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BIOLOGICAL AND ECONOMIC IMPACTS OF EMERGING POTATO TUBER NECROTIC VIRUSES AND THE DEVELOPMENT OF COMPREHENSIVE AND SUSTAINABLE MANAGEMENT PRACTICES

NON-TECHNICAL SUMMARY: The US potato industry is under threat from newly emerged potato viruses that render potatoes unmarketable. Our overall goal is to reduce the impact of these tuber necrotic viruses by working with all sectors of the potato industry to develop and implement new practices leading to a healthier potato crop and higher farm income. Virologists and plant pathologists will develop improved diagnostic methods to rapidly determine the type of virus and amount of disease on a farm. Technologies will be transferred to growers and seed inspectors so they can better make appropriate disease management decisions. Host plant resistance to virus disease is the best management option, but few virus resistant potato varieties exist. Virologists and potato breeders will work in concert to develop molecular markers to shave years and considerable cost off the development and release of new virus resistant potatoes. Until virus resistant potatoes are developed, potato growers need short term options to better manage virus disease on the farm. Entomologists, vector biologists, plant pathologists, and horticulturists will work to better understand the factors contributing to the spread of viruses onto and within a farm, and how the viruses impact tuber quality and processing traits during harvest and storage. This information will lead to regionally appropriate disease management strategies, as well as reduce the amount of virus in the crop and its impact on tuber quality. Economists will conduct a cost-benefit analyses of existing seed regulations, as well as possible new regulations suggested by scientists, to help the potato industry decide whether changes in farm practices, seed certification programs, and national and state regulations are worthwhile.

OBJECTIVES: Viruses are the major disease problem affecting the seed potato industry. Failure to adequately control viruses decreases the amount of certified seed available and creates downstream hardship for commercial growers. Shortage of certified seed regionally encourages movement of seed potatoes and their associated viruses across regions, and has contributed to the recent emergence of tuber necrotic viruses in all seed and commercial production regions. Tuber defects resulting from tuber necrotic viruses have expanded the significance of virus disease from strictly a seed issue, to a quality issue

impacting all sectors of the industry. Our overall goal is to reduce the impact of tuber necrotic viruses to manageable levels by engaging all sectors of the potato industry to modifying existing practices. A cost-benefit analyses of scientific recommendations will be conducted when appropriate to assist industry and regulatory agencies in deciding acceptability of proposed changes to farm practices, certification programs, and national and state regulations. The three major goals are:1. Assist seed certification agencies to amend current practices and improve their ability to detect, monitor and regulate virus in seed stocks. Specifically we will study or develop:a. Diagnostics for virus identification in foliar and tuber tissue, and vector populations from soil.b. Scientifically and economically feasible alternatives to the current post-harvest field grow-out.c. Inspector training for field detection of PVY, PMTV and TRV and apps for data collection.2. Assist breeding programs to develop improved methods to identify and characterize useful virus resistance. Specifically we will study or develop:a. Expression of tuber necrosis induced by PVY, PMTV and TRVb. Genetic markers for resistance to virus infection/replication and tuber symptom development.3. Assist growers with cost effective risk assessment tools to manage virus impacts on the farm. Specifically we will study or develop:a. Risk and economic analyses of virus incidence in seed potatob. Risk models for aphid management and timing of harvest to minimize disease.c. Impact of virus and timing of infection on tuber value at harvest and out of storage.

APPROACH: Basic science methods will be employed to better understand the geographic and genetic diversity and evolution of tuber necrotic virus populations and their vector populations. These data are critical to the development of improved diagnostic methods that can be evaluated in a variety of locations and conditions, and by different levels of technical expertise. Technologies will be transferred during formal laboratory and field exercises and through on-line training modules. This will help to ensure that any new methods are likely to be implemented and will lead to improved decision making.Reactions of potato varieties to the various virus and vector populations will be evaluated at multiple locations in different environments to better understand the biotic and abiotic factors influencing the impact of viruses on plant health and tuber quality, and will better define levels and mechanisms of plant resistance or defense against virus disease. A better understanding of the spectrum of potato plant reactions to the various tuber necrotic viruses will facilitate the selection and development of potato breeding populations best suited for the discovery and characterization of molecular markers useful for rapid selection of virus resistant potato clones. Usefulness of any markers will be evaluated in multiple breeding programs associated with the project. Robust markers and protocols will be distributed to other breeding programs via the website and meeting presentations.Controlled and replicated field and greenhouse experiments using selected potato varieties representing all market classes and all virus strains and species will generate data on virus impacts on tuber quality and yield. Harvested tubers stored under different conditions will be used to evaluate virus impacts on processing and end-use parameters. Many of these characteristics will be evaluated in collaboration with the processing industry so the benefits of the research can directly impact the consumer of potato products.Field studies and publically available agricultural databases will provide information on spatial and temporal aspects of virus vector populations, cropping and landscape use and diversity, and virus incidence. All of these data will be used to build predictive models to refine regional best management practices that growers can employ to reduce the effects of virus disease on the potato crop. Validation of models will occur in different locations and useful information will be transferred to growers via grower conferences, on-line resources and other outreach activities.

PROGRESS: 2016/09 TO 2017/08
Target Audience:Target audiences for the project include seed certification and regulatory

agencies that work to maintain high seed potato quality, potato farmers, processors, industry reps, crop consultants, county extension personnel, as well as the scientific community. Changes/Problems:There are no changes planned for overall objectives, but strategies will be modified based on results and on changing needs of the US potato industry. Most notable is a greater emphasis on PMTV and TRV. Additional funding was obtained from the APHIS 10007 Farm Bill program to investigate PMTV and TRV incidence in seed potatoes, to improve PMTV and TRV detection in dormant tubers, and to develop management plans that can reduce PMTV and TRV infestations. These efforts dovetail with our ongoing efforts on PVY diagnostics, genetic diversity of tuber necrotic viruses, and the evaluation of resistance and symptoms in potato cultivars and breeding lines. As a result more resources from the SCRI grant are being directed to development of tuber diagnostics on a scale appropriate for seed certification. This includes taking a new look at sampling and testing requirements based on the end use of a seed lot rather than the current one-size-fits-all approach. All sampling and testing protocols will be predicated on economic analyses so that end products fit within funding constraints of seed lot evaluation. Additional funds will also be directed at expanding diagnostics for the soil-borne vectors of PMTV and TRV and will include testing for virus harbored by the vector. Based on data generated in Years 1 and 2 it has become clear that evaluation for reaction to PMTV and TRV cannot be based solely on tuber symptoms at harvest. Additional virus testing is needed to determine if cultivars possess qualitative or quantitative resistance or if they are tolerant of infection. Testing also needs to be done at various times after harvest to determine actual infection incidence as well as potential for vertical transmission to the following year's crop. This is especially critical when characterizing breeding material that can be used to develop new resistant cultivars. To this end more resources will be directed toward testing tubers from PMTV and TRV trials On-farm management will shift focus to include experiments investigating the use of resistant cultivars and chemical management of soil-borne vectors to reduce levels of powdery scab and PMTV on infested land. Work will continue on risk models for PVY epidemics, but will focus on model development. New aphid data will be collected in only two states, ME and WA, in 2017. Storage and quality efforts will be focused on larger sample sizes to better mimic processing attributes at commercial facilities. What opportunities for training and professional development has the project provided?Eleven post-doctoral associates, 16 graduate students and 24 undergraduate students were actively engaged in pursuing the goals of this project, furthering their training and experience in virology, vector biology, entomology and plant breeding. How have the results been disseminated to communities of interest?The results of this project have disseminated to the potato industry, including seed certification and regulatory agencies, and potato growers and processors, through presentations at conferences, trade shows and magazines, webinars, websites and workshops, as well as via personal consultation with project staff. The results have reached the scientific community largely through publications in scientific journals and presentations at professional conferences. What do you plan to do during the next reporting period to accomplish the goals?Goal 1. Assist seed certification agencies to amend current practices and improve their ability to detect, monitor and regulate virus in seed stocks. 1.a. Diagnostics for virus identification in foliar and tuber tissue, and vector populations from soil. A national survey of PVY will again be conducted with the 2018 crop (in January 2019). Additional PMTV and TRV isolates collected from multiple sites across the U.S. will be characterized and sequenced to better understand their genetic diversity. Pictures of foliar and tuber symptoms for each virus on widely grown potato cultivars will be posted on a redesigned project website. Based on findings from post-harvest testing, protocols to improve the identification of tuber necrotic viruses and virus strains will be modified as needed. The emphasis will be to develop scientifically robust and economically feasible high throughput diagnostics for use with dormant tubers that can detect multiple viruses and possibly other pathogens. One approach will be to produce a multiplex real time PCR-based assay that can be customized for pathogens of importance or concern that year.

Assays will be validated and compared to schemes currently used by seed certification programs. Spectral measurements taken at the canopy level will be used to further evaluate whether reflectance spectroscopy can be used to detect virus infection in foliage. Goals of these experiments are to reveal additional sources of variation that might aid in resolving infection status and to advance the application of near-contact, proximal remote-sensing measurements of reflectance in monitoring plant status. The qRT-PCR soil assay for Spongospora subterranea will be transferred to additional public and private testing labs. The assay will also be modified to quantify levels of PMTV in S. subterranea. A qRT-PCR assay to quantify levels of stubby root nematode (the vector of TRV) will begin beta testing using soil samples from farm fields known or suspected to be infested. Budget cuts have put plans to investigate the genetic diversity of Spongospora populations on hold until additional resources can be identified. Progress on developing a hydroponic system to allow the interaction between potato and Spongospora/PMTV to be studied under controlled conditions will be evaluated in Sept 2017 to determine if additional resources will be expended in Years 4 and 5. 1.b. Scientifically & economically feasible alternatives to the current post-harvest field grow-out. Seed certification agencies currently collect and test 400 tuber samples from each seed lot when assessing virus incidence, regardless of intended use. Based on changes in virus tolerances dictated by National Harmonization Standards, seed certification programs are now seeking to optimize resource allocation depending on the intended use of a seed lot, e.g. to replant for seed increase vs plant for food production. We are currently working with commercial companies to optimize materials and reagents for large-scale sampling and testing. Our goal is to expand testing to include PMTV and TRV in addition to PVY. Methods used by European labs for nucleic acid extraction will be optimized for use with the multiplex virus assays needed to evaluate US seed lots. Once we have established a direct tuber testing assay that is as reliable for virus detection as data from winter grow outs, we will conduct economic and risk analyses to compare costs and the quality/quantity of data. These analyses will aid seed certification programs, regulatory agencies, and growers in making decisions about modifying current seed certification programs. 1.c. Inspector training for field detection of PVY, PMTV and TRV and apps for data collection. A one day school will be held in June/July 2018 at Othello, WA, Presque Isle, ME and Hancock, WI to train seed certification inspectors, growers, and other interested parties in the visual identification of virus infected potatoes. Twenty cultivars important to each growing region will be infected with three strains of PVY and plots of each cultivar-strain combination will be available for visual inspection during the course. A short course in lab diagnostics will also be taught to acquaint class participants with the latest developments we've made in diagnostic technologies. Goal 2. Assist breeding programs to develop improved methods to identify and characterize useful virus resistance. 2.a. Expression of tuber necrosis induced by PVY, PMTV and TRV Additional cultivars and breeding lines will be screened for their reaction to multiple PVY isolates. This includes 50 cultivars that will be exhibited in demonstration plots in 2018.Evaluation of foliar and tuber symptoms will be done following the same procedures used in previous years. Assessing resistance of the offspring of crosses made between PMTV- or TRV-resistant and susceptible clones will continue in 2017 and 2018 to help breeders identify markers that can be used in marker-assisted selection. Material to be screened include the A02062-1TE family (parents were a breeding clone with known resistance to both PMTV and TRV and Alturas, a potato cultivar susceptible to both viruses) and the A15001 family (parents were Castle Russet, which is resistant to both PMTV and TRV, and a cultivar susceptible to both viruses). Approximately 200 clones from the A15001 family will be evaluated for resistance to PMTV, and 125 will be screened for resistance to TRV. 2.b. Genetic markers for resistance to virus infection and tuber symptom development. Markers tightly linked to a PVY resistance gene from S. chacoensewill be evaluated for suitability in tracking the gene in cultivated potatoes. An ongoing effort to develop markers for incomplete, strain-specific PVY resistance (manifested as a restriction of virus movement) will be evaluated in September 2017 to determine if additional

resources will be allocated in years 4 and 5. Goal 3. Assist growers with cost effective risk assessment tools to manage virus impacts on the farm. Specifically we will study or develop: 3.a. Risk and economic analyses of virus incidence in seed potato Additional data are being collected from seed certification programs to validate and refine economic models that will identify acceptable virus levels for certification and recertification of seed potatoes. 3.b. Risk models for aphid management and timing of harvest to minimize disease. Aphid, weather, and landscape crop data will be integrated and used to determine which aspects of environment correlate with aphid abundance, diversity and phenology. The timing of aphid captures will be associated with NOAA surface weather data so that model output will include a prediction of when aphid flights are expected to occur in seed production regions. Field-scale data from digitized fields will be generated from the National Agricultural Imagery Program and each agricultural field will be identified as a field management unit (FMU) for each of the last 7 years (2006-2013). Post-harvest data on PVY incidence available from seed certification programs will be cross-referenced with the FMUs. Generalized additive mixed models together with random effects approaches will be used to identify sources of variation in time (phenology) and space (landscape) that contribute to the risk of PVY spread. 3.c. Impact of virus and timing of infection on tuber value at harvest and out of storage. Experiments will be conducted in 2017 to investigate the effects of seed-borne vs current season infection on the incidence and severity of tuber cracking. Separately, multiple cultivars will be grown in TRV and PMTV infested plots in ND and WA, and then sent to ID for analysis of quality and processing parameters. Individual tubers will be evaluated at harvest for internal and external symptoms, fry color and quality, and presence or absence of virus.

IMPACT: 2016/09 TO 2017/08
What was accomplished under these goals? Goal 1. Assist Seed Certification Agencies to Amend Current Practices and Improve Their Ability to Detect, Monitor and Regulate Virus in Seed Stock. Continued monitoring of potato virus Y (PVY) strains has shown that the most common strain in seed growing states is now PVYNWi. The tuber necrotic strain (PVYNTN) is present in all seed production regions and accounts for ~25% of the total isolates collected. Although not the most common strain nationwide, PVYNTN is the predominant strain in the northeast. While the PVYN:O strain is still found in most areas, its frequency has decreased precipitously. Similarly, the once ubiquitous ordinary strain of PVY (PVYO) now accounts for less than 5% of isolates from seed growing states. Understanding the frequency and distribution of PVY strains is important for developing appropriate management strategies. Testing for presence of potato mop top virus (PMTV) and tobacco rattle virus (TRV) in seed lots imported into WA from around the US and Canada revealed that <2% of the lots were infected, less than we had expected given anecdotal reports from growers and processors of high incidence in some commercial fields. Sequencing TRV isolates from within the US has shown some variation, but all isolates are closely related to each other and different from European isolates. US isolates are most similar to isolates from Asia, but the two groups can be distinguished with restriction enzymes. Some US isolates no longer have a gene required for nematode transmission. PMTV isolates from across the US are highly conserved and closely related to isolates from Europe. As for PVY, understanding variation in PMTV and TRV is important for developing appropriate diagnostic assays and management strategies. Spongospora subterranea is a fungal vector of PMTV. This project developed a new assay to quantify levels of S. subterranea in soil, which has already been adopted by growers and labs in five states. Knowing how much vector is present helps assess risk prior to planting. The assay is also being used to evaluate management strategies, including whether cultivars resistant to Spongospora result in less PMTV in subsequent years. Similarly, an assay to quantify levels of the nematode vectors of TRV is progressing and should begin beta testing in 2017. A major focus has been the development of optimized diagnostic assays to detect PVY, PMTV and TRV directly from dormant tubers. For two years we

compared the ability of an RT-PCR assay to detect PVY with 1) visual assays (growing plants during the winter and looking for symptoms) as well as 2) ELISA testing of leaf tissue. The RT-PCR and ELISA results were comparable, but both were less sensitive than visual assessment. Nevertheless, the cost of direct tuber testing was less than the methods now in use. Remote sensing that detects subtle differences in the wavelengths of light reflected off foliage looks promising as a method to identify potato varieties, and to distinguish between healthy and virus-infected plants. This technology may offer a rapid and cost effective mechanism to survey large fields and accurately determine disease incidence and distribution. A demonstration plot in Othello, WA in 2016 showcased 43 potato cultivars infected with three common PVY strains. Seed certification is currently dependent upon foliar symptoms to evaluate virus levels in seed lots. The demonstration made it clear to the 140 growers, industry representatives, seed inspectors and researchers who attended that new recombinant strains of PVY induce very mild symptoms in many cultivars. These mild symptoms can easily be missed during field inspections, leading to erroneous levels of virus being recorded. Industry was highly appreciative of this effort and plans are now underway for similar plots to be grown at three locations in 2018. Goal 2. Assist Breeding Programs to Develop Improved Methods to Identify and Characterize Useful Virus Resistance. Currently no widely accepted cultivars are resistant to PVY, PMTV or TRV. Until such varieties become available, providing data on reaction to virus infection allows growers to select cultivars that express mild or no tuber symptoms. Over the past year, 25 additional cultivars were evaluated for their reaction to ten PVY isolates. Only a few cultivars were highly susceptible to tuber necrosis. In general, foliar symptoms elicited by PVY strains ranged from mild to severe, in the following order N:O<Nwi<NE-11≈NTN<O. Over 60 cultivars were evaluated for a second year for reaction to PMTV and TRV in ND, and for TRV in WA. Forty-three cultivars were found to be insensitive to PMTV-induced tuber necrosis. In contrast, only eight cultivars were deemed insensitive to TRV. Ten cultivars were classified as insensitive to both viruses. Four markers for a new PVY resistance gene originating from a wild potato species, Solanum chacoense, have now been identified. These markers will make it easier for breeders to incorporate this gene into new varieties. Potato tuber necrotic ringspot disease (PTNRD) is a tuber deformity associated with infection by PVYNTN, but the symptoms are only expressed in some cultivars. Regions on chromosomes 4 and 5 linked to PTNRD expression have now been found, this information will be useful for follow-up studies to develop molecular markers for PTNRD expression. Although the development of virus resistant potatoes was not in the original work plan due to time constraints (it takes over a decade to develop a new variety), the tri-state breeding program recently released 'Castle Russet', which is immune to PVY, extremely insensitive to TRV and highly insensitive to PMTV. Goal 3. Assist Growers with Cost Effective Risk Assessment Tools to Manage Virus Impacts on the Farm. On farm management of tuber necrotic viruses in the field has focused on PVY due to an absence of data on the impact and distribution of PMTV and TRV in seed potato production. Efforts are focused on using existing resources and data available in the upper Midwest to better understand aphid flight patterns and the role of surrounding crops and vegetation in aphid dispersal and virus spread. Aphid seasonal phenologies are being modeled with landscape data on crop type and location to estimate the risk of Potato virus Y spread in the coming year. Additional data on seasonal aphid phenologies and PVY incidence were obtained in ME, OR and WA and these data will be used along with crop landscape data available from USDA to validate the models developed for the Midwest. PVY, PMTV and TRV are all suspected of diminishing tuber quality, but conclusive data from controlled trials has been lacking. An association between PVY infection and tuber cracking has now been shown for five specialty potato cultivars, although tuber cracking did not result in storage weight loss in any trial. In a separate study we monitored four processing cultivars after infection with three strains of PVY. Fry quality was not seriously affected in any cultivar x virus combination. Levels of PMTV and TRV were low in harvested tubers in both 2015 and 2016. For the 2015 crop, PMTV and TRV levels increased dramatically in

storage, but the same effect was not observed in 2016. Similar to what we found with PVY-infected tubers, in our controlled studies processing quality was not affected by PMTV or TRV infection. This contrasts with reports from processing plants that fry and chip quality is degraded when infected tubers are processed. We have previously assessed the relationship between virus incidence in seed and ensuing yield and grade (quantity and quality). Based on that data a calculator has now been constructed that adjusts the price of seed so that a grower is held economically harmless from buying infected seed (i.e., projected reductions in quantity and quality are used to reduce seed price in a way that per acre returns remain constant).

PUBLICATIONS (not previously reported): 2016/09 TO 2017/08

1. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Alyokhin, Andrei, Buzza, Aaron, Feldstein, Larry and Dwyer, James. Role of Non-Crop Hosts in Epidemiology of PVY on Maine Potato Fields. Western Extension Research Activity (WERA89) meeting, San Diego, California. April 2017.
2. Type: Journal Articles Status: Published Year Published: 2016 Citation: Bag, S., Frost, K., Rondon, S.I., Charlton, B.A., and D. Walenta. 2016. Variation in aphid abundance and Potato virus Y incidence in Oregon potato. Phytopathology 106 (Suppl. 4) S4.44.
3. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Bag, S., Rondon, S., Frost, K., Walenta, D. and B. Charlton. 2016. Monitoring aphids and potato virus Y in seed and commercial fields in Oregon. XXV International Congress of Entomology, September 25-30, Orlando, FL, USA.
4. Type: Theses/Dissertations Status: Published Year Published: 2016 Citation: Beissinger, A. 2016. Proactive approaches for managing Potato virus Y in western Washington. M.S. Thesis, WSU Plant Pathology Department, Pullman, WA
5. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Beissinger, A., Benedict, C.A., Goldberger, J., and Inglis, D.A. 2016. A sociological assessment of Potato virus Y in western Washington: Barriers and bridges to adopting new management practices. Ann. Mtg. Amer. Phytopath. Soc., S106:S4.119 Tampa, FL
6. Type: Other Status: Submitted Year Published: 2017 Citation: Beissinger, A., Benedict, C., Gundersen, B., and Inglis, D.A. 201x. Managing Potato virus Y in western Washington. WSU Extension Technical Bulletin
7. Type: Journal Articles Status: Under Review Year Published: 2017 Citation: Beissinger, A., Goldberger, J.R., Benedict, C.A., and Inglis, D.A. 201x. Seed potatoes, virus management, and the non-adoption of an agricultural innovation. Rural Sociol.
8. Type: Journal Articles Status: Under Review Year Published: 2017 Citation: Beissinger, A. Gunderson, B., and Inglis, D. 201x. Comparison of two detection methods for Potato virus YN-Wi at four potato growth stages. Plant Health Progress
9. Type: Other Status: Published Year Published: 2017 Citation: Bethke, Paul. Effect of in-season PVY inoculation on post-harvest quality of fresh market and processing potatoes. WERA89 meeting. March 8-9, 2017.
10. Type: Journal Articles Status: Published Year Published: 2015 Citation: Brown, C. R. 2015. Russet Burbank: No Ordinary Variety. HortScience. 50:157-160
11. Type: Journal Articles Status: Published Year Published: 2016 Citation: Carroll, J.E., Smith, D.M., and Gray, S. M. 2016. Preferential acquisition and inoculation of PVYNTN over PVYO in potato by the green peach aphid Myzus persicae (Sulzer). J. Gen. Virol. 97, 797?802.
12. Type: Journal Articles Status: Published Year Published: 2016 Citation: Chikh-Ali, M., Vander Pol, D., Nikolaeva, O.V., Melzer, M.J., and Karasev, A.V. 2016. Biological and molecular characterization of a tomato isolate of Potato virus Y (PVY) of the PVYC lineage. Archives of Virology 161: 3561?3566.
13. Type: Other Status: Published Year Published: 2017 Citation: Dwyer, J., Dill, J., Alyokhin, A., Buzza, A. and Dwyer, M. Presentation: Aphid Populations and Potato Virus Y

Trends in Maine. Western Extension Research Activity (WERA89) meeting, San Diego, California. April 2017.
14. Type: Journal Articles Status: Published Year Published: 2017 Citation: Elwan, E.A., Abdel Aleem, E.E., Fattouh, F.A., Green, K.J., Tran, L.T., and Karasev, A.V. 2017. Occurrence of diverse recombinant strains of Potato virus Y circulating in potato fields in Egypt. Plant Disease, published on-line April 17, 2017 (http://dx.doi.org/10.1094/PDIS-02-17-0275-RE).
15. Type: Journal Articles Status: Published Year Published: 2017 Citation: Frederick, ZAT, Cummings, TF, Brown, CR, Quick, RA, Zasada, I, Johnson, DA. 2017. Evaluation of Solanum sisymbriifolium as a Potential Inoculum Source of Verticillium dahliae and Colletotrichum coccodes. http://dx.doi.org/10.1094/PDIS-07-16-1077-RE
16. Type: Other Status: Published Year Published: 2017 Citation: Frost, K.E. 2017. Sampling, bulking, and detection of low-probability events. WERA89: Potato virus and virus-like disease management working group, San Diego, CA. March 8 & 9, 2017.
17. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Fulladolsa, A.C., Jansky, S.H., Halterman, D.A., Charkowski, A.O. 2016. Development of molecular markers tightly linked to Potato virus Y resistance gene Rychc in a diploid potato population. 2016 APS Annual Meeting. Tampa, FL, USA.
18. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Fulladolsa, A.C. 2017. Potato virus Y resistance in North American potatoes. UW-Extension and Wisconsin Potato and Vegetable Growers Association Grower Education Conference. Stevens Point, WI, USA.
19. Type: Other Status: Published Year Published: 2017 Citation: Fulladolsa, A.C., Jansky, S., Charkowski, A. 2017. Mapping a Potato virus Y resistance gene in Solanum chacoense. WERA89 Meeting: Potato viruses and virus-like disease management. San Diego, CA, USA.
20. Type: Journal Articles Status: Submitted Year Published: 2017 Citation: Fulladolsa, A.C., La Plant, K.E., Groves, R.L., Charkowski, A. Potato plants grown from minitubers are delayed in maturity, but are not more susceptible to Potato virus Y than plants grown from conventional seed. Amer. J. of Potato Res.
21. Type: Journal Articles Status: Published Year Published: 2016 Citation: Funke, C., Frost, K., Olsen, N., and A.V. Karasev. 2016. Strain specific resistance to Potato virus Y (PVY) in potato efficiently reduces the prevalence of the PVYO strain under semi-field conditions. Phytopathology 106 (Suppl. 4) S4.199.
22. Type: Journal Articles Status: Published Year Published: 2017 Citation: Funke, C.N., Nikolaeva, O.V., Green, K.J., Tran, L.T., Chikh-Ali, M., Quintero-Ferrer, A., Cating, R., Frost, K.E., Hamm, P.B., Olsen, N., Pavek, M.J., Gray, S.M., Crosslin, J.M., and Karasev, A.V. 2017. Strain-specific resistance to Potato virus Y (PVY) in potato and its effect on the relative abundance of PVY strains in commercial potato fields. Plant Disease 101: 20-28 (http://dx.doi.org/10.1094/PDIS-06-16-0901-RE)
23. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Gray et al. Evolving disease dynamics of the Potato virus Y complex affecting the US potato crop: A group effort between selection pressure and farming practices. Seminar at the European Association of Potato Research conference, Slovenia, June 2016.
24. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Gray et al. Evolving disease dynamics of the Potato virus Y complex affecting the US potato crop: A group effort between selection pressure and farming practices. Seminar at the International Plant Virus Epidemiology Symposium, France, June 2016.
25. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Gray et al. Emerging and Re-emerging Tuber Necrotic Potato Viruses: Challenges to the seed certification process. Seminar at the Syngenta Potato Conference, December 2016.
26. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Gray et al. Why commercial potato growers should care about PVY. Michigan

Potato Conference, Mt. Pleasant, MI. January 2017.
27. Type: Conference Papers and Presentations Status: Other Year Published: 2017 Citation: Gray et al. Potato virus Y; Seed potato?s #1 problem; An unintended consequence of science as well as regulatory and farming practices. Seminar at the USDA ARS and Boyce Thompson Institute, Ithaca, NY. March 2017.
28. Type: Other Status: Published Year Published: 2017 Citation: Gray et al. Potato virus Y; Seed potato?s #1 problem; An unintended consequence of science as well as regulatory and farming practices. Seminar at the Departments of Plant Pathology and Entomology, North Carolina State University, Raleigh, NC. April 2017.
29. Type: Journal Articles Status: Published Year Published: 2017 Citation: Green, K.J., Brown, C.J., Gray, S.M., and Karasev, A.V. 2017. Phylogenetic study of recombinant strains of Potato virus Y. Virology 507: 40-52.
30. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Groves, R.L., Frost, K.E., and A. Charkowski. 2016. Grower-driven data reveals first principles in the management of Potato virus Y incidence in seed potato production. XXV International Congress of Entomology, Orlando, FL, September 25-30.
31. Type: Other Status: Published Year Published: 2017 Citation: Groves, R., Wenninger, E., Benedict, C., Rondon, S., Dwyer, J., Alyokhin, A., Lagos-Kutz, D., and K. Frost. Relationship of aphid abundance and diversity to local landscape. WERA89: Potato virus and virus-like disease management working group, March 8 & 9, 2017, San Diego, CA.
32. Type: Other Status: Published Year Published: 2016 Citation: Gudmestad, Neil. Varietal Sensitivity to TRV and PMTV. MN Area II Research Committee Meeting, Alexandria, MN, November 22, 2016
33. Type: Other Status: Published Year Published: 2017 Citation: Gudmestad, Neil. Potato Cultivar Susceptibility to Mop Top and Tobacco Rattle Viruses. Potato Expo, San Francisco, CA, January 4, 2017.
34. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Gudmestad, Neil. Potato Cultivar Susceptibility to Mop Top and Tobacco Rattle Viruses. Potato Expo, San Francisco, CA, January 5, 2017
35. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Gudmestad, Neil. Varietal Sensitivity to TRV and PMTV. Northern Plains Potato Growers Association Research Reporting Conference, Grand Forks, ND, February 21, 2017
36. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Huang, D. and Yan, G. P. 2016. Real-time and conventional PCR assays for identifying the stubby root nematode Paratrichodorus allius. American Phytopathological Society Annual Meeting, Tampa, FL, July 30-August 3, 2016.
37. Type: Journal Articles Status: Published Year Published: 2017 Citation: Huang, D., Yan, G. P., and Skantar, A. M. 2016. Development of real-time and conventional PCR assays for identifying stubby root nematode Paratrichodorus allius. Plant Disease 100: (in press)(http://dx.doi.org/10.1094/PDIS-10-16-1431-RE).
38. Type: Journal Articles Status: Submitted Year Published: 2017 Citation: Huang, D., Yan, G. P., and Skantar, A. M. 2017. Quantification of Paratrichodorus allius in DNA extracted from soil using TaqMan Probe and SYBR Green real-time PCR assays. Nematology 19:
39. Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2017 Citation: Huang, D., Yan, G. P., Plaisance, A., Gudmestad, N. C., Whitworth, J., Frost, K., Brown, C. R., Hafez, S. L., Handoo, Z. A., and Skantar, A. M. 2017. Molecular detection, identification and quantification of Paratrichodorus allius from nematode individuals, communities and soil DNA. Abstracts of 56th Annual Meeting of the Society of Nematologists, Williamsburg, Virginia, August 13-16.
40. Type: Other Status: Published Year Published: 2016 Citation: Inglis, D.A. ?Cracked? potato tubers and Potato virus Y. Invited PAA Forum article, Spudman magazine, June 2016.
41. Type: Conference Papers and Presentations Status: Published Year Published: 2016

Citation: Inglis, D.A., Gundersen, B., and Beissinger, A. 2016. Evidence that tuber cracking in potato can be caused by Potato virus Y. Ann. Mtg. Pacific Div. Amer. Phytopathol. Soc. 106:S4.199, La Conner, WA
42. Type: Conference Papers and Presentations Status: Submitted Year Published: 2017 Citation: Inglis, D.A., Gundersen, B., Beissinger, A., and Karasev, A.V. 2017. Reactions of five fresh market potato varieties with three Potato virus Y strains. Ann. Mtg. Amer. Phytopath. Soc., S10x:xxx, San Antonio, TX
43. Type: Other Status: Published Year Published: 2017 Citation: Inglis, D.A., Gundersen, B., Beissinger, A., and Karasev, A.V. 2017. Interactions of three PVY strains with five fresh market potato varieties. WERA89 meeting, San Diego, CA. Mar 8, 2017.
44. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Karasev, A. Composition of Potato virus Y strains in Idaho seed potato between 2012 and 2015. American Phytopathological Society, Pacific Division Annual Meeting, La Conner, WA June 29-30, 2016.
45. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Karasev, A. Characterization of recombinant Potato virus YNTN (PVYNTN) isolates from Sulawesi, Indonesia. 108th Annual Meeting of the American Phytopathological Society, July 30 - August 3, 2016, Tampa, FL
46. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Karasev, A. Genetic diversity and evolution of Potato virus Y. 3rd International Congress of Biotechnology and Biodiversity (III CIBB), Guayaquil, Ecuador, October 13, 2016.
47. Type: Journal Articles Status: Published Year Published: 2017 Citation: Karasev, A.V. (2017) Strain-specific resistance to Potato virus Y (PVY) in potato and its effect on the relative abundance of PVY strains in commercial potato fields. Plant Disease 101: 20-28 (http://dx.doi.org/10.1094/PDIS-06-16-0901-RE)
48. Type: Other Status: Published Year Published: 2017 Citation: Karasev, A.V., Funke, C.N., Frost, K.E., and N. Olsen. 2017. Strain-specific resistance to PVY in potato and its effect on prevalence of PVY strains in the field. WERA89: Potato virus and virus-like disease management working group, San Diego, CA. March 8 & 9, 2017.
49. Type: Journal Articles Status: Published Year Published: 2016 Citation: Kaur, N., Cating, R.A., Dung, J.K.S., Frost, K.E., Robinson, B.A., and P.B. Hamm. 2016. First report of Potato mop-top virus infecting potato in Oregon. Plant Disease 100:2337.
50. Type: Other Status: Published Year Published: 2017 Citation: McIntosh, C., Rosenman, J., Nolte, P. Predicting end of season PVY Levels and the impact of PVY on size and grade. WERA89: Potato virus and virus-like disease management working group, March 8 & 9, 2017, San Diego, CA.
51. Type: Journal Articles Status: Published Year Published: 2017 Citation: Mondal, S., Lin, Y.H., Carroll, J.E., Wenninger, E.J., Bosque-Perez, N.A., Whitworth, J.L., Hutchinson, P., Eigenbrode, S., Gray, S.M. 2017. Potato virus Y transmission efficiency from potato infected with single or multiple virus strains. Phytopathology, 107:491-498.
52. Type: Journal Articles Status: Awaiting Publication Year Published: 2017 Citation: Mondal, S. and Gray, S.M. 2017. Sequential acquisition of Potato virus Y strains by Myzus persicae favors the transmission of the emerging recombinant strains. Virus Research.
53. Type: Journal Articles Status: Published Year Published: 2017 Citation: Novy, RG, Whitworth, JL, Stark, JC, Schneider, BL, Knowles, NR, Pavek, MJ, Knowles, LO, Charlton, BA, Sathuvalli, V, Yilma, S, Brown, CR, Thornton, M, Brandt, TL, Olsen, N. 2017. Payette Russet: a Dual-Purpose Potato Cultivar with Cold-Sweetening Resistance, Low Acrylamide Formation, and Resistance to Late Blight and Potato Virus Y. Am. J. Potato Research.
54. Type: Other Status: Published Year Published: 2017 Citation: Olsen, N., Woodell, L., Andros, M., Karasev, A., Whitworth, J., Frost, K., Brown, C. and N. Gudmestad. 2017. Impact of virus infection on symptoms and quality of potato tubers in storage. WERA89: Potato virus and virus-like disease management working group, March 8 & 9, 2017, San

Diego, CA.
55. Type: Other Status: Published Year Published: 2017 Citation: Pappu, H.R., N. Gudmestad, J. Whitworth, and C. Brown. Update on the genetic diversity of potato mop top and tobacco rattle viruses. WERA89 meeting, San Diego, CA. Mar 8, 2017.
56. Type: Other Status: Published Year Published: 2016 Citation: Pavek, M.J.* and Z.J. Holden. 2016. Washington commercial seed lot trials. A summary of the 2016 Washington state commercial seed lot trial. Washington State University Special Report.
57. Type: Other Status: Published Year Published: 2016 Citation: Pavek, M.J.* and Z.J. Holden. 2016. Washington commercial potato seed lot and demonstration trials, in Northwest Potato Consortium Progress Reports for Research Conducted in 2015.
58. Type: Other Status: Published Year Published: 2017 Citation: Pavek, M.J.* and Z.J. Holden. 2017. Washington commercial potato seed lot and demonstration trials, in Northwest Potato Consortium Progress Reports for Research Conducted in 2016.
59. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Raikhy, G., N. Gudmestad, S.M. Gray, and H.R. Pappu (2016). Genetic diversity of Tobacco rattle virus isolates in the US. Paper presented at the 16th triennial meeting of the Virology Section of the European Association of Potato Research. May 31st to June 3rd 2016.
60. Type: Other Status: Other Year Published: 2017 Citation: Rondon, S.I., Bag, S., Frost, K., Charlton, B., and D. Walenta. 2017. Aphid abundance and potato virus Y incidence in Oregon. WERA89: Potato virus and virus-like disease management working group, March 8 & 9, 2017, San Diego, CA.
61. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Rondon. S.I., Bag, S., Vinchesi, A., Goyer, A. and K. Frost. 2016. PVY vectors, vector-plant interactions and novel control methods in the western United States. 16th triennial meeting of the virology section of the European Association of Potato Research, May 31 ? June 3, Ljubljana, Slovenia.
62. Type: Other Status: Published Year Published: 2017 Citation: Townsend, P. Reflectance spectroscopy, remote sensing and potato physiology and disease. WERA89 meeting, San Diego, CA. March 8, 2017.
63. Type: Other Status: Published Year Published: 2016 Citation: Whitworth, J. Potato virus Y is an industry-wide problem; challenges in removing PVY from seed. Potato Association of America Annual Meeting, Grand Rapids, MI, Aug. 1, 2016.
64. Type: Other Status: Published Year Published: 2016 Citation: Whitworth, J. PVY Demonstration Plot Othello, WA Part of SCRI Potato Virus Grant. National Potato Council Disease Management Subcommittee Washington DC, Dec. 2, 2016.
65. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Whitworth, J. Demonstration Plots Show the True Nature of Potato virus Y Problems: A Research Update. Washington/Oregon Potato Conference, Kennewick, WA, Jan 26, 2017.
66. Type: Journal Articles Status: Published Year Published: 2016 Citation: Yan, G. P., Plaisance, A., Huang, D., Upadhaya, A., Gudmestad, N. C., and Handoo, Z. A. 2016. First report of the stubby root nematode Paratrichodorus allius on potato in North Dakota. Plant Disease 100: 1247 (http://dx.doi.org/10.1094/PDIS-11-15-1350-PDN).
67. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Yan, G. P., Huang, D., Plaisance, A., Gudmestad, N. C., Whitworth, J., Frost, K., Brown, C. R., Ye, W., Crow, B., and Hafez, S. L. 2017. Species and population densities of stubby root nematodes from multiple states in the United States. American Phytopathological Society Annual Meeting, San Antonio, TX, August 5-9.
68. Type: Other Status: Published Year Published: 2017 Citation: Yan, G. P., Huang, D., and Plaisance, A. 2017. Developing Real-Time PCR assays for identification and quantification of stubby root nematode Paratrichodorus allius in soil. Annual Meeting WERA89, San Diego, CA, March 8-9.

69. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Yan, G. P., Plaisance, A., Huang, D., and Handoo, Z. A. 2016. First detection of the stubby root nematode Paratrichodorus allius on potato in North Dakota and on sugarbeet in Minnesota. American Phytopathological Society Annual Meeting, Tampa, FL, July 30-August 3, 2016.
70. Type: Other Status: Published Year Published: 2017 Citation: Yan, G. P., Huang, D., and Plaisance, A. Developing real-Time PCR assays for identification and quantification of stubby root nematode Paratrichodorus allius in soil. Annual Meeting WERA89, San Diego, CA, March 8-9, 2017.
71. Type: Other Status: Published Year Published: 2017 Citation: Zidack, N., Gray, S. Ugly Fight: Battling Tuber Necrotic Viruses. Potato Grower, May 2017.

PROGRESS: 2015/09/01 TO 2016/08/31
Target Audience:Target audiences for the project include seed certification and regulatory agencies that work to maintain high seed potato quality, potato farmers, processors, industry reps, crop consultants, county extension agents, as well as the scientific community. Changes/Problems:No major changes in objectives or strategies to meet objectives are planned for the 2016 (Year 2) field season. Data from the 2016 field season will be evaluated to determine if any changes or modifications are warranted for the Year 3 field season in 2017. An increased interest by the potato industry in the incidence and distribution of PMTV and TRV in seed and its potential impact on commercial production has prompted an expansion of efforts to evaluate the 2016 seed potato crop. A sampling scheme is being developed to collect tubers from late generation seed lots in all or most seed production states. Dormant tubers will be tested in several of the labs participating in the project. The exact number of tubers to be collected and the labs to do the testing will be determined following the outcome of ongoing testing of tubers from the 2015 crop. Costs associated with the testing of seed potato lots for PMTV and TRV will likely be redirected from other research objectives, namely a reduction and redirection of some of the aphid survey and collection activities. What opportunities for training and professional development has the project provided?Ten post-doctoral associates, 9 graduate students and 24 undergraduate students were actively engaged in pursuing the goals of this project, furthering their training and experience in virology, vector biology, entomology and plant breeding. How have the results been disseminated to communities of interest?The results of this project have disseminated to the potato industry, including seed certification and regulatory agencies, and potato growers and processors, through presentations at conferences, trade shows and magazines, webinars, websites and workshops, as well as via personal consultation with project staff. The results have reached the scientific community largely through publications in scientific journals and presentations at professional conferences. What do you plan to do during the next reporting period to accomplish the goals?Goal 1. Assist seed certification agencies to amend current practices and improve their ability to detect, monitor and regulate virus in seed stocks. Specifically we will study or develop: 1.a. Diagnostics for virus identification in foliar and tuber tissue, and vector populations from soil. Plans are moving forward to work with state seed certification agencies to conduct a thorough survey of seed lots to be entered into re-certification for incidence and strain type of PVY, PMTV and TRV. Based on findings from the post-harvest testing, protocols to improve the identification and separation of tuber necrotic viruses and virus strains will be modified as needed. Additional PMTV and TRV isolates collected from multiple sites across the U.S. will be characterized and sequenced to better understand the genetic diversity of these viruses. These data will aid efforts to develop durable virus resistance and improve diagnostic methods. Pictures of foliar and tuber symptoms for each of the major tuber necrotic virus on widely grown potato cultivars are being posted on a redesigned project website (www.potatovirus.com). Protocols used to assay leaf tissue are being optimized to work on tuber tissue. The use of reflectance spectroscopy to discern

potato varieties and virus infection at the leaf level is promising. Research going forward will include spectral measurements at the canopy-level. Outcomes of these experiments will 1) reveal additional sources of variation that might aid in resolving the infection status of different potato varieties using spectroscopic approaches, and 2) advance the application of near-contact, proximal remote-sensing measurements of reflectance in monitoring plant status. The qRT-PCR assays for the powdery scab pathogen (Spongospora subterranea) cystosori and stubby root nematodes will be tested using field soils representing a wide range of soil types that vary in texture, organic matter, pH, and clay content to determine if the RT-PCR quantification method we have developed can quantify the powdery scab pathogen and nematodes in soils typical of those used for potato production. A soil testing service available to potato growers is anticipated by the end of 2016. 1.b. Scientifically & economically feasible alternatives to the current post-harvest field grow-out. Once we have shown that direct tuber testing is as reliable for virus detection as data from the winter grow outs, economic and risk analyses will compare costs and the quality/quantity of data. These analyses can aid seed certification programs, regulatory agencies, and growers in making decisions about modifying current seed certification programs. 1.c. Inspector training for field detection of PVY, PMTV and TRV and apps for data collection. No training schools are scheduled for year 3 of the grant. Work will continue with the national industry to implement a revised Tuber Necrotic Virus Management plan as part of the recently adopted National Harmonization Standards for Seed Potatoes. These formal agreements present a unified program to facilitate domestic and international trade of US potatoes. Goal 2. Assist breeding programs to develop improved methods to identify and characterize useful virus resistance. Specifically we will study or develop: 2.a. Expression of tuber necrosis induced by PVY, PMTV and TRV A second year of field evaluations of 60+ cultivars for PMTV and TRV susceptibility and symptom expression is planned for sites in ND and WA. Greenhouse studies continue in NY, ID, and WA to evaluate cultivars for reactions to a panel of PVY strains. 2.b. Genetic markers for resistance to virus infection/replication and tuber symptom development. Work continues to develop mapping populations useful in identifying reliable markers for potato tuber necrotic ringspot disease (PTNRD) expression and the presence of the Ny and Ry resistance genes. The chromosome location of the new Rychc gene and its genetic makeup is expected by the end of 2016. A better marker for this gene will increase the efficiency of selection and allow breeders to more effectively combine this source of PVY resistance with other sources of resistance thus reducing the probability of the virus overcoming the resistance. Family A15001 now in tissue culture will be planted in the greenhouse in 2016 to develop minitubers that will then be evaluated for their response to infection by PMTV and TRV in ND and WA field trials in 2017. In addition, 16 unrelated breeding clones derived from Kiva/Teena and designated as PMTV resistant based on two years of ND field screenings conducted by N. Gudmestad will be evaluated in replicated field trials in Aberdeen in 2016. Those clones having acceptable agronomics will then be submitted for PMTV and TRV resistance screenings in the field in ND and WA in 2017. An additional five clones from the Kiva/Teena populations also were retained for use as parental material in 2017. Goal 3. Assist growers with cost effective risk assessment tools to manage virus impacts on the farm. Specifically we will study or develop: 3.a. Risk and economic analyses of virus incidence in seed potato Additional data are being collected from participating seed certification programs to validate and refine the model Dr. McIntosh is developing to better identify acceptable virus levels for certification and recertification of seed potatoes. The overall objective is to define virus tolerance levels that will minimize production impacts and maximize economic benefits. 3.b. Risk models for aphid management and timing of harvest to minimize disease. Data collected during the 2015-16 growing seasons will be compiled and analyzed for use in building models that identify risk factors in the landscape that contribute to aphid vector abundance, timing of flights and spread of PVY into and within seed potato fields. During the 2016 production season additional aphid and virus data will be collected in ME, WA, OR and ID using standardized

protocols developed by Dr. Rondon. Based on a review of the 2015-16 aphid and virus data, a decision will be made on whether to continue this work for a third year in all locations or focus on one eastern and one western location. 3.c. Impact of virus and timing of infection on tuber value at harvest and out of storage. Greenhouse and field experiments are being conducted to investigate the effects of seed-borne vs current season infection on the incidence/severity of tuber cracking. The 2015/2016 experiments will be repeated starting in 2017 using additional potato varieties that are reported by growers to be impacted by tuber cracking. It is anticipated that the data on effects of virus infection on tuber quality, processing quality and storability generated in the 2015 and 2016 growing seasons will provide definitive information on the 4 cultivars being investigated. If so, additional cultivars will be tested in 2017 and 2018. Additionally, the effects of storage on tuber symptom development will move from an evaluation of named cultivars to an evaluation of breeding lines that have shown some degree of resistance to one or more viruses in previous year experiments.

IMPACT: 2015/09/01 TO 2016/08/31
What was accomplished under these goals? Although much progress was made under each of the project's research objectives, none of the work from essentially the first year of funding of this 5 year award has been completed or is being translated for use on farm or in seed certification programs. However, preliminary information is being related to project stakeholders through workshops, meeting presentations and our website. Seed certification laboratories have been adopting some of the testing procedures outlined in this report and discussions are ongoing regarding the need to include additional tuber necrotic viruses into seed certification beyond the current limited inspections when seed is being shipped off the production farm. Goal 1. Assist seed certification agencies to amend current practices and improve their ability to detect, monitor and regulate virus in seed stocks. Continued monitoring of PVY strain incidence indicates that the ordinary strain of PVY continues to decline in prevalence and distribution. The recombinant strains continue to increase and are now the predominant type of PVY in all seed production areas. Most of the recombinant strains are not tuber necrotic, although the tuber necrotic strain is widely distributed and accounts for more than 20% of the total isolates identified over the past year. We have very little information on the distribution or incidence of PMTV and TRV in seed potatoes. There are an increasing number of reports from commercial growers, processors and packing houses that symptoms typical of these viruses are being observed more frequently than in the past and a preliminary study of seed potatoes imported into WA found detectible levels of these viruses in 2-3% of the seed lots tested. Increased surveillance activities for these viruses are planned for Year 3. While sensitive diagnostic assays exist for known strains of PMTV and TRV, we know little about the genetic diversity of these viruses in the U.S. potato crop. As was shown for PVY, the genetic diversity of the virus populations will affect diagnostic efficiency and management options. Isolates of PMTV and TRV collected from around the U.S. are being analyzed for genetic differences. Several labs are developing or modifying diagnostic assays that would allow testing of dormant tubers for virus infection. This would provide an alternative to a winter grow-out in HI or FL to determine post-harvest virus levels for recertification/certification. While due to the sheer numbers of samples a direct tuber test could not preclude a winter grow-out, it would provide growers an alternative test to get results earlier for seed lots needing shipment prior to February. New remote sensing tools that use subtle differences in the wavelengths of light reflected off foliage look promising as a method to identify potato varieties, and distinguish between healthy and virus-infected plants. New diagnostic tools to test soil for the presence and quantities of the soil-borne vectors of PMTV and TRV are proving reliable and beta testing will begin in Year 3. The tools would provide growers the option of testing soil from fields prior to planting to identify the risk of the viruses and their vectors to the potato crop. A one day school was held June 20th, 2016 at Othello, WA to train seed certification

inspectors, growers, and other interested parties in the visual identification of virus infected potatoes. Tubers from 42 major cultivars infected with various strains of PVY were planted and were available for visual inspection during the course. A short course in lab diagnostics, ELISA and RT-PCR, was also taught to acquaint class participants with the latest diagnostic technologies. The school was attended by over 130 seed certification inspectors, potato growers, industry representatives, as well as and university and extension personnel representing most seed potato growing states. Demonstration plots and discussions presented hands on training in the detection and diagnosis of PVY in an effort to further reduce virus incidence in seed potatoes and spread of PVY on the farm. We have been working to revamp our project website and move it to a Cornell University domain for ease of support and to gain some longer term stability. The picture gallery of virus symptoms has been a favorite of our stakeholders and customers and we are continually expanding and updating that feature. Members of our project have had a presence at every major state and national potato meeting in 2015 and 2016. Several of us traveled to Slovenia in June to attend the European Meeting of Potato Researchers and the International PVY-wide meeting. We met with representatives of the Swiss and Dutch Seed Potato Certification programs. Both of their programs recently moved towards direct tuber testing to determine virus levels in the seed crop and they have offered to share protocols and data. Goal 2. Assist breeding programs to develop improved methods to identify and characterize useful virus resistance. Evaluations of popular North American cultivars for their reactions to PVY, PMTV and TRV are moving forward in various locations. Twenty seven cultivars have been evaluated against a panel of PVY isolates representing all prevalent strains. Only a few are highly susceptible to tuber necrosis. Over 60 cultivars were evaluated in field trials for their reactions to PMTV and TRV. There is a wide range of susceptibilities to tuber symptoms, but a lack of controlled studies will necessitate multiple years of study to develop a comprehensive and reliable assessment that is of practical use for growers. Genetic markers for PVY resistance are in hand and are being evaluated. Marker development for tuber necrosis and strain specific PVY resistance is moving forward using populations of potatoes that are segregating for these traits. Markers for PMTV and TRV resistance will be more difficult to develop due to the need for field evaluation of the segregating populations, but the appropriate populations are being developed and methods to evaluate PMTV and powdery scab resistance under controlled conditions are being investigated. Goal 3. Assist growers with cost effective risk assessment tools to manage virus impacts on farm. On farm management of tuber necrotic viruses is currently directed toward PVY due to an absence of data on the impact and distribution of PMTV and TRV with respect to seed potato production. The focus will be expanded as new information is obtained. Efforts are focused on using existing resources and data available in the upper Midwest to better understand aphid flight patterns and the role of surrounding crops and vegetation in aphid dispersal and virus spread. Additional data on virus incidence are being sought from seed certification agencies elsewhere in the U.S. Several labs are also acquiring new knowledge of aphid populations and virus sources and these data will expand the usefulness of the risk models being developed in the upper Midwest. PVY, PMTV and TRV are all suspected of having a significant impact on tuber quality at harvest, during storage and also on processing attributes, but conclusive data from replicated and controlled trials are generally lacking. Data from the 2015 growing season indicates that PVY infection is related to tuber cracking in some varieties, but other environmental factors also play a role. Incidence and severity of tuber necrosis associated with PVY, PMTV or TRV can change in storage in a cultivar dependent manner. Tuber quality and processing attributes can be affected by virus infection. Data are preliminary and suggest that impacts are virus and cultivar dependent. Materials and methods to be used in experiments conducted in 2016 and beyond are being evaluated and improved.

PUBLICATIONS: 2015/09/01 TO 2016/08/31

1. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Alyokhin, A. Managing non-persistently transmitted aphid-borne viruses: Perceptions and reality. Symposium ?Beyond Corn and Soybeans...Challenges to Integrated Pest Management in Specialty Crops.? Annual Meeting of the Entomological Society of America, Minneapolis, MN. November 15-18, 2015.
2. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Alyokhin, A. Con- and heterospecific influences on potato colonization by three species of aphids. Annual Meeting of the Entomological Society of America, Minneapolis, MN. November 15-18, 2015.
3. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Alyokhin, A. and A. Buzza. 2016. Epidemiology of Potato Virus Y in Northern Maine. Northeastern Plant, Pest, and Soils Conference, Philadelphia, PA. January 3-7, 2016.
4. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Bag, S., K. Frost, S.I. Rondon, B.A. Charlton, and D. Walenta. ?Variation in aphid abundance and Potato Virus Y incidence in Oregon potato?. APS Annual Meeting. 30 July 30-Aug 3, 2016. Tampa, FL.
5. Type: Journal Articles Status: Accepted Year Published: 2016 Citation: Bag, S., Frost, K., Rondon, S.I., Charlton, B.A., and D. Walenta. 2016. Variation in aphid abundance and Potato virus Y incidence in Oregon potato. Phytopathology (accepted).
6. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Bag, S., S.I. Rondon, K. Frost, D. Walenta, and B. Charlton. 2016. Monitoring aphids in seed and commercial potato fields in Oregon. In 75th annual Pacific Northwest Insect Management Conference. Jan. 11-12, Portland, OR. Section V: 59-62.
7. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Bag, S., Rondon, S., Frost, K., Walenta, D. and B. Charlton. 2016. Monitoring aphids and potato virus Y in seed and commercial fields in Oregon. XXV International Congress of Entomology, September 25-30, Orlando, FL, USA.
8. Type: Journal Articles Status: Published Year Published: 2015 Citation: Benedict, C., McMoran, D., Inglis, D., and Karasev, A.V. 2015. Tuber symptoms associated with recombinant strains of Potato virus Y in specialty potatoes under northwestern Washington growing conditions. American Journal of Potato Research 92: 593-602.
9. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Brown, Chuck, Potato EXPO ?Breeding for resistance to Corky Ringspot.? , Potato Expo, Las Vegas, NV, January 12, 2016.
10. Type: Journal Articles Status: Published Year Published: 2016 Citation: Carroll, J.E., Smith, D.M., and Gray, S. M. 2016. Preferential acquisition and inoculation of PVYNTN over PVYO in potato by the green peach aphid Myzus persicae (Sulzer). J. Gen. Virol. 97: 797?802.
11. Type: Journal Articles Status: Published Year Published: 2015 Citation: Cating, R. A., C.N. Funke, N. Kaur, P.B. Hamm, and K.E. Frost, 2015. A multiplex reverse transcription (RT) high-fidelity PCR protocol for the simultaneous detection of six viruses that cause potato tuber necrosis. American Journal of Potato Research 92:536-540.
12. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Charkowski, Amy O. 2016. Tuber necrotic viruses in potato. UW-Extension and Wisconsin Potato and Vegetable Growers Association Grower Education Conference. Stevens Point, WI, USA.
13. Type: Journal Articles Status: Published Year Published: 2015 Citation: Chikh-Ali, M., Alruwaili, H., Vander Pol, D., and Karasev, A.V. 2015. Molecular characterization of recombinant strains of Potato virus Y from Saudi Arabia. Plant Disease 100: 292-297.
14. Type: Journal Articles Status: Published Year Published: 2015 Citation: Chikh-Ali, M., Bosque-Perez, N., Vander Pol, D., Sembel, D., and Karasev, A.V. 2015. Occurrence and molecular characterization of recombinant Potato virus YNTN (PVYNTN) isolates from

Sulawesi, Indonesia. Plant Disease 100: 269-275.
15. Type: Journal Articles Status: Published Year Published: 2015 Citation: Chikh-Ali, M., Naidu, R., and Karasev, A.V. 2015. First report of Potato virus Y (PVY) strain PVYC associated with a tomato disease in Kenya. Plant Disease 100:864.
16. Type: Journal Articles Status: Published Year Published: 2014 Citation: 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 (PVYZ) in potato. American Journal of Potato Research 91: 649-654.
17. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Couture, J. J. 2015. Mapping variation in vegetation functioning using imaging spectroscopy (Invited), American Geophysical Union (AGU) Fall Meeting. Dec. 18, 2015.
18. Type: Journal Articles Status: Published Year Published: 2015 Citation: Domfeh, O., Bittara, F., and Gudmestad, N.C. 2015. Sensitivity of potato cultivars to Potato Mop Top virus-induced tuber necrosis. Plant Dis. 99:788-796.
19. Type: Journal Articles Status: Published Year Published: 2015 Citation: Domfeh, O., Thompson, A.L. and Gudmestad, N.C. 2015. Sensitivity to tuber necrosis caused by Potato Mop Top virus in advanced potato (Solanum tuberosum L.) breeding selections. Amer. J. Potato Res. 92:636-647.
20. Type: Journal Articles Status: Published Year Published: 2016 Citation: Domfeh, O. and Gudmestad, N.C. 2016. Moisture management as a potential disease control strategy for Potato Mop Top virus-induced tuber necrosis. Plant Dis. 100:418-423.
21. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Fulladolsa, A.C., Jansky, S.H., Halterman, D.A., Charkowski, A.O. 2015. Identification and evaluation of SNP and SCAR markers linked to the Rychc gene for resistance to Potato virus Y in diploid potato populations. 2015 APS Annual Meeting, Pasadena, CA, USA.
22. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Fulladolsa, A.C. 2015. Resistance: the race against the disease. UW-Extension and Wisconsin Potato and Vegetable Growers Association Grower Education Conference. Stevens Point, WI, USA.
23. Type: Theses/Dissertations Status: Published Year Published: 2015 Citation: Fulladolsa Palma, Ana Cristina. 2015. Management of Potato virus Y in potato. PhD diss., University of Wisconsin-Madison.
24. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Fulladolsa Palma, Ana Cristina, Shelley H. Jansky, Dennis A. Halterman, and Amy O. Charkowski. 2016. Marker development for the Rychc Potato Virus Y resistance gene in a diploid potato population. APS Annual Meeting, Tampa, FL.
25. Type: Journal Articles Status: Accepted Year Published: 2016 Citation: Funke, C.N., Nikolaeva, O.V., Green, K.J., Tran, L.T., Chikh-ali, M., Quintero-Ferrer, A., Frost, K.E., Cating, R.A., Hamm, P.B., Olsen, N., Pavek, M.J., Gray, S.M., Crosslin, J.M., and A.V. Karasev. Strain-specific resistance against potato virus Y (PVY) and strain composition of PVY isolates circulating in commercial potato fields.
26. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Gray, S.M., Karasev, A., and Whitworth, J. 2016. Evolving disease dynamics of the Potato virus Y complex affecting the US potato crop: A group effort between selection pressures and farming practices. 16th Meeting of the Virology Section of the European Assoc. of Potato Research, Ljubljana, Slovenia
27. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Gray, S.M., Karasev, A., and Whitworth, J. 2016. Evolving disease dynamics of the Potato virus Y complex affecting the US potato crop: A group effort between selection pressures and farming practices.13th International Plant Virus Epidemiology Symposium, Avignon, France.
28. Type: Conference Papers and Presentations Status: Published Year Published: 2015

Citation: Groves, R.L. Charkowski, A.O. and Bethke, P. 2015. Influence of viral stresses on potato storage quality. In Proceedings of the 2015 University of Wisconsin - Wisconsin Potato and Vegetable Growers, Grower Education Conference , UW- Madison College of Agriculture and Life Sciences, Research Division and UWEX, Feb. 3-5, Steven?s Point, WI, 22:1pp.
29. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Groves, R.L., Frost, K.E., Charkowski, A.O., Duerr, E., Huseth, A.S. and Crockford, A.B. ?Data Driven IPM: Accurate Predictions of Risk for Plant Protection?. P-IE Section Symposium, Insecticide Resistance Management (IRM) vs. Integrated Pest Management (IPM): Overlap and Conflicts, IRAC US Symposium Series No. 11. Entomological Society of America Annual Meeting, Minneapolis, MN, November 15-18, 2015.
30. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Frost, K.E., Gevens, A.J. and Groves, R.L. 2015. Web-based pest and disease forecasting tool for enhanced processing vegetable crop management. In Proceedings of the 2015 Wisconsin Crop Management Conference Abstracts, January, 13-15, Alliant Energy Center, Madison, WI.
31. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Groves, R.L., Frost, K.E. and Huseth, A.S. 2015. Modeling Potato virus Y incidence in seed potato production using grower-driven data and landscape analyses. In Proceedings of the 2015 AFRI NIFA Sponsored Workshop: Enhancing Risk Index-Driven Decision Tools for Managing Insect Transmitted Plant Pathogens, Conference Abstracts, May 14-16, Asilomar Conference Grounds, Pacific Grove, CA. (http://ucanr.edu/sites/tospo/).
32. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Inglis, D.A. and Gundersen, B. 2015. Impact of Potato virus Y on the quality of specialty potato tubers. Pg. 7-14 in Proceedings of the Washington-Oregon Potato Conference. January 27-29, Kennewick, WA.
33. Type: Conference Papers and Presentations Status: Submitted Year Published: 2016 Citation: Huang, D. and Yan, G. P. 2016. Real-time and conventional PCR assays for identifying the stubby root nematode Paratrichodorus allius. American Phytopathological Society Annual Meeting, Tampa, FL, July 30-August 3, 2016.
34. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Karasev, A.V. ?A novel strain of Potato virus Y from tomato?, 107th Annual Meeting of the American Phytopathological Society, August 3, 2015, Pasadena, CA.
35. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Karasev, A.V. ?Molecular characterization of recombinant strains of Potato virus Y from Saudi Arabia?, 107th Annual Meeting of the American Phytopathological Society, August 3, 2015, Pasadena, CA.
36. Type: Other Status: Published Year Published: 2015 Citation: Karasev, A.V. ?A global overview of biological and molecular research on Potato virus Y?, R.E.F. Matthews Lecture, 12th Australasian Plant Virology Workshop, September 17, 2015, Fremantle, Western Australia.
37. Type: Other Status: Published Year Published: 2015 Citation: Karasev, A.V. ?Characterization of recombinant strains of Potato virus Y from seed potato in Saudi Arabia and in Indonesia?, 12th Australasian Plant Virology Workshop, September 18, 2015, Fremantle, Western Australia.
38. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Karasev, A.V. ?Changes in the Potato virus Y strain composition in the U.S. potato and reactions of potato cultivars to different strains of the virus?. Invited talk, Western Australia Seed Potato Producers? Meeting, September 21, 2015, Manjimup, Western Australia.
39. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Klein, M.L. and S.I. Rondon. 2016. Spatial and temporal analysis of aphids in eastern Oregon. In 75th annual Pacific Northwest Insect Management Conference. 11-12

Jan. Portland, OR. Section V. Pp 62-64.
40. Type: Journal Articles Status: Awaiting Publication Year Published: 2015 Citation: Mondal, S., E.J. Wenninger, P.J.S. Hutchinson, J.L. Whitworth, D. Shrestha, S.D. Eigenbrode, and N.A. Bosque-P?rez. 2015. Comparison of transmission efficiency of different isolates of Potato virus Y among three aphid vectors. Entomologia Experimentalis et Applicata.
41. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Mondal, S., Carroll, J. E., and Gray, S.M. 2016. Aphid transmission of multiple strains of Potato virus Y acquired either sequentially or from mixed infections. 16th Meeting of the Virology Section of the European Assoc. of Potato Research, Ljubljana, Slovenia.
42. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Mondal, S., Carroll, J. E., and Gray, S.M. 2016. Aphid transmission of multiple strains of Potato virus Y acquired either sequentially or from mixed infections. 13th International Plant Virus Epidemiology Symposium, Avignon, France.
43. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Mondal, S., Lin, Y.H. and Gray, S.M. 2016. Potato cultivar and virus isolate affect the disease dynamics of mixed-strain infections of Potato virus Y. 16th Meeting of the Virology Section of the European Assoc. of Potato Research, Ljubljana, Slovenia.
44. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Mondal, S., Lin, Y.H. and Gray, S.M. 2016. Potato cultivar and virus isolate affect the disease dynamics of mixed-strain infections of Potato virus Y. 13th International Plant Virus Epidemiology Symposium, Avignon, France.
45. Type: Other Status: Published Year Published: 2015 Citation: Olsen, N. and A. Karasev. 2015. Going viral: discerning among common virus-induced diseases. Potato Grower Magazine 44(9):32. September 2015.
46. Type: Other Status: Published Year Published: 2016 Citation: Pavek, M.J. and Z.J. Holden. 2016. Washington commercial potato seed lot and demonstration trials, in Northwest Potato Consortium Progress Reports for Research Conducted in 2015, 10 pages
47. Type: Other Status: Published Year Published: 2015 Citation: Pavek, M.J., N.R. Knowles, Z.J. Holden. 2015. In-field testing to identify new potato varieties and best management practices for Washington growers. Washington State Potato Commission Progress Reports for Research Conducted in 2014.
48. Type: Other Status: Published Year Published: 2015 Citation: Pavek, M.J. and Z.J. Holden. 2015. Washington commercial potato seed lot and demonstration trials. Washington State Potato Commission Progress Reports for Research Conducted in 2014.
49. Type: Other Status: Published Year Published: 2015 Citation: Pavek, M.J. and Z.J. Holden. 2015. Washington commercial seed lot trials. A summary of the 2015 Washington State commercial seed lot trial. Washington State University Special Report.
50. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Plaisance, A. and Yan, G. P. Comparison of two nematode extraction techniques. 54th Annual Meeting of the Society of Nematologists, East Lansing, MI, July 19-24, 2015.
51. Type: Other Status: Published Year Published: 2015 Citation: Robinson, A., Domfeh, O., and Gudmestad, N. C. 2015. Potato Tuber Viruses: Mop-Top Management. ND Extension Circular A1777. 2pp.
52. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Rondon. S.I., Bag, S., Vinchesi, A., Goyer, A. and K. Frost. 2016. PVY vectors, vector-plant interactions and novel control methods in the western United States. 16th triennial meeting of the virology section of the European Association of Potato Research, May 31 ? June 3, Ljubljana, Slovenia.
53. Type: Journal Articles Status: Published Year Published: 2015 Citation: 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 92: 38-48.
54. Type: Conference Papers and Presentations Status: Published Year Published: 2016

Citation: Wenninger, E., A. Alyokhin, J. Dill, J. Dwyer, K. Frost, R. Groves, S. Rondon, and C. Benedict. 2016. Seasonal aphid captures in potato and implications for spread of potato virus Y. Potato Expo, Las Vegas, Nevada. January 12-14, 2016.
55. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Whitworth, J., Tuber necrotic viruses: Impacts on tuber quality and farm profitability. Potato Expo 2015, Orlando, FL, Jan. 8, 2015.
56. Type: Conference Papers and Presentations Status: Submitted Year Published: 2016 Citation: Yan, G. P., Plaisance, A., Huang, D., and Handoo, Z. A. 2016. First detection of the stubby root nematode Paratrichodorus allius on potato in North Dakota and on sugarbeet in Minnesota. American Phytopathological Society Annual Meeting, Tampa, FL, July 30-August 3, 2016.
57. Type: Journal Articles Status: Published Year Published: 2016 Citation: Yan, G. P., Plaisance, A., Huang, D., Upadhaya, A., Gudmestad, N. C., and Handoo, Z. A. 2016. First report of the stubby root nematode Paratrichodorus allius on potato in North Dakota. Plant Disease 100: http://dx.doi.org/10.1094/PDIS-11-15-1350-PDN.
58. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Yan, G. P. and Gudmestad, N.C. Stubby root nematode as the virus vector of corky ringspot disease of potato. 54th Annual Meeting of the Society of Nematologists, East Lansing, MI, July 19-24, 2015.
59. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Yan, G. P., Plaisance, A., and Ye, W. Plant-parasitic nematodes on field crops in Southeastern and Northeastern North Dakota. American Phytopathological Society Annual Meeting, Pasadena, CA, August 1-5, 2015.
60. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Raikhy, G., Gudmestad, N.C., Gray, S.M. and Pappu, H.R. 2016. Genetic diversity among Tobacco rattle virus populations in the US. 16th Meeting of the Virology Section of the European Assoc. of Potato Research, Ljubljana, Slovenia.
61. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Raikhy, G., Gray, S.M., Krueze, J. and Pappu, H.R. 2016. Global analysis of the migration pattern and evolutionary lineages of Potato virus Y. 16th Meeting of the Virology Section of the European Assoc. of Potato Research, Ljubljana, Slovenia.
62. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Raikhy, G., Gudmestad, N.C., Gray, S.M. and Pappu, H.R. 2016. Genetic diversity among Tobacco rattle virus populations in the US. 13th International Plant Virus Epidemiology Symposium, Avignon, France.
63. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Raikhy, G., Gray, S.M., Krueze, J. and Pappu, H.R. 2016. Global analysis of the migration pattern and evolutionary lineages of Potato virus Y. 13th International Plant Virus Epidemiology Symposium, Avignon, France.
64. Type: Journal Articles Status: Published Year Published: 2015 Citation: Ramesh, S.V., G. Raikhy, C.R. Brown, J.L. Whitworth, and H.R. Pappu. 2015. Complete genomic characterization of Potato mop top virus from the United States. Archives of Virology DOI 10.1007/s00705-014-2214-0

PROGRESS: 2014/09/01 TO 2015/08/31
Target Audience:Target audiences for the project include seed certification and regulatory agencies that work to maintain high seed potato quality, the potato farmers, processors and consumers they serve, as well as the scientific community. Changes/Problems:Although we were notified the grant was awarded on September 12, 2014, funds were not released to Cornell University until March 4, 2015. Most of the Subcontracts were in place by April 20, 2015. NIFA allows grantees to back charge expenses to the start of the grant (September 1, 2014), but most universities only allow accounting transfers up to 90 days prior to the start of the subaccount. Accordingly, much of the year 1 budget expenses started in January or

later. Additionally, hiring of personnel was not allowed until accounts were in place. Despite the lack of funding and dedicated project personnel during the first 7-8 months of the grant, progress was made and preparations for the 2015 potato production season were completed. However, the timeline a number of project objectives was shifted into the second term. What opportunities for training and professional development has the project provided?Four post-doctoral associates, 3 graduate students and 4 undergraduate students were actively engaged in pursuing the goals of this project, furthering their training and experience in virology, vector biology, entomology and plant breeding. How have the results been disseminated to communities of interest?The results of this project have disseminated to the potato industry, including seed certification and regulatory agencies, and potato growers and processors, through presentations at conferences, trade shows, webinars, websites and workshops, as well as via personal consultation with project staff. The results have reached the scientific community largely through publications and presentations at professional conferences. What do you plan to do during the next reporting period to accomplish the goals?1. Assist seed certification agencies to amend current practices and improve their ability to detect, monitor and regulate virus in seed stocks. Specifically we will study or develop: 1.a. Diagnostics for virus identification in foliar and tuber tissue, and vector populations from soil. Pictures of foliar and tuber symptoms for each of the major PVY strains on widely grown potato cultivars will be posted on a redesigned project website (www.potatovirus.com). The multiplex RT-PCR protocol (developed in the Hamm lab at OSU) that detects six major potato viruses will be validated using tubers from several different potato cultivars. A second year of spectral measurement data will be collected at the PHT in Hawaii and in fields in WI. Additional PMTV and TRV isolates collected from multiple sites across the U.S. will be characterized and sequenced to better understand the genetic diversity of these viruses. Efforts will continue to quantify the soil borne vectors of PMTV and TRV from soil samples. 1.b. Scientifically and economically feasible alternatives to the current post-harvest field grow-out. Experiments in year 2 will focus on optimizing the use of existing RT-PCR protocols for diagnosing virus infection in dormant tubers and comparing results with those obtained by current protocols. 1.c. Inspector training for field detection of PVY, PMTV and TRV and apps for data collection. A two day school is planned for June 2016 at Othello, WA to train seed certification inspectors, growers, and other interested parties in the visual identification of virus infected potatoes and in the laboratory analysis of foliar and tuber samples. 2. Assist breeding programs to develop improved methods to identify and characterize useful virus resistance. Specifically we will study or develop: 2.a. Expression of tuber necrosis induced by PVY, PMTV and TRV Experiments to evaluate PMTV and TRV resistance/susceptibility in widely grown NA cultivars will be repeated in year 2. Evaluations of NA cultivars for PVY-induced tuber necrosis resistance/susceptibility will continue. 2.b. Genetic markers for resistance to virus infection/replication and tuber symptom development. Research described for Year 1 activities will continue. Additional crosses may be necessary to obtain populations that are segregating for the traits to be mapped. 3. Assist growers with cost effective risk assessment tools to manage virus impacts on the farm. Specifically we will study or develop: 3.a. Risk and economic analyses of virus incidence in seed potato Additional data to be collected from participating seed certification programs to validate and refine the model Dr. McIntosh is developing. 3.b. Risk models for aphid management and timing of harvest to minimize disease. 2015 data will be compiled and analyzed in models that identify risk factors in the landscape that contribute to aphid vector abundance, timing of flights, and spread of PVY. During the 2016 production season additional aphid and virus data will be collected in ME, WA, OR and ID. 3.c. Impact of virus and timing of infection on tuber value at harvest and out of storage. Virus-infected (PVY, PMTV and TRV) tubers collected from the various field trials grown in 2015 will be evaluated for internal and external symptom expression (at harvest and during storage) as well as for quality and processing attributes.

IMPACT: 2014/09/01 TO 2015/08/31
What was accomplished under these goals? Goal 1. Assist seed certification agencies to amend current practices and improve their ability to detect, monitor and regulate virus in seed stocks. To help seed certification programs better identify virus-infected plants during inspections, plant samples from winter grow-out test plots in Hawaii and Florida were collected in January and analyzed to detect and characterize the PVY strains prevalent in seed production areas. The ordinary strain of PVY (PVYO) continues to decline in prevalence relative to the recombinant and tuber necrotic strains, PVYNWi, NO, NTN. As a result, modifications and improvements were made to a PCR-based diagnostic assay to better detect and differentiate PVY strains. Efforts continue to document the foliar symptoms that each of the different PVY strains and strain variants induce on widely grown potato cultivars. To help get information to growers and regulatory programs more quickly, without needing to wait for a grow-out of tubers, a multiplex RT-PCR protocol was developed. This new method can accurately and simultaneously detect six important potato viruses -alfalfa mosaic virus,potato leaf roll virus,potato mop top virus,potato virus Y,tobacco rattle virus, tomato spotted wilt virus - in a single sample. This assay has been optimized to detect viruses in dormant tubers but also works with foliar samples. To determine if it is possible to differentiate potato varieties based on how leaves reflect light, foliar spectral measurements were collected in January from over 700 samples in Hawaii. Initial findings suggest that it is possible to accurately classify varieties using foliar reflectance, but reveal that it is important to fully characterize the spectral range within a variety. Variety identifications were best accomplished using healthy plants. Preliminary analyses found that leaf reflectance could correctly identify virus-infected plants with a mean accuracy of 73%. PMTV isolates from around the U.S. were sent to Washington State University to characterize genetic diversity. To date, the sequence of a WA isolate of PMTV indicated it was closely related to virus isolates from northern Europe. We'd like to understand whether PMTV and TRV issues parallel that with PVY, i.e., are there a wide diversity of virus types that require different strategies for detection and management, or are PMTV and TRV essentially homogeneous across the U.S.? A quantitative real-time PCR assay is being developed to determine population densities of the TRV vector, stubby root nematodes, in soil. Preliminary experiments looked at nematode species composition and relative numbers from soil samples collected in ND. A total of eight groups of plant-parasitic nematodes were detected; six of these contained stubby root nematodes. At the location where variety resistance trials will be conducted, stubby root nematode density averaged 23 nematodes/kg of soil. This will be compared with levels at harvest to quantify resistance levels of varieties to stubby root nematodes. A duplex RT-PCR assay was developed to quantify levels of the fungal vector of PMTV,Spongospora subterranea(Ss). The standard curve implemented with this assay will facilitate and permit normalization of Ss across soil samples. A major thrust of this project is to develop methods and diagnostic tools that allow direct testing on dormant tubers. Preliminary experiments looked at the effects of taking cores from tubers before they were shipped to the post-harvest test site in Hawaii.None of the cored tubers developed rot and tubers cored immediately before gassing (to break dormancy) had higher emergence than uncored tubers. The benefit of coring was reduced if the tubers were allowed to suberize. Coring also enhanced the stem number and overall vigor of the potatoes. Goal 2. Assist breeding programs to develop improved methods to identify and characterize useful virus resistance. Greenhouse experiments are continuing in NY and ID to evaluate susceptibility of important North American potato cultivars to tuber necrosis caused by PVY. Field plots were established in WI, OR and WA to evaluate response to three common strains of PVY. The focus is on a limited number of cultivars important in those regions; fry processing cultivars in OR, specialty varieties in WA, and chip and tablestock clones in WI. A field site for testing varietal reactions to PMTV was established in ND. This is on a private farm that has had issues with PMTV and powdery scab for several years. Two field sites, in ND and WA, were established to test reaction to TRV. At both

locations and at the PMTV location in ND, replicated plots of 68 potato cultivars were established. Foliar symptom expression will be recorded weekly and tubers will be harvested and evaluated for symptom expression and also checked for the presence of virus to determine relative susceptibility/resistance scores. Two markers were developed for a PVY resistance gene originating from a wild species, Solanum chacoense. Plants are now being grown for a few additional crosses to validate the PCR-based markers. Two populations (Waneta x Pike, Pike x Superior) were evaluated in NY to develop genetic markers linked to potato tuber necrotic ringspot disease (PTNRD) expression. Tuber disease expression segregated in the Waneta x Pike population and true seed was sent to Michigan State University to establish a mapping population. This population will be phenotyped and genotyped in 2015 to identify genetic markers for PTNRD. A cross between Russet Norkotah and Yukon Gold was made to develop a population for mapping several PVY strain-specific resistance genes. A small number of genotypes from this population will be tested in 2015 and if they segregate for resistance, true seed will be sent to Michigan State University (MSU) to develop and genotype a mapping population. Breeding clones derived from potato cultivars Kiva and Teena appear, based on two years of field screening, to be resistant to PMTV and have been planted in Aberdeen, ID to be evaluated for agronomic characteristics. Crosses of PMTV and TRV- resistant breeding clones with the susceptible cultivar Alturas have also been made. A small number of genotypes from each population will be tested in 2015 and if they segregate for resistance, true seed will be sent to MSU for genotyping.
Goal 3. Assist growers with cost effective risk assessment tools to manage virus impacts on farm. A preliminary economic model was developed that balances the costs and benefits of allowable virus levels in seed and assumes a competitive market. The model accounts for potato yields and the costs of growing suitable seed potatoes, both of which are affected by the maximum allowable virus levels for certified seed. Changes in virus tolerance limits are influenced by the price of potatoes, the relationship between potato yields and standards, and the fraction of seed potatoes that meet the certification standard. Refinement of the model continues as additional data is gathered from seed certification agencies. Aphid flight and species composition data was obtained for the central U.S. (WI, MI, MN, ND) for 2005-14, from ME for 2010-2012, and from CO for 2010-2014. These data are being used to develop models that predict risk periods for virus transmission. The USDA provides yearly maps that show the spatial arrangement of all agricultural fields in any area of the U.S. Coupling this with virus incidence data from seed certification agencies and the aphid data above is being used to develop and test models that predict virus incidence at the end of the season in potato seed fields. Plots have been planted to provide virus-infected tubers of several important processing (chip and fry) varieties for storage and quality trials, to determine if PVY, PMTV and/or TRV infection has a significant impact on tubers quality during storage and/or affects quality of the final products.

PUBLICATIONS: 2014/09/01 TO 2015/08/31
1. Type: Other Status: Published Year Published: 2015 Citation: Alyokhin, A. 2015. Preventing the Spread of Potato Viruses: What Insecticides Can and Cannot Do. Webinar presented for the Pest Management Network, available at http://www.plantmanagementnetwork.org/edcenter/seminars/potato/PotatoViruses/
2. Type: Journal Articles Status: Awaiting Publication Year Published: 2015 Citation: Cating, R. A., C.N. Funke, N. Kaur, P.B. Hamm, and K.E. Frost, 2015. A multiplex reverse transcription (RT) high-fidelity PCR protocol for the simultaneous detection of six viruses that cause potato tuber necrosis. American Journal of Potato Research 92: In press.
3. Type: Other Status: Published Year Published: 2015 Citation: Dwyer, J. D. 2015. When is the Best Time to Initiate PVY/Aphid Management Strategies. Spudlines, Volume 50 (3).
4. Type: Other Status: Published Year Published: 2015 Citation: Dwyer, J. D. 2015. Aphid Populations in 2014. Spudlines, Volume 50 Number 3.
5. Type: Journal Articles Status: Awaiting Publication Year Published: 2015 Citation:

Fulladolsa, A. C., F. M. Navarro, R. Kota, K. Severson, J. P. Palta, and A. O. Charkowski. 2015. Application of marker assisted selection for Potato virus Y resistance in the University of Wisconsin Potato Breeding Program. American Journal of Potato Research. In press.
6. Type: Journal Articles Status: Published Year Published: 2014 Citation: Groves, R.L., Frost. K.E. and Huseth, A.S. 2014. Integrating grower-driven and publically held data for improved plant protection. Phytopathology 104:S3. pp.159.
7. Type: Journal Articles Status: Published Year Published: 2015 Citation: Mallik, I. and Gudmestad, N.C. 2015. First report of Potato Mop Top virus causing potato tuber necrosis in Colorado and New Mexico. Plant Dis. 99:164.
8. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Plaisance, A. and Yan, G. P. (2015). Comparison of two nematode extraction techniques. 54th Annual Meeting of the Society of Nematologists, East Lansing, MI, July 19-24. (Abstract)
9. Type: Journal Articles Status: Published Year Published: 2015 Citation: Ramesh, S.V., G. Raikhy, C.R. Brown, J.L. Whitworth, and H.R. Pappu. 2015. Complete genomic characterization of Potato mop top virus from the United States. Archives of Virology DOI 10.1007/s00705-014-2214-0.
10. Type: Journal Articles Status: Published Year Published: 2015 Citation: Weber, B. N., R. A. Witherell, and A. O. Charkowski. 2015. Low-cost potato tissue culture with microwave and bleach media preparation and sterilization. American Journal of Potato Research 92:128-137.
11. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Yan, G. P. and Gudmestad, N.C. (2015). Stubby root nematode as the virus vector of corky ringspot disease of potato. 54th Annual Meeting of the Society of Nematologists, East Lansing, MI, July 19-24. (Abstract)
12. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Yan, G. P., Plaisance, A., and Ye, W. (2015). Plant-parasitic nematodes on field crops in Southeastern and Northeastern North Dakota. American Phytopathological Society Annual Meeting, Pasadena, CA, August 1-5. (Abstract)
13. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Alyokhin, A. 2014. Compatibility issues in chemical control of aphids on potato. 2014 Potato Pest Management Conference, Presque Isle, ME.
14. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Alyokhin, A. 2015. Potato Virus Y management: Challenges and options. 30th Annual Maine Potato Conference, Caribou, ME.
15. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Alyokhin, A., R. Groves, S.I. Rondon, E. Wenninger, A. Murphy, A. Buzza, S. Mondal, and R. Cating. 2015. Landscape effects on the epidemiology of Potato Virus Y. Potato Expo, Orlando, Florida.
16. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Chikh-Ali, M. and Karasev, A.V. ?Genetic diversity of Potato virus Y strains circulating in potato crops in Saudi Arabia and in Indonesia?, Annual Meeting of the Idaho Association of Plant Protection, November 5, 2014, Jerome, ID
17. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Dwyer, J. D. 2014. Aphid Populations in 2014: Management Strategies. 2014 Potato Pest Management Conference, Presque Isle, ME.
18. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Dwyer, J. D. 2015. Potato Pest Management, Agricultural Trade Show. Augusta, Maine.
19. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Dwyer, J. D. 2015. Aphid Flights and Control Strategies. 30th Annual Maine Potato Conference, Caribou, ME.
20. Type: Conference Papers and Presentations Status: Published Year Published: 2015

Citation: Funke, C. and Karasev, A.V. ?Changes in PVY strains circulating in potato in the PNW, and reactions of potato cultivars to different strains of PVY?, WERA-89 Potato Virus Research Meeting, March 4, 2015, San Diego, CA
21. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Gray, S.M. 2014. Potato Virus Y (PVY): A rapidly changing problem for the seed and commercial potato industries. Annual meeting of the Korean and Japanese Plant Pathology Societies, Busan, S. Korea.
22. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Gray, S.M. 2015. Biological and Economic Impacts of Emerging Potato Necrotic Viruses and The Development of Comprehensive and Sustainable Management Practices. Washington/Oregon Potato Conference, Kennewick, WA.
23. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Gray, S.M. 2015. Potato Virus Y (PVY): A rapidly changing problem for the seed and commercial potato industries. Maine Potato Growers.
24. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Groves, R.L., 2014. Frito Lay North America, Seed Seminar, ?Aphid Modeling: and Management of Potato virus Y?. February 18, FLNA Headquarters, Plano, TX.
25. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Groves, R.L., E.J. Duerr, A.O. Charkowski, A.B. Crockford, and A.S. Huseth.ESA Section Symposium, 2014. Effects of Cropping System Landscapes on the Ecology and Management of Insect Vectors and Transmitted Pathogens, ?Influence of regional landscapes on Potato virus Y incidence in seed potato?. ESA Annual Meeting, Portland, OR, November 18, 2014.
26. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Inglis, D.A. Jan 29, 2015. Impacts of Potato virus Y on the quality of specialty potato tubers. Washington/Oregon Potato Conference, Kennewick, WA.
27. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Inglis, D.A. Feb 27, 2015. Potato pathology research projects in 2014. Western Washington Potato Workshop, Mount Vernon, WA.
28. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Inglis, D.A. Mar 4, 2015 Special seminar on Potato virus Y in western Washington. WSU Graduate Students, Mount Vernon, WA.
29. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Inglis, D.A. Mar 6, 2015. Potato virus Y and the quality of specialty potato tubers. Narrated presentation delivered electronically to Klamath Falls Potato Growers.
30. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Karasev, A.V. ?PVY strains in Idaho seed supply and new sources of resistance?, Idaho Seed Potato Growers? Seminar, January 20, 2015, Pocatello, ID
31. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Karasev, A.V. ?Changes in PVY strains circulating in potato in the PNW, and reactions of potato cultivars to different strains of PVY?, Washington and Oregon Potato Conference, January 29, 2015, Kennewick, WA
32. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Karasev, A.V. ?Resistance to Potato virus Y in potato and classification of PVY strains?, Department of Plant Pathology, University of Helsinki, March 2, 2015, Helsinki, Finland.
33. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Karasev, A.V. Strain-specific resistance against PVY in potato. J.R. Simplot Company, Plant Sciences Division, March 25, 2015, Boise, ID
34. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Karasev, A.V. and Kuhl, J.C. ?Changes in PVY Strain Composition & New sources of PVY Resistance for Potatoes?, Idaho Potato Conference, January 22, 2015, Pocatello, ID.
35. Type: Conference Papers and Presentations Status: Published Year Published: 2015

Citation: Rondon, S. PNW updates and PVY information continuously provided online at ?Potato Update? http://oregonstate.edu/dept/hermiston/trap-reports.
36. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Wenninger, E.J. and S. Mondal. ?Contribution of non-colonizing aphids to PVY incidence in potato in Southern Idaho.? Montana Potato Conference, Missoula, MT, 2014.
37. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Wenninger, E.J., S. Mondal, and D. Shrestha. ?Interactions of PVY with its aphid vectors.? Potato Virus WERA meeting, San Diego, CA, 2015.
38. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Wenninger, E.J., S. Mondal, and D. Shrestha. ?Interactions of PVY with its aphid vectors.? Idaho Seed Potato Grower?s Seminar, Pocatello, ID, 2015.
39. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Whitworth, J. and Karasev, A.V. ?Mop Top, Tobacco Rattle & Other Tuber Necrotic Viruses?, Idaho Potato Conference, January 21, 2015, Pocatello, ID.