POTATOES & PESTS

# PAPAS

Actionable Science Against Nematodes

# 2024 ANNUAL REPORT

# Systems Approach to Nematode Control in U.S. Potato Production

PotatoNematodes.org

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POTATOES & PESTS
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## Plant-parasitic nematodes in U.S. potato production:

**Potato Cyst Nematodes (PCN)**
*Globodera spp.*
Pale Cyst (*G. pallida*)
Golden (*G. rostochiensis*)

**Root-Knot Nematodes (RKN)**
*Meloidogyne spp.*
Columbia Root-Knot (*M. chitwoodi*)
Northern Root-Knot (*M. hapla*)

**Lesion Nematodes**
*Pratylenchus spp.*

**Stubby Root Nematodes**
*Paratrichodorus spp.*

Potato breeder Dr. Walter De Jong evaluating tuber yield, shape, and size at a Cornell University field trial.

## Plant-Parasitic Nematodes Threaten the US Potato Industry

Potato nematode infestations can significantly reduce crop yield, marketability, and processing quality, leading to severe economic losses for commercial growers. There is no "silver bullet" for controlling potato nematodes, and management options for growers are limited.

The long-term goal of PAPAS is to develop multiple proven methods to better control plant-parasitic nematodes and reduce their economic damage in potato crops.

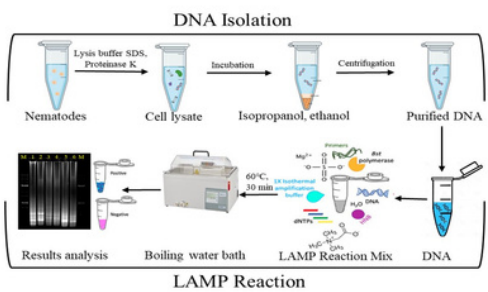
**The objectives of the PAPAS USDA NIFA Coordinated Agricultural Project, Systems Approach to Nematode Control in U.S. Potato Production, are:**

1. Deploy improved diagnostics and predictive models to provide growers with decision support and economic thresholds for potato nematodes.
2. Accelerate development of commercial potato varieties with nematode resistance through traditional breeding methods.
3. Explore novel nematicide production from compounds of litchi tomato (*Solanum sisymbriifolium*).
4. Deliver information to the industry for more effective, sustainable nematode management and more productive potato crops.

# OBJECTIVE 1

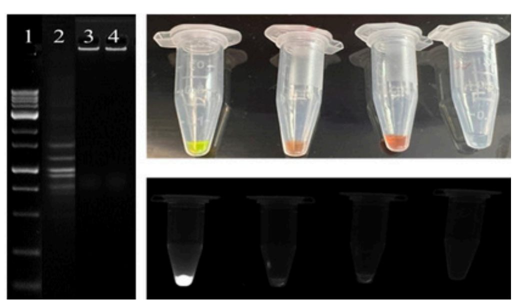
## Provide decision support tools to growers and industry members affected by nematode infestations by deploying improved diagnostics, predictive models, and economic thresholds.

### 1A: Develop molecular nematode diagnostics for root-knot nematode and potato cyst nematode pathotypes




**Developed a LAMP assay for identifying PCN**

The assay provides a rapid, sensitive, and reliable diagnostic for *G. pallida*, without cross-reacting with *G. rostochiensis* or *G. ellingtonae*, which share similar morphological features.



## 1B: Decision Support Systems (DSS) for use by growers and regulators

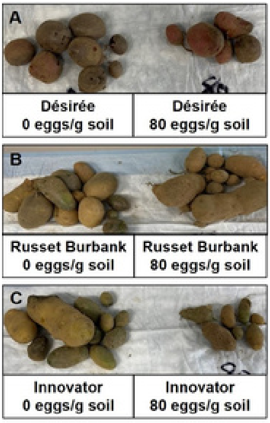
### Damage caused by RKN varies among potato varieties

A field trial in Hermiston, OR, showed significant northern root-knot nematode (*Meloidogyne hapla*) damage to 'Russet Ranger' tubers compared to 'Russet Burbank' and 'Clearwater.' These findings guide growers in NRKN-infested areas to select tolerant varieties to reduce tuber damage.

Grad student Gabby Studebaker evaluating potato damage caused by NRKN at Hermiston, OR field trial

### The one-two punch of litchi tomato *(Solanum sisymbriifolium)* and potato resistant varieties for *G. pallida* eradication

Microplots demonstrated that resistant potato in rotation can greatly reduce *G. pallida* similar to the trap crop litchi tomato. The resistant variety considered was ‘Innovator.’ These results are encouraging for the deployment of russet-type varieties with pale cyst nematode resistance when they become available.




### Predictive models to assess the tolerance of several potato varieties to *G. pallida*

While both 'Desiree' and 'Russet Burbank' are highly susceptible based on nematode reproduction rates, their tolerance differs. 'Desiree' is highly intolerant, with significant yield reductions upon infection. In contrast, the indeterminate 'Russet Burbank' shows notable tolerance, with only slight overall yield reductions even at high infestation levels, though infected plants produce smaller tubers, reducing the proportion of No. 1 grade potatoes. Despite being resistant, 'Innovator' is highly intolerant, with drastically reduced yields when infected.

## 1B continued...

**Developed a high-throughput staining method for assessing RKN damage to tubers**

Stains were evaluated under different parameters, such as time of staining and application of heat, for ability to stain nematodes. This method has potential for application in the processing facility to grade tubers for RKN damage.

CRKN egg mass stained blue (left) and external damage on potato (right)

**Prototype of 'PAPAS Chatbot' AI decision support system developed**

This chatbot will enable the comprehensive search of information in peer-reviewed publications. It will eventually be available to growers, processors, and decision makers interested in exploring potato nematode literature and looking for answers regarding topics such as management, damage, and non-chemical alternatives.

## 1C: Evaluate nematode economic impact through economic analyses

**Developed potato enterprise budgets and determined economic impact of plant-parasitic nematodes on potato production**

Focusing on fumigation and resistant potato varieties like 'King Russet' in six major potato-producing states, the economic impact of nematodes was assessed. Infected fields (100 acres) in 2022 caused a $7.5 million total economic loss. Resistant varieties were profitable for growers and boosted state economic activity, demonstrating that adopting resistant varieties like 'King Russet' benefits the broader US potato industry.

## OBJECTIVE 1 ANTICIPATED GOALS FOR YEAR 3

- Continue to work with diagnostic laboratories to extend and implement molecular nematode identification tools.
- Conduct additional field trials to define the damage potential of RKN to potato and to find new ways to manage RKN and PCN.
- Analyze historical PCN data to support decision-making by growers and regulators.
- Define the vertical and horizontal distribution of plant-parasitic nematodes in potato fields, as well as seasonal population dynamics to assist growers with decision support for sampling and management.
- Demonstrate the power of deploying potatoes with resistance to nematodes through economic analyses and field data.

# OBJECTIVE 2

## Accelerate the development of novel potato varieties with resistance to plant-parasitic nematodes.

### 2A: Exploration of novel pathways for nematode immunity in litchi tomato (*Solanum sisymbriifolium*)

The circled portion of these leaves have been infected with a pale cyst nematode-induced gene from litchi tomato, showing the resulting cell death that it causes on the top (left) and bottom (right) of the leaf.

**Identified genes and pathways in litchi tomato that confer resistance to PCN and RKN**

Using the newly annotated litchi tomato genome, 13 resistance-related genes were identified as differentially expressed after root-knot nematode inoculation. Previous research shows some litchi tomato genes, expressed in potato, likely enhance resistance to these nematodes. One gene studied induces cell death, a common plant resistance mechanism.

**Identified a pathway important for nematode parasitism**

*Globdera pallida* utilizes a protein called RHA1B, an enzyme that targets the potato gene NILR1 for degradation, facilitating successful nematode parasitism. Findings demonstrate that when NILR1 pathway is compromised, a potato plant becomes more susceptible to *G. pallida*. This work led to cloning of the litchi tomato homolog of NILR1 to be studied in relation to potato NILR1.

## 2B: Evaluate select *Solanum* species for their response to root-knot and potato cyst nematodes

### Wild *Solanum* relatives of potato screened for nematode resistance

Selected clones have been identified with resistance to PCN. These sources of resistance are compatible with *S. tuberosum* germplasm and readily incorporated into most potato breeding programs using traditional crosses. Both Oregon and Idaho breeding programs have included some of the identified clones in their winter crossing blocks.

### *Solanum brevicaule* clone Y1-5, *S. hougassi,* and *S. bulbocastanum* identified with resistance to PCN and RKN

Progeny from Y1-5 crossed with a susceptible clone are being evaluated to locate resistance genes in the potato genome. Sequencing of Y1-5 will aid in identifying candidate resistance genes to *G. rostochiensis*. Root-knot nematode resistance from *S. hougassi* has been introduced into potato-aligned germplasm, though further crosses are needed. Additionally, *M. chitwoodi* resistance from *S. bulbocastanum* has been linked to a candidate gene on potato chromosome 11, enabling the development of improved molecular markers.

Clone *S. boliviense* with hybridization tags (Aberdeen breeding program) during winter crosses (2023-2024).

## 2C: Development and application of new molecular markers linked to resistance

**Markers developed to assist with identifying resistance to RKN and PCN**

In four breeding programs (ID, NY, OR, WA), selected clones have been screened for PCN resistance genes using molecular markers. Results have helped identify parents for subsequence crossing, as well as clones for advancement.

Research continues to explore the development of new and better markers for known resistance genes. PCN resistance was investigated in a cross between PCN-resistant ‘Eden,’ and susceptible cultivar ‘Western Russet,’ providing important genetic information associated with *G. pallida* resistance in a tetraploid potato population. Genomic regions were associated with reduced cyst number and reduced eggs/cyst. Molecular markers have been identified in these regions and further research will associate these markers with resistant traits.

A17045-1PCN3,4
(Basin Russet x La Belle Russet)

A18590-11PCN2,3,4
(Tokio x Mountain Gem Russet)

**Two potato breeding clones selected by the Aberdeen potato breeding program with resistance to potato cyst nematode.**

## 2D: Utilization of molecular markers linked to PCN and RKN resistance genes to pyramid multiple genes into adapted germplasms

**Progress toward pyramiding nematode resistance genes into potato**

***PCN***: Multiple resistance genes for pale cyst nematode were combined to enhance resistance and reduce the likelihood of resistance-breaking nematode populations. Examples include combining GpaIV and GpaV genes, which may increase resistance, and GpaV and Grp1 genes on chromosome 5, with ongoing evaluations to determine their individual and combined contributions. A similar strategy was applied to golden nematode resistance, combining the H1 gene (resistant to Ro1) with resistance to Ro2.

***RKN***: Clones carrying resistance to *M. chitwoodi* from *S. bulbocastanum* or *S. hougasii* were crossed with russet-type clones resistant to PCN. While breeding is time-intensive, increasing nematode resistance in breeding clones boosts the likelihood of future varieties carrying multiple resistances.

Scenes from the New York breeding program, Fall 2024.
Left: digging of breeding material. Right: selection of promising clones.

# OBJECTIVE 3

## Develop novel chemistries for nematode management in commercial potato production.

### 3A: Quantify the ability of litchi tomato fractionated extracts to disrupt PCN and RKN development

Litchi tomato growing in the greenhouse for compound extraction

**Solvent extracts from litchi tomato suppress RKN and PCN**

A gradient of solvents extracted secondary metabolites from litchi tomato (*S. sisymbriifolium*) stems, leaves, and roots. These extracts reduced PCN hatch by 49.5% and 68.3%, respectively, compared to potato root diffusate controls. Similar effects were observed on RKN egg hatch and juvenile viability.

Master's student Koy Chandler performing compound extraction from litchi tomato

## 3B: Purify, identify, and optimize bioactive compounds from litchi tomato

**Nematode inhibitory extracts from litchi tomato identified**

A potent inhibitory extract was fractionated into five parts, and experiments on RKN and PCN egg hatch were conducted. Preliminary results showed specific fractions inhibited root-knot nematode egg hatch. Biochemical analysis of RKN-infected litchi tomato identified candidate compounds induced by nematodes, with two purified compounds proving toxic in viability tests. Additionally, litchi tomato roots infected with PCN had higher levels of toxic compounds, suggesting these are transported to the roots after infection.

## OBJECTIVE 3 ANTICIPATED GOALS FOR YEAR 3

- Quantify the ability of litchi tomato fractionated extracts to disrupt PCN and RKN development.
- Write manuscript about the effects of the litchi tomato extracts on RKN egg hatch and viability.
- Purify, identify, and optimize bioactive compounds from litchi tomato.
- Perform additional experiments with litchi tomato fractions on RKN and PCN egg hatching and viability.
- Perform biochemical analysis of the most active fraction to develop "compound profile."
- Perform additional fractionations, if necessary, to further narrow down the list of active, toxic compounds.
- Compare results across the three following experiments: 1) untargeted metabolomics; 2) gene expression analysis in litchi tomato after nematode infection; 3) fraction compound analysis.
- Metabolomics will tell us what compounds are present in the plant, gene expression reveals which genes are active, and fraction analysis helps focus on specific types of compounds in more detail.

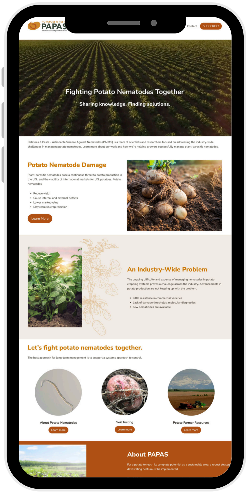
# OBJECTIVE 4

## Deliver information learned from this project to potato growers, industry members and other stakeholders.

### 4A: Disseminated relevant results for nematode control to the industry through appropriate outlets, allowing all levels of industry access

**Visit PotatoNematodes.org**

Our website has become a key resource for nematode control information. Graduate students supported by the project have created numerous fact sheets and videos on topics like plant-parasitic nematodes, potato cyst nematode life cycles, and breeding for Columbia root-knot nematode resistance. Involving graduate students in outreach is uncommon but provides valuable training and fosters future agricultural scientists committed to stakeholder engagement.




**Visit PAPAS social media**

Regular posts on Facebook (facebook.com/potatonematodes) and LinkedIn (linkedin.com/company/potatonematodes) provide additional outlets for public (not just potato industry) engagement. The Facebook channel has 297 followers while LinkedIn has 421 at the time of this writing. Who knew that so many people were interested in microscopic worms?

## 4B: Plan and execute innovative, hands-on workshops that allow industry processors and/or regulators to learn new diagnostic methods and predictive modeling outputs

**Train-the-trainer and DSS workshops offer hands-on training in diagnostics and decision support systems**

Scheduled for July 2025, train-the-trainer workshops will teach molecular diagnostic methods at labs in Washington, Michigan, and New York, targeting regulatory, industry, and academic participants to enable them to train others. DSS workshops in year 4 will train farmers, students, and regulators on using the system to manage nematode-infested fields.

## 4C: Provide in-field demonstration plots of resistant cultivars in the market classes that pertain to pertinent growing areas

An on-farm twilight meeting in Dansville, NY in late August gave local growers an opportunity to learn about the relative strengths and weaknesses of several candidate chipping varieties resistant to the golden cyst nematode.

# PAPAS Published Content

**Factsheets / Handouts**

- Columbia Root-Knot Nematode
- Northern Root-Knot Nematode
- Nematode Resistance
- Combating Parasitic Nematodes
- Success in Developing Nematode Resistant Potato
- Breeding for Columbia Root-Knot Nematode Resistance
- Developing Data-Driven and Interactive AI Capabilities for Potato Nematode Decision Support
- Diagnostic Molecular Markers for Identification of Different Races of Columbia Root-Knot Nematode
- Research for a More Targeted Approach to Potato Cyst Nematode Management
- Golden Nematode: A Devastating Potato Pest
- Potato Economics
- Breeding for Potato Cyst Nematode Resistance in the Russet Market Class
- Use of Molecular Markers with Conventional Breeding
- *Solanum sisymbriifolium* for Control of Nematodes
- Why Industry Participation is So Important in Potato Breeding
- Root Lesion Nematodes
- Erosion of Potato Resistance to *Globodera pallida*
- Distribution of Potato Cyst Nematodes Globally
- Life History and Spread of PCN
- Plant-Parasitic Nematode Characteristics
- Field Microplot Setup for the Pale Cyst Nematode, Regulated Pest of Potato in Idaho

**Newsletters**

- PAPAS Newsletter #1 December 2023
- PAPAS Newsletter #2 March 2024
- PAPAS Newsletter # 3 June 2024

**Blog Series**

- Selecting for Success in Potato Breeding

V**ideos**

- Soil Sampling for Plant-Parasitic Nematodes
- Potato Damage from Root-Knot Nematode
- Acid Fuchsin Potato Root Staining for Pale Cyst Nematode
- On-Farm Trial Planting: Cornell Potato Breeding Program
- Potato Planting: Cornell Potato Breeding Program
- Making Litchi Tomato Extracts

**Reports / Papers**

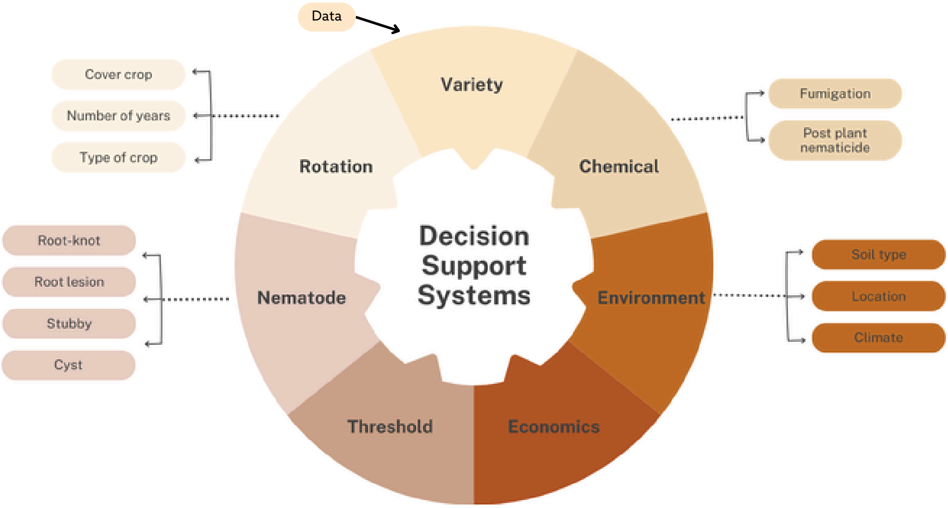
- Hickman, P., & Dandurand, L. M. 2024. Trap crops and crop rotation for eradication of the pale cyst nematode in Idaho. Western SARE final project report for GW21-222. https://projects.sare.org/project-reports/gw21-222/
- Hickman, P., & Dandurand, L.M. (Mar 2024). Investigating susceptible and resistant potato at varying population densities of the pale cyst nematode, *Globodera pallida* [Poster]. American Phytopathological Society Pacific Division Meeting. Corvallis, OR.
- Ibrahim, H., Nchiozem-Ngnitedem, V., Dandurand, L.M., and Popova, I. 2024. Naturally- occurring nematicides of plant origin – two decades of novel chemistries, Pest Management Science, in review.
- Ibrahim, H., Dandurand, L.M., and Popova, I. 2024 Metabolomic profile of *Solanum Sisymbriifolium*, in preparation.
- Schulz, L., Popova, I., & Dandurand, L. M. (2024). Toxic Effects of the Trap Crop *Solanum sisymbriifolium* on the Hatch and Viability of *Globodera pallida*. Journal of Nematology 56(1).

# PAPAS Published Presentations/Posters

- Baker, H. V., L. Schulz, L. M. Dandurand, and I. A. Zasada. 2024. How does prolonged exposure to extracts of litchi tomato, *Solanum sisymbriifolium*, impact egg hatch of Meloidogyne hapla? Journal of Nematology 56:11 (poster presentation)
- Dandurand, L.M., Zasada, I.A., Gleason, C., Kuhl, J., De Jong, W.S., and Watson, P. 2024. PAPAS: Actionable science against nematodes. Journal of Nematology 56:35. (oral presentation)
- Hickman, P., and Dandurand, L.M. 2024. Potato nematodes. Annual Idaho Potato Conference. Pocatello, ID.
- Hickman, P., and Dandurand, L.M. 2024. Impact of varying population densities of the pale cyst nematode, *Globodera pallida* on susceptible and resistant potato. 56:45 (oral presentation)
- Hickman, P., & Dandurand, L.M. 2024. Investigating a potential inhibitive effect of high population densities on hatch of the pale cyst nematode, *Globodera pallida* Journal of Nematology 56:46 (poster)
- Hickman, P., & Dandurand, L.M. 2024. Potato nematodes. Annual Idaho Potato Conference. Pocatello, ID.
- Ibrahim, H., Dandurand, LM, Popova, I. 2024. LC-MS/MS-Qtof Screening and identification of glycoalkaloids from the leafy shoots of *Solanum Sisymbriifolium*", ASA, CSSA, SSSA International Annual Meeting, San Antonio, TX.
- Novy, R. G., Whitworth, J., Kuhl, J. C., Dandurand, L.-M., Zasada, I., De Jong, W., & Wang, X. 2024. Breeding for resistance to potato cyst nematode (PCN) in the russet market class as a component of an integrated approach for PCN management in the U.S. Poster presented at the 12th World Potato Congress, Adelaide, Australia.
- Popova, I. 2024. Biopesticides development and use in organic and conventional crop production, St. Joseph Valley ACS Section, Notre Dame University, Notre Dame, IN.
- Schulz, L., and Dandurand, L.M. 2023. Toxic effects of the trap crop, *Solanum sisymbriifolium*, on the pale cyst nematode, *Globodera pallida*. EPPN Seminar. University of Idaho, Moscow, ID.
- Schulz, L., Popova, I., and Dandurand, L.M. 2023. Toxic effects of the trap crop *Solanum sisymbriifolium* on the pale cyst nematode. Idaho Association of Plant Protection. Rupert, ID.
- Schulz, L., and Dandurand, L.M. 2024. Toxic effects of the trap crop, *Solanum sisymbriifolium*, on the pale cyst nematode, *Globodera pallida*.
- Schulz, L., Popova, I., and Dandurand, L.M. 2024. *Solanum sisymbriifolium* extract effects on *Globodera pallida*. Journal of Nematology 56:52. (oral presentation)
- Schulz, L., Baker, H.V., Zasada, I.A., and Dandurand, L.M. 2024. *Solanum sisymbriifolium* soil amendment effect on *Globodera pallida*. In Journal of Nematology 56:53 (poster presentation)
- Silvestre, R., Dandurand, L.-M., Novy, R., Whitworth, J., Zasada, I. A., and Kuhl, J. C. 2024. Mapping resistance to the potato cyst nematode, *Globodera pallida*, in a russet-type potato population. 6th Symposium of PCN Management, Harper Adams University, United Kingdom.
- Studebaker, G., Zasada, I.A. and Sathuvalli, S. 2024. Impacts of root-knot nematodes (*Meloidogyne chitwoodi* and *M. hapla*) on potato yield and quality in the Pacific Northwest. Journal of Nematology 56:149. (poster presentation)
- Studebaker, G., Zasada, I.A. and Sathuvalli, S.2024. Impacts of root-knot nematodes (*Meloidogyne chitwoodi* and *M. hapla*) on potato yield and quality in the Pacific Northwest. Potato Association of America Meeting, Portland, OR.
- Zasada, I.A. 2024. Sampling for nematodes, what you need to know. to Conference, Kenniwick, WA.
- Zasada, I.A., and Studebaker, G. 2024. Update on PAPAS and nematode field trials. OSU Hermiston Field Day, Hermiston, OR.

# Systems Approach to Nematode Control in U.S. Potato Production

Combined management efforts help potato growers better protect yields and reduce economic losses from plant-parasitic nematodes.




Results of the PAPAS project will help protect potatoes against plant-parasitic nematodes and provide more tools to combat the pests. Our efforts directly help potato growers and the industry as whole by:

Maintaining market confidence in the efficacy and durability of the regulated nematode eradication program.

Developing faster, more reliable molecular diagnostic assays to help with management decisions and provide means to assess risk.

Improving options for nematode control, such as resistant varieties and nematicides.

# Sharing knowledge. Finding solutions.

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**Meet our team of scientists and researchers focused on addressing the industry-wide challenges in managing potato nematodes.**

### PAPAS Project Director:
- Louise-Marie Dandurand, University of Idaho

### Project Co-Directors:
- Walter DeJong, Cornell University
- Cynthia Gleason, Washington State University
- Joseph Kuhl, University of Idaho
- Philip Watson, University of Idaho
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- Sagar Sathuvalli, Oregon State University
- Inna Popova, University of Wisconsin
- Marisol Quintanilla, Michigan State University

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- Zarah Bita Amiri
- Koy Chandler
- Faith Fishburn
- Sarah Hale
- Paige Hickman
- Hashim Ibrahim
- Nataniel Jablonski
- Chloe Lewis
- Hans Mejia
- Lindsay Schulz
- Chandni Shah
- Pia Spychalla
- Gabby Studebaker

**Thank you to our partners who help ensure the sustainability and success of our organization and its mission.**

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Oregon State University | Michigan State University | Washington State University | Wisconsin University of Wisconsin–Madison

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# PAPAS

Actionable Science Against Nematodes

## Delivering New Solutions to Sustainably Manage Potato Nematodes

**PAPAS is on a mission to create better tools and strategies to fight one of the most destructive pests affecting potato crops: plant-parasitic nematodes.**

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