021-1T, RB, OR05039-4*, and CO05068-1RU had relatively little effect on change in stem end fry color. AO02060-3*, AO01114-4*, RB and A06021-1T showed reduced ability to recondition stem versus bud ends following storage at 40°F, indicating increased susceptibility to sugar end development relative to the other clones.
- OR05039-4, POR06V12-3*, AO02060-3, A03158-2TE and AO01114-4* were resistant to blackspot, with an average of 21% (stem end) in the controlled impact study (3-state average). These entries also scored lowest in bruise severity, averaging 1.5/5 (1= no bruise; 5= 100% of impact area is dark). RR*, A03921-2, and CO05068-1RU were highly susceptible with 90, 75 and 72% bruise, respectively. Bruise severity was also greatest in these four entries (average 3.1/5).
- ID-grown tubers (8-10-oz) had the highest L/W ratios (2.1) compared with those grown in WA (1.7) and OR (1.8) (Table 6). A02507-2LB* and CO05068-1RU had the lowest L/W ratios (avg. 1.5), indicating round tubers (Fig. 12). Low length to width ratio was also an issue with A02507-2LB in the 2011, 2012 and 2013 trials. RR, RB, OR05039-4*, CO05175-1RU and A06084-1TE had the highest L/W ratios (1.9-2.2). CO05068-1RU, A03921-2, A03158-2TE* and A02507-2LB* had the greatest variation in L/W ratios of 8- to 10-oz tubers across production sites (Fig. 13). In contrast, the L/W ratios of AO02060-3 and OR05039-4* were least affected by growing location.
- On average, 97% of tubers of AO02060-3, A02424-83LB, CO05068-1RU and A03158-2TE had 0.7-inch-long (1.8 cm) sprouts after 60 days storage at 48°F compared with 91% of RR tubers (avg sprout length = 0.8 inch (2.0 cm)). Sprouting of A02507-2LB*, OR05039-4* and AO01114-4* averaged 28% with sprout lengths ranging from 0.04-0.13 inches (0.1-0.6 cm) compared with 9% of RB tubers sprouting (0.1-cm sprouts). A06021-1T had the longest dormancy with only 2% of tubers peeping.
- A03158-2TE*, A06084-1TE and A03921-2 produced sprouts averaging 6.9 inches after 7 months storage, considerably longer than RR (4.0 in) and RB (3.3 in), indicating relatively short dormancy. In contrast, A02507-2LB* and A06021-1T produced 1.3 and 1.7-in-long sprouts, respectively, after 7 months, indicating shorter dormancy than RB.
- When stored for 7 months, RB produced USDA 2 fries from all states. The remaining entries fried USDA 0-1 regardless of production site. When averaged across states, A02507-2LB (51.9 ref units) and POR06V12-3 (50.1 ref units) produced the lightest fries. Uniformity of fry color was unacceptable for eleven of the thirteen entries. A02507-2LB and POR06V12-3 were the only two entries to produce uniform fries from all three states, which may indicate high tolerance of heat stress. Unfortunately, A02507-2LB has low L/W ratios (1.41 WA, 1.70 ID, 1.43 OR). The extent of heat tolerance and management techniques to increase L/W ratio are under investigation.

Table 4. Accumulated total postharvest ratings of 2014 Regional Trial clones (ranked on total score).

	WA		ID		OR		3 State av.
Clone	Rating Total §	Discard §§	Rating Total §	Discard §§	Rating Total §	Discard §§	Rating Total
4 A02507-2LB	36.4		30.6		36.0		34.3
11 CO05068-1RU	29.3		28.9		30.2		29.5
6 A03921-2	26.3		26.3		30.9		27.8
8 A06084-1TE	25.2	Sp. Gr.	30.0	Sp. Gr.	27.6	Sp. Gr.	27.6
13 OR05039-4	26.7		25.2		29.3		27.1
9 AO01114-4	27.5		26.2		26.9		26.9
14 POR06V12-3	26.7		26.6		26.7		26.7
10 AO02060-3	23.0		25.4		24.6	Sp. Gr.	24.3
3 A02424-83LB	19.1	Sp. Gr.	26.2		27.3		24.2
1 Ranger Russet	20.9		22.2		28.5		23.9
12 CO05175-1RU	20.9		24.3		24.4	Sp. Gr.	23.2
7 A06021-1T	16.1	Sp. Gr.	26.1		26.1		22.8
5 A03158-2TE	20.1	Sp. Gr.	18.0		21.9	Sp. Gr.	20.0
2 Russet Burbank	15.1		10.9	Sp. Gr. 44°F	12.6	Sp. Gr.	12.9
	23.8		24.8		26.6		25.1

§ maximum rating possible = 38

§§ Values for the indicated evaluation are lower than the rejection level.

Table 5. Effect of production site on the ability to retain at-harvest French fry processing color (stem end) in 2014 Regional clones stored at 48 and 44°F for 60 days. Mean separation by LSD ($P \leq 0.01$).

State	At Harvest Photovolt	Storage Temp 48°F	Storage Temp 44°F
		(% at-harvest photovolt)	
WA	34b	92	88
ID	43a	67	61
OR	35b	108	104

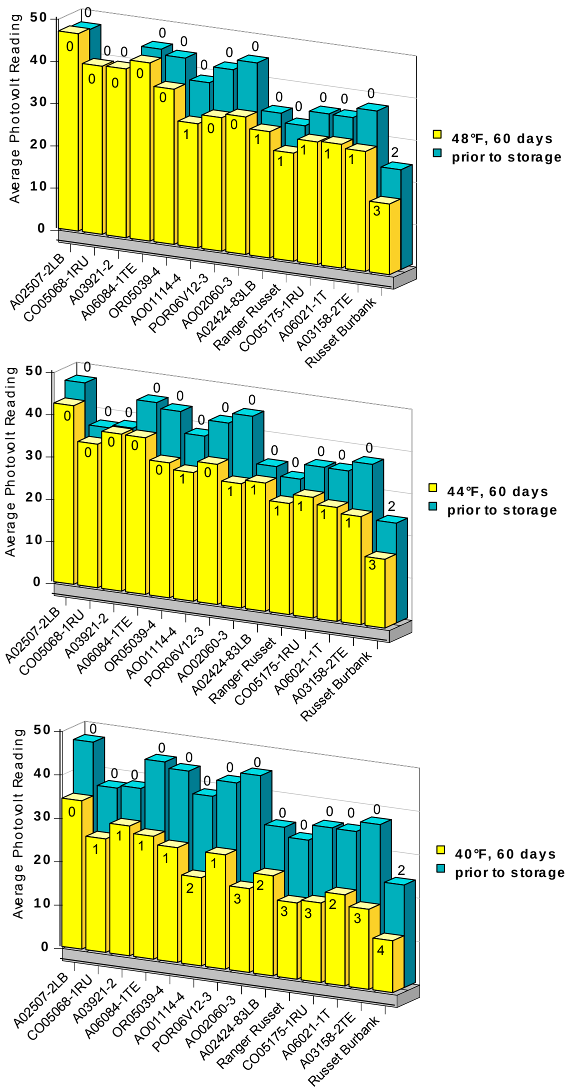


Fig. 8. Comparison of before-storage (dark bars) and after-storage (light bars) colors of the stem ends of French fries for Regional clones (3-state average). Tubers were stored for 60 days at 48, 44 and 40°F. High reflectance values indicate light colored fries. Clones are ranked from highest (left) to lowest (right) postharvest merit. USDA fry colors are shown.

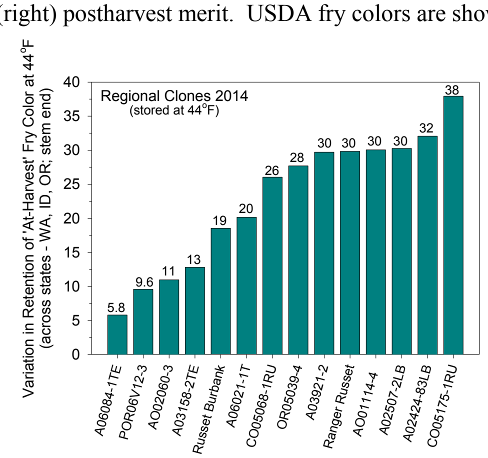


Fig. 10. Variability in retention of 'at harvest' French fry color (stem end) following storage for 60 days at 44°F. Variability is expressed as the standard deviation for percent of at-harvest fry color for tubers processed out of 44°F calculated across WA, ID, & OR production sites.

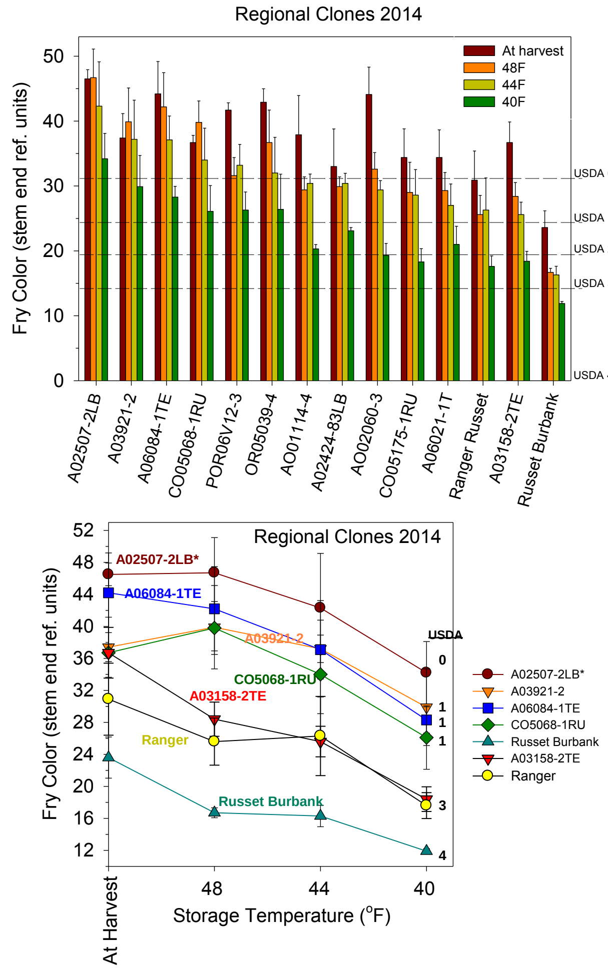


Fig. 9. Top: At-harvest and after-storage French fry colors (stem end) of clones in the Regional Trial. Tubers were stored for 60 days at 48, 44 and 40°F. The clones are ranked from best to worst based on fry color of the 44°F-stored tubers. High reflectance values indicate light colored fries. **Bottom:** Effects of storage temperature on the change in French fry processing quality (stem end fry color) for the best and worst performing clones in the Regional Trial.

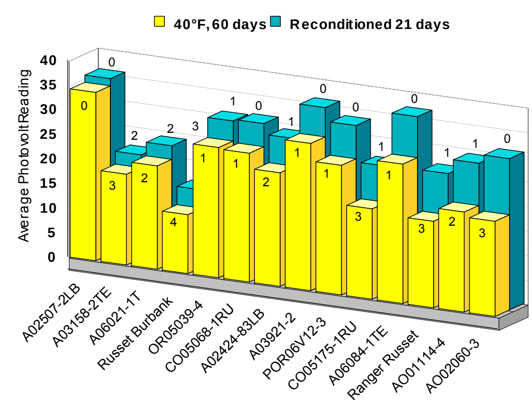
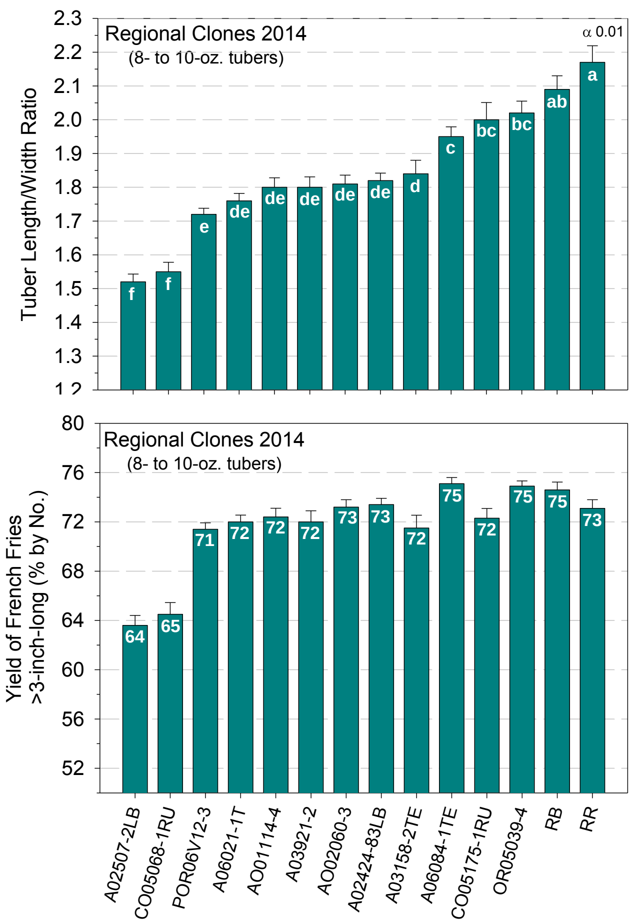


Fig. 11. Reconditioning ability of clones in the Late Season Regional Trial. Tubers were reconditioned at 60°F for 21 days following storage for 60 days at 40°F. Fry color is plotted as photovolt reflectance (stem end) averaged across states. High values indicate lighter fries. Clones are ranked from least to greatest difference in fry color with reconditioning. Numbers in bars are USDA values for the darkest (usually stem) end of the French fries.

Table 6. Tuber Length to width ratios and estimated yields of French fries for 8- to 10-oz tubers from clones and cultivars produced in the 2014 Regional Trial. Data was averaged over fourteen clones to reveal the significant ($P \leq 0.01$) main effect of growing region.

State	Tuber Length/Width	Yield of French Fries (≥3") By number	By fresh wt.
WA	1.69c	69.0	87.0
ID	2.06a	74.8	91.9
OR	1.79b	71.4	89.2



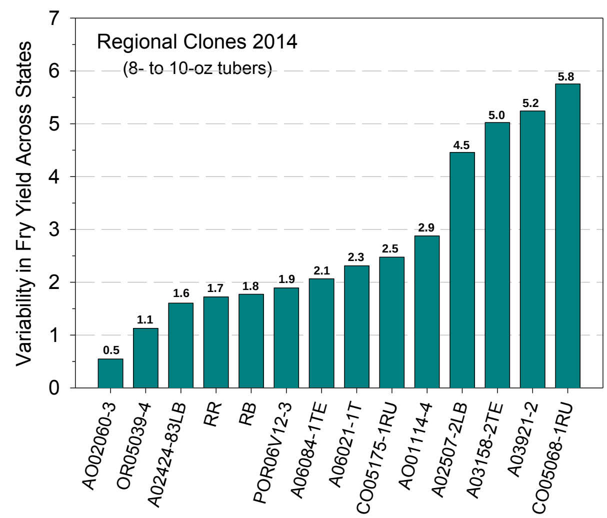


Fig. 13. Relative ranking of clones in the Late Season Regional Trial for variability in yield of French fries prepared from 8- to 10-oz tubers. Variability is expressed as the standard deviation calculated across production sites for the yield of fries ≥3 inches in length (% by number). High values reflect more variation in tuber shape and thus fry yield from state to state.

2013 Long-term Storage Evaluations

Clones retained in the trials for further testing are also evaluated for long-term storability in late spring following the year of harvest. The tubers are initially held at 48°F (9°C) until mid to late December and then transferred to 44°F (7°C) where they remain until late April. Sugar levels are estimated and the tubers are French fried directly from storage with no reconditioning period. The degree of sprouting is also assessed in late April.

Long-term Storage of 2013 Tri-State Clones retained in the Tri-State Trial (evaluated in spring 2014): In addition to Ranger and Russet Burbank (RB), three clones were retained from the 2013 Tri-State Trial. When averaged across states, the numbered entries produced 30% lighter fries than RB and Ranger (44 vs 34 ref units) and the uniformity of fry color was substantially better for all clones relative to RB and Ranger (Table 7A). Sprout lengths ranged from 3.2 to 4.0 inches when averaged across states and were highly variable depending on clone and state.

Table 7A. Evaluations of French fry color, tuber reducing sugars, and sprout growth after long-term storage of Tri-State clones from the 2013 trials. Tubers were stored at 48°F from harvest to December 21, 2013 and then placed at 44°F until evaluations April 28, 2014.

	PHOTOVOLT READING				USDA	% REDUCING SUGAR			Sprouting	
Clone	stem	bud	avg	DIFF	COLOR	stem	bud	avg	percent	length (in.)
Washington										
1 Ranger Russet	27.3	40.4	33.8	15.9	1	1.7	0.7	1.2	100	4.0
2 Russet Burbank	22.5	46.0	34.2	23.5	2	2.3	0.5	1.4	100	5.0
3 A0073-2	40.5	49.7	45.1	9.3	0	0.7	0.5	0.6	100	3.5
4 A03141-6	39.2	44.3	41.7	5.2	0	0.8	0.6	0.7	100	4.0
5 AOR06070-1KF	36.8	45.2	41.0	8.6	0	0.9	0.6	0.7	100	3.0
		LSD 0.05	*3.4*	*5.0*						
Average	33.3	45.1	39.2	12.5	0.6	1.3	0.6	0.9	100	
Idaho										
1 Ranger Russet	27.9	42.1	35.0	15.4	1	1.6	0.6	1.1	100	4.0
2 Russet Burbank	24.5	47.0	35.8	22.5	1	2.0	0.5	1.3	100	0.5
3 A0073-2	38.2	48.2	43.2	10.8	0	0.8	0.5	0.7	100	2.5
4 A03141-6	41.1	52.0	46.6	10.9	0	0.7	0.5	0.6	100	2.0
5 AOR06070-1KF	48.7	51.6	50.2	5.9	0	0.5	0.5	0.5	100	6.0
		LSD 0.05	*4.4*	*5.8*						
Average	36.1	48.2	42.1	13.1	0.4	1.1	0.6	0.8	100	
Oregon										
1 Ranger Russet	27.0	42.0	34.5	15.0	1	1.7	0.7	1.2	100	4.0
2 Russet Burbank	22.0	42.3	32.2	20.2	2	2.4	0.6	1.5	100	4.0
3 A0073-2	40.6	47.0	43.8	6.5	0	0.7	0.5	0.6	100	5.5
4 A03141-6	40.2	45.0	42.6	6.0	0	0.7	0.6	0.6	100	3.5
5 AOR06070-1KF	34.5	46.7	40.6	12.3	0	1.0	0.5	0.8	100	1.5
		LSD 0.05	*4.7*	*4.8*						
Average	32.8	44.6	38.7	12.0	0.6	1.3	0.6	0.9	100	

Date test performed:
Washington April 28
Idaho April 28
Oregon April 28

Long-term Storage of 2013 clones retained in or advanced to the 2014 Regional Trial (evaluated in spring 2014):

Four clones were advanced from the 2013 Tri-State Trial into the 2014 Regional Trial (A03921-2, A06021-1T, A06084-1TE & AO03123-2) (Table 7B). Seven clones were retained in the Regional Trial. When averaged across states, A02507-2LB (51.9 ref units) and POR06V12-3 (50.1 ref units) produced the lightest fries. Uniformity of fry color was unacceptable for eleven of thirteen entries. A02507-2LB and POR06V12-3 were the only two entries to produce uniform colored fries from all three states. A03158-2TE had the shortest dormancy with the longest sprouts (9") while A02507-2LB (1") had the shortest average sprout length (these results have been consistent over the last 4 years).

Table 7B. Evaluations of French fry color, tuber reducing sugars, and sprout growth after long-term storage of Regional clones from the 2013 trials. Tubers were stored at 48^{o}F from harvest to December 21, 2013, and then placed at 44^{o}F until evaluation April 29-May 1, 2014.

	PHOTOVOLT READING				USDA	% REDUCING SUGAR			Sprouting	
Clone	stem	bud	avg	DIFF	COLOR	stem	bud	avg	percent	length (in.)
Washington										
1 Ranger Russet	27.3	40.4	33.8	15.9	1	1.7	0.7	1.2	100	4
2 Russet Burbank	22.5	46.0	34.2	23.5	2	2.3	0.5	1.4	100	5
3 A02424-83LB	34.1	47.4	40.7	13.3	0	1.1	0.5	0.8	100	5.5
4 A02507-2LB	51.7	52.7	52.2	3.7	0	0.5	0.5	0.5	100	1.5
5 A03158-2TE	36.7	43.0	39.8	12.3	0	0.9	0.6	0.8	100	9
6 A03921-2 §	41.4	49.5	45.4	8.9	0	0.7	0.5	0.6	100	4.5
7 A06021-1T §	27.5	41.8	34.7	14.3	1	1.6	0.7	1.2	100	2
8 A06084-1TE §	43.6	50.1	46.8	7.9	0	0.6	0.5	0.6	100	6.5
9 AO01114-4	33.7	47.0	40.4	13.3	0	1.1	0.5	0.8	100	3
10 AO02060-3	34.2	44.8	39.5	12.1	0	1.0	0.6	0.8	100	4.5
11 AO03123-2 §	46.5	49.2	47.8	6.1	0	0.5	0.5	0.5	100	2
12 OR05039-4	29.5	46.8	38.2	17.3	1	1.4	0.5	1.0	100	3
13 POR06V12-3	47.0	53.2	50.1	6.8	0	0.5	0.6	0.5	100	4.5
		LSD 0.05	*4.0*	*5.4*						
Average	36.6	47.1	41.8	12.0	0	0.9	0.5	0.8	100	
Idaho										
1 Ranger Russet	28.1	40.6	34.3	12.5	1	1.6	0.7	1.1	100	4
2 Russet Burbank	23.5	46.7	35.1	23.6	2	2.2	0.5	1.3	100	1
3 A02424-83LB	42.8	51.6	47.2	11.7	0	0.6	0.5	0.6	100	4
4 A02507-2LB	51.3	55.3	53.3	4.6	0	0.5	0.5	0.5	100	1
5 A03158-2TE	38.0	39.1	38.6	7.0	0	0.8	0.8	0.8	100	6
6 A03921-2	42.3	51.5	46.9	9.2	0	0.6	0.5	0.6	100	2.5
7 A06021-1T	33.2	44.7	38.9	11.5	0	1.1	0.6	0.8	100	0.5
8 A06084-1TE	52.6	54.1	53.4	3.9	0	0.5	0.5	0.5	100	5
9 AO01114-4	35.0	46.2	40.6	11.2	0	1.0	0.5	0.8	100	1.5
10 AO02060-3	43.0	49.7	46.3	6.9	0	0.6	0.5	0.6	100	2.5
11 AO03123-2	40.6	51.7	46.1	13.1	0	0.7	0.5	0.6	100	1.5
12 OR05039-4	39.3	49.7	44.5	10.8	0	0.8	0.5	0.6	100	3
13 POR06V12-3	48.5	53.0	50.8	4.8	0	0.5	0.6	0.5	100	3.5
		LSD 0.05	*3.6*	*4.7*						
Average	37.7	47.5	42.6	11.4	1	1.1	0.6	0.8	100	
Oregon										
1 Ranger Russet	27.0	42.0	34.5	15.0	1	1.7	0.7	1.2	100	4
2 Russet Burbank	22.0	42.3	32.2	20.2	2	2.4	0.6	1.5	100	4
3 A02424-83LB	33.5	46.7	40.1	16.4	0	1.1	0.5	0.8	100	4
4 A02507-2LB	48.0	52.4	50.2	5.4	0	0.5	0.5	0.5	100	1.5
5 A03158-2TE	40.0	45.1	42.6	7.8	0	0.7	0.6	0.6	100	13
6 A03921-2	43.5	53.4	48.5	9.9	0	0.6	0.6	0.6	100	8.5
7 A06021-1T	29.8	35.0	32.4	7.9	1	1.4	1.0	1.2	100	2.5
8 A06084-1TE	29.2	44.9	37.0	15.7	1	1.5	0.6	1.0	100	7
9 AO01114-4	30.9	45.4	38.2	14.5	0	1.3	0.6	0.9	100	9
10 AO02060-3	43.3	42.7	43.0	5.1	0	0.6	0.6	0.6	100	6
11 AO03123-2	39.2	47.3	43.3	8.8	0	0.8	0.5	0.6	100	4
12 OR05039-4	36.5	46.9	41.7	11.5	0	0.9	0.5	0.7	100	4.5
13 POR06V12-3	49.2	49.4	49.3	6.9	0	0.5	0.5	0.5	100	3.5
		LSD 0.05	*4.5*	*5.7*						
Average	36.3	45.7	41.0	11.2	0	1.1	0.6	0.8	100	

§ Advanced from 2013 Tri-State Trial

Date test performed:

Washington	April 29
Idaho	April 30
Oregon	May 1

2014 WA TRI-STATE RED AND SPECIALTY TRIAL

Entrees in the Tri-state Red and Specialty Trials are evaluated for their suitability as fresh market potatoes. The specialty entries include varieties and clones with various combinations of skin and flesh colors. The 2014 trial consisted of two cultivars and eight numbered clones (Table 8A). The trial was grown at Othello and harvested in early August. Cooking and culinary evaluations were completed between Aug. 18-22.

Table 8A. Relative processing and culinary qualities of clones in the 2014 WA Tri-State Red/Specialty Trial. Clones are rated on a 1 to 5 scale (5 is best) for texture, flavor, tuber center, skin characteristics, and after-cooking darkening. The points are then totaled for each cooking protocol and summed to produce a total score.

	Clone	Boiled (25 max)	Baked (25 max)	Microwaved (25 max)	Total (75 max)
1	Chieftain	17.3	17.7	20.0	55.0
6	A02267-1Y	16.8	18.5	19.3	54.6
5	Yukon Gold	17.5	18.2	17.8	53.5
4	COA07365-4RY	17.1	17.6	18.2	52.9
7	A05182-7RY	16.9	17.9	17.9	52.7
8	POR07PG20-2	18.5	16.9	17.1	52.5
10	NDA081451CB-1CY	14.3	18.8	18.2	51.4
3	A05180-3PY	17.4	16.6	17.1	51.0
9	POR07PG3-1	16.4	16.4	17.9	50.7
2	NDA050237B-1R	18.9	16.7	14.6	50.2

French Fried:	Aug. 19
Chipped:	Aug. 19
Baked:	Aug. 18
Boiled:	Aug. 20
Microwaved:	Aug. 22
Cooking Time:	Aug. 20

- The top scoring clones were Chieftain and A02267-1Y with 55 and 54.6 points in the 2014 culinary evaluations. A05180-3PY has reddish-purple skin and creamy flesh. Chieftain and NDA050237B-1R have white flesh and red skin. COA07365-4RY has red skin and yellow flesh.
- The specialty entries, POR07PG20-2 and A05182-7RY, have pinkish yellow skin with yellow flesh while Yukon Gold, A02267-1Y, POR07PG3-1 and NDA081451CB-1CY have yellow skin and flesh. As in previous years, culinary scores were high with all entries receiving 67 to 73% of total points possible.
- A02267-1Y produced the lightest French fries (USDA 1) while POR07PG20-2 produced the darkest fries (USDA 4). Fries from all other entries were rated as USDA 2 or 3.
- Following the same trend as when French fried, A02267-1Y produced the lightest chips with a SFA rating of 3.1. Chips from all other entries were darker with ratings ranging from 4.1 to 5 on the SFA scale.
- The range in ratings of baked samples in the 2014 trial was relatively narrow (16.4-18.8 out of 25) (Table 8A). All entries had moderate to slight after cooking darkening when oven baked. Texture of the baked samples was favorably rated as “creamy” or “fluffy”; those rated as pasty were NDA050237B-1R and A05180-3PY. The flavor of most of the baked samples was rated “bland” while A02267-1Y and POR07PG20-2 received “good” ratings. Tuber centers of baked samples

received acceptable ratings of “mushy” for all entries. Skins of the baked samples were also rated as acceptable (“steamy”) for all entries except Chieftain and A05180-3PY which were rated as “crispy”.

- All entries showed slight to moderate sloughing when boiled. POR07PG20-2 also had moderate after cooking darkening. All other entries had slight after cooking darkening when boiled. The texture of all boiled samples was favorably rated as “creamy”. With exception of NDA081451CB-1CY which was unacceptable, the flavor of all boiled samples was rated as either “good” or “bland”. The tuber center of all entries was rated as “mushy”.

- Cooking time for boiled samples was assessed again this year. Cores of tuber tissue (1.3 cm diameter x 1.3 cm long) from the stem and bud ends of all entries were immersed in boiling water and the time to penetration of a 90-g probe was recorded. Stem end cores averaged 5.5 min to fully cook compared with 4.6 min for bud end cores (Table 8B). Cooking times (stem end) ranged from 4.6 min (POR07PG3-1) to 6.4 min (Chieftain). All entries cooked relatively quickly this year with averages of stem and bud ends ranging from 4.4 minutes (A02267-1Y, 2nd yr) to 5.8 (Chieftain).

- Microwaving produced “slight” or “moderate” after cooking darkening in all entries. The texture of all microwaved samples was favorably rated as “creamy” or “fluffy” except NDA050237B-1R which was “pasty”. The flavor ratings for all entries ranged from “bland” to “good” except for NDA050237B-1R which was unacceptable and received a “somewhat raw” tuber center rating for the 2nd year. All other entries received “mushy” tuber center ratings.

Table 8B. French fry and chip processing quality of clones in the 2014 WA Tri-State Red/Specialty Trial. Colors of French fries are given in photovolt reflectance units, which were translated into USDA fry colors (0-4, 4 = darkest). Potato chip colors were rated using the Snack Food Association chip color charts (1=lightest to 5=darkest). Relative cooking time for boiled samples (1.3 cm x 1.3 cm cores) is also given for each clone.

		(French Fried)		(3/8 x 1 1/8" slices)							**(Chips)**	**(BOILED Cooking Time)**		
		Raw				After Frying					Av of 7 raters	Time to Breakdown (min)		
	Clone	Stem	Bud	Average	Difference	Stem	Bud	Average	Difference	USDA	SFA	Stem	Bud	Average
1	Chieftain	55.3	54.4	54.9	1.6	21.9	25.1	23.5	3.7	2	4.9	6.4	5.3	5.8
2	NDA050237B-1R	58.1	59.5	58.8	2.6	17.1	20.2	18.6	4.0	3	5.0	6.0	5.0	5.5
3	A05180-3PY	56.0	54.6	55.3	4.0	19.1	18.3	18.7	2.9	3	5.0	5.3	4.7	5.0
4	COA07365-4RY	54.7	53.2	53.9	2.3	21.2	21.6	21.4	3.2	2	5.0	6.2	5.0	5.6
5	Yukon Gold	53.8	54.0	53.9	3.5	15.9	26.7	21.3	11.9	3	5.0	5.4	4.6	5.0
6	A02267-1Y	57.1	54.7	55.9	3.3	25.8	42.5	34.1	17.2	1	3.1	4.8	4.0	4.4
7	A05182-7RY	59.6	59.5	59.5	3.2	19.0	24.6	21.8	5.6	3	4.7	4.7	4.5	4.6
8	POR07PG20-2	48.3	47.0	47.6	2.5	11.2	20.6	15.9	9.5	4	5.0	5.7	4.5	5.1
9	POR07PG3-1	53.4	51.5	52.5	2.3	23.7	29.1	26.4	6.4	2	4.1	4.6	4.4	4.5
10	NDA081451CB-1CY	56.1	55.5	55.8	1.7	20.6	24.5	22.6	6.4	2	5.0	5.7	4.3	5.0
	*LSD 0.05 **			*1.9*	*1.5*			*2.7*	*3.6*			*1.6*	*1.0*	
	Average	55.2	54.4	54.8	2.7	19.6	25.3	22.4	7.1	3	4.7	5.5	4.6	5.0

*Differences between clones equal to or greater than the LSD 0.05 are significant.
SFA 1 (lightest) to 5 (darkest).

PUBLICATIONS 2014/2015

Wohleb, CH, Knowles, NR and MJ Pavek. 2015. Plant Growth and Development. *In* The Potato Botany, Production and Uses, DA Navarre and MJ Pavek ed., 1st edition, CABI Press (invited chapter) ch 5 pp. 64-82 (in press).

Green, A.R., Nissen, M.S., Kumar, G.N.M., Knowles, N.R., and ChulHee Kang. 2013. Characterization of *Solanum tuberosum* multicystatin and significance of core domains. Plant Cell 25:5043-5052.

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ABSTRACTS, PRESENTATIONS & REPORTS 2014

Knowles, N.R., M.J. Pavek, and L.O. Knowles. 2015. Nitrogen modulates physiological maturity and tuber N content to affect postharvest processing and nutritional qualities. Proceedings of the 98th Annual Meeting of the Potato Association of America. Am. J. Pot. Res (in press).

Knowles, N.R. and L.O. Knowles. 2015. Sprout inhibition by α,β-unsaturated aliphatic carbonyls – discovery, chemistry and physiological responses. Proceedings of the 98th Annual Meeting of the Potato Association of America. Am. J. Pot. Res (in press).

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Novy, R., J. Whitworth, J. Stark, B. Charlton, S. Yilma, V. Sathuvalli, N.R. Knowles, M. Pavek, R. Spear, T. Brandt, N. Olsen, M. Thornton, C. Brown, and J. Debons. 2015. A02507-2LB and A03158-2TE: Promising breeding clones from the Northwest (Tri-State) Potato Variety Development Program. Am. J. Pot. Res (in press).

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Knowles, N.R. and L.O. Knowles. 2014. Managing physiological age and productive potential of seed potatoes. International Potato Technology Expo, February 21-22, Charlottetown, PEI, Canada (invited speaker).

Kumar, G.N.M. and N.R. Knowles. 2014. Wound response is activated in tubers infected with zebra chip. Proceedings of the 97th Annual Meeting of the Potato Association of America. Am. J. Pot. Res 91:51-52.

Knowles, N.R., N. Fuller and L.O. Knowles. 2014. Storability and processing quality of new clones and cultivars. Cultivar Performance Workshop, Annual Washington and Oregon Potato Conference, Jan. 27-30, Kennewick, WA.

Knowles, N.R., M.J. Pavek, N. Fuller and L.O. Knowles. 2014. Post harvest quality of new clones and cultivars. *In* Washington State Potato Commission Progress Reports for the year 2013, 22 pages.

Knowles, N.R., L.O. Knowles, G.N.M. Kumar, M.J. Pavek. 2014. Developmental profiles and physiological processes affecting quality of seed and processing potatoes. *In* Washington State Potato Commission Final Reports for the year 2013, 25 pages.

Annual Progress Report – January 2015

TITLE: Development of Molecular Markers to Quantify Resistance Gene Dosage in Potato

PERSONNEL: Joseph Kuhl (UI), Rich Novy (USDA, ARS), Jonathan Whitworth (USDA, ARS), Sagar Sathuvalli (OSU), Solomon Yilma (OSU)

REPORTING PERIOD: January 2015

ACCOMPLISHMENTS/RESULTS:
Procedure 1: Identify CAPS markers in the literature linked to genes of interest, *Ry*$_{adg}$, *Ry*$_{sto}$, *Ry-*$_{fsto}$, *Rx1*, and *Gpa2*. Reproduce CAPS results in a small number of lines and clone fragments from resistant and susceptible lines. Sequence cloned fragments. Use aligned sequences to design PyroMark assays to detect resistant allele single nucleotide polymorphism.

Progress: The cloning and sequencing of CAPS markers in the regions of *Ry*$_{adg}$, *Ry*$_{sto}$, *Rx1*, and *Gpa2* has been completed for the CAPS markers initially identified. These sequences have been used to develop pyrosequencing markers assays for allele dosage determination. Unfortunately PCR optimization and initial testing of pyrosequencing assays has not progressed as quickly as planned. The presence of secondary PCR fragments and sub-optimal allele detection with pyrosequencing has required new assays to be developed and tested. The development and testing of additional assays has required additional time prior to assay validation (Procedure 2 below) using segregating populations. Additional fragments from all the gene regions (*Ry*$_{adg}$, *Ry*$_{sto}$, *Rx1*, and *Gpa2*) have been sequenced to enhance our understanding of the regions after the first pyrosequencing assays could not be optimized. This data has been used to generate new pyrosequencing assays. A new strategy using nested PCR has been initiated for *Rysto* and *Rx1/Gpa2*. The idea is to amplify a large region (thousands of nucleotides) surrounding the resistance genes, and use that PCR product as template for primers closely flanking the pyrosequencing target area.

Procedure 2: Optimize PCR conditions for PyroMark assay. Validate markers on progeny from a segregating population, test several populations if possible. If necessary redesign primers, optimize and retest with segregating popultions.

Progress: A protocol has been designed for *Ry*$_{adg}$ that appears to accurately detect dosage in a limited number of individuals. The next step is to test this pyrosequencing protocol on additional progeny from multiple populations. Advances have been also been made with the protocol for *Rx1/Gpa2*. We are close to generating PCR products from the *Rx1/Gpa2* region that are of sufficient quantity and quality to move to pyrosequencing. If these results can be confirmed with replication the *Rx1/Gpa2* assay can also be moved to testing with pyrosequencing. Work is continuing to optimize assays for *Ry*$_{sto}$. As new assays are designed PCR optimization is being initiated. Validation of assays will occur after assays past the initial testing phase.

PUBLICATIONS:
N/A

PRESENTATIONS & REPORTS:
N/A

Annual Progress Report
Northwest Potato Research Consortium

TITLE: Breeding for Quality, Disease Resistance, and Yield in Potato

PERSONNEL: Jeff Stark: Research Agronomist, Univ. of Idaho
Rich Novy: Breeder / Geneticist, USDA-ARS
Jonathan Whitworth: Plant Pathologist, USDA-ARS

REPORTING PERIOD: January 1, 2014 to December 31, 2014.

ACCOMPLISHMENTS:

Release documents are being prepared for A01010-1, A02507-2LB, A02062-1TE and A03158-2TE, pending final approval from the Tri-State Committee. A01010-1 is a high yielding, late season russet selection with excellent culinary quality for the fresh market and good resistance to blackspot bruise and hollow heart. This selection is also being evaluated by industry collaborators for use in producing fresh-cut fries. A02507-2LB is a low acrylamide selection with excellent processing quality. It also has resistance to a wide range of diseases including late blight, early blight, Verticillium wilt, PVY, black dot, and corky ringspot. A02507-2LB has performed well in the National Fry Processing Trial and seed production has been fast-tracked to facilitate commercial field evaluations in 2016. A03158-2TE was a top yielding selection in both the early and late regional trials with excellent culinary quality and shows considerable promise for fresh pack production and early harvest processing. A02062-1TE is a very attractive russet clone with a high percentage of US No. 1's and has performed well in the early regional trial as well as in trials in other locations in North America.

The primary goal of the potato breeding program is to develop and commercialize new potato varieties to benefit all segments of the potato industry. These new varieties that are being prepared for release in 2015 have improved yield, processing quality, and greater genetic resistance to major pests and diseases, as well as higher levels of resistance to stresses than current standard varieties. In addition, they all exhibit increased nutrient use efficiency and higher tuber quality than the industry standards. Some also have significantly higher levels of vitamin C and protein and lower levels of acrylamide. These attributes will allow producers to grow potatoes more efficiently with less fertilizer, pesticides and water, while providing consumers with a more nutritional food source.

RESULTS:

In 2014, potato breeding clones, including over 100,000 single hills (1st field generation clones), were planted, maintained, and harvested at three seed sites, with advanced breeding clones being evaluated in 32 replicated field trials in six locations across southern Idaho for their potential as new potato varieties. Particular emphasis was placed on selecting breeding clones with adaptation to local conditions, dual utility with use in both fresh and processing markets, production efficiency, and multiple disease resistances. In 2014, 36 entries from the Aberdeen program were entered in advanced agronomic and processing trials in the Tri-State and Western Regional to assess their performance relative to industry standards. We had seven russet entries in the Western Regional Trials in 2014: A02424-83LB, A02507-2LB, A03158-2TE, A02062-1TE, A03921-2, A06021-1T, and A06084-11. We also had 15 russet varieties in the early and late season Tri-State Variety Trials, 13 selections in the Tri-State and Western Regional Specialty Trials, and 1 entry in the Western Regional Chipping Trial. Sixteen advanced breeding clones and varieties from our program were also entered into the 2014 National Fry Processing Trial (NFPT) which seeks to identify processing varieties having low acrylamide that could be rapidly adopted by the U.S. potato processing industry. In addition, the breeding program is progressing in developing germplasm with genetic resistance to PVY, PVX, and PLRV, PMTV, late blight (foliar and tuber), zebra chip, nematodes, corky ringspot and zebra chip disease. New varieties will continue to be released in cooperation with the University of Idaho Nuclear Seed Program, private seed growers in the state, and the processing and fresh pack industries.

Additional studies were conducted in 2014 designed to compare nitrogen use efficiency of 5 new releases from the breeding program with that of Russet Burbank. The N response results show that the potential for improving the efficiency of N fertilizer use through the use of these newer potato varieties is substantial for each of the new selections evaluated in the trial, ranging from 10-35%. Reducing fertilizer applications per unit of yield produced would not only provide a considerable economic benefit to growers but would also provide environmental benefits and contribute significantly to the sustainability of potato production systems. Additional studies were conducted to determine optimal seed management practices, seed piece spacing, and vine kill timing for several of the advanced clones in the regional trial.

PUBLICATIONS:

Forty cultivars have been released with cooperators in the Tri-State Program. Thirty-two of these have been described in journal articles in the American Journal of Potato Research. Project leaders routinely publish popular articles and extension bulletins in order to transfer information about new varieties to the potato industry. Below is a list of recent publications:

Novy, R.G., J.L. Whitworth, J.C. Stark, B.A. Charlton, S. Yilma, N.R. Knowles, M.J. Pavek, R.R. Spear, T.L. Brandt, N. Olsen, M. Thornton, C.R. Brown. 2014. Teton Russet: An Early-Maturing, Dual-Purpose Potato Cultivar Having Higher Protein and Vitamin C Content, Low Asparagine, and Resistances to Common Scab and Fusarium Dry Rot. American Journal of Potato Research 91:380-393.

Whitworth, J.L., R. G. Novy, J. C. Stark, S.L. Love, M.K. Thornton, B.A. Charlton, S. Yilma, N. R. Knowles, M. J. Pavek, X. Wang , J.J. Pavek. 2014. Huckleberry Gold: A specialty market potato with purple skin, yellow flesh, high tuber antioxidants, and resistance to potato cyst nematode (H1) and Potato virus X (Nb and Rx1). American Journal of Potato Research 91: 447-458.

Diaz-Montano, J., B.G. Vindiola, N. Drew**,** R.G. Novy, J. C. Miller, and J.T. Trumble. 2014. Resistance of selected potato genotypes to the potato psyllid (Hemiptera: Triozidae). *American Journal of Potato Research.* 91:363–367.

Shrestha,D., E.J.Wenninger, P.J.S. Hutchinson, J.L. Whitworth, S. Mondal, S.D. Eigenbrode, and N.A. Bosque-Perez. Interactions among potato genotypes, growth stages, virus strains, and inoculation methods in the potato virus y and green peach aphid pathosystem. Environmental Entomology 43[3], 662-671. 2014.

Brandt, T., N. Olsen, J. Stark, R. Novy and J. Whitworth. Storage Management of Teton Russet Potatoes. University of Idaho CIS (in press).

PRESENTATIONS AND REPORTS:

Presentations

Stark, J. Idaho Potato Breeding Program Review. Idaho Seed Potato Grower's Seminar. Jan. 21, 2014. Pocatello ID

Stark, J. Moving Up the Learning Curve on New Potato Varieties. University of Idaho Potato Conference. Jan. 22, 2014, Pocatello, ID.

Stark, J. University of Idaho Potato Variety Development Program. University of Idaho Potato Conference. Jan. 22-23, 2014, Pocatello, ID.

CSI Idaho: New Technologies for Disease Identification. Presented by Whitworth at the Univ. of Idaho Potato Conference, Pocatello, ID, Jan. 22, 2014

Update on the National Fry Processing Trial and SCRI Acrylamide Reduction Project. Presentation given by Novy at the 45th and 46th Annual Idaho Potato Conferences. 1/22/13 and 1/22/2014.

Stark, J.. University of Idaho Potato Breeding Report. Tri-State Technical Committee Meeting and WERA 27 Meetings. Jan. 27, 2014.

Stark, J. Critical Decision Points for Managing New Potato Varieties. Washington-Oregon Potato Conference. Jan, 28, 2014, Kennewick, WA.

Recognizing and Managing Bacterial Ring Rot. Presentation given by Whiworth via webinar from Aberdeen, ID at UC/OSU Klamath Basin Potato Seminar, March 5, 2014.

One presentation of breeding and variety development research conducted at Aberdeen and subsequent tour of facilities was given to five Russian potato growers at the request of an ID industry representative who is seeking to export seed to Russia (March 2014).

Assessing Potato virus Y resistance in advanced breeding lines and new cultivars from U.S. potato breeding programs. Presented by Whitworth at Potato Association of America annual meeting, Spokane, WA, July 30, 2014.

A02507-2LB and A03158-2TE: Promising breeding clones from the Northwest (Tri-State) Potato Variety Development Program. Presentation given by Novy at the 98th Annual Meeting of the Potato Association of America, Spokane, WA. 7/31/2014.

Reports

Development of cold chipping varieties for the western US. Research Report to the U.S. Potato Board/Snack Food Association, 12 p.

Potato Variety Development and Improvement in the Northwest, Annual Report to NIFA 120 p.

Final Report

TITLE: Selecting Specialty Potato Varieties

PERSONNEL: Mike Thornton, Project Leader, Parma
Ransey Portenier, Research Technician, Parma
Oksana Adams, Research Assistant, Parma
Jeff Stark, Research Agronomist, Idaho Falls
Peggy Bain, Research Technician, Aberdeen

REPORTING PERIOD: July 1, 2014 to January 1, 2015

ACCOMPLISHMENTS:
For the past six years this project has led the evaluation of new specialty breeding lines from ID, OR and WA. These trials are conducted at two locations in ID, and the data is summarized along with similar trials in OR and WA. When combined with the subsequent two years of evaluations in the western regional trials, the results provide a more robust data set for making decisions on release and naming of new specialty cultivars to be marketed through PVMI. A recent example of the outcome of this project is the release of Huckleberry Gold, which is a unique variety with bright purple skin and dark yellow flesh.

RESULTS:
Objective 1- Identify and completely evaluate within Idaho growing areas tri-state potato germplasm with specialty characteristics.

Field Evaluations - Seed of two standard potato cultivars and 10 breeding lines were obtained from Rich Novy (USDA/ARS, Aberdeen) and from Brian Charlton (OSU, Klamath Falls). This seed was used in replicated trials at both the Parma and Aberdeen R&E Centers. The seed was cut, organized into a randomized, four-replicate trial, and planted at the Aberdeen and Parma R & E Centers.

Chieftain, A05180-3PY, A02267-1Y, A05182-7RY, NDA081451CB-1CY and A06293-3Y all produced total yields above 400 cwt/acre at Parma (Table 1). Many of these same breeding lines were also among the highest yielding selections at Aberdeen (Table 2). Chieftain, and Yukon Gold had the highest proportion of tubers over 10oz at Parma, while Chieftain and NDA050237B-1R had the highest proportion of large tubers at Aberdeen. Tubers above 10 oz are not generally desirable for the specialty market. A premium yield category (2-6oz) was added to capture the perceived optimum size of specialty tubers for fresh market. NDA050237B-1R, A05180-3PY, COA07365-4RY, A02267-1Y, A05182-7RY, NDA081451CB-1CY and A06336-5Y tended to have the highest premium yield at both locations (Tables 1 and 2).

Specific gravity ranged from 1.058 to 1.084 at Parma, and from 1.057 to 1.082 in Aberdeen (Tables 1 and 2). NDA050237B-1R had the lowest specific gravity at both locations, while Yukon Gold was highest. Specific gravity greatly effects cooking quality, and this information should be used with the culinary evaluations reported in the WSU cultivar report to make decisions about appropriate uses for these new potential varieties.

Most of the entries showed very few external and internal defects. The exceptions were Yukon Gold, A02267-1Y, POR07PG20-2 for scab, Yukon Gold for hollow heart, and A05180-3PY for growth cracks (Tables 1 and 2).

Table 1. Yield and quality characteristics of two standard specialty potato cultivars and ten breeding lines grown in Parma, ID during 2014. [1]

Cultivar/ Breeding line	Total Yield	No. 1 Yield	Premium Yield (2-6oz)	Yield >10 oz	Specific Gravity	Maturity	Scab	Hollow Heart (%)	Growth Crack
Chieftain	414	373	107	117	1.067	3.5	5.0	0.0	4.5
NDA050237B-1R	328	287	144	49	1.058	3.0	5.0	0.0	4.4
A05180-3PY	466	393	198	30	1.067	4.0	5.0	2.5	3.3
COA07365-4RY	303	281	184	9	1.072	2.0	5.0	0.0	5.0
Yukon Gold	385	350	60	170	1.084	3.0	5.0	12.5	4.8
A02267-1Y	456	391	283	7	1.067	4.0	5.0	2.5	5.0
A05182-7RY	470	388	296	10	1.073	4.0	5.0	5.0	5.0
POR07PG20-2	286	213	184	2	1.062	2.0	2.6	0.0	5.0
POR07PG3-1	331	284	172	18	1.072	2.0	5.0	2.5	5.0
NDA081451CB-1CY	451	400	268	14	1.083	3.5	5.0	0.0	5.0
A06293-3Y	446	417	296	3	1.060	3.0	5.0	0.0	4.8
A06336-5Y	353	289	258	0	1.066	2.0	4.3	0.0	4.9

[1] Yields are reported in cwt/A. Merit score is based on appearance characteristics and rated on a 1-5 scale, where 5 = exceptionally good. Maturity is rated 1-5, where 5 = very late. Scab, growth cracks (GC), and second growth (Knobs) are rated 1-5, where 5 = none. Hollow heart (HH) is reported as the percentage of 10 tubers showing the defect.

Table 2. Yield and quality characteristics of two standard specialty potato cultivars and nine breeding lines grown in Aberdeen, ID during 2014. [1]

Cultivar/Breeding line	Total Yield	No. 1 Yield	Premium Yield (2-6oz)	Yield > 10 oz	Specific Gravity	Maturity	Scab	Hollow Heart (%)	Growth Crack
Chieftain	463	443	96	155	1.072	4.0	5.0	0.0	4.8
NDA050237B-1R	472	438	165	126	1.057	3.5	4.8	2.5	5.0
A05180-3PY	492	438	211	58	1.070	3.5	3.8	0.0	3.0
COA07365-4RY	397	334	310	0	1.072	2.0	4.0	0.0	5.0
Yukon Gold	297	265	110	49	1.082	1.0	1.3	2.5	5.0
A02267-1Y	442	382	262	17	1.067	3.0	2.0	0.0	5.0
A05182-7RY	312	238	196	1	1.067	4.5	3.5	0.0	5.0
POR07PG20-2	226	109	104	0	1.055	2.0	4.0	0.0	5.0
POR07PG3-1	302	236	186	3	1.068	2.0	3.0	0.0	5.0
NDA081451CB-1CY	546	451	379	5	1.080	3.5	3.3	0.0	5.0
A06336-5Y	403	299	284	1	1.067	2.0	5.0	0.0	5.0

[1] Yields are reported in cwt/A. Merit score is based on appearance characteristics and rated on a 1-5 scale, where 5 = exceptionally good. Maturity is rated 1-5, where 5 = very late. Scab, growth cracks (GC), and second growth (Knobs) are rated 1-5, where 5 = none. Hollow heart (HH) is reported as the percentage of 10 tubers showing the defect.

Biochemical Assessments- The cultivars and breeding lines showed a range of biochemical characteristics, such as solids, antioxidant levels, glycoalkaloids, and Vitamin C content (Table 3). None of the glycoalkaloid levels were high enough to cause concern, while POR07PG20-2 showed exceptional antioxidant concentration and Yukon Gold was noteworthy for high Vitamin C content.

Table 3. Biochemical characteristics of two standard specialty potato cultivars and ten breeding lines grown in Parma, ID during 2014.

Clone	Solids Oven Dry (%)	Antioxidants (ug/g FW) [1]	Glycoalkaloids (mg/100 g FW)	Vitamin C (mg/100 g FW)
Chieftain	19.2	465.5	1.55	29.4
NDA050237B-1R	18.6	343.3	2.52	23.9
A05180-3PY	18.8	323.6	0.28	32.4
COA07365-4RY	17.5	276.3	1.71	34.1
Yukon Gold	18.4	371.4	2.87	46.8
A02267-1Y	17.6	360.4	1.57	30.7
A05182-7RY	18.5	341.2	1.85	28.3
POR07PG20-2	18.7	698.5	1.05	33.1
POR07PG3-1	17.1	294.9	1.60	31.3
NDA081451CB-1CY	18.0	296.0	2.16	36.7
A06336-5Y	23.4	246.5	0.83	32.6

[1] Higher numbers for antioxidant capacity indicate potentially greater health benefits.

Storage Evaluations- Skin color and appearance were rated at harvest, and again after several months storage at 45 ^{o}F. Tubers were also hand brushed during the November evaluation to gauge how they might look after running through a fresh pack facility (Figure 1).

Figure 1. Post-storage ratings for two of specialty potato cultivars grown in Parma, ID during 2014. Illustrates the improvement in appearance after brushing seen for some entries.

Most entries had very good skin appearance in October (2 months after harvest), but appearance declined between October and November (Table 4). The exceptions were the two POR entries, which had very poor appearance on both dates due to excessive sprouting and shriveling during storage. Brushing improved the appearance of most entries, especially those with dark skin color.

Table 4. Post-storage ratings and dormancy length for two standard specialty potato cultivars and ten breeding lines grown in Parma, ID during 2014.

Clone	Appearance Oct 8[1]	Appearance Nov 14[1]	Appearance after brushing[1]	Dormancy length (days)
Chieftain	4.5	3.0	3.5	93
NDA050237B-1R	4.0	4.0	4.0	79
A05180-3PY	4.0	4.0	5.0	79
COA07365-4RY	3.0	2.0	3.0	64
Yukon Gold	3.0	2.0	2.5	64
A02267-1Y	3.0	4.0	5.0	64
A05182-7RY	4.5	3.0	3.0	93
POR07PG20-2	1.0	1.0	1.0	0*
POR07PG3-1	1.0	1.0	3.0	0*
NDA081451CB-1CY	2.0	2.0	2.5	21
A06293-3Y	4.5	3.0	3.5	93
A06336-5Y	4.0	2.0	3.0	79

[1] Rate on a 1 = very poor to 5 = very good scale.
* Some tubers were sprouted at harvest.

Objective 2- Cooperate with the Pacific Northwest variety development program to identify specialty breeding lines with potential for release.

Nine of the breeding lines evaluated in 2014 have been in the specialty trial for at least two years. Total yield, premium yield and merit scores for those lines and two standard cultivars are summarized in tables 5 and 6. The best performing breeding lines in these tables should be considered for advancement to the Western Regional trial, with the balance discarded due to poor performance. A05182-7RY and NDA081451CB-1CY have been the two lines with consistently high merit scores, while POR07PG20-2 has not performed well at either location.

Table 4. Compilation of two years of data for breeding lines grown in Parma as part of the specialty potato trial 2013-2014.

Cultivar/Breeding line	2013			2014		
	Total Yield	Premium Yield (2-6oz)	Merit	Total Yield	Premium Yield (2-6oz)	Merit
Yukon Gold	500	114	2.6	385	60	2.9
Chieftain	740	219	2.5	414	107	3.0
NDA050237B-1R	601	219	2.8	328	144	3.4
A05180-3PY	705	289	3.1	466	296	2.7
COA07365-4RY	579	369	3.4	303	184	2.9
A02267-1Y	779	344	3.1	456	283	3.8
A05182-7RY	608	293	4.0	470	296	3.9
POR07PG20-2	429	245	2.8	286	184	2.3
POR07PG3-1	596	329	3.3	331	172	2.5
NDA081451CB-1CY	805	519	3.0	451	268	4.1
A06293-3Y	643	379	3.3	446	296	4.0

[1] Yields are reported in cwt/A. Merit score is based on appearance and agronomic characteristics and rated on a 1-5 scale, where 5 = exceptionally good.

Table 5. Compilation of multiple years of data for breeding lines grown in Aberdeen as part of the specialty potato trial 2013-2014.

Cultivar/Breeding line	2013			2014		
	Total Yield	Premium Yield (2-6oz)	Merit	Total Yield	Premium Yield (2-6oz)	Merit
Chieftain	461	122	3.0	463	96	2.3
NDA050237B-1R	345	177	4.0	472	165	3.0
A05180-3PY	435	146	2.5	492	211	2.0
COA07365-4RY	260	195	4.0	397	310	2.8
Yukon Gold	280	134	2.7	297	110	1.8
A02267-1Y	382	225	2.5	442	262	2.0
A05182-7RY	415	258	3.9	312	196	3.8
POR07PG20-2	112	40	2.5	226	104	2.7
POR07PG3-1	297	187	3.3	302	186	2.7
NDA081451CB-1CY	583	378	4.0	546	379	3.3

[1] Yields are reported in cwt/A. Merit score is based on appearance and agronomic characteristics and rated on a 1-5 scale, where 5 = exceptionally good.

PUBLICATIONS:

Whitworth, J.L., R.G. Novy, J.C. Stark, S.L. Love, M. Thornton, B.A. Charlton, S. Yilma, N.R. Knowles, M.J. Pavek, X. Wang and J.J. Pavek. 2014. Huckleberry Gold: A specialty market potato cultivar with purple skin, yellow flesh, high tuber antioxidants, and resistance to potato cyst nematode (H1) and potato virus X (Nb and Rx1). *American Journal of Potato Research* 91:447-458.

PRESENTATIONS & REPORTS:

Thornton, M. Specialty varieties. Potato Variety Selection Advisory Committee meeting. Aberdeen, ID, March 5, 2014.

TITLE: CONSUMER-ORIENTED POTATOES: DEVELOPING TRISTATE VARIETIES WITH SUPERIOR APPEARANCE AND NUTRITIONAL VALUE

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REPORTING PERIOD: 2014

INTRODUCTION:

Since the mid-90s consumption of potatoes has been steadily declining and reached historic lows. The rationale for this research remains the fact that consumer demand is a key component of grower profitability. Therefore it is important that research be undertaken that focuses on consumer-desired traits. Most potato research in the Northwest is production oriented, focusing on important issues such as disease and crop management. While this generates valuable information for growers, it does little to appeal to consumers (the end user) or sway nutritionists (the opinion makers). An ideal approach for research aimed at enhancing grower profitability would balance production- and consumer-oriented research.

Criticism about potatoes from some nutritionists can cause the public to perceive potatoes as unhealthy, leading to decreased sales. Per capita consumption is about 25 lbs per person less today than ten years ago. In addition to the ongoing debate about the nutritional value of potatoes that has been going on for about a decade, there are two newer developments involving nutrition that present both opportunities and risk for the industry.

Popular dietary trends come and go, but in contrast to the ever present, but short-lived dietary fads, the sheer magnitude of the obesity epidemic may be a game changer in terms of potential dietary shifts and regulatory changes. In 2013 the American Medical Association classified obesity as a disease. 155 million U.S. adults, roughly 50% of the population, are overweight or obese. The health cost of obesity to the U.S. economy is estimated to be in the hundreds of billions annually. Moreover, the obesity epidemic has become a global occurrence, generating global debate. The scale and urgency of the obesity surge suggests government regulators and health-professionals are likely to increasingly target foods perceived to be unhealthy.

New cultivars are being developed with traits important for production and processing, such as improved disease resistance. It is critical that these future cultivars also have desirable nutritional traits that preserve, protect and maximize the nutritional content of potatoes. Scientific evidence supporting the healthfulness of potatoes can help protect potatoes from being easy targets, and at the same time positively influence both the public and health-professionals. For years, potatoes were the single vegetable excluded from the WIC program, but Congress recently passed legislation to allow potatoes to be purchased within the WIC program. Research into the nutritional composition of potatoes and their role in health has been going on around the country for the last several years. Such research scientifically documented the nutritional content of potatoes and may have provided scientific support for the inclusion of potatoes in school lunches and WIC.

Unfortunately, some have the misperception that potatoes provide "empty calories." In actuality, potatoes are a nutrient-dense food, not an "empty calorie food." This is clearly seen if one compares the amounts of various vitamins, minerals and phytonutrients provided per calorie of potato. Nutrient-dense foods provide an equal or greater amount of nutritional value as they do calories. There is evidence that the public is placing increased emphasis on the perceived nutritional content of foods. For example a Dec 8th, 2014 USA Today article titled 'McDonald's same-store sales get fried' stated **"***Shares tumbled nearly 4% Monday to $92.61 after the fast-food giant posted its biggest domestic same-store sales drop in more than a decade. McDonald's faces a number of near-term headaches as CEO Don Thompson remains under intense pressure to right the ship. Most critical: younger customers attracted to the better-for-you, customized kinds of offerings from rivals such as Chipotle and Panera. As the USA experiences a "sea change" in fast-food consumption...*"

Potatoes are consumed on a far greater scale than just those sold in quick service restaurants and there are indications that the obesity epidemic is triggering major shifts in consumer eating habits across the board, with a greater emphasis on perceived "healthy" fare than ever before. This all emphasizes the importance of nutrition for the potato industry. Research by our group and others can help ensure potatoes remain a nutrient dense food and support a key role for potatoes in providing nutrition and global food security in the coming years. In our view, it is important to continue to develop potato's nutritional potential. Such an objective has not been a primary goal of breeding programs in the developed world. Limitations for developing higher-phytonutrient potatoes are lack of knowledge about the mechanisms that control tuber phytonutrient content and quick methods to screen germplasm for phytonutrient content, as breeding programs can produce many more crosses than can screened for nutritional content.

RESULTS

Pending data: *in addition to the research below, this project is in progress and more data will be forthcoming. It took several months to freeze dry all the samples from the fall harvest. These samples are now in the process of being analyzed. We also have an ongoing cold storage study with tubers from the fall harvest that will be extensively analyzed once the final storage timepoint is reached.*

High antioxidant white potatoes: because white potatoes are consumed in far greater quantities than yellow-, red- or purple-flesh potatoes, a goal is to develop a higher-antioxidant white potato. Despite evaluating over hundreds of different types of white potatoes for antioxidants over the last several years, we've yet to find any that have the amounts found in red/purple types. Therefore finding a white breeding line with higher antioxidants will likely require screening a large number of lines to improve the odds. For it to be feasible to screen lots of lines fast methods are needed, otherwise it is too labor intensive to do such screening. We are evaluating possible fast, crude methods. An approach that appears to have promise is using a leaf press to extract the juice from tuber slices. The juice is then assayed in 96-well microplates. We are continuing to tweak this approach, and as we accumulate more data, we can better evaluate its merits. Normally a breeding line will not be evaluated for phytonutrient content until many years into its development, but our screening has potential to identify and fast-track a promising antioxidant line earlier in its development. While screening this germplasm for antioxidants, it is possible to evaluate certain other criteria for relatively little additional effort, so we also measure total phenolics, polyphenol oxidase activity and browning. **Table 1** shows the results of screening over 230 Tri-State single hill breeding lines from Aberdeen, ID for antioxidant activity [Total phenolics (TP) and FRAP] and polyphenol oxidase enzyme activity. Tuber browning or blackening can be caused by various factors and is influenced by both genotypical and environmental factors. The mechanism(s) that control tuber bruising are not fully understood, but include enzymes, minerals and tuber metabolites including phenolic compounds. One key enzyme is polyphenol oxidase (PPO), an enzyme that has a positive role in the tubers ability to resist disease and stress, but under some conditions leads to tuber discoloration. This approach using tuber juice should be considered a preliminary screen, because it is much faster, but not as quantitative as slower assays. This was considered a worthwhile tradeoff to allow screening more material, keeping in mind the methods limitations. A10068-3, A10681-3 and A10182-10 showed among the highest antioxidant activities of all lines examined, and among these lines may be the most likely candidates to be higher in antioxidants because they tested high when measured in both the TP and FRAP assays. Among all lines, TP ranged from 0.99 to 2.38, whereas FRAP ranged from 0.21 to 1.24. We suspect the TP data, which suggests about a 2.4 fold difference in antioxidant capacity among the lines, may be more robust than the FRAP data, which suggests a six-fold difference. However, using the two different antioxidant methods offers a useful redundancy for this high-throughput approach, without adding much additional labor. PPO activity ranged from non-detected/trace amounts to 3.8 relative units among the lines. PPO activity is involved in bruising and browning, but other mechanisms are also involved. Teasing out how all the various factors that can influence bruising/browning interact is complicated and not yet fully understood. No correlation was observed between PPO activity and the amount of total phenolics present.

Table 1. The results of screening over 230 Tri-State single hill breeding lines from Aberdeen, ID. Total phenolics (TP) is a measure of the amount of antioxidant capacity and besides polyphenols and also detects vitamin C. FRAP is another type of antioxidant data and should correlate with total phenolics. PPO measures polyphenol oxidase enzyme activity, which can affect bruising. Activity was typically measured in 10 microliters of tuber juice. These are all relative amounts and are only applicable for comparing among the different lines in the Table.

Table 1. Polyphenol oxidase, total phenolics (TP) and FRAP antioxidant activity in single hill lines from Aberdeen, ID.

	PPO	TP	FRAP		PPO	TP	FRAP
A09079-1	1.1 ± 0.11	1.5 ± 0.10	0.530 ± 0.042	A10751-1	1.5 ± 0.25	1.4 ± 0.31	0.44 ± 0.139
A09079-3	2.8 ± 0.52	1.8 ± 0.25	0.693 ± 0.094	A10751-2	0.9 ± 0.39	1.7 ± 0.09	0.48 ± 0.032
A09079-4	2.3 ± 0.08	1.6 ± 0.08	0.589 ± 0.101	A10751-3	1.1 ± 0.17	1.4 ± 0.03	0.38 ± 0.035
A09096-1	1.8 ± 0.21	1.5 ± 0.04	0.468 ± 0.037	A10756-1	3.6 ± 0.44	1.4 ± 0.04	0.59 ± 0.047
A09176-1	2.2 ± 0.06	1.5 ± 0.06	0.723 ± 0.052	A10760-3	1.5 ± 0.35	1.3 ± 0.14	0.36 ± 0.037
A10063-1	2.4 ± 0.08	1.5 ± 0.19	0.589 ± 0.131	A10766-6	3.7 ± 0.36	1.9 ± 0.36	0.86 ± 0.051
A10068-1	3.3 ± 0.25	1.7 ± 0.17	0.656 ± 0.121	A10791-1	0.5 ± 0.03	1.7 ± 0.06	0.39 ± 0.023
A10068-2	2.3 ± 0.21	1.6 ± 0.01	0.602 ± 0.057	A10906-1	0.8 ± 0.24	1.5 ± 0.17	0.52 ± 0.024
A10068-3	3.2 ± 0.73	2.2 ± 0.10	0.946 ± 0.072	A10906-2	1.3 ± 0.04	1.2 ± 0.13	0.37 ± 0.081
A10068-4	1.9 ± 0.12	2.0 ± 0.02	0.761 ± 0.140	A10921-1	1.5 ± 0.40	1.1 ± 0.09	0.40 ± 0.073
A10068-6	2.6 ± 0.02	2.1 ± 0.16	0.708 ± 0.020	A10921-2	0.4 ± 0.06	1.3 ± 0.03	0.36 ± 0.014
A10071-1	2.3 ± 0.13	1.7 ± 0.37	0.596 ± 0.132	A10934-4	2.1 ± 0.78	1.2 ± 0.17	0.30 ± 0.016
A10071-2	0.9 ± 0.56	1.7 ± 0.07	0.541 ± 0.019	A10934-7	1.2 ± 0.15	1.1 ± 0.19	0.33 ± 0.047
A10071-3	1.2 ± 0.01	2.1 ± 0.03	0.658 ± 0.026	A10935-1	1.6 ± 0.14	1.5 ± 0.05	0.44 ± 0.083
A10083-2	0.5 ± 0.03	1.6 ± 0.09	0.451 ± 0.035	A10936-8	0.8 ± 0.04	1.5 ± 0.16	0.58 ± 0.123
A10083-5	0.5 ± 0.14	1.7 ± 0.13	0.560 ± 0.015	A10943-5	1.5 ± 0.36	1.3 ± 0.03	0.35 ± 0.041
A10086-1	1.4 ± 0.52	1.5 ± 0.14	0.729 ± 0.019	A10943-6	0.8 ± 0.11	1.7 ± 0.25	0.39 ± 0.179
A10086-2	1.1 ± 0.11	1.7 ± 0.10	0.676 ± 0.122	A10944-7	1.4 ± 0.39	1.5 ± 0.03	0.42 ± 0.036
A10086-3	1.8 ± 0.13	1.5 ± 0.04	0.487 ± 0.028	A10946-2	1.5 ± 0.08	1.6 ± 0.35	0.38 ± 0.086
A10094-1	0.6 ± 0.07	2.0 ± 0.06	0.607 ± 0.032	A11216-1	1.4 ± 0.21	1.7 ± 0.08	0.48 ± 0.023
A10094-10	0.8 ± 0.63	1.7 ± 0.15	0.515 ± 0.029	A11230-2	2.0 ± 1.12	1.4 ± 0.15	0.52 ± 0.024
A10094-3	1.2 ± 0.08	1.4 ± 0.02	0.455 ± 0.011	A11230-4	2.8 ± 0.36	1.7 ± 0.12	0.50 ± 0.126
A10094-4	1.5 ± 0.60	1.7 ± 0.17	0.552 ± 0.045	A11238-1	0.9 ± 0.00	1.5 ± 0.02	0.47 ± 0.001
A10094-6	0.6 ± 0.02	2.0 ± 0.06	0.631 ± 0.038	A11238-2	1.6 ± 0.44	1.4 ± 0.05	0.50 ± 0.004
A10094-7	1.0 ± 0.10	1.8 ± 0.22	0.565 ± 0.077	A11238-3	1.0 ± 0.27	1.7 ± 0.29	0.50 ± 0.079
A10094-8	0.7 ± 0.04	2.0 ± 0.07	0.598 ± 0.011	A11247-1	1.8 ± 0.43	1.5 ± 0.43	0.69 ± 0.259
A10095-1	1.8 ± 0.87	1.7 ± 0.22	0.593 ± 0.070	A11248-2	2.0 ± 0.04	1.8 ± 0.31	0.65 ± 0.171
A10095-2	1.0 ± 0.26	1.9 ± 0.47	0.582 ± 0.153	A11248-4	0.8 ± 0.09	1.5 ± 0.03	0.48 ± 0.006
A10096-1	1.7 ± 0.05	1.6 ± 0.10	0.562 ± 0.019	A11248-5	1.8 ± 0.49	1.9 ± 0.18	0.76 ± 0.174
A10096-2	1.0 ± 0.27	1.5 ± 0.05	0.523 ± 0.022	A11248-6	1.6 ± 0.33	1.1 ± 0.02	0.46 ± 0.008
A10096-3	0.6 ± 0.10	1.3 ± 0.10	0.479 ± 0.055	A11251-1	1.3 ± 0.50	1.5 ± 0.15	0.57 ± 0.199
A10096-4	1.2 ± 0.18	1.2 ± 0.06	0.444 ± 0.014	A11251-2	1.7 ± 0.36	1.6 ± 0.20	0.42 ± 0.003
A10096-5	0.7 ± 0.40	1.8 ± 0.29	0.563 ± 0.151	A11256-4	1.4 ± 0.18	1.6 ± 0.10	0.60 ± 0.085
A10105-1	0.7 ± 0.42	1.5 ± 0.23	0.473 ± 0.044	A11256-7	3.1 ± 0.52	2.0 ± 0.24	0.74 ± 0.094
A10113-1	2.2 ± 0.38	1.8 ± 0.35	0.668 ± 0.172	A11256-8	1.2 ± 0.55	1.6 ± 0.32	0.86 ± 0.432
A10113-2	0.8 ± 0.15	1.4 ± 0.19	0.426 ± 0.060	A11267-1	2.4 ± 0.19	1.7 ± 0.16	0.48 ± 0.004
A10113-3	1.0 ± 0.03	2.1 ± 0.26	0.841 ± 0.097	A11267-2	1.5 ± 0.17	1.7 ± 0.02	0.58 ± 0.084
A10113-4	2.0 ± 0.13	1.5 ± 0.05	0.517 ± 0.023	A11267-3	2.1 ± 0.06	1.9 ± 0.04	0.61 ± 0.011
A10118-1	0.7 ± 0.00	1.3 ± 0.14	0.466 ± 0.015	A11267-4	2.3 ± 0.30	1.7 ± 0.01	0.46 ± 0.022
A10121-1	1.5 ± 0.53	1.8 ± 0.08	0.590 ± 0.028	A11281-1	1.2 ± 0.53	2.2 ± 0.51	0.65 ± 0.314
A10121-2	1.3 ± 0.10	1.6 ± 0.04	0.470 ± 0.030	A11737-2	1.1 ± 0.24	2.0 ± 0.59	0.66 ± 0.231
A10121-3	0.1 ± 0.03	1.8 ± 0.08	0.497 ± 0.011	A11737-4	1.7 ± 0.54	2.0 ± 0.14	0.94 ± 0.221
A10121-4	0.5 ± 0.09	1.6 ± 0.03	0.474 ± 0.019	A11741-2	1.9 ± 0.35	1.6 ± 0.04	0.45 ± 0.124
A10121-5	0.8 ± 0.44	1.6 ± 0.10	0.493 ± 0.021	A11741-3	0.8 ± 0.39	1.7 ± 0.14	0.46 ± 0.003
A10122-1	1.4 ± 0.13	1.3 ± 0.19	0.509 ± 0.083	A11750-1	1.4 ± 0.04	1.7 ± 0.09	0.56 ± 0.064
A10122-2	1.1 ± 0.31	1.4 ± 0.10	0.460 ± 0.058	A11756-7	0.7 ± 0.14	1.4 ± 0.06	0.42 ± 0.027
A10122-3	1.6 ± 0.25	1.8 ± 0.12	0.657 ± 0.018	A11850-2	0.6 ± 0.11	1.3 ± 0.16	0.39 ± 0.012
A10122-4	0.4 ± 0.47	1.3 ± 0.08	0.509 ± 0.033	A11853-1	2.2 ± 0.72	1.5 ± 0.27	0.61 ± 0.286
A10122-5	0.7 ± 0.11	1.5 ± 0.02	0.356 ± 0.094	A11853-2	1.1 ± 0.18	1.5 ± 0.13	0.54 ± 0.094
A10130-2	1.3 ± 0.22	2.2 ± 0.14	0.386 ± 0.038	A11853-4	2.4 ± 0.11	1.5 ± 0.12	0.54 ± 0.129
A10130-4	0.9 ± 0.60	1.6 ± 0.40	0.357 ± 0.117	A11871-1	nd	1.4 ± 0.05	0.35 ± 0.034
A10130-5	3.4 ± 0.67	1.8 ± 0.19	0.417 ± 0.114	A11888-1	0.3 ± 0.24	1.4 ± 0.16	0.40 ± 0.035
A10130-6	1.1 ± 0.69	1.9 ± 0.19	0.355 ± 0.102	A11928-3	1.0 ± 0.55	1.5 ± 0.37	0.51 ± 0.281
A10131-1	1.9 ± 0.08	1.5 ± 0.30	0.210 ± 0.026	A11928-4	0.8 ± 0.04	1.2 ± 0.18	0.40 ± 0.095

Table 1 cont.

	PPO	TP	FRAP		PPO	TP	FRAP
A10133-1	0.9 ± 0.71	1.5 ± 0.03	0.267 ± 0.019	A11941-18	2.4 ± 1.35	1.4 ± 0.55	0.51 ± 0.194
A10134-1	2.6 ± 0.43	1.6 ± 0.18	0.305 ± 0.045	A11941-5	2.1 ± 1.02	2.4 ± 0.07	0.88 ± 0.268
A10140-1	0.8 ± 0.16	1.8 ± 0.16	0.332 ± 0.008	A11941-6	0.7 ± 0.46	1.4 ± 0.07	0.43 ± 0.112
A10140-5	1.4 ± 0.20	1.6 ± 0.07	0.357 ± 0.022	A11941-7	3.3 ± 0.48	1.6 ± 0.34	1.00 ± 0.133
A10141-2	1.2 ± 0.10	1.8 ± 0.04	0.438 ± 0.119	A11947-8	0.5 ± 0.00	1.2 ± 0.07	0.29 ± 0.069
A10141-3	0.9 ± 0.01	1.6 ± 0.17	0.301 ± 0.096	AF5599-1	0.8 ± 0.05	1.6 ± 0.28	0.49 ± 0.202
A10143-10	2.2 ± 0.04	1.8 ± 0.08	0.533 ± 0.001	AF5604-2	0.7 ± 0.21	1.3 ± 0.05	0.33 ± 0.103
A10143-12	1.8 ± 0.15	1.8 ± 0.26	0.236 ± 0.044	AF5604-3	0.7 ± 0.12	1.3 ± 0.22	0.33 ± 0.040
A10143-3	0.9 ± 0.02	2.0 ± 0.23	0.382 ± 0.021	AF5609-1	0.6 ± 0.03	1.5 ± 0.01	0.40 ± 0.082
A10143-4	0.9 ± 0.30	1.5 ± 0.01	0.228 ± 0.017	AF5613-3	0.9 ± 0.04	1.4 ± 0.28	0.45 ± 0.123
A10143-5	0.7 ± 0.16	1.8 ± 0.26	0.330 ± 0.006	AF5613-4	0.4 ± 0.14	1.6 ± 0.27	0.36 ± 0.086
A10143-6	1.1 ± 0.32	2.1 ± 0.13	0.354 ± 0.057	AF5613-6	1.1 ± 0.19	1.5 ± 0.28	0.44 ± 0.217
A10143-9	1.4 ± 0.05	1.6 ± 0.15	0.235 ± 0.009	AF5614-1	0.5 ± 0.05	1.6 ± 0.13	0.47 ± 0.090
A10144-1	0.9 ± 0.21	1.3 ± 0.06	0.332 ± 0.013	AF5621-17	0.4 ± 0.10	1.7 ± 0.21	0.31 ± 0.053
A10145-1	2.3 ± 0.66	1.7 ± 0.53	0.576 ± 0.273	AF5621-9	0.6 ± 0.31	1.7 ± 0.49	0.45 ± 0.188
A10150-1	2.0 ± 0.13	1.7 ± 0.04	0.475 ± 0.070	AF5624-2	0.5 ± 0.07	2.0 ± 0.10	0.38 ± 0.064
A10154-1	2.4 ± 0.89	1.9 ± 0.05	0.406 ± 0.017	AF5624-5	1.0 ± 0.33	1.5 ± 0.07	0.34 ± 0.097
A10158-1	1.6 ± 0.84	2.1 ± 0.12	0.794 ± 0.002	AF5624-6	0.2 ± 0.54	1.7 ± 0.40	0.34 ± 0.130
A10172-5	1.0 ± 0.34	1.9 ± 0.05	0.672 ± 0.065	AF5624-8	2.3 ± 0.02	1.6 ± 0.10	0.50 ± 0.183
A10172-6	0.5 ± 0.09	2.0 ± 0.11	0.520 ± 0.114	AF5644-2	0.9 ± 0.16	1.4 ± 0.12	0.39 ± 0.094
A10182-10	1.6 ± 0.01	2.4 ± 0.04	1.236 ± 0.116	AF5644-3	0.8 ± 0.38	1.4 ± 0.17	0.38 ± 0.087
A10182-11	0.9 ± 0.23	2.3 ± 0.31	0.731 ± 0.155	AF5648-1	1.3 ± 0.40	1.5 ± 0.09	0.65 ± 0.219
A10182-12	1.2 ± 0.01	2.1 ± 0.19	0.745 ± 0.036	AF5651-1	1.7 ± 0.76	2.1 ± 0.22	0.80 ± 0.135
A10189-1	0.5 ± 0.22	1.5 ± 0.08	0.411 ± 0.034	AF5651-12	0.7 ± 0.45	1.4 ± 0.22	0.34 ± 0.013
A10195-1	0.5 ± 0.10	1.3 ± 0.19	0.482 ± 0.043	AF5651-9	0.7 ± 0.39	1.4 ± 0.15	0.38 ± 0.072
A10195-2	1.3 ± 0.38	1.7 ± 0.05	0.782 ± 0.002	AF5652-4	0.9 ± 0.01	1.5 ± 0.12	0.50 ± 0.172
A10195-3	0.7 ± 0.02	1.9 ± 0.01	0.642 ± 0.031	AF5652-6	1.2 ± 0.07	1.4 ± 0.02	0.51 ± 0.103
A10195-5	0.6 ± 0.56	1.8 ± 0.18	0.737 ± 0.074	AF5654	0.4 ± 0.34	1.6 ± 0.17	0.41 ± 0.105
A10195-6	0.5 ± 0.14	1.3 ± 0.13	0.447 ± 0.024	AF5656-16	0.7 ± 0.91	1.2 ± 0.01	0.27 ± 0.005
A10206-2	0.6 ± 0.02	1.5 ± 0.21	0.678 ± 0.170	AF5656-20	0.3 ± 0.11	1.7 ± 0.13	0.47 ± 0.083
A10208-1	1.5 ± 0.05	1.6 ± 0.02	0.521 ± 0.006	AF5656-3	nd	1.2 ± 0.05	0.30 ± 0.003
A10228-1	1.7 ± 0.37	2.0 ± 0.07	0.817 ± 0.135	AF5656-4	0.5 ± 0.15	1.6 ± 0.05	0.34 ± 0.017
A10228-2	0.9 ± 0.11	1.6 ± 0.17	0.536 ± 0.007	AF5661-2	nd ± 0.15	1.6 ± 0.22	0.33 ± 0.012
A10229-1	0.7 ± 0.21	1.3 ± 0.04	0.424 ± 0.027	CO10048-1	1.4 ± 0.39	1.4 ± 0.12	0.44 ± 0.111
A10229-2	0.7 ± 0.01	1.7 ± 0.25	0.657 ± 0.120	CO10051-1	0.5 ± 0.01	1.3 ± 0.07	0.36 ± 0.018
A10233-2	1.6 ± 0.06	1.6 ± 0.05	0.638 ± 0.099	CO11009-1	0.7 ± 0.04	2.0 ± 0.03	0.54 ± 0.111
A10544-2	1.8 ± 0.10	1.8 ± 0.19	0.599 ± 0.125	CO11009-6	2.3 ± 0.36	1.7 ± 0.08	0.71 ± 0.061
A10584-1	1.0 ± 0.05	1.6 ± 0.46	0.646 ± 0.361	CO11012-15	1.4 ± 0.14	1.6 ± 0.18	0.45 ± 0.114
A10592-4	2.0 ± 0.45	1.6 ± 0.09	0.730 ± 0.081	CO11012-17	0.8 ± 0.06	2.2 ± 0.20	0.76 ± 0.019
A10592-9	1.1 ± 0.19	1.8 ± 0.13	0.927 ± 0.106	CO11012-23	1.2 ± 0.25	1.5 ± 0.02	0.49 ± 0.027
A10617-3	1.5 ± 0.11	1.3 ± 0.06	0.450 ± 0.070	CO11012-3	0.4 ± 0.04	1.6 ± 0.07	0.41 ± 0.003
A10634-2	2.0 ± 0.07	1.4 ± 0.11	0.363 ± 0.076	CO11012-5	0.2 ± 0.14	1.6 ± 0.06	0.43 ± 0.078
A10637-1	2.6 ± 1.60	1.8 ± 0.34	0.576 ± 0.061	CO11102-4	1.2 ± 0.05	1.9 ± 0.02	0.75 ± 0.170
A10637-3	2.4 ± 0.36	1.5 ± 0.07	0.529 ± 0.033	CO11196-1	0.8 ± 0.10	1.6 ± 0.21	0.56 ± 0.057
A10642-3	0.7 ± 0.10	2.1 ± 0.36	0.604 ± 0.219	CO11196-3	0.8 ± 0.15	1.5 ± 0.16	0.32 ± 0.026
A10651-1	0.7 ± 0.15	1.8 ± 0.39	0.692 ± 0.149	CO11196-8	0.7 ± 0.08	2.0 ± 0.08	0.41 ± 0.097
A10655-1	0.7 ± 0.09	2.1 ± 0.04	0.688 ± 0.188	CO11296-3	0.8 ± 0.09	1.6 ± 0.11	0.55 ± 0.078
A10658-1	0.8 ± 0.39	1.6 ± 0.30	0.623 ± 0.237	CO11350-3	0.8 ± 0.18	1.2 ± 0.07	0.42 ± 0.059
A10664-10	0.8 ± 0.04	1.5 ± 0.15	0.474 ± 0.048	CO11371-2	0.5 ± 0.08	1.4 ± 0.15	0.45 ± 0.048
A10664-8	0.5 ± 0.08	1.4 ± 0.03	0.338 ± 0.039	ND113038B-1	0.8 ± 0.23	1.6 ± 0.10	0.43 ± 0.030
A10675-1	0.9 ± 0.02	2.0 ± 0.20	0.577 ± 0.135	ND113078CB-1	0.4 ± 0.08	1.3 ± 0.01	0.33 ± 0.004
A10675-6	0.9 ± 0.13	1.3 ± 0.13	0.329 ± 0.105	ND113099-1	2.2 ± 0.36	1.7 ± 0.15	0.48 ± 0.134
A10681-2	1.8 ± 0.02	1.8 ± 0.23	0.545 ± 0.183	ND113099-4	1.1 ± 0.07	2.1 ± 0.61	0.61 ± 0.235
A10681-3	1.1 ± 0.30	2.2 ± 0.52	0.968 ± 0.365	ND113476CB-2	0.8 ± 0.17	2.0 ± 0.00	0.61 ± 0.016
A10681-4	1.5 ± 0.77	1.8 ± 0.17	0.693 ± 0.012	ND113498B-1	1.1 ± 0.11	1.8 ± 0.10	0.53 ± 0.006
A10693-1	2.2 ± 0.23	1.0 ± 0.14	0.259 ± 0.019	ND113498B-3	2.3 ± 0.26	1.5 ± 0.09	0.43 ± 0.002
A10701-2	0.2 ± 0.45	1.1 ± 0.03	0.241 ± 0.026	ND113500AB	2.1 ± 0.10	1.7 ± 0.13	0.44 ± 0.011
A10741-1	0.9 ± 0.09	1.6 ± 0.03	0.405 ± 0.015	ND113503AB-3	1.2 ± 0.50	1.4 ± 0.06	0.37 ± 0.006
A10741-3	0.8 ± 0.02	1.7 ± 0.02	0.631 ± 0.000	W12011rus-5	2.0 ± 0.67	1.2 ± 0.05	0.44 ± 0.054
A10741-4	0.2 ± 0.07	1.6 ± 0.21	0.326 ± 0.070	W12012rus-2	nd	1.3 ± 0.12	0.29 ± 0.027
A10741-5	0.5 ± 0.04	1.4 ± 0.12	0.364 ± 0.022	W12012rus-3	nd	1.4 ± 0.07	0.25 ± 0.011
A10743-1	0.5 ± 0.15	1.4 ± 0.18	0.426 ± 0.095	W12058rus-1	0.0 ± 0.08	1.5 ± 0.05	0.33 ± 0.002

Total protein present in various genotypes. Potatoes does not contain high amounts of protein compared to foods like beef or beans, but they do have meaningful amounts. Moreover, potato protein is of high quality in terms of having a balanced amino acid composition. Ensuring that consumers understand potatoes also provide protein can help counter the perception that they only provide carbohydrates. Similarly, identifying/developing potatoes with even higher amounts of protein would be a significant achievement. For this reason we screened advanced material from the TriState or Western Regional trials. Phytonutrients will vary from year to year and location to location. Thus it is not correct to think that any cultivar has an absolute amount of any compound. It is more accurate to realize a given phytonutrient will vary within a defined range for a given cultivar. That said, although the amounts of a given compound will vary in a cultivar, our work suggests that the amount of a given phytonutrient in a "high" cultivar will vary within a range that exceeds the range of which a "low" cultivar concentrations will vary. I.e. a standout cultivar will remain a standout, even when in the lower part of its range for a given year or location. Recognizing that amounts vary, we screened the protein content of cultivars grown in multiple locations to see how much variation was present. Protein was measured in Russet Burbank, AmaRosa, Purple Pelisse, Atlantic, and Bintje that were grown in Prosser, Aberdeen, Ontario and Klamath Falls. As seen in **Figure 1** the protein content of Russet Burbank and Atlantic varied the least among the four locations, whereas AmaRosa had the most variation.

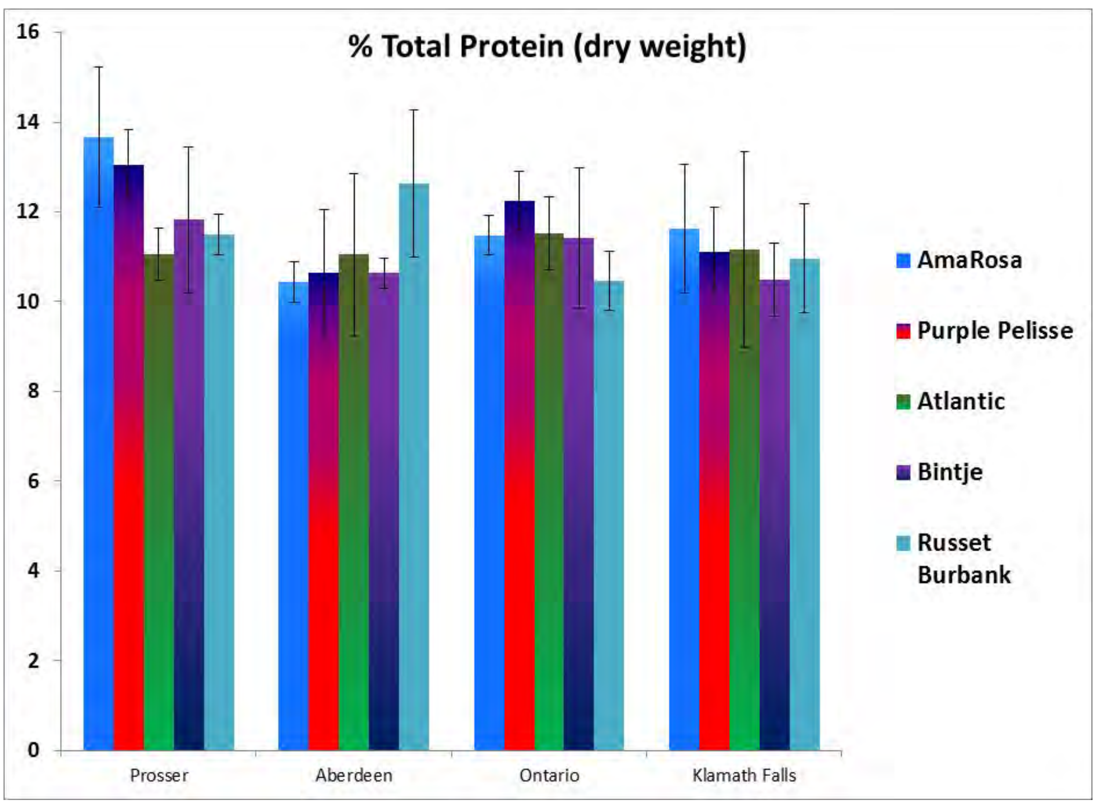


Figure 1. Total protein in five cultivars grown in four different locations in 2014. The Y-axis shows the percent protein on a dry weight basis.

Total protein in Russet Burbank ranged from 10.5% in Ontario to 12.6% in Aberdeen, whereas the red fingerling AmaRosa ranged from 10.4% in Aberdeen to 13.7% in Prosser. When the mean protein amount was calculated among the different locations, all five cultivars had similar amounts of protein relative to each other **(Figure 2)**. This is in contrast to the data shown in **Table 2**, which shows a much greater range of protein content among a larger number of lines. So one should not assume based on **Figure 2** that different cultivars will have similar

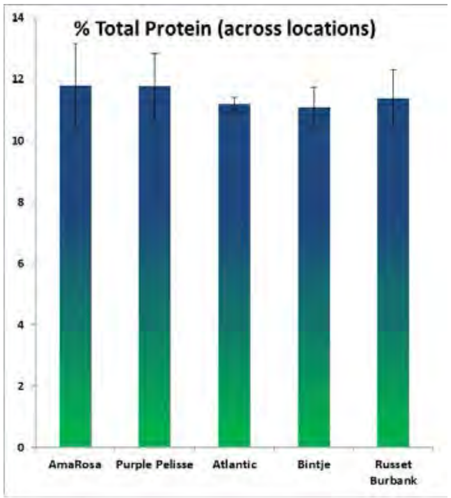


Figure 2. Average total protein in five cultivars across 4 locations. Error bars show standard deviation.

Table 2. Percent total protein (dry weight basis) in plants grown in Othello or Parma.

Othello

Total Protein	**Averagestd de**
AO2267-1Y	9.2 ± 1.9
AO2424-83LB	12.5 ± 1.8
AO2507-2LB	11.0 ± 0.9
AO3158-2TE	12.1 ± 1.0
AO3921-2	12.5 ± 0.0
AO5180-3PY	9.9 ± 2.1
AO5182-7RY	9.0 ± 3.4
AO6021-1T	11.4 ± 0.6
*AO6084-1TE	14.9 ± 0.5
AOO1114-4	10.1 ± 2.4
AOO2060-3	10.7 ± 2.6
Burbank	11.3 ± 0.4
Chieftan	10.4 ± 1.5
COO3276-5RU	12.1 ± 1.6
COO5068-1RU	10.9 ± 1.4
COO5175-1RU	11.8 ± 1.0
NDA050237B-1R	7.7 ± 1.2
Norkotah	11.2 ± 2.0
*ORO5039-4	11.6 ± 3.7
PORO6V12-3	10.4 ± 2.4
PORO7PG 3-1	9.2 ± 0.4
PORO7PG20-2	10.2 ± 1.9
Ranger	12.9 ± 1.5

Parma

Total Protein	**Average**	**std dev**
AO2267-1Y	8.9	± 2.3
AO2424-83LB	9.7	± 0.3
AO2507-2LB	9.3	± 0.9
AO3158-2TE	11.2	± 0.4
AO3921-2	9.0	± 1.6
AO5180-3PY	8.0	± 1.9
AO5182-7RY	8.5	± 2.7
AO6021-1T	11.4	± 0.8
AO6084-1TE	12.5	± 1.9
AO6293-3Y	8.8	± 1.7
AO6293-3Y	9.0	± 0.6
AO6336-5Y(?)	8.8	± 1.7
AOO1114-4	9.0	± 2.0
AOO2060-3	10.9	± 2.0
Burbank	11.1	± 0.2
Chieftan	8.9	± 2.6
COAO7363-4RY	9.8	± 0.5
NDA050237B-1R	6.7	± 0.4
NDA081451CB-CY	7.6	± 1.5
Norkotah	10.3	± 1.1
ORO5039-4	11.3	± 3.4
PORO6V12-3	9.4	± 1.7
PORO7PG 3-1	9.1	± 0.5
PORO7PG20-2	9.4	± 0.3
Ranger	10.4	± 2.1
Yukon Gold	7.3	± 0.8

protein profiles, because as seen in **Table 3** there is a marked range of protein content found. Protein ranged from 6.7% in NDA050237B-1R to 14.9% in AO6084-1TE. Based on the literature, a historic average for total protein in potatoes is ~10% on a dry weight basis. Therefore, relative to the historic average, AO6084-1TE grown in Othello provides roughly 50% more protein than is typical and 100% more protein than the lowest genotypes measured in **Table 2**. Supporting the evidence that AO6084-1TE is high in protein is that it also tested the highest among the lines grown in Parma. Reproducibility across locations adds confidence to the consistency of the line. ORO5039-4 had considerable variation (as seen by the error bars), which complicates interpretation, because in both Parma and Othello, two of the biological replicates had high readings and the third gave a low reading. ORO5039-4 may be worth taking a closer look at however, because if we consider each rep individually instead of taking an average as shown in **Table 2**, then ORO5039-4 had two of the three highest readings among all lines from Parma and two of the top ten from Othello.

Factors that influence tuber skin color and appearance: For fresh market potatoes, appearance is a major determinant of consumer buying decisions for potatoes. Visual appearance is primarily a function of tuber size and shape, color and freedom from blemishes. Anthocyanins are the compounds responsible for red or purple skin color. There is much circumstantial evidence that soil type, nutrition and other factors all play a large role in determining skin appearance, particularly for red-skinned cultivars. However, there is little research data available to back up these observations. We were able to document the extent to which soil texture influences skin color of two common red-skinned varieties (Red Lasoda and Chieftan). This is the first time this has been done under controlled field conditions in the NW, and may provide insight into additional ways to improve appearance of specialty potatoes through modifying soil characteristics.

Preliminary field trials were conducted at Parma, ID to determine the influence of soil type on skin color of Red Lasoda and Chieftan, two commonly grown red-skinned potato varieties. Samples of three soil types (sandy loam, silt loam, muck) were collected and placed into 5 gallon buckets that were buried in a replicated plot design in the field. Soils were fumigated with metam sodium and concentrations of major nutrients adjusted to consistent levels prior to being placed in the field. A single seed piece was planted in each bucket, and other cultural practices, including irrigation, were conducted according to standard practices. At harvest, tubers were evaluated for skin color and overall appearance both visually, and with a hand-held colorimeter.

Soil type did not have a consistent effect on tuber number, but did impact visual tuber appearance (**Table 3**). Tubers produced in muck soil were visually darker than those produced in sandy loam or silt loam soils (**Figure 3**). The colorimeter did not necessarily corroborate the visual ratings, as and chroma (color intensity) and hue angle (tint) were not significantly affected by soil texture.

A second experiment evaluated the potential use of the growth regulator methyl jasmonate to improve skin color. Field trials were conducted at Parma, ID to determine the influence foliar applications of two rates of methyl jasmonate (low rate = 100 micromolar, high rate = 1 millimolar) on skin color of Red Lasoda. Growth regulator applications were made on June 9 and June 19, coinciding with early tuber development. At harvest, tubers were evaluated for skin color and overall appearance both visually, and with a hand-held colorimeter.

Foliar applications of methyl jasmonate had no influence on tuber number, yield or skin color (**Table 4**). This is in contrast to what we have seen from applications of the growth regulators 2,4-D (a synthetic auxin) and ethephon (a liquid formulation of ethylene) in past

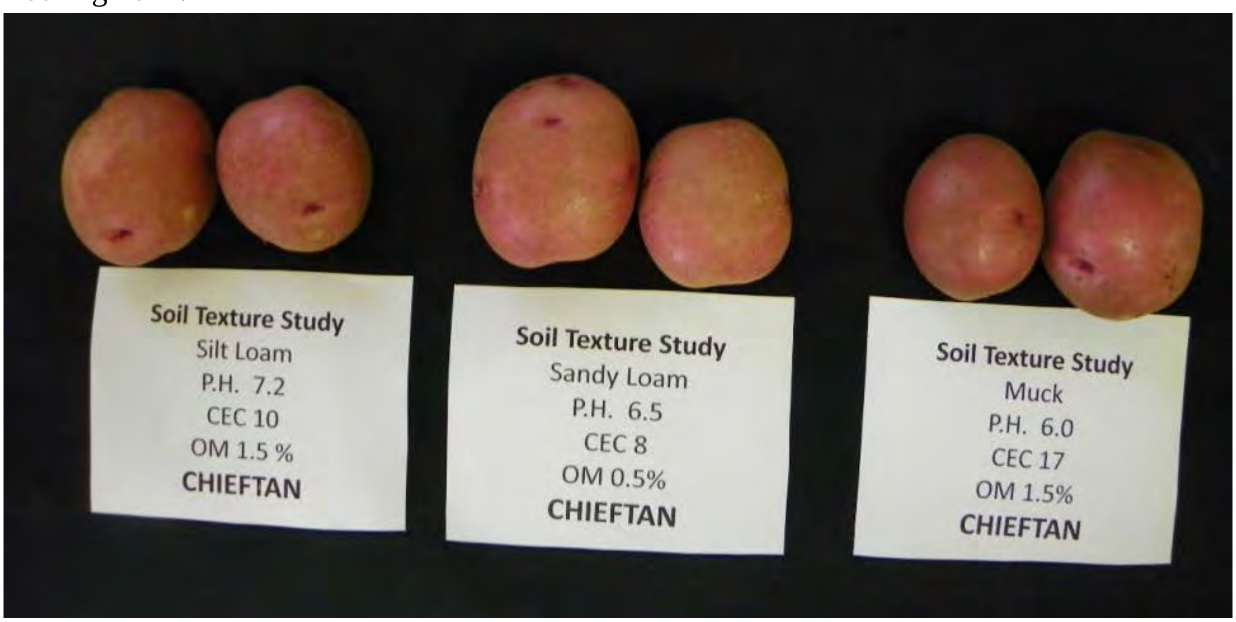
Table 3. Impact of soil texture and variety on tuber number, visual skin color, chroma and hue angle of tubers produced at Parma, ID during 2014. Values are means of 5 replications.

Soil type	**Tuber number per plant**	**Visual tuber color***	**Chroma**	**Hue angle**
Sandy Loam	6.6a^	2.2b	26.4a	22.1a
Silt Loam	5.4a	1.9b	25.6a	24.0a
Muck	6.5a	3.1a	25.3a	22.0a
Variety				
Red Lasoda	5.6a	2.2a	28.0a	21.4a
Cheiftan	3.3a	2.6a	23.8a	24.2a
ANOVA (p>F)				
Soil	0.1598	0.0855	0.0001	0.1489
Variety	0.3210	0.0001	0.5698	0.5666
Soil X Variety	0.6629	0.3314	0.6386	0.8658

^ Means followed by the same letter are not significantly different ($p < 0.05$)

* Based on a 1= light pink, 5 = very dark red scale

Figure 3. Impact of soil texture on skin color of Red Lasoda tubers produced at Parma, ID during 2014.



trials. It is possible that methyl jasmonate is too volatile to be absorbed into the leaf surface and/or too volatile to persist long enough to have an effect. Alternatively, the rates applied may have been suboptimal. Additionally, jasmonate may have complex interactions with environment or factors influenced by environment. Based on promoter sequence analysis of genes known to regulate anthocyanins in potatoes, and the role of jasmonate in anthocyanin biosynthesis in other crops we still think it likely that jasmonate has an important role in potato anthocyanin regulation but further work is needed to understand how or if jasmonate can be used to improve appearance.

Table 4. Impact of foliar application of methyl jasmonate on tuber number, total yield, visual skin color, chroma and hue angle of Red Lasoda tubers produced at Parma, ID during 2014. Values are means of 4 replications.

Treatment	Tuber number per plant	Total yield (cwt/ac)	Visual tuber color*	Chroma	Hue angle
Non-treated	8.5a^	867a	1.5a	25.8a	33.8a
Low rate	8.3a	857a	1.5a	24.9a	35.8a
High rate	9.7a	893a	1.5a	24.8a	36.4a
ANOVA (p>F)					
Treatment	0.0880	0.8725	0.0855	0.1966	0.2467

^ Means followed by the same letter are not significantly different ($p < 0.05$)

* Based on a 1= light pink, 5 = very dark red scale

HPLC analysis of tuber phytonutrients. Tubers from Othello and Parma were freeze-dried, extracted and analyzed for various phytonutrients including chlorogenic acid and ascorbic acid (Vitamin C). Chlorogenic acid (CGA) is typically the most abundant antioxidant in tubers. Chlorogenic acid concentrations were relatively consistent in the same lines grown in Othello or Parma (**Figure 4**). In both locations PORO7PG20-2 had the highest CGA concentrations. Interestingly, several of the white genotypes, including AO6084-1TE, the line that tested high in protein had high amounts of CGA for white potatoes. We've screened hundreds of white potatoes over the years and Norkotah typically has the highest antioxidant and chlorogenic acid values and Chieftan is also typically high. AO6084-1TE AO6021-1T and AOO1114-4 all rivaled Norkotah and were high in both locations. Much more variability between locations was found for ascorbic acid **(Figure 5).** Ranger is known to have among the highest vitamin C concentrations of any of the russets and contained the highest amounts in Othello and among the highest in Parma. AO6084-1TE which is high in protein and chlorogenic acid, also had amongst the highest concentations of vitamin C in both Parma and Othello. AO2424-83LB and AO3921-2 also had high amounts in both locations. PORO7PG20-2 showed a dramatic difference between locations, 829 in Othello and 2190 in Parma. The error bars for this line (**Figure 5**) show that variation was reasonable at each location, so this was not a case of one rep throwing off the numbers. Interestingly, while the lines at Othello tended to have higher amounts of protein than the same lines grown at Parma, the Parma lines tended to have higher amounts of vitamin C than those grown at Othello.

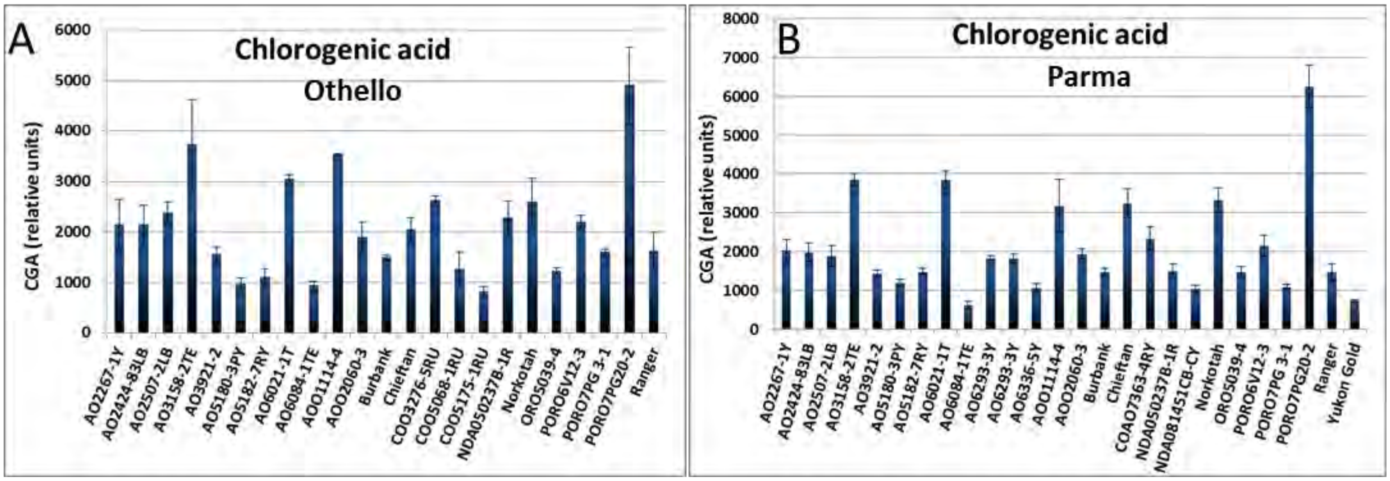


Figure 4. Chlorogenic acid concentrations (relative units) in potatoes grown in Othello or Parma. Std Deviation is shown. Measured with HPLC.

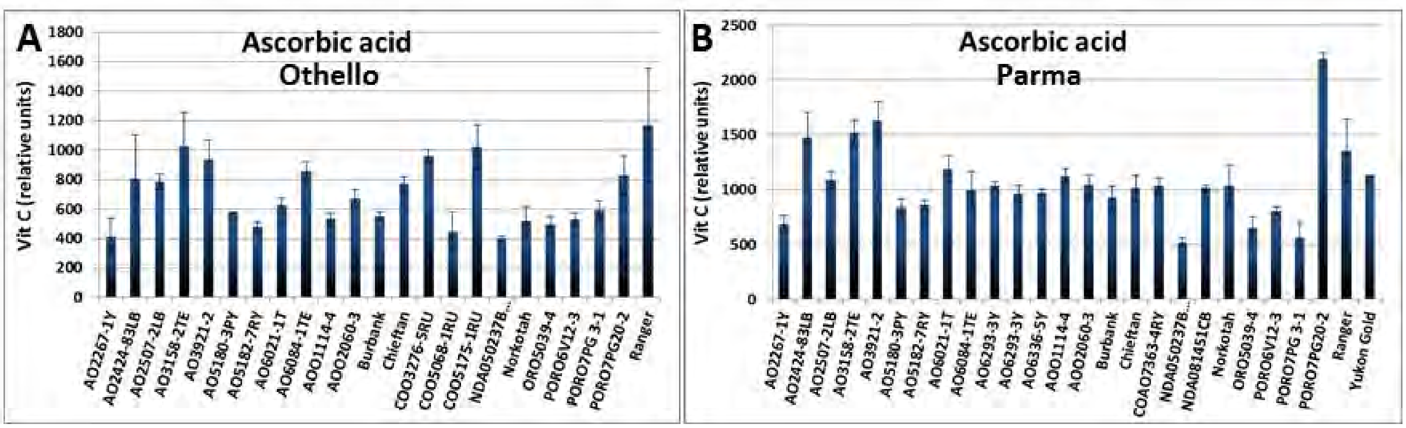


Figure 5. Ascorbic acid concentrations (relative units) in potatoes grown in Othello or Parma. Std Deviation is shown. Measured with HPLC.

Why do some potatoes have more phytonutrients than others?

We don't really know yet. If we better understood what controls tuber phytonutrient content, then approaches such as marker assisted selection could be used to develop superior cultivars. The major antioxidant in most potatoes is chlorogenic acid (CGA), a colorless compound. However, for reasons not yet understood, red and purple potatoes contain much more of this colorless antioxidant than do white or yellow. Despite evaluating hundreds of different types of white potatoes for antioxidants, we've yet to find any that have the amounts found in red/purple types.

In some tubers, especially white tubers, over 80-90% of the total tuber phenylpropanoids (aka antioxidants, aka phenolics) is chlorogenic acid. Why potatoes have so much of this one compound is not understood. One of the roles in planta for CGA is disease resistance, as it has been shown to contribute to resistance in other plants against various microbial pathogens and insect pests. Because CGA makes such a large contribution to a tuber's antioxidant capacity how it is regulated is of particular interest. Adding to the importance and interest of CGA is that it is a colorless compound, so there is no reason white potatoes should have less CGA than red/purple flesh potatoes. Anthocyanins are also phenylpropanoids and make a large contribution to the antioxidant capacity of red/purple potatoes, but because these are pigments, they cannot be present in white potatoes (but CGA can). For these reasons we wanted to know more about CGA metabolism in potatoes. We showed that CGA is made in potatoes by the enzyme *hydroxycinnamoyl-CoA:quinate hydroxycinnamoyl transferase* (*HQT)*. Sugar treatments increased the accumulation of CGA correlated with the increased expression of *phenylalanine ammonia-lyase* (*PAL)* rather than *HQT*. Transient expression of the potato MYB transcription factor *StAN1* (Anthocyanin1) increased CGA. RNAi suppression of *HQT* resulted in over a 90% reduction in CGA and resulted in early flowering. Tubers with reduced amounts of CGA showed less blackening 24 hours after being sliced **(Figure 6)**. The reduction in total phenolics and antioxidant capacity was less than the reduction in CGA, suggesting flux was rerouted into other phenylpropanoids. To better understand how

Figure 6. Top row shows RNAi tubers 24 hours after slicing and bottom shows wild type tubers. Differences in darkening are apparent.

reducing CGA affected overall phenylpropanoid metabolism, we conducted network analysis using LCMS (**Figure 7**). This showed distinct patterns in different organs, with anthocyanins and phenolic acids showing negative correlations in leaves and flowers, and positive in tubers. Some flavonols increased in flowers, but not in leaves or tubers. Anthocyanins increased in flowers and showed a trend to increase in leaves, but not tubers. *HQT* suppression increased biosynthesis of caffeoyl polyamines, some of which are not previously reported in potato. Decreased *PAL* expression and enzyme activity was observed in *HQT* suppressed lines, suggesting the existence of a regulatory loop between CGA and PAL. Because chlorogenic acid has been implicated as a resistance factor to thrips (a sucking insect), we examined whether plants with reduced CGA affected psyllid feeding, but failed to find any difference in psyllid feeding behavior. Collectively, this research showed that CGA in potatoes is synthesized through *HQT* and *HQT* suppression altered phenotype and redirected phenylpropanoid metabolism. While our results indicated that *HQT* is the main route for CGA synthesis in potatoes and HQT suppression rerouted flux to HCAAs, anthocyanins and flavonols, such increases were not sufficient to offset the decrease in CGA, and the phenylpropanoid pathway was down-regulated. The data support *PAL* expression being a primary determinant of CGA synthesis, along with important roles for sucrose and StAN1. An interesting question is to what extent a specific phenylpropanoid branch can be increased in potatoes without concomitantly increasing other branches, because effective strategies to increase one phenylpropanoid branch may also require that *PAL* be up-regulated. This may be reflected in the observation that all high-phenylpropanoid potatoes identified to date have not only high amounts of CGA, but also anthocyanins. This work shows that potato phenylpropanoid metabolism can be markedly changed and provides insights into how one might develop potatoes that have ideal amounts and types of phenylpropanoid phytonutrients for human health and plant performance.

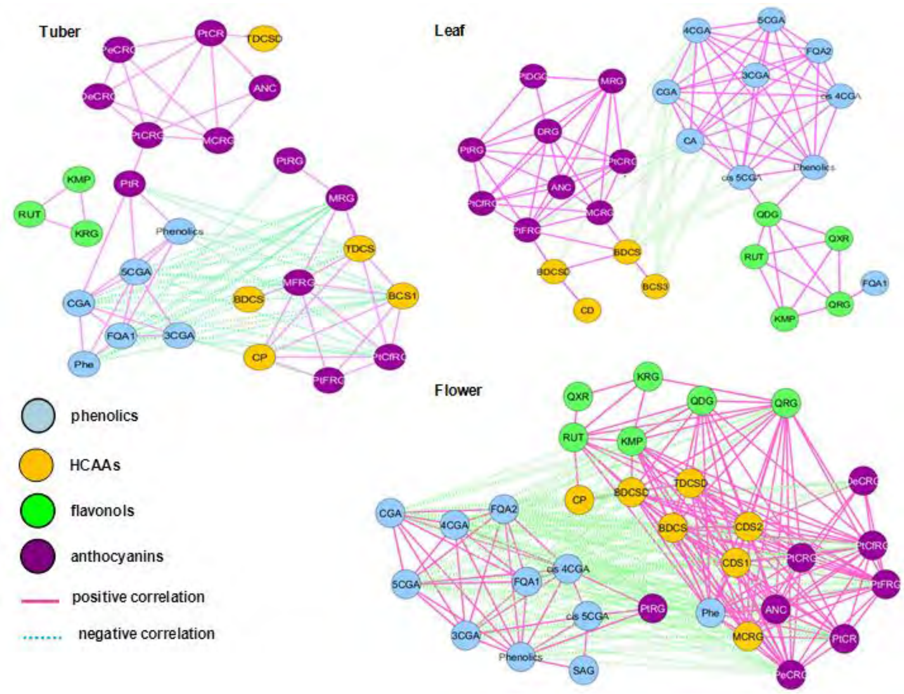


Figure 7. Network analyses of potato phenylpropanoid metabolism in tubers, flowers and leafs. Compounds were measured by LCMS and correlations between different metabolites determined.

Presentations and Publications: Portions of this work have been published in the Plant Biotechnology Journal, in a book chapter and at the 2014 Potato Association of American Annual Meeting in Spokane. Other portions of this research will be published in the future. Some of the work was presented at the 2014 Oregon/Washington Potato Conference and will be presented next week at the Idaho Potato School in Pocatello and in two weeks at the 2015 Oregon/Washington Potato Conference.

PROGRESS REPORT

Project number: 3055-5259

TITLE: Effects of in-season management & stress on retention of postharvest quality

PERSONNEL & COOPERATORS

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BACKGROUND & OBJECTIVES

A main focus of the proposed research is to determine how in-season management and stress during production affect retention of postharvest quality in new or soon-to-be-released cultivars from the PNW potato variety development (NWPVD) program. Environmental and cultural conditions during growth interact to affect postharvest quality and storability of potatoes. Isolating the effects of abiotic stressors (e.g., heat, water, nutrients) on subsequent retention of postharvest quality is challenging, given the many interacting variables that affect crop development in a production setting. My program is evaluating the tolerance of new and soon-to-be-released cultivars to selected stress conditions imposed during different phases of crop development on at-harvest and postharvest qualities. **The overarching objective is to identify robust genotypes that are inherently more capable of withstanding stress (heat, water, nutrients) than the mainstay cultivars Ranger Russet and Russet Burbank, specifically for retention of postharvest process and seed quality.** The stressors of interest include heat, water and nutrients (N and P). The heat cable plots and VRI irrigation systems at Othello are ideally suited for imposing these in-season stresses in replication at one site. Effects of the stressors on postharvest physiological processes (e.g. respiration, sweetening, LTS resistance, dormancy, shrink) important to quality retention are under investigation. The research will help define best management practices (BMPs) for growing each cultivar for maximum yield and storage potential.

Objectives

1. Produce detailed growth, development and storability profiles for Clearwater and Dakota Russet under four levels of in-season N (ranging from deficit to excess), model the attainment of tuber physiological maturity and determine subsequent effects of the N levels on retention of nutritional

and process qualities during storage.

2. Screen cultivars/clones for tolerance to high soil temperature imposed during tuberization, bulking and maturation for effects on postharvest physiology, storability and quality as process and seed potatoes (Sage Russet, Clearwater, Ranger, A02138-2, POR06V12-3, A02507-2LB).
3. Evaluate the effects of P nutrition on retention of process quality (RR, RB, UR, Alpine, Sage, Teton, Alturas).
4. Determine the effects of water stress imposed at critical periods of tuber development on productivity, water use efficiency, crop value, postharvest physiology and retention of process quality (Teton, Alturas, Targee, Classic, Clearwater, GemStar, Ranger, RB, Umatilla).

The first year in-season trials for all four objectives were completed in 2014. Postharvest studies to assess effects of the various management and stress treatments are currently in progress. Multiple years of trial data will be required to fully accomplish the objectives and to formulate management recommendations that will ultimately impact production. Details of the results from the 2014 trials are summarized below.

RESULTS

<u>Objective 1</u> – growth & development profiling in response to N.

- The 2014 growing season was one of the warmest on record with monthly maximum temperatures during May, June and July at Othello averaging 3.6^{o}F above the average of the last 5 years (2009-13). The result was ~26% more GDD (base temp 45^{o}F) accumulating from 60 to 140 DAP (+364 GDD) compared with the average over the last 3 years (2011-13). Growth and yield responses to many treatments in 2014 were no doubt altered by the unusually high temperatures.
- The N fertigation schedule is outlined in Table 1. Petiole N levels decreased from 52 to 114 DAP and correlated well with the N rates (Fig. 1).
- Dakota produced less foliage that began to senesce earlier than Clearwater (Figs. 2&3). N stimulated foliar growth in both cultivars, but more so in Clearwater than Dakota (Fig. 2; Tables 3&5).
- Despite the significant increases in foliar growth with increasing N, yield of Clearwater was not affected by N, and yield of Dakota increased only slightly (by ~1.5 T/A) with increasing N (Figs 2&3; Tables 3&5). These results are contrary to the responses characterized for many russet cultivars (e.g. Alpine, Sage, Ranger, Alturas, Premier, etc.) in past multi-year studies and may be due to the excessive heat during 2014. Total and U.S. #1 yields of six other clones (numbered entries from the late Regional Trial) were also insensitive to these N levels in 2014 (data not shown). N rate did, however, affect various indices of crop growth and development for Clearwater and Dakota as described below.
- Increased N stimulated early foliar development and shifted the timing of 50% HI later for both cultivars. For example, 50% HI in Clearwater grown with 170 lb/A N occurred 10 d earlier at 13.3 T/A of foliage and tubers (26.6 T/A total) than at 450 lb/A N. Maximum foliar FW occurred at the same time regardless of N rate (~92 and 84 DAP for Clearwater and Dakota, respectively). However, at 170 lb/A N, tuber growth predominated over foliar growth at max foliar development, resulting in 56% HI for Clearwater. This HI may represent a source sink imbalance (too little foliar growth & too much tuber growth at 93 DAP), which may limit yield potential. The 450 lb/A N rate stimulated ~4 T/A more foliar growth, which was maintained longer into late bulking than with 170 lb/A N for both cultivars (Fig. 3). Final yields, however, were not affected by N in Clearwater and were only slightly higher at 450 lb/A N in Dakota (Fig. 6).
- On average, yields in the majority of trials at Othello were lower than in previous years. The lack of a yield response to N in 2014 may be due to the excessively high heat. Foliar growth was stimulated by N but this did not translate to yield. In a reasonably typical ‘cooler’ year, tuber

yield often correlates directly with N-induced increases in foliar growth. In a hot year, this correlation would appear to fall apart - foliar growth increases with N but tuber growth does not. Multiple seasons will be required to fully characterize this response. The practical implications of these findings could be the ability to reduce N during excessively warm growing seasons with no impact on yield, which may boost economic returns.

- Average tuber fresh wt increased linearly with time in Clearwater and tubers were ultimately smaller than Dakota, indicating that Clearwater was continuing to develop (bulk) tubers to season end (Figs. 4&5).
- Clearwater tubers contained higher sucrose levels than Dakota throughout the season (Figs. 4&5). Clearwater tubers also had higher gravities than Dakota tubers regardless of N rate (Figs. 4&5).
- Increasing N delayed the attainment of maximum gravity in Clearwater but not Dakota tubers, which reached a maximum at 106 DAP on average (Figs. 4&5).
- Clearwater tubers had higher concentrations of reducing sugars at most sampling dates than Dakota tubers (Figs. 4&5).
- Dakota tubers reached physiological maturity (PM) earlier than Clearwater. Increasing N delayed PM more in Clearwater than Dakota (Figs. 4&5, Fig. 7).
- The increase in stem end reducing sugars following PM was much greater in Clearwater than Dakota, leading to non-uniform fry color shortly after harvest.
- The postharvest phase of this study is currently underway to determine the effects of N on changes in process quality and acrylamide precursors (reducing sugars & asparagine) at different temperatures during full season storage.

<u>Objective 2</u> – screening for high temperature tolerance

- The heat cable plots were used to screen advanced clones for heat tolerance for retention of process quality and low temperature sweetening (LTS) resistance. Ranger, A02138-2, POR06V12-3 and A02507-2LB were exposed to +14^{o}F soil temperatures for 20 and 40 days starting ~80 (early bulking) or 120 days after planting (late bulking/maturation). The numbered entries were conventionally bred to have a high degree of resistance to LTS. Soil temperature profiles are shown in Fig. 8A.
- Specific gravities were lower in tubers grown at elevated temperature regardless of duration of exposure (20 vs 40 days) and timing (early vs late bulking). However, gravities were lowest when heat was applied during early bulking (80-120 days) compared with late bulking/maturation (120-160 days) (data not shown).
- Heat-related changes in resistance to LTS were evaluated directly following harvest by following changes in fry color and sugars over a 30-day storage period at 39^{o}F. Early season heat reduced the resistance to LTS in A02138-2 and POR06V12-3 more than late season heat (Fig. 8B). Although A02507-2LB tubers had some IBS, resistance to LTS in this clone was largely unaffected by soil temperature, indicating higher tolerance of heat.
- To further evaluate the effects of heat on retention of LTS resistant phenotype, a postharvest heat stress study was conducted. Tubers were subjected to a heat priming (stress) period of 21 days at 90^{o}F soon after harvest. This treatment had no deleterious effect on fry color (Fig. 9). Tuber samples were then placed at 39^{o}F to sweeten for an additional 32 d. Changes in fry color and sugars were then evaluated. Relative to the other clones, A02507-2LB retained a USDA 0 fry color following 32 d storage at 39^{o}F regardless of the prior heat priming treatment. In contrast, fry colors of heat stressed tubers of A02138-2 and POR06V12-3 deteriorated substantially at 39^{o}F, indicating significant loss of inherent resistance to LTS. Sugar analysis and associated enzyme profiling are underway to determine the mechanism of heat tolerance in A02507-2LB relative to the other clones.

<u>Objective 3</u> – impact of P nutrition on retention of process quality

- Seven cultivars (Alpine, Alturas, Ranger, RB, Sage, Teton, Umatilla) were grown with varying levels of P in 2014 field studies. Effects of P on yield and tuber quality are described in the report submitted by Mark Pavek. Tubers from low- and high-P plots are currently in a postharvest study to follow changes in process quality and sugars over a ~210-day interval of storage at 44^{o}F.
- Tuber samples taken at harvest have been lyophilized and are being processed for P determination at the analytical sciences laboratory, Univ. of Idaho. Results will be presented in next year's report.

<u>Objective 4</u> – water stress and use efficiency

- Nine cultivars **(**Teton, Alturas, Targee, Classic, Clearwater, GemStar, Ranger, RB, Umatilla) were grown full season under two water regimes, 67 and 100% evapotranspiration (ET) for potato. Evapotranspiration was estimated by a modified Penman method and calculated using AgWeatherNet data (http://weather.wsu.edu/awn.php?page=wateruse) collected at WSU Othello, WA from June 3 to September 17, 2014. Planting date was April 15, 2014, vines were mowed Sept., 15 and tubers harvested Oct. 1.
- Cumulative water application amounts (irrigation + rainfall) were quantified with rain gauges located in the center and periphery of each mainplot. Plots were irrigated by central pivot with VRI technology. The design was a split plot with irrigation level as mainplot and cultivar as subplots (4 replications, 16.7-ft plots, 10-inch in-row spacing).
- Fig. 10 shows the amount of water received by the plots (irrigation + precipitation) relative to the ET needs of potato from June 3 to Sept. 17. Total precipitation during this growing period was only 12 mm (0.47 in). Estimated seasonal ET was 564 mm (22.2 in) in 2014, which was 6.4 to 9.9% higher (7.8% avg) than during the previous 4 years (2010-2013), reflecting the warmer growing season.
- Water application totals were close to the target amounts of 65 and 100% ET (Fig. 10A). A total of 13.4 (340 mm) and 20.7 inches (526 mm) were applied from June 3 to Sept. 17. Adding the estimated difference in soil water content (~1.5 inches) between the beginning and end of the growing season to cumulative water application totals brings the total water applied to 14.9 and 22.3 inches (378 and 566 mm) for the two treatments over the season. These rates equate to ~67 and 100% of the ET needs for potato in 2014.
- The ANOVA for total and U.S. #1 yields showed significant main effects of water and cultivar (Fig. 10B). There was also a significant interaction of water x cultivar to affect U.S. #1 yields. On average, total and U.S. #1 yields were 7.7 and 6.7% lower, respectively, when the cultivars were grown at 67% ET compared with 100% ET (Fig. 10C). Marketable yield (U.S.#1 + <4 oz tubers) was 8.8% lower under the water stress regime. Averaged over the cultivars, water stress specifically decreased the number of tubers per plant and per acre, and the yields of <4 oz, 12-14 oz, and >14 oz tubers.
- Fig. 11 shows the effects of decreased water on marketable yields and tuber size distributions of Alturas, Classic and GemStar Russet, the three cultivars most impacted by water stress. Decreases in marketable yield were 22.2% (Alturas), 16.8% (Classic) and 13.5% (GemStar). Water stress shifted the tuber size distribution profiles toward greater percentage of smaller size tubers for all three cultivars. Collectively, these effects reduced overall crop values by $1,752/A, $876/A and $771/A for Alturas, Classic and GemStar, respectively.
- Interestingly, the remaining six cultivars (Alpine, Targee, Teton, Ranger, RB and Umatilla) were mostly insensitive to reduced water for effects on marketable yield and tuber size distribution (Fig. 12).

- Water use efficiencies (WUE) for total (Fig. 10D), U.S. #1 and marketable yields (data not shown) were affected by water level and cultivar with no interaction. WUE ranged from 20 to 46 cwt/A/inch, depending on cultivar and water level. Averaged over cultivars, WUEs were 38% (total yield) and 40% (U.S. #1 yield) greater at 67% ET than at 100% ET (Fig. 10B). GemStar, Targee, Burbank and Alturas were the most efficient at producing yield per unit water, averaging 37 and 33 cwt/A/inch of water for total and U.S. #1 yields, respectively (Fig. 10B). In contrast, Alpine and Teton Russet were least efficient, averaging 26 cwt/A/inch for total yield and 22 cwt/A/inch for U.S. #1 yield.

	Date	Seasonal N Rates (lb/A)*			
		170	250	350	450
		In-season N (lb/A)			
14 DAE	6/4	0	5	10	30
21 DAE	6/11	-	25	25	40
28 DAE	6/17	-	20	30	35
	6/20	-	20	20	30
	6/25	-	10	20	30
	7/2	-	-	20	25
	7/9	-	-	20	25
	7/16	-	-	10	25
	7/23	-	-	10	20
	7/30	-	-	10	20

*Includes 170 lb/A (190 kg/ha) N residual.

Table 1. Fertigation schedule for Clearwater and Dakota Russet N rate trial in 2014 (Othello, WA). Planting date was April 21. Plots contained 170 lb/A residual N at planting. Fertigation began approximately 14 days after emergence (DAE) on June 4 (44 DAP). Row closure occurred about 57 DAP (28 DAE). Fertigation ceased after the June 25 application (65 DAP) for the 250 lb/A treatment and after July 30 (100 DAP) for the 350 and 450 lb/A treatments.

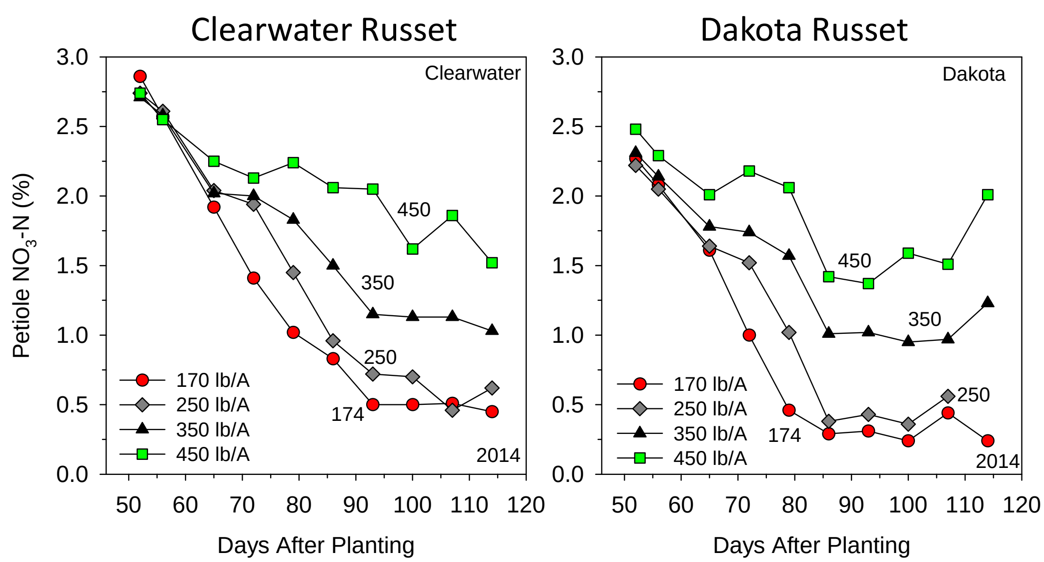
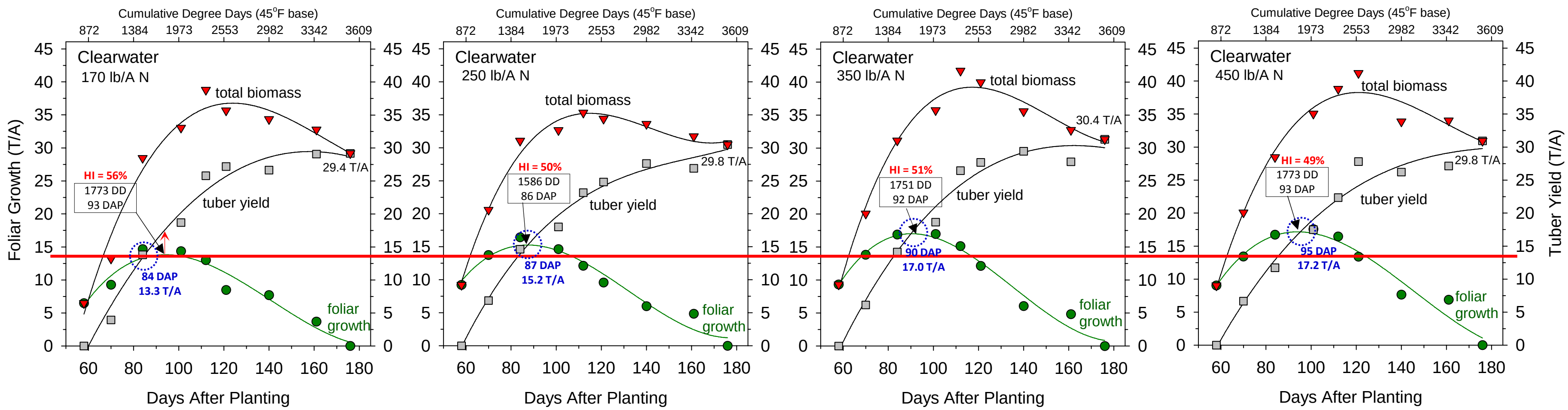


Fig. 1. Changes in petiole nitrate-N of Clearwater and Dakota Russet grown with four rates of seasonal N at Othello, WA in 2014. Planting date was April 21 and plots were harvested Oct. 14 (176 DAP).

Clearwater Russet, Othello, WA (2014)



Dakota Russet, Othello, WA (2014)

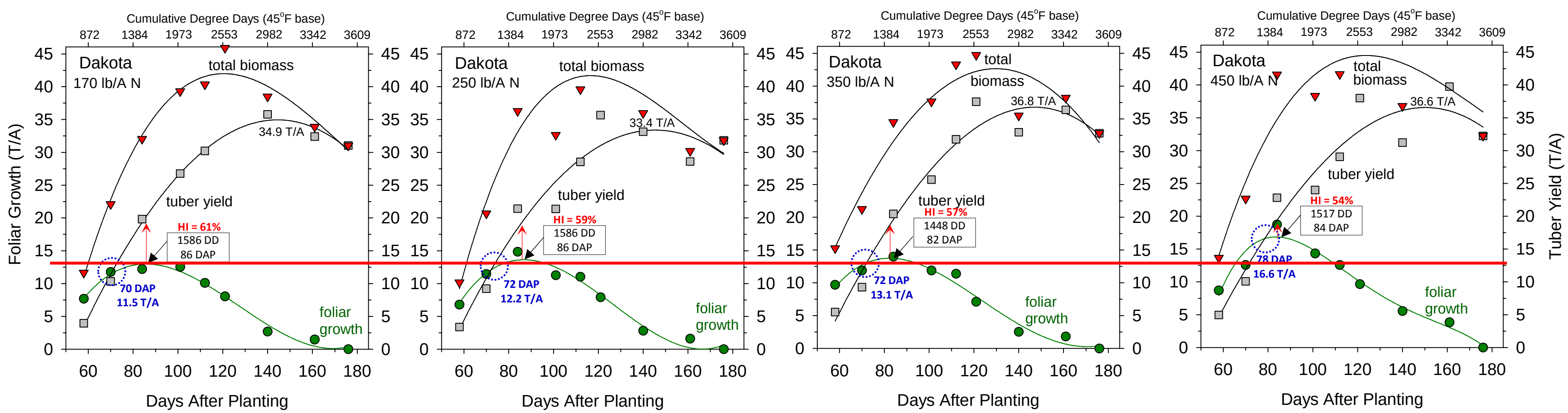


Fig. 2. Foliar and tuber growth of **Clearwater Russet** (top row) and **Dakota Russet** (bottom row) under four levels of nitrogen (N) at Othello, WA in 2014. Planting date was April 21 and plots were harvested Oct. 14 (176 DAP). Cumulative degree days (DD) are shown on the top axis of each graph. DAP, DD, and harvest indices (HI) at maximum foliar growth are indicated for each cultivar and N level. Harvest index equals tuber fresh weight as percent of total plant (tubers + foliage) fresh weight at maximum foliar growth. The DAP to 50% HI are also indicated (where foliar and tuber growth curves intersect). Foliar and tuber yields are equal (shown in blue) at 50% HI.

N Response Trials
Foliar & Tuber Growth

Clearwater Russet

Dakota Russet

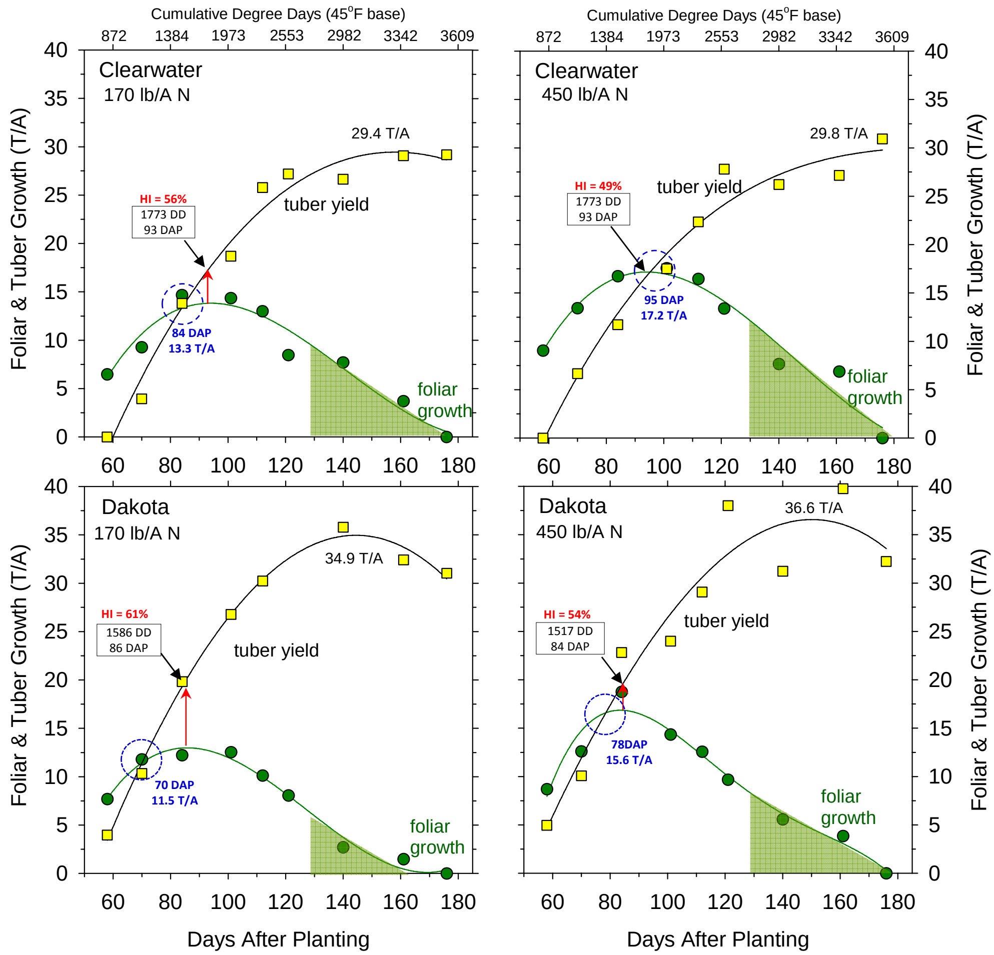


Fig. 3. Foliar and tuber growth of **Clearwater Russet** (top row) and **Dakota Russet** (bottom row) at the lowest (170 lb/A N) and highest (450 lb/A N) nitrogen levels in 2014. Planting date was April 21 and plots were harvested Oct. 14 (176 DAP). Cumulative degree days (DD) are shown on the top axis of the Clearwater graphs. DAP, DD, and harvest indices (HI) at maximum foliar growth are indicated for each cultivar and N level. Harvest index equals tuber fresh weight as percent of total plant (tubers + foliage) fresh weight at maximum foliar growth. The DAP to 50% HI are also indicated (where foliar and tuber growth curves intersect). Foliar and tuber yields are equal (shown in blue) at 50% HI. The area under the foliar growth curves from 130 DAP to season end has been shaded to visually resolve the effects of cultivar and N on late season vine growth.

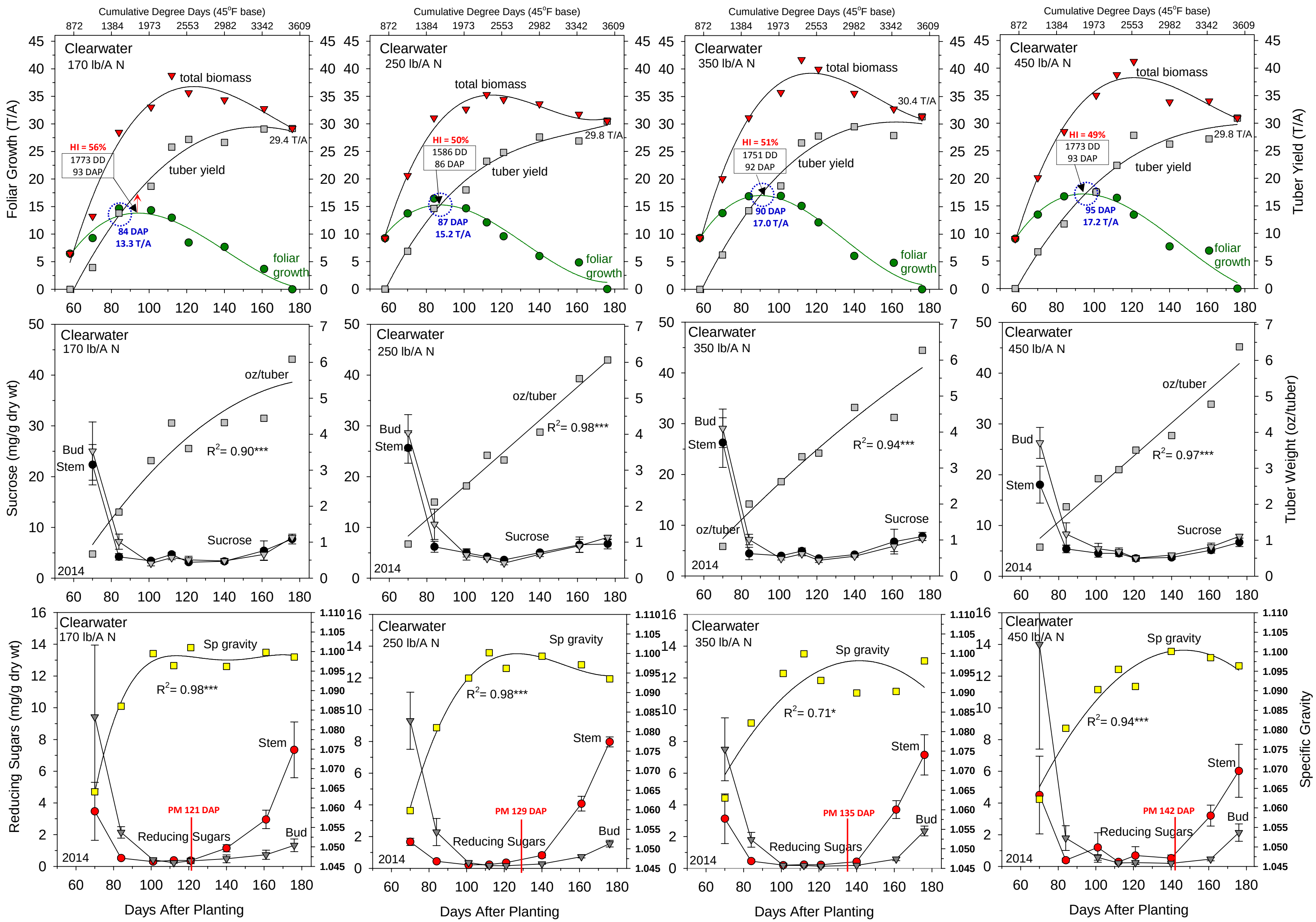


Fig. 4. (top row) Foliar and tuber growth responses of **Clearwater Russet** to four levels of seasonal nitrogen (N) at Othello, WA in 2014. Cumulative degree days (DD) at the corresponding days after planting (DAP) along with DAP, DD, and harvest indices (HI) at maximum foliar growth are indicated (top row). Foliar and tuber growth indices (top row) are defined in Figs 2 and 3. Changes in tuber sucrose concentrations, average tuber weights (middle row), reducing sugars (glucose and fructose) and specific gravity (bottom row) were profiled as components of physiological maturity (PM). PM was estimated at 121, 129, 135, and 142 DAP as N rate increased from 170 to 450 lb/A (bottom row). Effects of N on maturity indices are summarized in Tables 2 and 3.

Table 2. Effects of N rate on crop maturity indices of **Clearwater Russet** at Othello, WA (2014). Planting date was April 21 and tubers were harvested Oct. 14 (176 DAP). Maturity indices were derived from regressions of foliar growth, tuber growth, and carbohydrate data versus DAP for each N regime (see Fig. 4).

Clearwater 2014			DAP to		Days After Planting (DAP) to				
Nitrogen[1]	50% HI		Maximum	HI[2]	Max	Max	Min	Min Red.	Physiological
lb/A	*DAP*	*T/A*	Foliar F.Wt.	*%*	Yield	Gravity	Sucrose	Sugars[3]	Maturity[4]
170	84	13.3	93	55.7	158	112	115	97	121
250	87	15.2	86	49.3	164	127	119	108	129
350	90	17.0	92	50.9	162	142	121	115	135
450	95	17.2	93	49.3	167	146	139	117	142
R^2	0.99***	0.99**	0.06ns	0.72ns	0.70*	0.99**	0.96ns	0.99***	0.99***
Trend	L	Q	-	Q	L	Q	Q	Q	L

[1]N rates include ca. 174 lb/A residual N at planting. [2]HI= tuber wt/tuber wt + foliar wt at maximum foliar development. [3]DAP to reach minimum reducing sugar concentration in the stem end of tubers. [4]Physiological maturity is the average DAP to reach maximum yield, specific gravity, minimum sucrose, and minimum reducing sugars in tubers. *,**,***P<0.1, 0.05 and 0.01, respectively, for linear (L) or quadratic (Q) correlation coefficients (vs. N rate).

Table 3. Effects of N rate on foliar growth, tuber yield, and specific gravity of **Clearwater Russet** at Othello, WA (2014) (see Fig. 4).

Clearwater 2014			Specific Gravity[2]	
Nitrogen[1]	Max. Foliar Biomass	Final Tuber Yield[2]	Maximum	At harvest
lb/A	*T/A*	*T/A*	*SG*	*SG*
170	13.8	29.4	1.099	1.099
250	15.3	29.2	1.100	1.094
350	17.0	30.4	1.098	1.091
450	17.2	29.8	1.100	1.095
R^2	0.99**	0.44ns	0.02	0.98*
Trend	Q	Q	-	Q

[1]N levels include ca. 174 lb/A residual N at planting. [2]Derived from regressions of yield and gravity vs DAP. *,**,***P<0.1, 0.05 and 0.01, respectively, for linear (L) and quadratic (Q) correlation coefficients (vs. N rate).

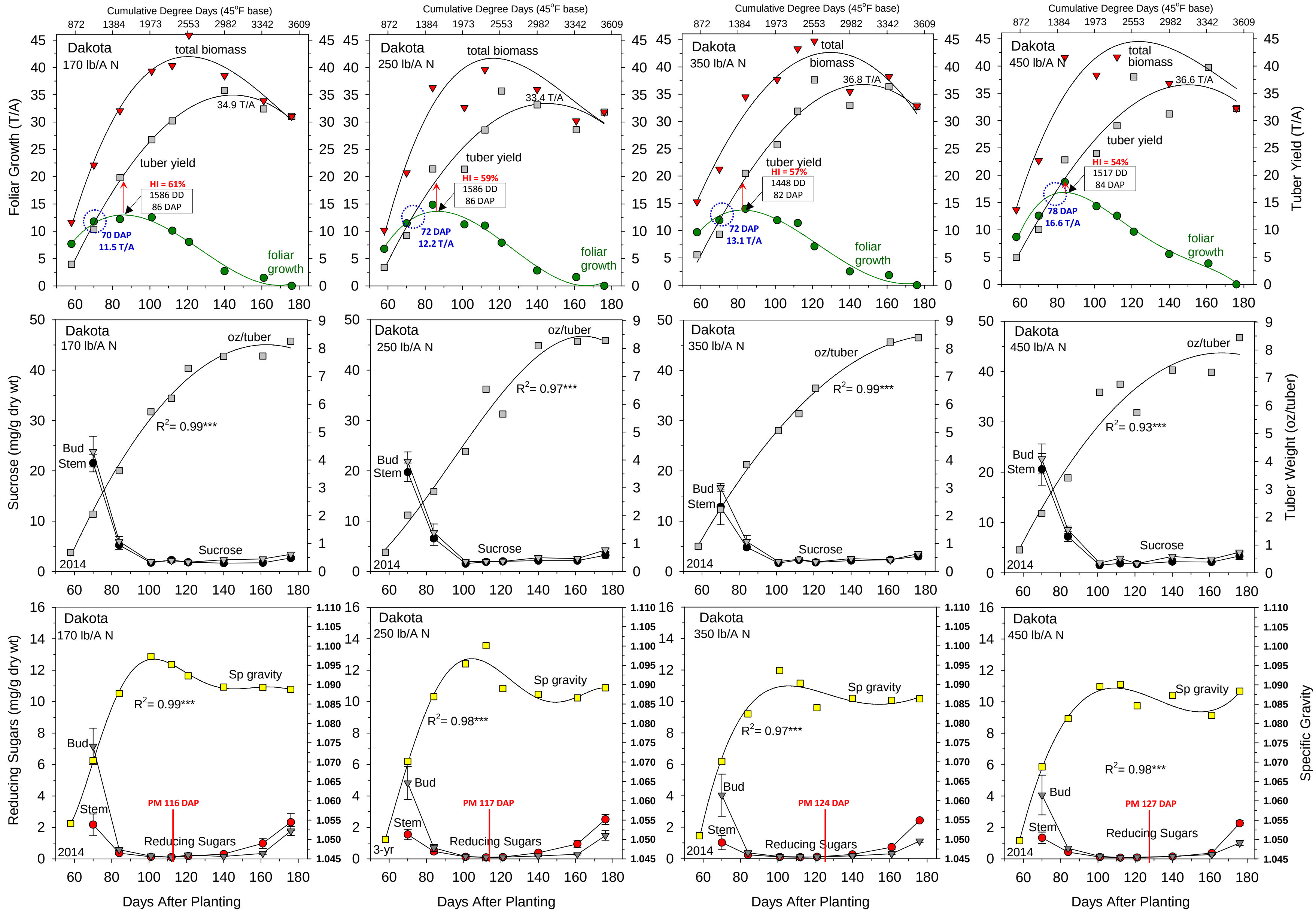


Fig. 5. (top row) Foliar and tuber growth responses of **Dakota Russet** to four levels of seasonal nitrogen (N) at Othello, WA in 2014. Cumulative degree days (DD) at the corresponding days after planting (DAP) along with DAP, DD, and harvest indices (HI) at maximum foliar growth are indicated (top row). Foliar and tuber growth indices (top row) are defined in Figs 2 and 3. Changes in tuber sucrose concentrations, average tuber weights (middle row), reducing sugars (glucose and fructose) and specific gravity (bottom row) were profiled as components of physiological maturity (PM). PM was estimated at 116, 117, 124, and 127 DAP as N rate increased from 170 to 450 lb/A (bottom row). Effects of N on maturity indices are summarized in Tables 3 and 4.

Table 4. Effects of N rate on crop maturity indices of **Dakota Russet** at Othello, WA (2014). Planting date was April 21 and tubers were harvested Oct. 14 (176 DAP). Maturity indices were derived from regressions of foliar growth, tuber growth, and carbohydrate data versus DAP for each N regime (see Fig. 5).

Dakota 2014			DAP to		Days After Planting (DAP) to				
Nitrogen[1]	50% HI		Maximum	HI[2]	Max	Max	Min	Min Red.	Physiological
lb/A	*DAP*	*T/A*	Foliar F.Wt.	*%*	Yield	Gravity	Sucrose	Sugars[3]	Maturity[4]
170	70	11.5	86	61.2	145	105	111	102	116
250	72	12.2	86	58.9	145	105	110	107	117
350	72	13.1	82	57.2	148	105	122	121	124
450	78	16.6	84	53.6	150	110	121	127	127
R^2	0.82*	0.98*	0.46ns	0.98***	0.98*	0.95ns	0.74ns	0.97**	0.95**
Trend	L	Q	LT	L	Q	Q	L	L	L

[1]N rates include ca. 174 lb/A residual N at planting. [2]HI= tuber wt/tuber wt + foliar wt at maximum foliar development. [3]DAP to reach minimum reducing sugar concentration in the stem end of tubers. [4]Physiological maturity is the average DAP to reach maximum yield, specific gravity, minimum sucrose, and minimum reducing sugars in tubers. *,**,***P<0.1, 0.05 and 0.01, respectively, for linear (L) or quadratic (Q) correlation coefficients (vs. N rate).

Table 5. Effects of N rate on foliar growth, tuber yield, and specific gravity of **Dakota Russet** at Othello, WA (2014) (see Fig. 5).

Dakota 2014				
	Max. Foliar	Final Tuber	Specific Gravity[2]	
Nitrogen[1]	Biomass	Yield[2]	Maximum	At harvest
lb/A	*T/A*	*T/A*	*SG*	*SG*
170	13.0	34.9	1.097	1.089
250	13.6	33.4	1.097	1.089
350	13.8	36.9	1.090	1.087
450	16.9	36.6	1.089	1.088
R^2	0.95ns	0.51ns	0.87*	0.60ns
Trend	Q	L	L	Q

[1]N levels include ca. 174 lb/A residual N at planting. [2]Derived from regressions of yield and gravity vs DAP. *,**,***P<0.1, 0.05 and 0.01, respectively, for linear (L) and quadratic (Q) correlation coefficients (vs. N rate).

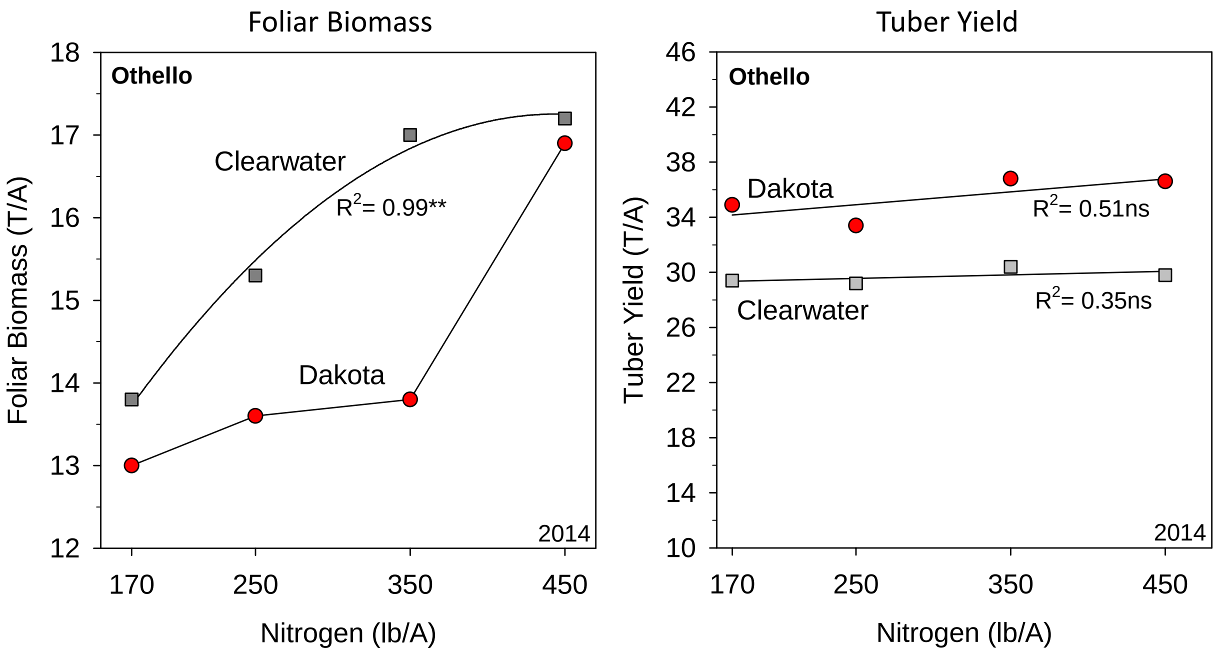


Fig. 6. Maximum foliar biomass production (left) and tuber yields (right) of Clearwater and Dakota Russet as affected by N rate at Othello, WA in 2014. Planting and harvest dates were April 21 and Oct. 14, respectively. Maximum foliar biomass and tuber yields at each N level were derived from regressions (Fig. 2). In contrast to foliar growth, tuber yields did not respond to increasing N.

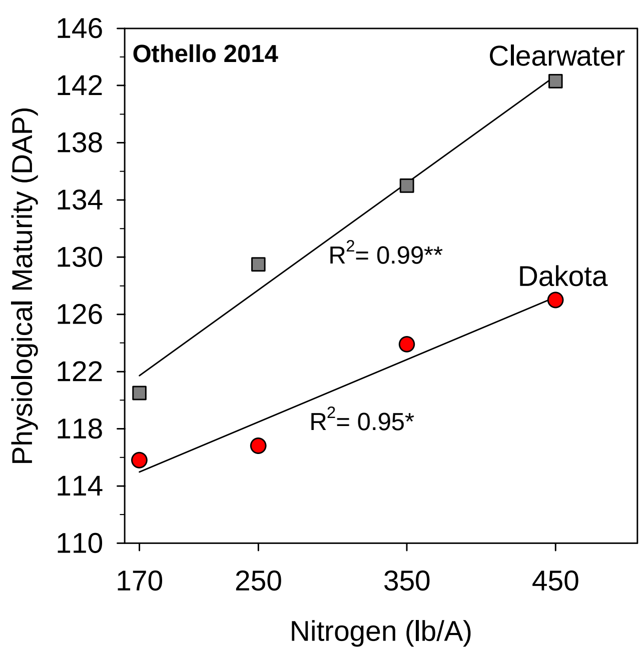


Fig. 7. Effects of N rate on days after planting to physiological maturity (PM) in 2014 for Clearwater and Dakota Russet tubers. PM is the average of DAP to reach max yield, max specific gravity, minimum sucrose, and minimum reducing sugars in tubers (see Figs. 4 & 5; Tables 2 & 4). Dakota reached PM earlier than Clearwater. Past work with other cultivars has shown that tubers should be harvested soon after PM for best quality and storability.

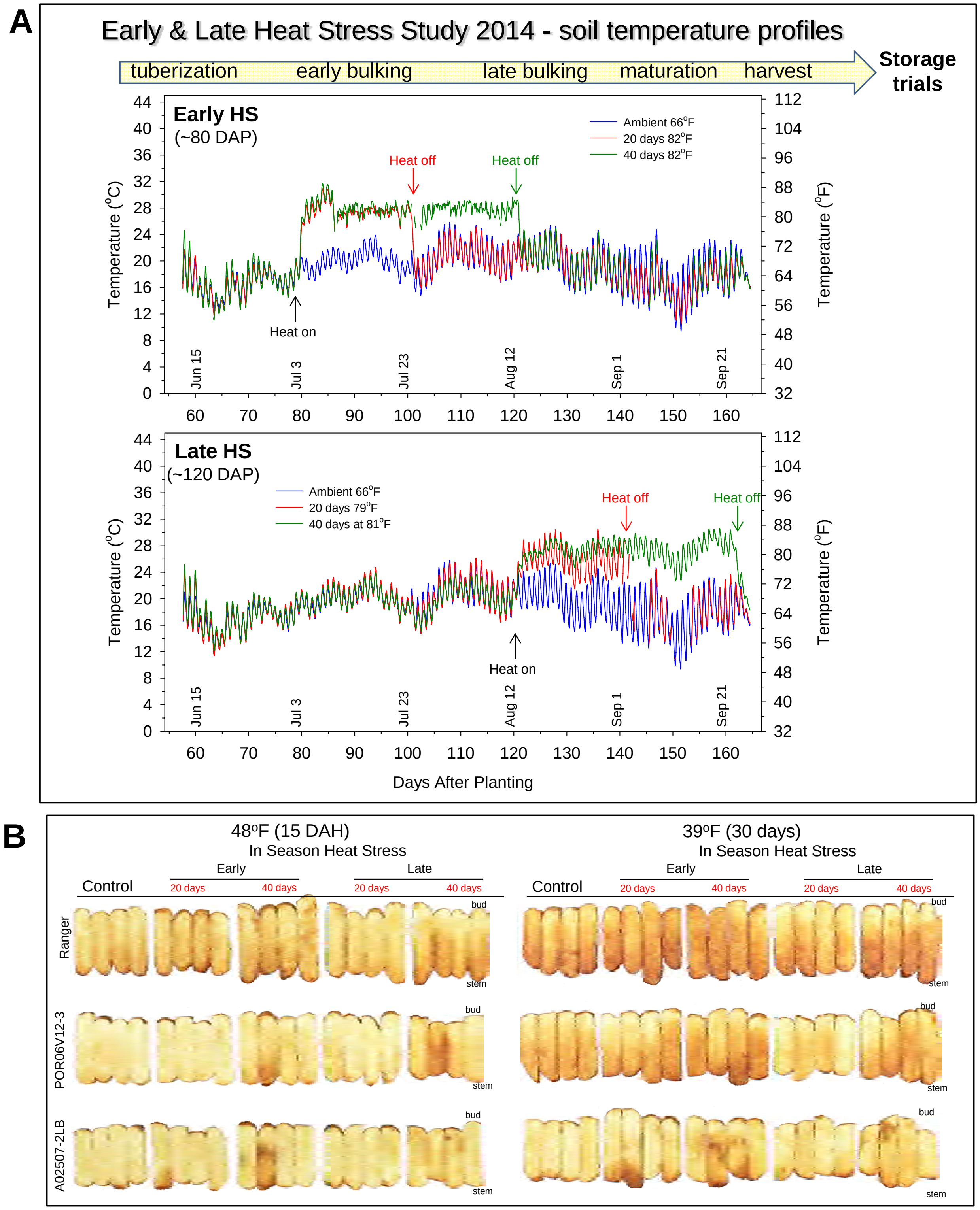


Fig. 8. **(A)** Diurnal soil temperature profiles showing application of early (top graph) and late (bottom graph) heat stress (HS) treatments in 2014. Ranger, A02138-2, POR06V12-3 and A02507-2LB were exposed to ~+14°F soil temperatures for 20 and 40 days starting ~80 (early bulking) or 120 days after planting (late bulking/maturation). Tubers were planted April 16 and harvested Oct. 2, 2014. **(B)** Following harvest, tubers were wound healed at 48°F for 15 days and then stored at 39°F for 30 days to evaluate the effects of in-season heat on retention of LTS resistant phenotype. Relative to the other clones, A02507-2LB showed increased tolerance of heat for retention of fry color during LTS (A02138-2 is not shown).

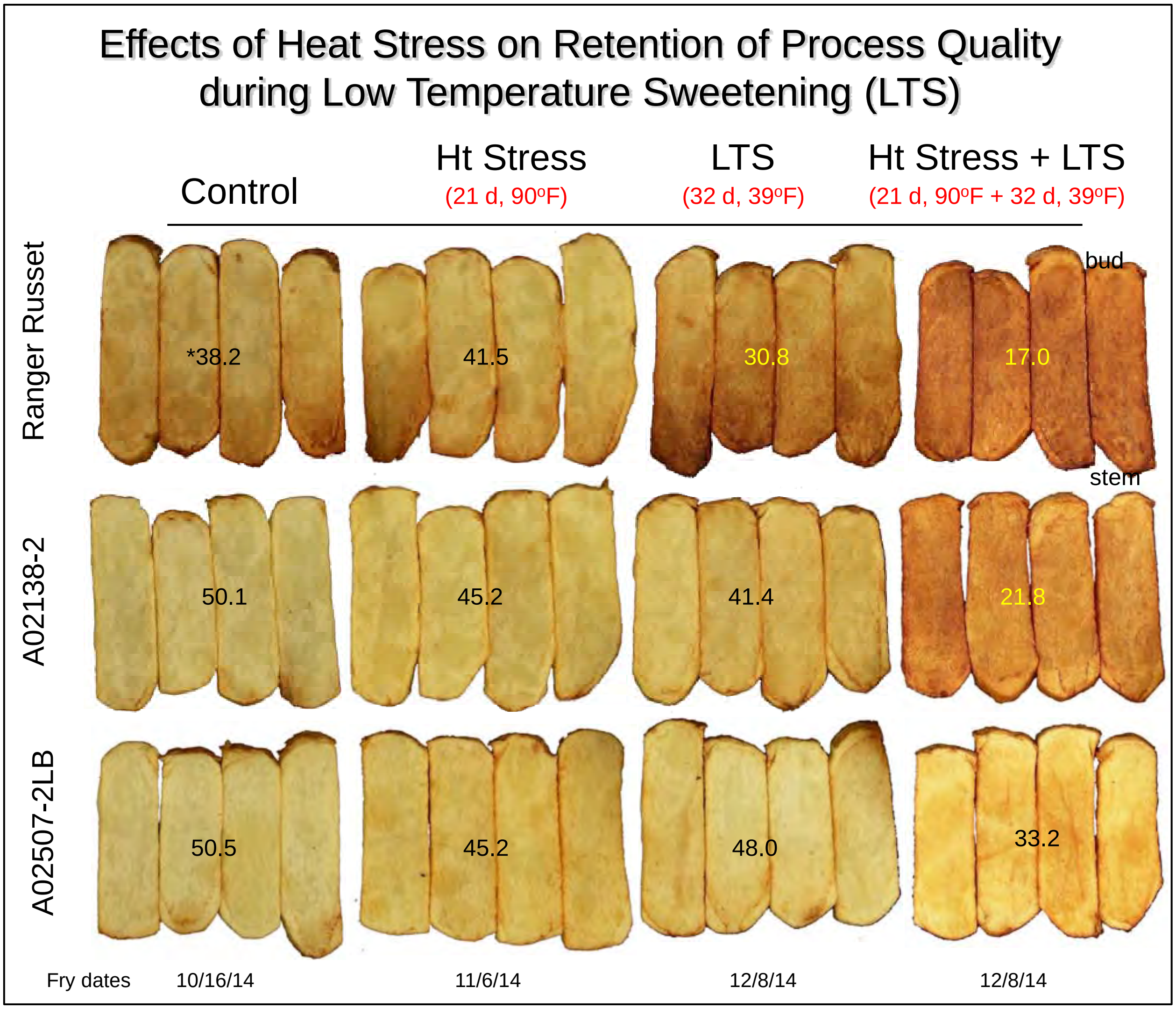
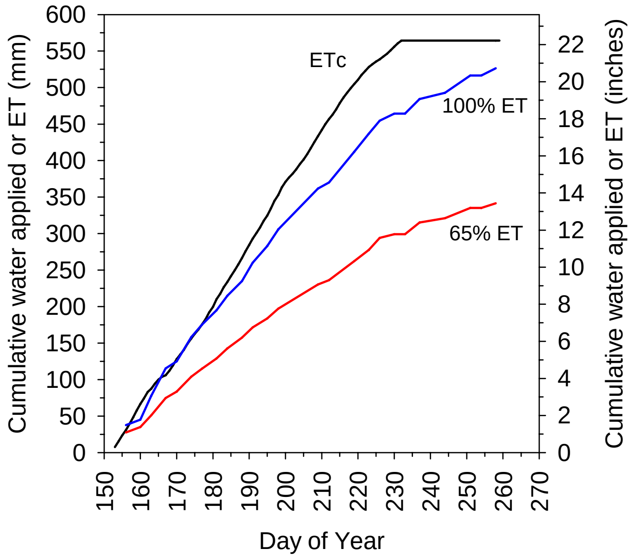


Fig. 9. Effects of postharvest heat stress on LTS at 39°F. Tubers were subjected to a heat priming (stress) treatment at 90°F for 21 days prior to storing for an additional 32 days at 39°F to stimulate LTS. Control tubers were stored continuously at 48°F. A02138-2 and A02507-2LB are highly resistant to LTS at 39°F as indicated by the light colored fries. However, A02138-2 loses its LTS resistant phenotype if heat stressed prior to storage at low temperature. In contrast A02507-2LB is more tolerant of heat stress for retention of LTS phenotype. Darker fries indicate higher buildup of reducing sugars. Numbers are the average (bud and stem end) photovolt reflectance values of 12 tubers.

A



B

Source		*F*-value	
	DF	Total Yield	U.S. #1
Water	1	8.87**	5.74*
Cultivar	8	14.45***	13.35***
Water x cultivar	8	ns	2.56*
Water main effects		WUE total yield (cwt/A/inch)	WUE U.S. #1 yield (cwt/A/inch)
100% (22.3 inches)		27.9b	24.2b
67% (14.9 inches)		38.5a	33.8a
$LSD_{0.05}$		1.7	1.6
Cultivar main effects		WUE total yield (cwt/A/inch)	WUE U.S. #1 yield (cwt/A/inch)
GemStar		36.0a	34.5a
Targee		36.8a	33.1ab
Burbank		37.9a	32.6ab
Alturas		37.9a	30.5bc
Ranger		35.0a	29.8bc
Classic		30.2b	28.5c
Umatilla		34.3a	28.3c
Alpine		25.5c	22.1d
Teton		25.5c	21.9d
$LSD_{0.05}$		3.6	3.4

C

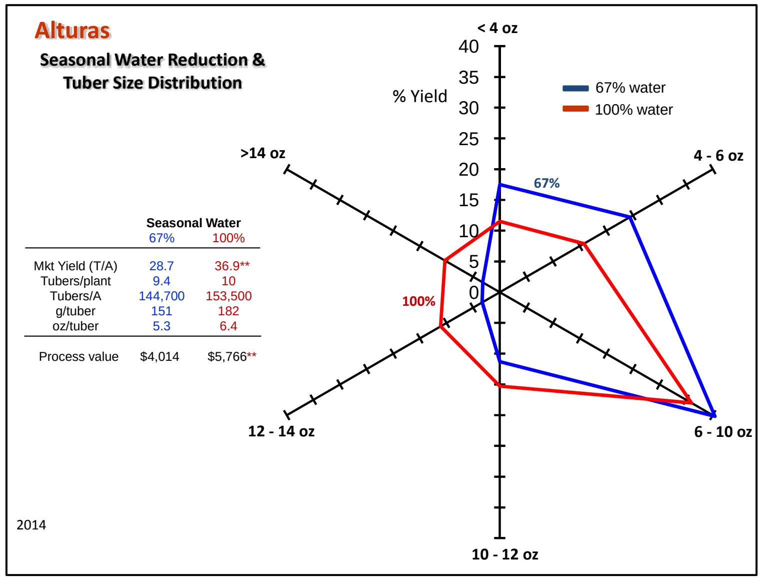
Yield Component	Seasonal Water Level	
	100%*	67%
Total Yld (T/A)	31.1	28.7**
U.S. #1 Yld (T/A)	27.0	25.2*
<4 oz (T/A)	3.8	2.9**
4-6 oz (T/A)	5.1	5.0
6-10 oz (T/A)	10.1	10.5
10-12 oz (T/A)	3.6	3.5
12-14 oz (T/A)	2.8	2.3*
>14 oz (T/A)	5.4	3.8*
Mkt Yld (T/A)	30.8	28.1**
oz/tuber	7.1	7.0
Tubers/plant	8.0	7.3*
Tubers/A (1000's)	123,200	112,800*
sp gravity	1.073	1.074

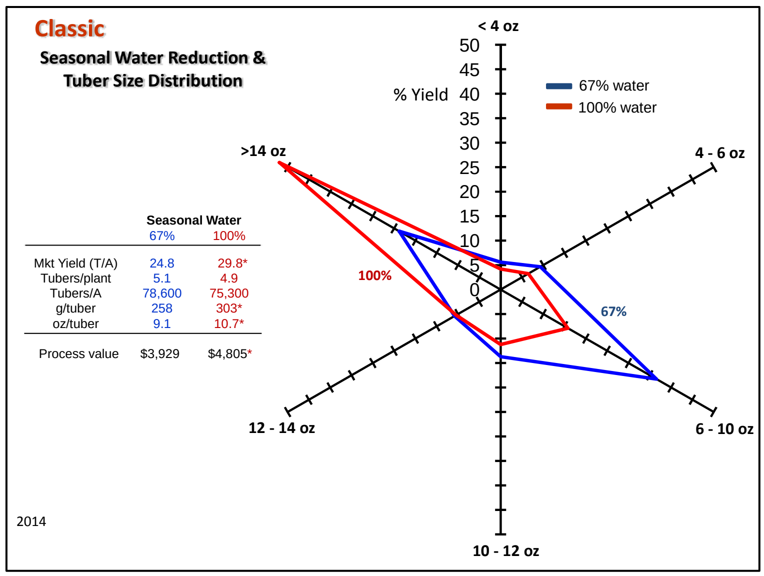
D

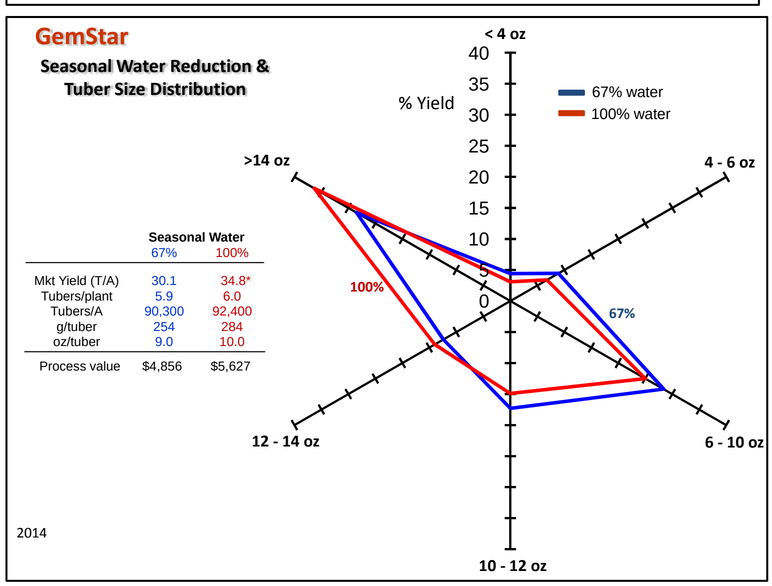
Yield Component	Seasonal Water Level	
	100%*	67%
	WUE *cwt/A/inch*	
Alturas	35.0a	40.8a
GemStar	31.2ab	40.7a
Targee	30.8ab	42.7a
Burbank	30.3b	45.5a
Umatilla	30.0b	39.6ab
Ranger	27.8b	42.2a
Classic	26.9b	33.5bcd
Alpine	20.3c	30.8d
Teton	19.8c	31.1cd
$LSD_{0.05}$	4.5	6.3
Water	<0.001	
Cultivar	<0.001	
Water x cultivar	ns	

Fig. 10. (A) Cumulative water applied (irrigation + precipitation) to achieve target regimes of 65 and 100% evapotranspiration (ET) for potato in 2014. Evapotranspiration was estimated from AgWeatherNet data at WSU Othello, WA from June 3 to September 17. Planting date was April 15, vines were mowed Sept. 15 and tubers were harvested Oct. 1. Estimated seasonal ET was 564 mm (22.2 in) in 2014, which was 6.4 to 9.9% higher (7.8% avg) than during the previous 4 years (2010-2013). Including water applied prior to emergence, plots received 14.9 and 22.3 inches (378 and 566 mm) total over the season. These rates thus equated to ~67 and 100% of ET. **(B)** Summary of ANOVA for total and U.S. #1 yields produced by nine cultivars grown at 67 and 100% ET (*,**,****P*<0.05, 0.01 and 0.001, respectively). Water use efficiencies (WUE, cwt/A/inch) for the main effects of water and cultivar are given. Letters indicate mean separation via LSD (*P*<0.05). **(C)** Main effects of water level (averaged over 9 cultivars) on tuber yield components and specific gravity (*,***P*<0.05 and 0.01, respectively). **(D)** Water use efficiencies for total yield of each cultivar grown at 100 and 67% ET. The main effects of water and cultivar on WUE were significant (*P*<0.001). Cultivars are ranked from highest to lowest WUE at 100% ET.

Fig. 11. Effects of seasonal water regime on tuber size distributions of Alturas, Classic and GemStar Russet. Cultivars were grown at 67 or 100% ET water levels in 2014. Planting date was April 15, vines were mowed Sept. 15 and tubers were harvested Oct. 1. Plots received 14.9 and 22.3 inches (378 and 566 mm) total water over the season. Yields of the six tuber size classes are expressed as percentage marketable yield (U.S. #1 + <4-oz tubers). Inset tables compare marketable yields, number of tubers per plant, average tuber fresh weights, and crop values between water regimes (*,***P*<0.05 and 0.01, respectively). Gross values were estimated with a mock contract for frozen processing that focused on tuber yield and size distribution only. Incentives for bruise, specific gravity, etc. were not included.







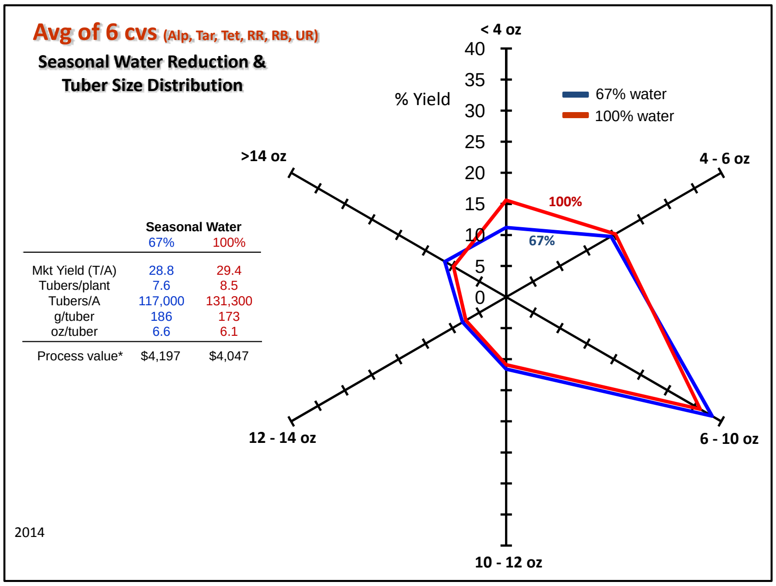


Fig. 12. Average effects of seasonal water regime on tuber size distributions of six cultivars (Alpine, Targee, Teton, Ranger, RB and Umatilla) in 2014. In contrast to Alturas, Classic and GemStar (see Fig. 11), the marketable yields of these six cultivars were not significantly affected by water level. The cultivars were grown at 67 or 100% ET water levels. Planting date was April 15, vines were mowed Sept., 15 and tubers were harvested Oct. 1. Plots received 14.9 and 22.3 inches (378 and 566 mm) total water over the season. Yields of the six tuber size classes are expressed as percentage marketable yield (U.S. #1 + <4-oz tubers). Inset tables compare marketable yields, number of tubers per plant, average tuber fresh weights, and crop values, which were not affected by the water levels. Gross values were estimated with a mock contract for frozen processing that focused on tuber yield and size distribution only. Incentives for bruise, specific gravity, etc. were not included.

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ANNUAL PROGRESS REPORT SUBMITTED TO THE POTATO CONSORTIUM

TITLE: Methods of sprout and disease suppression of potatoes in storage

PERSONNEL: Nora Olsen, Extension Potato Specialist, UI Kimberly R & E Center
Mary Jo Frazier, Support Scientist 3, UI Kimberly R & E Center
Sherilyn Peck, Graduate Student, UI Kimberly R & E Center

REPORTING PERIOD: July 1, 2014 - Dec 1, 2014

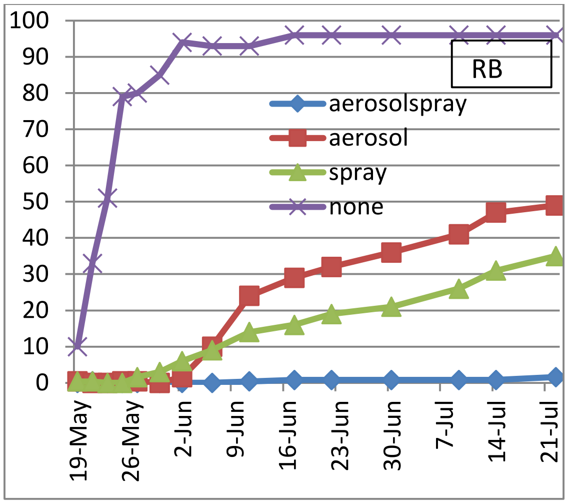
ACCOMPLISHMENTS: *This project was initiated in the spring 2014 and is currently in progress with storage studies. Below is a summary to date and a final report will be submitted in September 2015.*

Results from the first objective and study indicate the very low risk of sprout development when both an aerosol and EC spray application of CIPC is made to potatoes prior to export. An EC application alone is a deterrent, but will not provide assurance of limited to no emergence. Export negotiations can rely upon this data to ensure the country of the low risk in importing US potatoes that have been treated with aerosol and EC-CIPC applications. Differences in varieties were observed, although if both CIPC applications are used, the results were similar. A journal publication was published highlighting results from previous CIPC impacts on plant performance and can be used as an official document for export negotiations. The fourth objective that investigates early storage management temperature conditions on tuber quality response. This project is still in progress, but yielding interesting results to date. This study emphasizes the impact of early storage management and results show the negative consequences of decay due to warm early storage temperatures and processing quality implications of lower temperatures.

RESULTS:

Objective 1. Evaluate the impact of aerosol and/or EC-CIPC applications on subsequent crop productivity of three varieties for export considerations.

Three varieties of seed potatoes (Russet Burbank, Russet Norkotah, and Yukon Gold) were obtained in the fall of 2013. Half of each variety was treated with thermal application of CIPC on 11/26/13. The other half of the seed was stored under similar conditions (42°F/95% RH) in a non-CIPC treated storage. Shortly before planting (4/21/14) each treatment was split into two treatments, one received CIPC applied as an EC spray and one treatment received no CIPC spray. Emergence and vigor were evaluated for each treatment (Fig. 1-3). Plots were harvested (9/17/14), graded (9/18/14), and calculating yield for the CIPC treated seed have been accomplished (Table 1). Specific gravity of harvested tubers were not significantly different (Table 2) between the treated and non-treated in Russet Burbank or Russet Norkotah, but was higher for the untreated Yukon Gold. Russet Norkotah seed which received both spray and aerosol CIPC did not produce enough tubers to measure specific gravity. Seed for next year's study has been obtained and treated with aerosol CIPC.



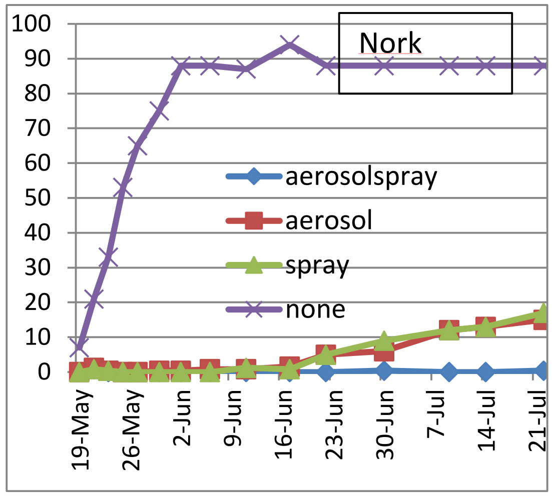


Fig 1. Emergence of R. Burbank after CIPC Fig. 2 Emergence of R. Norkotah after CIPC

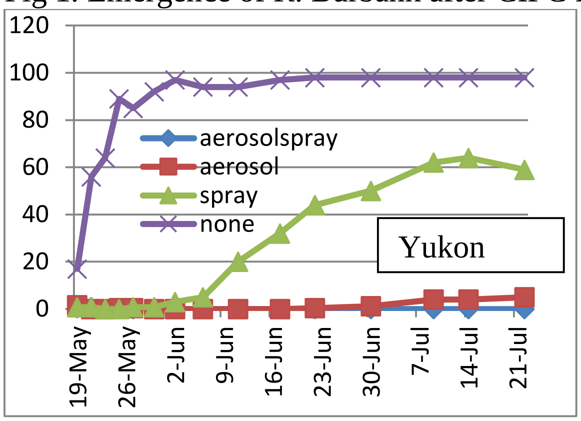


Fig 3. Emergence of Yukon Gold after CIPC treatments

Table 1. Yield (cwt/A) of three varieties after seed treatment with CIPC. 2014.

	Russet Burbank	Yukon Gold	Russet Norkotah
	Yield (cwt/A)		
UTC	711	453	572
CIPC aerosol	260	88	25
CIPC spray	202	78	295
CIPC aerosol and spray	10	3	0
LSD0.05	89	67	47

Table 2. Specific gravity of three varieties after seed treatment with CIPC.

	Russet Burbank	Yukon Gold	Russet Norkotah
UTC	1.074	1.085	1.073
CIPC aerosol	1.072	1.076	1.077
CIPC spray	1.071	1.078	1.072
CIPC aerosol and spray	1.074	1.078	NA
LSD0.05	NS	0.007	NS

Objective 2. Identify and evaluate novel chemistries as alternatives to CIPC.

Potatoes have been harvested and placed in storage to be treated with a new compound (pelargonic acid) at the appropriate time. We also plan to test a thermal application of peroxyacetic acid on silver scurf and other diseases.

Objective 3. Finalize CIPC based publications for US stewardship documentation and export negotiations.

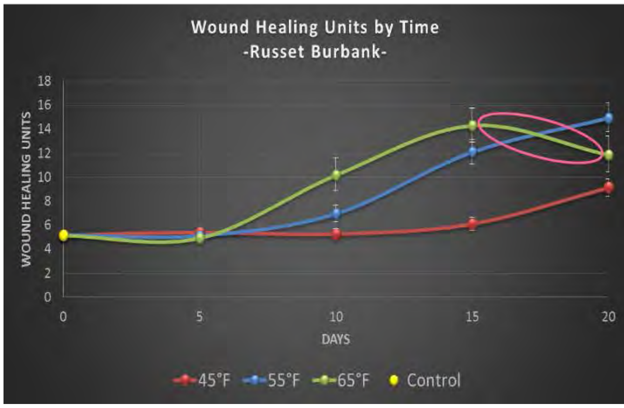
A refereed journal article documenting the emergence and yield of CIPC treated seed has been written, accepted for publication, and in press. It is currently available on-line. The article, 'The Effects of Chlorpropham Exposure on Field-Grown Potatoes', will be published in the American Journal of Potato Research. A bulletin is in preparation on a CIPC sampling procedure, CIPC residues in storages, and swabbing equipment and storage material for CIPC.

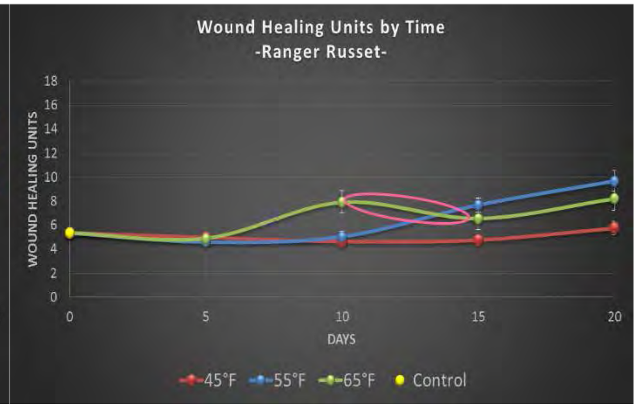
Objective 4: Investigate early storage management temperature conditions on tuber quality response.

This project is still in progress, but results to date are presented below. Clearwater Russet will be evaluated for wound healing and suberization. The wound healing and suberization study will be repeated again on all three varieties this winter/spring.

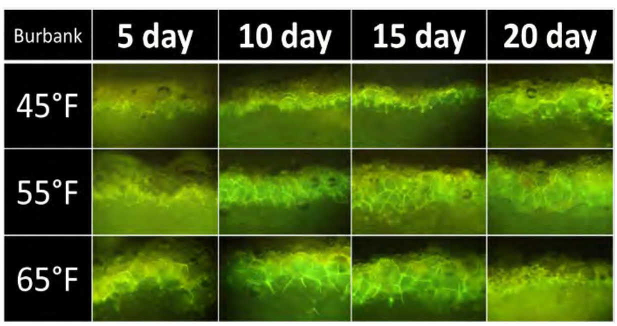
<u>Wound healing cores</u>
Cores of Russet Burbank and Ranger Russet were taken with a 15 mm cork borer. Cores were then wound healed in an incubator for 0, 5, 10, 15, or 20 days at 45, 55 or 65°F and 95% relative humidity. After the wound healing period was over, cores were placed in drying oven to be force desiccated for two hours. During the forced desiccation period, weight loss of the cores is recorded. The weight loss during the 2 hour period is linear. The inverse of the slope of the weight loss lines are then used to calculate resistance to weight loss, or wound healing units. Cores from the above mentioned samples were evaluated under fluorescent microscopy for depth of suberization as well as number of cells suberized.

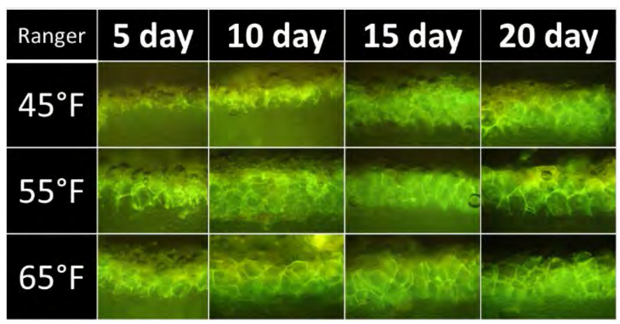
For both Ranger Russet and Russet Burbank, there were no significant differences in wound healing after 5 days of curing regardless of temperature. By 10 days, wound healing units were significantly higher at 65°F than at 55°F and 45°F. Wound healing units were also significantly higher at 55°F than at 45°F for both Ranger Russet and Russet Burbank. At 15 and 20 days, wound healing units at 65°F were significantly lower than at 55°F due to decay of the cores. This emphasizes the concern for elevated breakdown of tissue at extended warmer (65°) early storage temperatures. Wound healing units at 45°F were still significantly lower than at 55°F and 65°F. Russet Burbank showed greater wound healing at 65°F curing at 15 days than 5 and 10 days, but tissue began to deteriorate by 20 days at this warmer temperature.





In the absence of decay, microscopy data supported slower wound healing at 45°F, as observed in the whole cores stated above. In Ranger Russet, the depth and number of cells with suberin deposition were not significantly different when cores were cured at 55°F for 10 days and 65°F for 20 days. There was no advantage to curing Ranger Russet at 65°F longer than 10 days. Whole core data showed that prolonged curing at 65°F resulted in decay. In Russet Burbank, suberin deposition increased with time and temperature in storage; each 10 degree increase in curing temperature shortened the duration to complete suberization by 5 days.



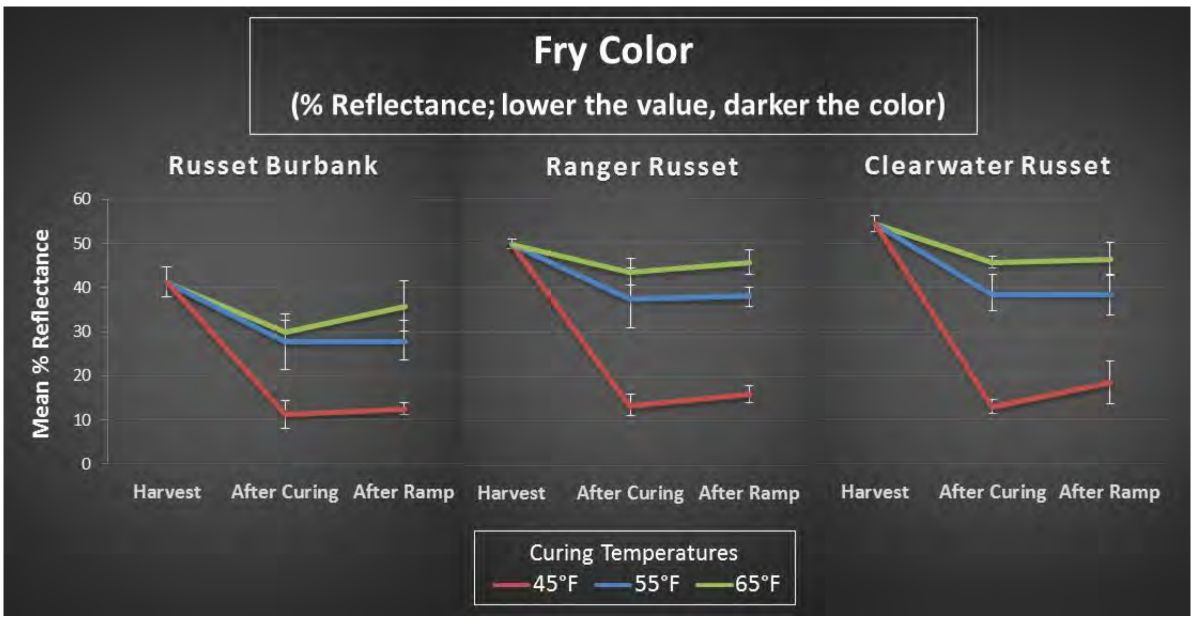


Weight loss and quality in storage

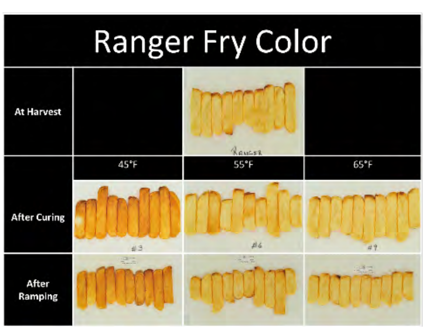
Sample bags of Russet Burbank, Ranger Russet and Clearwater Russet were placed in the storage bins at the Kimberly Potato Storage Research Facility in Kimberly, Idaho at the time of harvest. Samples were cured at 45, 55 or 65°F for 2 weeks, then ramped 0.5°F/day to the holding temperature of 48°F. Weight loss was recorded weekly for the first two months of storage. After that, weight loss is being recorded each month. Weight loss in Russet Burbank, Ranger Russet and Clearwater Russet was significantly higher at 65°F curing than at 45 or 55°F.

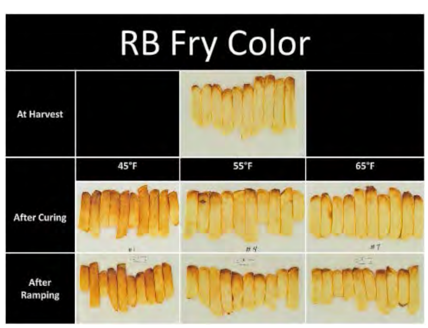
Quality of Russet Burbank, Ranger Russet and Clearwater Russet cured at 45, 55 or 65°F was evaluated by fry color measurements and sugar analysis at harvest, after curing and after ramping. Additional sampling will occur throughout the rest of the storage season.

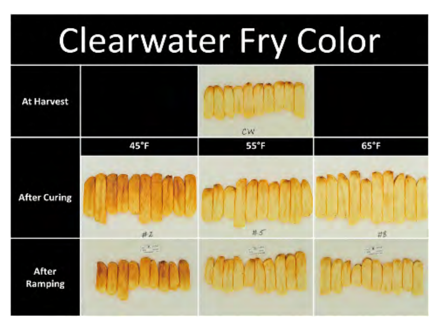
Percent Weight Loss After Two Months in Storage			
Curing Temperature	Russet Burbank	Ranger Russet	Clearwater Russet
45°F	3.9 % b	3.7% b	4.1% b
55°F	3.6 % b	4.0% b	3.4% b
65°F	4.6% a	5.4% a	5.5% a
Tubers were cured for 2 weeks. Ramping occurred 0.5 degrees/day. Final holding temperature of 48°F.			



Fry color of Russet Burbank, Ranger Russet, and Clearwater Russet was significantly darker if cured at 45°F. Clearwater Russet fry color was significantly darker when cured at 55°F than 65°F. Russet Burbank and Ranger Russet fry color was significantly darker at 55°F curing than at 65°F, but only observed at the end of ramping.



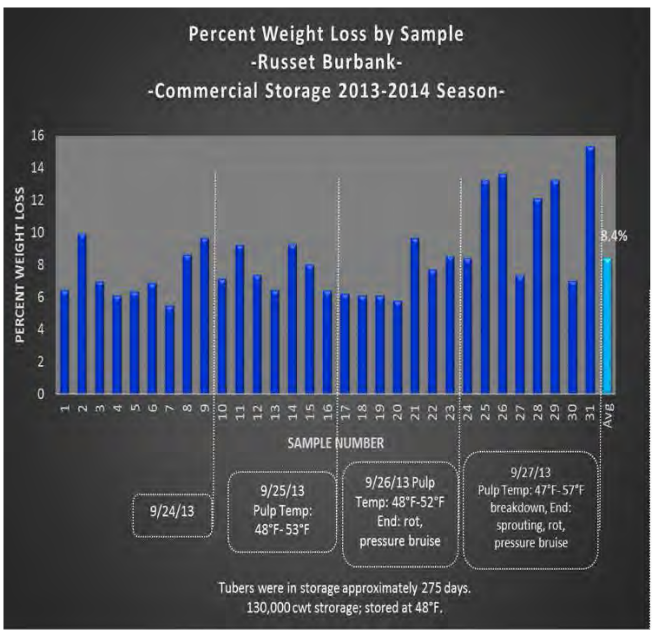


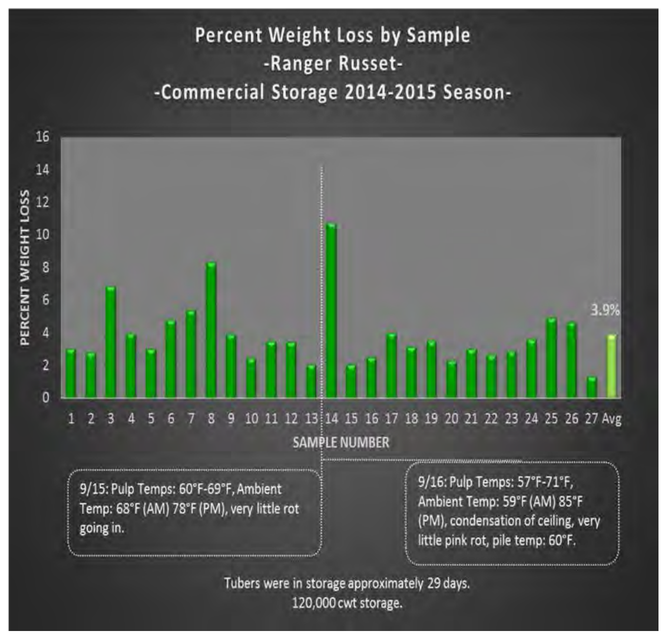


Weight Loss in Commercial Storage

In 2013, 30 40-lb bags of Russet Burbank and Ranger Russet potatoes were placed in grower storages. Bags were placed on top and in the pile. Initial weight was recorded at harvest and end weight was recorded when storage bins were unloaded. Overall weight loss was recorded for each sample bag. Weight loss for a Russet Burbank commercial storage in the 2013-2014 averaged 8.4% after 275 days in storage. In 2014-15, weight loss sample bags were placed into one Ranger Russet commercial storage, two Russet Burbank storages, and two Clearwater storages.

Weight loss for a Ranger Russet storage in the 2014-2015 storage averaged 3.9% weight loss after 29 days in storage when the potatoes were removed. That is a significant weight loss for 1 month in storage, but Pythium leak and high pulp temperatures probably contributed to this higher loss. The other storages will be monitored until emptied in 2015.





Conclusions to date based upon initial data collection

- Wound healing and suberin deposition were slower at 45°F curing temperature than at the warmer curing temperatures. Decay was rarely observed at this lower temperature regardless of the delay in suberization and wound healing. Fry color was negatively impacted at this lower temperature. This emphasizes the impact of cooler temperatures at or after harvest that can impact processing quality long-term, but indicates fresh potato growers have this option of getting potatoes to cooler temperatures faster.
- Curing temperature of 65°F resulted in faster wound healing and suberization, but prolonged duration (greater than 10 days) at this temperature resulted in tissue decay.

Weight loss was also greater at this curing temperature, although lighter fry color was observed. This stresses the need to remove field heat as quickly as possible. If potatoes are warm at harvest, cool to 55°F by 15 days for Russet Burbank and 10 days for Ranger Russet to minimize decay.

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ANNUAL PROGRESS REPORT SUBMITTED TO THE POTATO CONSORTIUM

TITLE: Storage Requirements for New and "Potential Release" Cultivars for the Potato Industry

PERSONNEL: Nora Olsen, Extension Potato Specialist, UI Kimberly R & E Center
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REPORTING PERIOD: July 1, 2014 – December 1, 2014

ACCOMPLISHMENTS:
The progress report for the 2013-14 storage season was submitted in September 2014. This report covers the period beginning July 1, 2014. Potatoes are still in storage and evaluations are continuing. The final report will be submitted in September 2015.

During the 2014-15 storage season 6 potato clones/cultivars, A02424-83LB (1st year), A03158-2TE (2nd year), A02507-2LB (3rd year), POR06V12-3 (1st year), A0073-2 (1st year), and Russet Burbank were evaluated for storage performance. Assessments included fry color, glucose and sucrose concentrations, Fusarium dry rot susceptibility, weight loss potential and dormancy length. These assessments plus general observations on storability provided information for best management practices for potential new cultivars and to identify pros and cons of the cultivars in storage. Highlights of each clone to date in field and storage: POR06V12-3 had acceptable fry color at harvest and high specific gravity (1.093). A03158-2TE had the lowest specific gravity of the clones evaluated, no sugar ends were seen at harvest, and had acceptable fry color at harvest. A02507-2LB has exceptional initial processing qualities and no sugar ends, but previous research has indicated the potential for greater weight loss, susceptibility to Fusarium dry rot, and presence of internal brown spot may limit quality consistency and/or long-term storability. The slower emergence and maturity would need to be managed with this clone. A0073-2 showed good potential processing quality. A02424-83LB had acceptable fry color, but did show sugar end development at harvest. Data collected over the storage season will provide additional information on each clone. If the clone is deemed as a potential release to the industry, results from a 3-year study will be compiled into a bulletin for easy dissemination to the industry.

RESULTS:

Six potato clones/cultivars, A02424-83LB, A03158-2TE, A02507-2LB, POR06V12-3, A0073-2, and Russet Burbank were planted at the Kimberly R&E Center on April 18, 2014. Emergence differences among the cultivars were noted early in the season (Fig. 1). Both A0073-2 and POR06V12-3 emerged 4 days after A02424-83LB, RB and A03158-2TE. A02507-2LB emerged about 7 days later than A02424-83LB, RB and A03158-2TE. There were no significant differences in final stand count between the clones. There was a high percentage of visual PVY infection in the A03158-2TE plants. Initial tests were confirmed with an Agdia immunostrip disease test kit and results from Dr. Alex Karasev indicated it is the N:O strain of PVY. Vine health assessments (percent green vines) were made in August and September (Fig. 2). A03158-2TE matured earlier than the other clones and A02507-2LB and POR06V12-3 had the greenest vines at vine kill (~90%). Plots were mechanically vine killed on September 4, 2014 and harvested on September 22, 2014. Specific gravity was evaluated on harvested tubers (Table 1). POR06V12-3 had the highest specific gravity and A03158-2TE had the lowest.

Tuber baseline glucose and sucrose concentrations and fry color and quality were established on September 25, 2014 (Table 2). Fry color analysis is performed concurrent with sugar extraction. Fry color was determined on 10 planks per sample after cooking in canola oil at 375°F for 3.5 minutes. Percent reflectance is read with a Photovolt reflectometer on both the bud and stem ends of each plank. The planks are also scored subjectively for mottling and sugar end presence. All clones had acceptable fry color and no sugar ends were observed in A03158-2TE and A02507-2LB. Glucose concentrations were very low in A0073-2 and A02507-2LB. Sucrose level was highest in A02424-83LB. Preliminary evaluations on tuber firmness were also performed on September 25, 2014 by utilizing an Extech penetrometer of the six clones at harvest. At harvest 3 tubers per rep were placed on a table against a wall and the penetrometer fitted with the 8mm tip was pressed against the middle of the tuber. There were no significant differences between the clones at harvest in tuber firmness (Table 1).

After harvest, the six cultivars were cured for 14 day at 55°F, ramped 0.5°F/day to a final holding storage temperatures of 42, 45, and 48°F and plus or minus CIPC. Dormancy break in all treatment combinations (plus and minus CIPC, 3 storage temperatures, 6 cultivars) will be monitored. Additional in-storage evaluations will be performed for glucose and sucrose concentrations, fry color and quality, penetrometer readings (tissue firmness), weight loss, Fusarium dry rot susceptibility and CIPC response after harvest and throughout storage at three storage temperatures (42, 45, and 48°F). Sprout rating and weight will be recorded monthly. CIPC was applied on Nov 25, 2014 as a thermal aerosol at a rate of 22 mg/kg. CIPC residue analysis is performed by The Idaho Department of Agriculture Food Quality Assurance Laboratory in Twin Falls, ID on three replications per month typically in December, March, and June. Cultivar response to CIPC treatment and storage temperature will be followed for nine months (July 2015).

The Fusarium dry rot susceptibility study was initiated on October 1, 2014; three replications of 25 pounds each were bruised by dropping samples 4.7 ft through a vertical chamber comprised of a series of baffles made from potato harvester chain and then inoculated with a solution of *Fusarium sambucinum* spores. Dry rot samples were cured at 55°F and then ramped to 45ºF at 0.5°F/ day. Tubers will be evaluated for incidence and severity of dry rot in February 2015 approximately four months after inoculation to allow decay to develop. Weight loss data is collected on 3 replicates (10 lb sample size) per variety at 42, 45 and 48°F plus CIPC on a monthly basis beginning in October 2014 and ending in June 2015

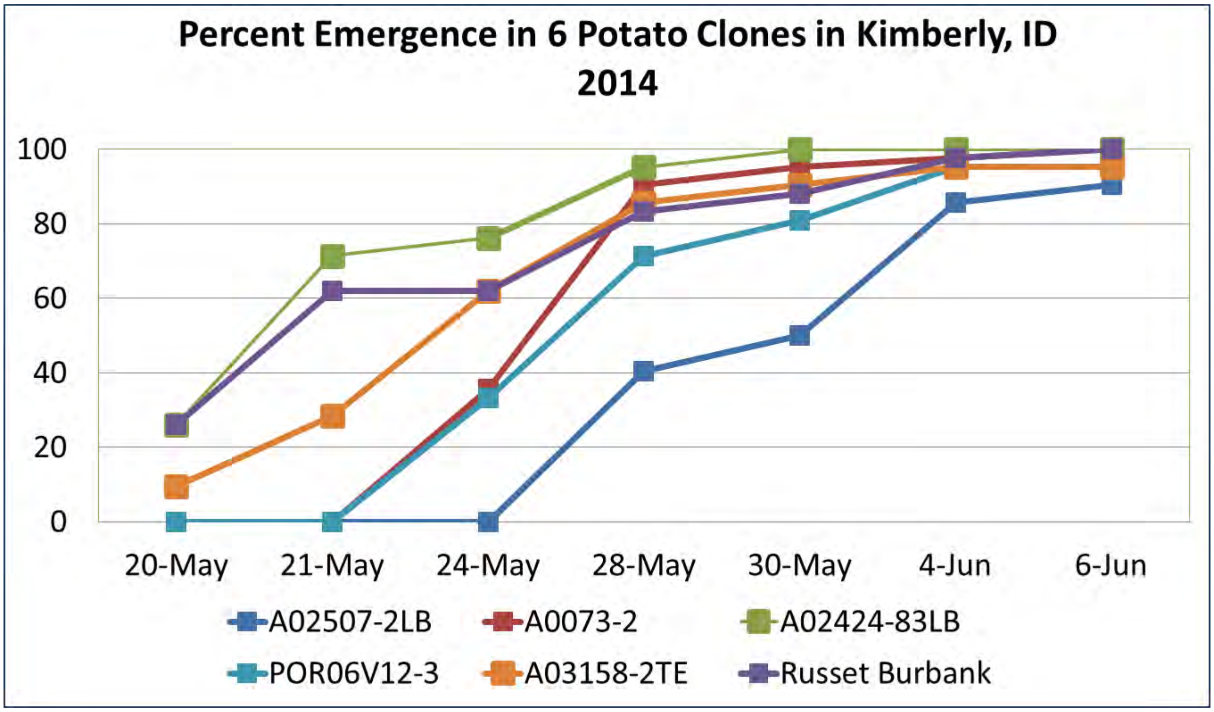


Figure 1. Percent emergence in six potato clones in Kimberly, ID 2014.

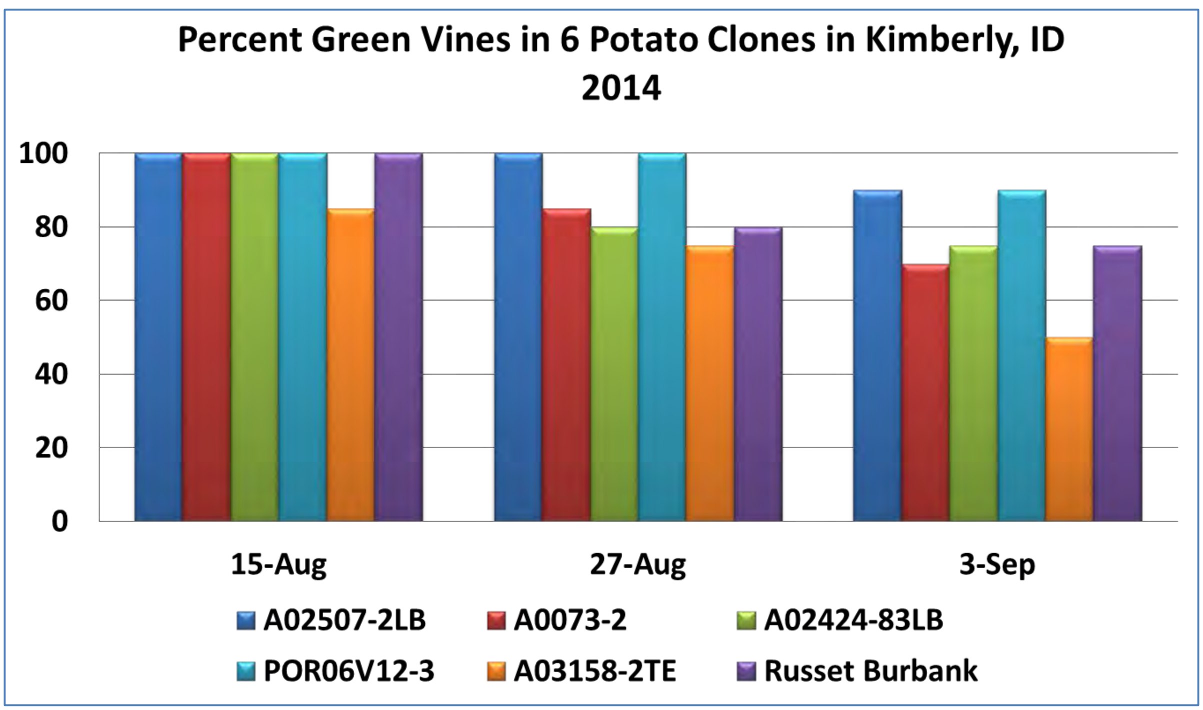


Figure 2. Percent green vine in six potato clones in Kimberly, ID 2014 at three dates prior to vine kill.

Table 1. Specific gravity and mean tuber tissue firmness (Newtons) at harvest of six potato cultivars grown at Kimberly, ID 2014.		
Cultivar	Specific Gravity	Newtons
Russet Burbank	1.082	44.8
A02424-83LB	1.088	44.1
A03158-2TE	1.077	53.7
A02507-2LB	1.088	57.5
POR06V12-3	1.093	45.5
A0073-2	1.085	41.7
Lsd 0.05	0.004	ns

Table 2. Fry color and sugar levels from 6 potato cultivars taken 3 days after harvest in 2014.

Cultivar	Stem End % Reflectance[1]	Bud End % Reflectance	Mottling Severity[2]	% Sugar End	Glucose % FWT	Sucrose %FWT
Russet Burbank	45.9	51.2	1.2	73	0.041	0.129
A02424-83LB	51.8	55.8	1.8	40	0.032	0.162
A03158-2TE	52.0	51.1	1.6	0	0.035	0.095
A02507-2LB	57.4	54.1	1.0	0	0.006	0.115
POR06V12-3	53.7	51.2	1.1	20	0.021	0.110
A0073-2	55.4	53.4	1.0	33	0.015	0.108
Lsd 0.05	4.2	2.0	0.3	59	0.008	0.012

[1]% reflectance to USDA fry color rating #1≥ 43, #2 < 43 but ≥ 35, #3 < 35 but ≥26, #4 < 26
[2]Mottling severity 1=no mottling 2=mild 3=moderate 4=severe

PUBLICATIONS:

T.L. Brandt, N. Olsen, J. Stark, R. Novy and J. Whitworth. 2014. Storage Management of Teton Russet Potatoes. University of Idaho Education Publications. In Press.

PRESENTATIONS & REPORTS:

Brandt and Olsen. 2014. Kimberly Potato Storage Advisory Committee Meeting. Kimberly, ID. November 13, 2014.

Brandt, T. and N. Olsen. 2014. Weight Loss in Storage in Russet Burbank and New Potato Varieties. 98th Annual Meeting of the Potato Association of America. Spokane, WA. July 29, 2014.

PROGRESS REPORT

PROJECT NO: 4045

TITLE: In-Field Testing to Identify New Potato Varieties and Best Management Practices for Washington Growers.

PERSONNEL: Mark J. Pavek (Project Leader), N. Richard Knowles, Zachary J. Holden
Grad Students: Rhett Spear, Chandler Dolezal, Seth Shelton, Kathryn Bolding

COOPERATORS: Local growers and industry representatives

REPORTING PERIOD: 2014

PURPOSE:

- Identify and evaluate advanced generation clones and cultivars for adaptability to the various potato producing regions throughout Washington.
- Identify how growth and development characteristics of recently released cultivars differ from traditional Washington varieties.
- Use information from all research trials to develop management recommendations for the new cultivars to ensure profitable, sustainable potato production for the Washington potato industry.

JUSTIFICATION:

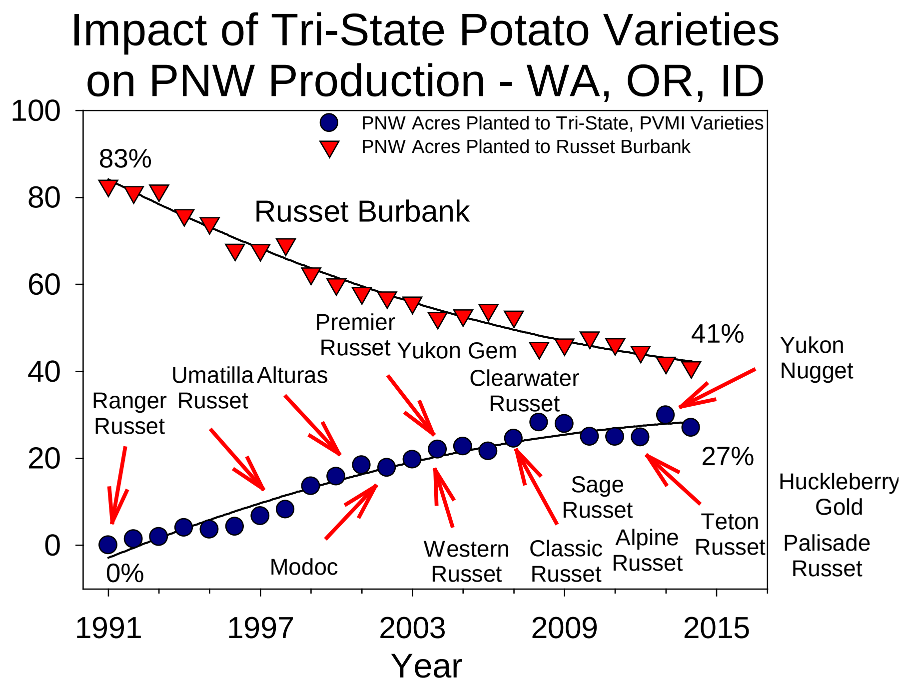
Washington potato growers face many economic threats including foreign competition, changes in consumer preferences, new environmental regulations, loss of plant protection chemicals, increased input costs, new pest and disease pressures, as well as unpredictable growing conditions. Potato cultivars need to be continuously improved to meet the changing conditions and demands of the industry. Value of new varieties comes in the form of improved quality and marketability, increased yield, and decreased inputs due to disease and pest resistance and improved fertilizer- and water-use efficiency. The overall impact of new cultivars will be profitable and sustainable production for the grower, improved competitiveness of the Washington potato industry, a healthy, inexpensive food supply for American consumers, and contribute to a healthy environment.

2014 RESEARCH TRIALS CONDUCTED USING THIS PROJECT FUNDING:

Trial	Type/Purpose	Harvest Timing	Location
Early Tri State	Variety	Early	Othello
Late Tri State	Variety	Late	Othello
Early Regional	Variety	Early	Othello
Late Regional	Variety	Late	Othello
Tri-State Red&Spec	Variety	Early	Othello
NFPT Variety Trials	Search for low acrylamide varieties	Late	Othello
SCRI Acrylamide	Agronomy trial to identify acrylamide var.	Late	Othello
Rejuvenate x Var	Does Rejuvenate work?	Late	Othello
Clearwater R. N Fert	Identify profit maxing in-season N rates	Late	Othello
Dakota R. N Fert	Identify profit maxing in-season N rates	Late	Othello
Cultivar x N Fert	Identify profit max in-season N x 6 varieties	Late	Othello
Phosphorus Source	Do different types of P work better?	Late	Othello
Phosphorus Additives	Do additives make P more available to plants?	Late	Othello
In-season Phos vs pre	Does in-season P work as well as pre-plant?	Late	Othello
Row Width x Var	Is a 34 inch row width best for all varieties?	Late	Othello
Hail Damage	Simulate hail damage at diff growth stages	Early & Late	Othello
Tuber shape trial	Can we make round var long?	Late	Othello
Water deficit trial	Do some varieties grow better with less water	Late	Othello
10-Hill Selection	Selection of new varieties in Othello	Late	Othello

2014 ACCOMPLISHMENTS:

The effect of the Tri-State Potato Variety Development Program on the Northwest potato industry has been substantial. **Ranger Russet, Umatilla Russet, Alturas, Bannock Russet, and Clearwater Russet**, are examples of russet cultivars released from the Tri-State program that have greatly benefited the United States and Northwest potato industry, being the 2nd, 4th, 7th, 8th, and 15th most widely grown cultivars in the United States in 2014, respectively, with Tri-State varieties representing 25%, or 264,000 acres, of the fall crop nationally. (NASS, Crop Production, November, 2014). **Ranger Russet, Umatilla Russet, and Alturas** were the 2nd, 4th, and 5th most widely grown cultivars in the PNW (ID, OR, WA) in 2014, respectively, and accounted for 27% of the PNW planted acreage. Varieties recently released by the Tri-State program are now produced on more than 141,000 acres in the Pacific Northwest with value to growers estimated at approximately $510 million. Compared with 2012, the 2014 US farm-gate value of Tri-State varieties increased by approximately $15 million.



2014 RESULTS:

Highlights from of all 2013 variety and cultural management trials are presented below.

2014 VARIETY RELEASES:

None in 2014, 3 in the pipeline for 2015.

GRADUATING CLONES

Each year several clones graduate from the advanced regional variety trials (Early Harvest Regional Variety Trial and Late Harvest Regional Variety Trial). Upon graduation, they are either named and released as a new variety or dropped. Table one displays the multi-year summaries of several graduating clones along with several standard reference varieties. A02062-1TE (early- to mid-harvest) and A03158-2TE (mid- to late-harvest) have promise as fresh pack varieties. A03158-2TE may also work well as a processing variety, especially as a mid- to late-harvest direct process variety as it typically has higher > 6 oz yields than Ranger Russet, Umatilla Russet and Russet Burbank. A02057-2LB and AO02060-3 are potential late harvest processing clones. A02057-2LB has long dormancy which may exceed Russet Burbank. A couple of issues with A02057-2LB is that its tubers tend to grow round in the Columbia Basin, it has mild Internal Brown Spot (IBS), and it is slow to emerge due to its long dormancy (a positive for storage)

ADVANCED VARIETY TRIAL RESULTS

For all variety trials, each entry is rated and assigned a merit score for overall fresh pack performance and overall processing performance (field performance and post-harvest performance). Merit scores for all trials can be found in the annual variety evaluation book from the WSU Potato Group and online at www.potatoes.wsu.edu. Tables 1 and 2 below, display multi-year results of advanced clones trialed in the Early- and Late-Harvest Regional Trial. During 2014, the Tri-State Group and PVMI will soon decide their fate.

Top Performing Advanced Russet-Type Clones

Below is a list of russet-type clones that performed well in the WA variety trials. Although none are market-ready, these clones hold the most potential of making it to the market place.

Advanced Entries – Regional

Fresh Market

Early Fresh: A02060-1T, A03158-2TE, A02062-1TE

Late Fresh: POR06V12-3 and A06021-1T, A03158-2TE

Process Market

Early Process: A03921-2, A02060-1T, and A03158-2TE

Late Process: POR06V12-3, A03921-2, and A02507-2LB

2014 Top Performing Specialty Clones and Potential Discards

Below is a list of specialty-type clones that performed well in the WA variety trials. Although none are market-ready, these clones hold the most potential of making it to the market place.

Red/Specialty Advanced Entries – Regional

Visual Standouts (nice color, skin, size distribution, & shape):

Red-purple/Yellow flesh: COA07365-4RY. *Yellow flesh:* NDA08145-1CB-1CY, A05182-7RY.

Suggested Discards: A05180-3PY.

Table 1. Early and late harvest multi-year summaries for graduating russet-type clones and reference varieties.

Multi-Year Summaries of Graduating Russet Entries and Reference Varieties										
								Merit Scores (5 = Best)		
								Field Performance		Postharvest
Entry	Year	Early/Late* Harvest Total Yield	US # 1 & 2 Yield > 6 oz	Specific Gravity	Average Tuber Weight/ Number per Plant	Bruise Blackspot/ Shatter	Internal** Issues	Early/Late Fresh	Early/Late Process	Processing Performance
		CWT/A	% of Total		oz/number	%				
A02062-1TE	2014	450	80	1.074	8.6/5.4	none	none	3.5	2.6	-
(Early Harvest)	2013	477	59	1.069	5.5/8.4	none	none	5.0	4.0	-
data only	2012	368	50	1.067	5.5/7.5	none	none	2.6	2.2	-
	2011	442	81	1.075	7.6/6.1	0/39	none	4.0	2.2	-
	2010	518	87	1.073	7.2/6.4	15/8	none	1.9	2.0	-
	Early to mid harvest variety. Fresh market standout at least one year. Often looks like a long Russet Norkotah. May be too long at times; ends can be pointy. Dark russeting, nice shape overall.									
A02507-2LB	2014	352/684	76	1.090	7.5/7.9	19/75	3% IBS	1.3/2.4	2.0/3.5	4.8
	2013	317/756	77	1.094	7.4/8.3	25/50	21% IBS	0.6/1.8	0.9/3.7	4.4
	2012	312/899	79	1.087	7.7/10.2	3/90	5% IBS	0.6/2.9	3.2/4.2	4.7
	2011	388/816	83	1.096	8.4/8.7	30/50	8% BC, 3% IBS	2.0/3.3	3.2/4.1	4.4
	Late harvest variety. IBS and short/round shape a concern in the Columbia Basin, not recommended for fresh pack due to shape and appearance. Slow emergence, not an early harvest variety. On the other hand, this variety has good dormancy for storage.									
A03158-2TE	2014	543/814	83	1.074	10.1/7.0	13/45	13% HH	3.8/1.8	4.2/3.6	2.6
	2013	505/844	70	1.075	7.3/9.5	33/33	8% HH, 6% IBS	2.9/3.0	2.4/3.4	2.3
	2012	463/872	78	1.077	7.6/9.9	18/71	none	2.5/2.8	4.2/3.4	3.1
	2011	551/892	87	1.081	9.4/8.5	3/42	3% HH	4.4/4.5	4.2/3.3	4.6
	Nice shape, deeper eyes, high market yield. Fresh market standout at least one year. Hollow heart may be an issue in locations with high incidence, 17% HH early harvest 2013, 13% HH early harvest 2011. Specific gravity similar or lower than R. Burbank. Fresh pack or process market, typically mid to late maturity, but could kill early for early to mid harvest.									
AO02060-3	2014	467/672	75	1.079	7.8/7.5	17/40	none	1.4/2.5	2.7/3.2	3.0
	2013	524/696	70	1.080	7.3/7.7	21/44	6% HH, 3% IBS	2.8/0.9	2.9/2.7	2.9
	2012	402/669	65	1.081	6.2/9.4	10/73	none	1.1/1.1	3.1/2.7	3.9
	2011	403/724	83	1.081	8.6/7.4	23/43	none	3.1/2.8	3.1/3.9	4.8
	2010	615/721	67	1.089	6.0/10.4	6/88	none	3.1/2.8	-	-
	Mostly nice shape; however, it is somewhat short/round. Fresh market standout at least one year. Skin may produce spotty/non-uniform russeting, which may be an issue for fresh market. A mid to late harvest is prefered with this variety.									
Ranger R.	2014	524/681	76	1.077	8.9/6.6	49/19	3% IBS	NA	4.3/2.5	2.8
	2013	479/821	75	1.085	7.9/8.4	29/45	none	NA	2.7/4.4	3.8
	2012	396/852	86	1.085	9.6/7.7	50/50	3% IBS	NA	3.1/4.6	3.1
	2011	468/735	75	1.086	7.5/8.4	49/46	3% IBS	NA	3.1/3.5	4.1
	2010	630/782	78	1.091	7.6/9.0	29/52	none	NA	3.5/3.7	3.5
	Long, shape variable at times, yet uniform other times									
R. Burbank	2014	466/730	63	1.077	9.4/6.8	31/61	3% HH, 6% IBS	0.9/0.4	1.3/1.2	2.0
	2013	364/738	67	1.075	8.0/7.5	22/47	9% HH, 3% BC	1.2/0.6	1.4/1.7	1.9
	2012	364/710	63	1.076	7.0/8.8	27/57	10%HH, 20% BC	0.5/0.9	1.0/1.6	1.9
	2011	487/641	68	1.076	6.8/8.2	6/24	35%HH, 21% BC	2.3/1.3	3.3/1.5	3.9
	2010	676/683	70	1.079	7.1/8.2	19/62	10% HH, 19% BC	1.9/3.0	3.2/2.3	2.4
	Shape typically variable, often with many growth cracks and knobs									
R. Norkotah	2014	465/730	73	1.068	7.5/8.0	22/11	none	2.3/3.5	NA	NA
	2013	364/598	58	1.067	5.7/8.5	18/33	3% HH, 3% IBS	2.0/1.0	NA	NA
	2012	355/522	56	1.072	5.7/8.0	14/59	none	1.3/1.2	NA	NA
	2011	360/506	48	1.070	5.1/8.6	0/38	5% HH, 10% BC	1.1/1.6	NA	NA
	Shape and skin typically very uniform, size profile typically on the small side									
Shepody	2014	553	84	1.073	9.9/5.8	13/0	none	NA	3.8	-
(Early Harvest)	2013	354	77	1.062	7.9/4.4	5/10	none	NA	2.6	-
only	Early-harvest processing variety. Post-harvest merit not available as this and most varieties typically produce acceptable fries directly from the field.									

*Early Harvest ~ 110 days after planting, Late Harvest ~ 150 DAP.
**HH = Hollow heart, BC = brown center, IBS = internal brown spot.

Table 2. Early and late harvest multi-year fresh market merit score summaries for advanced russet-type clones and reference varieties.

FRESH MARKET MERIT - ADVANCED LINES

2010-2014

(5 = best) - Entries ranked by means

EARLY HARVEST - Fresh Market Merit Scores

	Entry	Mean	2014	2013	2012	2011	2010
1	A06021-1T	**4.4**	4.9	3.9	-	-	-
2	CO03276-5RU	**3.7**	3.9	3.3	3.8	-	-
3	A02062-1TE	**3.4**	3.5	5.0	2.6	4.0	1.9
4	A03158-2TE	**3.4**	3.8	2.9	2.5	4.4	-
5	CO05175-1RU	**2.8**	2.8	-	-	-	-
6	AO01114-4	**2.8**	4.9	1.6	3.1	3.0	1.4
7	AO02060-3	**2.3**	1.4	2.8	1.1	3.1	3.1
8	POR06V12-3	**2.2**	2.8	2.8	1.0	-	-
9	Shepody	**2.1**	1.9	2.3	-	-	-
10	Ranger Russet	**2.1**	2.6	1.7	1.6	2.2	2.3
11	A03921-2	**2.0**	3.4	1.3	1.4	-	-
12	OR05039-4	**1.9**	1.8	1.8	0.9	3.0	-
13	Russet Norkotah	**1.8**	2.3	2.0	1.3	2.0	1.5
14	A06084-1TE	**1.7**	1.4	2.3	1.4	-	-
15	Russet Burbank	**1.5**	0.9	1.2	0.5	2.8	1.9
16	A02424-83LB	**1.3**	1.0	1.8	1.1	-	-
17	CO05068-1RU	**1.1**	1.1	-	-	-	-
18	A02507-2LB	**1.1**	1.3	0.6	0.6	2.0	-

LATE HARVEST - Fresh Market Merit Scores

	Entry	Mean	2014	2013	2012	2011	2010
1	CO05175-1RU	**3.7**	3.7	-	-	-	-
2	POR06V12-3	**3.5**	4.0	4.1	2.3	-	-
3	A03158-2TE	**3.0**	1.8	3.0	2.8	4.5	-
4	A02507-2LB	**2.6**	2.4	1.8	2.9	3.3	-
5	A03921-2	**2.5**	1.5	3.5	-	-	-
6	A06021-1T	**2.4**	3.2	3.4	0.8	-	-
7	OR05039-4	**2.3**	2.0	2.2	1.5	3.5	-
8	CO03276-5RU	**2.3**	2.3	-	-	-	-
9	Ranger Russet	**2.1**	1.3	0.9	1.8	2.9	3.9
10	Russet Norkotah	**2.0**	3.5	1.0	1.2	2.0	2.5
11	A06084-1TE	**2.0**	0.7	1.9	3.5	-	-
12	AO02060-3	**2.0**	2.5	0.9	1.1	2.8	2.8
13	CO05068-1RU	**1.9**	1.9	-	-	-	-
14	AO01114-4	**1.8**	0.7	1.0	1.4	3.5	2.3
15	Russet Burbank	**1.6**	0.4	0.6	0.9	2.7	3.3
16	A02424-83LB	**1.2**	1.0	0.6	2.0	-	-

For more information on these cultivars, see the Early and Late Harvest Regional Trial Sections in this Book. The dash (" - ") indicates the clone was not yet entered into the trial.

Table 3. Early and late harvest multi-year process market merit score summaries for advanced russet-type clones and reference varieties.

PROCESS MARKET MERIT - ADVANCED LINES

2010-2014

(5 = best) - Entries ranked by Field Performance means

EARLY HARVEST - Process Market Merit Scores

	Entry	Field Performance Mean	Field Performance Only* 2014	2013	2012	2011	2010
1	CO05175-1RU	**4.1**	4.1	-	-	-	-
2	A03921-2	**3.9**	4.7	3.7	-	-	-
3	A06021-1T	**3.7**	4.2	3.2	-	-	-
4	A03158-2TE	**3.5**	4.2	2.5	4.2	4.2	-
5	Ranger Russet	**3.5**	4.3	2.7	4.0	4.0	3.5
6	CO05068-1RU	**3.5**	3.5	-	-	-	-
7	AO01114-4	**3.4**	4.9	1.5	3.8	3.8	4.2
8	A02424-83LB	**3.3**	3.4	3.8	-	-	-
9	CO03276-5RU	**3.3**	4.0	2.8	-	-	-
10	Shepody	**3.2**	3.8	2.6	-	-	-
11	OR05039-4	**2.8**	3.1	2.2	3.8	3.8	-
12	A02062-1TE	**2.7**	2.6	4.0	2.2	2.2	2.0
13	POR06V12-3	**2.7**	2.7	2.6	-	-	-
14	AO02060-3	**2.6**	2.7	2.9	3.1	3.1	-
15	Russet Norkotah	**2.5**	2.6	2.0	3.2	3.2	2.6
16	Russet Burbank	**2.3**	1.3	1.4	4.0	4.0	3.6
17	A06084-1TE	**2.0**	2.2	2.2	-	-	-
18	A02507-2LB	**1.9**	2.0	0.9	3.2	3.2	-

*Postharvest values are not given for the Early Harvest Trial because all varieties typically fry well when delivered directly from the field and cold storage is not typical. The dash (" - ") indicates the clone was not yet entered into the trial.

LATE HARVEST - Process Market Merit Scores

Field & Postharvest Processing Performance

	Entry	All Years Field Mean	All Years Post Harvest Mean	2014 Field	2014 Post Harv	2013 Field	2013 Post Harv	2012 Field	2012 Post Harv	2011 Field	2011 Post Harv	2010 Field	2010 Post Harv
1	POR06V12-3	**4.6**	**3.8**	4.9	3.5	4.9	4.4	4.1	3.5	-	-	-	-
2	CO05175-1RU	**4.2**	**2.8**	4.2	2.8	-	-	-	-	-	-	-	-
3	CO05068-1RU	**4.1**	**3.9**	4.1	3.9	-	-	-	-	-	-	-	-
4	Ranger Russet	**4.0**	**3.4**	2.5	2.8	4.4	3.8	4.6	3.1	4.5	4.1	4.3	3.2
5	A02507-2LB	**3.9**	**4.6**	3.5	4.8	3.7	4.4	4.2	4.7	4.1	4.4	-	-
6	A03921-2	**3.7**	**3.9**	3.3	3.5	3.3	4.2	4.3	4.1	-	-	-	-
7	A02424-83LB	**3.5**	**2.9**	3.4	2.5	2.9	2.4	4.2	3.9	-	-	-	-
8	A03158-2TE	**3.4**	**3.2**	3.6	2.6	3.4	2.3	3.4	3.1	3.3	4.6	-	-
9	OR05039-4	**3.2**	**3.7**	2.9	3.5	3.9	2.7	2.8	3.6	3.2	4.8	-	-
10	AO02060-3	**3.1**	**3.7**	3.2	3.0	2.7	2.9	2.7	3.9	3.9	4.8	-	-
11	A06021-1T	**3.0**	**2.4**	2.8	2.1	3.2	2.6	-	-	-	-	-	-
12	AO01114-4	**2.9**	**3.7**	2.8	3.6	1.9	3.0	3.0	4.2	4.1	4.3	2.9	3.5
13	Russet Burbank	**2.3**	**2.6**	1.2	2.0	1.7	1.9	1.6	1.9	3.5	3.9	3.6	3.2
14	A06084-1TE	**2.1**	**3.7**	1.2	3.3	3.3	3.9	1.8	3.8	-	-	-	-

For more information on these cultivars, see the Early and Late Harvest Regional Trial sections in this book. Varieties with 'fresh' were designated for direct processing or fresh market only.

Rejuvenate x Variety Trial

Justification: Growers are using Rejuvenate even though no solid third-party research has been conducted to confirm it works.

Purpose: When applied on potato seed prior to planting at the recommended label rate of 0.16 oz/ton of seed, Rejuvenate is supposed to reduce stem and tuber number and increase average tuber weight. This study was conducted to evaluate Rejuvenate's effect on several varieties of commercially purchased seed.

Background: In 2013, Russet Burbank and Umatilla Russet seed was treated with Rejuvenate at three rates: 0-, 0.16- and 0.32-oz/ton of seed. In 2014 the experiment was repeated with the same three rates but another rate (0.24-oz/ton of seed) and Clearwater Russet were added to the trial. Emergence, stem and tuber number per plant, yield, tuber quality, and gross return were assessed. The trial was grown at the WSU Othello Research Farm under typical R. Burbank cultural management and harvested approximately 150 days after planting. Rejuvenate is a common compound 1-Naphthaleneacetic Acid, Potassium Salt (1-NAA acid) found on the shelves of most research laboratories.

Results: The commercially bought seed lots from all varieties both years produced less than 3 stems when left untreated (Table 4). In 2014, growers would have lost money if using Rejuvenate on Clearwater Russet at the labeled rate of 0.16 oz/ton of seed. On Russet Burbank and Umatilla Russet, there were no significant differences in gross return between the treated and untreated plants. When 2013 and 2014 data were combined, there were no significant differences between the treated and untreated gross returns (Table 4). Numerically, the labeled rate treatment produced a higher gross for Umatilla Russet than the untreated treatment, but there was high variation among the plots (data not shown) which through some doubt into whether or not Rejuvenate worked on these varieties. On occasion, Rejuvenate reduced stem and tuber number, but these trends were not consistent each year or for each variety (Table 4).

Recommendations:

If the growers typically get physiologically young seed with less than 3 stems on average, Rejuvenate may be a waste of money. We were told by the manufacturers that on physiological older seed with more than 3 stems, the results would be more dramatic and should help increase the growers' bottom line. Several issues: 1) how does the grower know when he has old or young seed 2) Research is needed on using Rejuvenate on older seed.

Rick Knowles conducted research in the past using the active ingredient of Rejuvenate (1-NAA acid) several years ago. He indicated that older (5.4 stems/plant) seed did see a higher reduction in stem and tuber number than younger seed (2.9 stems/plant) and that it had positive effects on the yield and tuber size from the older seed. He also indicated that higher rates of Rejuvenate reduced emergence rate. Based on his conclusions, it appears that growers with older seed may benefit from Rejuvenate, however, the rates he used may not have matched the labeled rate and he only tested one variety. This issue still lies – how can growers find out if there seed is physiologically old, before they plant. Winter grow-out of seed on bench tops in dark rooms (room temperature) may provide an indication of stem number prior to planting. These procedures and use of Rejuvenate warrant more investigation, until then, growers might experiment on half of a pivot, or conduct strip trials with several rows of treated versus untreated.

Table 4. Results from Rejuvenate x Variety trials for 2014 and 2013-14 combined in a two year summary. Although different rates are shown, the labeled rate is 0.16 oz/ton of seed.

2014 WSU Rejuvenate Trial

Variety	Rejuvenate Rate oz	Gross[A] $/A	Total Yield CWT/A	Market Yield CWT/A	US 1s > 4 oz %	US 2s > 4 oz %	Culls & < 4 oz %	US 1 & 2s > 6 oz %	SG	Average Tuber Weight oz	Average Tuber No. Per Plant	Average Tuber No. Per Stem	Average Stem No. Per Plant
Clearwater R	**0.00**	3600 a	545	535	80 ab	1 b	19 ab	61 ab	1.082	7.1 ab	6.6 a	3.3	2.02 a
	0.16	2730 b	458	448	77 b	2 ab	22 a	53 b	1.086	6.5 b	6.2 a	3.1	2.04 a
	0.24	2805 b	470	464	75 b	3 a	22 a	55 b	1.080	6.7 b	6.3 a	3.2	1.97 ab
	0.32	3100 ab	444	433	86 a	1 b	13 b	69 a	1.080	8.0 a	4.9 b	3.2	1.53 b
	pValue*	0.0677	ns	ns	0.0185	0.0837	0.0663	0.0446	ns	0.0584	0.0307	ns	0.1038
R. Burbank	**0.00**	4400	655	640	78	5	17	76	1.094	7.2	7.9	3.4	2.31
	0.16	4020	628	613	77	4	19	70	1.084	7.0	7.8	3.4	2.31
	0.24	4495	695	675	79	3	18	72	1.085	7.1	8.5	3.7	2.31
	0.32	4280	660	649	78	2	20	74	1.084	7.0	8.2	3.5	2.38
	pValue*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Umatilla R.	**0.00**	3105	567	550	69	0 c	31	52	1.094	5.7	8.8	3.9	2.29
	0.16	2960	568	540	66	3 a	31	53	1.090	5.7	8.6	4.0	2.16
	0.24	2580	525	508	67	1 bc	31	41	1.090	5.3	8.6	3.7	2.35
	0.32	2840	541	526	72	2 b	26	51	1.093	5.8	8.2	3.9	2.10
	pValue*	ns	ns	ns	ns	0.0068	ns	ns	ns	ns	ns	ns	ns

[A]Processing economic values - adjusted for Rejuvenate expense, $40/acre expense subtracted for each treatment except the non-treat
Stem & bud end seed pieces were separated by block/rep to increase statistical power by reducing variability within each block
***ns = values are not signficantly different at the 5% or 10% level via Fisher's LSD Test.**

2013-14 WSU Rejuvenate Trial (data averaged across both years)

Variety	Rejuvenate Rate oz	Gross[A] $/A	Total Yield CWT/A	Market Yield CWT/A	US 1s > 4 oz %	US 2s > 4 oz %	Culls & < 4 oz %	US 1 & 2s > 6 oz %	SG	Average Tuber Weight oz	Average Tuber No. Per Plant	Average Tuber No. Per Stem	Average Stem No. Per Plant
R. Burbank	**0.00**	3900	629	621	75	4	21	60	1.086	7.2	7.6	2.9	2.66
	0.16	3980	661	648	75	4	21	59	1.080	7.4	7.8	3.0	2.60
	0.32	3845	637	628	75	3	22	59	1.082	7.2	7.8	3.0	2.65
	pValue*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Umatilla R.	**0.00**	4080	700	685	73	1	26	51	1.093	6.6	9.2 a	3.5	2.64 a
	0.16	4205	700	676	73	3	24	54	1.088	7.0	8.8 ab	3.8	2.35 ab
	0.32	3980	668	647	77	2	21	55	1.094	7.4	8.0 b	3.8	2.13 b
	pValue*	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.0402	ns	0.0736

[A]Processing economic values - adjusted for Rejuvenate expense, $40/acre expense subtracted for each treatment except the non-treat
Stem & bud end seed pieces were separated by block/rep to increase statistical power by reducing variability within each block
***ns = values are not signficantly different at the 5% or 10% level via Fisher's LSD Test.**

Defining Optimum Row Width for Different Potato Varieties.

Justification: Literature that explains why C. Basin growers plant potatoes into 34 inch rows is elusive if not nonexistent.

Purpose: Identify the row width that maximizes grower revenue by optimizing land use efficiency, yield, and tuber size profile for certain varieties.

Background: Alturas, Russet Burbank, and Umatilla Russet were all planted into 30-, 32-, 34-, and 36-inch wide rows in 2011-13. Ranger Russet, Russet Norkotah and Chieftain were added during 2012-13. In 2014, The 36 inch row width was dropped because it returned low gross return all three years and a 28 inch row width treatment was added. We also added two new varieties, Teton Russet and Yukon Nugget. Typical in-season data and post-harvest data were captured. Varieties were allowed to grow for the full season and harvested after 150 DAP.

Results: In 2014, the 34 inch row width returned the highest gross return (Table 5). The results did not match those from 2011-13 (Table 6). In 2011-13, with the exceptions of R. Burbank and Ranger R. (Table 5), total yield and economic revenue increased as row width was reduced from 36 inches to 30 inches. Ranger produced the highest economic return at 32 inch row width in 2011-13, but in 2014, the highest was at 34 inch row width. Numerically, Alturas produced higher gross return in 2014 at the 28 inch row width and Teton at 30 inches. Neither of these was statistically significant, so more research is likely needed to smooth out the seasonal growth differences.

One might expect to see a decrease in average tuber size (weight/length) as rows are planted closer together – we have yet to see it. The plants appear to adjust tuber number per plant as the row width is altered. Similar to in-row spacing changes, as plants become closer together, they produce fewer tubers per plant. When they do this, the tubers benefit by getting more photosynthetic assimilates than if there were more tubers – hence the average tuber size per plant stays somewhat similar to that of wider spaced rows (Tables 4 & 5).

One theory on why the closer row widths didn't produce higher yields or gross than the wider row widths in 2014 was that there was reduced tuber bulking in late July, all of August, and early Sept due to excessive heat. Across all of our research trials in Othello, tuber bulking was slow to non-existent later in the summer due to high ambient temperatures. Perhaps the more closely spaced rows were relatively immature compared to the wider rows when the heat intensified. This is suspected because the closer spaced rows must grow more vine and foliage to compete (data not shown) for light. In the previous years, the extended growing season typical of the Columbia Basin, allowed tubers of the immature plants to bulk adequately prior to harvest.

Recommendations:

The 2014 season humbled us. We found that an unpredictable environment can have profound effects on this type of research. However, the reason we didn't stop this research after 3 years of positive results is because we wanted to make sure we could provide a sound recommendation that would hold true >90% of the time. At this time, growers should stay at the row width that has been working for them (likely 34 inches in the C. Basin) over the years. We will continue the small plot research until we feel there is no more to learn.

Table 5. Total yield, and seed-cost adjusted gross revenue differences across different row widths, averaged across three varieties (Alturas, Umatilla Russet, and Russet Burbank) and three years (2011-13). The gross return is based on the process market and values are expressed as a difference (%) in value from the widest row width (36 inches)

2014 WSU Row Width X Variety Trial

ENTRY	Row* Width inches	TOTAL YIELD (CWT/A)		US # 1's* > 4 oz	US # 2's* > 4 oz	Culls* & < 4 oz	(Final Harvest) AVERAGE TUBER WEIGHT oz	NUMBER Tubers/Plant	PROCESS YIELD US 1's and 2's > 6 oz	> 12 oz	PROCESS YIELD US 1's and 2's > 6 oz	> 12 oz	Specific Gravity	Seed-Cost Adjusted Process Value** Gross $/A
				——— % of Total Yield ———					% of Total Yield		CWT/A			
Alturas	28	605	543	78	4	18	7.5	5.8	69	24	417	143	1.080	3840
	30	661	531	68	5	27	7.7	6.7	60	19	397	125	1.081	3510
	32	588	493	70	4	26	7.1	6.8	60	20	353	120	1.076	2940
	34	720	611	72	4	24	7.2	8.9	59	13	425	96	1.072	3525
	p-Value	ns	ns	ns	ns	ns	ns	0.0009	ns	ns	ns	ns	0.0463	ns
	LSD							1.0					0.0063	
Ranger R.	28	676	661	83	6	11	7.7	6.3	76	20	514	133	1.085	4960
	30	741	734	89	5	6	8.5	6.7	81	32	600	240	1.083	5680
	32	696	676	85	4	11	8.2	6.9	76	30	529	206	1.079	4860
	34	796	782	84	6	10	8.4	8.4	77	39	613	309	1.080	5701
	p-Value	ns	ns	0.0462	0.0582	ns	ns	0.0118	ns	ns	ns	ns	0.0056	0.0029
	LSD			4.0	4.0			1.2						
R. Burbank	28	633	604	82	6	12	8.3	5.4	73	34	462	216	1.081	4270
	30	670	612	76	7	17	8.4	6.1	70	35	469	233	1.079	4260
	32	721	663	76	10	14	9.4	6.3	78	41	562	297	1.081	4830
	34	778	730	79	7	14	8.8	7.8	75	40	584	308	1.078	5040
	p-Value	ns	ns	ns	ns	ns	ns	0.0231	ns	ns	ns	ns	ns	ns
	LSD							1.4						
R. Norkotah	28	686	668	89	4	7	9.1	5.4	76	34	521	230	1.070	6055
	30	742	730	90	4	6	9.3	6.2	78	39	579	293	1.070	6570
	32	772	757	87	7	6	9.8	6.5	80	46	618	354	1.068	6350
	34	839	821	89	4	7	9.3	7.9	76	42	638	354	1.073	7210
	p-Value	ns	ns	ns	ns	ns	ns	0.0135	ns	ns	ns	ns	ns	ns
	LSD							1.3						
Teton R.	28	594	546	86	1	13	8.7	4.9	76	31	451	186	1.075	5180
	30	674	624	84	3	13	8.7	5.9	78	36	526	245	1.072	5930
	32	649	649	83	4	13	9.3	5.7	80	42	519	273	1.070	5550
	34	668	668	86	1	13	8.7	6.7	76	38	508	257	1.073	5495
	p-Value	ns	ns	ns	ns	ns	ns	0.0024	ns	ns	ns	ns	ns	ns
	LSD							0.7						
Umatilla R.	28	586	569	72	8	20	6.1	6.9	54	15	316	88	1.084	3590
	30	645	637	76	2	22	5.5	9.0	51	7	329	48	1.082	3810
	32	600	591	81	2	17	6.3	8.0	57	13	342	80	1.081	3680
	34	737	719	77	2	21	5.8	11.0	57	12	420	92	1.081	4530
	p-Value	ns	ns	ns	ns	ns	ns	0.0047	ns	ns	ns	ns	ns	ns
	LSD							1.9						
Chieftain	28	784	745	88	0	12	9.2	6.1	81	44	635	343	1.067	Not
	30	940	889	88	2	10	10.0	7.2	82	55	771	514	1.066	Calculated due
	32	808	802	92	1	7	9.1	7.3	83	45	671	361	1.065	to lack of
	34	809	795	89	0	11	8.1	8.7	76	35	615	281	1.068	pricing structure
	p-Value	ns	ns	ns	ns	ns	ns	0.0198	ns	ns	ns	ns	ns	
	LSD							1.4						
Yukon Nugget	28	542	520	70	1	29	5.1	7.6	49	8	266	42	1.082	Not
	30	573	551	73	1	26	5.1	8.5	52	11	298	64	1.080	Calculated due
	32	505	470	68	2	30	5.1	8.1	47	12	237	60	1.078	to lack of
	34	653	635	74	1	25	5.1	11.1	53	11	346	74	1.078	pricing structure
	p-Value	ns	0.0507	ns	ns	ns	ns	0.0017	ns	ns	ns	ns	ns	
	LSD		113					1.4						
Averaged across	28	630	599	82	4	14	7.9	5.8	72	27	454	173	1.079	4004
varieties grown	30	688	645	81	4	15	8.0	6.8	70	32	482	220	1.078	4250
2011-13	32	671	631	80	5	15	8.4	6.7	73	32	490	218	1.075	4140
(Uma, RB, Alt)	34	756	714	81	4	15	8.0	8.4	71	29	537	221	1.076	4725
	p-Value	0.0002	0.0001	ns	ns	ns	ns	0.0001	ns	ns	ns	ns	0.0011	0.0015
	LSD	54	49					0.5					0.002	370

*In-row spacing was 10 inches. Percent values may not total 100% due to rounding. ns = treatments are not significantly different from each other at the 5% level using Fisher's LSD Test. LSD = Least Significant Difference.

**Economic value based on a typical Columbia Basin processing or fresh market (R. Norkotah only) contract minus seed cost differences. Cut and treated (fungicide and insecticide) seed costs were estimated at $20.00/CWT. A seed piece weight of 3 oz was used in the seed cost calculation. A fresh market value was calculated for Russet Norkotah and Teton Russet. Chieftain and Yukon Nugget econ not calculated due to lack of a pricing structure

Table 6. Results from 2011-13 WSU row width by variety trial which included six varieties by four row widths.

2011-13 WSU Row Width X Variety Trial																
							(Final Harvest)		PROCESS YIELD						Seed-Cost	
	Row*	TOTAL		US # 1's*	US # 2's*	Culls*	AVERAGE TUBER		US 1's and 2's						Adjusted	
ENTRY	Width	YIELD		> 4 oz	> 4 oz	& < 4 oz	WEIGHT	NUMBER	> 6 oz		> 12 oz		Specific		Process Value**	
	inches	(CWT/A)		———— % of Total Yield ————			oz	Tubers/Plant	CWT/A				Gravity		Gross $/A	
Alturas	30	**788**	**a**	74	7	19	6.7	8.9	**522**	**a**	**143**	**a**	1.091		**4780**	**a**
(2011-13)	32	**729**	**ab**	73	6	21	6.6	9.1	**468**	**ab**	**133**	**a**	1.085		**4300**	**ab**
	34	**668**	**b**	74	8	18	6.7	8.6	**450**	**b**	**136**	**a**	1.082		**4170**	**b**
	36	**661**	**b**	75	5	20	6.6	9.1	**432**	**b**	**113**	**b**	1.082		**3975**	**b**
	p-Value	0.0024		ns	ns	ns	ns	ns	0.0024		0.0032		ns		0.0176	
Ranger R.	30	**735**	**ab**	75	4	22	6.2	9.2	**456**	**ab**	134		1.084		**4280**	**ab**
(2012-13)	32	**798**	**a**	76	6	18	6.5	9.9	**512**	**a**	137		1.088		**5030**	**a**
	34	**651**	**bc**	75	4	21	6.6	8.6	**411**	**bc**	139		1.086		**4020**	**b**
	36	**626**	**b**	79	4	17	6.6	8.7	**422**	**b**	134		1.084		**4060**	**b**
	p-Value	0.0016		ns	ns	ns	ns	ns	0.0432		ns		ns		0.0412	
R. Burbank	30	**669**	**a**	71	5	24	6.5	8.0	**408**	**a**	129		1.080		3920	
(2011-13)	32	**615**	**ab**	71	7	22	6.7	7.6	**382**	**ab**	138		1.082		3800	
	34	**594**	**bc**	75	6	19	6.6	7.8	**381**	**bc**	121		1.077		3870	
	36	**582**	**c**	74	6	20	7.1	7.7	**374**	**c**	156		1.079		3820	
	p-Value	0.0765		ns	ns	ns	ns	ns	0.0500		ns		ns		ns	
R. Norkotah	30	**617**	**a**	70	2	28	5.7	8.3	**310**	**a**	73		1.073		**3830**	**a**
(2012-13)	32	**582**	**a**	67	3	30	6.0	7.8	**305**	**a**	112		1.076		**3690**	**ab**
	34	**480**	**b**	64	2	34	5.5	7.1	**216**	**b**	72		1.071		**3020**	**c**
	36	**463**	**b**	67	2	32	5.5	7.2	**213**	**b**	69		1.071		**3090**	**bc**
	p-Value	0.0027		ns	ns	ns	ns	ns	0.0027		ns		ns		0.0418	
Umatilla R.	30	**778**	**a**	70	2	28	5.5	10.8	**391**	**a**	**83**	**a**	1.086		**4180**	**a**
(2011-13)	32	**670**	**b**	71	1	29	5.4	10.1	**308**	**b**	**65**	**b**	1.085		**3750**	**ab**
	34	**605**	**c**	71	2	27	5.5	9.1	**291**	**c**	**65**	**b**	1.086		**3445**	**b**
	36	**575**	**c**	71	2	27	5.6	10.0	**289**	**c**	**68**	**b**	1.084		**3250**	**b**
	p-Value	0.0001		ns	ns	ns	ns	ns	0.0001		0.0001		ns		0.0066	
Chieftain	30	**801**	**a**	91	2	6	9.5	6.6	**689**	**a**	**360**	**b**	1.067		na	
(2012-13)	32	**811**	**a**	92	1	7	9.2	7.8	**673**	**b**	**381**	**a**	1.066		na	
	34	**786**	**a**	92	2	7	9.7	7.2	**675**	**bc**	**362**	**b**	1.069		na	
	36	**640**	**b**	92	1	7	8.8	7.6	**531**	**c**	**262**	**c**	1.069		na	
	p-Value	0.0302		ns	ns	ns	ns	ns	0.0302		0.0204		ns			
Averaged across	30	**745**	**a**	71	5	**24 a**	6.3	9.2	**490**	**a**	**134**	**a**	**1.086**	**a**	**4290**	**a**
varieties grown	32	**671**	**b**	72	4	**24 a**	6.2	8.9	**414**	**b**	**123**	**ab**	**1.084**	**ab**	**3960**	**b**
2011-13	34	**612**	**c**	73	5	**22 b**	6.3	8.5	**388**	**c**	**111**	**b**	**1.082**	**b**	**3770**	**b**
(Uma, RB, Alt)	36	**616**	**c**	73	5	**23 ab**	6.4	9.0	**368**	**c**	**112**	**b**	**1.082**	**b**	**3745**	**b**
	p-Value	0.0001		ns	ns	0.0249	ns	ns	0.0001		0.0176		0.0159		0.0001	

*In-row spacing was 10 inches. Percent values may not total 100% due to rounding. B**olded** values are significantly different from each other at the 5% level using Fisher's LSD Test when followed by a different letter. Values for each variety and category are not significantly different if followed by the same letter.

**Economic value based on a typical Columbia Basin processing or fresh market (R. Norkotah only) contract minus seed cost differences. Cut and treated (fungicide and insecticide) seed costs were estimated at $20.00/CWT. A seed piece weight of 3 oz was used in the seed cost calculation. A fresh market value was calculated for Russet Norkotah.

Hail Damage Simulation/Potato Defoliation/Plant damage Trial

Justification: Potato defoliation trials have not been conducted in the C. Basin for a long time, if ever. In 2012 there was significant hail damage on several C. Basin farms. In our effort to aid the National Crop Insurance Service we are conducting this research with the goal of making sure growers with insurance receive the proper settlement, depending on the time of year.

Background: The trial is set up to review 4 damage levels of defoliation/simulated hail: 0, 33%, 66%, and 99%. The 4 damage levels are applied to potatoes at 3 different developmental stages: tuber initiation, early tuber bulk, and late tuber bulk. Each of these treatments was applied to a medium-maturing variety (Russet Norkotah TX278) and a late maturing variety (Ranger Russet) The details follow:

Two Varieties:
Medium Maturing Variety: Russet Norkotah TX278 Strain
Late Maturing Variety: Ranger Russet

Three Stages:
1) Tuber initiation: (WSU defined as about 40 to 50 DAP)
    a. Target 45 DAP for both varieties
2) Early Bulking: (WSU defined as 60 to 100 DAP)
    a. Target 70 DAP for RN 278
    b. Target 85 DAP for Ranger
3) Late Bulking (WSU defined as 110 to 140 DAP)
    a. Target 95 DAP for RN 278
    b. Target 120 DAP for Ranger

Damage Level:
1) Check – 0%
2) 33%
3) 66%
4) 99%

Results:
There were substantial losses from > 66% defoliation at all growth stages for both varieties; but the early bulking stage was most damaging to yield and economic value (Tables 7-9). Defoliation at tuber initiation reduced grower return by close to 30%; however, when 99% of the canopy was removed at early bulk and late bulk, as much as 80% and 45% of grower revenue was lost, respectively. Plants damaged early in the season (tuber initiation) were able to mostly recover unless the damage was severe (99%). As the plants matured, they had less season and vigor to overcome significant damage. We hope to repeat this study 1 more year.

Table 7. Effects of defoliation (0, 33%, 66%, and 99%) on RN TX278 and Ranger Russet at the tuber initiation stage across 2 years.

2013-2014 WSU Hail Damage/Defoliation Trials - DEFOLIATION AT TUBER INITIATION STAGE

Othello - WSU | Cooperator: Mark Pavek | Two Year Average

Tuber Initiation														
		Total Yield		Gross Value[A]						US # 1 & 2 Yield				
			Estimated		Estimated	US 1s	US 2s	Cullls &						
	Defoliation		Grower		Grower	> 4 oz	> 4 oz	< 4 oz	US1&2	< 4oz	4-8 oz	8-12 oz	12-16 oz	> 16 oz
Variety	%	CWT/A	Loss (%)	$/A	Loss (%)	% of total yield			> 6 oz %	% of Mkt yield				
Russet	0	582		4697		82	5	13	73	11	33	32	17	8
Norkotah	33	570	-2.0	4663	-0.7	83	6	11	81	6	21	29	23	21
TX278 Strain	66	547	-6.1	4325	-7.9	84	4	12	76	8	25	30	17	19
	99	450	-22.7	3421	-27.2	84	6	9	78	8	30	24	17	22
	LSD:	*38*		*660*		*ns*	*ns*	*ns*	*ns*	*4*	*6*	*ns*	*ns*	*10*
	*Pvalue**	*<0.0001*		*0.0037*						*0.1077*	*0.0025*			*0.0500*
	Linear or Quadratic Pvalue	*0.0044 quad*		*0.0953 quad*							*0.0006 quad*			*0.0245 lin*
Ranger	0	560		4019		87	5	9	79	8	29	34	19	10
Russet	33	545	-2.6	3977	-1.0	85	6	9	81	7	23	29	24	17
	66	477	-14.8	3500	-12.9	86	6	8	81	6	28	29	22	15
	99	442	-21.1	2983	-25.8	77	6	17	72	9	26	32	18	16
	LSD:	*100*		*824*		*5*	*ns*	*6*	*6*	*2*	*ns*	*ns*	*5*	*ns*
	*Pvalue**	*0.0749*		*0.0579*		*0.0077*		*0.0299*	*0.0286*	*0.0309*			*0.0907*	
	Linear or Quadratic Pvalue	*0.0132 lin*		*0.0111 lin*		*0.068 quad*		*0.0667 quad*	*0.0278 quad*	*0.0189 quad*			*0.0181 quad*	

[A]Fresh market economic values for R. Norkotah, process market value for Ranger Russet - both based on actual Columbia Basin price averages and market specifications.

*ns = values are not signficantly different at the 5% or 10% level via Fisher's Least Significant Difference (LSD) Test.

Tuber Initiation											
			TUBER				% INTERNAL DEFECTS			French Fry
		AVERAGE	NUMBER		% BRUISE				Internal	USDA Color
	Defoliation	TUBER	PER	SPECIFIC	Black		Brown	Hollow	Brown	Class
Variety	%	WEIGHT	PLANT	GRAVITY	Spot	Shatter	Center	Heart	Spot	0-4 (4 = dark)[b]
Russet	0	7.3	7.0	1.077	3	7	0	0	2	
Norkotah	33	9.5	5.3	1.073	9	10	0	2	0	
TX278 Strain	66	8.6	5.6	1.078	6	6	0	2	0	
	99	8.6	4.7	1.077	2	8	0	0	0	
	LSD:	*1.3*	*0.8*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	
	*Pvalue**	*0.0198*	*0.0002*							
	Linear or Quadratic Pvalue	*0.0221 quad*	*<0.0001 lin*							
Ranger	0	8.2	6.1	1.090	50	13	0	0	2	
Russet	33	9.4	5.4	1.093	42	7	0	0	2	
	66	8.7	4.8	1.093	33	5	0	0	2	
	99	8.4	4.6	1.091	32	2	0	2	0	
	LSD:	*ns*	*1.1*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	
	*Pvalue**		*0.0534*							
	Linear or Quadratic Pvalue		*0.0087 lin*							

*ns = values are not signficantly different at the 5% or 10% level via Fisher's Least Significant Difference (LSD) Test.

[b]USDA french fry color classification: 0 = extra light, 1 = light, 2 = medium light, 3 = medium, 4 = dark (rejected).

Medium Maturing Variety: Russet Norkotah TX278 Strain
Late Maturing Variety: Ranger Russet

Three Defoliation Stages:

1) **Tuber initiation**: (WSU defined 40 to 50 DAP)
a. Target 45 DAP for both varieties
2) **Early Bulking**: (WSU defined 60 to 100 DAP)
a. Target 70 DAP for RN 278
b. Target 85 DAP for Ranger
3) **Late Bulking** (WSU defined 110 to 140 DAP)
a. Target 95 DAP for RN 278
b. Target 120 DAP for Ranger

Table 8. Effects of defoliation (0, 33%, 66%, and 99%) on RN TX278 and Ranger Russet at the early bulking stage across 2 years.

2013-2014 WSU Hail Damage/Defoliation Trials - DEFOLIATION AT EARLY BULKING STAGE

Othello - WSU | Cooperator: Mark Pavek | Two Year Average

Early Bulk		Total Yield		Gross Value[A]						US # 1 & 2 Yield				
			Estimated		Estimated	US 1s	US 2s	Cullls &						
	Defoliation		Grower		Grower	> 4 oz	> 4 oz	< 4 oz	US1&2	< 4oz	4-8 oz	8-12 oz	12-16 oz	> 16 oz
Variety	%	CWT/A	Loss (%)	$/A	Loss (%)	% of total yield			> 6 oz %	% of Mkt yield				
Russet	0	536		4384		84	2	14	72	12	31	32	17	8
Norkotah	33	501	-6.6	4014	-8.5	82	3	14	72	12	33	30	16	10
TX278 Strain	66	447	-16.7	3186	-27.3	77	4	19	62	18	39	29	11	3
	99	244	-54.5	887	-79.8	43	9	49	32	47	31	12	3	7
	LSD:	*69*		*571*		*12*	*2*	*11*	*13*	*11*	*7*	*7*	*5*	*ns*
	*Pvalue**	*<0.0001*		*<0.0001*		*<0.0001*	*0.0006*	*<0.0001*	*<0.0001*	*<0.0001*	*0.0891*	*0.0001*	*0.0005*	
Linear or Quadratic Pvalue		*0.0027 quad*		*0.0002 quad*		*0.0015 quad*	*0.0284 quad*	*0.0013 quad*	*0.0041 quad*	*0.0015 quad*	*0.0521 quad*	*0.0060 quad*	*0.0817 quad*	
Ranger	0	584		4277		87	4	10	77	8	30	30	20	12
Russet	33	519	-11.0	3415	-20.1	75	8	17	67	10	37	30	14	8
	66	478	-18.2	2645	-38.2	61	12	27	56	15	40	30	10	4
	99	348	-40.3	1588	-62.9	63	10	27	41	25	55	14	5	1
	LSD:	*65*		*591*		*8*	*5*	*6*	*8*	*4*	*905971*	*7*	*7*	*6*
	*Pvalue**	*<0.0001*		*<0.0001*		*<0.0001*	*0.0157*	*<0.0001*	*<0.0001*	*<0.001*	*0.0009*	*0.0003*	*0.0002*	*0.0096*
Linear or Quadratic Pvalue		*<0.0001 lin*		*<0.0001 lin*		*0.0213 quad*	*0.0409 quad*	*<0.0001 lin*	*<0.0001 lin*	*0.0138 quad*	*0.0001 lin*	*0.0024 quad*	*0.0002 lin*	*0.0011 lin*

[A]Fresh market economic values for R. Norkotah, process market value for Ranger Russet - both based on actual Columbia Basin price averages and market specifications.

*ns = values are not signficantly different at the 5% or 10% level via Fisher's Least Significant Difference (LSD) Test.

Early Bulk			TUBER				% INTERNAL DEFECTS			French Fry
		AVERAGE	NUMBER		% BRUISE				Internal	USDA Color
	Defoliation	TUBER	PER	SPECIFIC	Black		Brown	Hollow	Brown	Class
Variety	%	WEIGHT	PLANT	GRAVITY	Spot	Shatter	Center	Heart	Spot	0-4 (4 = dark)[b]
Russet	0	7.4	6.4	1.078	9	5	0	2	0	
Norkotah	33	7.4	6.0	1.077	4	4	0	2	0	
TX278 Strain	66	6.2	6.3	1.077	0	5	2	2	2	
	99	4.1	5.0	1.070	2	20	0	16	0	
	LSD:	*0.9*	*0.9*	*0.0039*	*ns*	*ns*	*ns*	*6*	*ns*	
	*Pvalue**	*<0.0001*	*0.0279*	*0.0024*				*0.0002*		
Linear or Quadratic Pvalue		*0.0031 quad*	*0.0136 lin*	*0.0162 quad*				*0.0009 quad*		
Ranger	0	8.2	6.4	1.091	32	5	0	0	0	
Russet	33	7.5	6.2	1.089	33	8	0	0	0	
	66	6.6	6.3	1.083	22	5	0	0	0	
	99	5.0	6.1	1.072	22	7	0	0	0	
	LSD:	*0.7*	*ns*	*0.0047*	*ns*	*ns*	*ns*	*ns*	*ns*	
	*Pvalue**	*<0.0001*		*<0.0001*						
Linear or Quadratic Pvalue		*0.0574 quad*		*0.0112 quad*						

*ns = values are not signficantly different at the 5% or 10% level via Fisher's Least Significant Difference (LSD) Test.

[b]USDA french fry color classification: 0 = extra light, 1 = light, 2 = medium light, 3 = medium, 4 = dark (rejected).

Medium Maturing Variety: Russet Norkotah TX278 Strain
Late Maturing Variety: Ranger Russet

Three Defoliation Stages:

1) **Tuber initiation**: (WSU defined 40 to 50 DAP)
a. Target 45 DAP for both varieties
2) **Early Bulking**: (WSU defined 60 to 100 DAP)
a. Target 70 DAP for RN 278
b. Target 85 DAP for Ranger
3) **Late Bulking** (WSU defined 110 to 140 DAP)
a. Target 95 DAP for RN 278
b. Target 120 DAP for Ranger

Table 9. Effects of defoliation (0, 33%, 66%, and 99%) on RN TX278 and Ranger Russet at the late bulking stage across 2 years.

2013-2014 WSU Hail Damage/Defoliation Trials - DEFOLIATION AT LATE BULKING STAGE

Othello - WSU | Cooperator: Mark Pavek | Two Year Average

Late Bulk		Total Yield		Gross Value[A]						US # 1 & 2 Yield				
			Estimated		Estimated	US 1s	US 2s	Cullls &						
	Defoliation		Grower		Grower	> 4 oz	> 4 oz	< 4 oz	US1&2	< 4oz	4-8 oz	8-12 oz	12-16 oz	> 16 oz
Variety	%	CWT/A	Loss (%)	$/A	Loss (%)	% of total yield			> 6 oz %	% of Mkt yield				
Russet	0	600		4835		81	5	14	73	12	31	29	17	11
Norkotah	33	530	-11.7	4313	-10.8	82	4	14	71	13	33	29	16	8
TX278 Strain	66	481	-19.7	3478	-28.1	78	3	19	89	18	43	24	12	3
	99	408	-32.0	2627	-45.7	78	2	20	52	19	52	24	5	0
	LSD:	*71*		*758*		*ns*	*ns*	*3*	*8*	*3*	*9*	*ns*	*6*	*6*
	*Pvalue**	*0.0006*		*0.0002*				*0.0006*	*0.0002*	*0.0003*	*0.0017*		*0.0016*	*0.0089*
Linear or Quadratic Pvalue		*<0.0001 lin*		*<0.0001 lin*				*0.0002 lin*	*<0.0001 lin*	*<0.0001 lin*	*0.0002 lin*		*0.0901 quad*	*0.0011 lin*
Ranger	0	595		4310		83	5	12	74	10	31	29	20	10
Russet	33	577	-3.0	4019	-6.7	81	6	13	74	11	30	32	20	8
	66	525	-11.7	3637	-15.6	80	5	15	70	13	36	32	14	5
	99	507	-14.7	3361	-22.0	83	3	13	72	11	37	33	15	4
	LSD:	*67*		*489*		*ns*	*ns*	*ns*	*ns*	*ns*	*6*	*ns*	*ns*	*3*
	*Pvalue**	*0.0516*		*0.0067*							*0.0418*			*0.0165*
Linear or Quadratic Pvalue		*0.0079 lin*		*0.0009 lin*							*0.0132 lin*			*0.0024 lin*

[A]Fresh market economic values for R. Norkotah, process market value for Ranger Russet - both based on actual Columbia Basin price averages and market specifications.

*ns = values are not signficantly different at the 5% or 10% level via Fisher's Least Significant Difference (LSD) Test.

Late Bulk			TUBER				% INTERNAL DEFECTS			French Fry
		AVERAGE	NUMBER		% BRUISE				Internal	USDA Color
	Defoliation	TUBER	PER	SPECIFIC	Black		Brown	Hollow	Brown	Class
Variety	%	WEIGHT	PLANT	GRAVITY	Spot	Shatter	Center	Heart	Spot	0-4 (4 = dark)[b]
Russet	0	7.4	7.3	1.076	7	3	0	0	0	
Norkotah	33	7.3	6.5	1.074	7	8	0	0	0	
TX278 Strain	66	6.1	6.9	1.072	3	7	0	0	2	
	99	5.7	6.3	1.068	8	3	0	0	0	
	LSD:	*0.7*	*0.7*	*0.0022*	*ns*	*ns*	*ns*	*ns*	*ns*	
	*Pvalue**	*0.0002*	*0.0410*	*<0.0001*						
Linear or Quadratic Pvalue		*<0.0001 lin*	*0.0337 lin*	*<0.0001 lin*						
Ranger	0	7.7	6.7	1.089	35	3	0	0	0	
Russet	33	7.5	6.8	1.090	30	8	0	0	0	
	66	7.1	6.5	1.084	43	10	0	0	3	
	99	7.4	6.2	1.076	43	10	2	0	0	
	LSD:	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	
	*Pvalue**									
Linear or Quadratic Pvalue										

*ns = values are not signficantly different at the 5% or 10% level via Fisher's Least Significant Difference (LSD) Test.

[b]USDA french fry color classification: 0 = extra light, 1 = light, 2 = medium light, 3 = medium, 4 = dark (rejected).

Medium Maturing Variety: Russet Norkotah TX278 Strain
Late Maturing Variety: Ranger Russet

Three Defoliation Stages:

1) **Tuber initiation**: (WSU defined 40 to 50 DAP)
   a. Target 45 DAP for both varieties
2) **Early Bulking**: (WSU defined 60 to 100 DAP)
   a. Target 70 DAP for RN 278
   b. Target 85 DAP for Ranger
3) **Late Bulking** (WSU defined 110 to 140 DAP)
   a. Target 95 DAP for RN 278
   b. Target 120 DAP for Ranger

New Studies Initiated in 2014:

Several new studies were initiated in 2014. Because they there is only one year of data from each, they will not be discussed in detail. The trials are described below.

<u>Phosphorus Applied In-Season vs. Pre-emergent vs. a Combination of Both:</u> In the Columbia Basin, growers often apply some or all of their P prior to or at-planting, or soon after. Many growers also supplement the pre-emergent applications with in-season applications of 10-34-0 through the water (fertigated). We wanted to know if the water applied phosphorus was effective or made a difference in soil P, petiole P, or production. To do this, we applied 100- or 200-lbs P2O5 all at planting or all in-season through the water, or half at planting and half in-season (split) (Table 7); this was all compared to a non-treated control. The variety was Umatilla Russet.

Results: After adjusting for fertilizer expense, there were no significant differences among any of the treatments or the non-treated control for Gross return, or any other parameters (Table 6). Data from the soil and petiole collections were non-informative (data not shown), although some trends may appear after this research is repeated across years. Because there were no differences could be because the treatments didn't improve growth, the soil was so poor for P tie-up that no additional P worked, or the heat was so bad in 2014 that the results are not typical. This is a component of Chandler Dolezal's PhD research and will likely continue for 2 more years.

Recommendations: Continue to use P the way you have in the past if you believe it is beneficial. This research will continue for at least 2 more years and we will make a recommendation at that time if we feel anything should change.

Table 6. Yield, gross return and other data from pre-emergent phosphorus vs. in-season applied vs. split applied on Umatilla Russet in 2014.

2014 WSU In-season Phosphorus Trial Summary

Trt Mix	Gross[A] $/A	Total Yield CWT/A	Market Yield CWT/A	US 1s > 4 oz %	US 2s > 4 oz %	Culls & < 4 oz %	US 1 & 2s > 6 oz %	Specific Gravity	Average Tuber Weight oz	Average Tuber No. Per Plant
No P - Control	2430	489	486	64	1	35	34	1.089	4.8	9.0
100lbs P at Planting	2630	522	512	67	2	31	41	1.087	4.9	9.2
200lbs P at Planting	2290	473	465	63	4	32	40	1.087	4.9	8.6
100lbs P In-season	2390	487	483	69	1	31	35	1.089	4.9	8.8
200lbs P In-season	2360	478	470	67	2	31	40	1.088	4.9	8.6
100lbs P Split (75/25)[C]	2510	497	490	69	3	28	36	1.087	4.9	8.9
200lbs P Split (75/25)[C]	2360	483	477	71	1	28	39	1.087	5.0	8.4
LSD[B]	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
pValue	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

[A]Processing market economic values - Adjusted for differences in fertilizer expense, $0.70/lb P2O5.

[B]ns = values not significantly different at the 5% or 10% level via Fisher's LSD test; LSD = Least Significant Difference

[C]75% of total P was applied at planting, the remaining 25% was applied in-season

<u>Phosphorous Source Trial:</u>

Justification: Phosphorous (P) fertilizer has been made a target in the push to reduce phosphorous concentrations in surface water. This research is a pro-active response to identify products that work as well as conventional fertilizer, but with a slower release, or extended release.

Purpose: To provide growers with alternatives to conventional fertilizer.

Background: Various rates of P2O5 (0%, 50%, 75%, and 100%) were pre-plant incorporated as 11-52-0 (MAP) or Crystal Green (pelletized struvite, a human waste biosolid), or a combination of the two products and applied to P-deficient soil (Table 10). The variety used was Russet Burbank.

Results: All Crystal Green treatments yielded as high as or higher than the 11-52-0 treatments and the untreated controls (Table 10). The results are promising in that we may have found a good supplement to standard P fertilizer. This research is enticing and will be continued for at least two more years as a component of Chandler Dolezal's PhD research

Table 10. Effects of pre-plant phosphorus in the forms of 11-52-0 and Crystal Green (pelletized struvite) on yield, tuber weight and number, and gross return in 2014.

2014 WSU Crystal Green Phosphorus Trial Summary

Trt Mix	% of Recommended* P	(Not Adjusted for Fertilizer expense) Gross[A] $/A	Total Yield CWT/A	Market Yield CWT/A	US 1s > 4 oz %	US 2s > 4 oz %	Culls & < 4 oz %	US 1 & 2s > 6 oz %	Specific Gravity	Average Tuber Weight oz	Average Tuber No. Per Plant
No P - Control	**0**	3880	594	564	68	16	16	67	1.080	7.3	7.1
MAP 100%	**100**	4560	660	648	79	8	13	69	1.082	6.9	8.3
CG 25% MAP 75%	**100**	4700[C]	674[D]	656	84	2	14	66	1.085	6.8	8.7
CG 10% MAP 90%	**100**	4885[C]	692[D]	670	85	2	13	68	1.084	6.9	8.7
CG 15% MAP 85% GRA	**100**	4560	671[D]	660	84	3	13	67	1.081	7.0	8.3
CG 9% MAP 91% GRA	**100**	4530	666[D]	660	82	3	15	65	1.093	6.6	8.8
CG 50% MAP 50%	**75**	4240	642	610	77	7	16	64	1.084	6.8	8.2
CG 25% MAP 75%	**75**	4160	610	601	79	7	14	68	1.082	7.1	7.6
CG 100%	**100**	4380	649	640	83	6	12	65	1.081	6.8	8.2
CG 100%	**50**	4170	650	629	79	4	17	61	1.082	6.5	8.7
	LSD[B]	ns	ns	ns	ns	ns	ns	ns	ns	ns	1.1
	pValue	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.08

***Recommended P rate was 250 lbs P2O5. CG = Crystal Green, MAP = Monoammonium Phosphate**

[A]Processing market economic values - NOT ADJUSTED for differences in fertilizer expense, this should be done if CG expense/acre is available

[B]ns = values not significantly different at the 5% or 10% level via Fisher's LSD test; LSD = Least Significant Difference

[C]When treatments were compared individually in a pairwise comparison (opposed to a group comparison, as tabled) CG10MAP90 and CG25MAP75 100% were significantly higher than the control at the 5% level

[D]When treatments were compared individually in a pairwise comparison (opposed to a group comparison, as tabled) CG10MAP90, CG15MAP85 GRA, CG25MAP75 100%, and CG9MAP91 GRA were significantly higher than the control at the 5% level

Phosphorous Additives Trial:

Justification: This research is a pro-active response (Phosphorus ground water contamination) to identify products that allow us to use lower rates of fertilizer.

Purpose: Determine if products like AVAIL, Accomplish, or MESZ allow us to use lower rates of P fertilizer or enable recommended rates of P fertilizer to be available to the plant longer throughout the year.

Background: P Fertilizer was applied during planting in a liquid band 1-2 inches above the seed piece and to the side of the seed piece. The P fertilizer was in the form of 10-34-0 (50-, 100-, and 200-lbs/A P_2O_5), MESZ (50- and 100-lbs/A P_2O_5), Accomplish (50- and 100-lbs/A P_2O_5), and AVAIL (50- and 100-lbs/A P_2O_5) and applied to P deficient soils (< 14 ppm P) with a high pH (>7.0). The variety used was Umatilla

Results: None of the 10-34-0 products produced gross returns higher than the non-treated control (Table 11); however, AVAIL produced significantly more gross return per acre than all other treatments. Accomplish appeared to have performed well, but more years of research are needed to tease out significance. MESZ did not appear to help P availability to the potato plant. This research is enticing and will be continued for at least two more years as a component of Chandler Dolezal's PhD research

Table 11. Phosphorus additives MESZ, Accomplish, and AVAIL were tested against standard P fertilizer (10-34-0) and a non-treated control in 2014. The additives are supposed make P more available to the potato plant.

2014 Phosphorus Additives Trial Summary

Trt Mix	(Not Adjusted for Fertilizer expense) Gross[A] $/A	Total Yield CWT/A	Market Yield CWT/A	US 1s > 4 oz %	US 2s > 4 oz %	Culls & < 4 oz %	US 1 & 2s > 6 oz %	Specific Gravity	Average Tuber Weight oz	Average Tuber No. Per Plant
No P - Control	2420 bc	488 bc	482 abc	66	2	32	34	1.089	5.4	8.4
10-34-0 50lbs P	2340 c	472 c	463 bc	65	4	31	32	1.087	4.0	10.2
10-34-0 100lbs P	2300 c	476 c	470 bc	64	2	34	34	1.090	4.2	9.9
10-34-0 200lbs P	2280 c	433 c	424 c	68	5	27	39	1.089	4.9	7.8
MESZ 50lbs P	2310 c	472 c	463 bc	64	2	34	29	1.089	4.6	9.7
MESZ 100lbs P	2430 bc	485 c	476 abc	65	2	34	34	1.088	4.2	10.0
Accomplish 50lbs P	2770 abc	566 ab	554 a	63	2	35	33	1.088	5.2	9.6
Accomplish 100lbs P	2700 abc	565 ab	543 ab	63	2	35	37	1.091	5.8	8.5
Avail 50lbs P	2980 a	571 a	551 a	68	3	29	42	1.091	5.4	9.2
Avail 100lbs P	2870 ab	569 a	552 a	65	2	33	39	1.090	5.3	9.5
LSD[B]	504	79	81	ns	ns	ns	ns	ns	ns	ns
pValue	0.046	0.004	0.015	ns	ns	ns	ns	ns	ns	ns

*** Differing letter groups indicate statistal diffrences**

[A]Processing market economic values - NOT ADJUSTED for differences in fertilizer expense

[B]ns = values not significantly different at the 5% or 10% level via Fisher's LSD test; LSD = Least Significant Difference

<u>Defining Profit Maxing In-Season N Rates for Eight Cultivars:</u>

(See also N.R. Knowles 2014 progress reports for more information on this trial)

Purpose: Identify in-season nitrogen rates that maximize grower revenue by optimizing field performance and post-harvest quality attributes. In addition, understand the effects of in-season nitrogen on whole plant morphology and physiology in an effort to improve our ability to make management recommendation for these and other varieties.

Background: Four in-season nitrogen rates were applied to Clearwater Russet, Dakota R. A03158-2TE, POR06V12-3, GemStar R., A03921-2, A06084-1TE, and A02424-83LB with 0.15 in of water via a fertigation simulator. The rates were based on what might be typical for a Russet Burbank crop. All treatments received the same pre-plant fertilizer during a particular year. Petioles and soils were collected on a regular basis (Data not shown). Only the in-season physiology and morphology of Clearwater R. and Dakota R. is being analyzed by N.R. Knowles due to personnel, budget, and land restraints. The remaining varieties are treated similar with the exception of the intensive hand harvests and lab work being conducted on Clearwater R. and Dakota R.

Conclusion: The results from one year: Petiole and soil data indicate treatment differences (data not shown). Yield, specific gravity, and economic values (Table 12) were inconsistent across varieties. Moreover, the excessive heat during 2014 clearly stressed the plants during August and September. 2014 was not a typical year. Conclusions will not be drawn on one year of data. Readers should use discretion when reviewing the data due to the fact that it was from one year only. For more in-depth information on Clearwater Russet and Alpine Russet, see results in N.R. Knowles's report within this book.

Trials not shown:

Several trials were not discussed because someone else on the project reported their findings already or the commission doesn't fully fund them. In particular, the Tuber Shape and Water Deficit trials will be discussed by Rick Knowles in his report to the potato commissions.

Table 12. Defining profit maxing in-season N rates for eight cultivars. In-season N rates were 150-, 250-, 350-, and 450-lbs/A. The results for 2014 are shown below.

2014 In-Season N-Rate x Variety (1st year results)

	In-Season N-rate, lbs/A	Process Adjusted Gross Return ($/A)	Total Yield (CWT/A)
Clearwater Russet	150	3803	631
	250	3949	660
	350	4134	678
	450	4077	669
Dakota Russet	150	4669	665
	250	4665	681
	350	4745	702
	450	4472	690
A03158-2TE	150	3919	593
	250	4256	634
	350	4046	610
	450	3694	570
POR06V12-3	150	3166	546
	250	3434	566
	350	3273	561
	450	3108	526
GemStar Russet	150	4403	649
	250	4047	621
	350	3207	665
	450	4151	633
A03921-2	150	3969	612
	250	4018	632
	350	4180	642
	450	3953	619
A06084-1TE	150	2955	542
	250	2708	521
	350	2736	545
	450	2998	575
A02424-83LB	150	4033	656
	250	4167	652
	350	4298	679
	450	4770	727

Variety and BMP Final Thoughts:

The goal of the WSU Potato Program is to introduce new varieties and cultural and post-harvest management that will help keep Washington growers profitable without increasing the load on the environment. In order for growers to find success with the new varieties, the growth habits and cultural management recommendations for new varieties need to be established. In addition, new varieties need to be put through multiple tests to determine if they can be grown profitably with fewer inputs than traditional varieties. Our intent is to develop new and improved cultural management recommendations for new and existing cultivars. The positive gains we have been making on our research builds with each additional project. As our data-base increases, we will be able to provide timely and reliable information to potato producers in Washington. Further information on this year's variety trials can be found in detailed summaries on the web at potatoes.wsu.edu or within the 2014 WSU potato cultivar yield and postharvest quality evaluations.

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Research/Extension Progress Report 2014-2015 Funded Project

Title: Oregon Potato Variety Development Program

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Funding History:
Funding for 2014-2015 $116,001

Abstract:
Oregon State University (OSU) plays a key role in the Tri-State Potato Variety Development Program and is the only cooperating state with a complete breeding program. This unique role includes many facets including but not limited to the following: breeding, screening for disease and pest resistance, coordination of variety development efforts, evaluation of response to cultural management, and production of breeder seed for statewide, Tri-State, regional cooperators. The primary objectives of the Oregon Potato Variety Development Program are to develop superior varieties with high yield, improved fresh market or processing characteristics, genetic resistance to various pests and diseases, resistance to abiotic stresses, and improved nutritive properties while maintaining a visually attractive appearance. Varieties that meet one or more of these objectives have the potential to benefit all segments of the Pacific Northwest (PNW) potato industry.

The contribution of the Tri-State Potato Variety Development Program to the U.S. potato industry was recognized in 2010 with two awards for the program's success in variety development and subsequent utilization by industry. The first award was given by the Far West Region of the Federal Laboratory Consortium for Technology Transfer for *Outstanding Regional Partnership*, specifically the joint partnership of the Tri-State Program with PVMI. The second award was the 2010 USDA-ARS Technology Transfer Award given to five ARS scientists within the Tri-State Program for "Outstanding Efforts" in Technology Transfer for: *The development and transfer of new potato varieties in the Pacific Northwest.*

Certified potato seed acreage of Tristate advanced selections and released varieties totaled 17,728 acres, comprising 15% of all seed certified in the United States. Varieties recently released by the Tri-State program are now produced on over 120,000 acres in the Pacific Northwest with farm gate value to growers estimated at $500 million/year. This impact is expected to increase as superior varieties continue to be released

Key Words:
Oregon State University, Potato Variety Development, Tri-State, Value to Grower

Objectives:

1) Develop efficient potato varieties for processing, chipping, traditional fresh market, and specialty enterprises with efforts in each sector mirroring existing markets in Oregon.
2) Develop production management guidelines for selections nearing release with emphasis linked to major production regions in Oregon.

3) Identify and incorporate genetic resistance to various production concerns as dictated by industry needs.

Accomplishments:
Tri-State varieties continue to perform well in various production regions throughout the USA and abroad. Domestic certified seed of Tristate advanced selections and released varieties totaled 17,728 acres, 15% of all certified seed acreage. Varieties recently released by the Tri-State program are now produced on over 120,000 acres in the Pacific Northwest with a farm gate value to growers of $500 million. This economic importance is expected to increase.

Sage Russet has received considerable interest by PNW processors as a result of excellent performance in Tri-State and regional trials. Classic Russet continues to be evaluated and seed stocks have held constant the past three years. As a result, growers are continuing to improve production practices which should allow seed and commercial acreage to increase in the future.

Several specialty-type selections are continuing to experience increases in certified seed acreage. AmaRosa is currently one of the most widely planted red-skinned/red-fleshed varieties in USA certification programs. Purple Fiesta (Purple Pelisse) seed acreage was 15% of Purple Majesty, the most widely planted purple-skinned/purple-fleshed variety. Released Yukon Nugget as specialty potato. It is anticipated that this variety could supplant a portion of Yukon Gold acreage as it has a more diverse size profile which offers potential marketing advantages.

Four russet clones were evaluated in regional trials of which three russet clones (AO01114-4, OR05039-4 and POR06V12-3) will be retained for further evaluation in 2014. Performance of AO02060-3 will be solicited from Tri-state cooperators to see if continued testing is warranted. In the Tri-state trials, two russet clones and three specialty clones were evaluated and both the russet clones and two of three specialty clones were selected for advanced testing.

Oregon statewide trials included 20 russets, 5 chipping and 8 specialty clones. Of these clones 8 russet clones, 2 chipping clones and 4 specialty clones were promising and will be evaluated further in state wide advanced trials. The number of selections evaluated and selected were presented in Table 1.

Specific accomplishments at each Oregon location are summarized below.

HAREC:
- Evaluated 609 clones at 4-hill selections and selected 87 russet, 9 specialty and 15 chipping clones for next year evaluation at 17 Hills
- Evaluated 116 clones at 2 × 20 hill selections and selected 21 russet, 2 chip and 10 specialty clones for further evaluations
- Evaluated 39 state wide russet, 7 State wide chip and 17 state wide specialty clones and retained 5, 2, 4 clones in each category, respectively.
- Evaluated 62 advanced Tri-State and regional clones for fresh market, and processing use characteristics adaptable to the lower Columbia Basin.
- Evaluated 43 advanced regional, Tri-state and low acrylamide clones for their early die symptoms and PVY infection.
- Compiled and reported data from all the four research sites.
- Maintain Oregon Potato Breeding and Variety Development website and details can be found at http://cropandsoil.oregonstate.edu/group/potatoes
- Provide leadership for overall Oregon Potato Breeding and Variety Development and performed extension activities for potato growers at Columbia-basin

KBREC:

- Plant approx. 56,000 single-hill breeding selections from 365 different crosses and selected 896 russet, 93 chipper and 24 specialty clones for further evaluations
- Produced and stored seed of 62 advanced selections and check varieties (over 60,000 lbs) for distribution to Tristate, Regional, and Industry cooperators for trials in 2014
- Evaluated 21 Tristate russets for fresh market and processing use
- Evaluated all state wide and early generation material for their potential as a variety
- Packed and shipped seed to all Tristate, Regional, and Industry cooperators in 2014
- Performed extension activities for Klamath Falls Potato Growers

MES:

- Evaluated preliminary and advanced Oregon cultivars in 6 separate trials
- Evaluated selections under regional specialty trials

Impacts:

Potato crop value remains significant to Oregon agriculture and overall economic health of the state. Oregon potato producers sold more than $172 million of potatoes in 2012, making them the state's seventh largest crop and Oregon's leading vegetable crop in terms of gross farm gate sales. When considering processing value, the statewide economic footprint of potatoes is several times the farm gate value. Tri-State varieties play an important economic role in the PNW potato industry and have supplanted a significant portion of the Russet Burbank acreage in the PNW. Russet Burbank now comprises less than 50% of the total acres in Idaho, Oregon, and Washington combined.

Nationally, Tri-State advanced selections and released varieties are produced on approximately 18,170 acres of certified seed. This total is slightly more than 16% of all domestic seed supplies and has the potential to support approximately 220,000 acres of commercial potatoes nationwide. 'Ranger Russet', 'Umatilla Russet', 'Alturas', and 'Classic Russet' are the 5th, 6th, 11th, and 16th most widely planted varieties in the nation. Recently released varieties such as Owyhee Russet, Sage Russet, and 'Teton Russet' are garnering significant interest among processed and fresh market sectors throughout the nation. It is anticipated that these and other newer Tri-State russet-type varieties will continue to supplant even larger acreages of Russet Burbank in the coming years.

The Tri-State Variety Development Program is known and respected throughout the world as a leader in the development of superior potato varieties for multiple uses. The Potato Variety Management Institute, the marketing and regulatory arm of the program, has returned more than $500,000 dollars in royalty revenue back to the Tri-State program over the past three years. These funds will continue to play a larger role in supporting continued variety development efforts across the PNW as state and federal financial support continues to decline.

Relation to Other Research:

The Oregon Potato Variety Development Program provides unique selections for Tri-State evaluation and expanded regional testing in California, Colorado, and Texas. Oregon receives a one-third share of federal research funding for the Tri-State effort from multiple federal sources. Extension programs in all Oregon potato production areas coordinate activities with the variety development program and personnel to assist producers to rapidly adopt new varieties and appropriate management practices. Research and extension personnel work closely with Oregon seed and commercial growers to stimulate the marketing of promising new varieties and advanced selections.