ANNUAL RESEARCH REPORT

(Executive Summaries)

for

2024

California Tomato Research Institute

Published as an industry service by the Grower Members of the California Tomato Research Institute, Inc.

Top Research Outcomes

- **Broomrape:** Rimsulfuron chemigation now in grower hands – confirmation of 80% emergence reduction with no yield loss.
- **Sanitation:** Best practices expanded to harvest, hauling and field equipment, with effective quaternary ammonium options identified and other sanitizers ruled out.
- **Genetic Suppression Potential:** Suberin-enhanced root lines demonstrated in vitro broomrape suppression. Trials in 2025 will test hybrid performance and commercial breeding viability.
- **Transplanters:** 70% labor savings achieved with top-performing automated models.
- **Soil Disease Tools:** KPAM trials clarified performance zones; new Fusarium variety guide released.
- **Fusarium Diagnostics:** qPCR tools cut turnaround time from months to weeks.

Membership ROI

- $1.7 million in outside grants secured for grower-priority projects.
- $100,000 in direct CTRI research costs offset by co-funding from CLFP and CDFA.
- Every $1 of CTRI investment more than matched by outside sources or in-kind returns.

Advocacy & Critical Research Infrastructure Wins

- Led successful push to save the **Tomato Genetics Resource Center (TGRC)** at UC Davis. The new Director hire has been confirmed for 2025.
- CTRI named **Research Program Manager** for the new CDFA Broomrape Board, leveraging our platform at no extra cost to the industry.
- Successfully supported UCANR prioritization for the hiring of a Vegetable Weed Specialist and open Farm Advisor roles in key production regions.
- By advocating for USDA IR-4 and partnering with them for product registrations, we are in the pipeline for two novel broomrape mitigation materials earlier than possible otherwise.

What's Next in 2025

- Submitting a **Section 18 to CDPR for sulfosulfuron** to expand broomrape control.
- Deeper dive into yield differences in "new" vs. "old" tomato fields.
- Strengthening breeder pipelines and pre-breeding strategy through national collaboration.
- **Bindweed Suppression via Chemigation:** Testing whether the broomrape Matrix chemigation protocol can also suppress field bindweed, potentially offsetting labor costs and expanding ROI for growers even in broomrape-free fields.

Why It Matters

CTRI membership isn't charity, it's a business investment with a track record of return. Every dollar goes toward solving the problems that hit your bottom line: broomrape control, faster disease diagnostics, evaluating labor-saving tech, and more. These aren't theoretical tools, they're already making a difference in commercial fields. If you're not yet a member, now's the time to join your neighbors in shaping the future of this crop. For questions or to get involved, reach out to Zach Bagley at (530) 405-9469 or zach@tomatonet.org, or visit www.tomatonet.org.

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INTRODUCTION

What do you get when over two-thirds of California's processing tomato acreage unites behind a shared research mission?

You get broomrape control tools in the ground. You get new diagnostics for faster, smarter field decisions. You get millions in outside funding brought back into grower-priority projects. **You get an industry working together – solving today's problems and gearing up for tomorrow's threats.**

This report marks the **56th year of continuous research** sponsored by the voluntary members of the **California Tomato Research Institute (CTRI)** - growers who fund, direct, and benefit from this work.

CTRI exists to identify critical production challenges and to invest in the research solutions that move our industry forward. Projects are selected and funded by a grower-led Board using member assessments ($0.12 per paid ton in 2024). Since 1968, **more than 750 projects** have been supported - focused on pest management (350+), breeding and evaluation (150+), agronomics (150+), market/process quality (75+), and automation (25+).

In 2024, those investments delivered:

- A broomrape chemigation tool with 80% reduction in emergence, with no yield penalty.
- Side-by-side comparisons of new automated transplanters to assess labor savings and ROI.
- Diagnostic tools that cut Fusarium ID time from months to weeks.
- $1.7M in leveraged external funding secured through CTRI's direct support and engagement.
- Industry-wide wins on research policy, regulatory issues, and resource protection.

We're not just funding research - we're building coalitions between growers, processors, allied industry, and researchers to turn results into action. This report shares both our **impact in 2024** and where we're headed in **2025 and beyond.**

If you're already a member, thank you.

If you're not, take a look at what your neighbors are building.

And to every processor field rep, consultant, or industry partner - this is your reference when someone asks: *What is CTRI doing for me?*

Additional resources can be found by joining the CTRI industry email list: https://bit.ly/CTRIemails.

Questions? Contact Zach Bagley at zach@tomatonet.org or 530-405-9469.

California Tomato Research Institute

CTRI GROWER FUNDED RESEARCH: 2024			
2024 TOTAL AFTER FINAL BOARD DECISIONS & COST SHARING: $590,215			
Broomrape Containment, Control and Management		**Research Lead**	**Institution**
2020 Start	Broomrape: Devt. of Long Term Mgmt. Options: CA Commercial Field Conditions & Contained Research Facility Ongoing Work	Brad Hanson	UC Davis
2021 Start	Developing best equipment sanitation practices for broomrape and other high-profile soil borne pathogens; to mitigate field-to-field spread* - CLFP Co-Funding	Cassandra Swett	UC Davis
2022 Start	Determining the population structure of Phelipanche ramosa and Orobanche aegyptiaca field detections in California	Adam Schneider	UW-LaCrosse
2022 Start	Inducible Suberin for Tomato Drought Tolerance (root architecture)	Siobhan Brady	UC Davis
2023 Start	Detection of Broomrape Infestations with Remote Sensing* - CLFP Co-Funding	Alireza Pourezza	UC Davis
2023 Start	Screening of a VOC Sensor to Identify Broomrape Infestations* - CLFP Co-Funding	Cristina Davis	UC Davis
Agronomic/Water/Nutrient Management			
2023 Start	Evaluation of materials to mitigate negative effects of salinity and high temperatures on yields of processing tomatoes	Tom Turini	UC Extension
2023 Start	Climate Smart Mgmt. Innovations for Improved Soil Quality, and Productivity of CA Processing Tomatoes	Amelie Gaudin	UC Davis / UC Extension
2023 Start	KPAM in Soils with RKN AND Fungal Challenges - Impacts on Yield and Disease Severity	Patricia Lazicki	UC Extension
2024 New	Assessment of Novel Transplanter Performance and Economics	Patricia Lazicki	UC Extension
Germplasm and Variety Development			
1991 Start	C. M. Rick Tomato Genetic Resource Center	Roger Chetelat	UC Davis
2024 New	Leveraging germplasm resources for genetic discovery and deployment of salt stress resilience	Greg Vogel	Cornell
Insect & Invertebrate Management			
2024 New	Decoding Resistance-Breaking Root-Knot Nematodes: A Statewide Survey and the Path to Diagnostic Tools in California's Tomato Fields	Shahid Siddique	UC Davis
Pathogen Management			
2017 Start	Disease diagnosis, pathogen movement / emergence monitoring, new pathogen ID and F4 monitoring for the CA processing tomato industry	Cassandra Swett	UC Davis
2018 Start	Developing an integrated mgmt. strategy for F. falciforme vine decline in processing tomato, including co-management with Fusarium wilt	Cassandra Swett & Brenna Aegerter	UC Davis / UC Extension
2024 New	Evaluation of Insecticide Programs in Processing Tomatoes for the MGMT of BCTV and TSWV Vectors and Viruses	Tom Turini	UC Extension
2017 Start	Viral Diagnostics* - CDFA BCTV Control Board Co-Funding	Robert Gilbertson	UC Davis / UC Extension
Weed Control and Management			
2024 New	Controlling in-row weeds with post plant applications of pre-emergent herbicides	Scott Stoddard	UC Extension

Executive Summary: Field and Lab Research Towards Branched Broomrape Management

Lead Researcher: Brad Hanson, Cooperative Extension Weed Specialist, UC Davis Department of Plant Sciences
Co-PIs: Pershang Hosseini, Postdoctoral Scholar; Matthew Fatino, Postdoctoral Scholar
Collaborators: Eric Schreiner, Schreiner Bros Farming; Gene Miyao, Patricia Lazicki, Cassandra Swett, Coby Goldwasser

Duration of Research: 2019 - Ongoing

CTRI Funding in 2024: $54,347

Main Goal: To develop effective management strategies for broomrape in California tomato fields, addressing its status as a noxious weed and significant regulatory and agronomic challenges.

Objectives:

- Evaluate herbicide treatments, particularly chemigated rimsulfuron and preplant incorporated (PPI) sulfosulfuron.
- Assess new broomrape management strategies, including synthetic strigolactone "suicidal germination," crop susceptibility screening, flooding, and nutrient management approaches.
- Conduct large-scale field trials to validate broomrape control efficacy while ensuring no adverse impacts on tomato yield.

Key Takeaways from 2024 Work:

- **Herbicide Trials:** Chemigated rimsulfuron significantly reduced broomrape emergence (83% reduction in large-scale trials). The "stacked" treatment, including sulfosulfuron and maleic hydrazide, resulted in a 96% reduction.
- **Field Demonstration Trials:** Showed strong suppression of broomrape with no impact on tomato yields, supporting the adoption of chemigation-based herbicide programs. Of which, the rimsulfuron approach is already registered and available for use.
- **Planting Date Trial:** Later planting dates tended to have substantially less broomrape parasitism in a planting date experiment. Where feasible, at-risk or known-infested fields could be planted later in the production cycle to reduce broomrape incidence.
- **Greenhouse & Lab Research:** Synthetic strigolactones effectively stimulated broomrape germination in the absence of a host, reducing parasitism potential. Further greenhouse research and field testing is planned for 2025.
- **Flooding Studies:** Extended flooding, particularly in high temperatures, reduced broomrape germination, indicating a potential management strategy.
- **Crop Susceptibility Screening:** Nearly 50% of 34 tested crops could serve as broomrape hosts, emphasizing the need for crop rotation considerations.
- **Nutrient Management:** Preliminary data suggest that nitrogen fertilizers may influence broomrape seed viability, with ongoing trials expected to provide further insights.

Future Research Directions:

- Optimize application timing and dose refinements for chemigated rimsulfuron and sulfosulfuron to enhance control. Evaluated efficacy and crops safety of additional herbicides in this chemistry.
- Field trials to assess synthetic strigolactone treatments for inducing suicidal germination.
- Continued investigation of nitrogen management as a broomrape control strategy.
- Broader testing of crop rotation and varietal resistance strategies.

Challenges & Considerations:

- **Regulatory Hurdles:** Continued work needed to support future label expansion for sulfosulfuron and other chemistries.
- **Environmental Factors:** Variability in broomrape emergence based on soil moisture, temperature, and agronomic conditions necessitates additional regional research.

Outside Support/Funding:

- Significant in-kind support from growers and industry partners, including Schreiner Bros Farming and AgSeeds Unlimited.
- Associated research supported by CDFA Specialty Crop Block Grant #48529.
- Coordination with the CTRI- and CLFP-funded broomrape sanitation project led by Cassandra Swett.

For the full report, of this or any other 2024 CTRI grower funded project, please visit this link:

https://bit.ly/CTRI2024FullReport

Branched broomrape host screening in dedicated broomrape quarantine greenhouse. Host roots and broomrape attachments visible in the double-pot system (inset). *Photo credit – Hanson Lab, UCD*

California Tomato Research Institute

Executive Summary: Developing Best Management Practices for Mitigating Spread of Branched Broomrape and Other High-Profile Soil-Borne Pathogens

Lead Researcher: Cassandra Swett, Associate Professor of Cooperative Extension Plant Pathologist, UC Davis
Co-PIs: Brad Hanson, Patricia Lazicki, Justine Beaulieu, Pershang Hosseini, Zach Bagley
Collaborators: Brenna Aegerter, Humberto Izquierdo, David Viguie, Anthony Terranova, Carlos Zatarain

Duration of Research: 2021 - Ongoing

CTRI Funding in 2024: $54,158

Main Goal: To develop effective sanitation practices to prevent the spread of broomrape and other soil-borne pathogens, mitigating industry losses and improving regulatory compliance.

Objectives:

- Expand sanitizer recommendations and evaluate their efficacy against broomrape seed and high-impact pathogens.
- Assess the risk and cleaning challenges associated with various field equipment types and seasonal use.
- Develop and beta test an installed harvester cleaning prototype.
- Create outreach materials and best management practices (BMPs) for grower adoption of sanitation protocols.

Key Takeaways from 2024 Work:

- **Sanitizer Efficacy:** Quaternary Ammonia (QAC) is still the only tested sanitizer which works in reducing broomrape seed viability. Star San maintains effectiveness in the presence of debris and works against Fusarium wilt and bacterial canker, but does not reduce broomrape seed or southern blight sclerotia viability. Virkon and hydrogen peroxide showed limited effectiveness in the presence of soil debris.
- **Field Equipment Risk Assessment:** Spring field preparation equipment poses lower risk for transporting pathogens than harvesters which are used in the fall; it is likely that higher soil moisture during harvest leads to higher debris accumulation and thus higher microbial risk on harvesters but this needs to be tested.
- **Cleaning Protocol Development:** Existing commercial grower cleaning practices using pressurized air and QAC effectively reduced microbial risk, particularly on the Agriplanter and mulcher. These studies confirm prior findings that risk of moving pathogens drop when soil debris loads are <1 inch.
- **Industry Recommendations:** Growers now have access to improved sanitation BMPs and consultation support for field sanitation to limit broomrape spread.
- **Educational Materials:** Training slide decks and videos are in development to support grower and industry adoption of best practices.

Future Research Directions:

- Evaluate how seasonal soil moisture variation influences the risk of field equipment in moving pathogens and refine cleaning protocols accordingly.
- Expand sanitizer testing for broomrape seed viability and incorporate findings into an industry-ready sanitation guide.
- Beta test and refine an installed harvester cleaning prototype to improve sanitation efficiency.
- Develop a controlled study on sanitizer application volume and pressure to optimize effectiveness.
- Increase outreach efforts through digital content and in-person training sessions for stakeholders.

Challenges & Considerations:

- **Operational Feasibility:** Balancing the need for rigorous sanitation with the operational constraints of growers and custom harvesters.
- **Regulatory & Adoption Barriers:** Ensuring that sanitation protocols align with industry regulations while remaining practical for large-scale adoption.
- **Pathogen-Specific Strategies:** Tailoring sanitation approaches (such as specific sanitizers) to different pathogen types (parasitic plants, bacteria, fungi, nematodes etc), given varying effectiveness of sanitizers across the different kinds of organisms that cause disease.

Outside Support/Funding:

- Collaboration with grower cooperators, industry partners, and regulatory agencies, including the California Department of Food and Agriculture.
- Support from processing tomato stakeholders, including CTRI and regional farm advisors.

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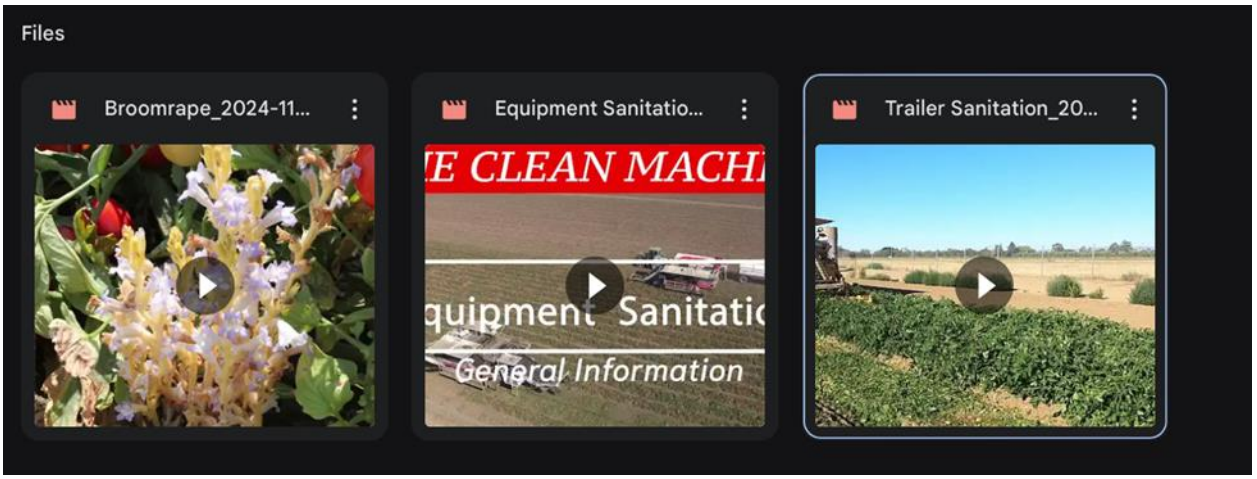

Screenshot of draft videos for the "Team Clean Machine" YouTube channel. *Photo credit – Swett Lab, UCD*

Executive Summary: Population Structure and Invasion History of Branch Broomrape in California

Lead Researcher: Adam Schneider, Ph.D., Assistant Professor, University of Wisconsin-La Crosse

Duration of Research: 2nd Year (Ongoing)

CTRI Funding in 2024: $36,876

Main Goal: To determine the invasion history and genetic structure of *Phelipanche ramosa* (branched broomrape) populations in California and their relationship to other global populations.

Objectives:

- Analyze genetic diversity and structure among historical and contemporary branched broomrape detections in California.
- Evaluate whether branched broomrape populations in California originated from a single introduction or multiple separate introductions.
- Evaluate relationships between Californian populations and Chilean populations of branched broomrape
- Suggest best strategies for containment and mitigation based on invasion history.

Key Takeaways from 2024 Work:

- **Single Introduction Hypothesis:** Genetic analyses strongly support the hypothesis that California's broomrape populations stem from a single historical introduction rather than multiple separate events.
- **Seed Bank Persistence:** Genetic consistency across outbreaks spanning decades suggests that long-lived dormant seeds, rather than new introductions, are responsible for periodic detections.
- **Distinct Genetic Lineages:** California's broomrape populations are distinct from those found in Chile and the eastern United States, confirming separate introductions from Eurasia.
- **Containment Strategy Recommendations:** Given the findings, containment will be most successful early detection and preventing seed movement within California rather than additional scrutiny of imported seed stocks.
- **Potential Reservoir Hosts:** While broomrape in California primarily parasitizes tomatoes, historical samples suggest occasional spillover to other weed species, warranting further study.
- **Peer-reviewed publication**: Some of the results have been published in a freely available, peer-reviewed journal article: https://bsapubs.onlinelibrary.wiley.com/doi/full/10.1002/ajb2.16456

Future Research Directions:

- Expand genetic comparisons between American and European populations to better understand the origin of the California introduction.
- Investigate potential non-tomato host species that may serve as reservoirs for branched broomrape persistence.

Challenges & Considerations:

- **Regulatory and Eradication Efforts:** Findings support current early detection and containment efforts as essential for preventing further spread.
- **Long Dormancy Period:** Management strategies should consider the possibility of viable broomrape seeds persisting in the soil for decades.
- **International Trade and Biosecurity:** While current evidence suggests no direct introduction from other regions, ongoing biosecurity measures should be maintained to prevent future introductions from contaminated seed sources.

Outside Support/Funding:

- Research collaboration with herbaria and private growers provided expanded access to historical sample and contemporary samples
- Supplementary funding from the University of Wisconsin-La Crosse supported expanded genetic comparisons with branched broomrape outside of California.

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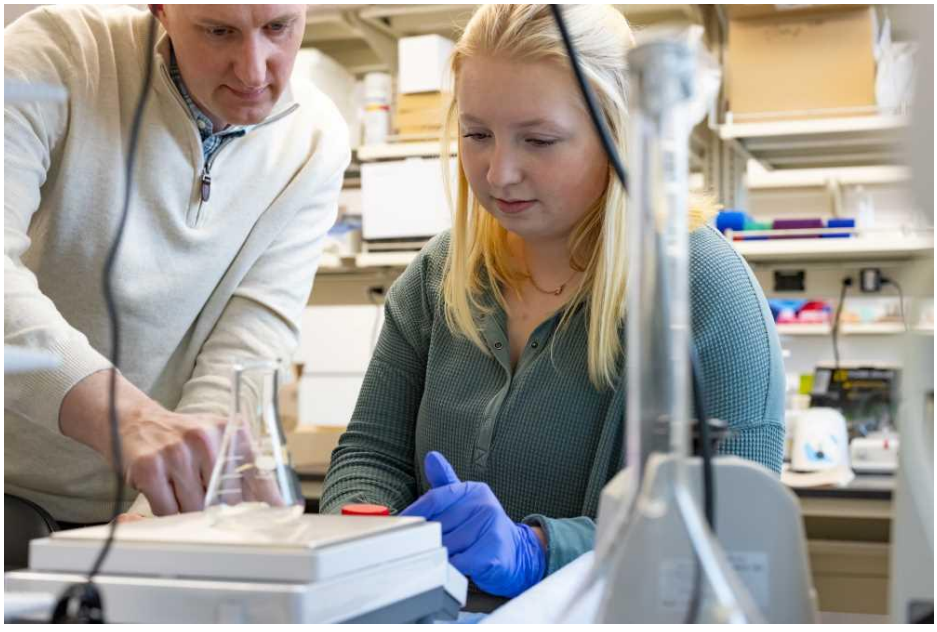

Adam Schneider, University of Wisconsin La Crosse assistant professor of biology, works with his research assistant Ellie Euler. *Photo credit – UWL*

California Tomato Research Institute

Executive Summary: Inducible Suberin for Tomato Drought Tolerance

Lead Researcher: Siobhan Brady, Ph.D., Department of Plant Biology and Genome Center, UC Davis

Duration of Research: 2021 - 2025

CTRI Funding in 2024: $87,866 (pending results for Objective 2)

Main Goal: To enhance drought tolerance in processing tomatoes by increasing suberin production in root systems, potentially mitigating water stress, broomrape infestation, and nematode infections.

Objectives:

- Identify commercially relevant tomato germplasm with variable suberin content.
- Develop tomato lines with targeted increased suberin production in the root exodermis.
- Evaluate the impact of suberin on drought tolerance, fruit yield, and pathogen resistance.
- Assess feasibility of using natural variation or CRISPR-based gene editing to fix suberin traits for commercial production.

Key Takeaways from 2024 Work:

- **Germplasm Screening:** Identified a promising commercial line with inducible suberin production under drought conditions.
- **Genetic Engineering Progress:** Developed transgenic tomato lines with targeted suberin enhancement using transcriptional regulators.
- **Field Readiness:** Successful hybridization of top-performing lines; field testing planned for 2025.
- **Pathogen Resistance:** Initial findings suggest increased suberin deposition may contribute to broomrape and nematode resistance; further validation needed.
- **Industry Collaboration:** Working with HM Clause and Bayer to translate research findings into commercial breeding strategies.

Future Research Directions:

- Conduct greenhouse and field trials in 2025 to confirm drought tolerance and yield benefits.
- Test pathogen resistance traits, focusing on broomrape suppression and nematode deterrence.
- Optimize genetic modifications to minimize growth penalties while maximizing suberin production.
- Expand collaborations with industry partners for commercial seed integration.

Challenges & Considerations:

- **Growth Trade-offs:** Some engineered lines exhibited reduced growth, requiring further optimization.
- **Regulatory and Industry Adoption:** Path to commercialization involves additional validation and regulatory approvals.

- **Field Conditions:** Ensuring laboratory results translate effectively to commercial field production settings.

Outside Support/Funding:

- In-kind support from HM Clause for germplasm selection and breeding guidance.
- Additional funding from USDA, HHMI, and NSF for personnel and laboratory resources.

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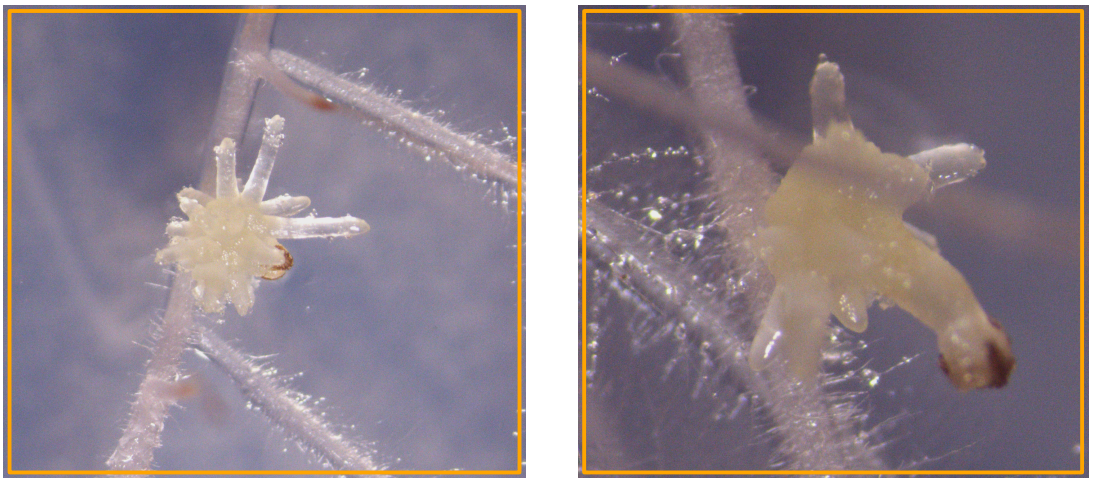

***In vitro* branched broomrape infection system.**

Executive Summary: Remote Sensing for Early Detection of Broomrape in Tomato

Lead Researcher: Alireza Pourreza, Ph.D., UC Davis
Co-PI: Mohsen B. Mesgaran, UC Davis
Collaborator: Hanan Eizenberg, Newe Ya'ar Research Center, ARO, Israel

Duration of Research: 2023 - Ongoing
CTRI Funding in 2024: $18,173

Main Goal: To develop a scalable, remote sensing-based monitoring system for early detection of broomrape infestations in tomato fields, enabling targeted management strategies.

Objectives:

- Integrate satellite imagery to detect broomrape infestations at a broad scale.
- Utilize drone-based imaging for high-resolution detection and mapping.
- Develop machine learning models to enhance detection accuracy.

Key Takeaways from 2024 Work:

- **Drone-Based Imaging:** Successfully used multispectral and hyperspectral imaging to differentiate broomrape-infested plants from healthy ones.
- **Satellite Monitoring:** Sentinel-2 satellite imagery effectively identified spectral signatures associated with broomrape infestations at 500+ Growing Degree Days (GDD).
- **Machine Learning Models:** Developed AI-based models, including LSTM and XGBoost, achieving high accuracy in detecting infested plants.
- **Scalability:** Demonstrated potential for integrating remote sensing into large-scale monitoring to improve early detection and intervention strategies.

Future Research Directions:

- Further refine models for enhanced detection across diverse environmental conditions.
- Conduct additional field trials to validate detection accuracy across different infestation levels.
- Develop user-friendly tools for growers to implement remote sensing technologies.

Challenges & Considerations:

- **Environmental Variability:** Spectral signatures can be influenced by weather and soil conditions, requiring adaptive modeling.
- **Data Processing Needs:** High-resolution remote sensing data requires substantial computational resources for real-time analysis.
- **Grower Adoption:** Ensuring practical usability and accessibility for farmers remains a priority.

For the full report, of this or any other 2024 CTRI grower funded project, please visit this link:

https://bit.ly/CTRI2024FullReport

Executive Summary: Screening of a VOC Sensor to Identify Broomrape Infestations

Lead Researcher: Cristina E. Davis, Ph.D., UC Davis
Collaborator: Brad Hanson, Ph.D., UC Davis

Duration of Research: 2023 - Ongoing
CTRI/CLFP Co-Funding in 2024: $68,828

Main Goal: To develop a portable sensor that can detect broomrape infestations in tomato fields by analyzing volatile organic compounds (VOCs) emitted by infected plants, enabling early detection before the parasite emerges.

Objectives:

- Optimize collection of tomato plant VOCs and refine machine learning models for broomrape detection.
- Deploy and test a field-ready sensor for real-time monitoring.

Key Takeaways from 2024 Work:

- **Greenhouse Study:** Improved VOC collection methods and doubled the sample size, achieving 80% detection accuracy to identify infected tomato plants.
- **Early Detection Potential:** Broomrape-induced VOC changes were detectable as early as three weeks post-infection, weeks before broomrape emerged from the soil.
- **Sensor Development:** Constructed a mobile VOC sensor for field use in nearby Woodland, CA, but delays prevented real-world testing during tomato plant growing season.

Future Research Directions:

- Conduct field trials with the mobile VOC sensor in commercial tomato farms.
- Further refine AI-driven detection models for higher specificity and sensitivity, and look at potentially confounding factors (e.g., other crop pests, abiotic and biotic stressors)
- Explore integration of VOC-based detection with other remote sensing tools.

Challenges & Considerations:

- **Field Deployment Delays:** Sensor completion was delayed, preventing field testing within the funding cycle. The team currently has a pending proposal with CLFP for field testing, and plan to apply for USDA funds for long-term financial investment.
- **Potentially Confounding Variables:** VOC profiles may vary under real-world conditions, requiring field validation.
- **Commercialization Pathway:** Further funding is needed to transition this technology to widespread grower adoption.

Outside Support/Funding: Have applied for CLFP funds, and will be applying for USDA funds.

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https://bit.ly/CTRI2024FullReport

Executive Summary: Evaluation of Materials to Mitigate Negative Effects of Salinity and High Temperatures on Processing Tomato Yields

Lead Researcher: Thomas A. Turini, UC ANR, Fresno County Cooperative Extension
Co-PIs: Isaya Kisekka, Ph.D., UC Davis; Felix Ogunmokun, UC Davis

Duration of Research: 2023 - Ongoing
CTRI Funding in 2024: $21,312

Main Goal: To evaluate biostimulant and soil surfactant applications as potential solutions for mitigating yield losses in processing tomatoes due to heat, drought, and salinity stress.

Objectives:

- Assess the effectiveness of **Skeepon**, an acetic acid-based plant activator, in reducing stress symptoms and improving yield.
- Evaluate **Proliferate**, a soil surfactant, for improving water distribution in subsurface drip irrigation systems.

Key Takeaways from 2024 Work:

- **Skeepon Trial:** Under severe heat and drought conditions, no significant improvements in yield or fruit quality were observed.
- **Proliferate Trial:** Study was abandoned due to irrigation infrastructure issues: Results from the 2023 study showed no detectable treatment effect.
- **Extreme Conditions:** Both trials faced unexpected irrigation challenges and prolonged high temperatures, limiting effectiveness.
- **Future Considerations:** Evaluation of these materials under more typical stress conditions rather than extreme drought and heat experienced during these studies may produce different results.

Future Research Directions:

- Conduct trials under moderate stress levels more reflective of commercial conditions.
- Address irrigation inconsistencies at research sites to ensure uniform trial conditions.
- Explore alternative application methods or combinations with other stress-mitigation techniques.

Challenges & Considerations:

- **Infrastructure Issues:** Irrigation system inconsistencies significantly impacted study outcomes.
- **Heat Stress:** High temperatures exceeding 110°F during critical growth stages posed severe challenges.
- **Practical Implications:** Findings indicate these products may not provide benefits under extreme stress but warrant further testing in milder conditions.

For the full report, of this or any other 2024 CTRI grower funded project, please visit this

link: https://bit.ly/CTRI2024FullReport

Executive Summary: Climate Smart Management Innovations for Improved Soil Quality and Productivity in California Processing Tomatoes

Lead Researcher: Amélie Gaudin, Ph.D., UC Davis
Co-PIs: Ryan Vroegindewey (Campbell Soup Company), Sarah Light (UCCE), Brenna Aegerter (UCCE)
Graduate Student Researchers: Peter Geoghan (UC Davis) and Mariana Munoz-Araya (UC Davis)

Duration of Research: 2023 - 2024
CTRI Funding in 2024: $18,997

Main Goal: To evaluate Climate Smart (CS) agricultural practices for improving soil health, yield resilience, and input efficiency in California's processing tomato systems.

Objectives:

- Categorize and assess the diversity of CS practices used by processing tomato growers.
- Quantify the impacts of CS practices on soil health indicators and yield outcomes.
- Provide science-based recommendations for scalable CS adoption.

Key Takeaways from 2024 Work:

- **Management Scoring Index:** Developed to assess the degree of CS adoption, identifying trends in soil carbon storage and microbial biomass.
- **On-Farm Evaluations:** Conducted soil health and productivity assessments on 18 commercial fields with varying levels of CS adoption.
- **Soil Health Benefits:** Fields with stacked CS practices (e.g., cover crops, compost, crop rotations, reduced tillage, livestock grazing) showed higher microbial activity, improved aggregate stability, and increased water-holding capacity.
- **Yield Comparisons:** Preliminary findings, from review of the Russell Ranch long term data, suggests that moderate CS adoption supports comparable yields while improving soil function.

Future Research Directions:

- Conduct long-term soil health monitoring to measure cumulative benefits of CS practices.
- Expand field trials to refine best management recommendations for CS adoption.
- Develop a best management practice (BMP) guide to assist growers in transitioning to CS systems.

Challenges & Considerations:

- **Economic Viability:** Ensuring cost-effective implementation of CS practices remains a priority.
- **Transitional Yield Variability:** Short-term yield fluctuations need to be better understood for grower adoption of climate smart practices.
- **Site-Specific Recommendations:** Variability in soil response underscores the need for context specific management strategies.

Outside Support/Funding: CDFA Specialty Crop Block Grant Program and Campbell Soup Company.

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https://bit.ly/CTRI2024FullReport

Executive Summary: Quantifying the Effects of K-Pam on Soil-Borne Disease and Yields in Lower Sacramento Valley Processing Tomato Fields

Lead Researcher: Patricia Lazicki, Ph.D., UCCE Vegetable Crops Advisor, Yolo, Solano, and Sacramento Counties
Cooperating Personnel: Blake Harlan, Chris McAllister (Harlan Family Ranch); Cassandra Swett (UC Davis); Spencer Bei, Aaron Black (Robben Ranch; 2023 trials)

Duration of Research: 2023 - Ongoing
CTRI Funding in 2024: $4,725

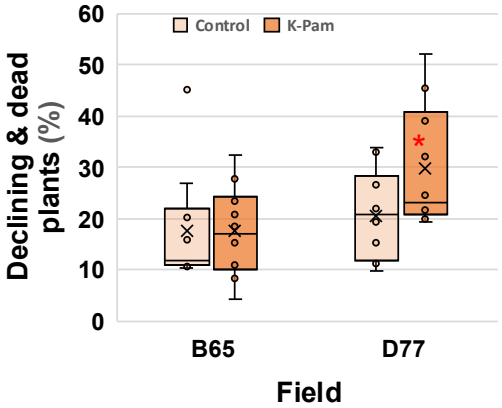
Main Goal: Quantify the effect of fumigation with K-Pam on: a) incidence and severity of soil-borne pathogens, especially the *Fusarium falciforme* complex of pathogens responsible for causing the disease fusarium stem rot and vine decline (FRD) and b) fruit yield and quality.

Objectives:

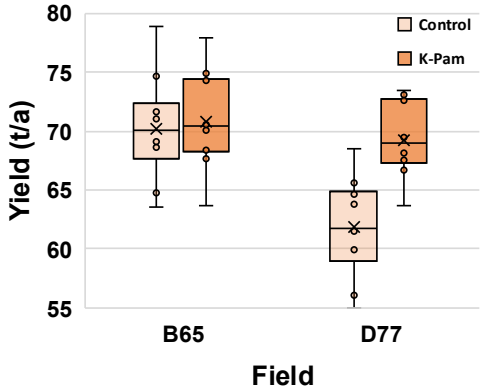
- Measure the impact of K-Pam on Fusarium stem rot and decline (FRD) and other soilborne pathogens.
- Assess effects on fruit yield and quality

Key Takeaways from 2024 Work:

- **Disease Impact:** Disease pressure was relatively low at both sites. K-Pam had no significant effect on disease severity at Field B65, where Fusarium and Verticillium wilt were present. At Field D77, where FRD was the only confirmed disease, treated plots paradoxically had a higher proportion of dead and declined plants and NDVI readings were significantly lower, indicating the control plots had larger, healthier vines.
- **Yield Effects:** Despite increased plant decline, K-Pam-treated plots at D77 yielded 7.5 t/a more than control plots, and had a significantly lower proportion of green fruit. At B65, no significant yield benefits were observed.



Percentage of dead and severely declined plants just before harvest (n=10)



*Total yields at B65 and D77 sites. **Indicates significant difference between treatments within a site at p<0.001 (n=10).*

- **Uncertain Mechanisms:** The increased yields but greater vine decline at harvest in D77 suggest K-Pam may provide benefits unrelated to FRD management, such as influencing nutrient availability or early-season plant vigor.
- **Past Findings:** These results are consistent with prior research indicating that K-Pam sometimes but not always boosts yields significantly. Past trials have shown yield increases of up to 26 t/a under certain conditions, but also cases where no benefits were observed. Yield increases are not always associated with lower disease incidence or severity.

Future Research Directions:

- Assess data from trials conducted since 2019 to help isolate factors that influence K-Pam's effectiveness in different fields and seasons.
- Examine whether K-Pam provides any additional benefits compared to or in combination with other management practices (e.g. a tolerant variety, or application of other products whose mode of action is to improve nutrient availability or root competitive ability) in FRD-infested fields

Challenges & Considerations:

- **Variable Efficacy:** K-Pam's effectiveness varies widely between sites and years. The reasons for this variation are not yet clear, making broad recommendations difficult.
- **Cost vs. Benefit:** At around $300/acre for a 30 gal/acre application, K-Pam application is a significant expense. Extrapolating yield averages across the field, fumigation with K-Pam resulted in a loss of $243.8/acre at site B65, but a profit of $543.75 at site D77 after accounting for K-Pam expense. More precise guidance is needed to ensure growers only apply it when a high likelihood of return exists.
- **Environmental & Regulatory Factors:** K-Pam is a restricted-use material with potential regulatory scrutiny over long-term environmental impacts. Understanding its exact mode of action may help determine whether its benefits can be replicated through other, less restrictive means.

Outside Support/Funding:

- Supported by CTRI and additional diagnostics conducted through UC Davis plant pathology research.
- Collaboration with industry partners and growers

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Executive Summary: Assessment of Novel Transplanter Performance and Economics

Lead Researcher: Patricia Lazicki, Ph.D., UCCE Vegetable Crops Advisor, Yolo, Solano, and Sacramento Counties
Co-PI: Ahmed Kayad, Ph.D., Agricultural Engineering Advisor, UCANR Intermountain Research and Extension Center

Duration of Research: 2023 - Ongoing
CTRI Funding in 2024: $9,305

Main Goal: To evaluate the performance and economic feasibility of automated transplanters compared to traditional planting systems in California's processing tomato production.

Objectives:

- Conduct field trials to compare four transplanter types in planting uniformity, stand establishment, and overall efficiency.
- Assess economic viability, including purchase and maintenance costs, labor requirements, and planting speed.
- Identify potential benefits and limitations of different planters for tomato growers.

Key Takeaways from 2024 Work:

- **Agronomic Performance:** Automated planters exhibited a higher incidence of planting skips than traditional planters. The Agriplanter had the most skips, while the FMAX carousel planter had the fewest.
- **Stand Establishment:** The FMAX also tended to have the fewest stand gaps 3 weeks after planting. However, the large majority of these skips and gaps were 2 plants long or less, and were relatively rare for all planters.
- **Yield and Quality:** No differences in fruit yield or quality were found among planter types.
- **Cost analysis:** Representative costs (purchase, maintenance, diesel, labor) associated with each planter were obtained through interviews with distributors, growers and custom planters and are presented in the report.
- **Strengths, Weaknesses, Opportunities, Threats:** Interviewees cited lower labor requirement and greater speed as main benefits of automated planters. They noted performance was poorer with cracked trays, uneven or leggy plants, or poor bed prep.

Future Research Directions:

- Evaluate adaptability of automated systems to different field conditions and transplant quality variations.

Challenges & Considerations:

- **Labor Savings vs. Initial Costs:** While automated transplanters reduce labor costs, high purchase expenses may offset savings for smaller operations (<~250 acres).
- **Field Adaptability:** Success depends on well-prepared beds and high-quality transplants; growers may need to adjust standard practices, and good communication with the nursery is key.

Estimated costs, from grower & distributor interviews. *Costs reflect only those directly associated with the machine itself, not the full cost of the planting operation. Calculations exclude forklift/water truck operator.*

		AgriP 3-row	Futura 3-row	FMAX 3-row	Finger 3-row
	Acres per shift (seasonal avg)*	16 – 30	10 – 20	10 - 11	11 - 12
	Shift length (hr)	10 – 12	8	8 - 8.5	8 - 8.5
	Acres/ man-hr (seasonal avg)**	0.5 - 0.9	0.4 - 0.8	0.2 - 0.3	0.1 - 0.2
	Avg crew wage($/hr)***	$80	$80	$137	$205
	Avg labor cost ($/acre)	$29 – 44	$32 – 43	$100 - 117	$137 - 145
	Estimated diesel cost ($/acre)[$]	$5.44 - $7.25	$7.16	$4.63	$3.86
	Estimated maintenance cost ($/acre)[$$]	$3.00	$5.10	$4.50	$7.00
	Total average running costs ($/acre)	**$45.85**	**$49.76**	**$117.63**	**$151.86**
Cost per acre (5-year depreciation schedule)	Example purchase price	$352,000	$198,000	$63,000	$7500 (used)
	1000 acre/yr	$116.25	$89.36	$130.23	$153.36
	1500 acre/yr	$92.78	$76.16	$126.03	$152.86
	2000 acre/yr	$81.05	$69.56	$123.93	$152.61

*Grower and distributor-reported seasonal estimate (integrates breaks, cleaning, maintenance)

** Calculated using grower estimates of daily acreage, crew size, and shift length; not including water truck/forklift
Assumes 3 crew on automated planters

*** Calculated using averages of grower-reported wages for farm and contract labor
(Contract wage: base: $16; supervisor: $18; contract fee: 42%. Farm wage: base: $19, machine-operator: $22; benefits: 35%)

[$] Calculated using grower reported diesel usage (per hour or per acre), California 5-yr average diesel cost of $4.63/gal

[$$] As reported by Ray Yeung (AgriPlanter, FMAX, Finger) and Todd Diederich and Brad Strock (Futura)

Outside Support/Funding:

- Collaboration with equipment manufacturers and commercial tomato growers and custom planting operations; equipment sanitation provision by local seed retailer and harvest logistics accommodation from the processor at two of the sites.

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https://bit.ly/CTRI2024FullReport

The Four planters compared in this study. ***Image Credit – Patricia Lazicki***

Executive Summary: Tomato Genetics Resource Center (TGRC) 2024 Annual Progress Report

Lead Researcher: Roger Chetelat, Ph.D., Director/Curator, UC Davis
Co-Investigators: Xiaoqiong Qin (Postdoctoral Researcher), Matt Valle (Assistant Curator)

Duration of Research: Ongoing
CTRI Funding in 2024: $25,000

Main Goal: To maintain and expand the genetic diversity of tomato germplasm collections, facilitate research and breeding advancements, and support the global scientific community with curated genetic resources.

Objectives:

- Preserve and distribute wild and cultivated tomato germplasm for research and breeding.
- Conduct genetic characterization and trait evaluation for key accessions.
- Advance studies on heat tolerance, seed vigor, and reproductive barriers in tomato breeding.
- Maintain international collaboration to ensure the long-term security of tomato genetic resources.

Key Takeaways from 2024 Work:

- **Germplasm Collection:** Maintained a collection of 4,536 accessions, performed 278 seed increases, of which 63 were of wild species accessions, and performed 31 progeny tests.
- **New Acquisitions:** Added 'Healani,' a disease-resistant cultivar from Hawaii, and recovered an 'extinct' accession of *S. corneliomulleri* from a German genebank.
- **Seed Viability & Storage:** 690 seed germination tests conducted; 258 samples sent to USDA's National Laboratory for Genetic Resources Preservation for backup storage.
- **Distribution & Utilization:** 4,179 seed samples distributed to 163 researchers in 15 countries; 92% utilization rate relative to size of the collection. Research using TGRC stocks led to over 139 new scientific articles, patents, theses and other publications.
- **Breeding Support:** Strong industry demand for pre-bred lines such as introgression lines (ILs) and recombinant inbred lines (RILs).
- **Research Contributions:** Identified QTLs for seed vigor and heat stress tolerance; conducted CRISPR-based gene editing to validate seed dormancy-related genes.
- **Pollen Rejection Mechanisms:** Advanced studies on genetic barriers in wide crosses using *S. pennellii* and *S. sitiens* introgression lines.
- **Digital Documentation:** Expanded database functionalities, redesigned labels for seed distribution, and improved online search tools for accessions.

Future Research Directions:

- Continue refining seed vigor and heat tolerance breeding strategies.
- Expand collaborations for mapping resistance traits and stress tolerance mechanisms.

Future Collection Management Goals

- Improve documentation and accessibility of TGRC germplasm data.

- Improve long-term storage strategies for high-value germplasm.

Challenges & Considerations:

- **Regulatory Hurdles:** Increasing phytosanitary restrictions affecting international seed shipments.
- **Resource Allocation:** Balancing collection maintenance with expansion and new research initiatives.
- **Adoption & Utilization:** Ensuring that germplasm resources meet industry needs for disease resistance and climate adaptation.
- **TGRC Leadership:** The Plant Sciences is currently recruiting an Assistant Professor / Director to lead the TGRC.

Outside Support/Funding:

- In 2024 the TGRC received support from the USDA, the Foundation for Food and Agriculture Research (for a research project which has been completed), and growers, processors and private seed companies via the TGRC endowment or direct support.
- Note that future funding from the USDA is uncertain going forward.

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Xiaoqiong Qin sampling plants in the greenhouse. Qin was featured in an article by Trina Kleist on the *S sitiens* introgression lines. *Photo credit – TGRC, UCD*

California Tomato Research Institute

Executive Summary: Leveraging Germplasm Resources for Genetic Discovery and Deployment of Salt Stress Resilience

Lead Researcher: Greg Vogel, Ph.D., Cornell University
Co-PI: Neil Mattson, Ph.D., Cornell University

Duration of Research: 2024 - Ongoing
CTRI Funding in 2024: $23,475

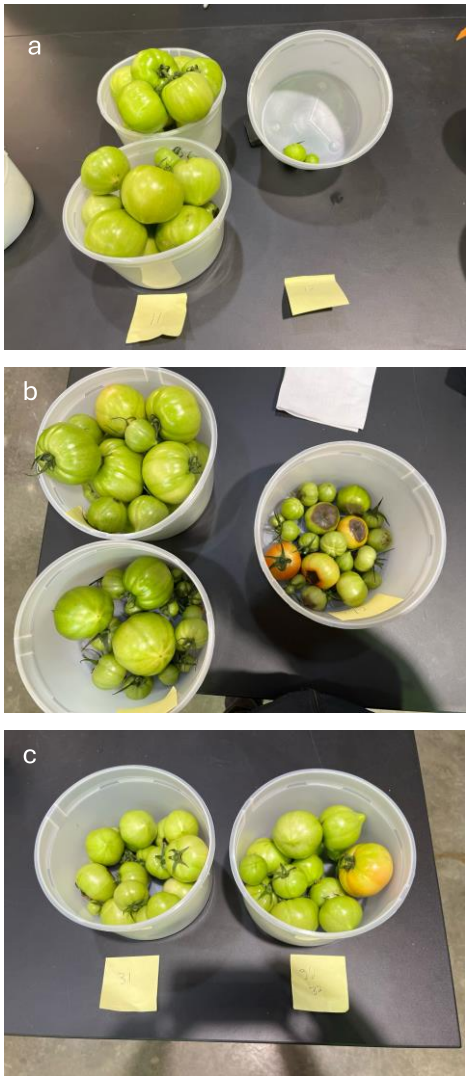
Main Goal: To identify and characterize salt stress resilience genes from wild tomato species *Solanum sitiens* for use in commercial tomato breeding programs to mitigate yield losses in saline soils.

Objectives:

- Validate the salt stress resilience of *S. sitiens* and its introgression lines (ILs).
- Increase seed availability of IL populations for future breeding and research.
- Identify ILs with superior salt stress resilience for breeding and molecular characterization.

Key Takeaways from 2024 Work:

- **Salt Tolerance Screening:** Greenhouse trials demonstrated that most *S. sitiens* ILs exhibit greater salt stress resilience compared to domesticated tomato (*S. lycopersicum*). While all accessions experienced yield declines under salt stress, 25 out of 27 ILs showed lower percent yield reduction than the *S. lycopersicum* parent LA4354.
- **Introgression Effects:** The IL with the slightest yield decline under salt stress displayed a 45% decline in yield, compared to 78% for LA4354.
- **Germplasm Development:** Seed stocks were increased for 35 ILs, providing a foundational resource for future breeding and genetic studies.
- **Breeding Insights:** Preliminary data suggest that multiple genes contribute to salt tolerance, distributed across different chromosomes. Further fine-mapping is needed to determine key loci for future deployment in breeding.



Above: *Green fruit harvests at the conclusion of the experiment for ILs representing a range of degrees of salt sensitivity. Top – LA5290, control on the left and salt on the right. Middle – LA5259, control on the left and salt on the right. Bottom – LA5264, control on the right and salt on the left.*

Future Research Directions:

- Test gene pyramiding strategies to assess the effect of combinations of multiple *S. sitiens* introgressions.
- Fine-map genetic loci associated with salt tolerance to develop molecular markers and genetic resources for breeding.
- Conduct field trials to validate salt resilience performance under commercial growing conditions.
- Develop breeder-ready donor lines and share findings with the tomato seed industry.

Challenges & Considerations:

- **Environmental Variability:** Greenhouse-based results must be confirmed in field trials under real-world conditions.
- **Linkage Drag:** Some salt-tolerant ILs also exhibit reduced overall vigor or other negative traits, requiring further selection and refinement.
- **Industry Integration:** Adoption of salt-tolerant germplasm will depend on balancing stress resilience with high-yield potential.

Outside Support/Funding:

- Additional funding from the Cornell College of Agriculture and Life Sciences.

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California Tomato Research Institute

Executive Summary: Decoding Resistance-Breaking Root-Knot Nematodes in California Processing Tomato Fields

Lead Researcher: Shahid Siddique, Ph.D., UC Davis
Duration of Research: 2024 - Ongoing
CTRI Funding in 2024: $33,422

Main Goal: To identify and map resistance-breaking root-knot nematode (RKN) populations in California tomato fields, improving diagnostic tools and guiding management strategies for growers.

Objectives:

- Conduct statewide sampling to isolate and identify resistance-breaking RKN populations.
- Sequence RKN field isolates to analyze genetic adaptations linked to resistance-breaking.
- Develop rapid diagnostic tools to detect resistance-breaking isolates.
- Identify alternative host crops for resistance breaking RKNs

Key Takeaways from 2024 Work:

- **Statewide Sampling & Mapping:** Collected 14 root-knot nematode isolates from processing tomato fields across California, mapped their distribution, and confirmed their resistance-breaking capacity.
- **Field & Lab Testing:** Verified resistance-breaking isolates through greenhouse assays on resistant and susceptible tomato varieties. All isolates induced galling at stable temperatures (25–27°C), confirming their ability to overcome Mi-1 resistance.
- **Genomic Analysis:** Began single egg mass isolations to purify nematode populations before sequencing. Three isolates have undergone DNA extraction, with full-genome sequencing planned for March 2025.
- **Secondary Pathogen Risk:** Field observations suggest that root-knot nematode infestations often coincide with secondary infections from Fusarium, Phytophthora, and Verticillium spp.
- **Diagnostic Tool Development:** Preliminary work is underway on a molecular diagnostic primer to rapidly detect resistance-breaking RKN strains, potentially reducing identification time from months to weeks.
- **Industry Engagement:** Collaborated with UC Riverside and agricultural partners to expand sampling efforts and enhance grower awareness.

Future Research Directions:

- Complete genome sequencing of all collected resistance-breaking isolates to identify key genetic markers associated with resistance-breaking.
- Validate diagnostic tools for rapid field detection.
- Expand sampling efforts to refine statewide distribution maps and inform grower management strategies.
- Investigate alternative host crops to determine RKN survival and spread mechanisms.

Challenges & Considerations:

- **Sampling Gaps:** Current data cover a small fraction of California's processing tomato acreage; further sampling is needed for a comprehensive assessment.
- **Environmental Influence:** Resistance-breaking behavior may vary by region, temperature, and soil conditions.
- **Grower Adoption of Diagnostics:** Ensuring practical, cost-effective implementation of new diagnostic tools and alternative hosts will be key to industry-wide adoption.

Outside Support/Funding:

- Collaboration with UC Riverside and UC Cooperative Extension for expanded sampling.
- Additional funding from USDA NIFA AFRI for whole-genome sequencing and molecular diagnostics development.

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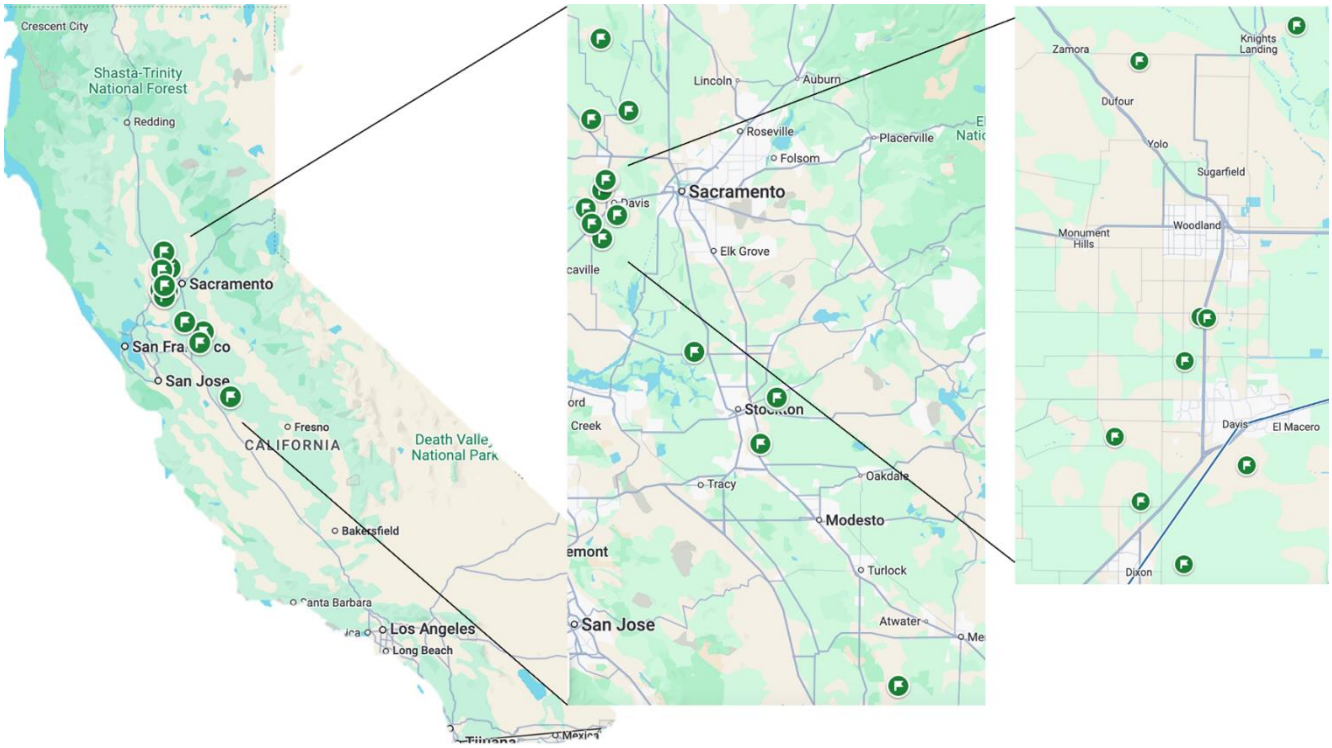

Collection sites of RKN resistance breaking populations.

Executive Summary: Disease Diagnosis, Pathogen Monitoring, and Outreach Support for California Processing Tomatoes

Lead Researcher: Cassandra Swett, Ph.D., UC Davis
Co-PIs: Frank Martin (USDA-ARS), Gary Vallad (University of Florida), Dave Geiser (Penn State)
Collaborators: Brenna Aegerter, Patricia Lazicki, Tom Turini, Scott Stoddard, Zheng Wang, Jaspreet Sidhu, Kamyar Aram, Yu Chen Wang

Duration of Research: Ongoing
CTRI Funding in 2024: $39,915

Main Goal: To provide accurate disease diagnosis, monitor emerging pathogens, and develop diagnostic tools to support California tomato growers in making informed management decisions.

Objectives:

- Diagnose and monitor tomato diseases across California to detect emerging threats.
- Develop and refine diagnostic tools for more accurate and rapid pathogen identification.
- Monitor for resistance-breaking strains of Fusarium wilt and Fusarium crown and root rot.
- Conduct outreach to communicate disease management strategies to growers and industry professionals.

Key Takeaways from 2024 Work:

- **Disease Diagnosis:** Processed 112 tomato samples from 19 counties, with putative Fusarium crown and root rot (38%) and Fusarium stem rot and decline (35%) being the most common diagnoses.
- **New Pathogen Detections:** Identified *Plectosphaerella cucumerina*, a previously unreported pathogen in California tomatoes, potentially causing wilt and root rot—cultures saved for downstream studies. Detected Alternaria stem canker (*A. solani*) in several fields–this is the first time this disease has been detected in the state in over a decade.
- **Resistance-Breaking Monitoring:** Established that Fusarium wilt detections in resistant cultivars were all race 3; race 4 remains undetected in California tomatoes. Resistance-breaking Fusarium crown and root rot was detected in five fields across four cultivars—the third year that potential resistance breaking has been detected and the first year with detection beyond a single cultivar. Confirmed that previous detections of Fusarium crown and root rot in a resistant cultivar were not resistance breaking.
- **Diagnostic Tool Development:** Beta-tested a new qPCR assay for *Fusarium oxysporum* identification, reducing false positives and improving diagnostic turnaround from over a month to 1-2 weeks. Progress was made in Fusarium stem rot and decline diagnostic tools, with several potential diagnostic markers identified based on analysis of over 70 genomes.
- **Outreach & Education:** Organized a Vegetable Disease Field Day and a Tomato Disease Researchers Roundtable, presented at industry events, developed a new ANR 800 series article on Fusarium wilt management, and made progress in development of a new UC IPM tomato disease diagnostic guide.

Future Research Directions:

- Expand disease monitoring efforts to track pathogen movement and resistance trends and continue to provide updates on disease trends to the community through outreach efforts.
- Expand diagnostic tool development for Fusarium species, particularly transfer of new market technology for Fusarium wilt to a more rapid diagnostic method using RPA, to reduce diagnostic time to 1-2 days.
- Improve diagnostic training for growers and advisors to enhance in-field identification capabilities.
- Conduct trials on stress-induced susceptibility to Fusarium wilt in resistant cultivars.

Challenges & Considerations:

- **Emerging Pathogens:** Potentially new pathogens continue to be detected, underscoring the need for continuous monitoring. If potentially new pathogens become common and are impacting yields, the existing isolate collection can be leveraged to conduct studies to confirm pathogenicity and development management tools.
- **Resistance Stability:** Increased detections of Fusarium in resistant cultivars raise concerns about environmental factors influencing resistance breakdown.
- **Diagnostic Adoption:** Ensuring that new diagnostic tools are widely accessible, cost-effective for growers and provide timely diagnosis.

Outside Support/Funding:

- Additional funding from USDA, NPDN, CDFA-DPR, and UC Davis research programs.
- Collaborations with UC IPM and industry stakeholders to enhance diagnostic resources.

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Table 1. Summary of Fol race emergence, resistance deployment and resistance breaking

Event	Fol race			
	Race 1	**Race 2**	**Race 3**	**Race 4**
Detected in CA	1940s	1970	1987	**Anticipated 2022-2028**
Resistance gene	I	I2	I3	none known
Years to initially find R gene	50 years	10 years	5 years	na
Resistance initially found	1939	1955	1980	na
Years from detection to resistance use in CA	15 years	5 years	22-29 years	Unknown
Resistant cultivars used in CA starting in	1959	1975	2009-2016	na
Years effective in CA	**11 years**	**12 years**	**Anticipate ~12 years**	**na**

Executive Summary: Developing an Integrated Management Strategy for Fusarium Stem Rot and Decline (FRD) in Processing Tomatoes

Lead Researcher: Cassandra Swett, Ph.D., UC Davis
Co-PIs: Myles Collinson (UC Davis), Brenna Aegerter (UCCE San Joaquin County), Zheng Wang (UCCE Stanislaus County), Tom Turini (UCCE Fresno County), Patricia Lazicki (UCCE Yolo-Solano-Sacramento counties)
Collaborators: Brad Hanson (UC Davis), AgSeeds, TS&L Seed Company

Duration of Research: 2018 - Ongoing
CTRI Funding in 2024: $59,590

Main Goal: To develop an integrated management toolkit for Fusarium stem rot and decline (FRD) in processing tomatoes by evaluating chemical, cultivar-based, rotational, and weed management strategies.

Objectives:

- Identify key Fusarium species responsible for FRD and determine their economic impact.
- Establish cultivar recommendations based on controlled and commercial field trials.
- Evaluate crop rotation strategies to reduce FRD incidence.
- Assess host status of weeds to refine targeted weed management approaches.

Key Takeaways from 2024 Work:

- **Pathogen Identification:** Confirmed that *Fusarium noneumartii* and *F. martii* are the primary drivers of FRD. *F. falciforme* causing a separate disease, Fusarium foot rot, which has no economic impact.
- **Cultivar Screening:** Among 18 tested cultivars, SY0275 had the lowest incidence of plant decline and the highest yield. Highly susceptible cultivars included SVTM09032 and N6475.
- **Rotation Trials:** Cool-season rotations varied widely in disease levels in tomato, in which levels were lowest in a cilantro rotation and highest in a wheat and a vetch rotation.
- **Commercial Field Studies:** Grower trials confirmed that fields rotated with wheat and safflower (which were high risk rotations in controlled studies) had higher FRD pressure than fields rotated with cucumber; repeated tomato rotations did not always increase disease severity likely reflecting variations in cultivar resistance and/or differences in environmental conditions across years.
- **Weed Host Range:** Confirmed that *F. noneumartii* infects multiple weed species, including black nightshade and pigweed, but does not affect cool-season weeds; cool season rotation studies showed no difference in tomato disease development with weedy compared to chemical fallow.
- **Chemical Management Support:** In ongoing fungicide trials, no single treatment has been consistently effective in controlling FRD.

Future Research Directions:

- Further refine cultivar screening to validate resistance across multiple growing regions.
- Complete final round of cool-season crop rotation trials and integrate results into best management guidelines.

- Develop predictive risk guidelines based on host status and soil conditions (specifically for cool season rotations) influencing FRD severity, contrast risk of short and long term fallow rotations, and continue to evaluate the effect of long-term-rotations on tomato disease losses.
- Evaluate integrated disease management approaches combining chemical, rotation, and cultivar-based strategies.

Challenges & Considerations:

- **Lack of Effective Rotations:** While some warm-season crop rotation can reduce FRD development, fallow is the lowest risk rotation. Cool-season rotations can pose a very high risk to disease development compared to chemical fallow and require further study to determine long-term viability and better understand why cool season crop rotations dramatically increase disease risk.
- **Varietal Resistance Stability:** Some resistant cultivars maintain yield despite FRD pressure, but broader testing is needed to ensure consistency. Longer term, breeding for highly resistant lines can be enhanced by removing parent lines with high susceptibility and selecting for materials with enhanced resistance traits. Identifying resistant wild lines can also help to improve resistance in the germplasm pool.
- **Pathogen Adaptation:** FRD has gone from being a minor to a very severe disease in recent years and it is unclear why. Studies indicate that this is not due to genetic changes in the pathogen, but it seems likely that increases in pathogen soil loads due to lack of management over 3 decades may be a contributing factor. As chemical use increases it could be possible for the pathogen to develop resistance to specific active ingredients. Given that current cultivar resistance is quantitative (derived from multiple genetic traits) it is unlikely that the pathogen will be able to break this resistance.

Outside Support/Funding:

- Additional funding from CDFA, CDPR, USDA, and private seed companies for cultivar screening and rotation trials.
- Industry collaboration with AgSeeds, TS&L, and processing tomato stakeholders to enhance disease management strategies.

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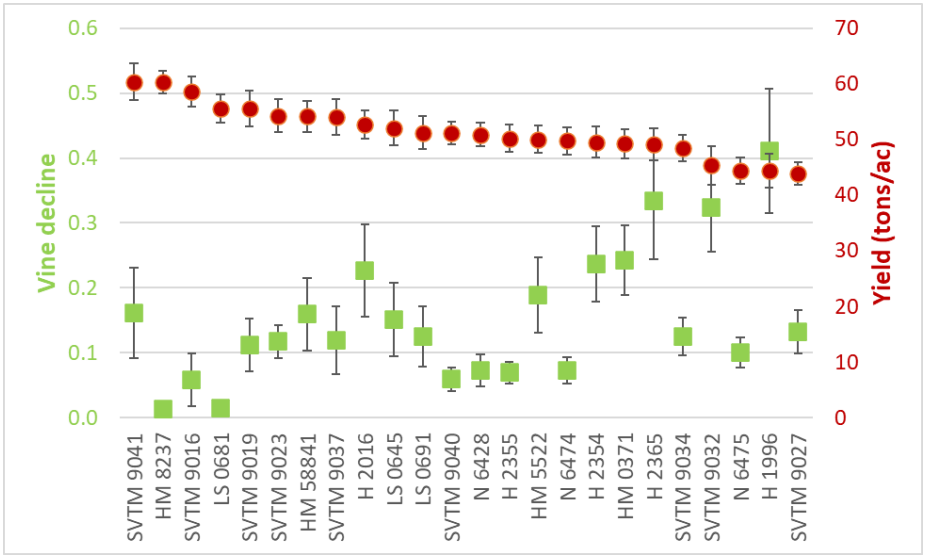

Mean of six locations of AgSeeds variety trials in commercial fields with disease pressure from Fusarium stem rot and decline (FRD). Error bars represent the standard errors of 18 observations (3 replicates x 6 locations).

Executive Summary: Evaluation of Insecticide Programs for the Management of BCTV and TSWV in Processing Tomatoes

Lead Researcher: Thomas A. Turini, UC Cooperative Extension, Fresno County
Duration of Research: 2024 - Ongoing
CTRI Funding in 2024: $7,715

Main Goal: To evaluate insecticide programs that mitigate losses caused by Beet Curly Top Virus (BCTV) and Tomato Spotted Wilt Virus (TSWV) in California processing tomatoes, particularly in light of recent regulatory restrictions on neonicotinoids.

Objectives:

- Assess the efficacy of mid-season insecticide programs for reducing BCTV incidence under the new regulatory environment.
- Evaluate alternative insecticides for their ability to control BCTV and TSWV vectors.
- Determine the economic viability of alternative insecticide programs in commercial tomato production.

Key Takeaways from 2024 Work:

- **Neonicotinoid Restrictions:** New California regulations prohibit post-bloom applications of neonicotinoid insecticides, limiting proven BCTV management options.
- **Verimark & Admire Effectiveness:** Pre-transplant Verimark (cyantraniliprole) and pre-bloom Admire (imidacloprid) are effective in reducing early BCTV infections but are unlikely to provide protection beyond 35 days post-plant.
- **Alternative Insecticides:** Assail (acetamiprid) and Sivanto (flupyradifurone) were tested as mid-season options but their effectiveness in reducing BCTV incidence was inconclusive due to low disease pressure in 2024.
- **TSWV Considerations:** TSWV Considerations: Tomato spotted wilt virus was present, but there were no differences in TSWV levels among treatments.
- **Regulatory & Economic Implications:** With neonicotinoids now limited, growers lack a reliable tool to prevent mid- to late-season BCTV infections, which can still cause substantial economic losses in high-pressure years.

Future Research Directions:

- Conduct trials in 2025 under anticipated higher disease pressure to validate alternative mid-season insecticide strategies.
- Explore new chemistries and Integrated Pest Management (IPM) approaches that remain compliant with evolving pesticide regulations.
- Investigate the role of early-season vector suppression in mitigating late-season disease outbreaks.

Challenges & Considerations:

- **Low 2024 Disease Pressure:** The limited incidence of BCTV and TSWV in this study prevented conclusive evaluation of mid-season treatments.
- **Regulatory Barriers:** The loss of post-bloom neonicotinoids leaves a significant gap in BCTV management, necessitating urgent development of alternative strategies.
- **Economic Feasibility:** Alternative insecticides must balance efficacy and cost-effectiveness to remain viable for large-scale adoption.

Outside Support/Funding:

- Additional funding from Bayer Crop Science ($3,000) and FMC ($6,000).
- A complementary IR-4 study ($15,000) evaluating early-season insecticide applications.

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transplant trt (22 May)[z]	pre-bloom drip (6 Jun)[y]	4th week post-plant (21 Jun)	6th week post-plant (5 Jul)	8th week post-plant (23 Jul)	BCTV incidence (%)			TSWV (%)	
					13-Jun	26-Jun	31-Jul	26-Jun	31-Jul
Verimark 13.5 fl oz					0.51	1.47	1.96	0.00	0.99
Verimark 13.5 fl oz	Admire Pro 10.5 fl oz				0.00	0.00	0.00	0.00	1.42
Verimark 13.5 fl oz		Beleaf 4.2 oz drip[y]	Exirel @20.5 fl oz foliar[x]		1.01	1.94	2.45	0.00	2.01
Verimark 13.5 fl oz		Beleaf 4.2 oz drip	Beleaf 4.2 oz drip	Exirel @20.5 fl oz/a foliar	0.00	0.48	0.00	0.00	0.00
Verimark 13.5 fl oz		Beleaf 4.2 oz drip	Beleaf 4.2 oz foliar	Exirel @20.5 fl oz/a foliar	0.00	0.00	0.00	0.00	1.00
Verimark 13.5 fl oz		Assail 30SC 3.4 fl oz			0.00	0.00	0.00	0.00	2.02
Verimark 13.5 fl oz		Mustang Mx 4 fl oz DF[w]			0.00	0.00	0.49	0.00	1.96
Verimark 13.5 fl oz		Sivanto 28 fl oz drip			0.00	0.51	0.51	0.00	0.97
Verimark 13.5 fl oz		Sivanto 9 fl oz foliar	Sivanto 9 fl oz foliar	Sivanto 9 fl oz foliar	0.00	0.00	0.50	0.00	2.50
	Admire Pro 10.5 fl oz		Assail 30SC 3.4 fl oz flr		0.00	1.68	1.68	0.00	0.50
	Admire Pro 10.5 fl oz		Mustang Mx 4 fl oz foliar		0.50	0.99	1.49	0.00	0.57
Untreated control					0.61	0.61	1.22	0.00	4.18
Probability					0.348	0.399	0.438	NS	0.408

[z] Verimark was applied to transplants on 22 May at a per acre equivalent of 13.5 fl oz.

[y] All drip-injected materials were applied with electric metering pumps over 30 minutes, which was followed by 2 hours additional irrigation.

[x] Broadcast foliar treatments were applied with a CO_2-pressurized back-pack sprayer at 30 psi in the equivalent of 30 gallons per acre with Dyne-Amic surfactant 0.25% v/v.

[w] Directed foliar treatments were applied with a CO_2-pressurized back-pack sprayer at 20 psi in the equivalent of 30 gallons per acre with Dyne-Amic surfactant 0.25% v/v.

California Tomato Research Institute

Executive Summary: Statewide Surveillance for Virus Diseases in Processing Tomatoes

Lead Researcher: Robert L. Gilbertson, Ph.D., UC Davis
Co-PI: Neil McRoberts, Ph.D., UC Davis
Collaborators: Tom Turini (UCCE Fresno), Patricia Lazicki (UCCE Yolo-Solano-Sacramento), Diane Ullman (UC Davis), other UCCE farm advisors, PCAs, and growers

Duration of Research: Ongoing
CTRI & CDFA BCTV Control Board Funding in 2024: $68,000

Main Goal: To provide rapid virus surveillance and diagnostics for viral diseases in California processing tomatoes and investigate the biology of emerging and resistance-breaking strains to support integrated management strategies.

Objectives:

- Monitor the prevalence and distribution of key tomato viruses, including Beet Curly Top Virus (BCTV) and Tomato Spotted Wilt Virus (TSWV).
- Investigate the spread and severity of resistance-breaking TSWV strains.
- Evaluate insect vector populations and their role in virus outbreaks.
- Improve forecasting models for thrips-based spread of TSWV.
- Provide timely outreach and management recommendations to growers and PCAs.

Key Takeaways from 2024 Work:

- **Low Virus Pressure:** Due to a cool, wet winter and spring, overall virus incidence in 2024 was low, similar to 2023.
- **Curly Top Disease (CTD):** No CTD was detected in Northern counties; low levels (~5%) were observed in Fresno, with minimal economic impact.
- **TSWV Spread:** Initial infections appeared in April-May, with low spread in Northern regions but higher incidence in Fresno, though late infections had limited yield impact.
- **Resistance-Breaking TSWV Strains:** Fresno samples were infected with the YPT strain; Northern counties had a mix of YPT and the newer CPN strain, with CPN dominating mixed infections.
- **Insect Vector Monitoring:** Low beet leafhopper populations correlated with reduced BCTV incidence. Western flower thrips were abundant, but analysis showed a high proportion of onion thrips (*Thrips tabaci*), which are weak TSWV vectors.
- **Varietal Screening:** Greenhouse trials of 13 commercial varieties confirmed all were susceptible to both YPT and CPN strains, with varying severity of symptoms.
- **Outreach Efforts:** Published thrips degree-day models, hosted disease management field days, and provided diagnostic support to growers.

Future Research Directions:

- Conduct further monitoring to determine whether cool-season conditions are limiting virus overwintering and vector populations.
- Expand thrips species identification to understand regional differences in TSWV transmission.
- Continue evaluation of varietal susceptibility and explore alternative resistance sources.
- Improve forecasting models to guide thrips and virus management strategies.

Challenges & Considerations:

- **Virus Adaptation:** The spread of resistance-breaking TSWV strains underscores the need for continuous surveillance.
- **Vector Management:** Thrips and beet leafhopper population dynamics remain unpredictable, making control efforts variable year-to-year.
- **Grower Adoption:** Ensuring that forecasting models and diagnostic tools are accessible and actionable for farm-level decision-making.

Outside Support/Funding:

- Additional funding from USDA, CDFA, and UC Davis research programs.
- Collaboration with the processing tomato industry to refine management recommendations and enhance disease mitigation strategies.

For the full report, of this or any other 2024 CTRI grower funded project, please visit this link:

https://bit.ly/CTRI2024FullReport

California Tomato Research Institute

Executive Summary: Controlling In-Row Weeds with Post-Plant Applications of Pre-Emergent Herbicides

Lead Researcher: Scott Stoddard, UC Cooperative Extension
Duration of Research: 2024 - Ongoing
CTRI Funding in 2024: $6,925

Main Goal: To evaluate the effectiveness of post-plant applied pre-emergent herbicides incorporated with a finger weeder for in-row weed control in processing tomatoes.

Objectives:

- Assess weed control efficacy of post-plant applications of Matrix (rimsulfuron), Prowl (pendimethalin), Devrinol (napropamide), and Sencor (metribuzin) when incorporated with a finger weeder.
- Compare weed control, hand weeding time, and costs between herbicide incorporation with the finger weeder versus traditional mechanical cultivation.
- Determine potential crop injury risks associated with post-plant herbicide incorporation.

Key Takeaways from 2024 Work:

- **Weed Control Efficacy:** Post-plant applications of Matrix, Prowl, Sencor, and Devrinol incorporated with the finger weeder improved weed control (84% - 94%) compared to herbicides alone (61% - 75%) and the finger weeder alone (15% - 75%).
- **Hand Weeding Time Reduction:** Improved weed control correlated with a significant reduction in hand weeding time, with the best treatment (Prowl + finger weeder) reducing labor from 25.2 to 6.5 hours per acre.
- **Crop Safety:** Minimal crop injury was observed across all locations and treatments.
- **Site Differences:** The finger weeder alone was effective at WSREC but less so at the commercial Merced site, likely due to later-emerging weed species in Merced.
- **Herbicide Incorporation Benefits:** Pre-emergent herbicides generally performed better when incorporated, with Devrinol and Prowl showing the greatest improvement in weed suppression when combined with the finger weeder.

Future Research Directions:

- Further investigate weed species response to herbicide incorporation across different field conditions.
- Optimize finger weeder settings for maximum weed removal without crop disturbance.
- Evaluate long-term impacts on soil structure and weed seed bank reductions.
- Conduct additional commercial field trials to refine practical recommendations for growers.

Challenges & Considerations:

- **Field Variability:** Weed species composition significantly influenced treatment efficacy, necessitating site-specific recommendations.
- **Timing of Cultivation:** The short effectiveness window for the finger weeder limits its usability without complementary herbicide programs.

Outside Support/Funding:

- Collaboration with commercial growers, including Seasholtz Farms, and support from the UC West Side Research and Extension Center.

For the full report, of this or any other 2024 CTRI grower funded project, please visit this link:

https://bit.ly/CTRI2024FullReport

The finger weeder at the Merced location, showing shanks and paddle wheels in front of the finger wheels to improve herbicide incorporation. *Photo credit – Scott Stoddard*

California Tomato Research Institute

CTRI GROWER FUNDED RESEARCH: 2025			
2025 TOTAL AFTER FINAL BOARD DECISIONS & COST SHARING: $757,178			
Broomrape Containment, Control and Management		**Research Lead**	**Institution**
2020 Start	Broomrape: Devt. of Long Term Mgmt. Options: CA Commercial Field Conditions & Contained Research Facility Ongoing Work	Brad Hanson	UC Davis
2021 Start	Developing best equipment sanitation practices for broomrape and other high-profile soil borne pathogens; to mitigate field-to-field spread* - CLFP Co-Funding	Cassandra Swett	UC Davis
2022 Start	Determining the population structure of *Phelipanche ramosa* and *Orobanche aegyptiaca* field detections in California	Adam Schneider	UW-LaCrosse
2022 Start	Developing Tomato Lines Resistant to Branched Broomrape, a Critical California Pest	Neelima Sinha	UC Davis
2022 Start	Inducible Suberin for Tomato Drought Tolerance (root architecture)	Siobhan Brady	UC Davis
2023 Start	Training and Refinement of Broomrape Detection Model using Satellite Imagery	Alireza Pourezza	UC Davis
2025 Start	Targeting Strigolactone Receptors in Branched Broomrape (*Phelipanche ramosa*)	Marco Burger	Salk Institute
2025 Start	Broomrape resistant, climate resilient tomato rootstocks for grafted processing tomatoes	Ryan Lefers	iyris
2025 Start	AgCeption In-Field Broomrape Detection System Development* - CDFA Broomrape Board Co-Funding	Chris Laudando	L&A
Agronomic/Water/Nutrient Management			
2025 Start	Exploring causal factors for the yield gap between “new” and “old” tomato fields	Patricia Lazicki	UC Extension
Germplasm and Variety Development			
1991 Start	C. M. Rick Tomato Genetic Resource Center	Roger Chetelat	UC Davis
2024 Start	Leveraging germplasm resources for genetic discovery and deployment of salt stress resilience	Greg Vogel	Cornell
2025 Start	Engineering broad and durable disease resistance: Genome Editing to modulate susceptibility genes against Fusarium wilt in tomato.	Daniel Rodriguez-Leal	University of Maryland
2025 Start	Marker-trait association study to develop DNA markers for RB-TSWV resistance in tomatoes	Reza Shekasteband	NCSU
Insect & Invertebrate Management			
2025 Start	Evaluation of management programs for Consperse stink bug management	Tom Turini	UC Extension
Pathogen Management			
2017 Start	Disease diagnosis, pathogen movement / emergence monitoring, new pathogen ID and F4 monitoring for the CA processing tomato industry	Cassandra Swett	UC Davis
2018 Start	Developing an integrated mgmt. strategy for F. falciforme vine decline in processing tomato, including co-management with Fusarium wilt	Cassandra Swett	UC Davis / UC Extension
2023 Start	Integrated solutions to address the issue of fusarium stem rot and vine decline (FRD) in processing tomato* - USDA IR-4 Funded	Patricia Lazicki	UC Extension
2025 Start	Evaluating the potential of Trichoderma biofungicides as preventative measurements for Fusarium stem rot and vine decline in processing tomato	Zheng Wang	UC Extension
2017 Start	Viral Diagnostics* - CDFA BCTV Control Board Co-Funding	Robert Gilbertson	UC Davis / UC Extension
2024 Start	Evaluation of Insecticide Programs in Processing Tomatoes for the MGMT of BCTV and TSWV Vectors and Viruses	Tom Turini	UC Extension
Weed Control and Management			
2025 Start	Evaluating chemigated rimsulfuron herbicide on field bindweed suppression in processing tomatoes	Scott Stoddard	UC Extension

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California Tomato Research Institute

CALIFORNIA TOMATO RESEARCH INSTITUTE, INC.

2024

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