

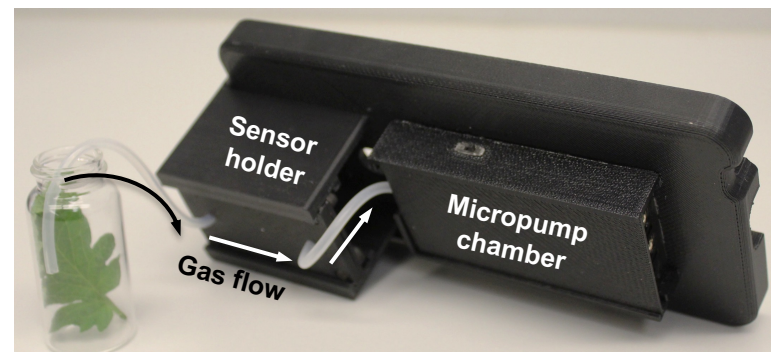
Field-Portable Plant Sensors

Microneedle-based plant DNA extraction

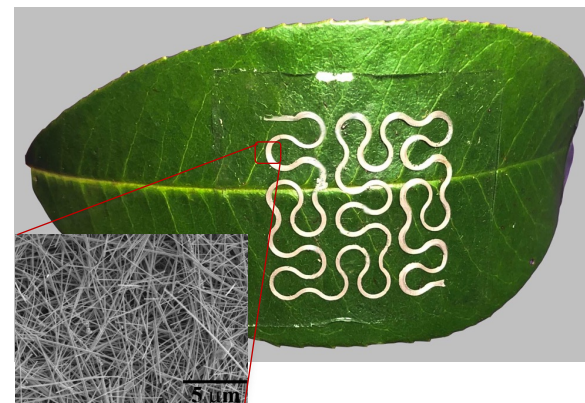


Collaborator: Zhen Gu (ZJU), Jean Ristaino (EPP, NCSU)

Plant VOC sensor



Plant wearables

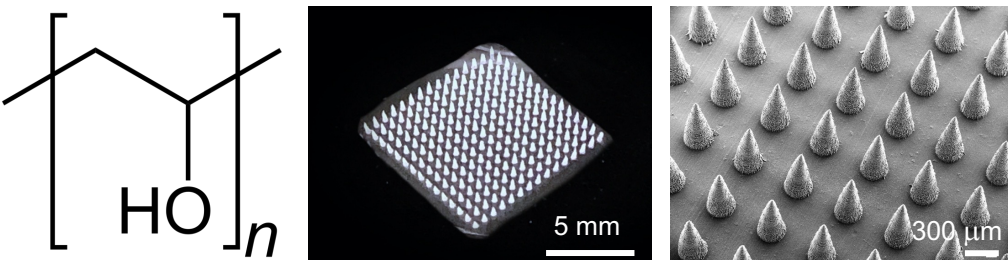


Collaborator: Yong Zhu (MAE, NCSU)

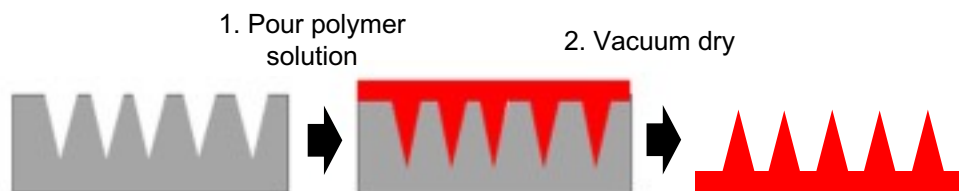
Wei Research Group, Chemical and Biomolecular Engineering, NC State
Contact: qwei3@ncsu.edu

Microneedle Patch for Rapid DNA Extraction

- Polyvinyl alcohol (PVA) microneedle (MN) patch



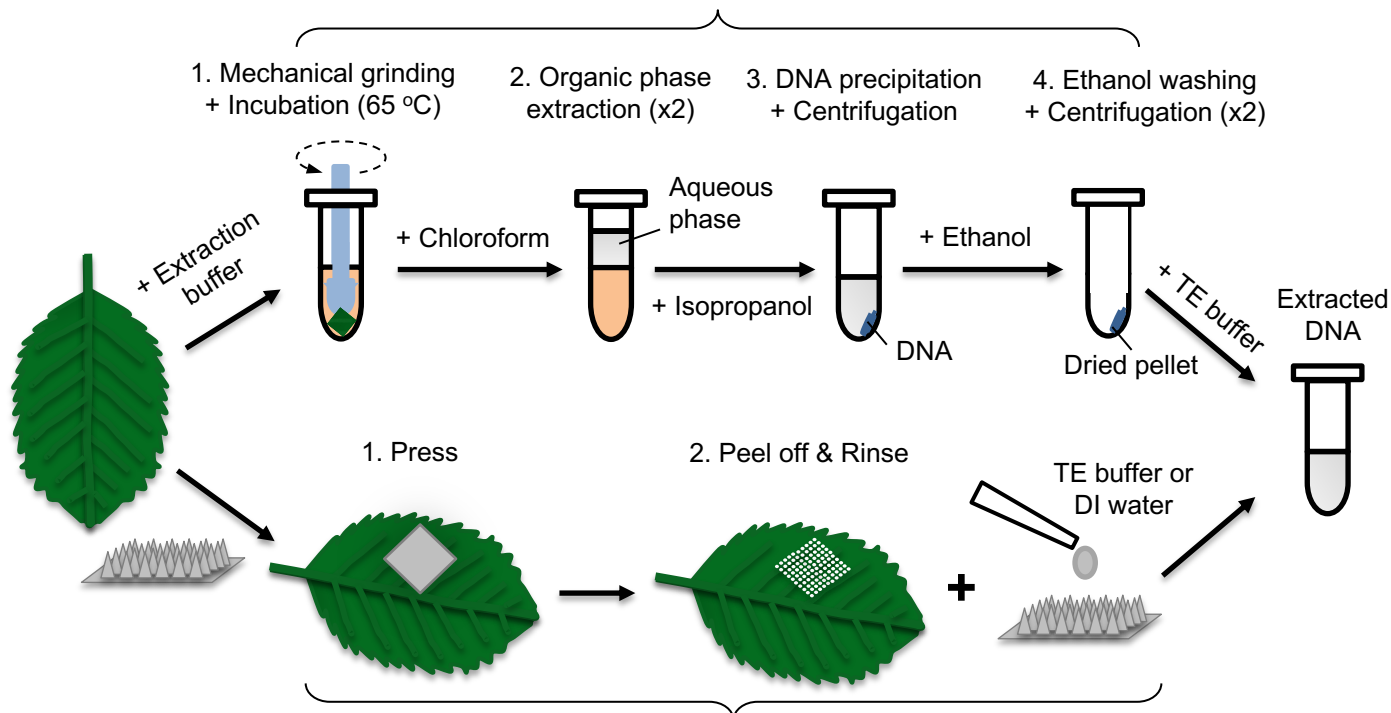
- Micromolding



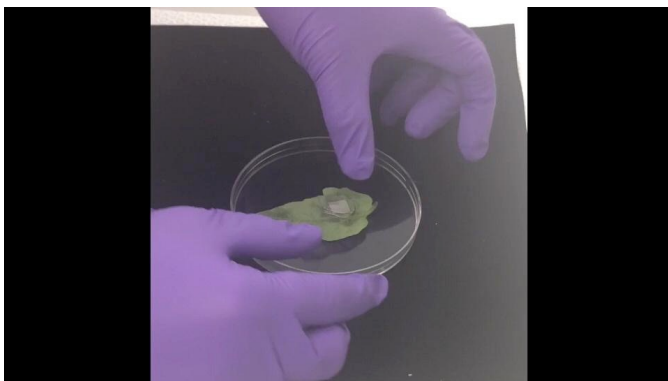
Collaborators: Jean Ristaino (NCSU), Zhen Gu (ZJU)

Simple Extraction Procedure

Conventional CTAB extraction (~3-4 hours)

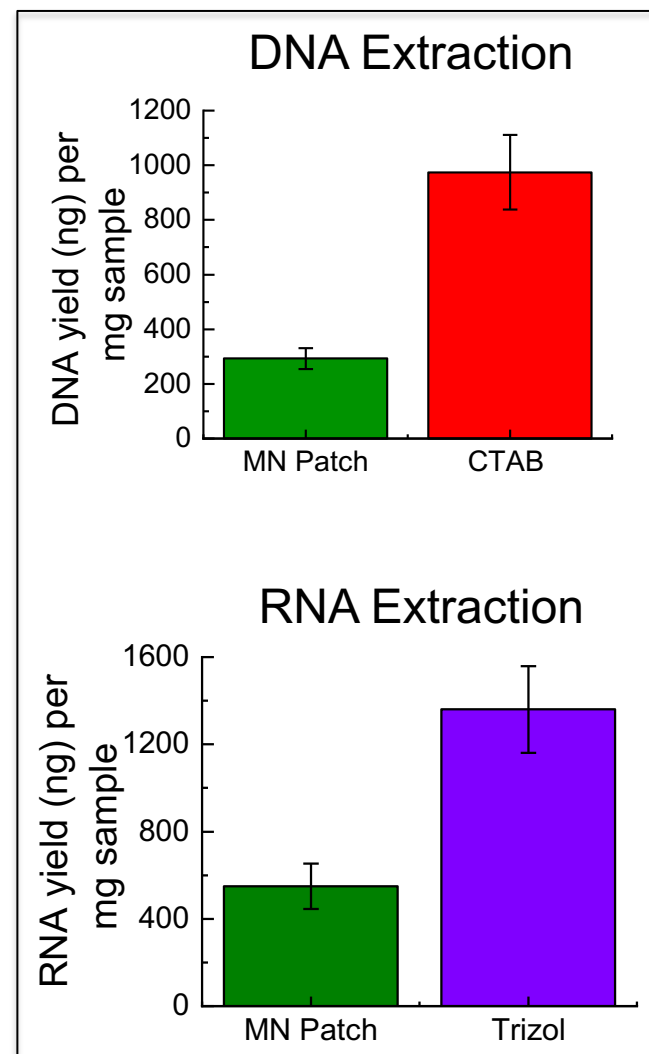
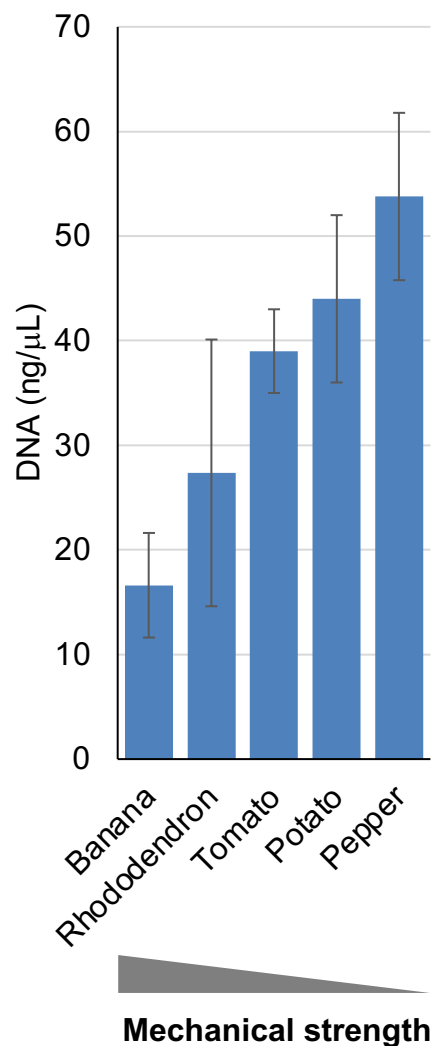
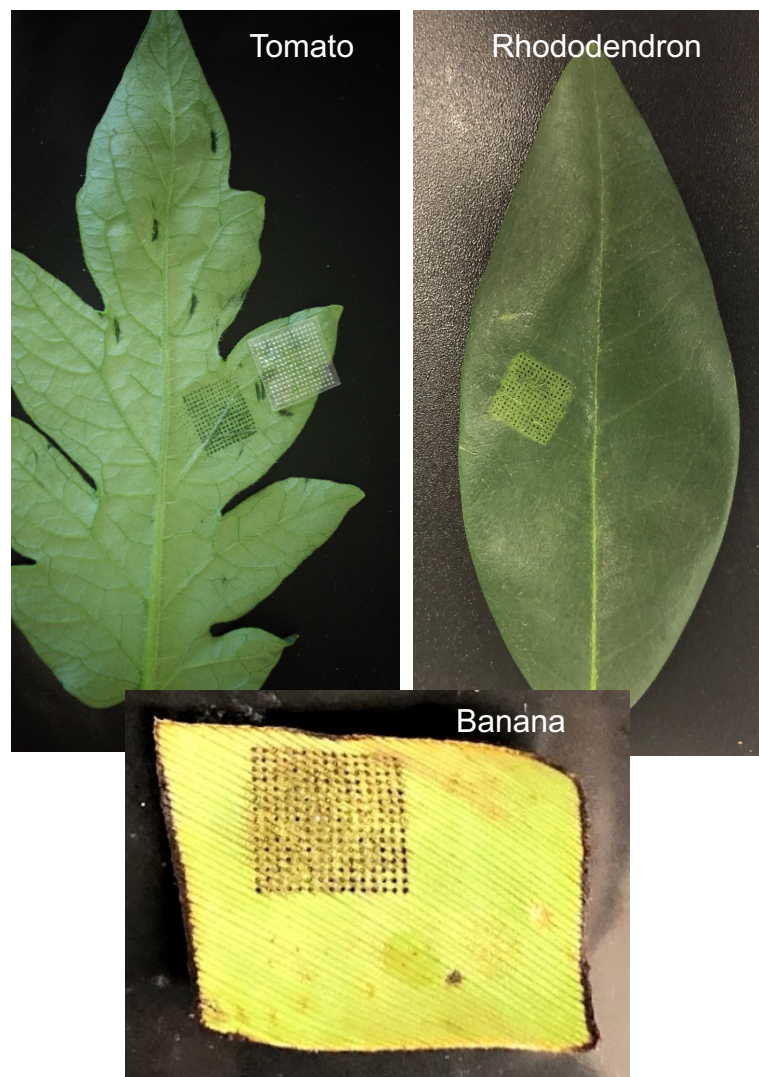


MN extraction (~ 1 min)



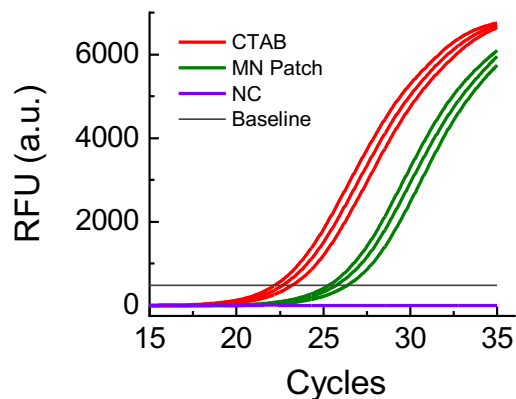
- **2 simple steps**
- **Complete < 1min**
- **Tissue/cell lysis free**
- **Purification-free**
- **A few cents per patch**

Applicable to Different Plants and Targets

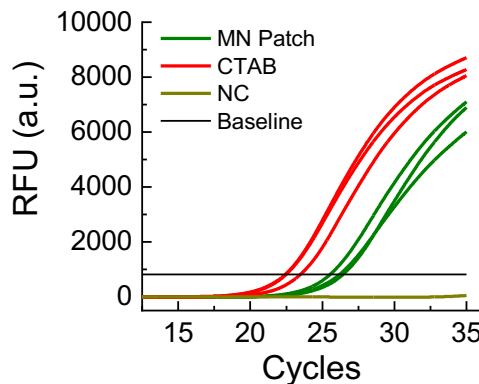


Direct Amplification of MN-Extracted DNA/RNA

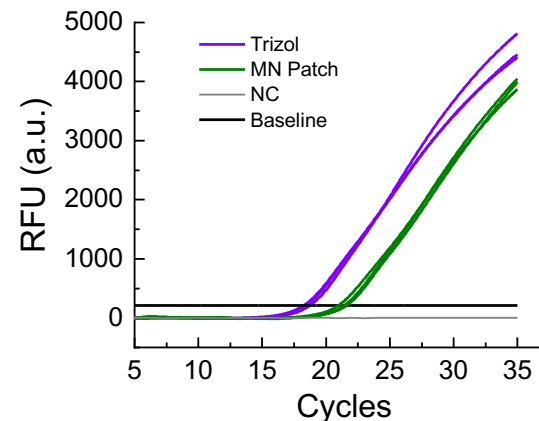
Host plant DNA analysis
(*rbcL* gene)



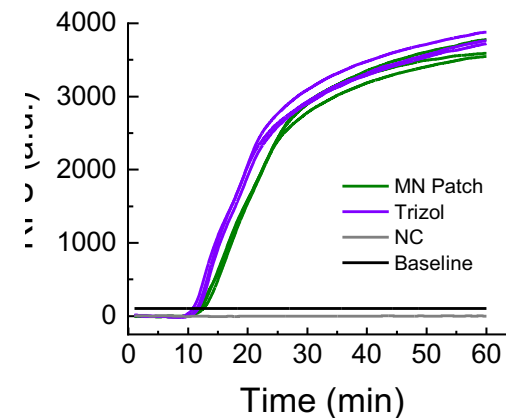
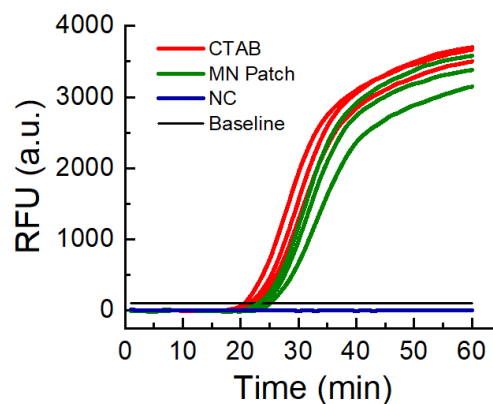
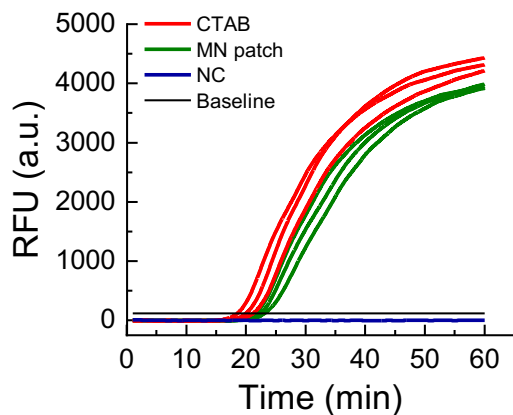
P. Infestans detection
(DNA pathogen)



TSWV detection
(RNA pathogen)

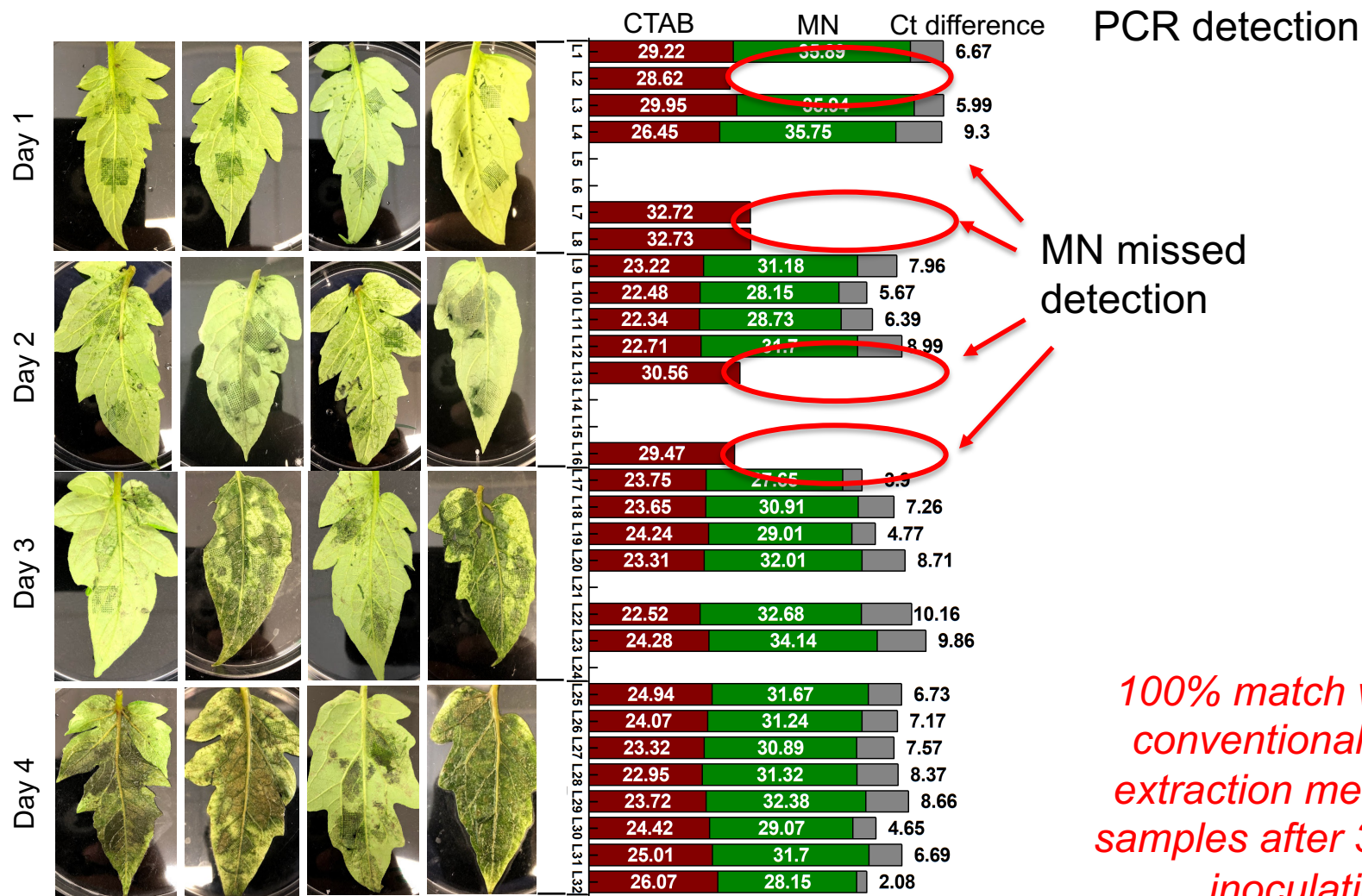


LAMP
/RT-LAMP

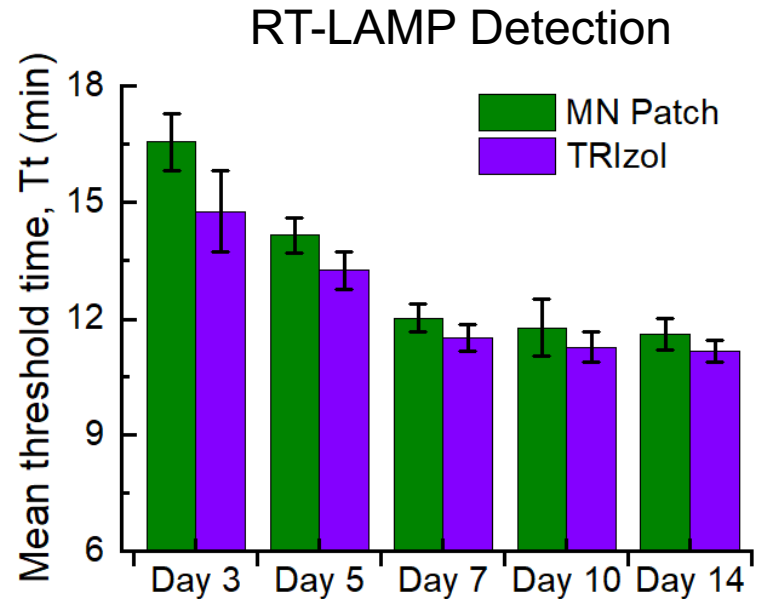
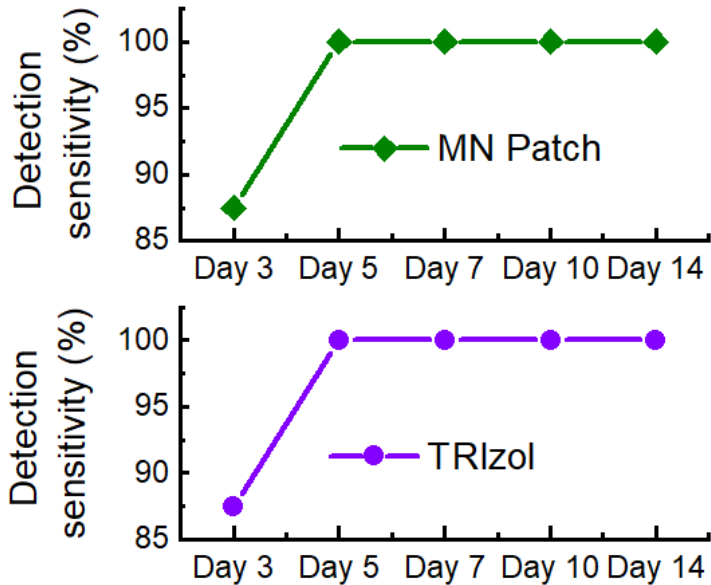


MN-extracted DNA/RNA is directly applicable for PCR or LAMP amplification without any purification.

Detection of Late Blight (*P. infestans*) in Tomato

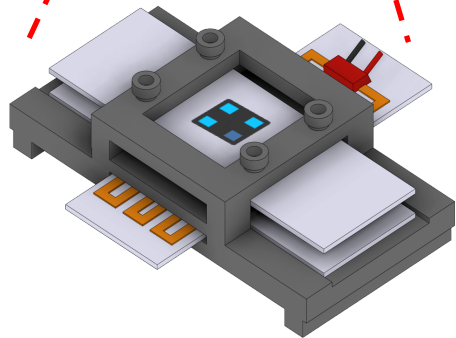
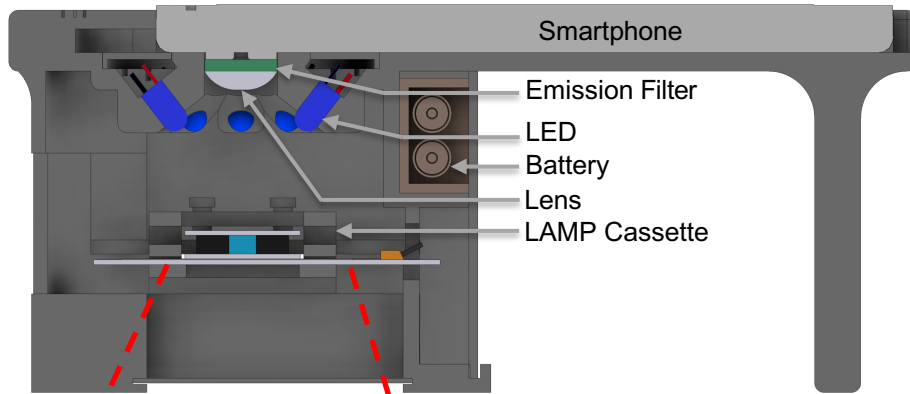


Detection of Tomato Spotted Wilt Virus (TSWV)

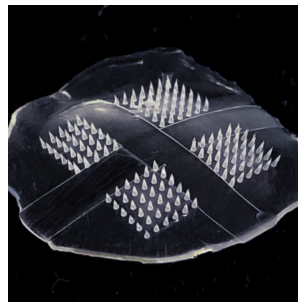


Integrated Microneedle-Smartphone Diagnostic Platform

Smartphone Fluorescent Reader

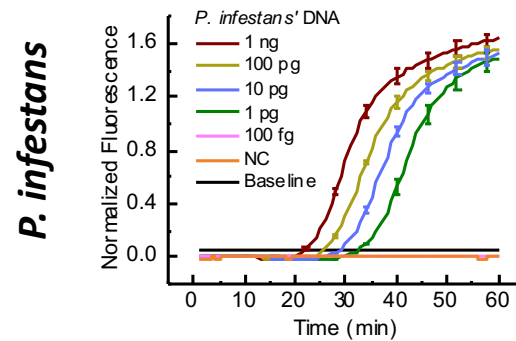


Heated sample cassette

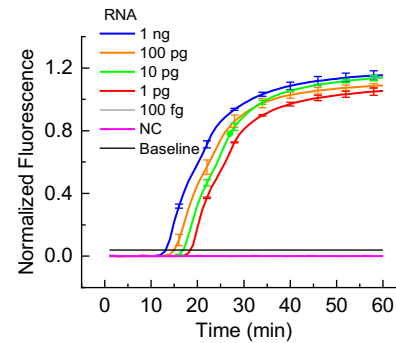


Patterned MN Patch

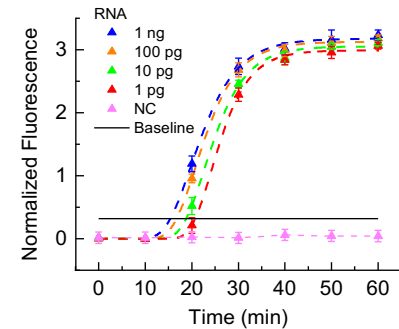
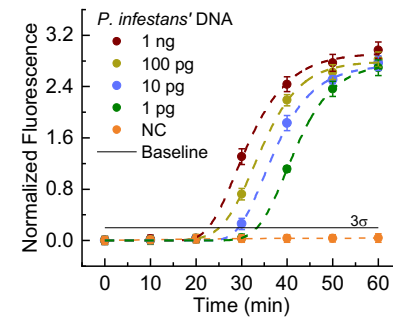
Benchtop real-time thermocycler



TSW



Smartphone-based Platform



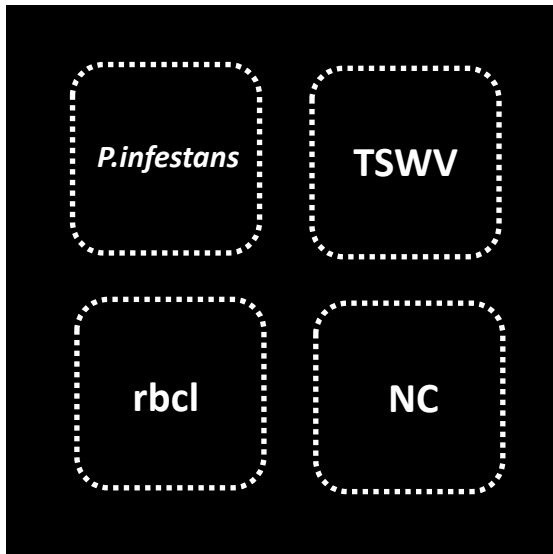
1 pg detection sensitivity on the smartphone

Collaborators: Jean Ristaino, Anna Whitfield (NCSU)

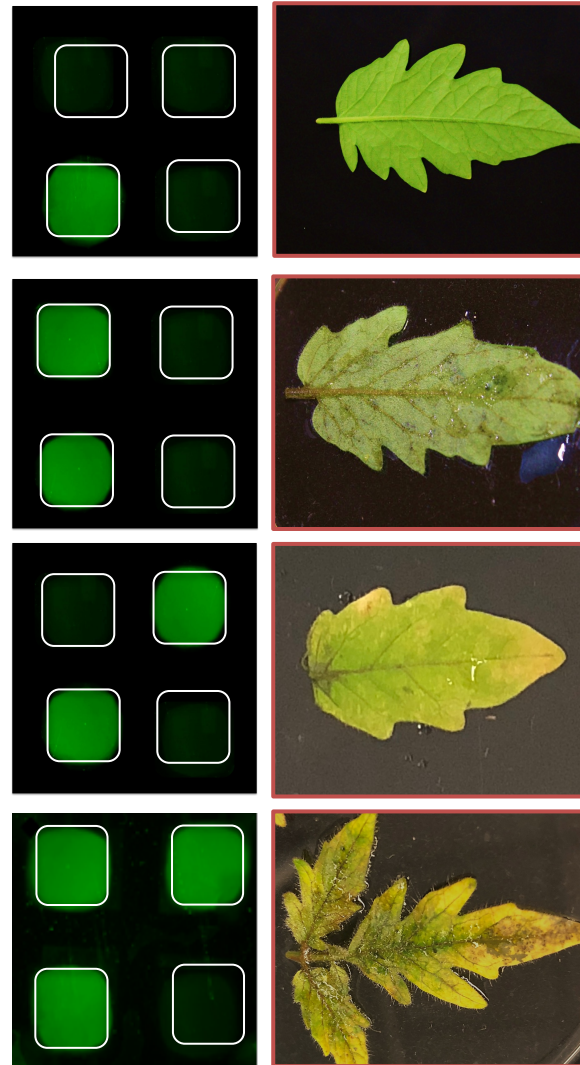
Multiplexed Plant Pathogen Detection on a Smartphone



Loading of LAMP primers



Smartphone images Leaf photographs



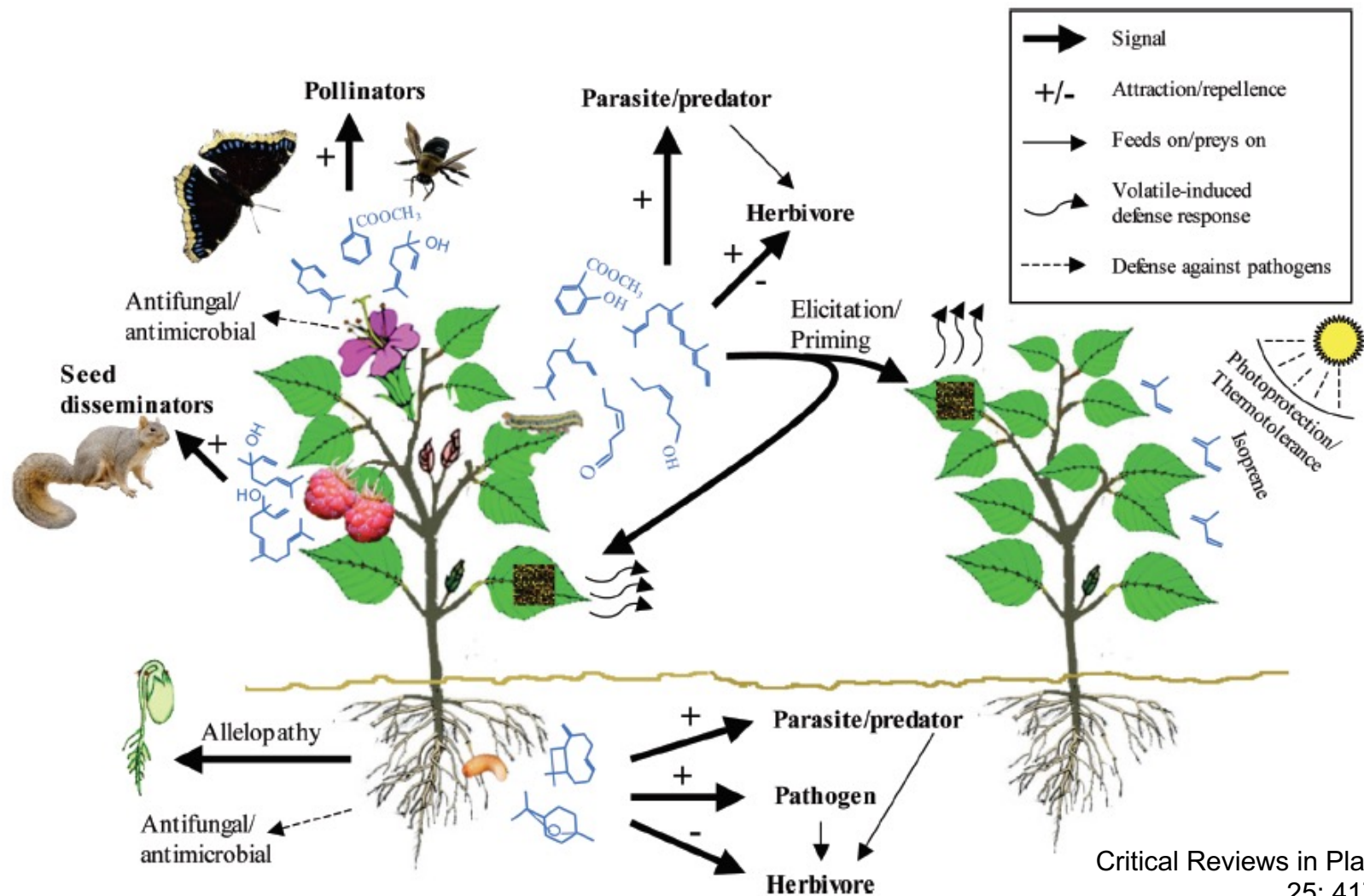
Healthy leaf

P. Infestans infected leaf

TSWV infected leaf

TSWV and *P. infestans* co-infected leaf

Volatile Organic Compounds (VOCs) as Noninvasive Diagnostic Markers

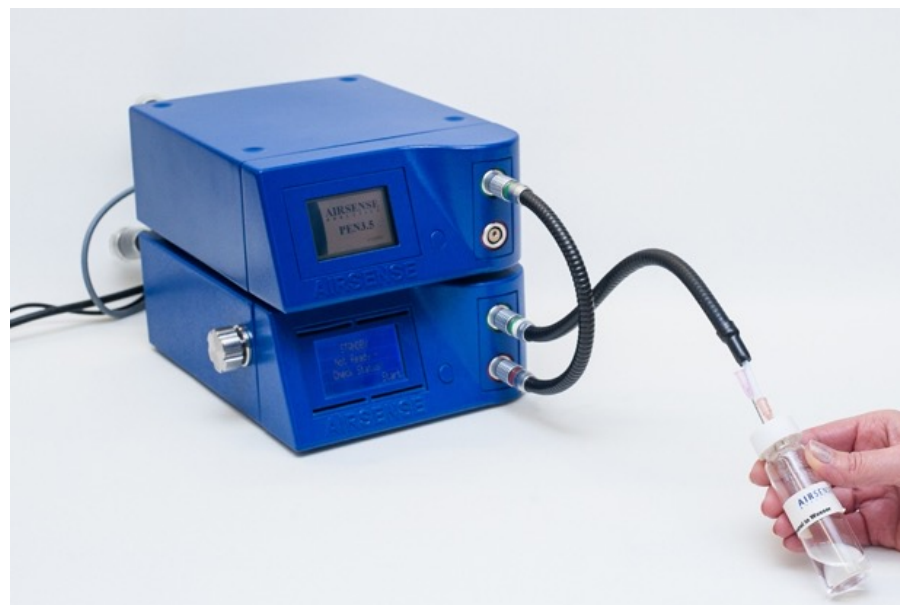


Current VOC Measurement Methods



SPME & GC-MS

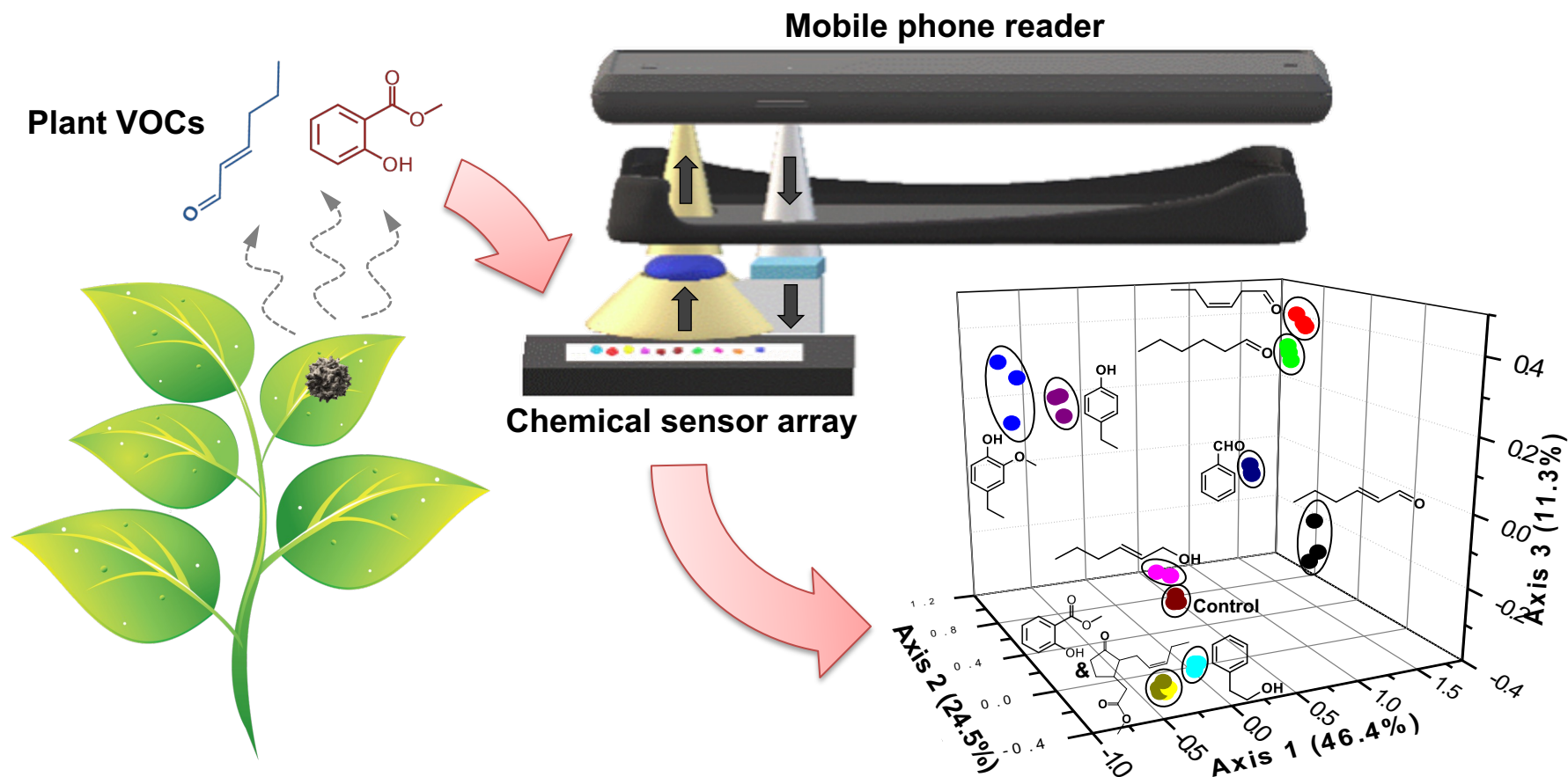
- Cost



Electronic nose (E-Nose)

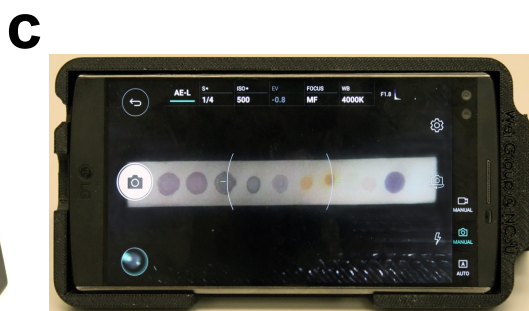
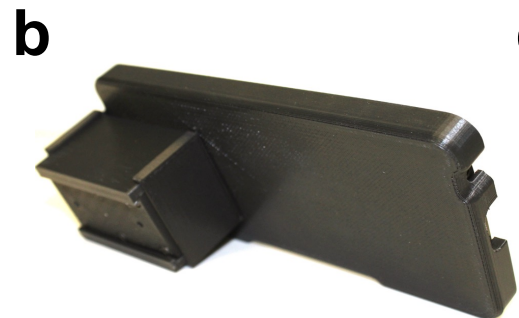
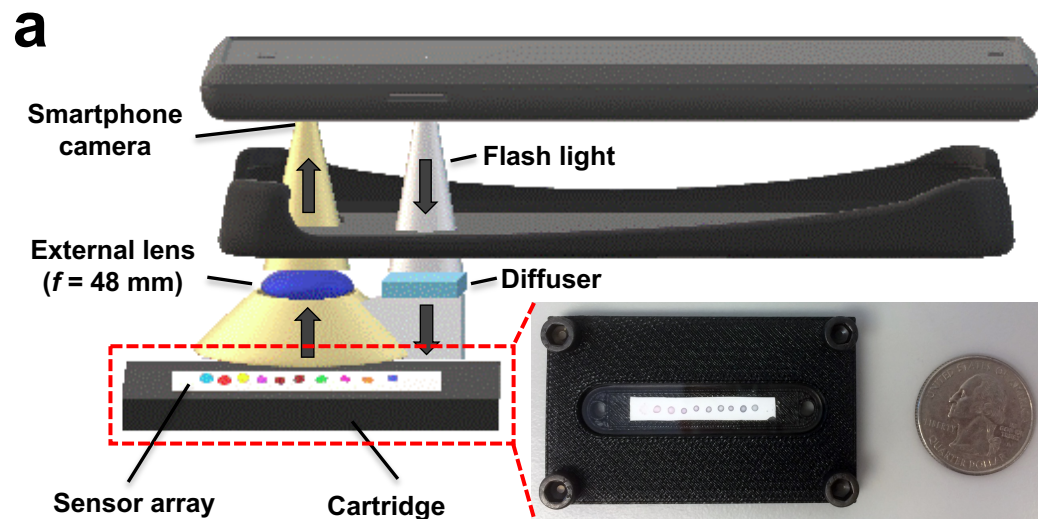
- Signal drift
- Humidity
- Selectivity

Noninvasive Plant Volatile Profiling

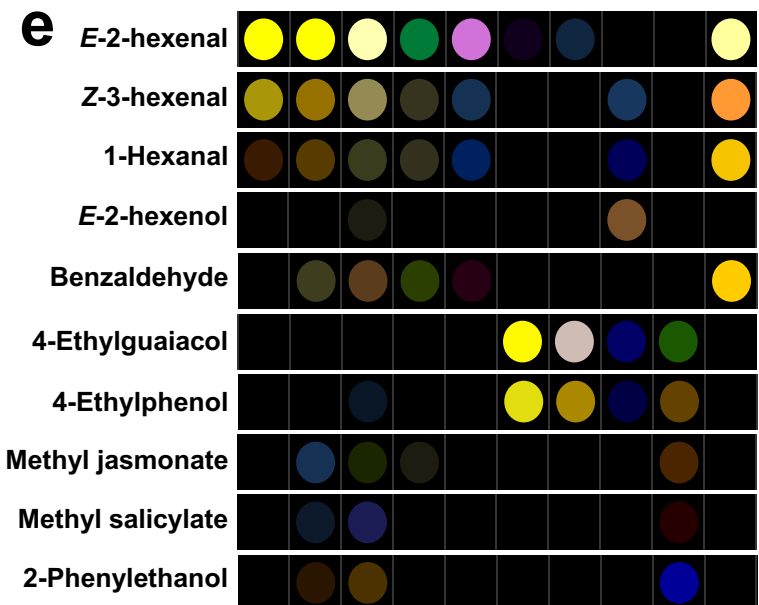
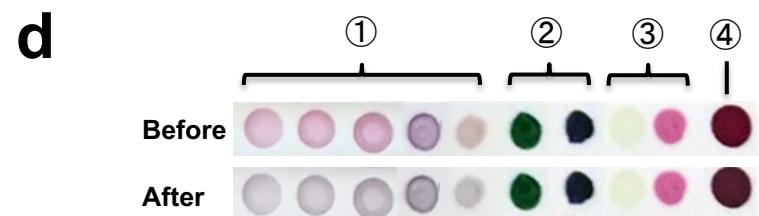


A Smartphone-Based Plant VOC Sensor

3D-printed Smartphone VOC Reader



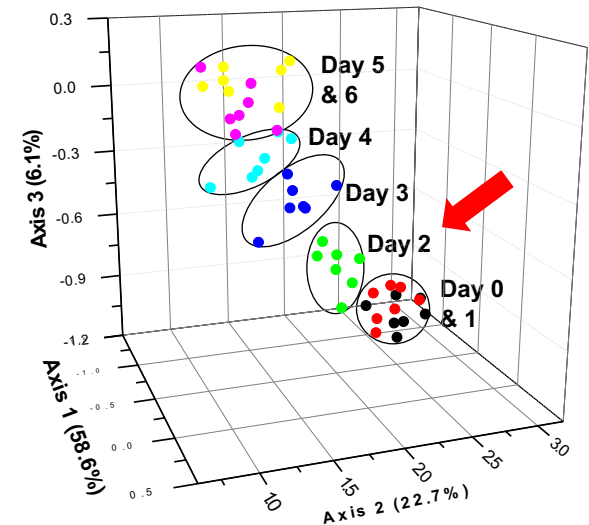
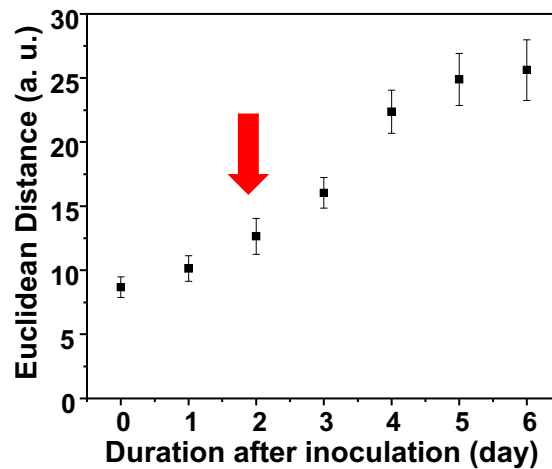
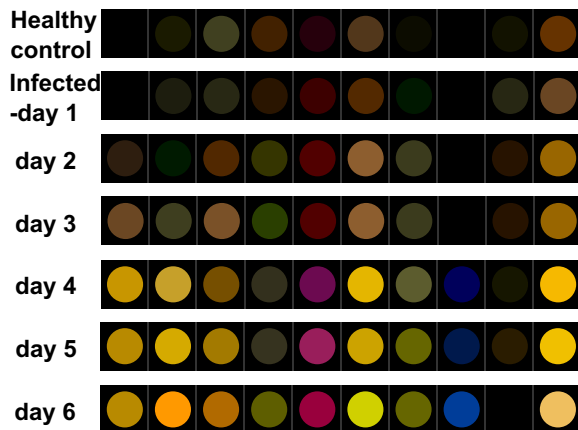
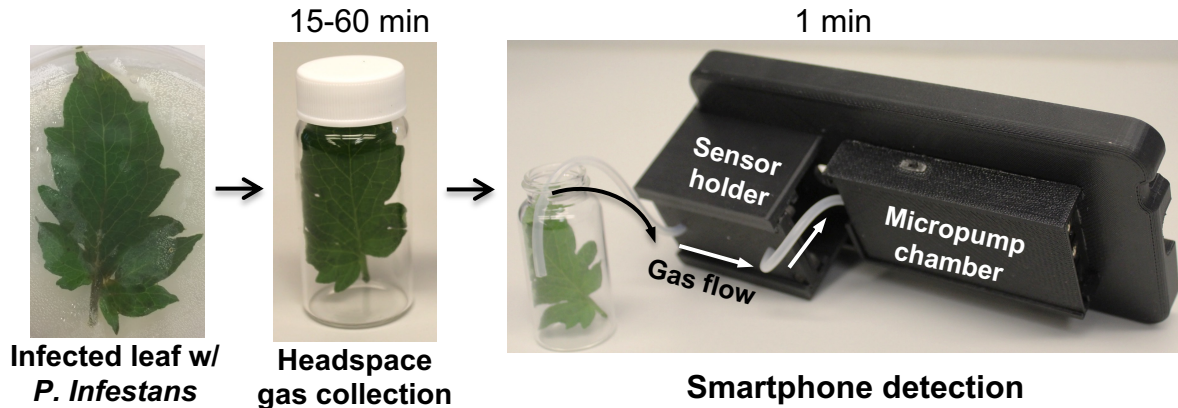
Multiplexed chemical sensor array



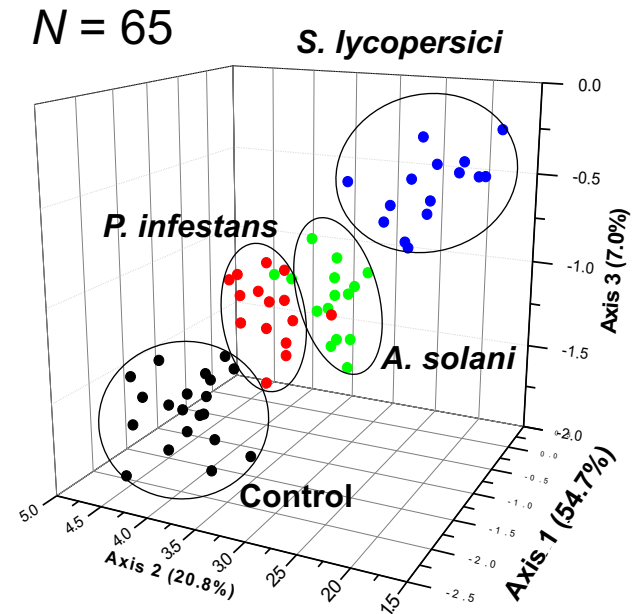
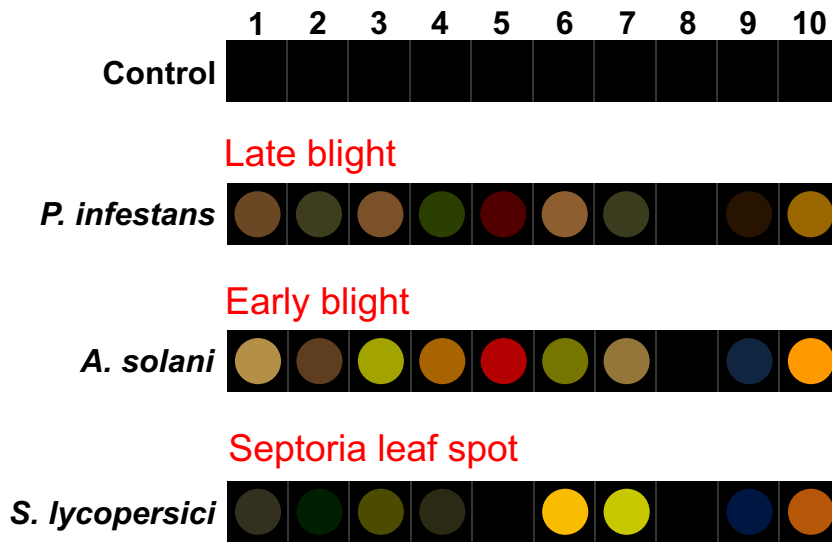
Region ①: Functionalized nanoparticles as specific chromogenic colorants

Early Detection of Late Blind (*P. Infestans*) After 2 Days of Inoculation

Detection workflow:



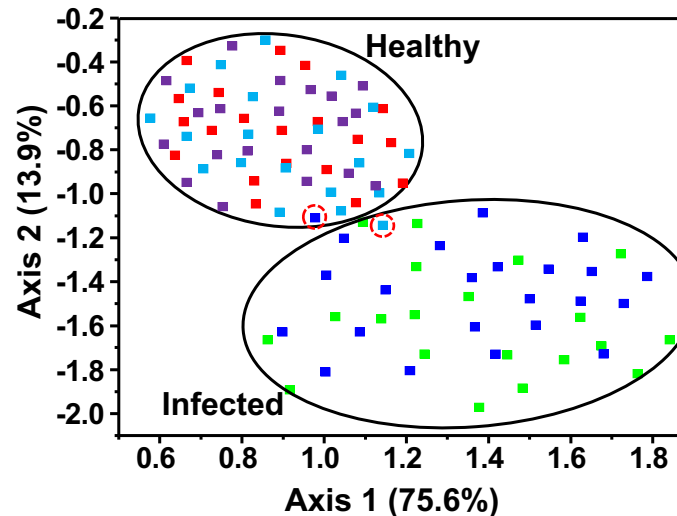
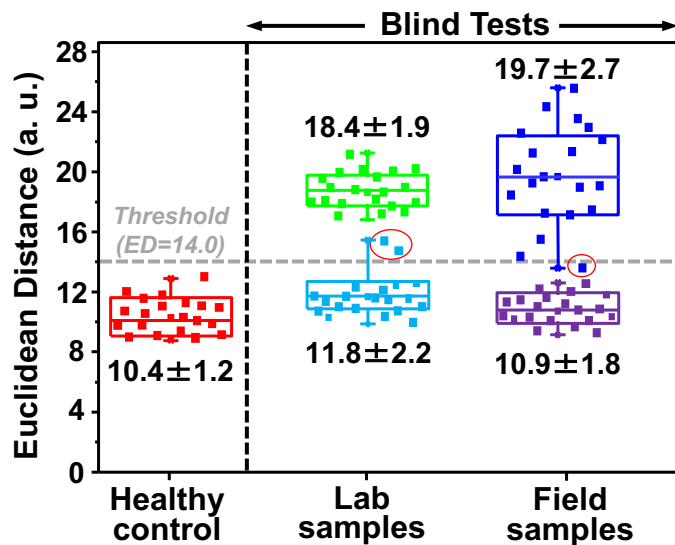
Differentiation of Other Pathogens With Similar Symptoms



Classification accuracy: 95.4%

Blind Tests with Field Samples

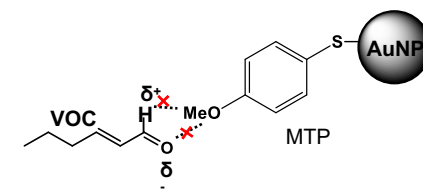
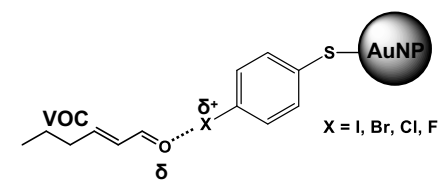
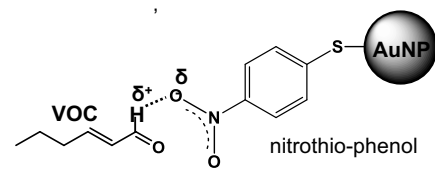
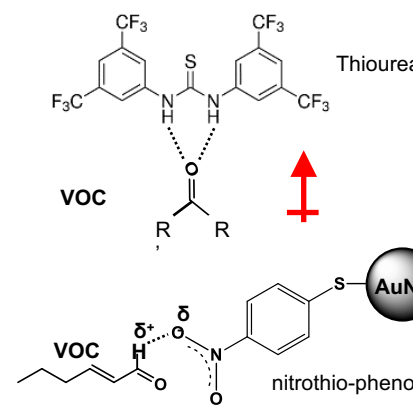
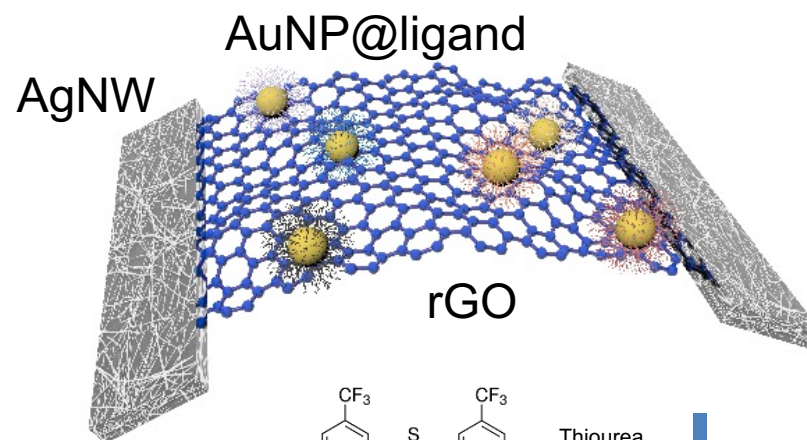
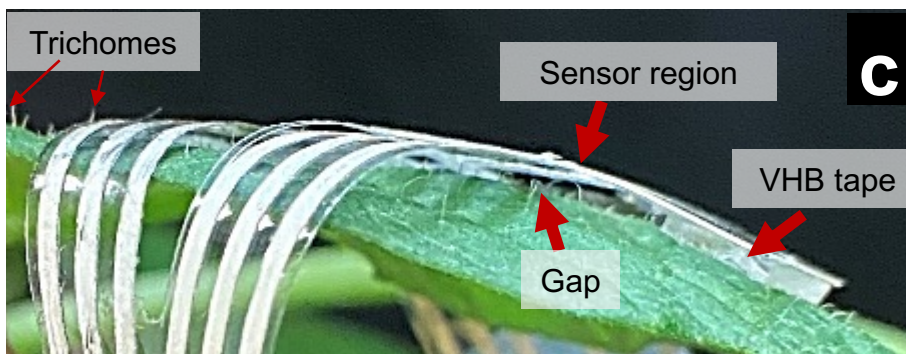
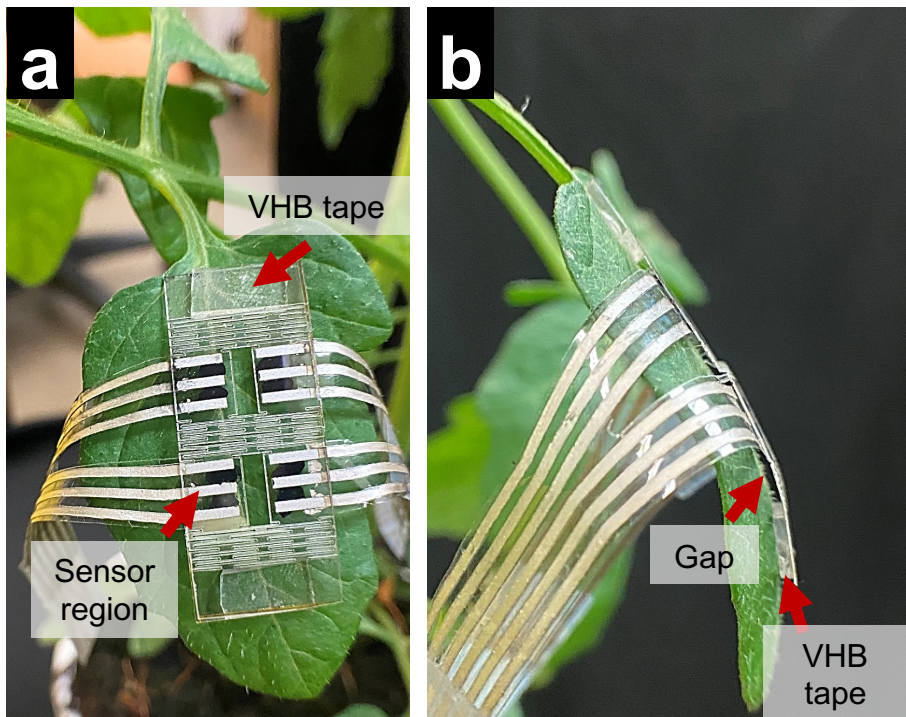
Infection reported in Haywood County, NC on Aug 20, 2018



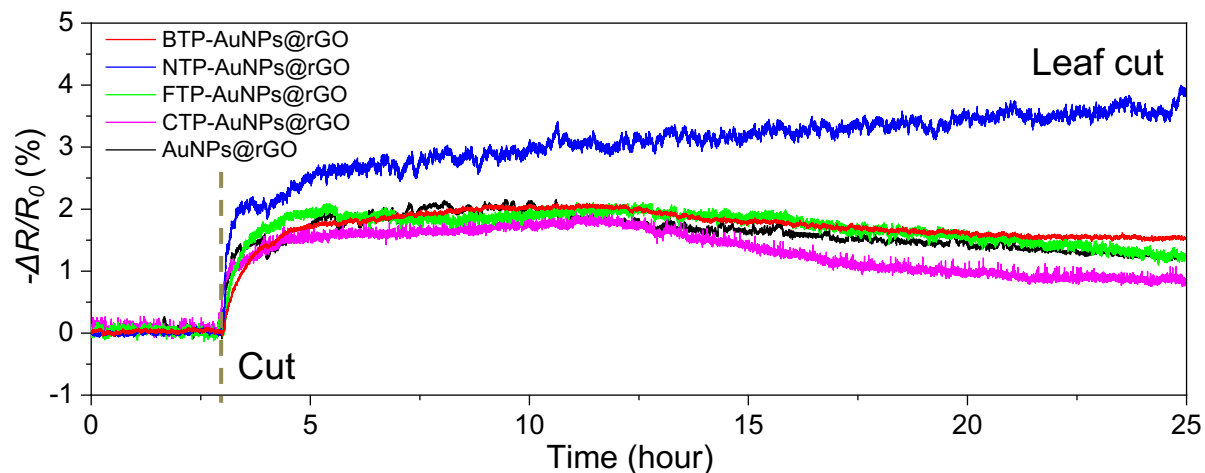
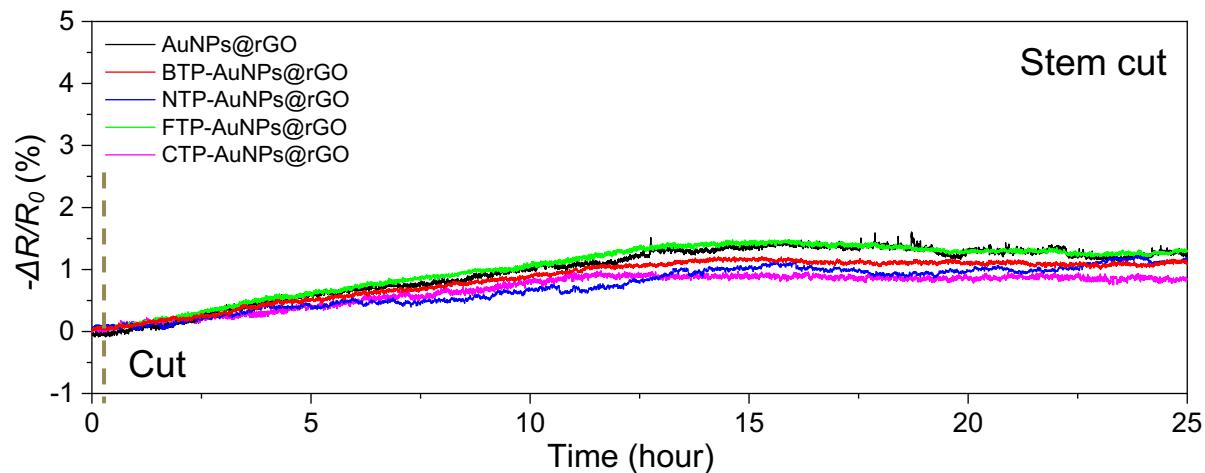
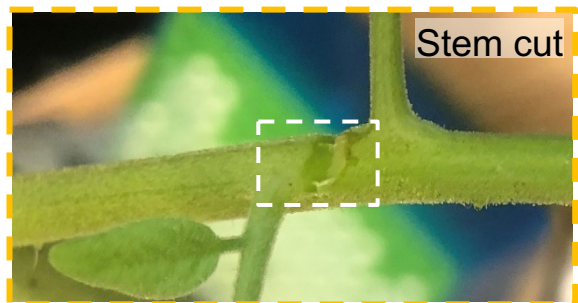
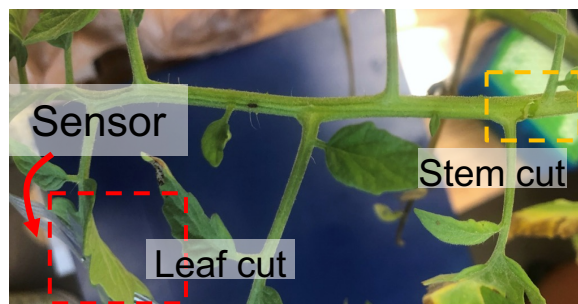
3 errors out of 100 samples tested in total

	Blind Lab Samples (n=40)		Blind Field Samples (n=40)	
	PCR	VOC	qPCR	VOC
True Positive (TP)	20	20	20	19
False Positive (FP)	-	2	-	0
True Negative (TN)	20	18	20	20
False Negative (FN)	-	0	-	1
Sensitivity (TP/P)	-	100%	-	95%
Specificity (TN/N)	-	90%	-	100%
Accuracy ((TP+TN)/n)	-	95%	-	97.5%

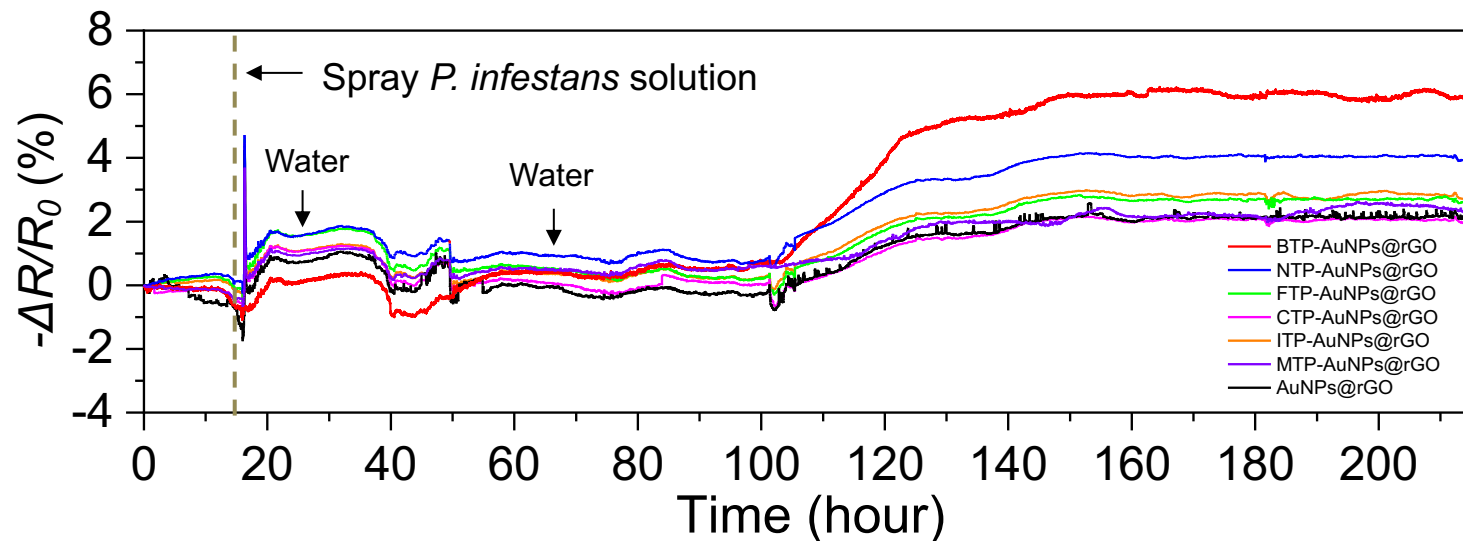
Plant Wearable Sensor for Continuous VOC Analysis



Detect Abiotic Stress: Mechanical Cutting



Detect Biotic Stress: Late Blight Disease (*P. infestans*)



Multifunctional Plant Wearable

Tomato Plant Infected with TSWV (tomato spotted wilt virus)

