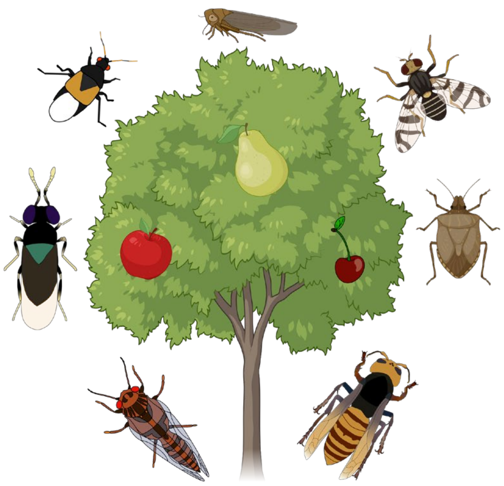
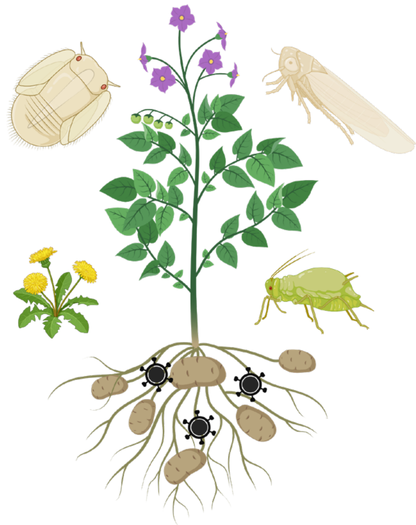
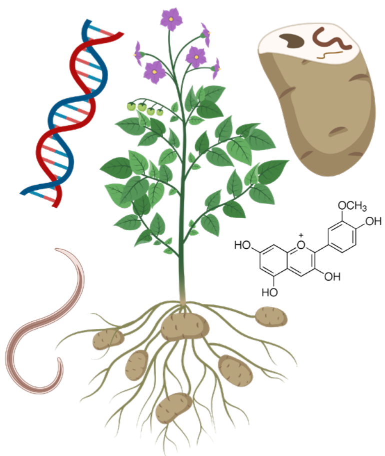
2022 Annual Report
Temperate Tree Fruit and Vegetable Research Unit
USDA-ARS







The IR-4 Project

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https://www.ars.usda.gov/pacific-west-area/wapato-wa/temperate-tree-fruit-and-vegetable-research/

Research Leader: Rodney Cooper (rodney.cooper@usda.gov)

Report Editor: Rebecca Schmidt-Jeffris (rebecca.Schmidt@usda.gov)

Mission Statement

The mission of the Temperate Tree Fruit and Vegetable Research Unit is to improve basic and applied information needed for the development of safe and environmentally sustainable methods for management of arthropod pests and plant pathogens of temperate tree fruits and vegetables, and to develop new potato varieties with improved pest and disease resistance, quality, and enhanced phytonutrient content.

Our CRIS (Current Research Information System) Projects

Tree Fruit Entomology: Integrated approach to manage the pest complex on temperate tree fruits

Potato Entomology: New technologies and strategies for managing emerging insect pests and insect transmitted pathogens of potatoes

Potato Germplasm: Developing new potatoes with improved quality, disease resistance, and nutritional content

IR-4 Project

Tree Fruit Entomology

2020-2025. The long-term objective of this project is to provide the basic and applied information needed for the development and transfer of safe and environmentally sustainable tools or methods for management of arthropod pests of temperate tree fruits.

1. Develop and improve tools and approaches for early detection, prediction, and monitoring of arthropod pests and their natural enemies in temperate tree fruits.
A. Determine if pre-harvest commercial pear is an acceptable host for apple maggot fly.
B. Identify volatile attractants from pear trees for early detection of orchard-colonizing winterform pear psylla.
C. Identify the primary non-orchard habitats that are sources of orchard-colonizing winterform pear psylla.
D. Identify the thermal tolerances of brown marmorated stinkbug and *Trissolcus japonicus* to more accurately determine potential establishment and spread.

2. Provide basic and applied information on the physiology and molecular biology of apple maggot, codling moth, and biology of generalist predators.
A. Determine the thermal kinetics of apple maggot.
B. Determine functions of proteins key to codling moth reproduction, development, physiology, and behavior.
C. Determine extent of cryptic species diversity in minute pirate bug fauna of the western U.S. in both orchard and non-orchard habitats.
D. Examine non-target effects of herbicides on key natural enemies of arthropod pests of apple and pear.

3. Test new strategies to control apple maggot and western cherry fruit fly, develop decision making models for pear psylla management based upon the presence and abundance of its key parasitoid, and develop practices to retain generalist natural enemies within orchards.
A. Improve control strategies for apple maggot in organic waste.
B. Develop pest management strategies for cherry fruit fly that incorporate newer and less toxic insecticides.
C. Model the relationship between estimated populations of *Trechnites* adults and rates of parasitism of pear psylla.
D. Develop management practices that increase the retention time of released natural enemies of arthropod pests of apple.

Scientists on this project: W.R. Cooper, D. Horton, L. Neven, R. Schmidt-Jeffris, J. Serrano, W. Walker

Potato Entomology

2020-2025

1. Develop new tools and approaches for examining landscape-scale movement by Hemipteran vectors and plant pathogens between non-crop plant species and potato fields.

A: Identify weedy plant sources of infective potato psyllids and beet leafhoppers entering potato fields of the Columbia Basin growing region.

B. Characterize genetic variation in beet leafhopper populations across geographic areas and between host species within the Columbia Basin and use these data to evaluate host-linked dispersal of leafhoppers into potato fields.

2. Describe the biology of Hemipteran vectors of potato pathogens in crop and non-crop habitats, including reproduction and development, feeding ecology, chemical ecology, seasonal phenology, interactions with natural enemies, and transmission/acquisition of pathogens.

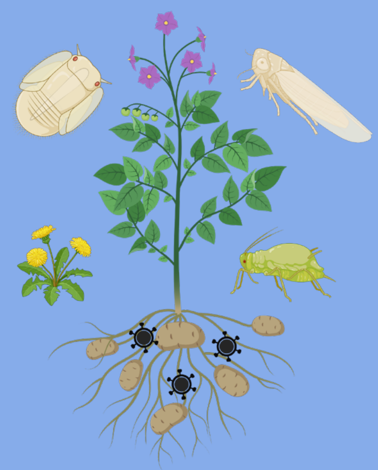
A. Characterize beet leafhopper feeding behavior and stylet penetration activities to examine acquisition and inoculation of BLTVA across host species.

B. Identify predator species important in reducing densities of potato psyllid and beet leafhopper in stands of weedy host plants.

3. Develop new or improved integrated management strategies to control emerging insect pests and insect-transmitted pathogens of potatoes.

A. Produce a "risk matrix" that ranks non-crop weedy plants as to importance as sources of infective potato psyllid or beet leafhopper arriving in potato fields and forward those rankings to the potato industry.

Scientists on this project: G. Angelella, W.R. Cooper, D. Horton



Potato Germplasm

2018-2023. Our goal is to develop or identify new breeding lines, germplasm and named cultivars with superior quality, disease and pest resistance, and nutritional value. This will involve collaborative and independent work by our three-person team using our respective expertise in potato breeding, molecular physiology and plant pathology.

1. Evaluate, identify, breed, and release potato germplasm with improved traits of interest, especially improved disease and pest resistance, and increased amounts of phytonutrients.

A. Develop breeding lines, cultivars or identify germplasm with enhanced amounts of phytonutrients and visual appeal.

B. Develop breeding lines, cultivars or identify germplasm with superior disease resistance with a focus on soil-borne diseases.

2. Characterize genetic, environmental, molecular, physiological, and biochemical factors that control accumulation of potato phytonutrients and mechanisms that lead to plant disease resistance, and use this knowledge to produce new superior potato cultivars.

A. Determine mechanisms that mediate tuber phytonutrient expression.

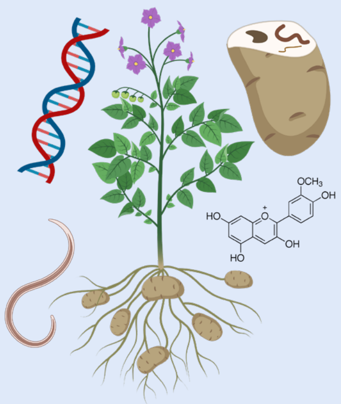
B. Increase information and develop methods with potential to be used for control of Potato Cyst Nematode (PCN) and for improved disease resistance.

3. Develop improved pathogen diagnostic techniques and phenotyping approaches that can be used for potato germplasm evaluation, development of host-resistance, and identification of emerging potato diseases.

A. Identify and characterize emerging and evolving pathogens and pests in the Pacific Northwest.

B. Characterize Tobacco rattle virus (TRV)-potato interactions to develop better detection methods and determine the relationship between viral titer, cultivar, symptoms and resistance.

4. Determine the value of advanced potato germplasm with particular attention to disease, pest, and stress resistance, yield, quality characteristics, and profitability parameters. Define cultural conditions which will optimize yield and quality of each clone.



Administrative Team

Administrative Officer: Jackdolyn Mooney

Program Support Assistant: Merilee Bayer

Office Automation Assistant: Michaela Gonzales

Financial Technician: Kevin Kenny

Maintenance Team

Facility Operations Specialist: John Harvey

Maintenance Mechanic: Sawyer Delp

Maintenance: Mark Heilman

Maintenance: Esaul Espana

Moxee Research Farm Team

Farm Manager: Jerald Gefre

Farm Staff: Rafael Reyes

IT Team

Information Technology Specialists:
Colleen Johnston
Bobbi Hendershott

TTFVRU greenhouse at night; Photo Credit: Good Fruit Grower

TTFVRU 2022 News and Achievements

Employee Recognition Awards

For extra effort above and beyond expectations to provide excellent service to stakeholders:
Pauline Anderson
Merilee Bayer
Rachel Cook
Heather Headrick
Jackie Mooney

For providing taxonomic assistance to stakeholders and ARS colleagues:
Tamera Lewis

For assisting colleagues in another lab at the Prosser facility:
Ricarda Castaneda

For training and mentoring a new permanent employee:
Millie Heidt

Other ARS Awards and Recognition

Lisa Neven, 30 Years of Serivice to USDA-ARS
Rebecca Schmidt-Jeffris, Pacific West Area Early Career Research Scientist of the Year

Professional Society Leadership

Entomological Society of America

Pacific Branch President, Rodney Cooper
Incoming co-Editor-in-Chief for *Journal of Economic Entomology*, Lisa Neven
Plant-Insect Ecosystems Section President, Rebecca Schmidt-Jeffris
Pacific Branch Executive Committee, Rebecca Schmidt-Jeffris
Pacific Branch Program Chair: Jackie Serrano

International Society of Chemical Ecology

Elected Councilor, Jackie Serrano

News at TTFVRU!

- Our Unit received a $2 million budget increase. These funds will support a new Research Molecular Biologist position at Wapato (search in progress) and six post doctoral positions at WSU. Renovations to the Wapato lab to support molecular biology research are ongoing.
- A new cherry block was established in the spring of 2022 to conduct research on little cherry and X disease. 100 trees ('Bing' and "Gabriel' mix) were planted with funds obtained from the Washington Tree Fruit Research Commission.
- A new farm worker was hired and we began process of hiring a new program assistant to help with administrative duties.
- Space is being renovated at the Prosser worksite to support the research of Dr. Swisher Grimm.

Dr. Gina Angelella. Potato Entomology

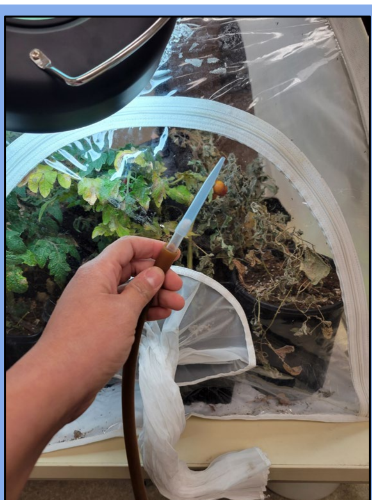
Permanent Technicians:
Joanna Galindo-Schuller & Millie Heidt

Additional Technical Support:
Ricarda Castaneda, Julianna Gainer, & AnaBeth Montemayor

Finding new control strategies for green peach aphid and potato leafroll virus (PLRV)

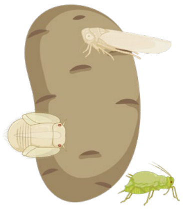
Conducting potato trial work

Green peach aphid, *Myzus persicae*, is the primary vector for PLRV, which was once a major threat to potato production. Over the past 30 years, PLRV and its vector have been successfully managed using neonicotinoid insecticides. Recent vows by Walmart, Costco, and other large customers to eliminate the use of neonicotinoids from their products once again makes PLRV a serious threat to US potato production. Our lab initiated a research project to test the efficacy of afidopyropen and other new insecticide chemistries on green peach aphid's ability to transmit PLRV. Foliar applications of afidopyropen reduces PLRV transmission to potato plants by 35% and reduces acquisition of PLRV by the aphid from infected plants by 89%. Aphids also fed/probed differently on potato plants treated with afidopyropen, suggesting it can change their behavior in a way which decreases the likelihood of virus transmission. Afidopyropen could be a new option for PLRV management, but future work testing its effectiveness at multiple post-application intervals and in field experiments is needed.



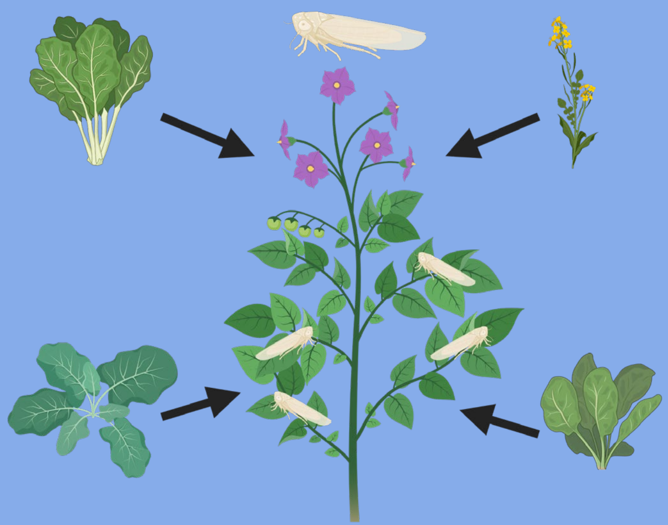
Joanna collecting potato psyllids from a laboratory colony

Julie & AnaBeth collecting samples from the field



Dr. Gina Angelella. Potato Entomology

Characterizing beet leafhopper population genetic variation in the Columbia Basin

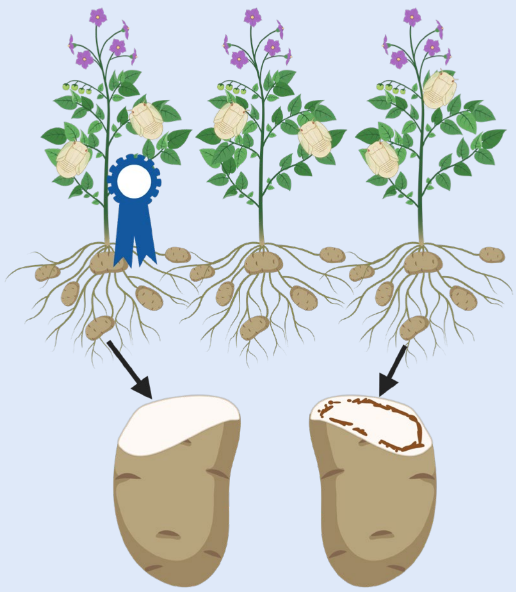


Genetic analysis indicates that beet leafhoppers in potatoes arrive from many different reservoir plants

The beet leafhopper, *Circulifer tenellus,* is a potato pest which causes both direct and indirect damage through feeding and transmission of a phytoplasma which causes purple top disease. Understanding pest dispersal and intraspecific population structure relative to crops could be key to optimizing management; however, much of what we know about beet leafhopper dispersal is from research conducted in the early to mid-1900s, and population genetic structure within the Northwest remained unknown. To address this, our lab has conducted RAD-seq analyses to generate SNPs and used them to assess the structure of beet leafhopper sub-populations. The beet leafhopper adults we analyzed were collected during 2020 from the Columbia Basin and Idaho from potato, sugar beet, and coriander fields, and from various non-crop hosts within Amaranthaceae and Brassicaceae. No population structure was evident among specimens grouped by host plant, nor by collection site within the Columbia Basin; however, there was some differentiation between Idaho, and Columbia Basin specimens potentially indicating limited movement. Thus, we could not infer beet leafhopper dispersal patterns from weedy- to crop-hosts, suggesting beet leafhoppers in potatoes can arrive from many different reservoir plant species.

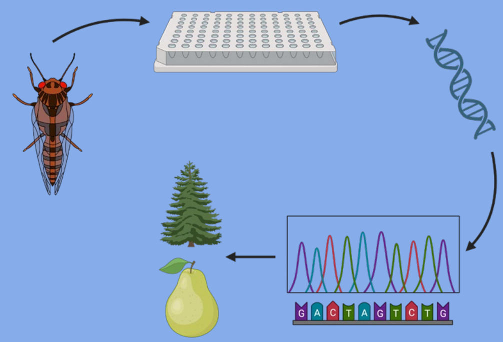
Working with an industry collaborator to quickly develop commercial potato varieties that are resistant to the zebra chip pathogen

Zebra chip disease in potatoes is caused by a bacterial pathogen, "*Candidatus* Liberibacter solanacearum", which is transmitted by the potato psyllid, *Bactericera cockerelli* (Hemiptera: Triozidae). Our lab has been working with an industry collaborator to evaluate whether new varieties of potato exhibit resistance to zebra chip. To do so, we conducted field cage trials in which we inoculated potato plants, harvested tubers, and scored raw and fried tubers for symptom severity. During the previous year, we found that 6 accession lines out of 19 demonstrated zebra chip symptoms in raw tubers, and 11 of 19 displayed symptoms following frying. Thus, the eight accession lines which lacked symptoms may exhibit resistance to the causative agent of zebra chip disease. This project is helping to develop effective management strategies for zebra chip by identifying potato lines exhibiting resistance.



Identifying potato lines resistant to zebra chip pathogen

Dr. Rodney Cooper. Plant-Insect Interactions: Potato and Tree Fruit Entomology



The Cooper lab uses molecular gut content analysis to answer research questions about insect host plant use

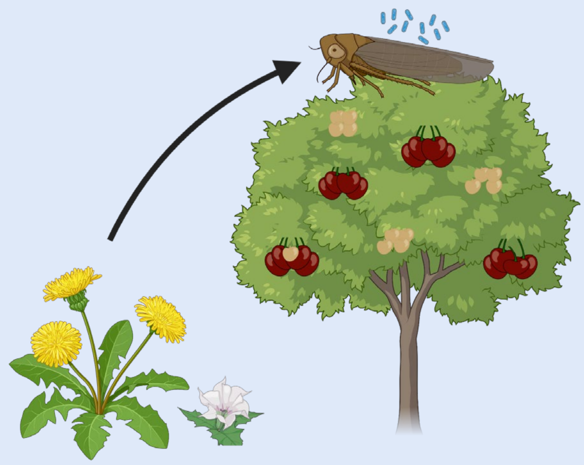
Permanent Technicians:
Heather Headrick & Pauline Anderson

Additional Technical Support:
Rachel Cook, Biological Science Technician
Bonnie Ohler, WSU Research Associate

Graduate Students:
Jillian Foutz (MS, WSU Entomology)

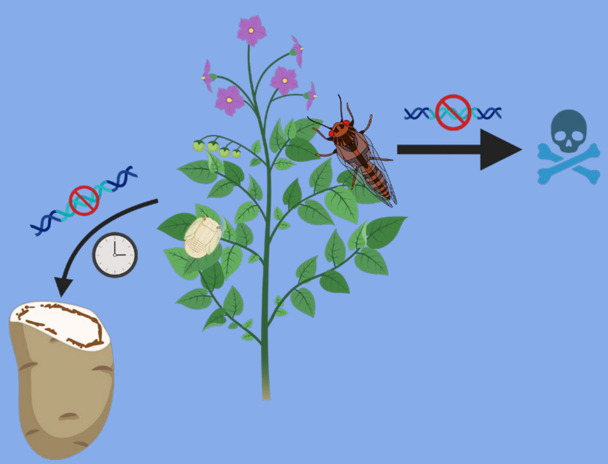
Non-crop sources of X-disease vectoring leafhoppers

The leafhoppers *Colladonus geminatus* and *C. reductus* transmit the pathogen that causes X-disease of cherry and other stone fruits in Washington. Laboratory studies showed that both leafhoppers develop on common broad leaf weeds, but it remains unknown which weeds are the primary sources of leafhoppers carrying the X-disease pathogen. Our team, in collaboration with Washington State University researchers, used molecular gut content analysis to identify the dietary histories of *Colladonus* leafhoppers captured in cherry and peach orchards. We found that most vectoring leafhoppers had previously fed upon dandelion and mallow, two weeds that are known to harbor the X-disease pathogen and that commonly grow in orchard drive rows. Most leafhoppers had also fed upon cherry or peach. Results support recommendations for broadleaf management within orchards to reduce risk of X-disease.



Dandelion and mallow can act as reservoirs for X-disease pathogen, which is moved by leafhopper vectors into stone fruits

RNA-based biopesticides to manage potato psyllid and zebra chip disease



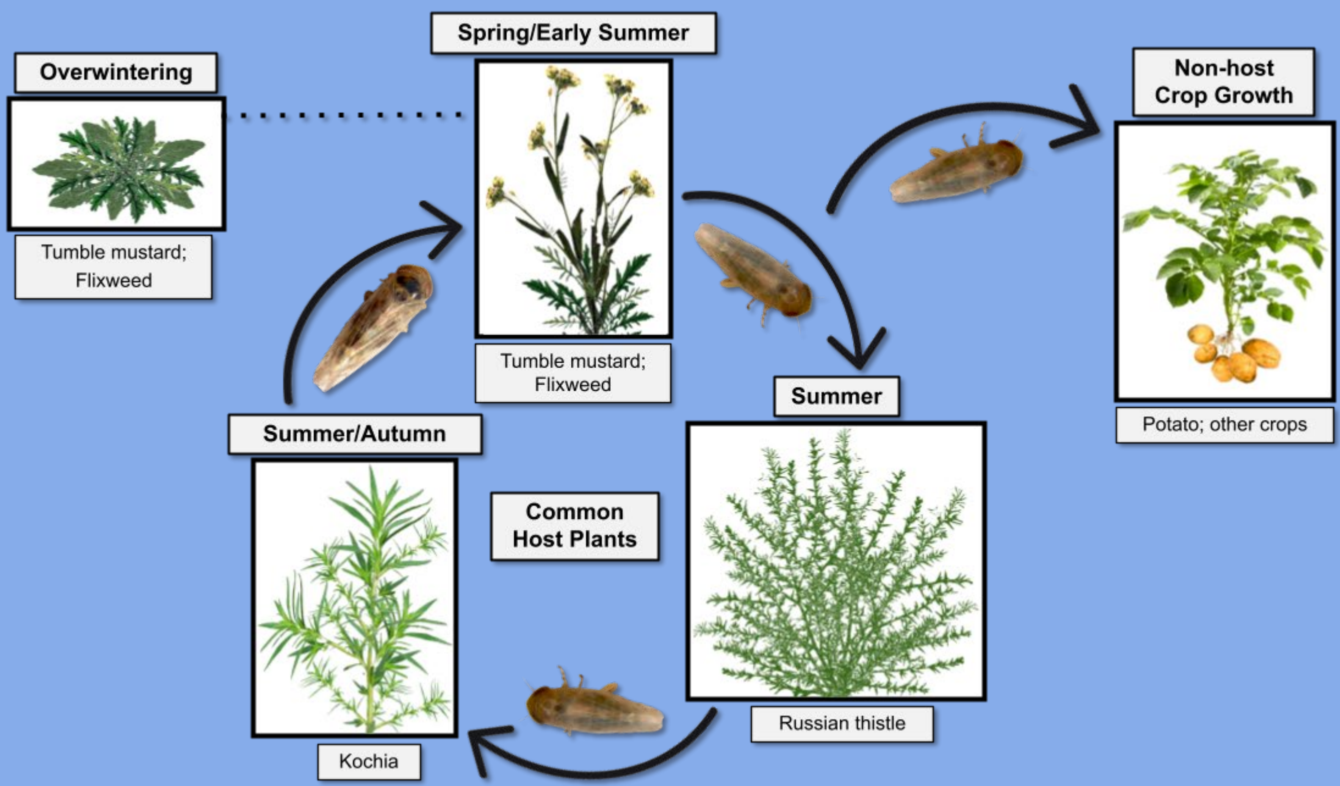
Altering gene expression to delay zebra chip onset and kill potato psyllids

Potato psyllid is the vector of the pathogen that causes zebra chip disease, which remains a threat to potato production in certain regions of the United States and Mexico. Our lab conducted a series of laboratory experiments to develop novel methods to control the zebra chip pathogen and its potato psyllid vector. We are targeting the genes of the zebra chip pathogen using technology called FANA. We previously showed that FANA delays the onset of zebra chip disease in plants, while more recent work has focused on finding more efficient application methods. We are using RNAi to silence expression of potato psyllid genes and have recently discovered several gene targets that cause mortality of potato psyllid adults. Results of this ongoing work will be used to develop RNA-targeting biopesticides to control potato psyllid and zebra chip disease.

Dr. Rodney Cooper. Plant-Insect Interactions: Potato and Tree Fruit Entomology

Non-crop sources of beet leafhoppers

Beet leafhopper is a vector of *Phytoplasma trifolii* and beet curly top virus, two pathogens that cause substantial economic losses in potatoes and other vegetables in the Pacific Northwest. In collaboration with researchers at WSU, we sampled non-crop habitats for beet leafhopper in the Columbia Basin. We found that beet leafhopper develops on weedy mustards in early spring, then disperses to Russian thistle and Kochia when the spring hosts senesce. It is during these dispersals from spring hosts that beet leafhopper transmits pathogens to potato and other vegetable crops. These results are being incorporated into prediction models that allow growers to time insecticide applications with beet leafhopper dispersals.



Dispersal of beet leafhopper from infested weedy hosts when they senesce transmits pathogens to potato; Diagram by J. Foutz

Beet leafhoppers: dark form, light form, and nymph; Photo credit: J. Foutz

Dr. Max Feldman. Potato Genetics: Potato Germplasm

Armando and Andrew harvesting seed tubers

Permanent Technician:
Andrew Bowker

Additional Technical Support:
Isaac Bestebreur
Charity Harmon
Armando Pena
Ryanna Stoval

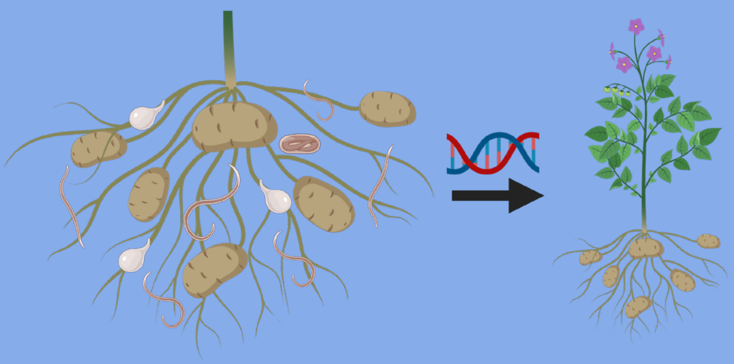
Development of pathogen resistant specialty potatoes

Consumer preference for highly nutritious food and ease of preparation are two major factors that have driven the increasing demand for fresh market baby potatoes. Our breeding program has generated and evaluated five breeding populations focused on the selection and advancement of potato varieties exhibiting marketable attributes (high yield and tuber set, solid skin and flesh color, consistent size and shape) and containing resistance to common viral and nematode pathogens. Five clones derived from the yellow (3 clones), red (1 clone), and purple potato (1 clone) fresh market classes were hybridized to a common parent (‘Barabara”) that expresses Potato virus Y, Potato virus X, Golden cyst nematode, and late blight resistance. Approximately 100 individuals from each cross were evaluated as 5-hill plots under center pivot irrigation in Pasco, WA. Large variation of tuber yield, starch content, tuber size, shape, skin and flesh color was observed across clones within and between breeding families. This phenotypic data, data from the upcoming 2023 field season, and genetic marker data acquired in 2023 will be used to select disease resistant individuals and map the genetic basis of agronomic and quality traits.

Breeding projects performed in cooperation with WSU Research and Extension in Pasco, WA are identifying high performing specialty potatoes varieties that are resistant to potato viruses and nematodes.

Dr. Max Feldman. Potato Genetics: Potato Germplasm

Advancement of a Columbia root-knot nematode resistance trait in russet germplasm



Using quantative genetics to more rapidly advance breeding for Columbia root knot nematode resistant potato lines

Columbia root-knot nematode (*Meloidogyne chitwoodi*) is one of the most common and destructive soil-borne pathogens found in potato growing regions of the Pacific Northwest. Mitigation of affected fields can only be achieved through fumigation which is expensive and unpopular. Our breeding program is using a quantitative genetics approach to advance a CRKN resistance trait discovered by our breeding program in the 1980s into potato varietals that meet the standards of the potato processing industry. In 2022, we performed seed increase of ~1600 clones, from 33 breeding families (50 clones/family) generated from crosses between 3 CRKN resistant parents and 11 russet varietals. Yield, tuber number, tuber size, shape, color and processing quality of these clones will be evaluated in the 2023 field season under center pivot irrigation at the WSU Research and Extension location in Othello, WA as 5-hill plots. Evaluation data will be used for the purpose of genetic mapping and clone advancement into larger multi-location trials or use as improved breeding parents that move this trait incrementally closer to variety release.

Screening wild diploid species for resistance to Potato mop-top virus

Potato mop-top virus (PMTV) is an emerging soil-borne pathogen vectored by powdery scab (*Spongospora subterranea*) that is a causal agent responsible for the development of necrotic lesions inside potato tubers. No known sources of resistance to PMTV have been identified in cultivated potato germplasm. Our breeding and pathology team performed a greenhouse-based germplasm screen to assess susceptibility of wild potato relatives to PMTV infection. In total 20 accessions, derived from 9 wild potato relative species, were inoculated with viruliferous powdery scab inoculum and root tissue was examined for viral infection using molecular diagnostic techniques (10 individuals per accession). A range of susceptibility to infection was found across accessions with a few exhibiting no infection (2 accessions) and one species (*Solanum chacoense*) exhibiting a low rate of infection across all individual plants (~5%). In 2023, we will increase the scale of this germplasm screen and re-evaluate material exhibiting resistance to PMTV infection for validation purposes. Identifying sources of PMTV resistance and the genomic regions linked to this trait is essential for the development of PMTV resistant potato varieties.

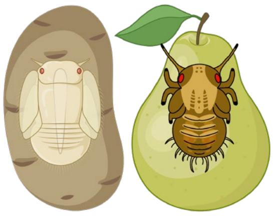
Rich Quick and Andrew Bowker isolating roots from wild potato relative accession inoculated with Potato mop-top virus.

Dr. Max Feldman. Potato Genetics: Potato Germplasm

Trait introgression and the development of self-compatible diploid germplasm

Hybridizations were performed at the diploid level to combine self-compatibility and resistance to *Verticillium dahliae* and *Globodera rostochiensis* derived from *Solanum brevicaule* accession PI 246536.

The ability to fix beneficial alleles in breeding lines, capture heterosis (aka hybrid vigor), and tremendously accelerate seed increase are a few of the enormous benefits of transitioning potato breeding into a diploid-hybrid breeding schema relative to the current tetraploid breeding system. Our team performed hybridizations focused on introgressing the *Sli* allele that confers self-compatibility into domesticated diploid potato clones and wild potato relative species known to express broad spectrum resistance to Potato virus Y, potato cyst nematodes, Colorado potato beetle (*Leptinotarsa decemlineata*), and verticillium wilt (*Verticillium dahlia*). In 2023, progeny (F1) from these populations will be selected for plant vigor, fertility, tuber yield and tuber quality and self-pollinated to generate mapping populations (F2) that will be evaluated in future field season for the purposes of genetic mapping and genomic selection. We also performed haploid extraction from popular tetraploid lines by crossing them to haploid inducer IVP101 in hopes of capturing yield and processing traits found in elite tetraploid germplasm so we can use these alleles for breeding in diploid systems. These efforts are laying the foundation for accelerated improvement of diploid potato germplasm.



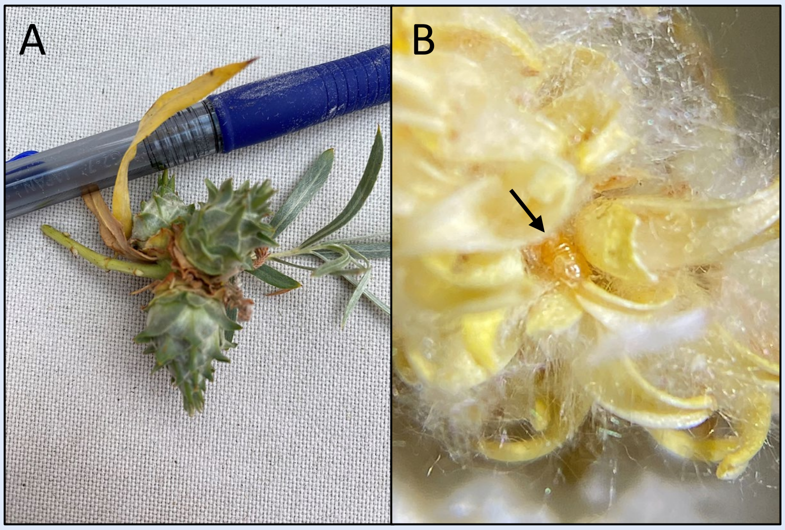
Dr. David Horton. Biological Control: Potato and Tree Fruit Entomology

The Horton lab studies the biology of many species of psyllids and their natural enemies

Permanent Technician: Tamera Lewis

Other technical support: Sally Longoria

A willow psyllid is found to host important parasite of pear psylla

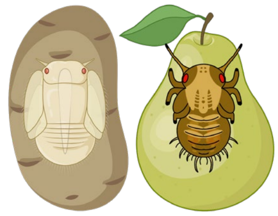


(A) Three pinecone-like galls from *Salix exigua*, showing overlapping bracts beneath which psyllid immatures (both healthy and parasitized) extensively accumulate; (B) *C. alba* nymph parasitized by *Trechnites* half buried in catkin of *Salix exigua*

Efforts to identify non-pest psyllids which are reservoirs of the pear psylla parasite *Trechnites* in North America have largely been unsuccessful. Funding provided by the Fresh and Processed Pear Research Committee and the Washington State Department of Agriculture was used to support field-surveys of non-pest psyllids for evidence of parasitism. Willows (multiple species), golden currant, and bitterbrush were surveyed. A willow psyllid (*Cacopsylla alba*) on sandbar willow (*Salix exigua*) was found to be a relatively common host of *Trechnites*. This psyllid occurs on catkins of the host or in galls produced by a small midge, and more occasionally on foliage; parasitized psyllids were collected from all structures, but especially from catkins and galls. Our survey indicates that *Salix exigua* is a potential reservoir of an important parasite of pear psylla. Studies are planned to confirm that specimens reared from willow psyllid will attack pear psylla.

Sandbar willow may be a reservoir for *Trechnites* outside of pear orchards

Adult *Trechnites* wasp inside a pear psylla mummy



Dr. David Horton. Biological Control: Potato and Tree Fruit Entomology

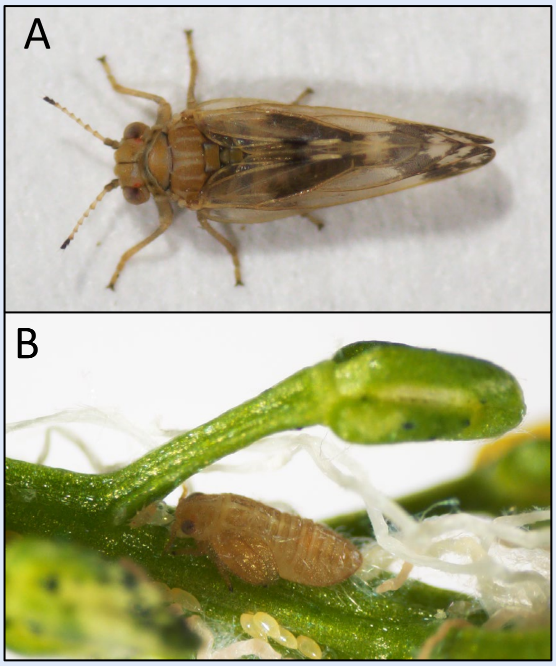
Discovery of a valuable predator of potato psyllid on weedy host plants

Whirligig mite feeding on a potato psyllid nymph

Densities of potato psyllid in a growing region depend on poorly understood processes that transpire on weedy host plants. One such process is biological control. Funding from the ARS/State Potato Research Program and the Northwest Potato Research Consortium was used by ARS and WSU scientists to develop a molecular tool for identifying DNA of potato psyllid in the guts of field-collected predators. The tool is highly specific to DNA of this pest. Assays of predators collected from psyllid host plants led to the unexpected discovery that an important predator of the psyllid under field conditions is whirligig mite (*Anystis*), known to voraciously feed on aphids but much less appreciated as a psyllid predator. Feeding trials confirmed its effectiveness as a psyllid predator. While *Anystis* is very common on weedy Solanaceae and almost certainly occurs in potato fields, little is known about the mite's seasonal presence, and studies are planned next year to develop sampling protocols for use in potato fields. Predator-release studies targeting localized infestations of psyllids and aphids in potato are also planned, with input and suggestions from Canadian scientists who have recently developed mass-rearing procedures for the mite. Our studies will help potato and other vegetable growers to incorporate *Anystis* into biological control programs directed at psyllid and aphid pests.

New state and host plant records of psyllids recently found to harbor Liberibacter plant pathogens

Epidemiology of Liberibacter-caused diseases in vegetable crops requires knowledge about taxonomy, biology (especially host plants), and distribution of psyllid vectors. Several new genetic types of Liberibacter recently discovered by K. Swisher Grimm occur in association with previously unidentified species of *Aphalara* psyllids, the first evidence that this psyllid genus hosts Liberibacter. Diversity, distribution, and host plants of *Aphalara* in North America are very poorly described, complicating efforts to understand the role of these psyllids in vectoring Liberibacter into crop plants. Morphological and molecular examination of *Aphalara* psyllids collected in Washington and Oregon identified 8 species, including 3 species not previously known to occur in the Pacific Northwest. Host plants were newly identified for several species and found to include plant taxa (mustards) which only rarely host *Aphalara*. Our taxonomic work with these psyllids, combined with distribution data and host records, will help us identify psyllid and plant reservoirs of Liberibacter pathogens which may also occur in vegetable crops.



(A) *Aphalara maculata* adult collected from Washington state (new state record); (B) nymphs and eggs of *A. maculata* on a species of mustard (previously unknown host plant).

Dr. Roy Navarre. Potato Physiology and Molecular Biology. Potato Germplasm

Potato harvest

Permanent Technician: Launa Cimrhakl

Developing new baby potato cultivars

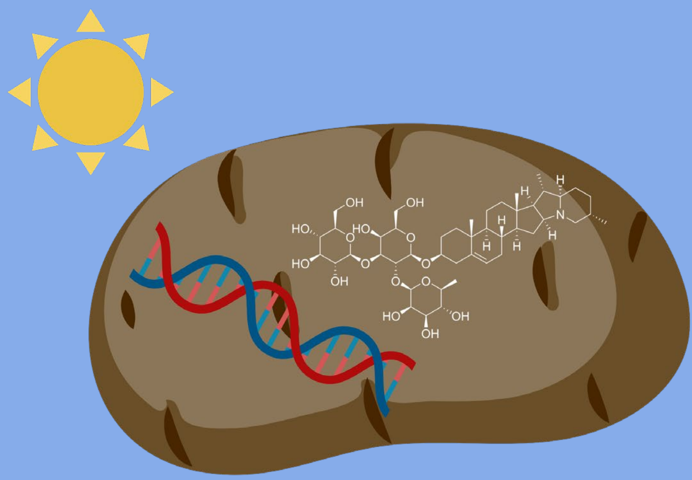
The potato greenhouse in Prosser

Consumer demand is strong for baby potatoes, but the biggest limitation for this market is the lower yields due to harvesting an immature crop and the resulting higher cost. A primary need is cultivars that produce a large number of small potatoes (tuber set), which is a very different trait than wanted for traditional potatoes. Our breeding program has produced 35-4, a potato that produces an extremely high tuber set, a rare trait. This potato has occasional pink splashes around the eyes, which is regarded as a defect that would impact sales. In 2022 we made numerous crosses using 35-4 to produce diverse new lines that keep the high-set trait, but have a uniform red, yellow, or white skin color, along with red, purple, white or yellow flesh color in a round or fingerling shape. Tubers from these crosses will be planted at Klamath Falls in 2023. New baby potatoes with high phytonutrient content, striking appearance, superior taste, smaller size and faster preparation can help ensure that growers have potatoes that appeal to evolving consumer preferences.

Dr. Roy Navarre. Potato Physiology and Molecular Biology. Potato Germplasm

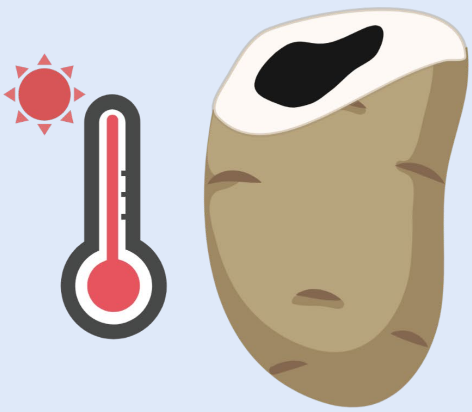
Evaluating the biochemistry and molecular control of glycoalkaloid synthesis

Glycoalkaloids are steroidal compounds produced by potatoes to help the plant resist pests and disease, but at too high a concentration these are toxic to humans, so new breeding lines must have less than 20 mg/100 g fresh weight. Glycoalkaloid amounts can occasionally spike to undesirable levels due to poorly understood environmental factors, in which case they can raise health concerns and cause trade issues. We used a biochemical approach and molecular approach, combined with network analysis to examine glycoalkaloid metabolism in response to light in multiple cultivars. Data analysis is underway and results point to certain genes, including some transcription factors, that appear to influence whether a line is prone to spikes. If a method was available that would show whether breeding lines are resistant to environmentally induced spikes, this would reduce a major concern of the industry and also make it easier to use wild potato germplasm in breeding that often has traits such as superior disease resistance, but often has high amounts of glycoalkaloids.



Finding breeding lines resistant to environmentally-induced glycoalkaloid spikes

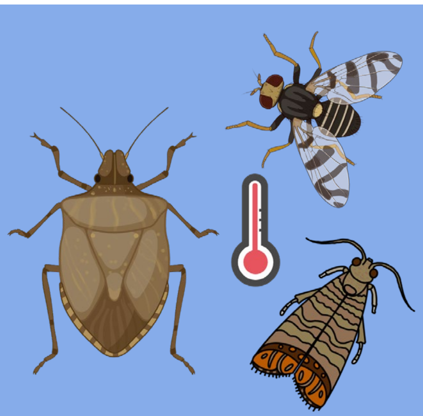
Developing a method to evaluate lines for susceptibility to discoloration



Developing an assay to induce internal discoloration in potatoes using heat exposure

Internal physiological defects in potatoes result in discolored potatoes, increasing waste and decreasing profits. Internals are evaluated in laborious, expensive field trials, which are complicated by poorly understood environmental factors that influence development of internals and can make it difficult to know whether a line is actually resistant to internals, or is just not showing symptoms because environmental factors were not conducive for symptom development. This limitation is the primary reason little is known about the genetics or biochemistry of internals. We are attempting to develop a lab assay to induce internals by incubating potatoes at high temperatures after harvest. We've tested multiple cultivars from multiple locations using a range of different temperatures and times of heat exposure and have been able to consistently induce certain internals such as blackheart. If a successful lab assay can be developed this would make it easier to develop resistant potatoes and to study the biological basis of internals.

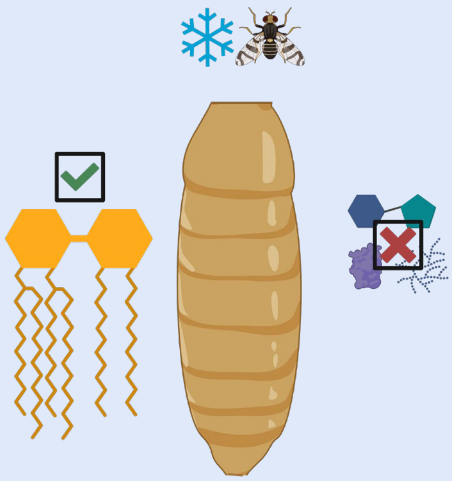
Dr. Lisa Neven. Insect Physiology: Tree Fruit Entomology



Thermal physiology of pest insects is one area of expertise in the Neven Lab

Permanent Technician: Michelle Watkins

Determining biochemical and metabolic aspects of western cherry fruit fly diapause



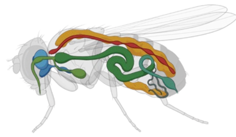
Diapausing western cherry frult fly pupae rely primarily on lipids for metabolism, instead of other macromolecules

Western cherry fruit fly is a native pest that has been identified as a pest of quarantine concern both internationally and domestically. Therefore, there is a zero tolerance for this pest in commercially produced sweet cherries. We conducted a multi-year project to determine the biochemical and metabolic aspects of diapause of this species to facilitate the development of pest risk models to aid regulatory agency management of this pest. We used biochemical assays for protein, lipids, total carbohydrates, and glycogen as well as using differential scanning calorimetry to determine the factors related to the maintenance and completion of diapause in this species. We found that diapausing pupae of western cherry fruit fly utilize primarily lipid reserves to support metabolism during diapause. We also determined that the metabolic rate of diapausing pupae was low enough to support a multi-year diapause in this species.

Using eDNA technology to find invasive species in green yard waste

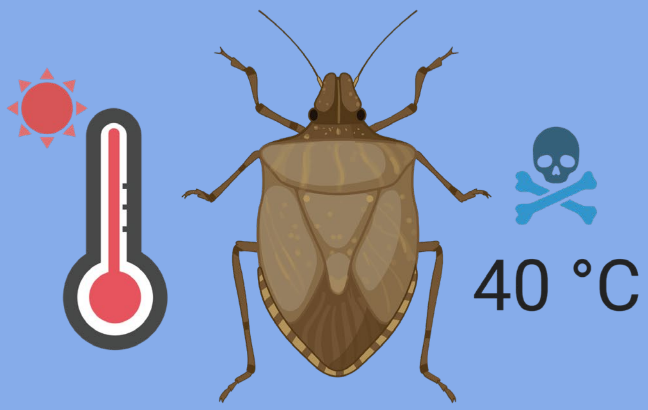
As large cities begin to overrun their landfill capacities, they begin to look for alternative locations to handle the waste stream. Seeing an opportunity to bring in revenue, rural communities offer to handle municipal waste in their landfills. Unfortunately, many rural communities are also locations of agricultural production, which are vulnerable to attacks by invasive species. We used a combination of ecological niche modeling and eDNA to determine whether green yard waste could be a pathway for invasive species to enter and establish in the landfill-receiving agricultural community. We found several quarantine-actionable pests in the green yard waste that pose a threat to agriculture in Washington State. Reports were made to federal and state regulatory agencies to aid in risk management decision making.

Hunting for pest DNA in yard waste



Dr. Lisa Neven. Insect Physiology: Tree Fruit Entomology

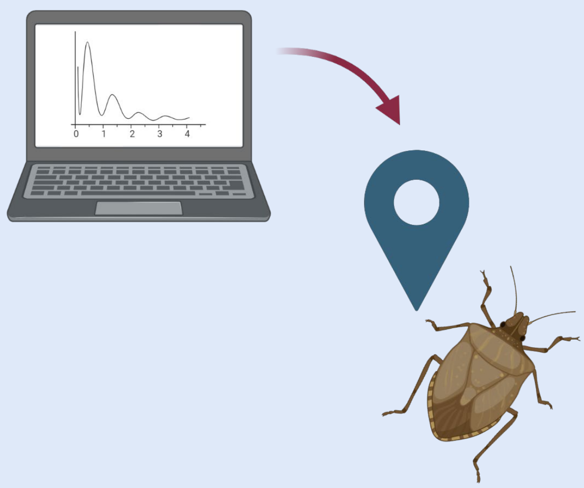
Metabolic rates and thermotolerance of brown marmorated stinkbugs



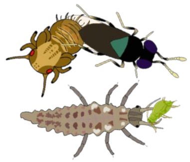
The brown marmorated stinkbug is an invasive species attacking hundreds of plants, many of which are important agricultural crops. To assist in the development of ecological niche models and risk management decision-making, we utilized differential scanning calorimetry to determine the metabolic rates of all developmental stages of brown marmorated stinkbugs, as well as diapausing adults. We also determined the upper and lower thermal limits for growth and development and upper and lower lethal temperatures for each developmental stage. We found that the upper and lower thermal limits for growth and development were very similar to those identified in degree-day models. We also determined that the 3^{rd} instar was the most thermotolerant developmental stage. All stages died at short-term (<1 hr) exposures to 40°C, which may be used in the development of postharvest and quarantine treatments.

Testing the utility of AI to determine optimal trap locations for invasive species

As humans continue to travel the globe, the spread of invasive species is becoming an ever-increasing problem. Our lab has been involved in the development of ecological niche and risk modeling to predict those locations most at risk of invasive species incursions. While these models have been useful, it does not address the problem that regulatory agencies face when trying to prevent or stem the establishment of these species. Researchers at WSU used ecological niche and transportation models to identify optimal locations to set detection traps for invasive species. We field tested this model for the invasive species, brown marmorated stinkbug. We set a total of 50 traps spanning from Kennewick to Ellensburg, WA and collected captures each week for a total of 17 weeks. Initial observations indicate the AI model was fairly accurate in determining the location and abundance of brown marmorated stinkbugs in this region.



Dr. Rebecca Schmidt-Jeffris. Biological Control: Tree Fruit Entomology



Our lab collaborates with growers and drone pilots to test natural enemy releases

Permanent Technician: Erica Moretti

Associate in Research: Danny Hausler

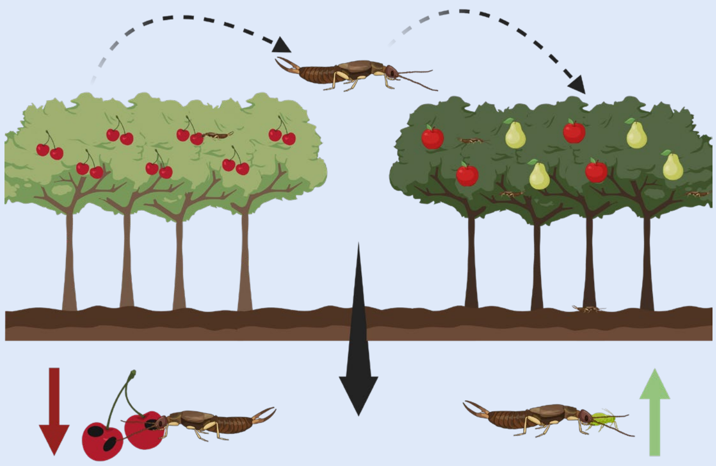
Postdoctoral Associate: Gabe Zilnik

Graduate Students:
Aldo Hanel (Ph.D., WSU Entomology)
Paul Bergeron (Ph.D., WSU Entomology, graduated)

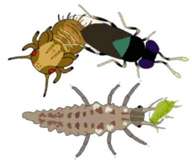
Other Technical Support:
Grace Douglas, Charlene Luna, JoMari Moreno, Josh Nelson-Ichido, Reina Reyna

Capture and augmentation of earwigs to increase pest control

Earwigs are becoming more appreciated as key predators of aphids and pear psylla in apples and pears, although they can cause damage to stone fruits like cherries. Our lab has been investigating whether stone fruit orchards can be a source of earwigs for augmentation in pears and cherries. We found that removing earwigs from stone fruit orchards can rarely decrease their numbers or damage. However, these orchards do provide many earwigs for augmentation. In apples and pears, we have found that earwig releases can decrease abundance of aphids, pear psylla, and spider mites. Releases were especially effective in orchards where earwigs have previously been absent. We have also found evidence that earwigs remain near their release area. Finally, we have shown that earwigs only cause damage to thin-skinned apples ('Honeycrisp') when other damage (stem end splits, hail) is already present. Moving earwigs from stone fruit into apples and pears is a viable option for increasing pest control, especially in orchards that have recently transitioned out of conventional spray programs. Growers are beginning to implement this tactic.



The Tree Fruit Biological Control Lab works on a variety of natural enemy species



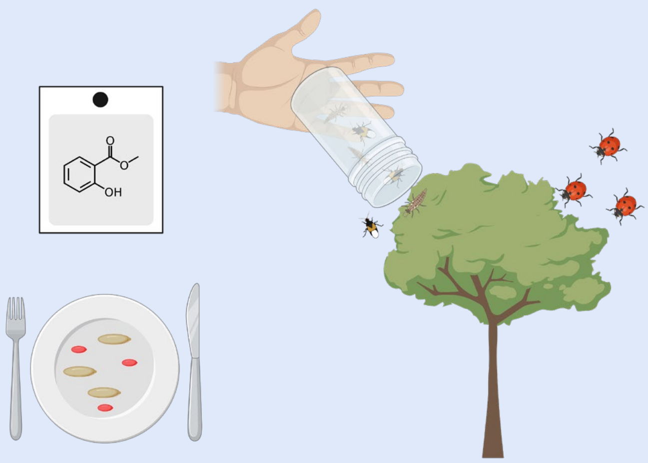
Dr. Rebecca Schmidt-Jeffris. Biological Control: Tree Fruit Entomology

Best methods for releasing lacewings to control aphids

Releasing commercially available predators in orchards is increasing in popularity, but growers do not have scientifically-based best-practice recommendations. Lacewings are one of the most commonly purchased natural enemies and are primarily used for aphid control in apple. Our lab conducted a series of field experiments to determine which lacewing species (*Chrysoperla carnea* or *C. rufilabris*), life stage (eggs or larvae), and release method (egg cards, hand-applied, drone-applied) resulted in the greatest reduction of aphids. In two trials, releases of *C. carnea* reduced apple aphids by 25-50%, but in another trial none of the treatments reduced aphid abundance. *Chrysoperla rufilabris* is not native and will not overwinter in Washington, but we did determine that released juveniles are able to develop into adults and reproduce. Even in treatments with high levels of aphid control, recovery of released lacewings is very low, indicating that recovery should not be used to determine release success. In general, results of releases were inconsistent between locations and years, indicating that more work is needed to fine-tune recommendations.

Increasing retention and recruitment of natural enemies

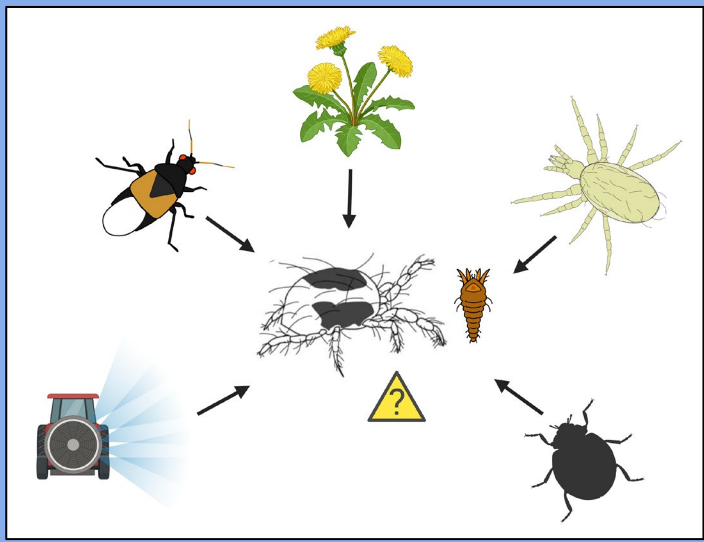
Purchased natural enemies can represent a significant management expense for growers that use them. This makes it particularly discouraging if they disperse after release instead of remaining in the orchard and controlling pests. Our lab conducted three field experiments in commercial apple, commercial pear, and research apple to determine if a lure (Predalure - methyl salicylate) and supplementary foods (*Ephestia* eggs, *Artemia* cysts) could retain released lacewings and minute pirate bugs and/or recruit resident natural enemies. While the releases of natural enemies decreased aphid populations in apple, the lure and food treatments did not increase retention or pest control. Releases in pears were not effective at pear psylla management. Lures were effective in increasing resident lacewings, spiders, and *Stethorus* and decreased spider mite numbers. There may be interactions between released and resident natural enemies and these retention tactics, which we will investigate using molecular gut content analysis.



Dr. Rebecca Schmidt-Jeffris. Biological Control: Tree Fruit Entomology

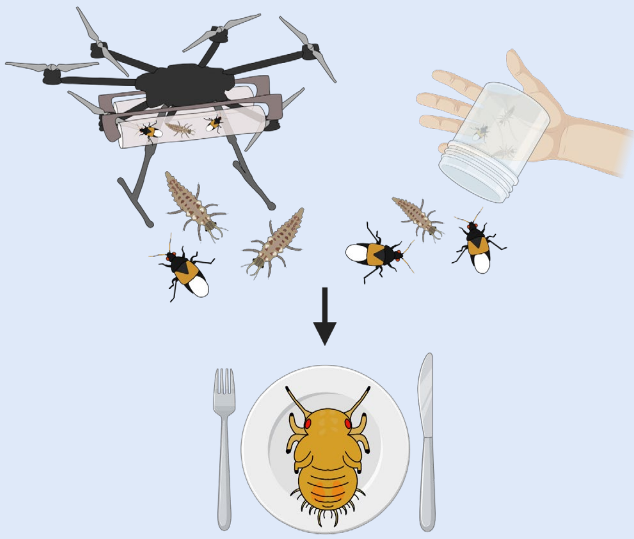
Survey of pest mite natural enemies in pear

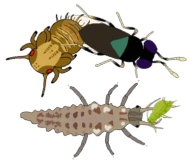
In apple, spider mites are known to be controlled primarily by phytoseiid predatory mites ("typhs"). However, in pear, predatory mites are less abundant, indicating that other natural enemies may play a more important role in spider mite and rust mite control. To determine what factors, including natural enemies, impact spider mite populations in pear, we surveyed over 15 orchards in the Yakima Valley, Wenatchee Valley, and Hood River pear growing regions with our WSU and OSU collaborators. We are also examining the effects of the weed community and management, pesticide applications, and pear psylla abundance. We are in the process of designing and optimizing primers for twospotted spider mite and pear rust mite to conduct gut content analysis on collected predators. In 2022, spider mites were nearly absent in Hood River, more abundant in Yakima, and are a significant issue in Wenatchee. As expected, phytoseiid populations were low and we suspect predatory bugs, *Stethorus*, and whirligig mites are the major mite predators in this system. Results from this project will be used to inform grower management practices to optimize natural enemy conservation and weed management for pest mite control.



Can purchased natural enemies control pear psylla?

It is becoming increasingly common for growers to purchase and release natural enemies for pest control in organic apples. We sought to determine if commercially available natural enemies were a viable option for controlling pear psylla in pears. We selected lacewings (*Chrysoperla carnea*) and minute pirate bugs (*Orius insidiosus*) as the natural enemies most likely to control pear psylla that are commercially available in the U.S. In two trials in an organic pear orchard, releases of these natural enemies by hand or by drone did not decrease pear psylla populations. It is likely that currently available commercial predators are not as suited to pear psylla control as resident natural enemies in orchards. We will conduct these trials again in 2023 in another orchard to determine if our results were site-specific. Other options for augmenting pear psylla natural enemies should be explored, including moving earwigs or *Trechnites insidiosus* to "inoculate" a pear orchard, or getting new commercially available natural enemies approved for sale in the U.S., such as whirligig mites or *Anthocoris* predatory bugs.





Dr. Rebecca Schmidt-Jeffris. Biological Control: Tree Fruit Entomology

What factors affect *Trechnites insidiosus* parasitism of pear psylla?

Trechnites insidiosus is a small wasp that is the most important parasite of pear psylla. It was deliberately released for pear psylla in Washington State in the 1960s and was likely accidentally introduced along with pear psylla prior to this. Very little is known about *T. insidiosus* biology or how to conserve it in pear orchards. After three years of trapping for *T. insidious* adults and monitoring parasitism in pear psylla nymphs via PCR, our lab has developed a model that will allow growers to estimate the expected level of parasitism in their orchard based on degree days and abundance of pear psylla and *T. insidiosus*. Additionally, we are in the process of creating a separate model to determine which management factors change *T. insidiosus* abundance, based on the results of a two-year (2021-2022) trapping survey in Washington and Oregon. Laboratory assays exposing *T. insidiosus* to pear pesticides indicate that it may be one of our most sensitive natural enemies. This information will be used to create recommendations to help growers monitor and conserve this important natural enemy.

Trechnites insidiosus egg (left) and larva (right) dissected out of pear psylla nymphs, indicated by arrows

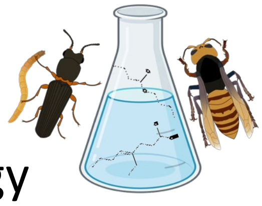
Can released mealybug destroyers control mealybugs?

Mealybugs are a very difficult to control pest in organic tree fruit due to their tendency to hide in small crevices, where contact with pesticide is limited. One potential option for control is to purchase and release mealybug destroyers, small ladybeetles that are specialized predators of mealybugs. Our lab has evaluated releases of these predators for three years and have found limited to no efficacy. Mealybug destroyers appear to rapidly disperse from the orchard after they are released. This is especially problematic due to the high cost of this particular natural enemy. At this time, mealybug destroyers do not appear to be a viable option for mealybug control in tree fruit. Growers should focus on other potential management strategies.

Holding mealybug destroyers prior to release

Finding a released lacewing weeks after release

Mealybug destroyer eating a mealybug



Dr. Jackie Serrano. Chemical Ecology: Tree Fruit Entomology

Dr. Serrano works to extract alarm pheromone (left) from northern giant hornets (right)

A bountiful catch of click beetles in a monitoring trap

Development of trapping systems for the invasive northern giant hornet in Washington state

Trap contents of a trap baited with alarm pheromone, used in Japan

Northern giant hornet (“murder hornet”) is an invasive species with the potential to devastate the beekeeping industry. Nests and individuals have been found in Washington State. Research into better and more species-specific attractants for NGH is ongoing and in 2022 we field tested a variety of different lures. These lures were based on prey volatiles and other reported *Vespa* attractant. We also tested a lure that contained components of the NGH alarm pheromone, which were previously identified in 2003. In the previous year, we reexamined the alarm pheromone in order to assess similarities and differences between previously identified compounds and hornets found Washington State. This led to the identification of several new compounds, which were also made into a lure for field testing. All lures were tested in Washington State, Japan, and South Korea. In Japan, the new alarm pheromone lure was highly successful in capturing worker and male hornets. More work is needed to evaluate lure components and release rates. Effective lures are needed for successful monitoring and removal programs.

Exploring the effects of trap type and placement on captures of adult *Limonius* wireworms

Limonius is a genus of wireworms that are major pests of many crops in the Pacific Northwest, including potatoes. The sex pheromone, limoniic acid, is attractive to several different species, however more research is needed to determine the best trap types for mass trapping and monitoring populations. We conducted an experiment testing Vernon Pitfall traps and UniTraps (with intercept panels) at ground level and one meter above ground. Our results showed that all traps were successful in catching male beetles, however the ground level traps captured significantly more beetles than those at one meter. Results from this study will result in improvements in wireworm monitoring.

Ground level traps (right) caught more click beetles than 1 m high traps (left)

Dr. Kylie Swisher Grimm. Potato Pathology: Potato Germplasm

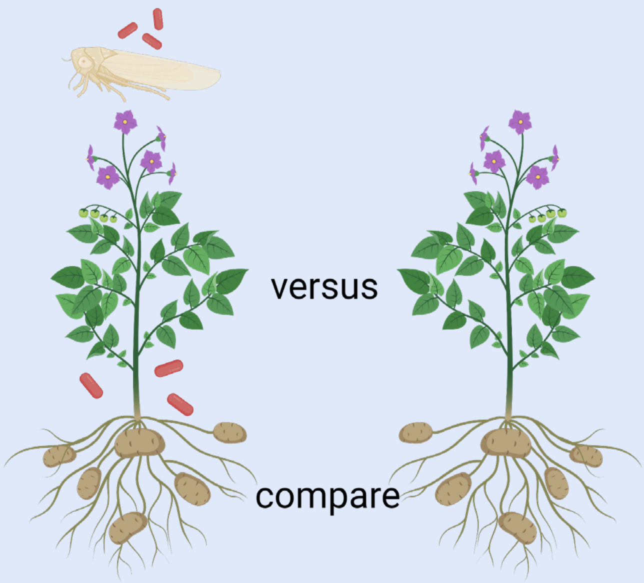
Our lab studies pathogens that impact potato yield and quality

Permanent Technician: Richard Quick

Additional Technical Support:
Stacey Pettit, Ricarda Castaneda, Chris Gorman

Impact of BLTVA phytoplasma on potato tuber yield and quality

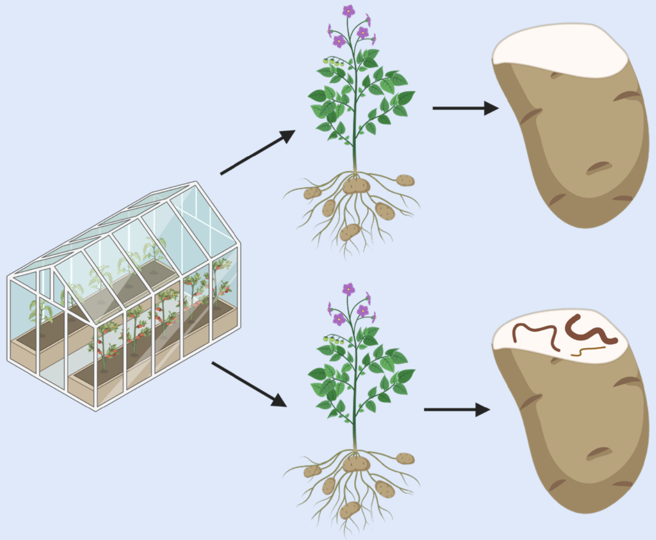
The *Beet leafhopper transmitted virescence agent* (BLTVA) phytoplasma has been a persistent problem in potato grown in the Columbia Basin of Washington and Oregon since it was first identified as the causal agent of potato purple top disease in the early 2000s. To assess the impact of BLTVA infection time on tuber yield and quality, our laboratory in collaboration with G. Angellela and R. Cooper, conducted caged field trials at the research farms in Prosser and Moxee. Potato plants were infected by releasing field-caught, naturally infected beet leafhoppers or by graft transmission with BLTVA-infected plant tissue at three different timepoints (June, July, and August) throughout the season. Despite poor inoculation success (16.7%, 6.3% and 0% for the June, July, and August timepoints, respectively), we believe that tuber yield and quality can still be compared between these infected plants and uninoculated control plants. It is anticipated that conclusions drawn from the yield and quality data will help growers improve their beet leafhopper management strategies.



The pipetting posse: Kylie Swisher Grimm, Richard Quick, & Stacie Pettit

Dr. Kylie Swisher Grimm. Potato Pathology: Potato Germplasm

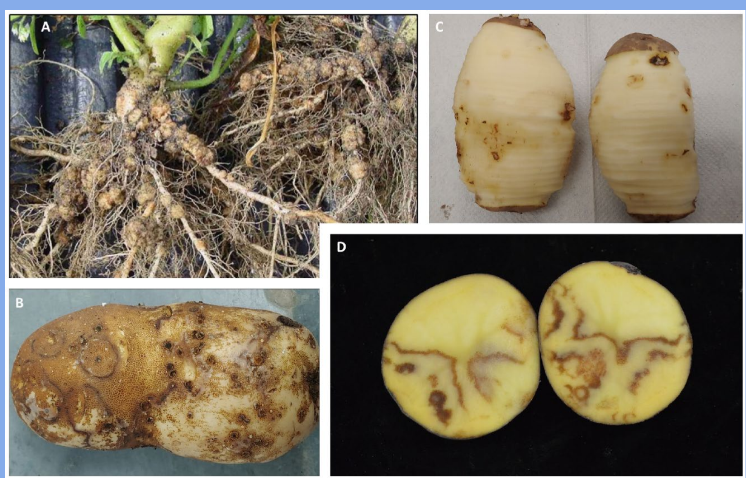
Rapid screening of potato germplasm for *Potato mop-top virus* resistance in the greenhouse



Potato mop-top virus (PMTV) has interrupted the export of potato from the United States in recent years indicating that there is a need to generate potato cultivars that are asymptomatic and do not contain detectable levels of the virus. Diploid germplasm from 9 wild potato relative species was selected and grown by Plant Geneticist Max Feldman (ARS-Prosser) to screen for resistance to PMTV by subjecting individual plantlets to PMTV-infected *Spongospora subterranea* sporosori applied directly to the soil in the greenhouse. Following ~12 weeks of pathogen exposure, roots and tubers were harvested from the individual plants and screened in the laboratory for PMTV. Of the 20 different accessions screened, 17 had PMTV infection rates between 16 and 90%. The remaining three accessions showed 0% infection, suggesting that the germplasm might contain resistance to PMTV. Further screening is planned to validate these initial results. Results from this screen demonstrate that the design of the greenhouse screen was successful and indicate that it will provide an excellent tool to breeders seeking to identify PMTV-resistant germplasm in a more rapid and consistent manner than through field screens.

Assessment of *Potato mop-top virus* and *Tobacco rattle virus* entering Washington State through seed

Seed certification programs are designed to reduce the level of pathogens entering commercial fields throughout the United States, but the soil-borne viruses, *Potato mop-top virus* (PMTV) and *Tobacco rattle virus* (TRV), are not among the pathogens that are screened. In collaboration with Washington State University scientist Mark Pavek, we screened the seed lots obtained from commercial potato growers in Washington State for PMTV and TRV from 2016 to 2022 to determine pathogen prevalence. TRV levels in the seed lots were negligible, but PMTV levels ranged from 1.76 to 5.50% each year. The PMTV-infected lots originated from seven different growing regions and were found in 23 different cultivars. Tuber symptoms caused by PMTV infection can lead to whole lot rejections at harvest, and since fields across the Columbia Basin harbor the vector of this virus, it is concerning that PMTV is entering Washington State fields through seed. Discussion is needed amongst the seed certification laboratories, seed growers and commercial growers to determine what measures should be taken in light of these findings.

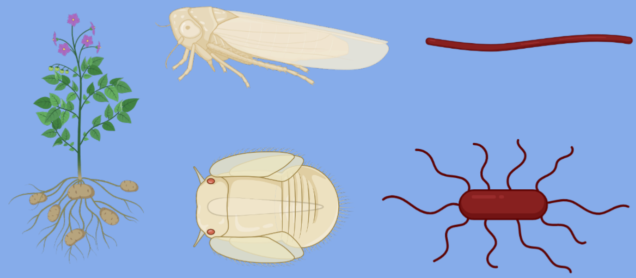


Potatomop-top virus is vectored to potato by *Spongospora subterraneana*, which causes (A) rootgalling and (b) powdery scab on tuber surfaces. Potato mop top virus causes internal tuber necrosis that can appear as small brown flecks or larger corky blemishes or arcs (C and D).

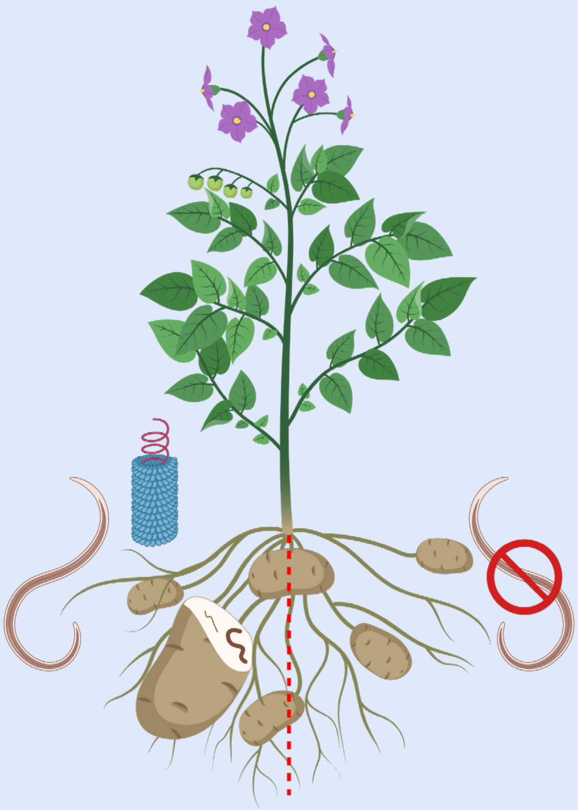
Dr. Kylie Swisher Grimm. Potato Pathology: Potato Germplasm

Development of a rapid insect extraction method and new beet leafhopper-associated pathogen detection assays

Insect-vectored pathogens can cause problems of economic proportion to vegetable and seed growers such as '*Candidatus* Liberibacter solanacearum' transmitted by the potato psyllid and BLTVA phytoplasma transmitted by the beet leafhopper. Knowledge of pathogen prevalence in these insects can aid growers in their integrated pest management decisions, but this requires near real-time pathogen data. To produce rapid insect diagnostic data, our laboratory collaborated with Washington State University scientists to develop and validate a high-throughput nucleic acid extraction method and improved beet leafhopper-associated pathogen detection assays. The high-throughput extraction method was successfully validated on both potato psyllids and beet leafhoppers and the pathogen detection methods were successfully validated on both plant and beet leafhopper specimens. These tools have already been utilized extensively by our laboratories and by other collaborators to rapidly process samples and will be a great asset for future projects.



Improving our understanding of *Tobacco rattle virus* through basic assays

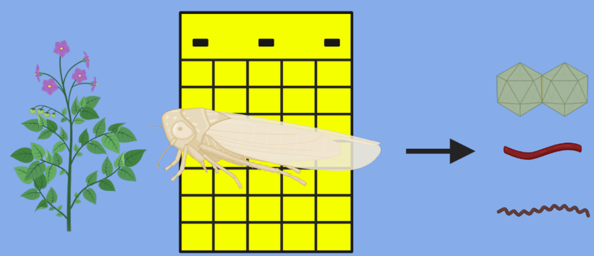


Tobacco rattle virus (TRV), vectored by the stubby root nematode, is among several RNA viruses that cause internal tuber necrotic symptoms that create significant problems for growers during tuber processing, as tubers can be flagged and rejected with corky ringspot disease symptoms that range from internal flecks or freckles to larger necrotic arcs and blemishes. In collaboration with Research Geneticist Max Feldman (ARS-Prosser), two replicated trials were conducted in the greenhouse to explore TRV movement and corky ringspot symptom development within a single plant. Using a unique split-pot design, half of the roots from each plant were inoculated with TRV-infected stubby root nematodes and half were grown in un-infested soil. Roots and tubers were tested from each treatment, and results indicated that TRV does not move systemically through the entire root system of a single plant. In a separate, replicated trial where plants were removed from infested soil at varying timepoints, results indicated that adequate elimination of viruliferous stubby root nematodes from soil can prevent corky ringspot symptoms from developing to high incidence levels at harvest. These studies highlight the importance of rapid elimination of viruliferous stubby root nematodes from a field if they are discovered mid-season to prevent symptom development in tubers and indicate that effective in-season stubby root nematode management tools are needed.

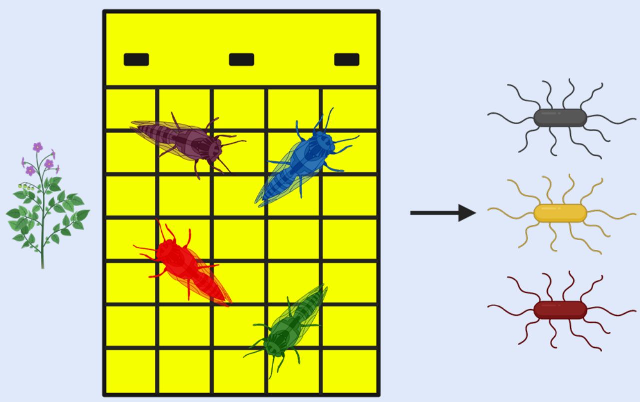
Dr. Kylie Swisher Grimm. Potato Pathology: Potato Germplasm

Assessment of pathogen prevalence in the beet leafhopper and associated crops in the Columbia Basin

The beet leafhopper is among several insect pests in the Northwestern United States that transmit pathogens to potato and other vegetable and seed crops. There are currently no control methods that target beet leafhopper-associated pathogens, so growers must control the insect vector through insecticide applications on their crop and nearby weedy host plants. Our laboratory and WSU collaborators tested beet leafhoppers collected on sticky cards placed near potato and other vegetable and seed crops in the Columbia Basin during the 2022 growing season for three beet leafhopper associated pathogens (*Beet curly top virus,* BLTVA phytoplasma, and *Spiroplasma citri*). *Beet curly top virus* levels were high throughout the season, *S. citri* levels were consistently low, and BLTVA phytoplasma levels peaked in mid-July. Weekly pathogen prevalence data was incorporated into the WSU Potato Decision Aid System, enabling growers to observe pathogen rates across seven different regions in the Columbia Basin throughout the season and providing them with the opportunity to incorporate this information into their pest management programs.

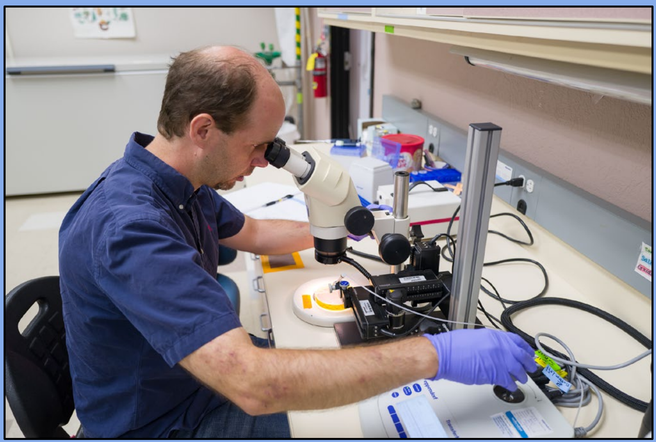


Three new '*Candidatus* Liberibacter solanacearum' haplotypes identified in four psyllid species



Many haplotypes of '*Ca.* L. solanacearum' have been associated with diseases in vegetable crops around the world. Previously, a new haplotype of '*Ca.* L. solanacearum', haplotype F, was discovered by our laboratory associated with zebra chip disease symptoms in potato. To identify the insect vector of this new haplotype, psyllid specimens collected from sticky traps placed near potato fields in the Klamath Basin of Oregon were analyzed for the presence of '*Ca.* L. solanacearum'. Infected specimens were further subjected to analysis of the '*Ca*. L. solanacearum' 16S RNA gene, and the nucleic and amino acid sequence of the 50S ribosomal proteins L10/L12 and the outer membrane protein genes. Three new haplotypes of the bacterium, including two variants of one haplotype were discovered, but haplotype F was not found. The insect specimens harboring the three new '*Ca*. L. solanacearum' haplotypes were of poor quality, so specimens of *Aphalara* spp. psyllids collected in the Pacific Northwest were taxonomically identified by D. Horton and this information was paired with the psyllid CO1 gene sequences obtained by molecular analysis. This led to the identification of four previously unknown psyllid species, including three *Aphalara* species, associated with '*Ca.* L. solanacearum'. The impact of these novel '*Ca.* L. solanacearum' haplotypes on Solanaceous crops, including potato, is still unknown, but future efforts will assess their impact on important crops in the northwest United States.

Dr. William Walker. Molecular Genetics: Tree Fruit Entomology



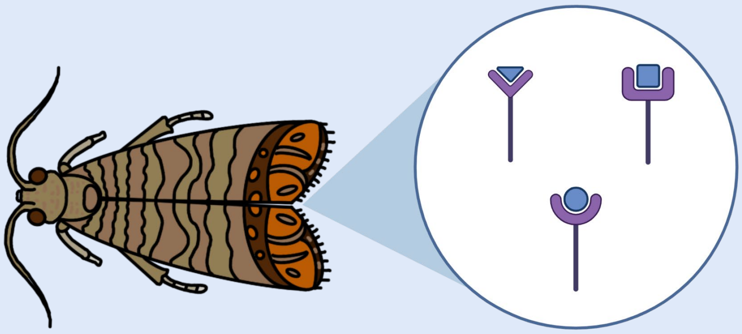
William Walker demonstrating codling moth egg injections; Photo credit: A. Langhans

Permanent Technician: Jennifer Stout

Additional Technical Support:
Janine Jewett, Dan Hallauer, MacKenzie Evans

Postdoctoral Associate: Robert de Moya

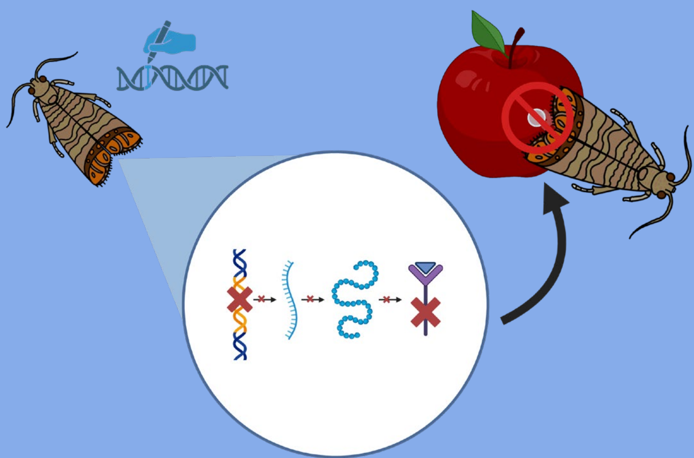
Odorant receptors expressed in female codling moth abdomen tip



Odorants have been used to successful control male codling moth by disrupting their detection of female-produced pheromones, thereby inhibiting mating. However, it is the female that lays the eggs to ultimately propagate the next generation. To further our knowledge about female codling moth olfactory-based behaviors, we studied odorant receptors expressed in the female abdomen tip, which is where the egg-laying organ (ovipositor) is located. We identified over 30 odorant receptors expressed in the female abdomen tip, and furthermore determined that abundance of at least 3 of these receptors is increased or decreased after mating. Odorant receptors increased after mating may be influencing egg-laying behavior. Further research is necessary to determine which odorants activate these odorant receptors and how those odorants might influence codling moth female egg-laying behavior.

CRISPR genome editing of a codling moth female-specific odorant receptor

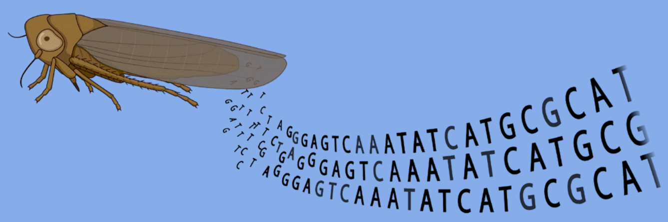
CRISPR-based genome editing is a powerful biotechnology that allows us to study the role of individual genes in agricultural pest insects, such as codling moth. Using methodology developed to implement CRISPR in codling moth, we have targeted a female-specific odorant receptor for deletion. Preliminary results indicate that efforts to delete a segment of the gene have been successful, and current efforts are aimed at generating a codling moth colony in which there is no functional copy of the odorant receptor gene. Future research will study olfactory-based behaviors in codling moth females that lack the CRISPR-deleted odorant receptor, with an ultimate goal to develop novel odorant-based disruption of egg-laying.



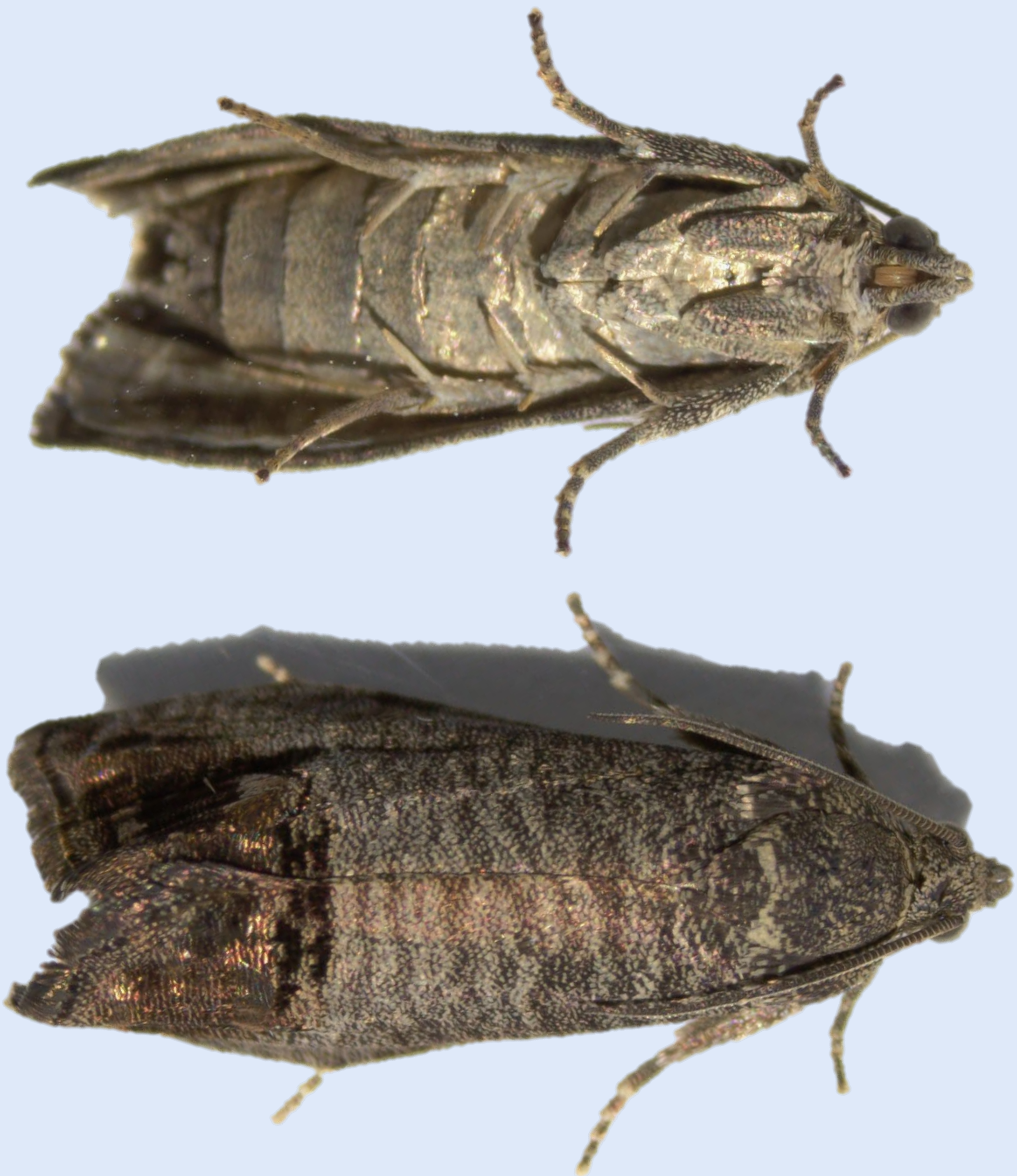
Gene editing with the goal to reduce egg-laying in codling moth

Dr. William Walker. Molecular Genetics: Tree Fruit Entomology

Genomic sequencing of leafhoppers that transmit the X-disease pathogen



Currently X-disease is ravaging cherry orchards in the Pacific North West, resulting in unmarketable cherries and destruction of the orchards. X-disease is caused by a phytoplasma bacteria that is transmitted by several different leafhopper species. Our laboratories have, for the first time, sequenced the genomes of two of the most prominent leafhopper species that transmit the X-disease pathogen in Washington. We are currently data-mining the genomes of these leafhopper species to identify candidate genes that would serve as good targets to disrupt the lifecycle of the X-disease pathogen.



Codling moth

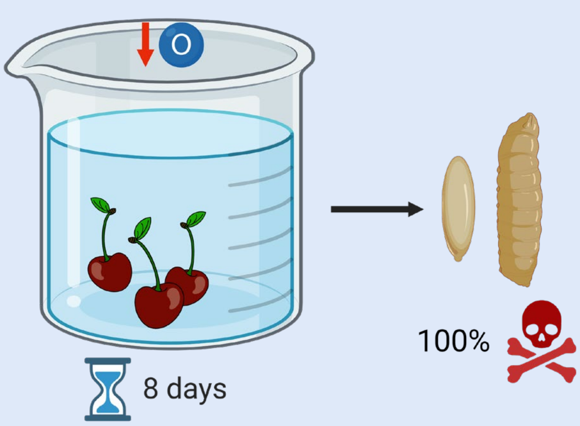
Dr. Wee Yee. Behavior, Ecology, and Management of Temperate Fruit Flies: Tree Fruit Entomology

Xander at work at Moxee Research farm

Permanent Technician: Alexander (Xander) Rose

Other Technical Support: Robert Goughnour

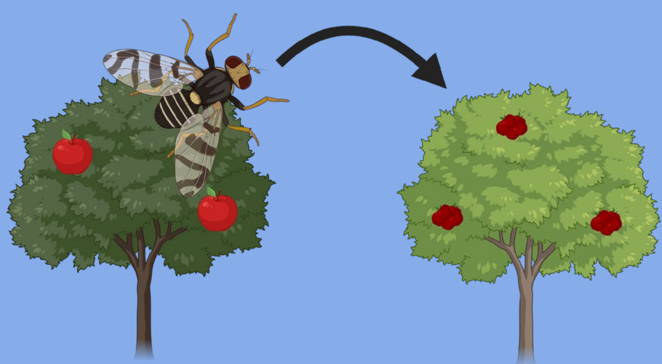
Mortality of western cherry fruit fly eggs and larvae in cherries submerged in hypoxic water



Western cherry fruit fly is a quarantine pest of cherry in western North America. Determining the water tolerance of its maggots in cherries can help us understand fly adaptations to stressful environments and also have practical value for sanitizing orchards. With colleagues at USDA-APHIS in Miami, FL, we determined the effects of submerging infested cherries in water for 4, 8, and 12 days on kill of fly eggs and maggots in the cherries. We found that 8- and 12-day water submersions killed 100% of eggs and maggots. Results may lead to water submersion of unpicked, infested fruit being a viable orchard sanitation method for managing fruit flies, in cherries and possibly other fruit systems.

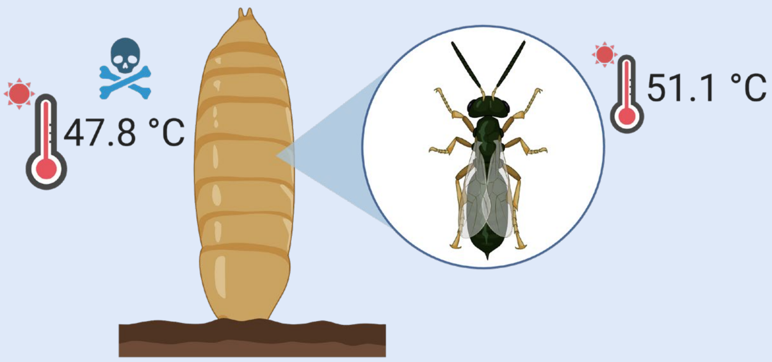
Evidence for adaptation of apple maggot on large-thorn hawthorn in Okanogan County, Washington State

Apple maggot fly is a quarantine pest of apple in western North America. Determining whether a fly population has adapted to non-apple host plants can affect fly management because managing the fly in apple alone would be insufficient to reduce the threat of flies attacking apples. With colleagues at the WSDA and the University of Notre Dame, we examined whether populations of flies attacking large-thorn hawthorn in north-central WA have adapted to the plant. We found evidence that the flies have adapted to large-thorn hawthorn, as flies from large-thorn hawthorn emerged earlier than flies attacking apple and the flies preferred to attack and lay eggs in the hawthorn over apple. Results suggest apple maggot flies can adapt quickly to hawthorn species, which could lead to host race formation and problems for pest management.



Dr. Wee Yee. Behavior, Ecology, and Management of Temperate Fruit Flies: Tree Fruit Entomology

Upper thermal limits of immature western cherry fruit flies and their pteromalid parasitoids inside fly puparia



Determining upper thermal limits of fruit fly pupae can have practical implications for disinfesting soils as well as for predicting differential impacts of global warming on flies and their parasites. We determined the upper thermal limits of western cherry fruit fly pupae and a wasp parasitoid inside the fly puparia. We found that all fly pupae were killed at 49.4°C and that the upper thermal limit of survival for fly pupae was 47.8°C, while for wasps it was 51.1°C. These results suggest that heat could be used to disinfest soils of puparia while sparing parasitoids. Survival of fly pupae and immature wasps may not be greatly impacted by global warming, but extreme temperature increases may be less detrimental to immature wasps.

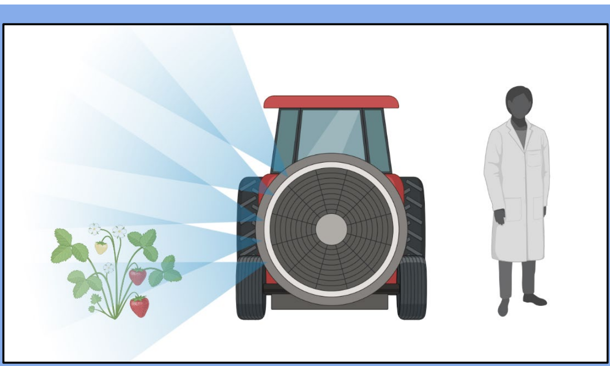
Cherry fruit fly pupal parasitoid, a pteromalid, potentially a species of *Halticoptera*

Western cherry fruit fly, *Rhagoletis indifferens*

Bagged cherries at Moxee research farm, part of fruit fly research projects

Apple maggot fly, *Rhagoletis pomonella*

IR-4 Project



Field and laboratory research leads to pesticide registrations for minor crops

Laboratory Research Director: Todd Wixson

Field Research Director: Duane Larson

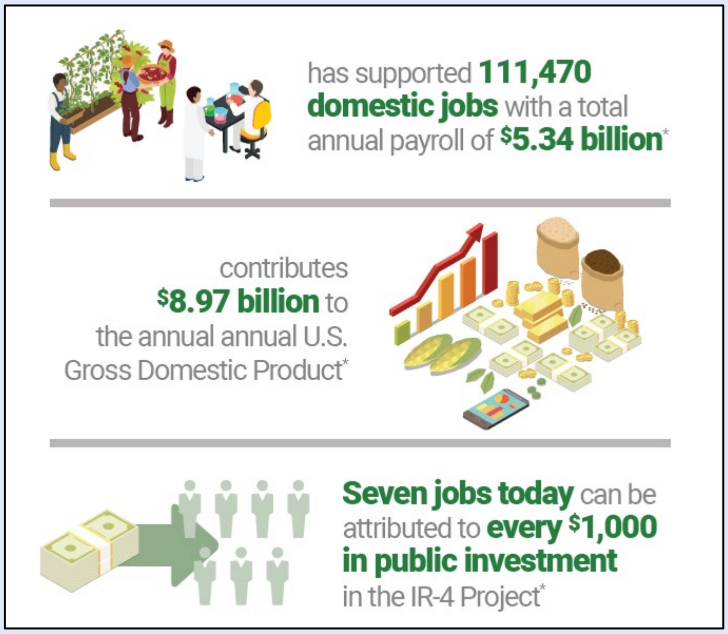
Technical Staff:
Song Jarman
Faradeh Rehfield
Anne Kenny-Chapman

History of the IR-4 Project

The IR-4 Project was established in 1963 by the U.S. Department of Agriculture to ensure that specialty crop farmers have legal access to safe and effective crop protection products.

Specialty crops include many of the fruits and vegetables recommended for a healthy diet, as well as the flowers, trees and shrubs that enhance our environment. According to the USDA, the Specialty Crops Competitiveness Act of 2004 defines specialty crops as, "Fruits and vegetables, tree nuts, dried fruits, horticulture, and nursery crops (including floriculture). Eligible plants must be cultivated or managed and used by people for food, medicinal purposes, and/or aesthetic gratification to be considered specialty crops."

Consumers demand high-quality food and plants, which makes managing the insects and diseases that damage specialty crops essential for both the agriculture community, as well as for public health.



What does IR-4 do?

Pests do not discriminate between major crops and specialty crops. While the crop protection industry focuses its research on major crops, such as corn, cotton and soybeans, growers of specialty crops are often left with fewer tools for effectively and safely managing pests. IR-4 conducts required research to meet this important need.

IR-4 works directly with crop growers, registrants of crop protection products and other members of the specialty crop community to develop data required by the U.S. Environmental Protection Agency for the registration of pest management tools for specialty crops. IR-4 also supports the registration of minor or specialty uses on major crops.

Without IR-4's work, there would be an increased risk of crop losses from pest damage, resulting in higher costs and decreased availability for consumers.

The IR-4 Project is technology neutral and committed to meeting the changing needs of specialty crop growers. Through advisory boards, workshops and strategic planning, new programs and initiatives have been added to assist specialty crop growers with their unique needs.

IR-4 research takes place at many land grant universities and USDA Agriculture Research Service facilities across the country. Regional field offices and state liaisons also work with local growers to identify safe and effective solutions for pest management.

IR-4 Project

Work at TTFVRU

The Minor Use Pesticide Residue Analysis Laboratory at TTFVRU has performed laboratory analysis on a variety of pesticide/crop combinations, including:

	Active ingredient	Crops
Fungicides	Azoxystrobin	fresh and dried herbs
	Dimethomorph	greens
	Ethaboxam	greens, cabbage, celery
	Fluazinam	carrots, greens, broccoli, cabbage
	Mefenoxam	beans, spinach
	Quinoxyfen	squash
Herbicides	Clethodim	spinach, broccoli, pears, cherries, peaches, plums, grapes, strawberries
	Flumioxazin	garlic, broccoli, peppers
	Pedimethalin	cantaloupe
	Quinclorac	asparagus, peppers, cucumbers
	Sethoxydim	berries, herbs
	s-metolachlor	greens, lettuce, berries, herbs
	Uniconazole	greens, brocolli, cabbage
	Etoxazole	berries

Project request process

Stakeholder events, consultations, and other technology transfer

In 2022, TTFVRU employees and affiliated students participated in 22 stakeholder events, providing information to ~3,000 stakeholders. Listed chronologically:

Schmidt-Jeffris, R. Bio-Control options and pesticide application strategies with beneficials. Wilbur-Ellis Grower Meeting. 4 January. 50 participants.

Schmidt-Jeffris R., Thompson, A., Hilton, R. Stakeholder input sessions and research updates: Augmentative biocontrol in orchards. Hood River, OR (5 January); Medford, OR (7 January). 15 participants.

Yee, W. Discovery of apple maggots infesting red-fruited hawthorn in Okanogan County. Apple Maggot Working Group Meeting, Ellensburg, WA. 20 January. 40 participants.

Yee, W. Heat kill of apple maggot pupae for application in disinfestation of green yard waste. Apple Maggot Working Group Meeting, Ellensburg, WA. 20 January. 40 participants.

Zilnik, G. Factors impacting *Trechnites insidiosus* in pear orchards. North Central Washington Pear Day. 20 January. 500 participants.

Feldman, M.J., Genetic mapping of corky ringspot resistance and other processing traits in a biparental linkage mapping population. Washington – Oregon Potato Conference, Cultivar Development Section. 25 January. 100 participants.

Angelella, G. Potato leafroll virus (PLRV): biology, management, and new research effort. Washington-Oregon Potato Conference. 26 January. 350 participants.

Navarre, R. Developing New Potatoes with Improved Quality and Nutritional Content. Cultivar Session, Oregon-Washington Potato Conference. 26 January. 150 participants.

Schmidt-Jeffris, R. Tactics to improve natural enemy releases in tree fruit. Apple Crop Protection Research Review. 26 January. 100 participants.

Yee, W. Apple maggot fly discovered in hawthorns in Okanogan Valley. Okanogan Horticultural Association Annual Meeting. 9 February. 50 participants.

Cooper, W.R. Little Cherry Disease Research at USDA. LCD Day. 9 February. 150 participants.

Cooper, W.R. Using transcriptomics to target key behaviors of pear psylla. Northwest Pear Research Review. 17 February. 100 participants.

Schmidt-Jeffris, R. Tactics to improve natural enemy releases in tree fruit. Northwest Pear Research Review. 17 February. 100 participants.

Zilnik, G. Incorporating trechnites into a psylla biocontrol program. Northwest Pear Research Review. 17 February. 100 participants.

Cooper, W.R. Identifying biological controls of insect vectors in non-crop habitats of the Columbia Basin. NW Potato Research Consortium. February. 75 participants.

Cooper, W.R. RNA-based pesticides to manage insect-vectored plant pathogens in potato. NW Potato Research Consortium. February. 75 participants.

Navarre, R. Development of better methods to determine cultivar resistance to internal discoloration from heat necrosis, after-cooking darkening, blackheart and hollow heart. NW Potato Research Consortium. February. 40 participants.

Navarre, R. TriState Technical Committee Annual Meeting. February 2022. 50 participants.

Navarre, R. Western Regional (WERA) Annual Meeting. February 2022. 55 participants.

Schmidt-Jeffris, R., Ludwick, D., Whitener, A., Smith, T. Organizers. National biological control field tour, supported by the Entomological Society of America. Wenatchee, WA. 8-10 May. 60 participants.

Stakeholder events, consultations, and other technology transfer

Feldman, M.J. Breeding for Columbia root-knot nematode resistance, Washington State University Potato Field Day. 23 June. 200 participants.

Swisher Grimm, K. Potato mop-top virus in Washington seed lots. WSU Othello Potato Field Day. 23 June. 100 participants.

Hanel, A., Schmidt-Jeffris, R. Earwig research updates. Pear Field Day, Medford, OR. 7 July. 40 participants.

Zilnik, G., R. Schmidt-Jeffris. Research Update on Trechnites insidiosus as a biological control agent of pear psylla. Pear Field Day, Medford, OR. 7 July. 40 participants.

Angelella, G. Beet leafhopper population structure in the Northwest. Potato Association of America Annual Meeting. 18 July. 50 participants.

Schmidt-Jeffris, R. Natural enemy releases for integrated pest management. Okanogan Horticultural Association Summer Field Day. Pateros, WA. 3 August. 42 participants.

Cooper, W.R. Experimental orchard for X-Disease and Little Cherry Disease research. NW Cherry and Stone Fruit Research Review. 8 November. 150 participants.

Cooper, W.R. Landscape biology of beet leafhopper and associated pathogens. Pacific Northwest Vegetable Association. 16 November. 300 participants.

Swisher Grimm, K. Beet leafhopper transmitted pathogens in the Columbia Basin. Pacific Northwest Vegetable Association Convention. 16 November. 100 participants

Cooper, W.R. Weedy hosts of X-Disease vectors. Washington State Tree Fruit Association. 7 December. 300 participants.

Schmidt-Jeffris, R. New Research Panel. Pear IPM Intensive. WSU Extension. Wenatchee, WA. 14 December. 220 participants.

Horton, D. Identified white grubs infesting potato fields at request of Washington Potato Commission.

Horton, D. Reviewed updated Pear Psylla Control webpage and the Natural Enemies Handbook at request of WSU-Extension

Outreach Events

In 2022, TTFVRU employees and affiliated students conducted outreach activities impacting over 15,000 individuals. Listed alphabetically:

Angellela, G. Volunteer Judge, 67th Mid-Columbia Science Fair. 6 March. 10 students.

Angellela, G. Hosted a McNair Scholars Program undergraduate research intern, Heritage University. Summer 2022.

Angellela, G. Presented at a Mini Career Fair at East Valley High School, Yakima, WA. 28 September. 800 students.

Cooper, R. University of Kentucky Dept. of Entomology Careers in Government Seminar. October. 10 graduate students.

Hanel, A. Hosted and mentored two Yakima Valley College interns. Summer 2022.

Neven, L. Mentored and hosted graduate student, Sam Strule, from George Washington University. Sam is studying diapause in mosquitoes and used the differential scanning calorimeter to determine metabolic rate of diapausing versus non-diapausing pupae.

Stout, J. Presentation in career fair at Junior Achievement World for Yakima Valley schoolchildren. 700 students. 29 April.

Swisher Grimm, K. Guided two WSU students running new molecular protocols and provided tools to help them successfully meet their research goals. Throughout 2022.

Swisher Grimm, K. Supervised/trained Columbia Basin College student in lab, greenhouse, and field. July.

Swisher Grimm, K. Spoke with Yakima Valley Community College professor about current research interests as part of Hispanic Serving Institution Fellowship. 22 July.

Walker, W. Hosted one student research intern from Heritage University for summer research project in ARS laboratory. June-August.

Walker, W. Hosted student and professor mentor from Yakima Valley College for summer research project in ARS laboratory. June-August.

Zilnik, G. Hosted and mentored a Heritage University NSF research intern. Winter.

Scientific presentations

In 2022, TTFVRU employees and affiliated students participated in 15 professional society conferences and other events, giving a total of 41 presentations.

Orchard Pest Management and Disease Conference. Portland, OR. 12-13 January 2022.

Bergeron, P. Apple integrated mite management: Where can we go next?

Hanel, A. Earwigs as biological control agents in temperate tree fruit orchards: What do we know and what is the way forward?

Pacific Branch Entomological Society of America. Santa Rosa, CA. 10-13 April 2022.

Angelella, G. Beet leafhopper (*Circulifer tenellus* Baker) population structure relative to host plant in the Northwest.

Cooper, W.R. Acquisition and transmission of the "*Candidatus* Liberibacter solanacearum" differs among *Wolbachia*-infected and uninfected haplotypes of *Bactericera cockerelli*.

Hanel, A., R. Orpet, R. Hilton, L. Nottingham, **R. Schmidt-Jeffris.** Back to basics: The dual role of earwigs in tree fruit orchards. Symposium: Sustainable Perennial Crops: Where we are and where do we need to go?

Ferguson, H., **R. Schmidt-Jeffris, R.**, M. Loeser. Undergraduate entomological research provides transformative learning experiences for Yakima Valley College students.

Schmidt-Jeffris, R. Making beneficial insect releases work in tree fruit. Symposium: Sustainable Perennial Crops: Where we are and where do we need to go?

Serrano J.M., G. Gries., J.G. Millar., W. van Herk. Development of tools for wireworm monitoring and management. Symposium: Behavioral Manipulation.

Walker, W. Molecular determinants of olfaction in female codling moth (*Cydia pomonella* L.). Symposium: Molecular ecology of insects: Interconnections, interactions, and interdependencies.

Zilnik, G. Anthropology to entomology and back again: Using grower behavior data to improve pest management. Symposium: Fresh faces of biological control: Graduating students and ECPs in the western U.S.

Entomological Society of America, Entomological Society of Canada, and Entomological Society of British Columbia Joint Annual Meeting. Vancouver, BC, Canada. 13-16 November 2022.

Angelella, G. Bee reproduction on farms relative to honey bee hives, wildflower plantings, and seminatural habitat. Symposium: Managed bees and wild bees: when does competition occur and how do we mitigate risk?

Cooper, W.R. Tracking landscape-level movements of insect vectors using molecular gut content analysis. Symposium: Masters of Manipulation: Plant-Pathogen-Vector-Symbiont Interactions and Novel Management Techniques.

Hanel, A., L. Nottingham, R. Orpet, R. Hilton, T. Northfield, **R. Schmidt-Jeffris**. Out-n-in insects: Earwigs as pests and natural enemies in temperate tree fruit orchards in the Pacific Northwest, USA.

Mendoza, A., **R. Schmidt-Jeffris**, **G. Zilnik.** Presence of *Wolbachia* in *Trechnites insidiosus* in the western United States.

Millar, J.G., **J.M. Serrano**, L. Williams III, S.T. Halloran, A.C. Grommes, A. Huseth, T.P. Kuhar, L.M. Hanks. Identification, synthesis, and testing of new sex attractant pheromones for North American click beetle species. *Presented for J.G. Millar.* Symposium: Clickbait: Click beetles and wireworms (Coleoptera: Elateridae) as inspiration.

Neven, L. Using eDNA to play 'wack-a-mole' with invasive species in green yard waste.

Serrano, J., **R. Cooper**, J. Millar, W.G. van Herk, G. Gries, R. Gries. Progress and prospects in the management of *Limonius* pests in the Pacific Northwest. Symposium: Clickbait: Click beetles and wireworms (Coleoptera: Elateridae) as inspiration.

Scientific presentations

Entomological Society of America, continued

Schmidt-Jeffris, R. Planes, drones, and automobiles: Deploying pest natural enemies. Symposium: Drones, Data and Cybernetic-Physical Systems: Technologies Impacting Pest Management.

Walker, W. Molecular biology of olfactory detection in female codling moth (*Cydia pomonella* L.).

Yee, W. Use of organic, food-grade hydrophobic coatings for protecting cherries against attack by cherry fruit fly.

Internal Seminar Series (chronological)

Feldman, M. Genetic mapping of Tobacco rattle virus resistance and other processing traits in a biparental linkage mapping population. 7 January.

Yee, W. Heat Treatments for Killing Apple Maggot Fly for Application in Disinfesting Organic Yard Waste. 21 January.

Neven, L. eDNA and Diapause: Up-dates from the Neven Lab. 4 February.

Cooper, R. Non-crop sources of insect vectors of crop pathogens. 18 February.

Walker, W. Molecular determinants of olfaction in female codling moth (*Cydia pomonella* L.). 18 March.

Hanel, A. The dual role of earwigs in temperate tree fruit orchards. 1 April.

Swisher Grimm, K. Vector-Borne Pathogens of Potato. 22 April.

Angelella, G. Potato entomology updates. 20 May.

Navarre, R. Maximizing the nutritional potential of potato. 3 June.

Schmidt-Jeffris, R. Aphid lions, coccinellids, and drones, oh my! Improving tree fruit biocontrol. 24 June.

Other meetings and events (chronological)

Navarre, R. The Nutritional Value of Potato. Guest lecture, University of Idaho. 15 January.

Walker, W. Status of Organic Fruit Industry in the USA. International Conference on Organic Fruit Growing, Virtual, 22 February.

Swisher Grimm, K. Understanding Tobacco rattle virus epidemiology in potato through basic and applied assays. WERA 89: Potato virus and virus-like disease management meeting. 15 March.

Feldman, M.J. Using UAVs to assess potato germplasm. S1069: Research and Extension for Unmanned Aircraft Systems (UAS) Applications in U.S. Agriculture and Natural Resources Annual Meeting. 16 May.

Swisher Grimm, K. Understanding Tobacco rattle virus epidemiology in potato through basic and applied assays. American Phytopathological Society Pacific Division. 22 June.

Feldman, M.J., Using traditional and remote sensing techniques to assess Colorado potato beetle host preference in the Columbia Basin. Breeding and Genetics Section, Potato Association of America. 19 July.

Angelella, G. Characterizing beet leafhopper subpopulations within the Columbia Basin. WERA 1007: Curtovirus Biology, Transmission, Ecology, and Management meeting. 26 July.

Cooper, W.R. Molecular gut content analysis to identify the non-crop sources of insect vectors of plant pathogens. Cornell University Dept. of Entomology Seminar Series. September.

Feldman, M.J. Empowering high-throughput phenotyping using UAV. Thinking Big: Visualizing the future of AG2PI, USDA-NIFA Agricultural Genome to Phenome Workshop. 9 September.

Schmidt-Jeffris, R. Building Biocontrol Better: Pushing boundaries for optimizing tree fruit pest management. Kansas State University. 20 September.

Feldman, M.J. Capacity building to support quantitative genetics in potato. USDA-ARS Show-and-tell, Prosser, WA. 8 December.

Publications

In 2022, TTFVRU scientists, technicians, and affiliated students published 27 peer-reviewed papers. TTFVRU employees and affiliates highlighted with bold font.

Baley, N., V. Sathuvalli, B.A. Charlton, C.C. Shock, S. Yilma, R. Qin, E. Feibert, M.I. Vales, R.G. Novy, J.L. Whitworth, C. Brown, **D.A. Navarre**, J.C. Stark, M.J. Pavek, N.R. Knowles, L.O. Knowles, J.M. Blauer, T.L. Brandt, Y. Wang, M. Thornton, R.R. Spear, N. Olsen. Echo Russet: A russet potato variety with a high yield of marketable tubers, high processing quality, and few tuber defects. American Journal of Potato Research 2022. DOI: 10.1007/s12230-022-09891-2

Beers, E.H., D. Beal, P. Smytheman, P.K. Abram, **R. Schmidt-Jeffris**, **E. Moretti**, K.M. Daane, K.M., C. Looney, C.-H. Lue, M. Buffington 2022. First records of adventive populations of the parasitoids *Ganaspis brasiliensis* and *Leptopilina japonica* in the United States. J. Hymenopt. Res. 91: 11-25.

Cattaneo, A.M., Witzgall, P., Kwadha, C.A., Becher, P.B., **Walker III, W.B.** 2022. Heterologous expression and functional characterization of *Drosophila suzukii* OR69a transcript variants unveiled response to kairomones and to a candidate pheromone. J. Pest. Sci. DOI: 10.1007/s10340-022-01585-2

Cooper, W.R., G. Esparza-Diaz, M.R. Wildung, **D.R. Horton**, and S.E. Halbert. 2022. Association of two *Bactericera* species (Hemiptera: Triozidae) with native *Lycium* spp. (Solanales: Solanaceae) in the potato growing regions of the Rio Grande Valley of Texas. Environ. Entomol. DOI: 10.1093/ee/nvac109

Cooper, W. R., **D.R. Horton**, **K. Swisher-Grimm, K. Krey,** M.R. Wildung. 2022. Bacterial endosymbionts of *Bactericera maculipennis* and three mitochondrial haplotypes of *B. cockerelli* (Hemiptera: Psylloidea: Triozidae). Environ. Entomol. 51: 94-107.

Cooper, W.R., A.T. Marshall, **J. Foutz**, M.R. Wildung, T.D. Northfield, D.W. Crowder, H. Leach, T.C. Leskey, S.E. Halbert, J.B. Snyder. 2022. Directed sequencing of plant specific DNA identifies the dietary history of four species of Auchenorrhyncha (Hemiptera). Ann. Entomol. Soc. Am. 115: 275-284.

Eigenbrode, S.D., S. Adhikari, E. Kistner-Thomas, **L. Neven**. 2022. Introduction to the collection: Climate change, insect pests, and beneficial arthropods in production systems. J. Econ. Entomol.115: 1315–1319.

Jiang, J., W. Feindel, **K.D. Swisher Grimm**, M.W. Harding, D. Feindel, S. Bajema, and J. Feng. 2022. Development of a loop-mediated isothermal amplification (LAMP) method to detect the potato zebra chip pathogen '*Candidatus* Liberibacter solanacearum' (Lso) and differentiate haplotypes A and B. Plant Dis. DOI: 10.1094/PDIS-09-22-2258-SR.

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Matias, F.I., A. Green, J.A. Lachowiec, D. LeBauer, **M. Feldman**. 2022. Bison-Fly: An open-source UAV pipeline for plant breeding data collection. Plant Phenome J. 5:1 e20048

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Publications

McCullough, C.M., H. Grab, **G. Angelella**, J. Samtani, E. Olimpi, S. Karpanty, and M. O'Rourke. 2022. Diverse landscapes but not wildflower plantings increase marketable crop yield. Agr. Ecosyst. Environ. 339: 108120.

Millar, J.G., L. Williams III, **J.M. Serrano**, S.T. Halloran, A.C. Grommes, L.M. Hanks. 2022. A symmetrical diester as the sex attractant pheromone of the North American click beetle *Parallelostethus attenuatus* (Say) (Coleoptera: Elateridae). J. Chem. Ecol. 48: 598–608.

Miller M.D., C.A. Schmitz-Carley, R.A. Figueroa, **M.J. Feldman**, D. Haagenson, L.M. Shannon. 2022. TubAR: an R Packager for Quantifying Tuber Shape and Skin Traits from Images. Am. J. Potato Res. 99: 258-267

Moretti, E.A., **C. Jones, R.A. Schmidt-Jeffris**. 2022. Alternative food sources for *Amblydromella caudiglans* (Phytoseiidae) and effects on predation. Exp. Appl. Acarol. DOI: 10.1007/s10493-022-00767-y

Navarre, D.A., M. Zhu, H. Hellmann. 2022. Plant antioxidants affect human and gut health, and their biosynthesis is influenced by environment and reactive oxygen species. Oxygen. 2: 348-370.

Neven, L.G., **W.L. Yee**. 2022. Metabolic reserves of diapausing western cherry fruit fly (Diptera: Tephritidae) pupae in relation to chill duration and post-chill rearing conditions. Front. Insect Sci. 2: 989673.

Prager, S.M., A. Cohen, **W.R. Cooper**, R. Novy, A. Rashed, E.J. Wenninger, C. Wallis. 2022. A comprehensive review of zebra chip disease in potato and its management through breeding for resistance/tolerance to '*Candidatus* Liberibacter solanacearum' and its insect vector. Pest Manag. Sci. 78: 3731-3745.

Schmidt-Jeffris, R.A., **E.A. Moretti**, **P.E. Bergeron**, **G. Zilnik**. 2022. Non-target impacts of herbicides on orchard spiders. J. Econ. Entomol. 115: 65-73.

Serrano, J.M., **P.J. Landolt**, **C. Reyes Corral**, J.G. Millar. 2022. Sex pheromones and sex attractants of species within the genera *Idolus* Desbrochers des Loges and *Dalopius* Eschscholtz (Coleoptera: Elateridae) in the western United States. Agric. For. Entomol. 24: 301–309

Swisher Grimm, K.D., **D.R. Horton**, **T.M. Lewis**, **S.F. Garczynski**, A.S. Jensen, and B.A. Charlton. 2022. Identification of three new '*Candidatus* Liberibacter solanacearum' haplotypes in four psyllid species (Hemiptera: Psylloidea). Sci. Rep. 12:20618.

Swisher Grimm, K.D., **R.A. Quick**, L. Cimrhakl, C. Brown, M.J. Pavek. 2022. Detection of potato mop-top virus in potato seed lots entering Washington State. Am. J. Potato Res. 99: 390-394.

Vales, M.I., D.C. Scheuring, J.W. Koym, D.G. Holm, S.Y.C. Essah, R.G. Wilson, J.K. Sidhu, R.G. Novy, J.L. Whitworth, J.C. Stark, R.R. Spear, V. Sathuvalli, C.C. Shock, B.A. Charlton, S. Yilma, N.R. Knowles, M.J. Pavek, C.R. Brown, **D.A. Navarre**, **M. Feldman**, C.M. Long, J.C. Miller Jr. 2022. Vanguard russet: A fresh market potato cultivar with medium-early maturity and long dormancy. Am. J. Potato Res. 99: 258-267.

Walker III, W.B., B.A. Mori, A.M. Cattaneo, F. Gonzalez, P. Witzgall, P.B. Becher. 2022. Comparative transcriptomic assessment of the chemosensory receptor repertoire of *Drosophila suzukii* adult and larval olfactory organs. Comp. Biochem. Phys. D. 45: 101049.

Yee, W.L., C. Kaiser. 2022. Evaluation of organic, food-grade hydrophobic coatings for suppressing oviposition and increasing mortality of western cherry fruit fly (Diptera: Tephritidae). Environ. Entomol. 51: 728-736.

Yee, W.L., R.B. Goughnour, A.A. Forbes, J.M. Milnes, J.L. Feder. 2022. Sensitivities to chill durations and no-chill temperatures regulating eclosion responses differ between *Rhagoletis zephyria* (Diptera: Tephritidae) and its braconid parasitoids (Hymenoptera: Braconidae). Environ. Entomol. 51: 440-450.

Yee, W.L., C. E. Kruger, T. O'Neill. 2022. Heat treatments for killing apple maggot fly (Diptera: Tephritidae) puparia for application in disinfesting organic yard waste. J. Econ. Entomol. 115: 493-500.

Other Publications

Conference Proceedings:

Walker III, W.B. 2022. Status of organic fruit industry in the USA. Proceedings of the 20th International Conference on Organic Fruit-Growing, Ed. Foerdergemeinschaft Oekologischer Obstbau (FOEKO) e.V., 2022: 133-134.

Trade Journals:

Cooper, R.W., **D.R. Horton**, **L. Neven**, **R. Schmidt-Jeffris**, **J. Serrano**, **W. Walker**, **W. Yee**. 2022. Good to know: integrated research. Entomologists at the USDA laboratory in Wapato, Washington, work to advance IPM for orchards. Good Fruit Grower, Issue: March 1st, 2022.

Schmidt-Jeffris, R. 2022. How can growers successfully release beneficial insects for pest control? New USDA research effort aims to find out. Good Fruit Grower. 73(2): 24-27.

Ongoing Grants

TTFVRU scientists expand the scope of their projects by obtaining additional funds through competitive grant programs and other agreements. These funds allow us to increase the amount and quality of information that we provide to our stakeholders. In 2022, TTFVRU scientists managed 469 agreements, including $1.5 million in new funds. Grants are listed by lead scientist (unless the lead is outside of the Unit). On many of these projects, other scientists within the unit are co-PIs.

Angelella, G. Exploring alternatives to neonicotinoids for insect-vectored virus management in potatoes. Washington State Commission on Pesticide Registration ($35,000) and Washington State Potato Commission ($21,358). 2022–2023.

Angelella, G. Identifying the sources of aphids and aphid-vectored viruses afflicting potato fields. Federal-State Partnership Potato Proposal. $36,517. 2022–2023.

Angelella, G. Assessing whether potato leafroll virus transmission and feeding behavior of the green peach aphid in potatoes is altered by afidopyropen, an insecticide with a novel mode of action. Federal-State Partnership Potato Proposal. $22,491. 2021–2022.

Angelella, G. Integrative approaches to understanding how vector proteins affect plant defense and plant-insect interactions. Federal-State Partnership Potato Proposal. $45,104.

Cooper, W.R. Areawide management of insect vectors in Columbia Basin vegetable and seed crops. ARS-Areawide Pest Management Program. $1,332,658 . 2019-2024.

Cooper, W.R. Characterization of novel viruses pathogenic to potato psyllid. ARS-State Potato Partnership Program (ONP). $39,000. 2021-2023.

Cooper, W.R. Experimental orchard for X-Disease and Little Cherry Disease research. Washington Tree Fruit Research Commission. $64,856. 2022-2025.

Cooper, W.R. RNA-based pesticides to manage insect-vectored plant pathogens in potato. Washington Potato Commission. $62,904. 2022-2025.

Cooper, W.R. Identifying Biological Controls of Insect Vectors in Non-Crop Habitats, Washington State Potato Commission. $32,000. 2022-2025.

Cooper, W.R. Biological control of insect pests in non-crop habitats. WSDA-Specialty Crop Block Grant. $249,292. 2023-2026.

Feldman, M.J. Application of image analysis techniques to quantify potato processing quality and disease symptomology. USDA-ARS State Partnership Program. $31,000. 2022.

Feldman, M.J. (Co-PI, PI: L. Dandurant) Systems approach to controlling nematodes in US potato production. USDA-NIFA, $130,000, 2022-2026.

Feldman, M.J. Empowering high-throughput phenotyping using UAVs. USDA-NIFA Agricultural Genome to Phenome Initiative Seed Grant. $19,000. 2021-2022.

Feldman, M.J. Advancement of disease resistant germplasm using quantitative genetics and marker-assisted selection, Northwest Potato Research Consortium. $30,000. 2022.

Feldman, M.J. Characterization of soil health parameters from nematode infested potato fields in the Columbia Basin. USDA-ARS State Partnership Program. $40,000. 2022.

Horton, D. Biological control of potato psyllid in non-crop habitats. USDA-ARS/State Partnership Potato Research Program. $90,000. 2020-2022.

Navarre, R. Managing Tuber Maturation for Improved Postharvest Quality and Retention. USDA-State Partnership Program. $38,386. 2022.

Ongoing Grants

Navarre, R. Effect of heat stress on glycoalkaloid amounts in potato tubers. USDA-State Partnership Program. $35,000. 2022.

Navarre, R. Development of better methods to determine cultivar resistance to internal discoloration from heat necrosis, after-cooking darkening, blackheart and hollow heart. $36,500. 2022.

Neven, L. Use of model systems to develop quarantine treatments. Agreement with Dr. Kambiz Esfandi, Science Team Leader – IDR, of Plant and Food New Zealand. 2022.

Neven, L. Agreement with Dr. Renate Smit, Hortgro Phytosanitary facility manager, HortGrow South Africa, to assist in development of phytosanitary treatments for tree fruit pests. 2022.

Schmidt-Jeffris, R. Factors that affect movement and distribution of pear psylla and its parasitoid *Trechnites* spp. in pear orchards. Washington State Commission on Pesticide Registration. $15,053. 2023-2024.

Schmidt-Jeffris, R. Oak leaf volatiles for pest suppression and disease management. Washington State Commission on Pesticide Registration. $30,605. 2022-2023.

Schmidt-Jeffris, R. What factors impact mite outbreaks in pear? Fresh and Processed Pear Committee Research. PI. $66,911. 2022-2024.

Schmidt-Jeffris, R. Movement and distribution of pear psylla and its parasitoid *Trechnites* spp. within pear orchards and the impact of management practices. Washington State Commission on Pesticide Registration. $20,596. 2022-2023.

Schmidt-Jeffris, R. (co-PI, PI: J. Lee) Areawide management of spotted-wing drosophila: Phase II implementing sustainable tools and parasitoid releases. USDA Areawide. Collaborator, PI: J. Lee. $45,000 (total $511,969). 2021-2022.

Schmidt-Jeffris, R. Tactics to improve natural enemy releases in tree fruit. Washington Tree Fruit Research Commission and Fresh and Processed Pear Committee Research (jointly funded). $208,591. 2021-2024.

Schmidt-Jeffris, R. (co-PI, PI: C. Adams) Calibrating current natural enemy action thresholds with lure-baited trap catch. Fresh and Processed Pear Committee Research. $16,223 (total $92,352). 2021-2023.

Schmidt-Jeffris, R. Developing augmentative biocontrol programs for northwest tree fruit. Western IPM Center Project Initiation Grant. $29,968. 2021-2022

Schmidt-Jeffris, R. New tools for improving biological control of pear psylla by Trechnites parasitoids. WSDA-Specialty Crop Block Grant. $245,974. 2020-2023.

Schmidt-Jeffris, R. Wigging out, then wigging in: removing earwigs from stone fruit and augmenting them in pome fruit. Western SARE Research and Education. $348,733. 2020-2023

Schmidt-Jeffris, R. Incorporating *Trechnites* into a psylla biocontrol program. Fresh and Processed Pear Committee Research. PI. $119,150. 2019-2024.

Serrano, J. ARS/State Potato Partnership. $122,322.

Serrano, J. (Funded Cooperator, ADODR: D. Cook) Plant Pest and Disease Management and Disaster Prevention Program (PPA 7721) Year 2. $67,188.

Serrano, J. Washington Tree Fruit Research Commission. $6,000.

Swisher Grimm, K. Pyramiding of *Potato Virus Y* and Columbia root-knot nematode resistances using greenhouse and molecular marker screening. Northwest Potato Research Consortium. $22,500. 2022.

Swisher Grimm, K. Exploring differences in *Paratrichodorus allius* populations through whole-genome sequencing and the effect of different potato cultivars on population fecundity. USDA-ARS/State Partnership Potato Research Program. $40,651. 2022.

Ongoing Grants

Swisher Grimm, K. Profiling pathogenic genome and gene expression variations in novel haplotypes of '*Candidatus* Liberibacter solanacearum' isolated from psyllid species collected from potato. USDA-ARS/State Partnership Potato Research Program. $50,387. 2021-2022.

Swisher Grimm, K. (Co-PI, PI: Wohleb) Regional sampling network for insect pests of potato in the Columbia Basin of Washington. Washington State Potato Commission. $12,000 ($103,257 total). 2020-2022.

Swisher Grimm, K. (Co-PI, PI: Karasev) Development of sustainable system-based management strategies for two vector-borne, tuber necrotic viruses in potato. NIFA- Specialty Crop Research Initiative. $146,636 ($5,756,299 total). 2020-2022.

Swisher Grimm, K. Managing Potato Purple Top Disease: Leafhopper and BLTVA landscape ecology. WSDA Specialty Crop Block Grant. $244,979. 2019-2022.

Swisher Grimm, K. Support for the investigation of emerging and persistent potato diseases in the Northwest. Northwest Potato Research Consortium. $48,000. 2019-2022.

Swisher Grimm, K. Assessment of beet leafhopper and BLTVA phytoplasma impact on potato tuber yield and quality. Washington State Commission on Pesticide Registration. $35,000. 2022.

Walker, W. Novel control of codling moth with RNA interference. Washington Tree Fruit Research Commission. $209,700. 2022-2025.

Walker, W. Genetic insights into leafhopper/phytoplasma interactions and gene-based immunization for plant disease control. WSDA-Specialty Crop Block Grant. $233,807. 2021-2024.

Walker, W. Genetic engineering of moth viruses for enhanced insecticidal efficacy. Washington Tree Fruit Research Commission. $180,000. 2021-2024.

Walker, W. Can we get codling moth females to stop laying eggs on apple? Washington Tree Fruit Research Commission. $120,427. 2021-2023.

Wee, Y. Submersion as a disinfestation method for fruit waste from fruit fly quarantine areas. Interagency Agreement with USDA-APHIS. $11,000. 2022.

Wee, Y. Organic, hydrophobic coatings to protect cherries against cherry fruit fly. Agreement with Oregon State University. $20,000. 2022.

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