The Persistent Threat of Emerging Plant Disease Pandemics: Mitigating Future Outbreaks

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Food Security Cluster

NC STATE UNIVERSITY


The future of food and agriculture
The global trends and challenges that are shaping our future
End hunger and all forms of malnutrition
5
Population growth, globalization, inequalities and climate change will accelerate distress migration
Improve income earning opportunities in rural areas and address the root causes of migration
7
Make food systems more efficient, inclusive and resilient
6
Globally, around one-third of all food produced is lost or wasted resulting in losses for farmers and unnecessary pressures on natural resources
~1/2 billion
people in more than 20 countries are affected by protracted crisis
Outbreak of transboundary pests and diseases of plants and animals is growing alarmingly
Prevent transboundary and emerging agriculture and food system threats
9
Address the need for coherent and effective national and international governance
10
Build resilience to protracted crises, disasters and conflicts
8
Food and Agriculture Organization of the United Nations
fao.org/publications/fofa/en
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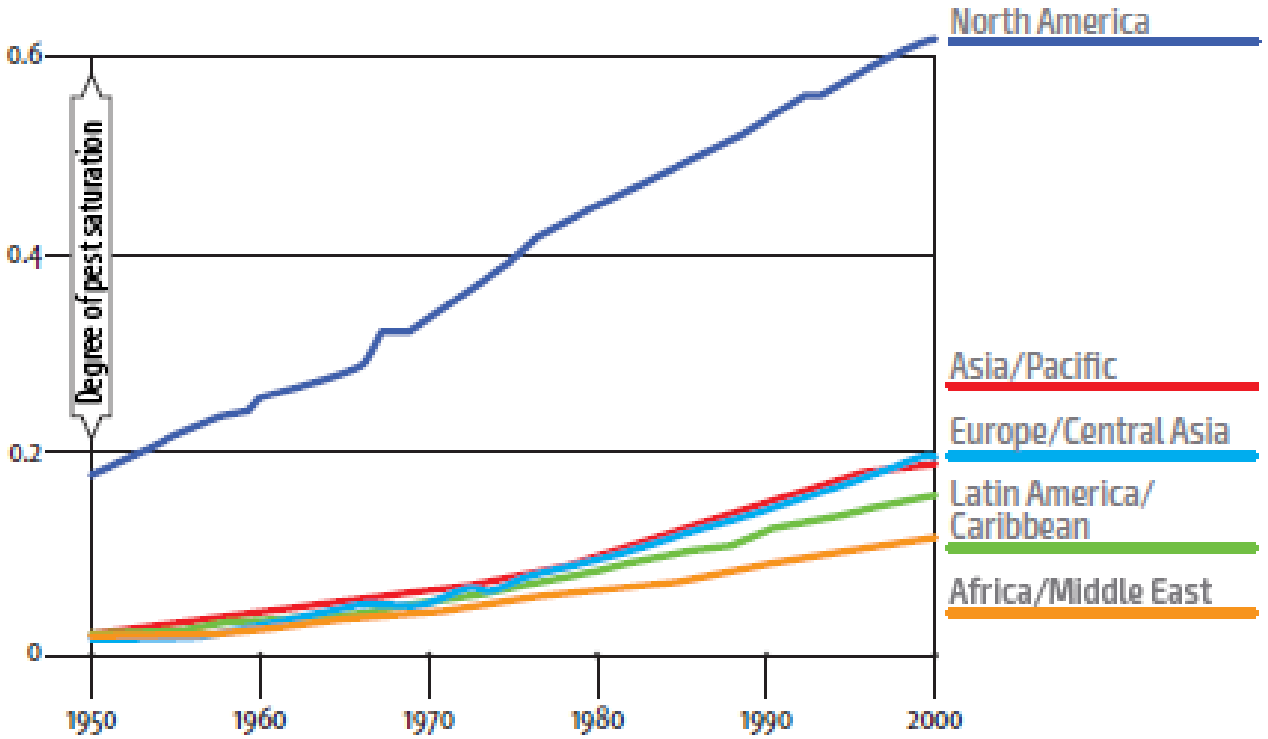
Figure 6.2 Global spread of crop pests and pathogens, 1950–2000



Note: The degree of pest saturation for a region is the mean of the degrees of saturation of countries in that region. The degree of saturation in a country is the number of crop pests and pathogens (CPPs) currently present divided by the number of CPPs that could occur.
Source: Bebber, Holmes and Gurr, 2014.

Potential for more emerging pests and pathogens

What are the Characteristics of Emerging Plant Diseases?

- Caused by pathogens that have increased in incidence, geographical or host range
- Have changed in pathogenesis
- Have newly evolved
- Have been discovered or newly recognized.

Coffee rust - coffee

Xylella fastidiosa – olives - Italy

Stem rust – wheat – EU, Africa and Asia

Panama disease – banana – South America

Emerging Plant Diseases

Late blight re-emerging disease:

A constraint to production worldwide - food security

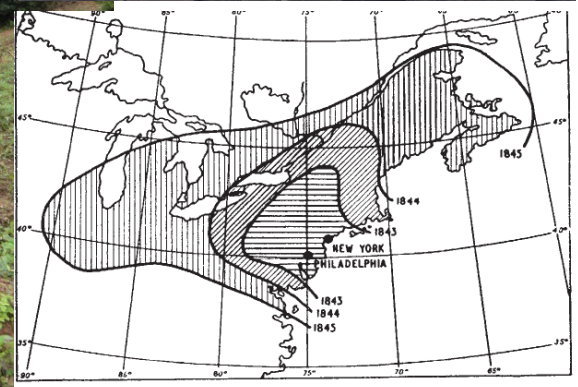


Fig. 1. Approximate extent of potato blight attacks in the United States and Canada during 1843–45 (after Stevens)

Has increased in incidence, geographical and host range

PERSPECTIVE

The persistent threat of emerging plant disease pandemics to global food security

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Edited by Barbara Valent, Kansas State University, Manhattan, KS, and approved April 7, 2021 (received for review November 30, 2020)

Plant disease outbreaks are increasing and threaten food security for the vulnerable in many areas of the world. Now a global human pandemic is threatening the health of millions on our planet. A stable, nutritious food supply will be needed to lift people out of poverty and improve health outcomes. Plant diseases, both endemic and recently emerging, are spreading and exacerbated by climate change, transmission with global food trade networks, pathogen spillover, and evolution of new pathogen lineages. In order to tackle these grand challenges, a new set of tools that include disease surveillance and improved detection technologies including pathogen sensors and predictive modeling and data analytics are needed to prevent future outbreaks. Herein, we describe an integrated research agenda that could help mitigate future plant disease pandemics.

emerging plant disease | plant pathology | food security

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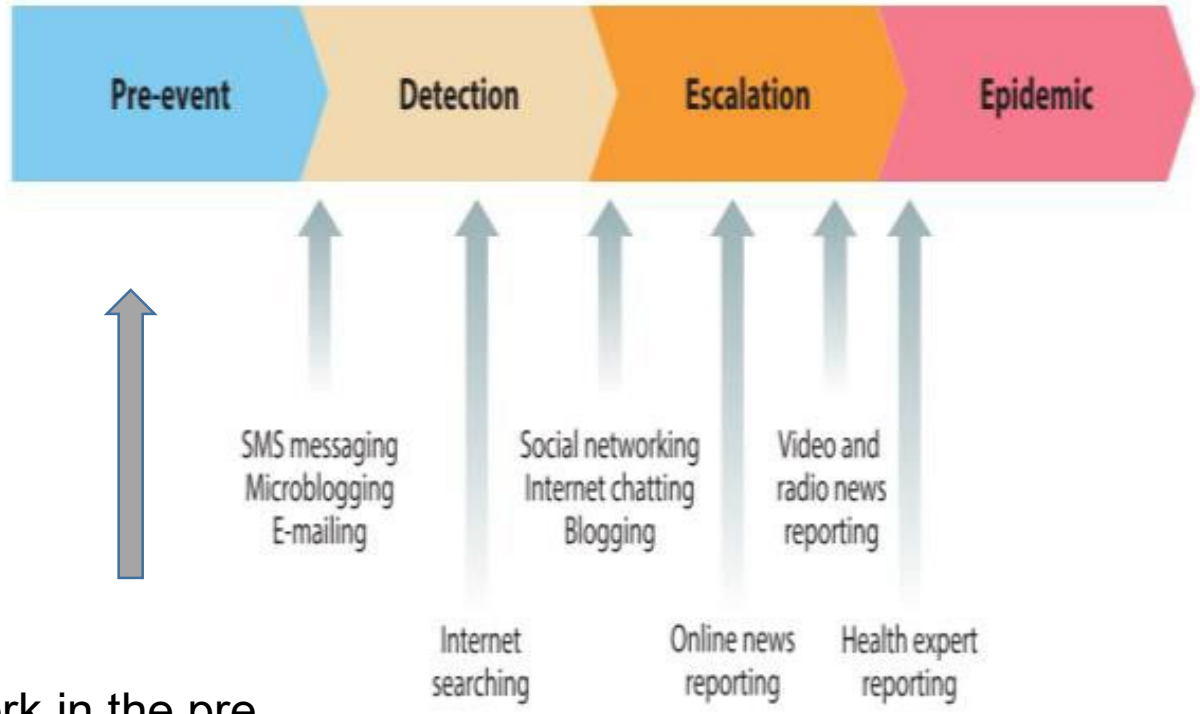
PNAS

Proceedings of the National Academy of Sciences of the United States of America www.pnas.org

- Need for surveillance
- Geospatial Analytics
- Earth Observations- remote sensing
- Sensors for early detection
- Pathogen Risk Modeling
- Data mining past and current reports, collections
- Population Genomics
- Digital Delivery of information to stakeholders

Disease Surveillance



Can we work in the pre event space – with all of the above disease surveillance tools to prevent escalation to epidemics?

From Scherm, H., Thomas, C. S., Garrett, K. 2014. Meta-analysis and other approaches for synthesizing structured and unstructured data in plant pathology. *Annu. Rev. Phytopathol.* **52**, 453-476.

Emergence of new late blight genotype

US-22 moved into home gardens on tomato transplants

- Climate change – rainy season
- Movement of infected tomato transplants
- Susceptible varieties

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OP-ED CONTRIBUTOR

You Say Tomato, I Say Agricultural Disaster

Karen Barbour

By DAN BARBER
Published: August 8, 2009

Tarrytown, N.Y.

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Science News

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Late Blight -- Irish Potato Famine Fungus -- Attacks U.S. Northeast Gardens And Farms Hard

ScienceDaily (July 5, 2009) — Home gardeners beware: This year, late blight -- a destructive infectious disease that caused the Irish potato famine in the 1840s -- is killing tomato and potato plants in gardens and on commercial farms in the eastern United States. In addition, basil downy mildew is affecting plants in the Northeast.

"Late blight has never occurred this early and this widespread in the U.S," said Meg McGrath, associate professor of plant pathology and plant-microbe biology.

One of the most visible early symptoms of the disease is brown spots (lesions) on stems. They begin small and firm, then quickly enlarge, with white fungal growth developing under moist conditions that leads to a soft rot collapsing the stem.

Classic symptoms are large (at least nickel-sized) olive-green to brown spots on leaves with slightly fuzzy white fungal growth on the underside when conditions have been humid (early morning or after rain). Sometimes the border of the spot is yellow or has a water-soaked appearance. Spots begin tiny, irregularly shaped and brown. Firm, brown spots develop on tomato fruit.

See Also:

Plants & Animals
- Endangered Plants
- Botany
- Pests and Parasites

Earth & Climate
- Grassland
- Rainforests
- Exotic Species

Reference
- Phytopathology
- Water mould
- Heirloom plant
- Tomato

Leaf lesions due to late blight. (Credit: Copyright College of Agriculture and Life Sciences, Cornell University)

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Plant Problems? Try BASF
Control downy mildew diseases with BASF Stature SC fungicide
www.BetterPlants.BASF.us

2009 Mazda Clearance
Inventory blowout pricing!
Dealers are liquidating inventory
Mazda.Reply.com

The New York Times

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July 18, 2009

Outbreak of Fungus Threatens Tomato Crop

By JULIA MOSKIN

A highly contagious fungus that destroys tomato plants has quickly spread to nearly every state in the Northeast and the mid-Atlantic, and the weather over the next week may determine whether the outbreak abates or whether tomato crops are ruined, according to federal and state agriculture officials.

The spores of the fungus, called late blight, are often present in the soil, and small outbreaks are not uncommon in August and September. But the cool, wet weather in June and the aggressively infectious nature of the pathogen have combined to produce what Martin A. Draper, a senior plant pathologist at the United States Department of Agriculture, described as an "explosive" rate of infection.

William Fry, a professor of plant pathology at Cornell, said, "I've never seen this on such a wide scale."

A strain of the fungus was responsible for the Irish potato famine of the mid- 19th century. The current outbreak is believed to have spread from plants in garden stores to backyard gardens and commercial fields. If it continues, there could be widespread destruction of tomato crops, especially organic ones, and higher prices at the market.

"Locally grown tomatoes normally get $15 to $20 a box" at wholesale, said John Mishanec, a pest management specialist at Cornell who has been visiting farms and organizing emergency growers' meetings across upstate New York. "Some growers are talking about $40 boxes already." Tomatoes on almost every farm in New York's fertile "Black Dirt" region in the lower Hudson Valley, he said, have been affected.

Professor Fry, who is genetically tracking the blight, said the outbreak spread in part from the hundreds of thousands of tomato plants bought by home gardeners at Wal-Mart, Lowe's, Home Depot and Kmart stores starting in April. The wholesale gardening company Bonnie Plants, based in Alabama, had supplied most of the seedlings and recalled all remaining plants starting on June 26. Dennis Thomas, Bonnie Plants' general manager, said five of the recalled plants showed signs of late blight.

"This pathogen did not come from our plants," Mr. Thomas said on Wednesday. "This is something that has been around forever."

Mr. Draper said the diseased seedlings, found in stores as far west as Ohio, were at least one source of the illness, but, he added, "It's possible that we are looking at multiple

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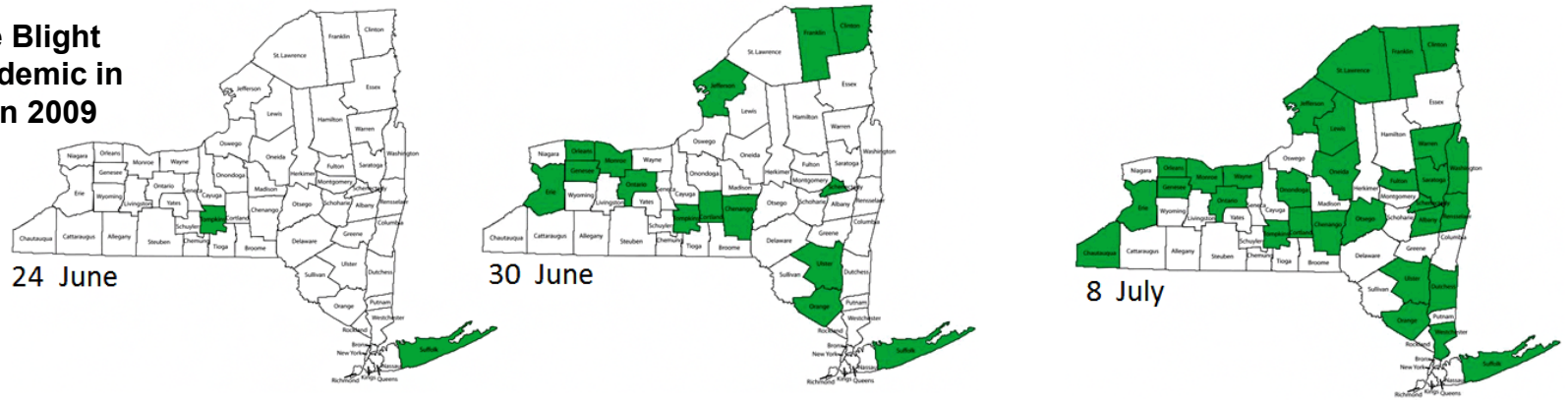
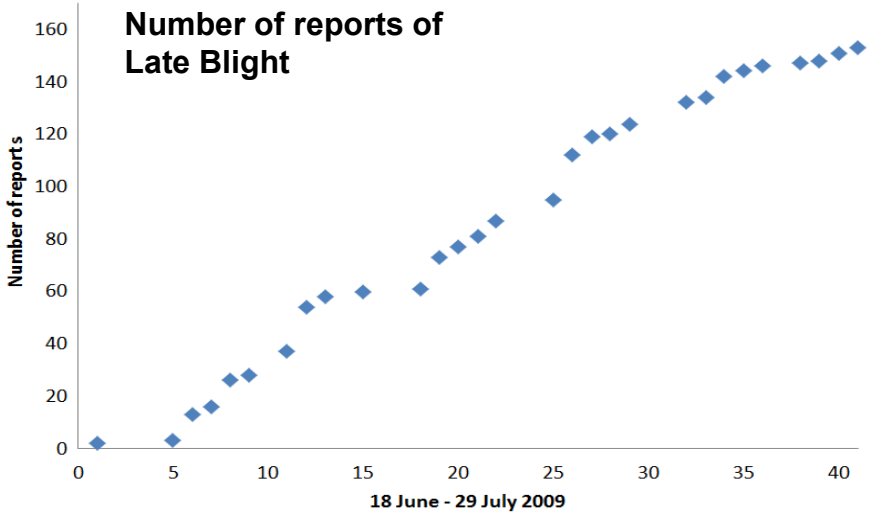
Late blight spreads fast - rapid pathogen detection

Late Blight Pandemic in NY in 2009



Spread by sporangia – spread in air – 100's of kilometers

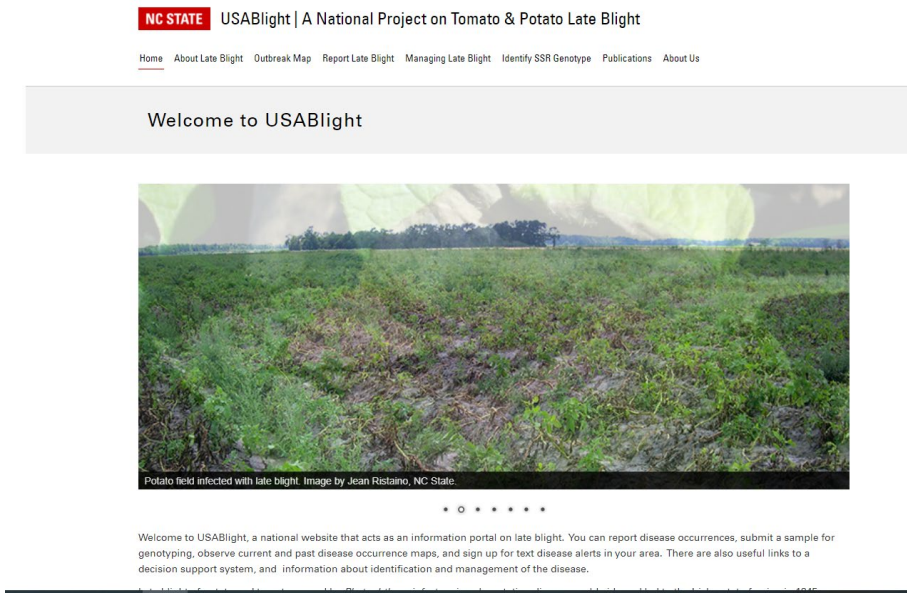


Fry et al, 2013 Plant Disease 2013, 97, 296-306

United States Department of Agriculture
National Institute of Food and Agriculture

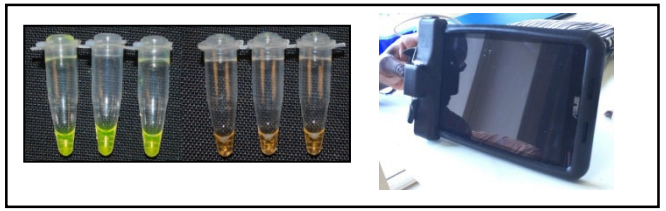
USABlight.org –Active Disease Surveillance

Sample Submission

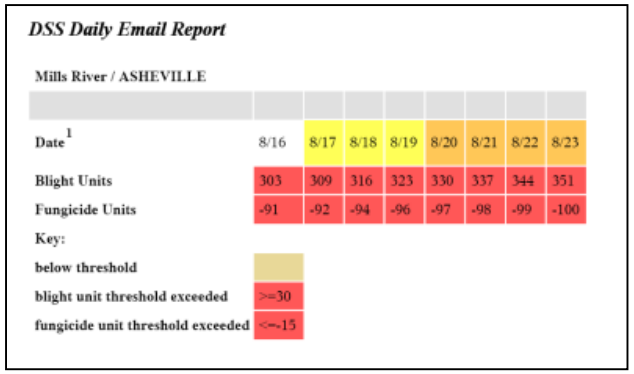


Alerts and Mapping

New Diagnostics



Fungicide Decision Support Tool



DSS Daily Email Report

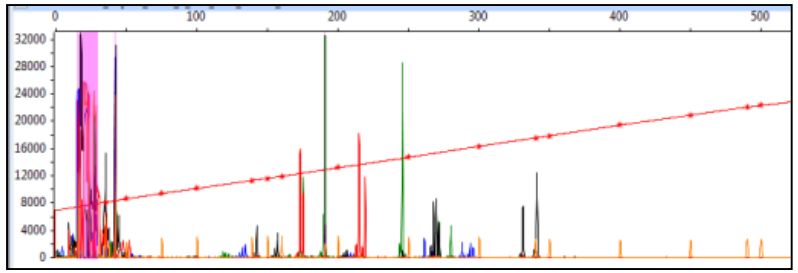
Mills River / ASHEVILLE

Date[1]	8/16	8/17	8/18	8/19	8/20	8/21	8/22	8/23
Blight Units	303	309	316	323	330	337	344	351
Fungicide Units	-91	-92	-94	-96	-97	-98	-99	-100

Key:

below threshold	
blight unit threshold exceeded	>=30
fungicide unit threshold exceeded	<=-15

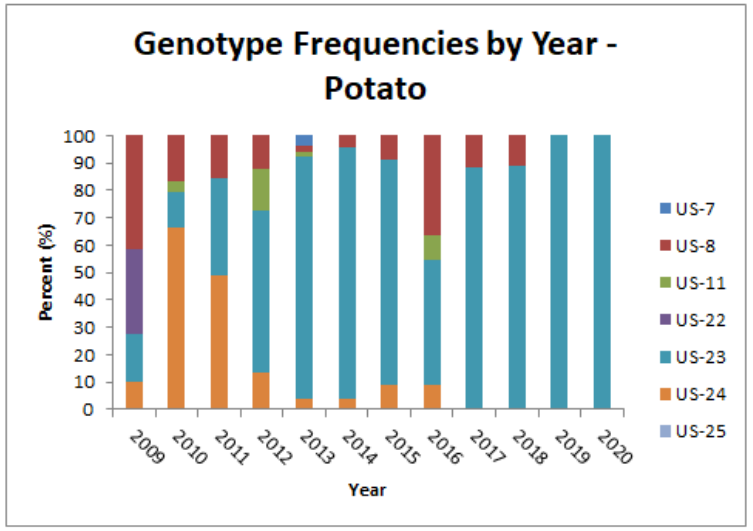
Genotyping

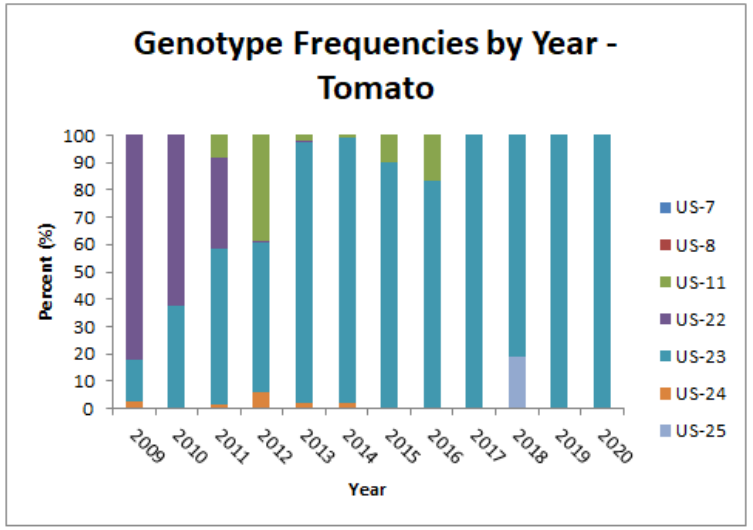


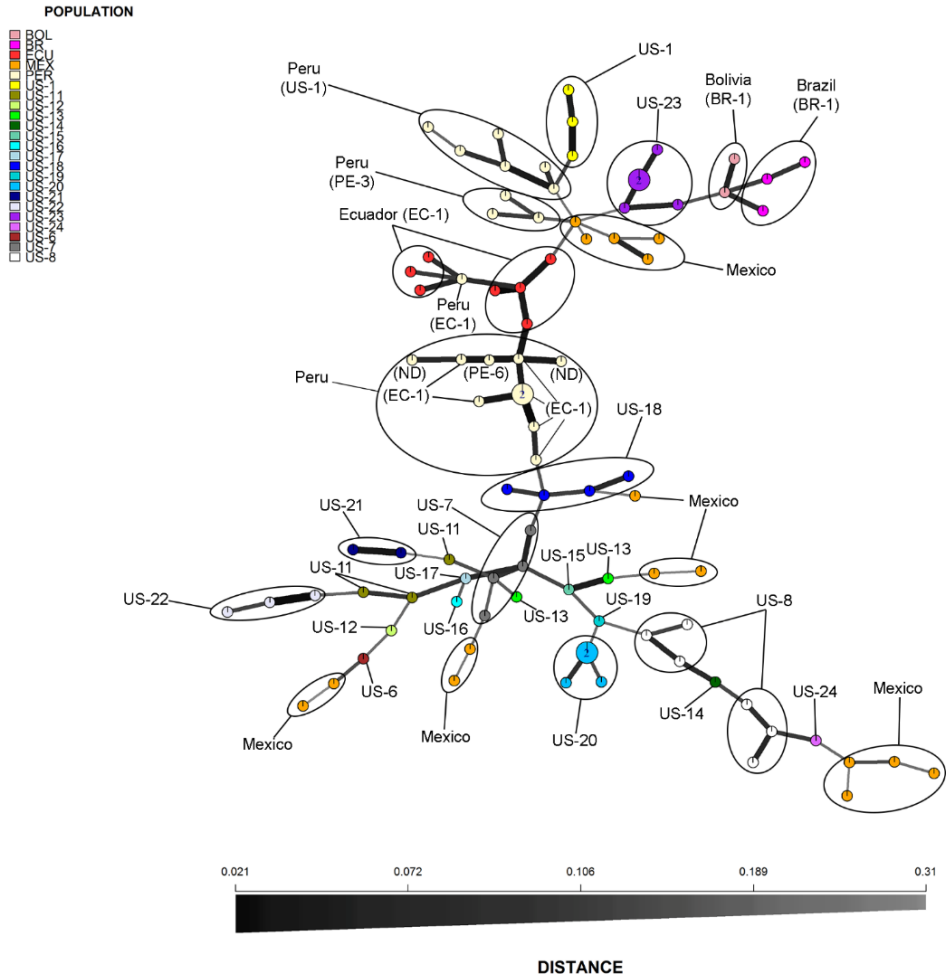
Evolution of new pathogenic lineages

- US-23 predominant on both potato and tomato and metalaxyl sensitive
- US-8 declined on potato - mefenoxam resistant
- In EU- Euroblight network reported fluazinam

Amanda Saville Jean Ristano



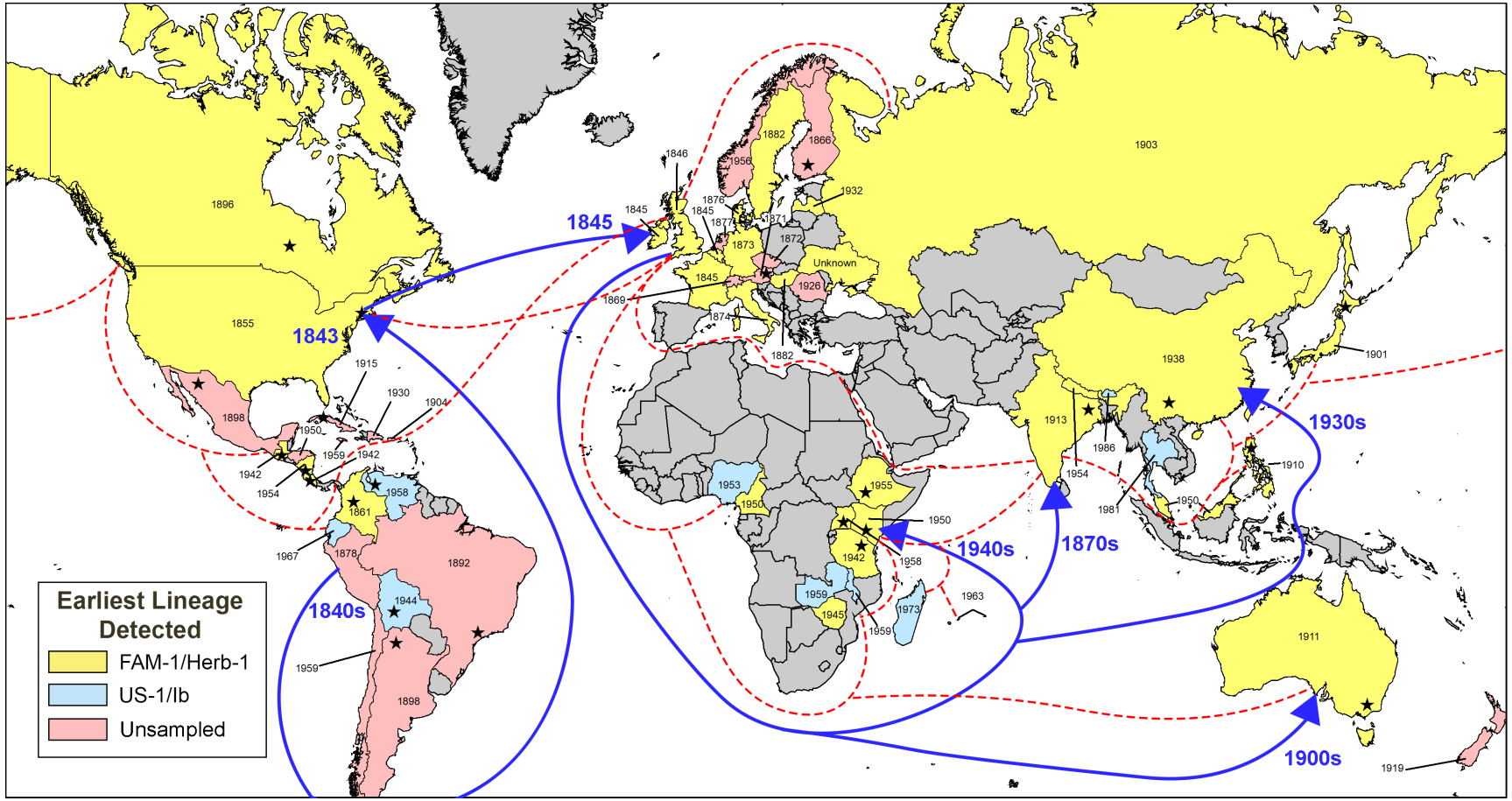




Saville, A. and Ristaino, J. B. 2019. Phytopathology 109:614-627.

Pathogen Genomic Surveillance – Identified *P. infestans* ancestral strain and tracked global spread

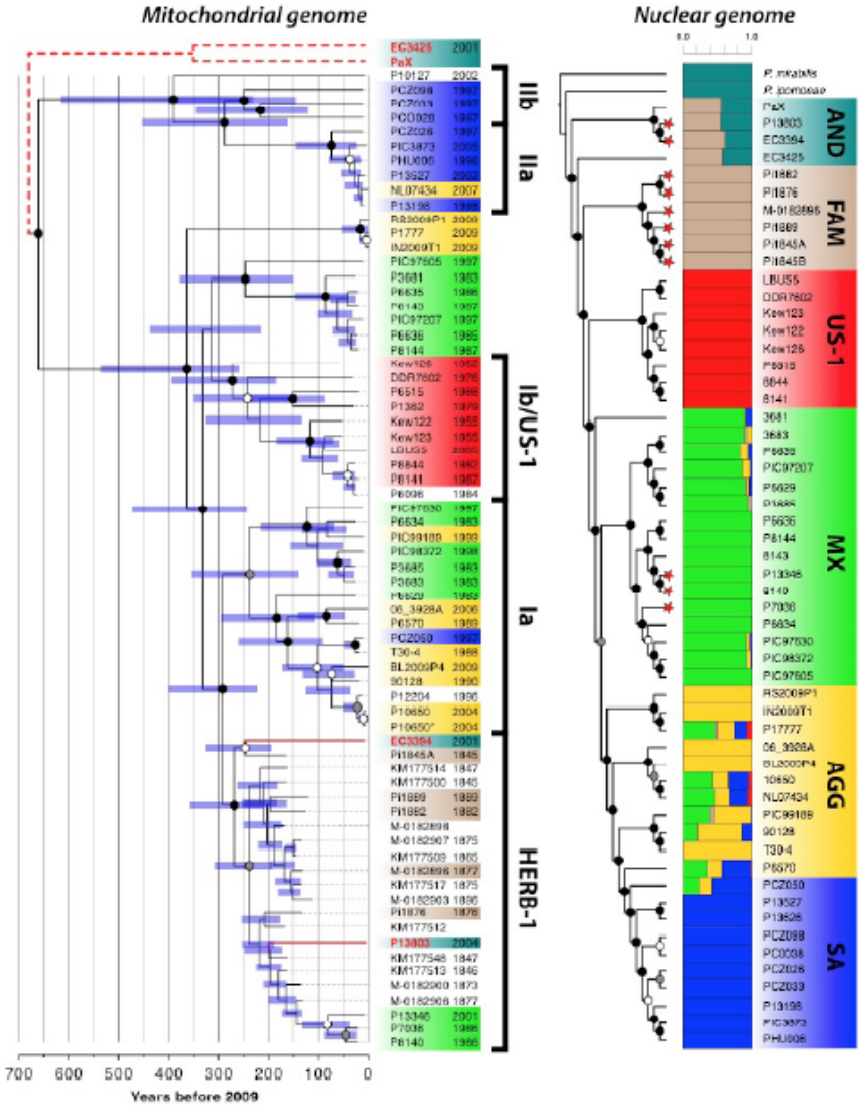
- Same ancestral lineage we named FAM-1 found in both US and EU.
- Migrated with British colonization to six continents
- FAM-1 lineage survived for over 100 years – found in mid 20th century in SE Asia and Central America
- US-1 emerged later



Saville and Ristaino. 2021. Nature Scientific Reports. 11:12335

Genomic surveillance of historic outbreaks – SNP analysis of nuclear and mit0genomes

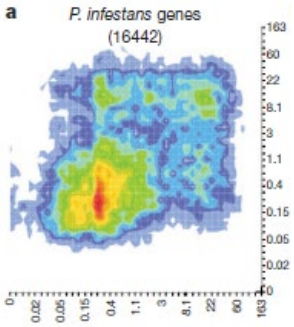
Genomic characterization of South American *Phytophthora* hybrid mandates reassessment of geographic origin of *Phytophtora infestans*. Martin et al, 2015. Mol. Biol. Evol. 33:478-491



Mike Martin
NTU, Norway

Jean Ristaino

Amanda Saville



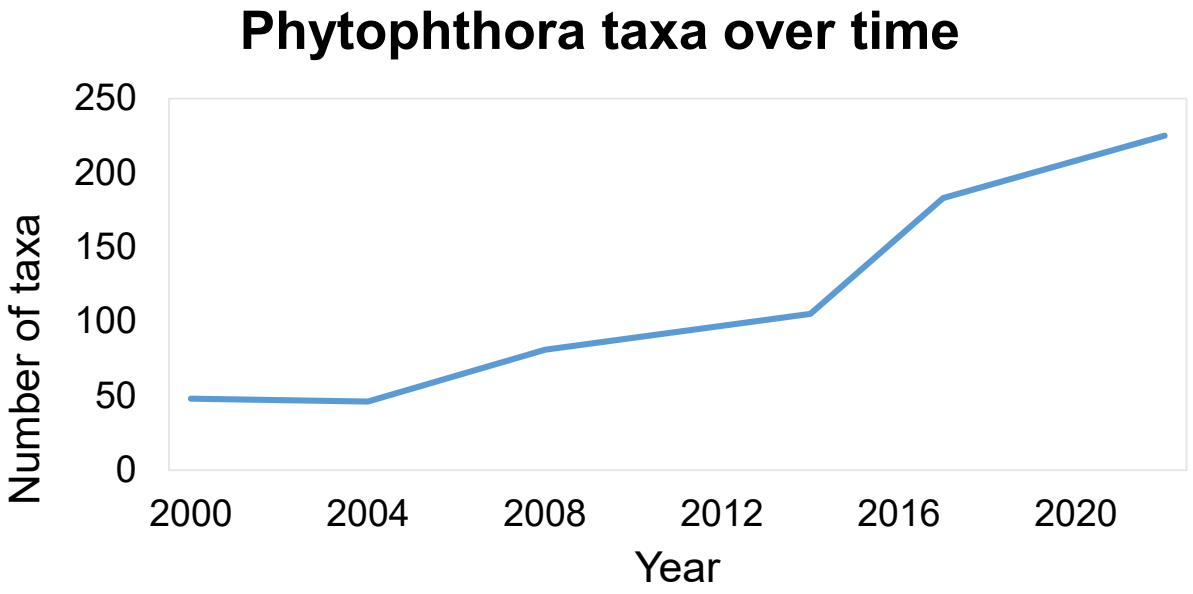
Mitogenomes

- Herb-1 lineage persists in *P andina* (Ia) from *S. betaceum* (red
- Divergence of Herb-1 mt lineage
- Herb-1 mtDNA lineage not strictly associated with FAM lineages of *P. infestans*

Nuclear genomes - 6 lineages

- *P. andina* from South America shows mixed ancestry with famine lineages and outgroup species indicating hybrid, basal in tree
- Famine era lineages form highly supported sister clade at base of tree
- US-1 and Mexican lineages diverged later
- Modern Mexican lineages and US aggressive lineages – admixture- MX likely source of some recent AGG lineages
- Modern SA lineages most derived and likely reintroduced from EU imported potato
- Ancestral lineages of the pathogen and the entre clade may be on wild *Solanum* hosts in SA

Increase in number of *Phytophthora* species described over past 20 years



Frontpage

NC State Researchers Assemble Pathogen 'Tree of Life'

April 3, 2023 | Mick Kulikowski

A Chilean potato plant shows leaf blight caused by Phytophthora. Photo courtesy of Jean Ristaino, NC State University.

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Allison Coomber, Amanda C. Saville, Ignazio Carbone, Jean B. Ristaino. 2023. An open access T-BAS phylogeny for emerging *Phytophthora* species. Plos One: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0283540

Phylogenomic and data analytics tools

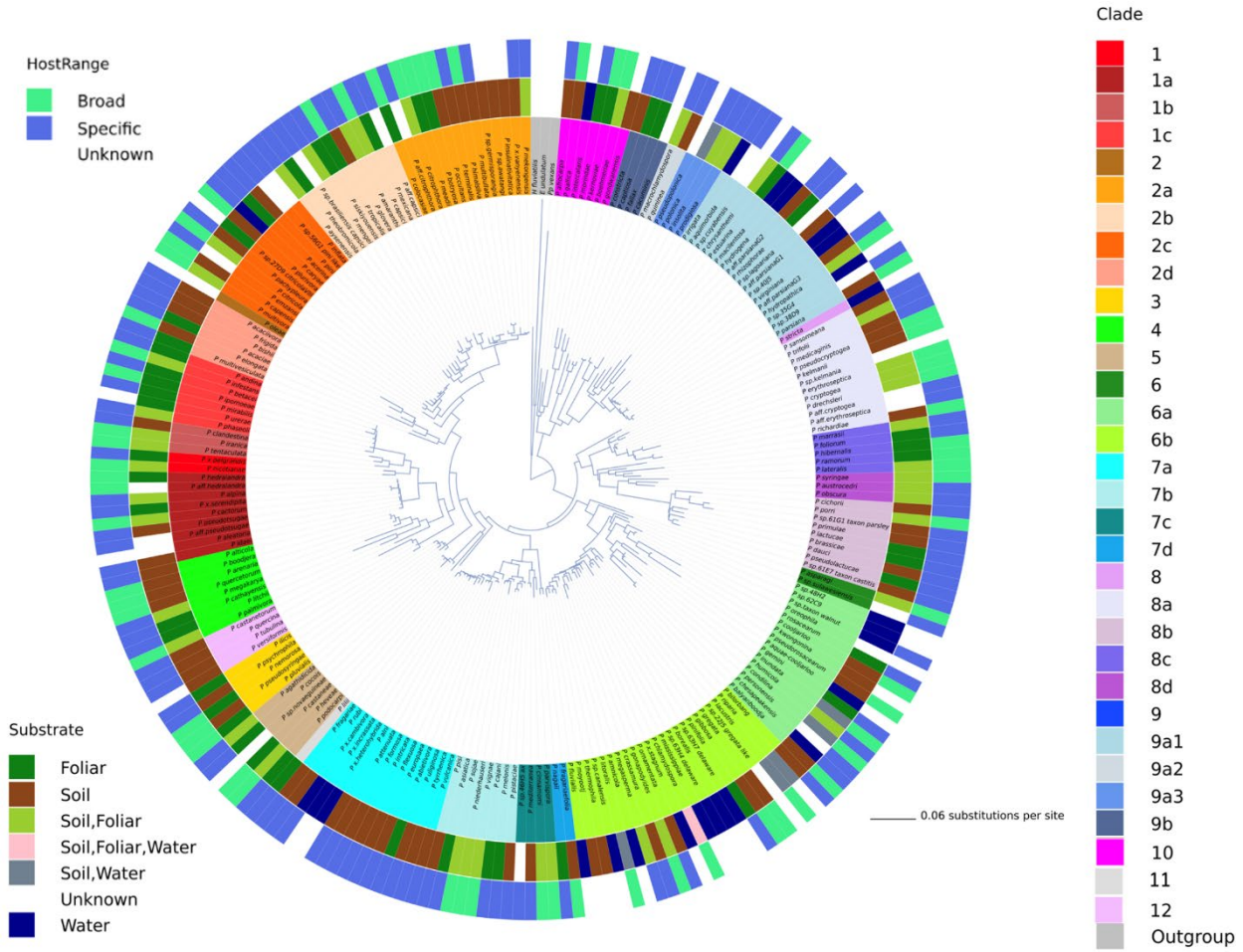
Developed a living open phylogenetic framework for "**Emerging *Phytopthoras***" using multilocus genotyping and T BAS

Allison Coomber Ignazio Carbone Jean Ristaino

- 8 nuclear loci
- 192 species
- 33 informal taxa
- Inferred with RaxML

Loci included

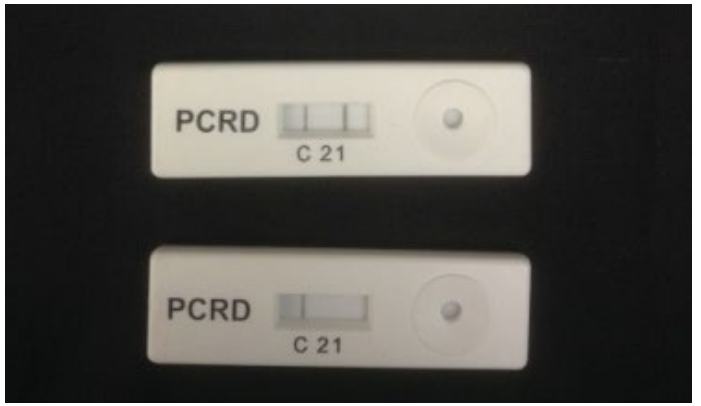
28S
60SL10
Btub
EF1a
ENL
HS90
ITS
TigA

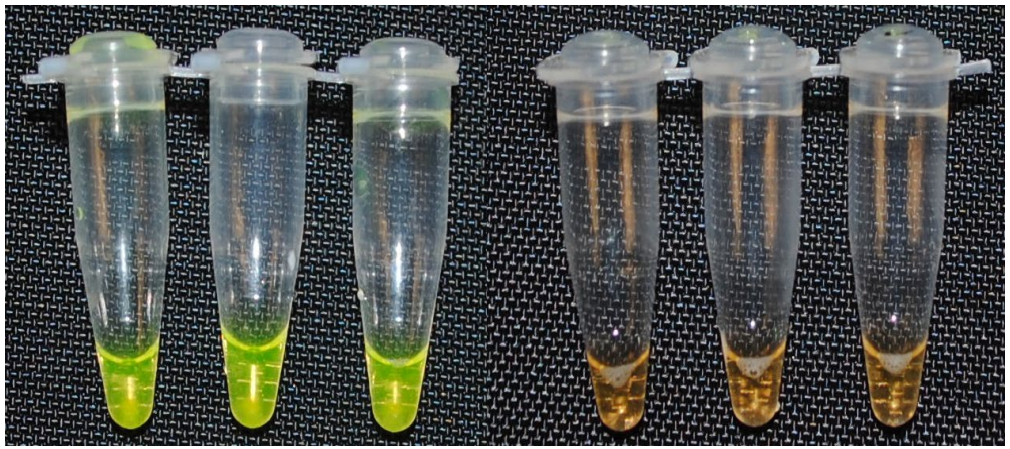


Allison Coomber, Amanda C. Saville, Ignazio Carbone, Jean B. Ristaino. 2023. An open access T-BAS phylogeny for emerging *Phytophthora* species. Plos One: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0283540

New rapid diagnostics to identify *P. infestans* LAMP Assay – real time in-field reporting

- LAMP primers can be designed to be specific to a particular pathogen
- Rapid protocol for field identifications
- Amplification product visualized in the field with visual nucleic acid stains (e.g. SYBR green or HNB)
- Can be adapted to lateral flow devices(LFDs)





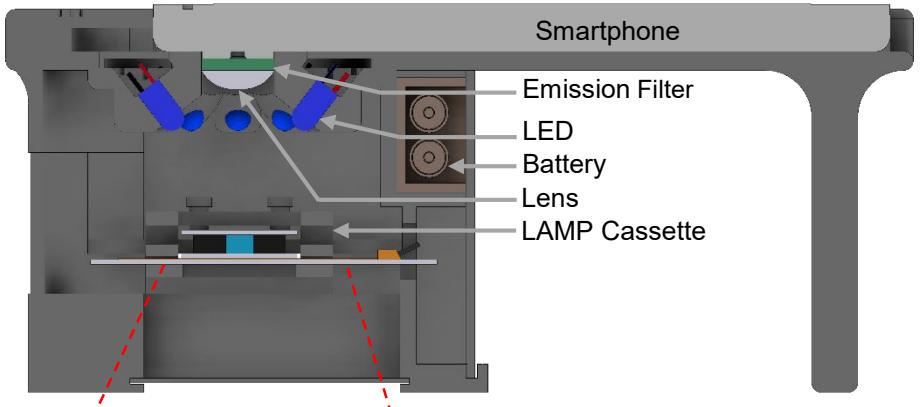
Samples with SYBR green. The three samples on the left are positive

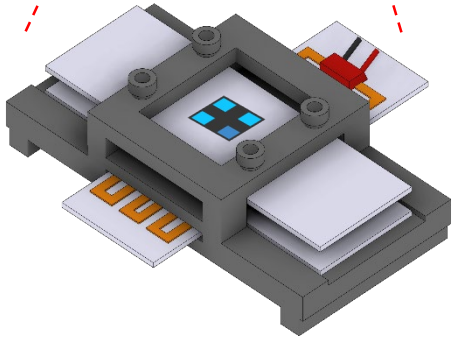
Ristaino et al., 2020. Comparison of LAMP, real-time and Digital PCR for detection of *Phytophthora infestans*. Plant Disease 104:708-716.

Integrated Microneedle smartphone LAMP Platform for Pathogen Identification in Planta

Qingshan Wei, Rajesh Paul, Jean Ristano

Smartphone Fluorescent Reader





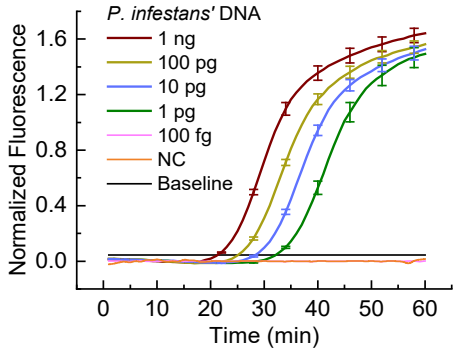
Heated sample cassette

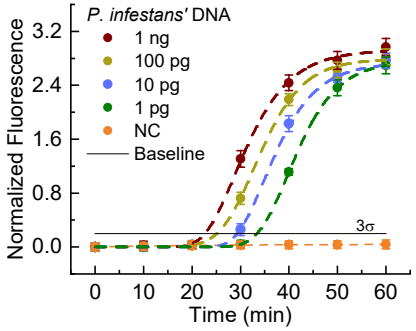
Patterned MN Patch

Benchtop real-time thermocycler

Smartphone-based Platform

P. infestans





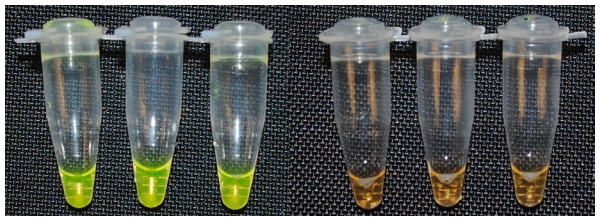
Paul, R., Saville, A. C., Hansel, J. C., Ye, Y., Ball, C. Williams, A., Chang, X., Chen, C., Gu, Z., Ristaino, J. B., and Wei, Q. 2019. Extraction of Plant DNA by Microneedle Patch for Rapid Detection of Plant Diseases. ACS Nano 13:6540-6549. DOI: 10.1021/acsnano.9b00193.

Multiplexed Tomato Pathogen Detection on a Smartphone

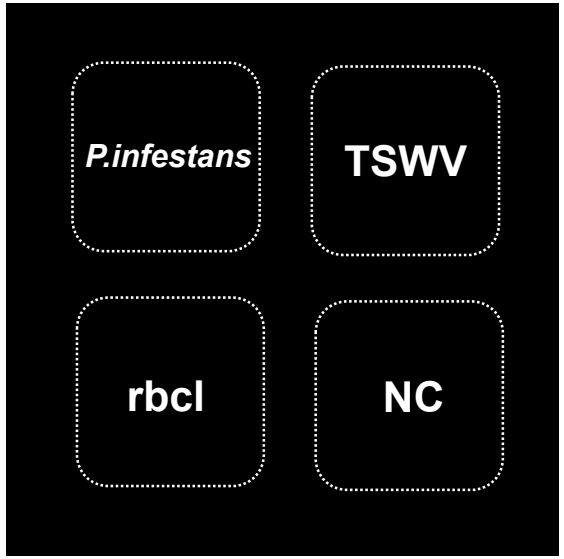
Information to aid resistance screening, track resistance breaking strains and guide management



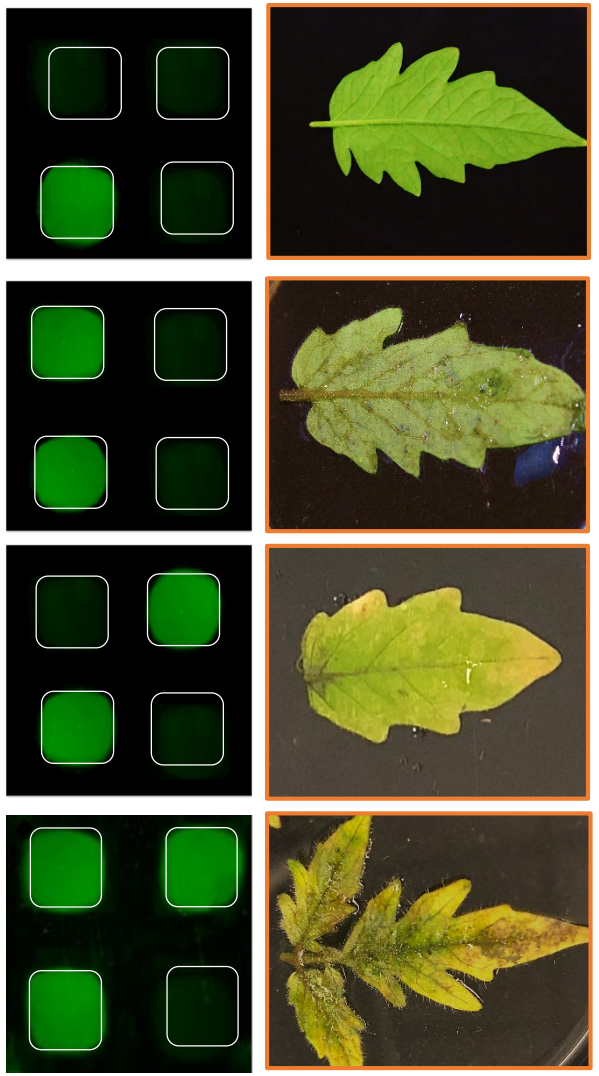

Q. Wei R. Paul A. Whitfield J. Ristaino



Loading of LAMP primers



Smartphone images **Leaf photographs**



Healthy leaf

P. Infestans **infected leaf**

TSWV infected leaf

TSWV and *P. infestans* co-infected leaf

Paul, R., Ostermann, E., Chen, Y., Saville, A. C., Yang, Y., Gu, Z., Whitfield, A. E. Ristaino, J. B., and Wei. Q. 2020. Integrated Microneedle-Smartphone Nucleic Acid Amplification Platform for In-Field Diagnosis of Plant Diseases. Biosensors and Bioelectronics 187:113312.

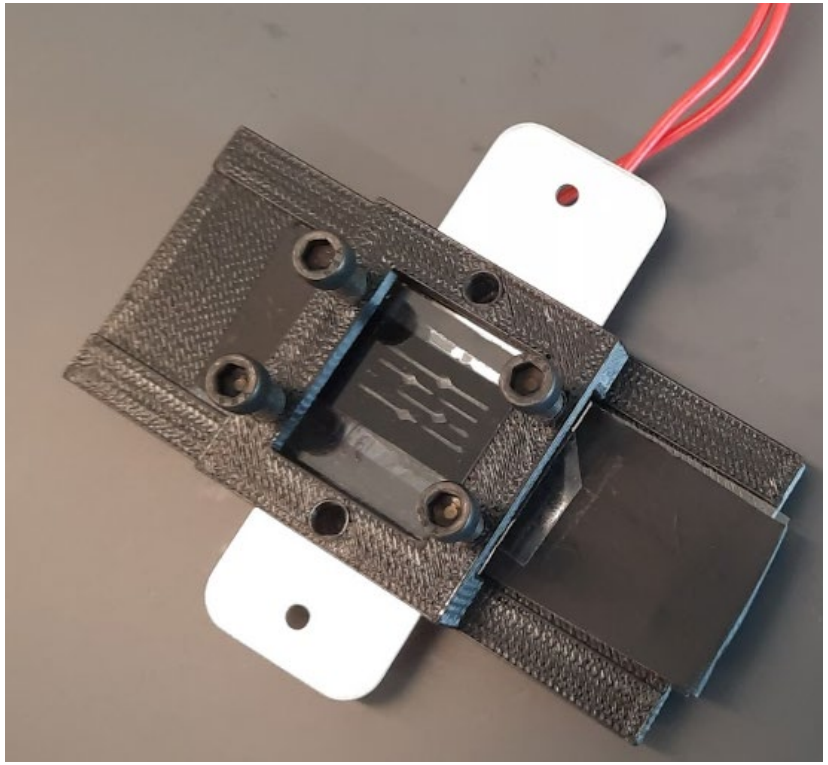
Version 2.0 Smart phone microfluidic LAMP cassette

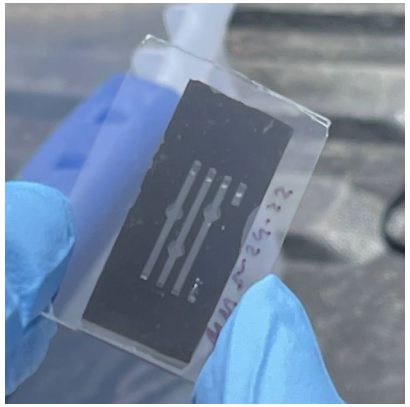

Q. Wei


J. Ristaino

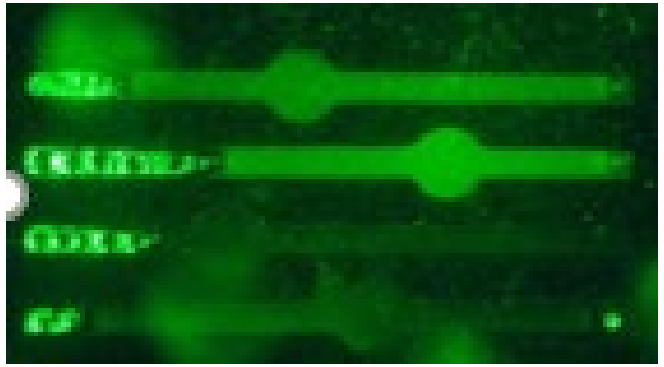

R. Paul


T. Shymanovich

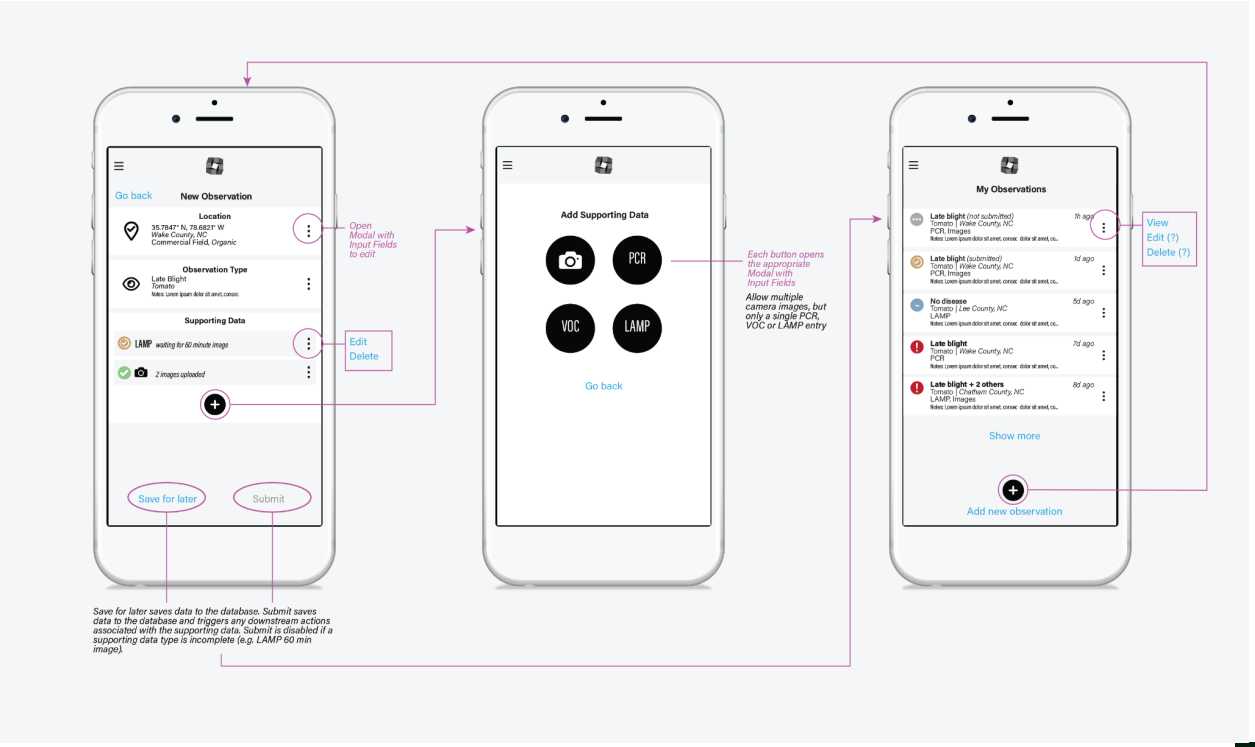


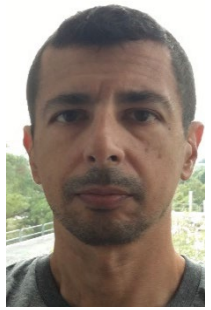


Field test was run summer 2022
- MN patch – DNA extractions
- Lyophilized reagents – further testing underway
- Slide heater device – redesign with makerspace lab in PSB



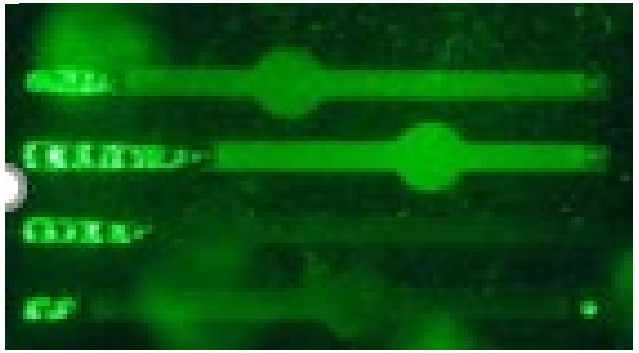
Link LAMP data collected in the field with PaDB by a web app



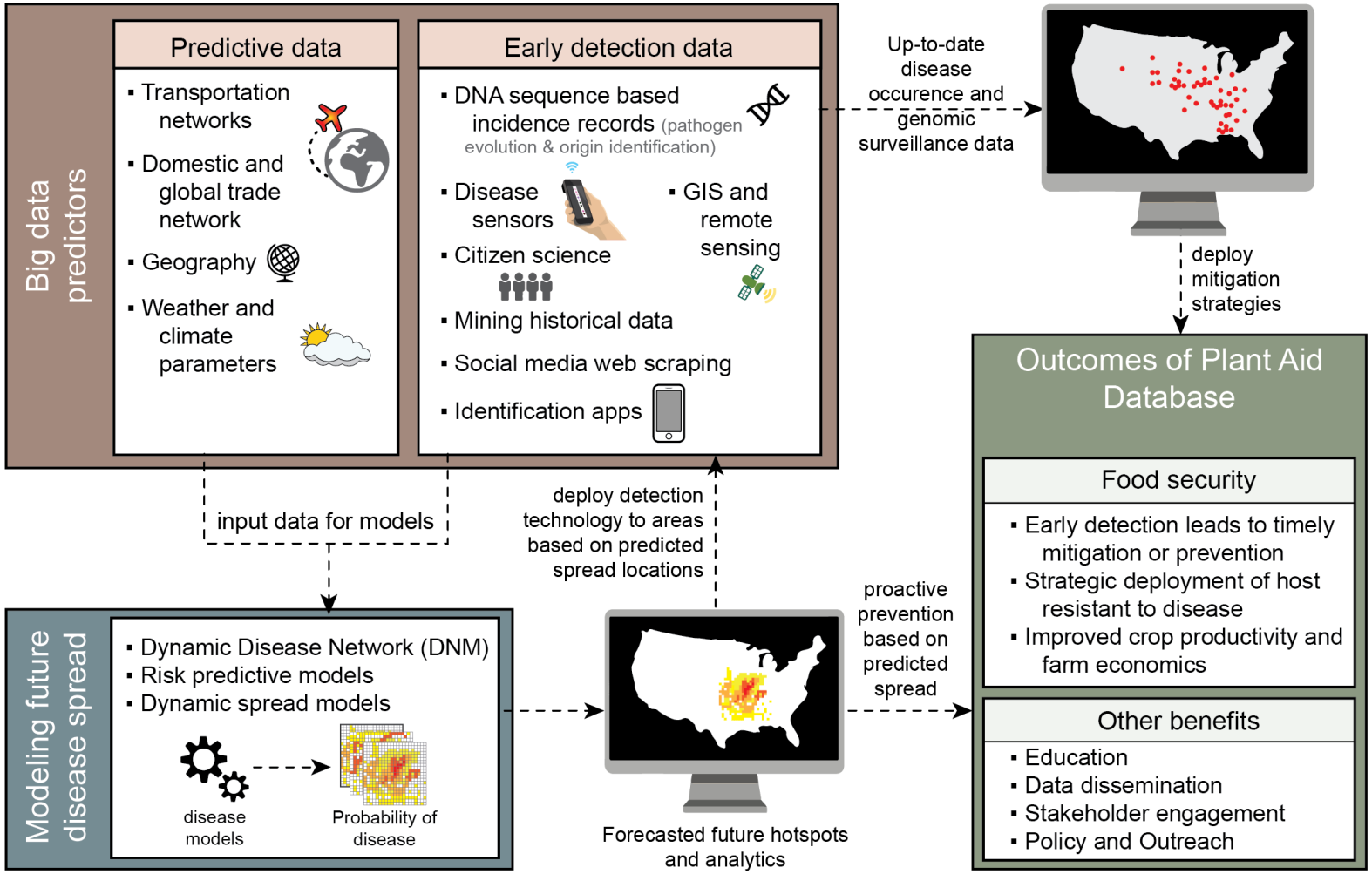


Chris Jones John Polo

-Image analysis software being trained to read the LAMP cassette redults
--Linking sensor data to PaDB platform

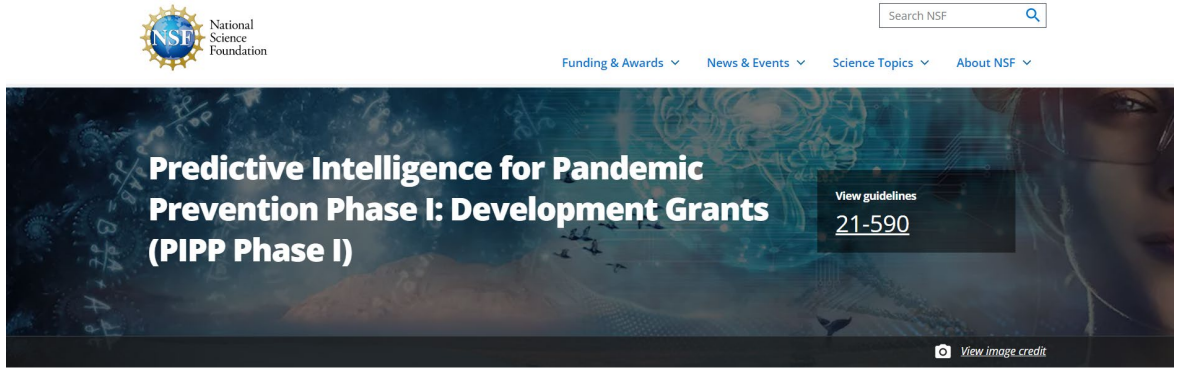


Plant Aid Database (PaDb)



Can We Predict the Next Plant Disease Pandemic? Todays Program

- Climate change and emerging disease risks
- Diagnostics from the ground up
- Diagnostics at the national and international levels
- Modeling, forecasting and decision support tools
- Population genomics
- Understanding and mitigating threats
- Plant Aid Database
- Group photo – 4 pm
- Poster session – 4-6 pm
- Building tour – 5:15



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J. Ristaino's laboratory website
http://ristainolab.cals.ncsu.edu//

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