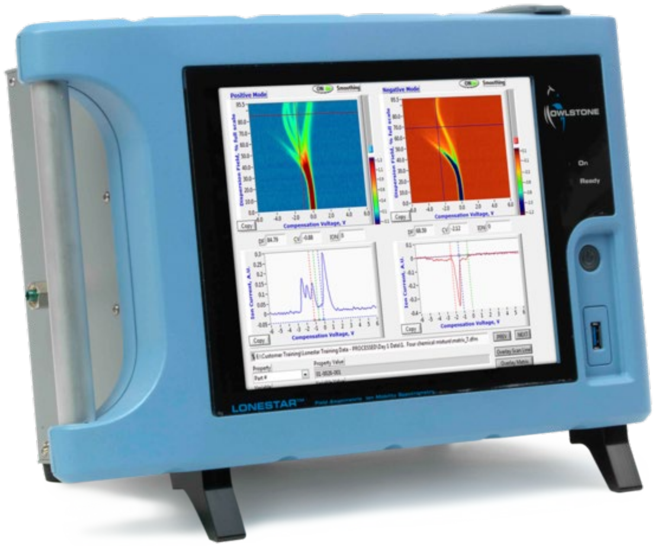
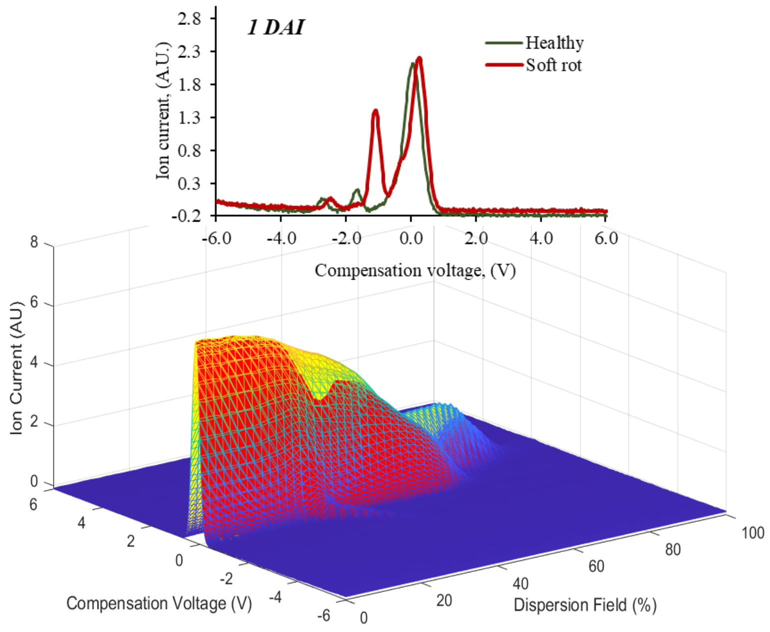
Future of Technology, Robotics, and Automation in Agriculture

Sindhuja Sankaran
Biological Systems Engineering

12 December 2023
Washington State Potato Summit





Sensing Technologies, Robotics, Automation

Abiotic stress | Biotic stress | Growth factors | Crop vigor | Produce quality | Yield potential | Crop loss mgt

Crop Breeding Programs

Phenotyping for genotype selection

Plant Biology Research

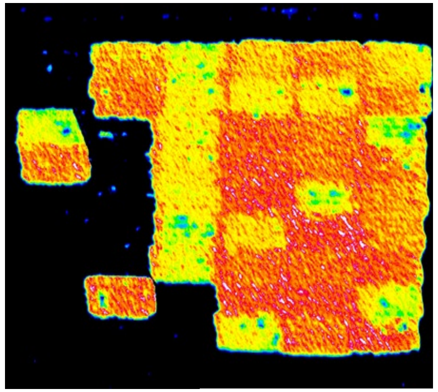
Monitoring physiology & crop status with sensing

Agronomy

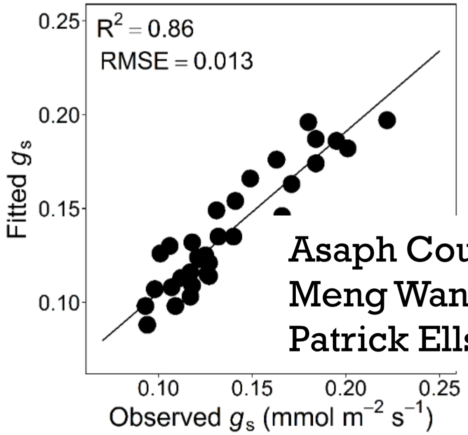
Optimizing agronomic inputs/processes

Precision Agriculture

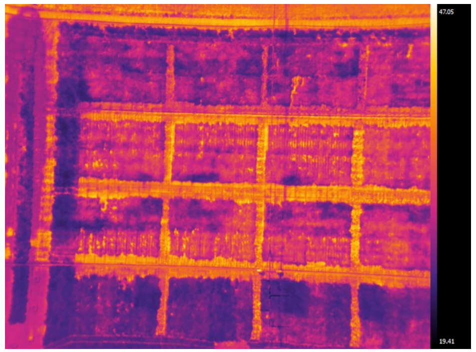
Production Mgt. – irrigation, disease, nutrient, etc.



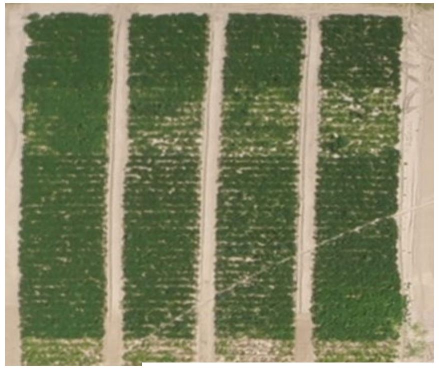
Mark Pavek



Asaph Cousins
Meng Wang
Patrick Ellsworth

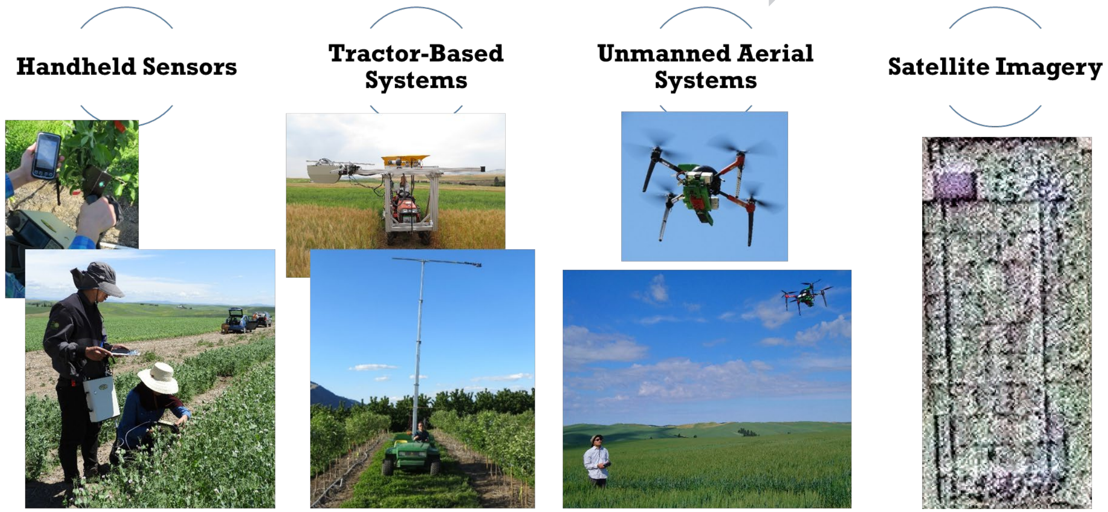


Rick Boydston

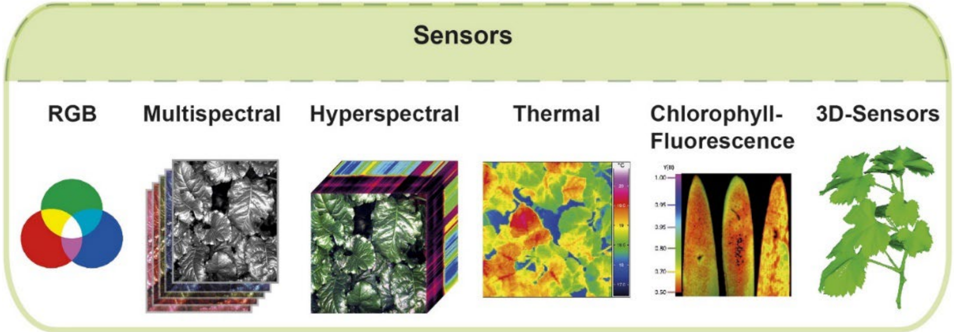


Dennis Johnson

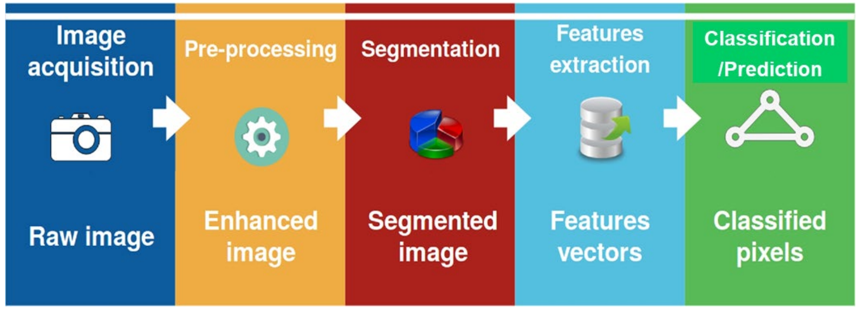
Sensing | Automation | Data Mining



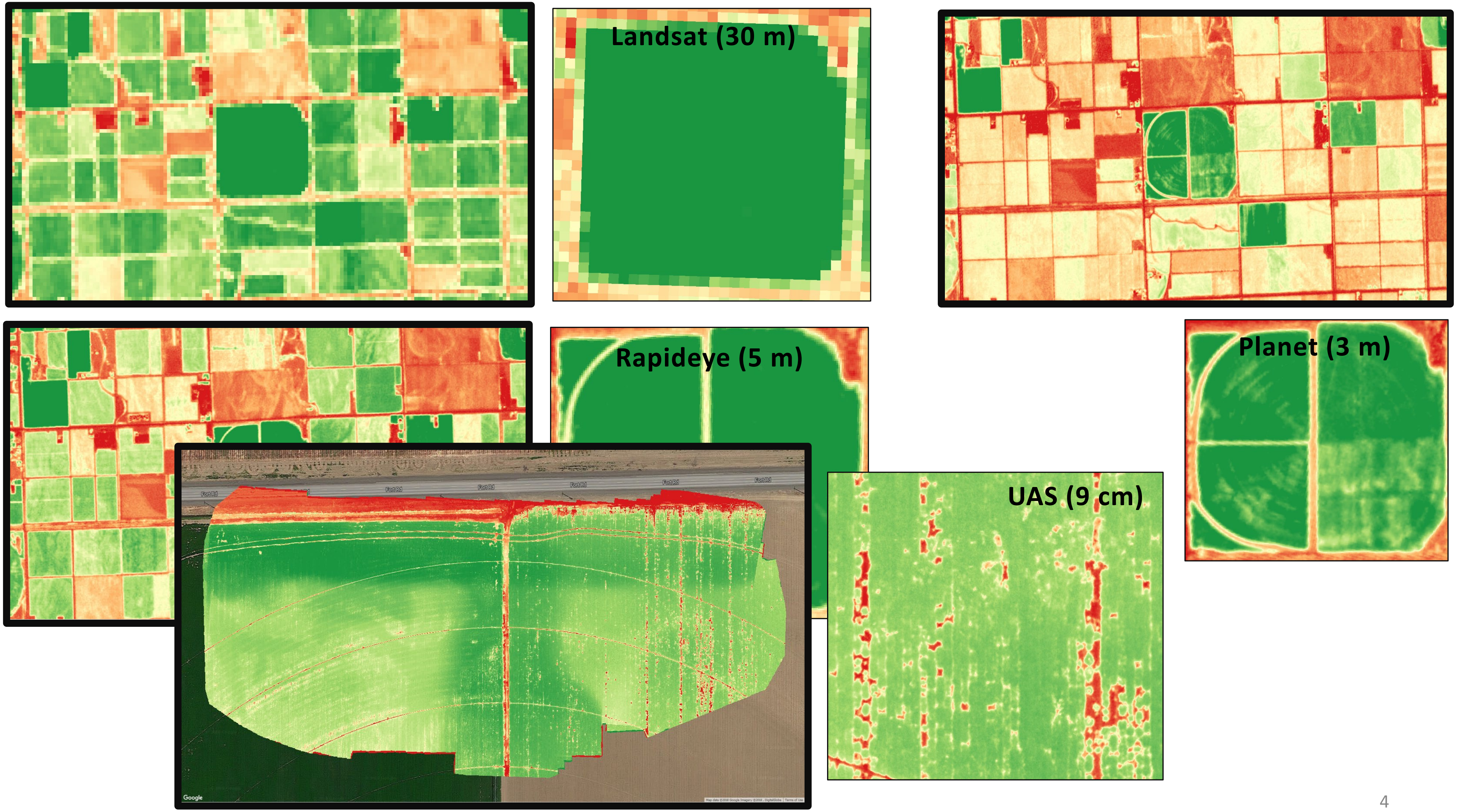
Data mining/machine learning approaches for image processing and data mining



Plant Disease, Vol 100, No 2, pg. 241-251, 2016.

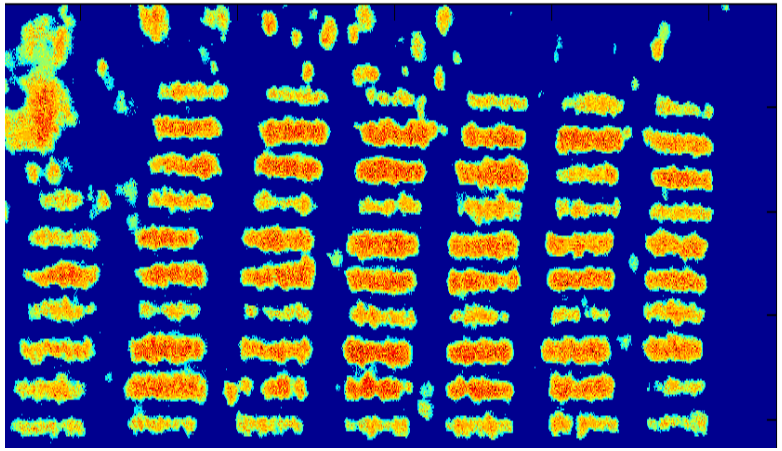


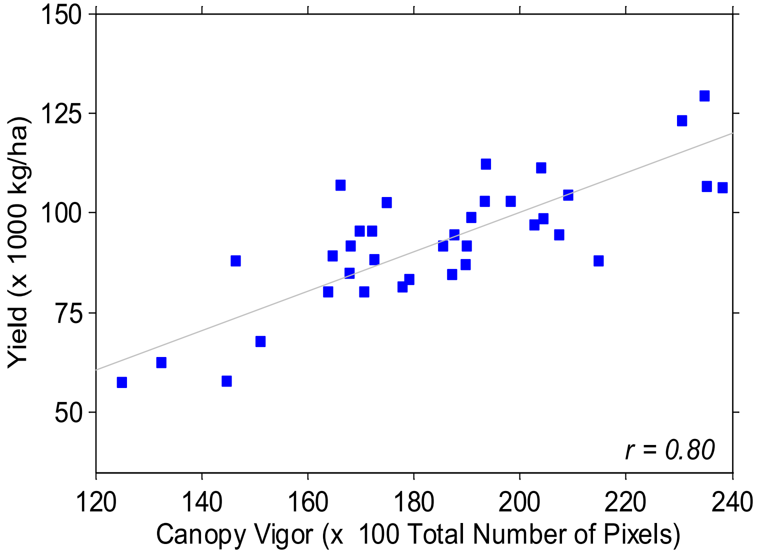
Adapted from: Gigascience, Volume 6, Issue 11, November 2017, gix092, https://doi.org/10.1093/gigascience/gix092


Landsat (30 m)
Rapideye (5 m)
Planet (3 m)
UAS (9 cm)
Google

Disease Detection

Potato virus Y





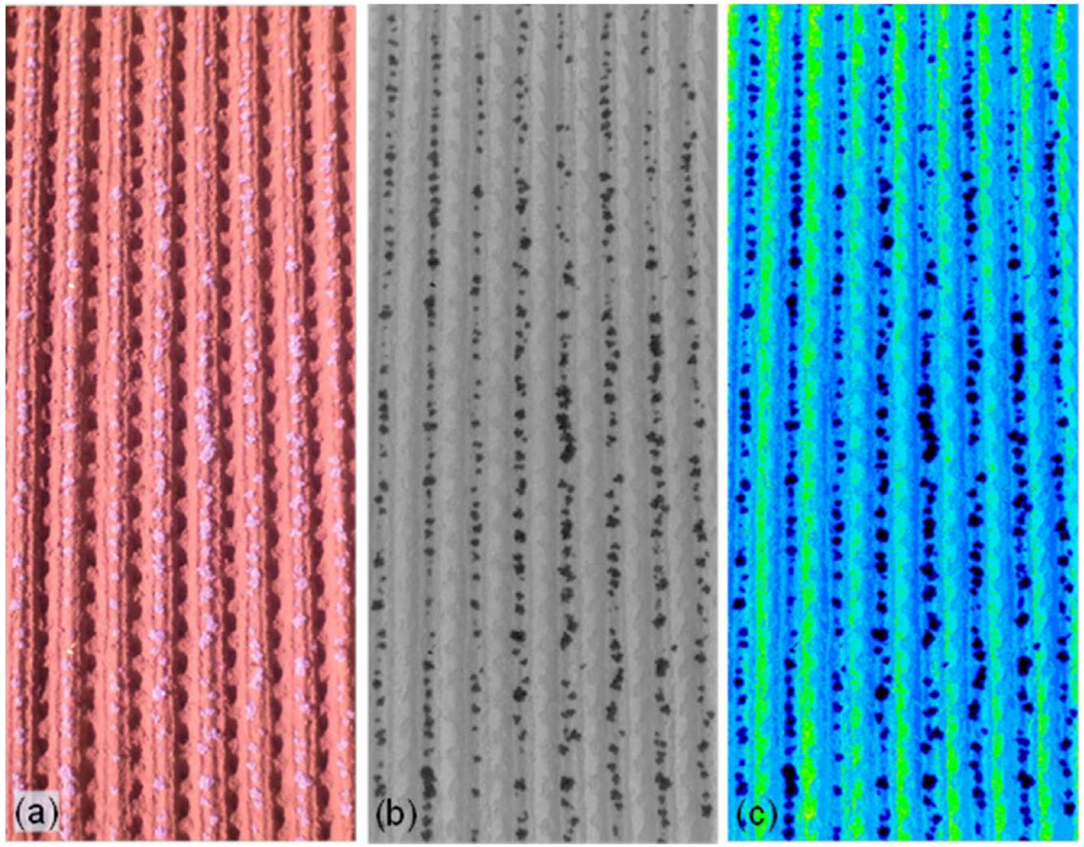
- 20 Russets + 10 Chip and Specialty
- 40 days after planting
- Also relevant for potato early die/late blight detection

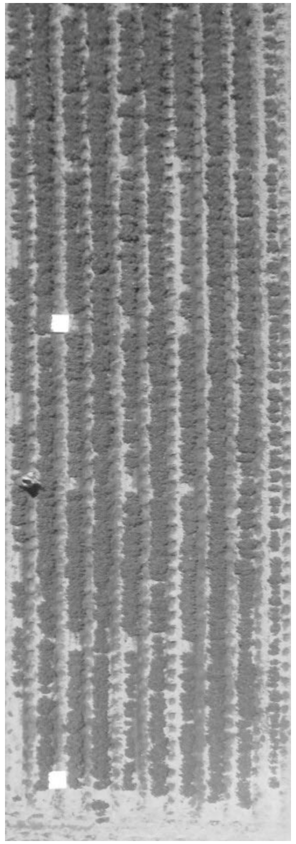
Sagar Sathuvalli,
Oregon State University
Lav Khot (WSU)

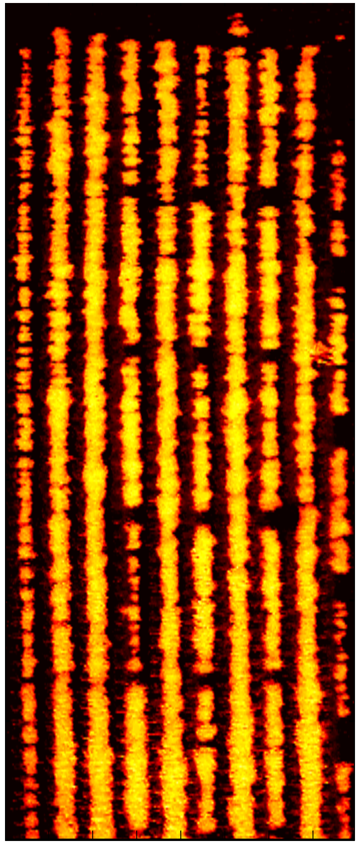
Sankaran, S., Khot, L.R., Zúñiga, C., Jarolmasjed, S., Sathuvalli, V., Vandemark, G., Miklas, P.N., Carter, A.H., Pumphrey, M.O., Knowles, N.R., and Pavek, M.J. 2015. Low-altitude, high-resolution aerial imaging systems for row and field crop phenotyping: A Review, European Journal of Agronomy, 70: 112-123.

Growth Factors

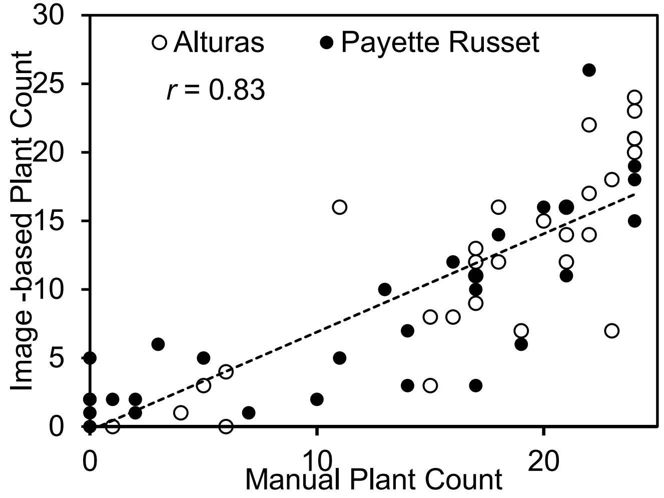
- Emergence and canopy closure
- Effect of growth regulator for early/delayed maturity







Juan José Quirós, WSU
Rick Knowles, WSU
Lisa Knowles, WSU



UAV imagery-based potato emergence 37 days after planting (images were acquired from 15 m altitude) (a) False color multiband image (R, G, NIR as RGB bands), (b) NDVI image in grayscale, and (c) pseudocolor image for better data visualization

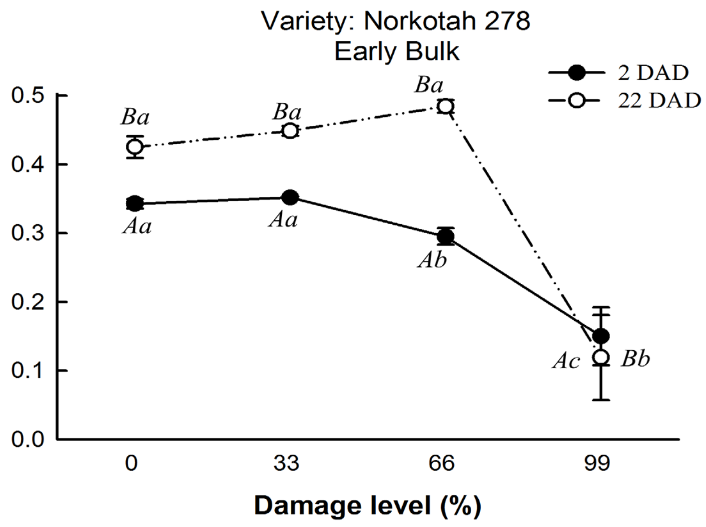
Sankaran, S., Quirós, J.J., Knowles, N.R., and Knowles, L.O. 2017. High resolution aerial imaging based estimation of crop emergence in potatoes. American Journal of Potato Research, DOI 10.1007/s12230-017-9604-2.

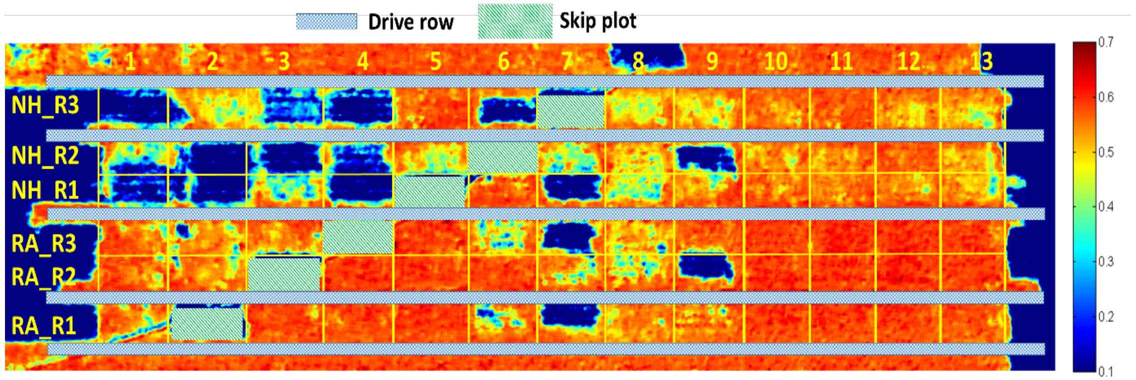
Hail Damage

Standard Method: Visual Rating

Russet Norkotah
Ranger Russet

Hail Damage during:
Tuber initiation
Early bulking
Late bulking

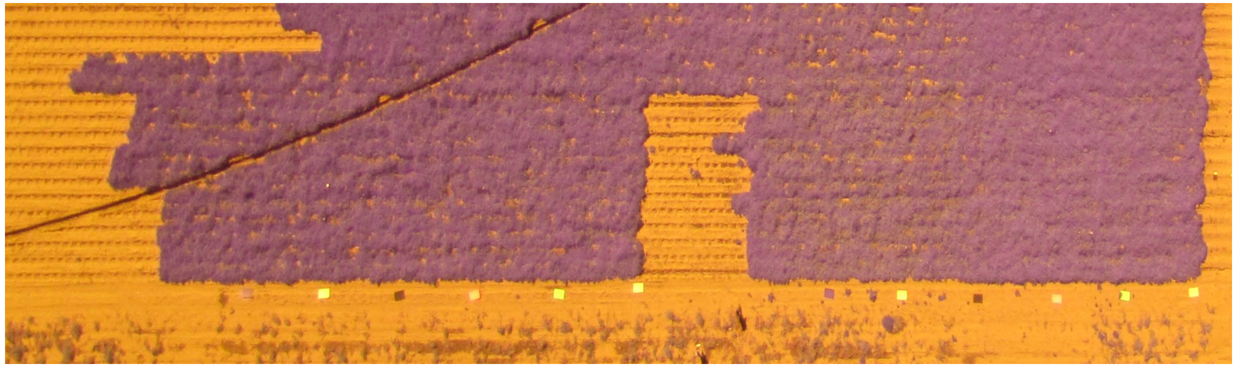




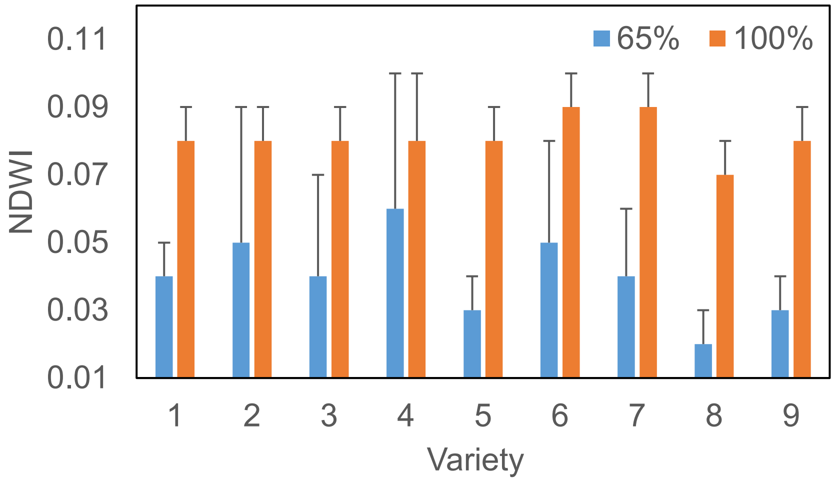
- Hail damage levels can be assessed if imaged within 10 days of damage.
- Hail during early bulking stage most damaging.

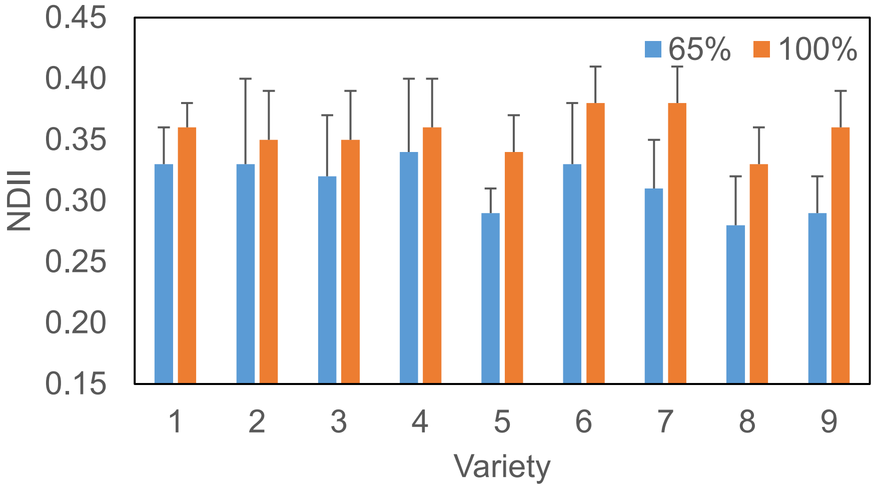
Zhou, J., Pavek, M.J., Shelton, S.C., Holden, Z.J., and Sankaran, S. 2016. Aerial multispectral imaging for crop hail damage assessment in potato. Computer and Electronics in Agriculture, 127: 406-412.

Water-Use Efficiency



- 9 potato varieties
- 2 irrigation conditions
- 20 seeds, 4 replicates
- 45 days after planting



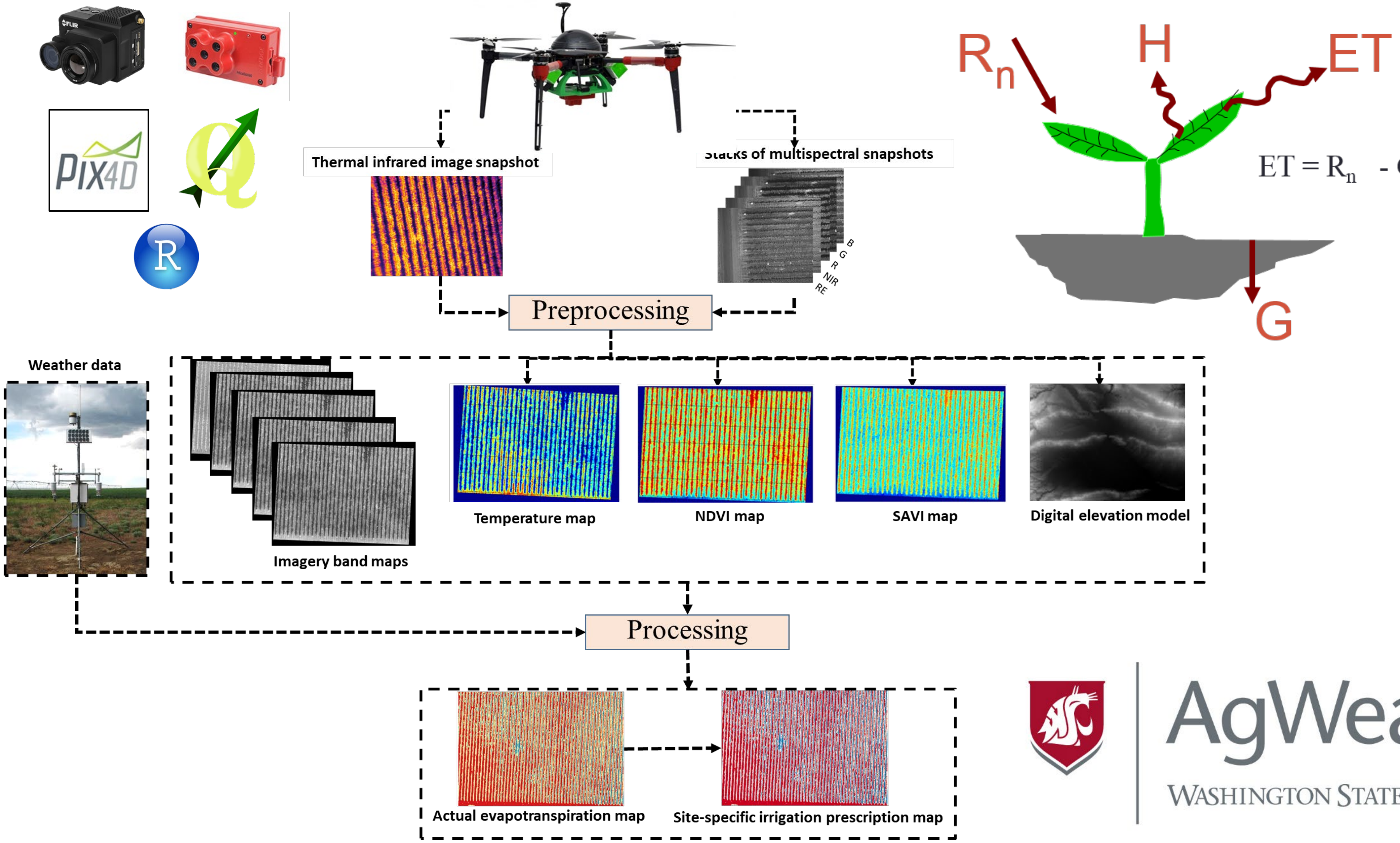


$$\mathrm{NDWI} = \frac{\mathrm{Green} - \mathrm{NIR}}{\mathrm{Green} + \mathrm{NIR}}$$

$$NDII = \frac{(\rho_{819} - \rho_{1649})}{(\rho_{819} + \rho_{1649})}$$

Carlos Zuniga, WSU
Sanaz Jarolmasjed, WSU
Rick Knowles, WSU
Mark Pavek, WSU

Irrigation Scheduling/ ET Estimation: Point vs. large scale



Dr. Lav R. Khot
Dr. Troy Peters
Dr. Claudio Stöckle

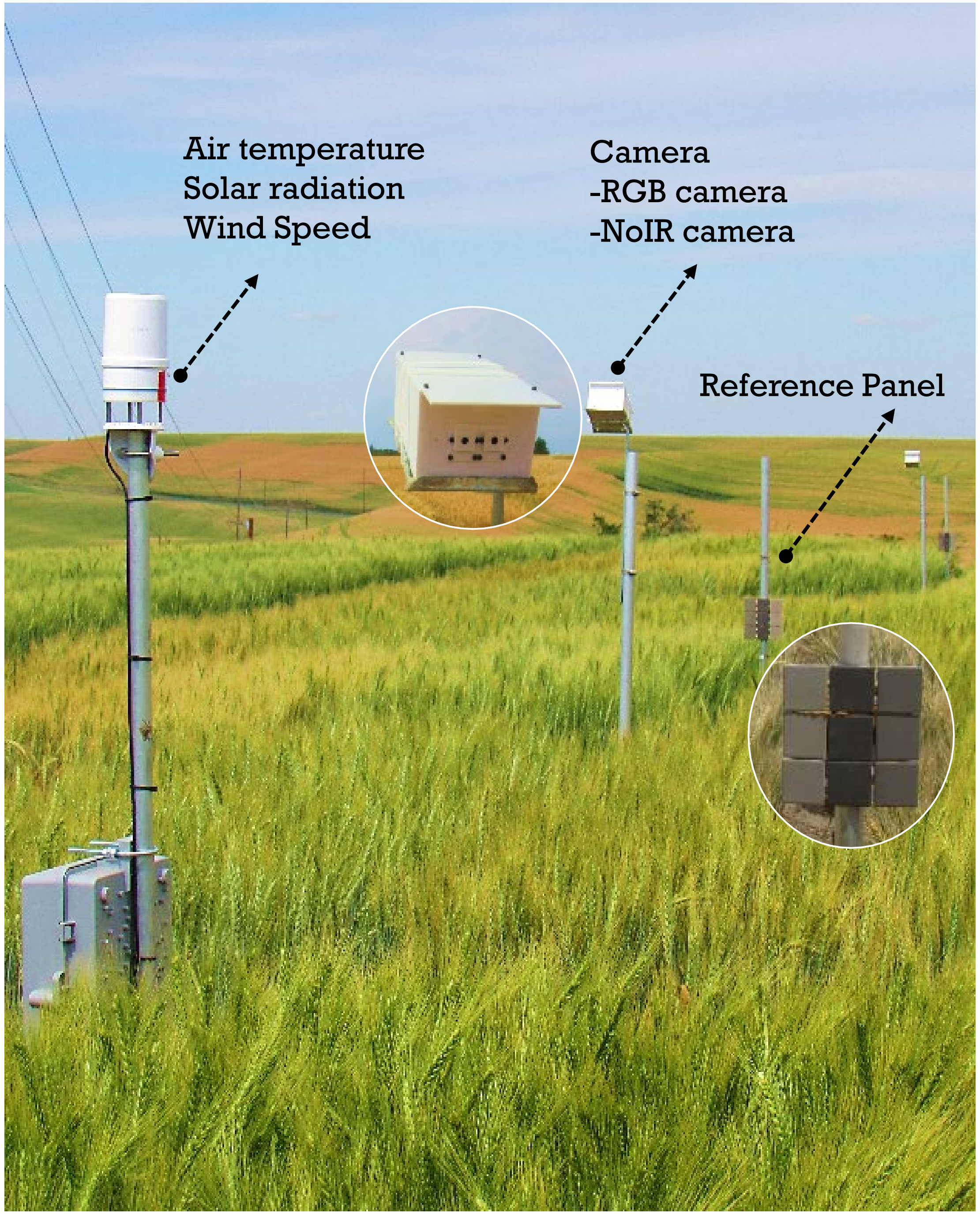
$$ET = R_n - G - H$$

METRIC MODEL

Dr. Lav R. Khot

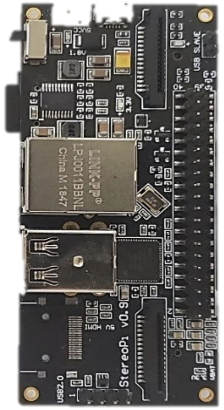
AgWeatherNet
WASHINGTON STATE UNIVERSITY

Development of a Raspberry pi-based sensor system for automated in-field monitoring



Raspberry Pi compute module 3+ lite

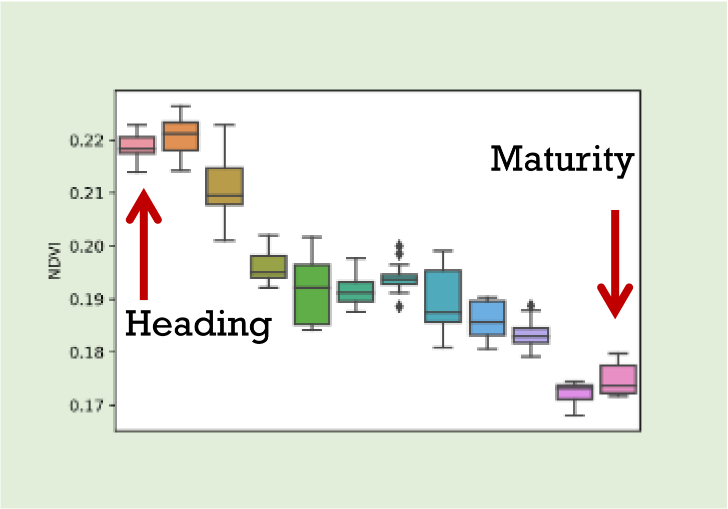
StereoPi



Witty Pi 3

Raspberry Pi camera V2

Raspberry Pi NoIR camera V2



Worasit Sangjan

Field Platforms

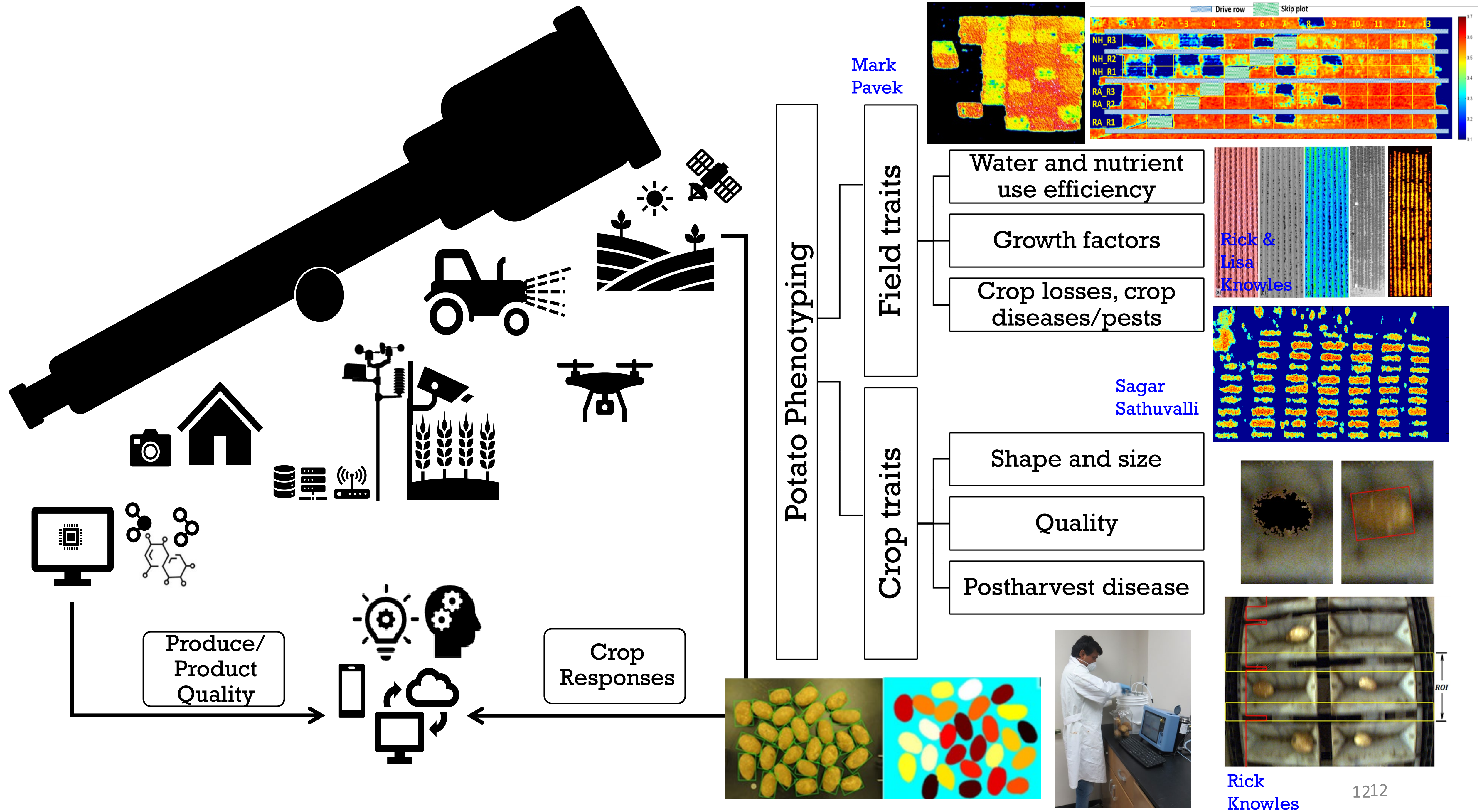
University of Arizona

Kansas State University

https://cropwatch.unl.edu/2022/sensors-pivot-automated-irrigation-scheduling-great-plains

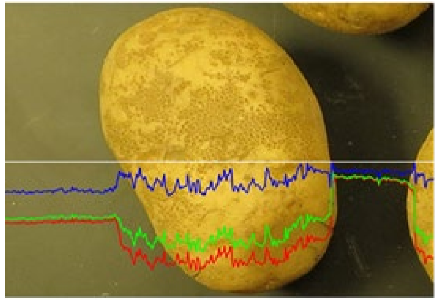
https://www.potatogrower.com/2018/11/selecting-chemicals-that-work-for

https://www.goodfruit.com/new-ways-to-spray/


Produce/ Product Quality
Crop Responses
Potato Phenotyping
Field traits
Crop traits
Mark Pavek
Drive row
Skip plot
NH_R3
NH_R2
NH_R1
RA_R3
RA_R2
RA_R1
Water and nutrient use efficiency
Growth factors
Crop losses, crop diseases/pests
Rick & Lisa Knowles
Sagar Sathuvalli
Shape and size
Quality
Postharvest disease
ROI
Rick Knowles

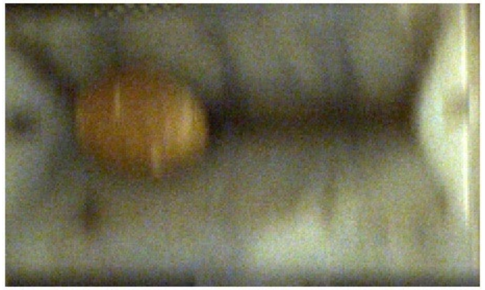
Tuber Size/Shape

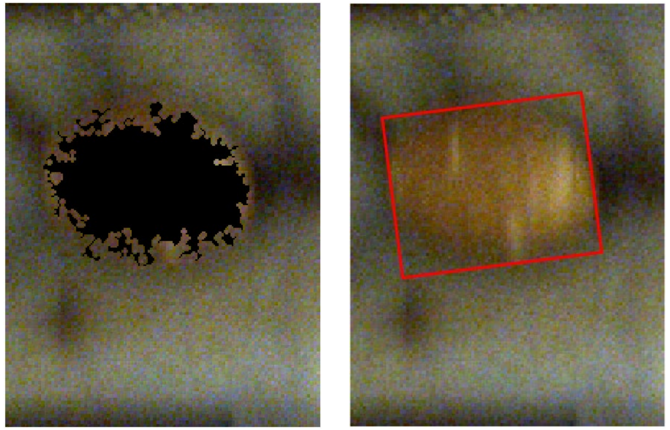
Standard Method: Caliper measurement

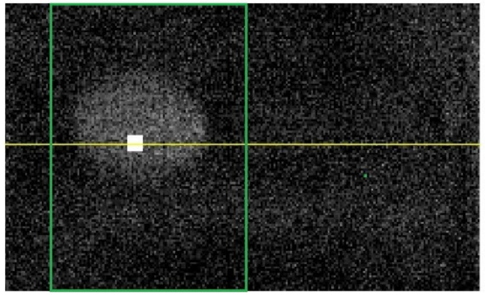


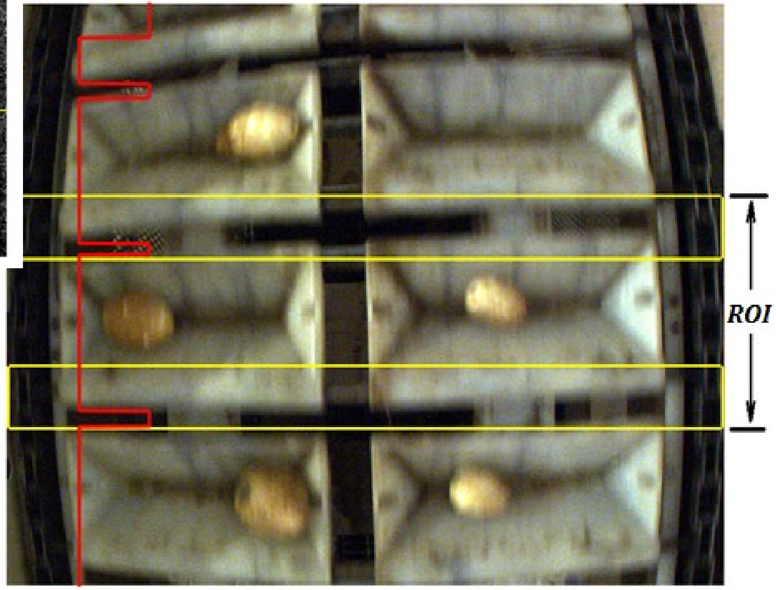
Accuracy range (%) = 95-100%

Dr. Yongsheng Si





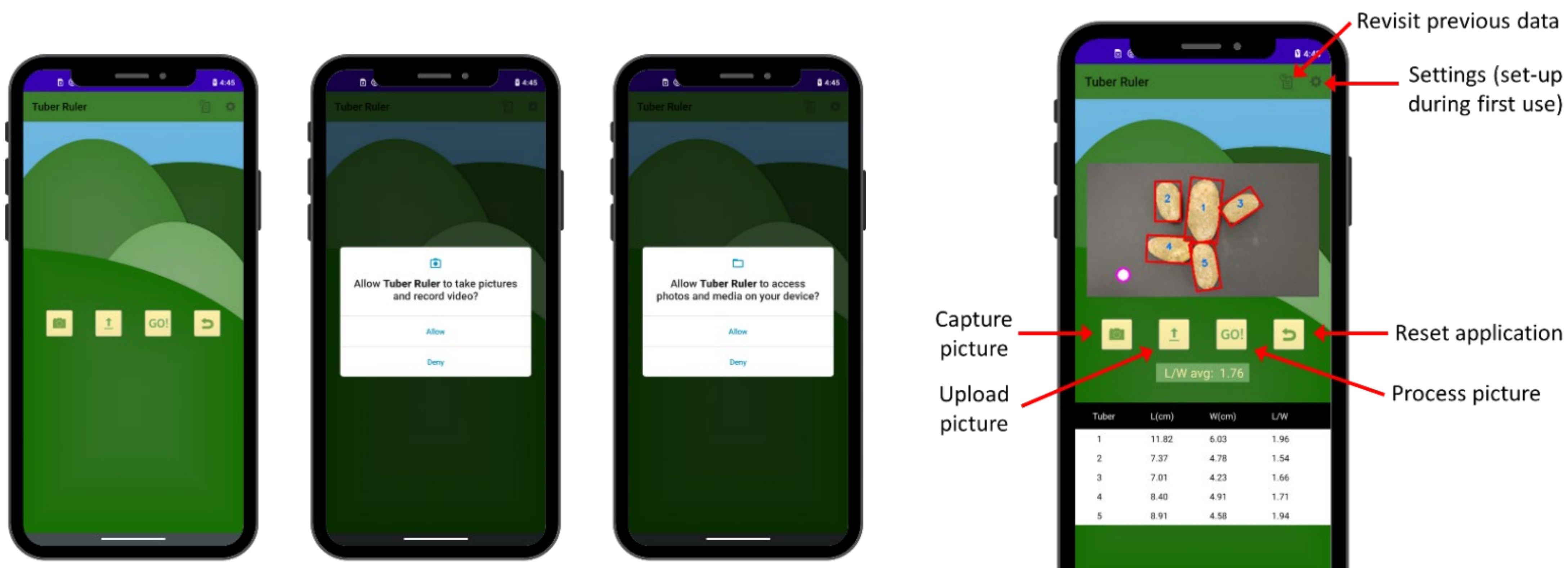




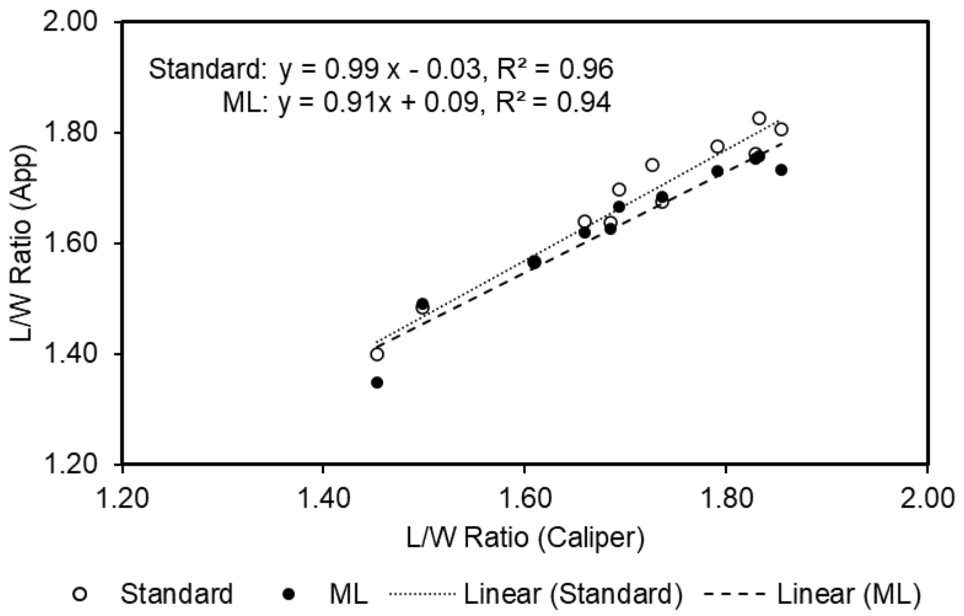
Yongsheng Si, WSU
Rick Knowles, WSU
Mark Pavek, WSU

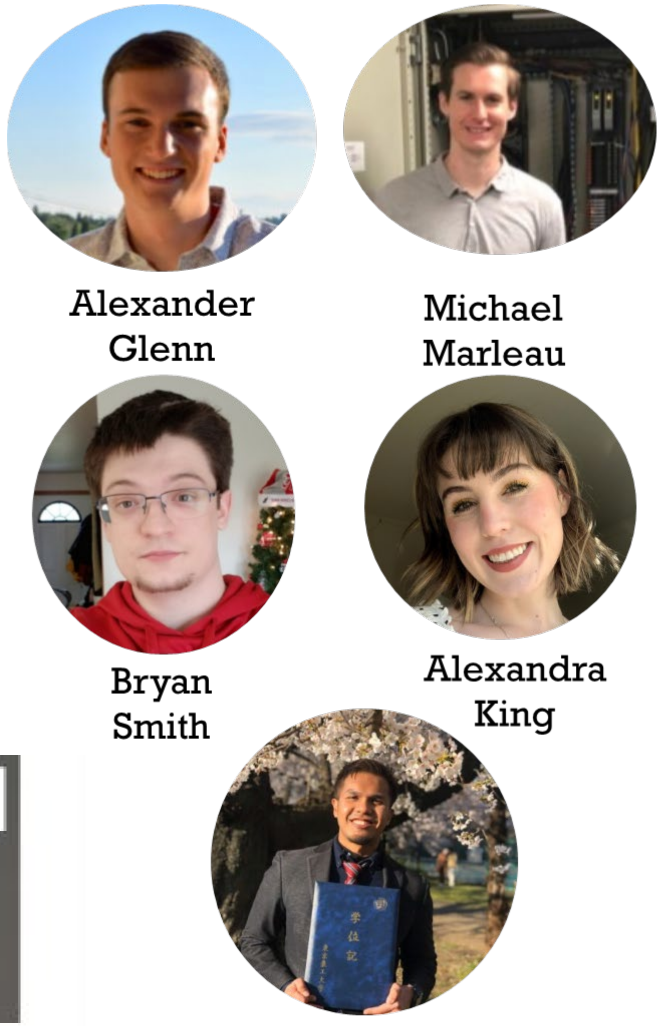
Si, Y., Sankaran, S., Knowles, N.R., and Pavek, M. 2017. Automated potato tuber length-width ratio assessment using image analysis. *American Journal of Potato Research,* 94 (1): 88-93; Si, Y., Sankaran, S., Knowles, N.R., and Pavek, M. 2017. Image-based automated potato tuber shape evaluation. Journal of Food Measurement and Characterization.

Tuber Ruler



App Home Screen | Camera Access | Device Media Access





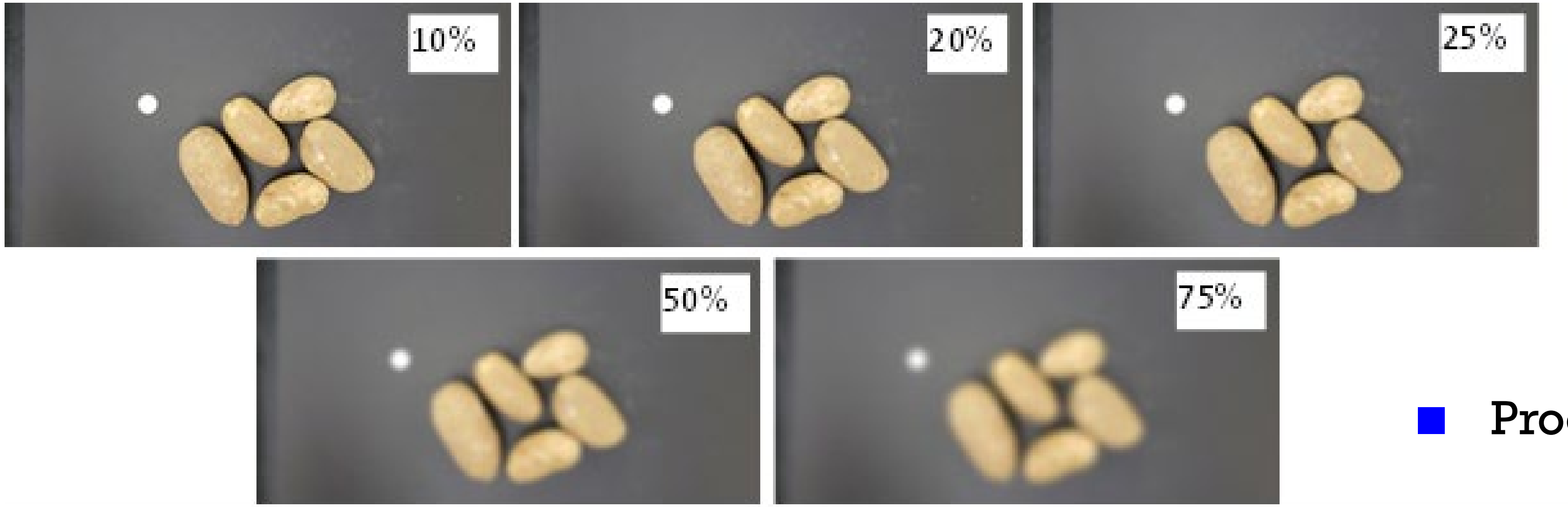
Alexander Glenn

Michael Marleau

Bryan Smith

Alexandra King

Kesevan Veloo

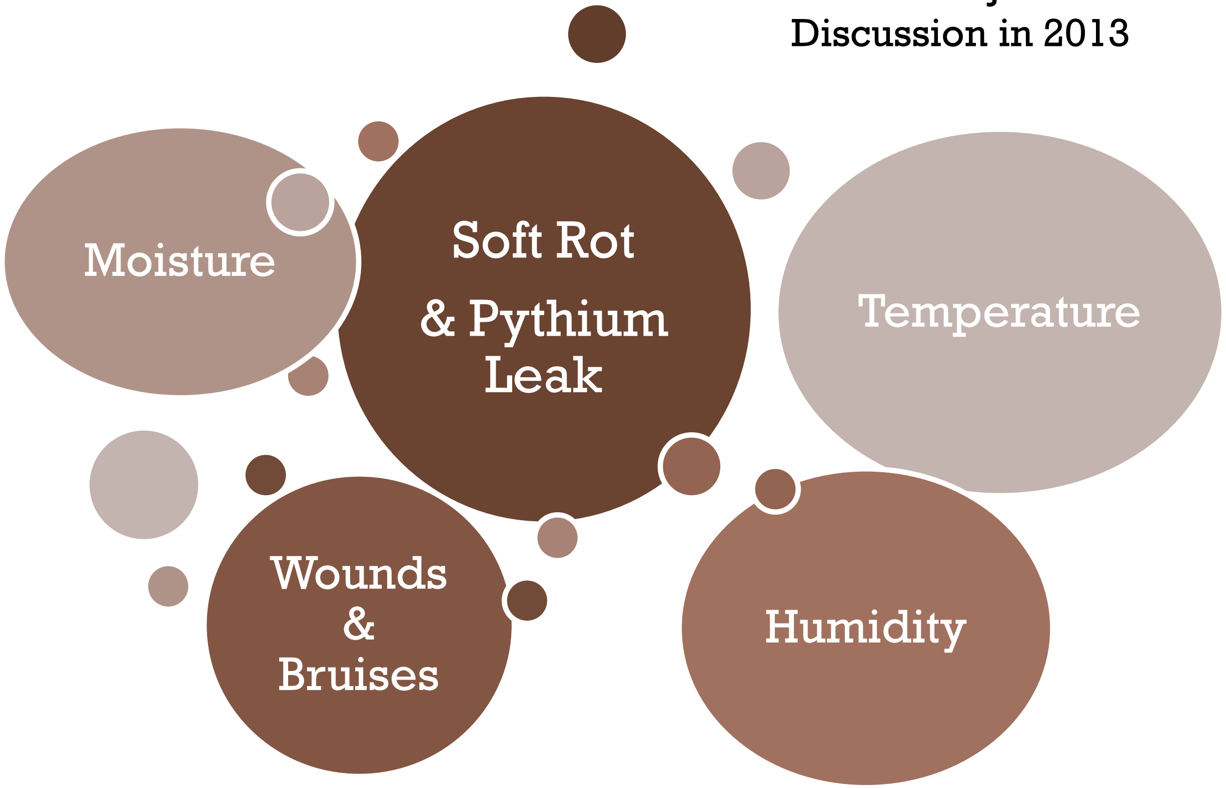


- Processing time: 2-4 s

Potato Rot

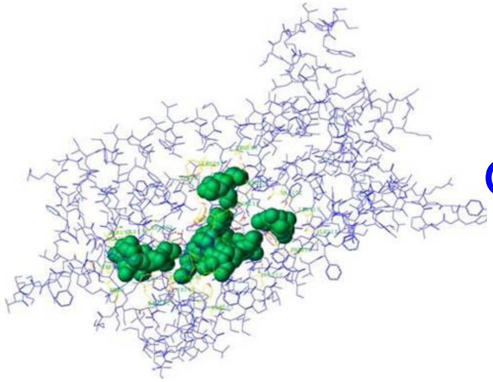
- Crop losses comes from bulk storage issues (Potato Stocks, 2021): 6-7.5%, 5-6 million metric tons.
- Several crop, field, harvest and storage aspects influencing these losses.

Dr. Dennis Johnson
Discussion in 2013

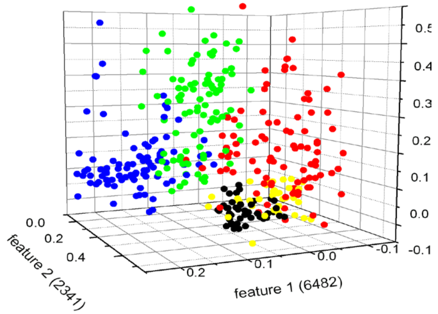


Biogenic Volatiles

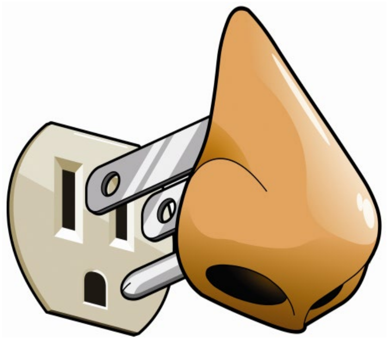
Bioinformatics



Chemometrics



Portable Sensor



Chemometrics

Engineering

Bioinfomatics

Biomarkers

Knowledge Network

Sensing

Network Tools

Network Tools

Interpretation

Adapted from: Dr. Cristina Davis, UC Davis

Integrating biomarkers and crop physiology

Potato Rot Detection

- Postharvest diseases: Soft rot (potential as secondary infection), Pythium leak (tubers are vulnerable and can spread quickly)
- Cultivars: Ranger Russet and Russet Burbank
- Volatile-based early detection: FAIMS-based detection
- Early detection can allow early management†

Students:
Dr. Rajeev Sinha
Mr. Gajanan Kothawade
Mr. Worasit Sangjan
Mr. Milton Valencia Ortiz





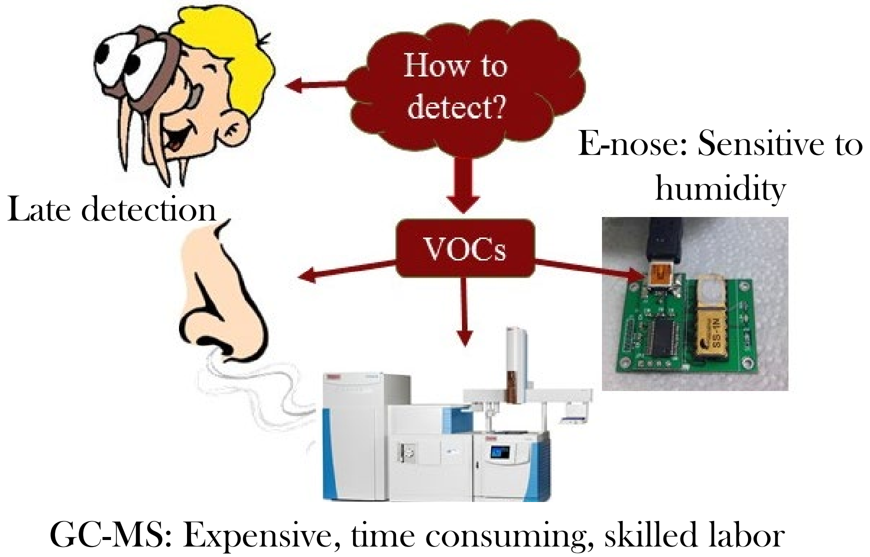
Dr. Brenda Schroeder


Dr. Lav R. Khot

Collaborators:
Mr. Scott D. Mattinson
Dr. Mark Pavek
Mr. Austin Bates

Specialty Crop Block Grant Program
WSDA 100 YEARS
AgriNorthwest

Methods to detect storage infections

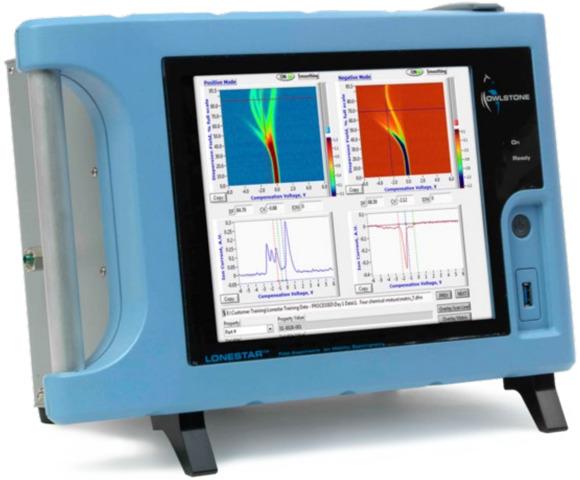


†*Olsen et al., 2006, University of Idaho Extension Article CIS1131*

FAIMS System

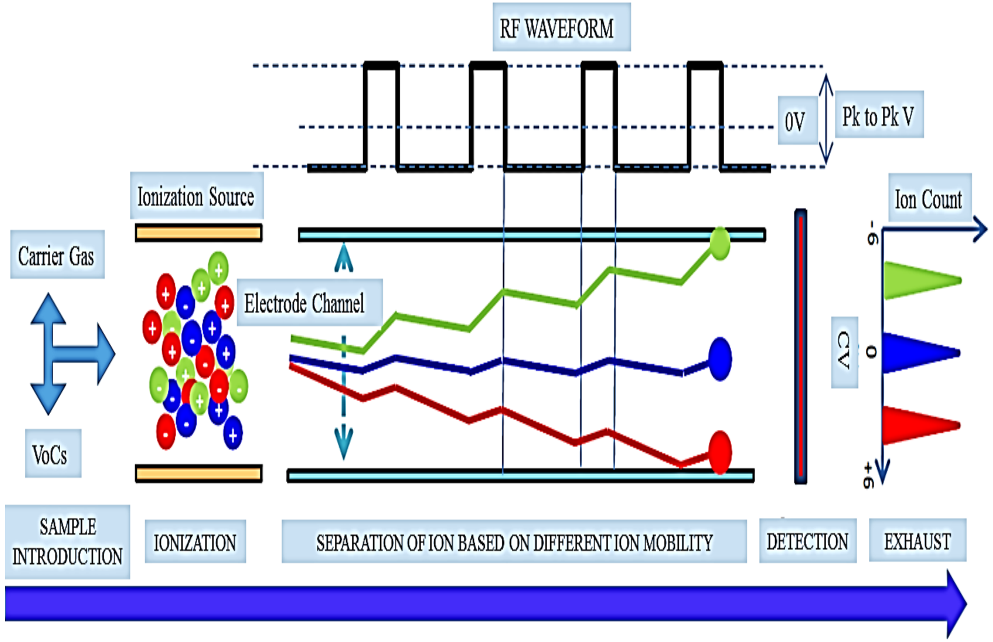
Field Asymmetric Ion Mobility Spectrometry (FAIMS)

Gas detection technology "Separate and identify ions mobility of chemicals"

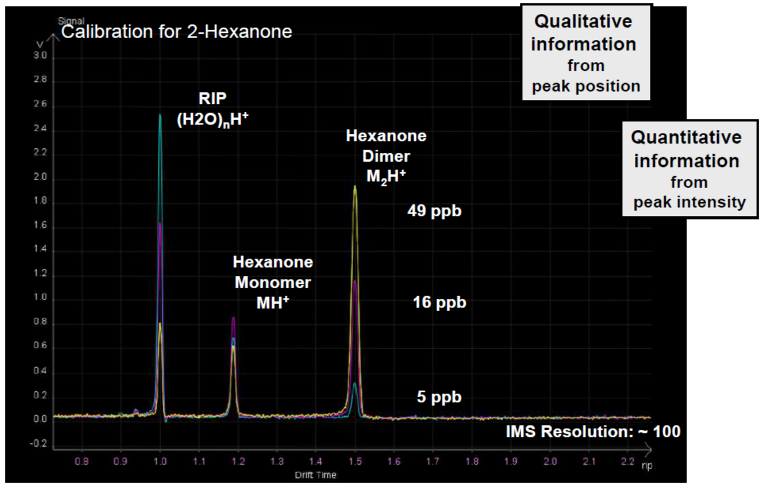


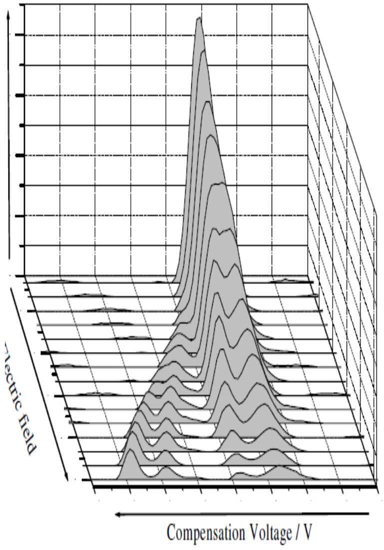
GC-MS:
- Golden standard
- Approved technology
- Available database
- Commonly used
- Low-throughput analysis

FAIMS:
- Easy-to-use
- Reliable
- Fingerprint detection
- Portable and flexible
- Rapid



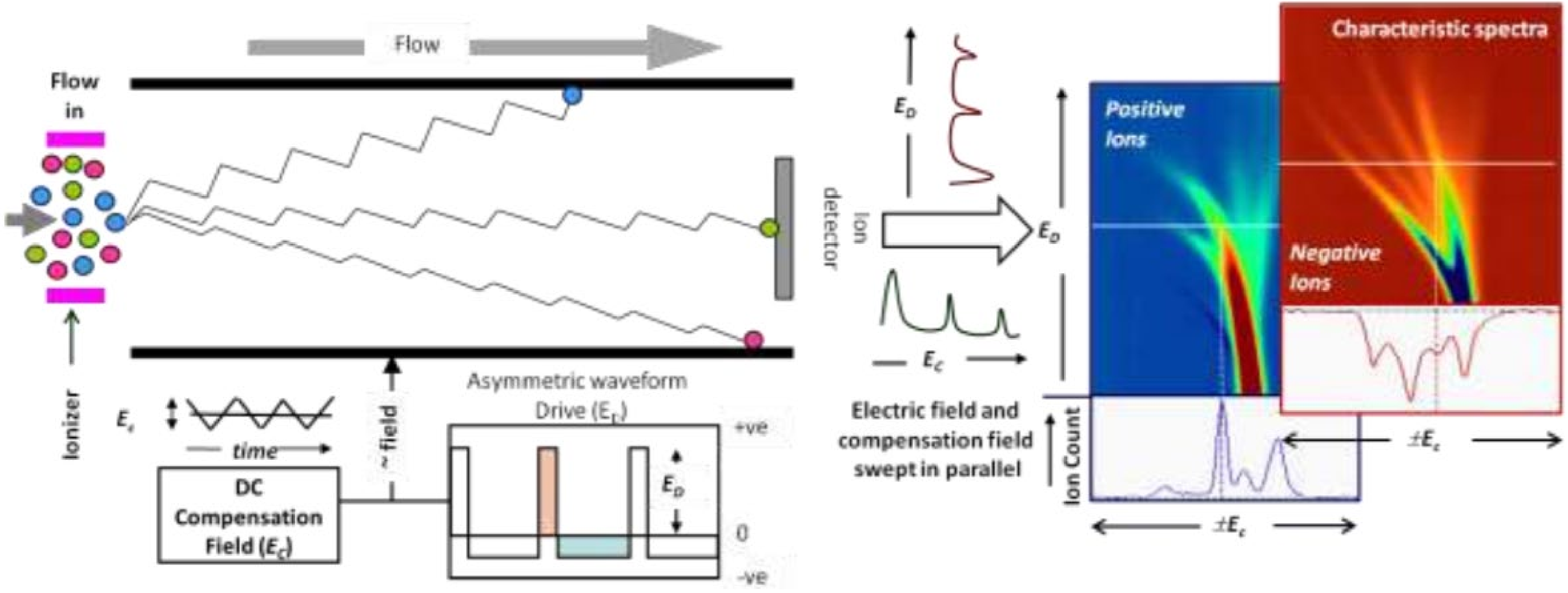
Working principle for FAIMS (ionization, separation & detection) *Source: Owlstone Lonestar Analyzer*





FAIMS System

- Sensitive to small changes to volatile profile
- Can be customized to detecting specific biomarkers
- Can be integrated with air circulation system



Working principle for FAIMS (ionization, separation & detection)
Source: Owlstone Lonestar Analyzer

Potato Rot Detection

FAIMS can detect soft rot and Pythium leak at 1 & 5-11 days after inoculation at 25°C & 4°C, respectively.

Postharvest Biology and Technology 135 (2018) 83–92

FAIMS based volatile fingerprinting for real-time postharvest storage infections detection in stored potatoes and onions

Rajeev Sinha[a,c], Lav R. Khot[a,c,*], Brenda K. Schroeder[b], Sindhuja Sankaran[c,a]

[a] *Center for Precision and Automated Agricultural Systems, IAREC, Washington State University, Prosser, WA, 99350, USA*
[b] *Department of Entomology, Plant Pathology and Nematology, University of Idaho, Moscow, ID, USA*
[c] *Department of Biological Systems Engineering, Washington State University, Pullman, WA, 99164, USA*

Postharvest Biology and Technology 181 (2021) 111679

Field asymmetric ion mobility spectrometry for pre-symptomatic rot detection in stored Ranger Russet and Russet Burbank potatoes

Gajanan S. Kothawade[a,b], Abhilash K. Chandel[a,b], Lav R. Khot[a,b,*], Sindhuja Sankaran[a,b,*], Austin A. Bates[c], Brenda K. Schroeder[c]

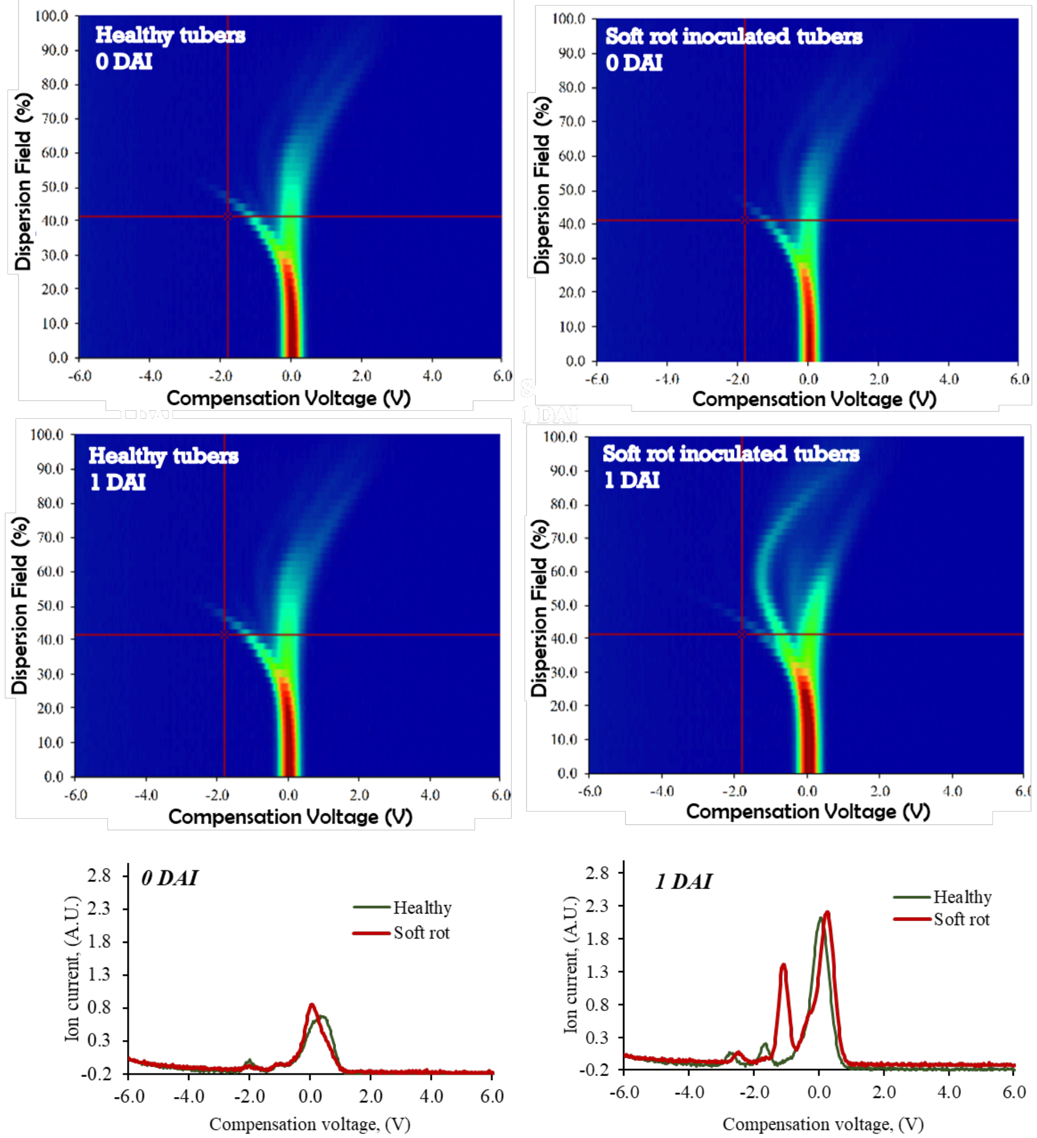
[a] *Department of Biological Systems Engineering, Washington State University, Pullman, WA, USA*
[b] *Center for Precision and Automated Agricultural Systems, Washington State University, Prosser, WA, USA*
[c] *Department of Entomology, Plant Pathology, and Nematology, University of Idaho, Moscow, ID, US*

Sensors 20 (2021) 7350

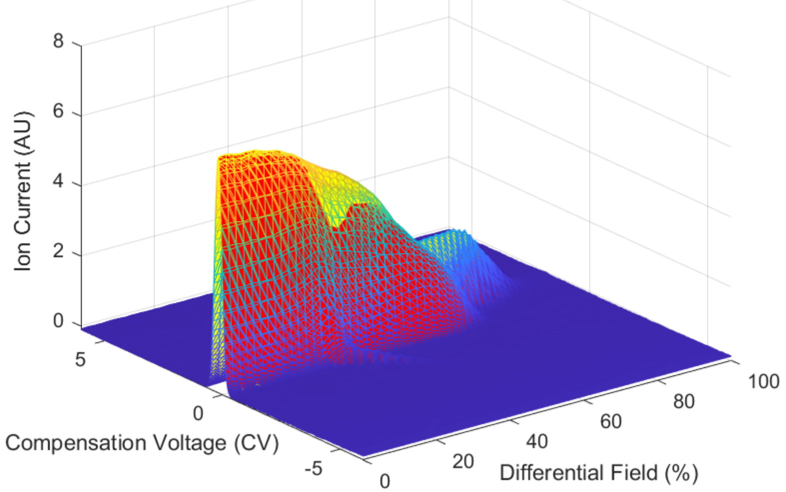
Feasibility of Volatile Biomarker-Based Detection of Pythium Leak in Postharvest Stored Potato Tubers Using Field Asymmetric Ion Mobility Spectrometry

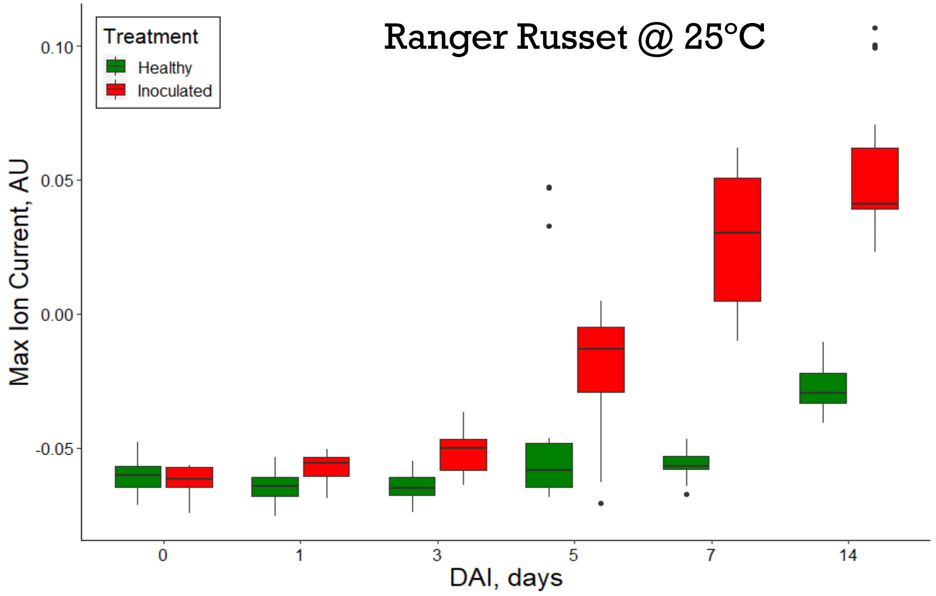
Gajanan S. Kothawade[a,b], Sindhuja Sankaran[a,b,*], Austin A. Bates[c], Brenda K. Schroeder[c], Lav R. Khot[a,b,*],

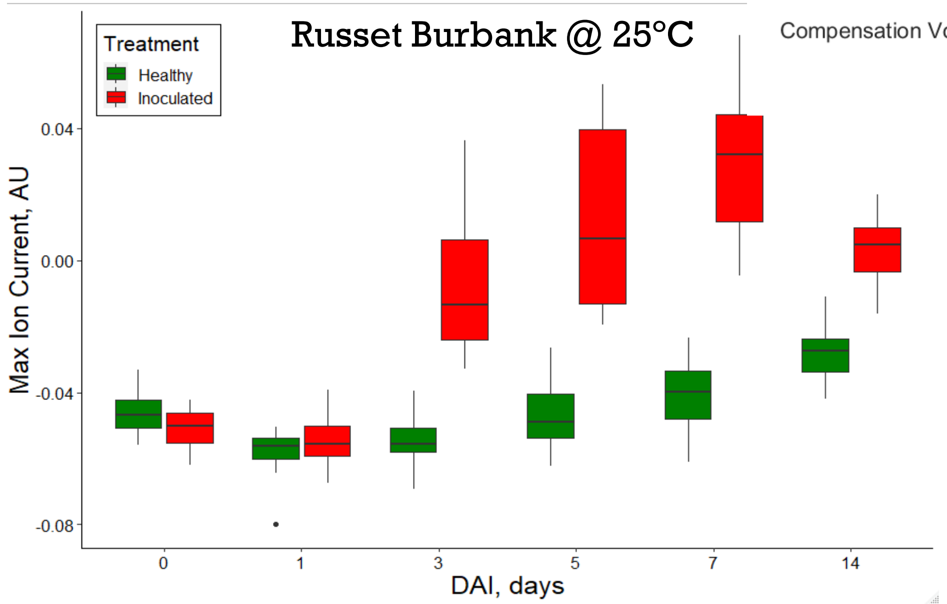
[a] *Department of Biological Systems Engineering, Washington State University, Pullman, WA, USA*
[b] *Center for Precision and Automated Agricultural Systems, Washington State University, Prosser, WA, USA*
[c] *Department of Entomology, Plant Pathology, and Nematology, University of Idaho, Moscow, ID, US*



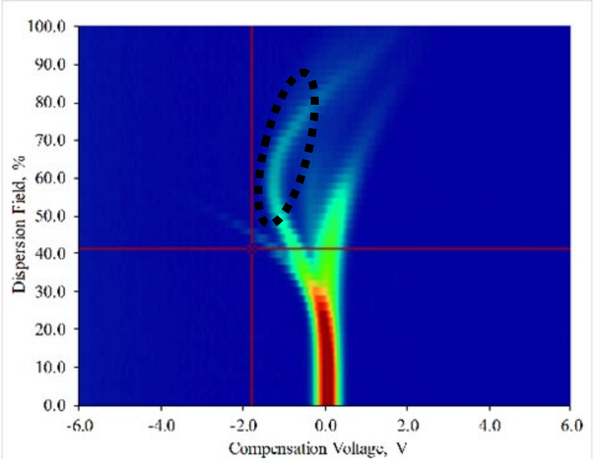
Potato Rot Detection







N, N-dimethyl methylamine



Normalized ion current at 74% of the dispersion field and compensation voltage of -1.31 Volts showing the temporal progression of healthy and **Pythium leak** inoculated samples

Next Steps

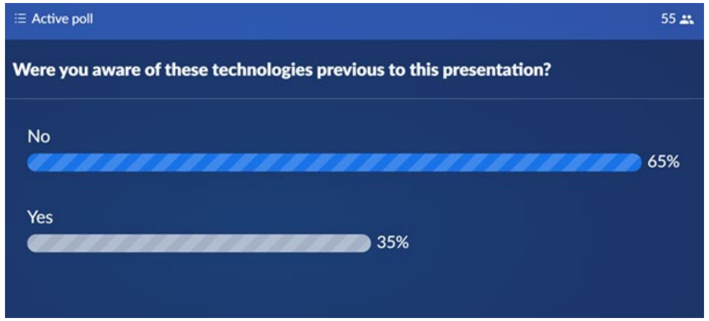
- In storage environment

Who are you going to call? Rotbusters!

September 5, 2019

August 29, 2019 | Capital Press

WASHINGTON OREGON POTATO CONFERENCE 2022
www.potatoconference.com



Next Steps

- In storage environment

Dr. Brenda Schroeder

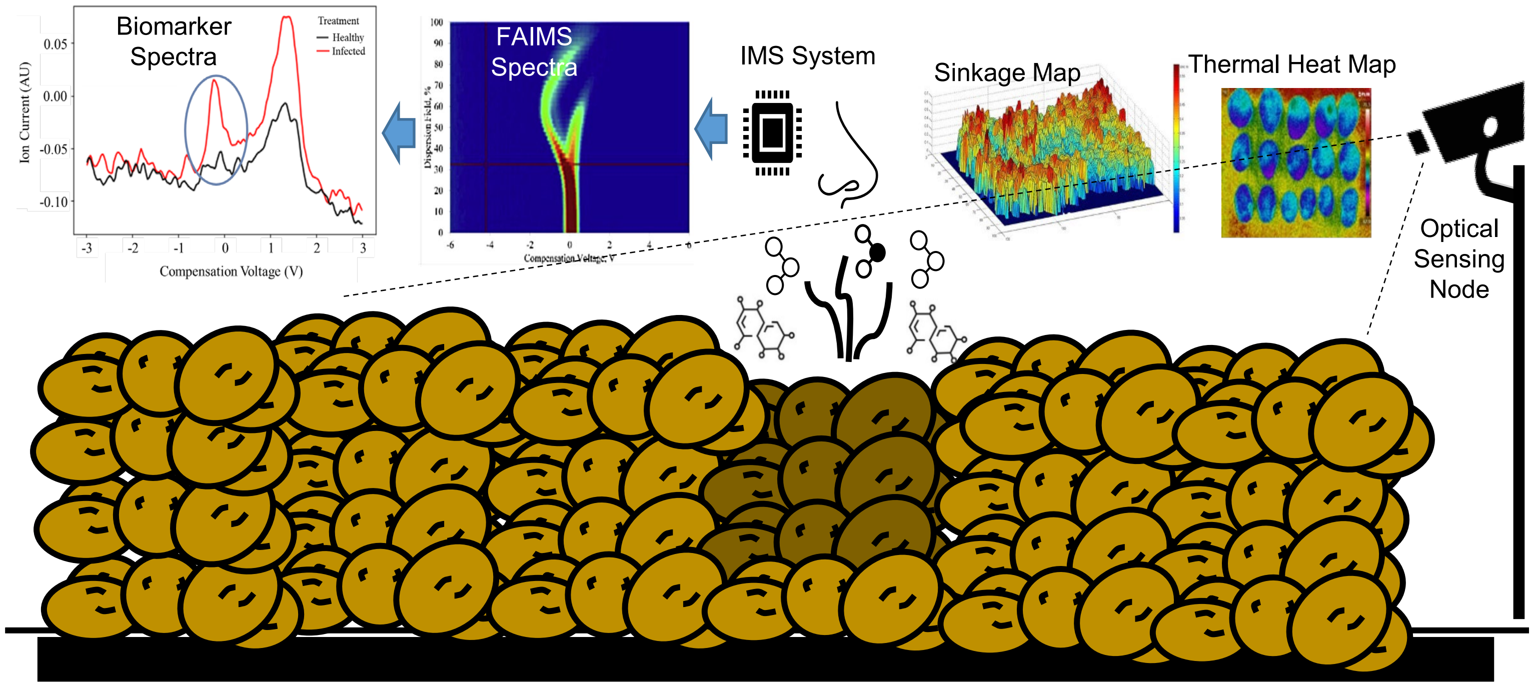
Dr. Gustavo Teixeira

United States Department of Agriculture

National Institute of Food and Agriculture

AgriNorthwest

Good Land - Good People - Good Food



Washington Potatoes

McCain

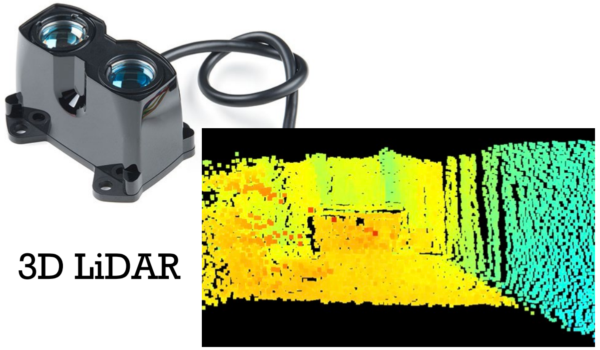
Simplot

Oregon Potatoes

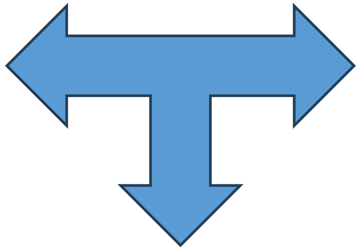
Potatoes USA

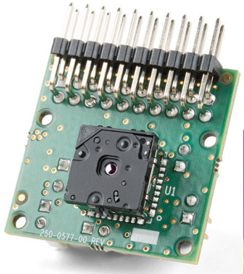
Dr. Jake Blauer

Integrated Sensor System

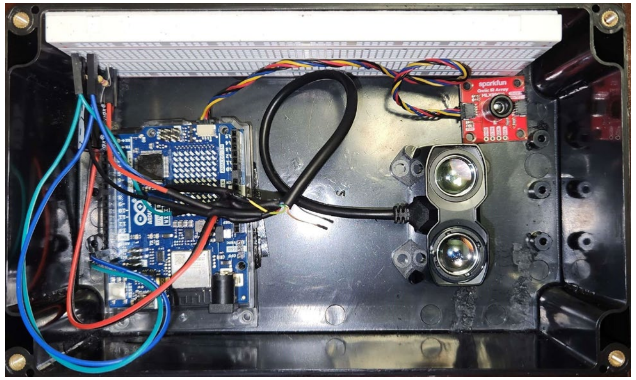


3D LiDAR





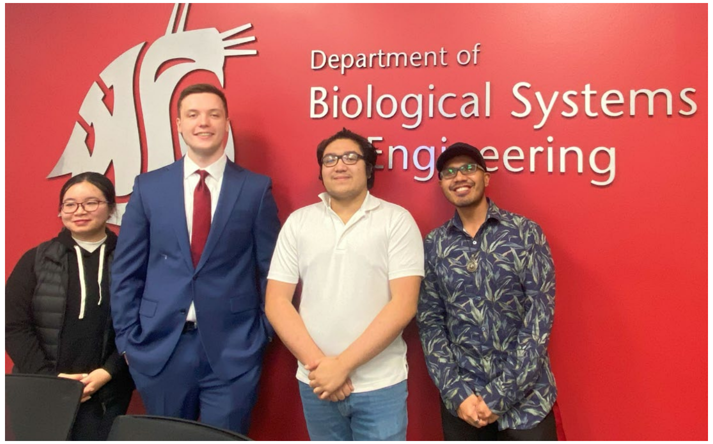
Thermal
Camera



Battery-Powered
Arduino Board:
Mini-Computer

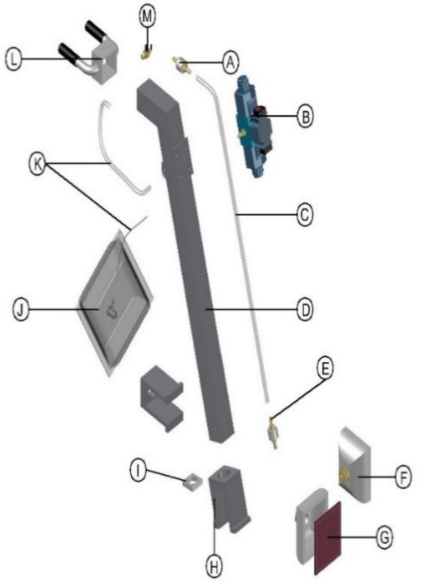
Potential to add temperature, humidity, and CO_2 sensors

Edge/Cloud Computing: Data Processing and Transfer

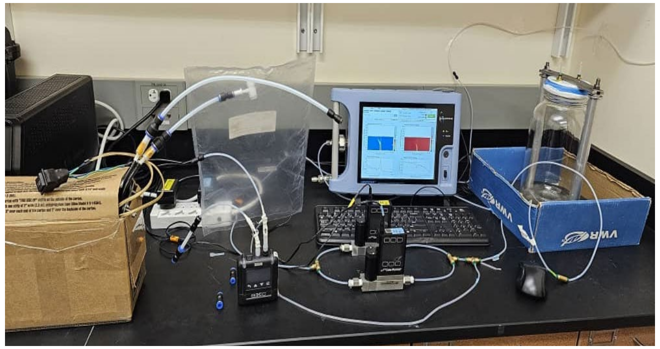


Trang Mai Hoang
Aidan Christopher Gooding
Henry Le
Kesevan Veloo

VOCs Sampling System



Schematics of the VOCs sampling system

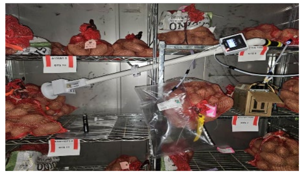


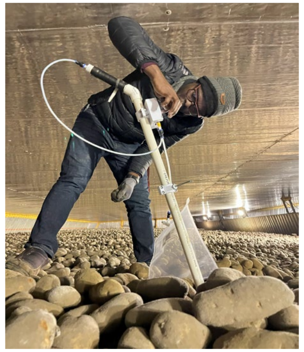
Tedlar bag sampling and analysis

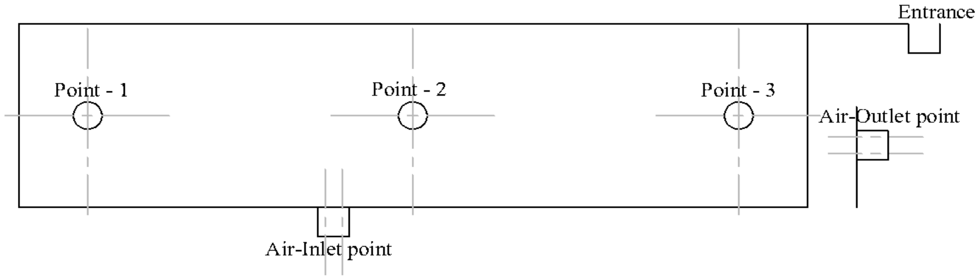
Kingsley Umani

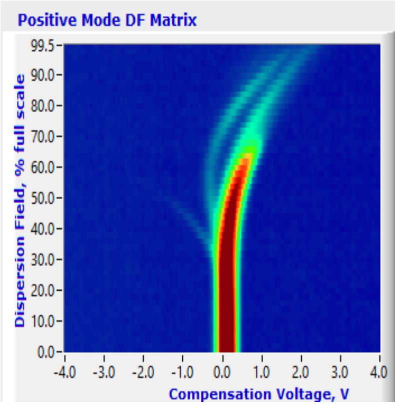
Background VOCs in Storage

Preliminary sample collection for VOCs		
Storage type	**Rate (ml/min)**	**Sampling point(s)**
Bulk	375	5 (3 points on the pile surface, 1 at the air inlet duct, and 1 at air exit from pile)

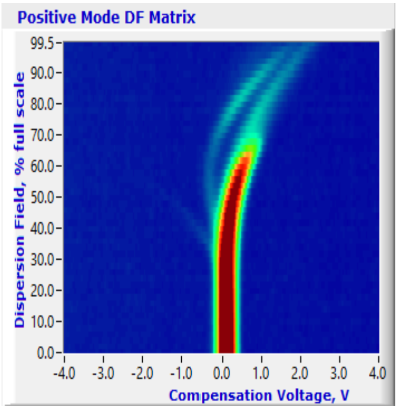




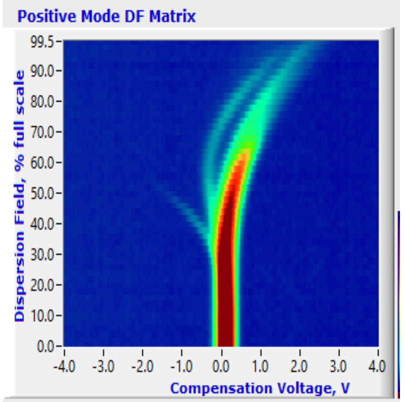




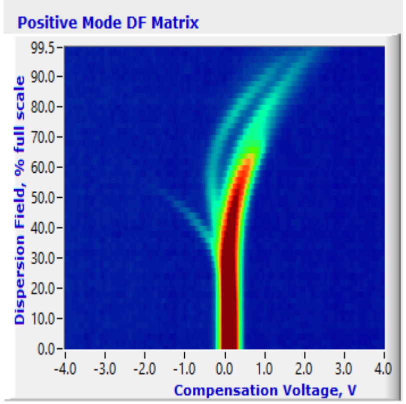
Point 1



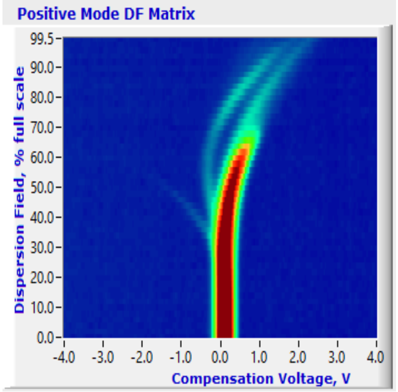
Point 2



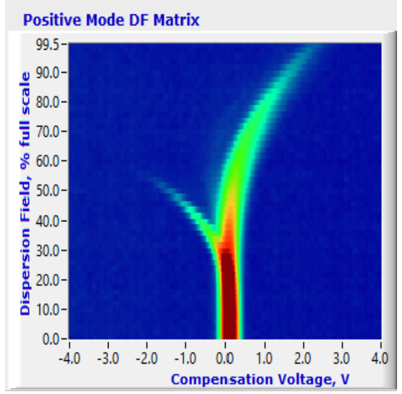
Point 3



Inlet base



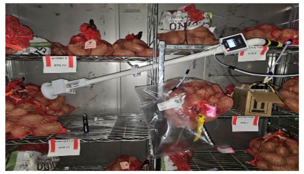
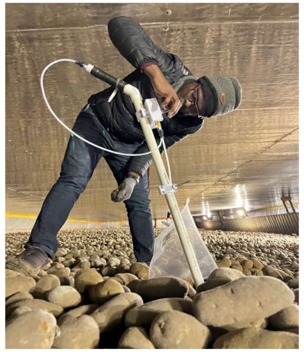
Outlet

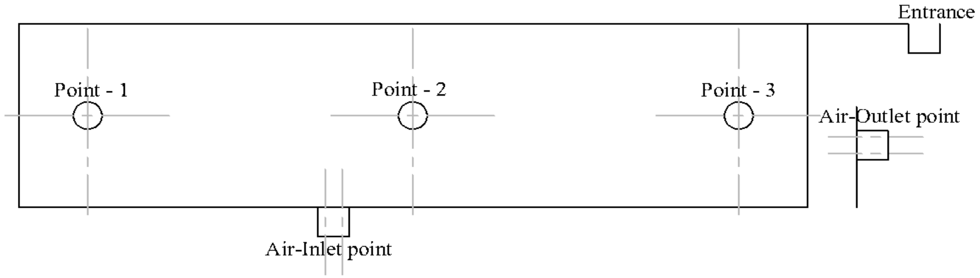


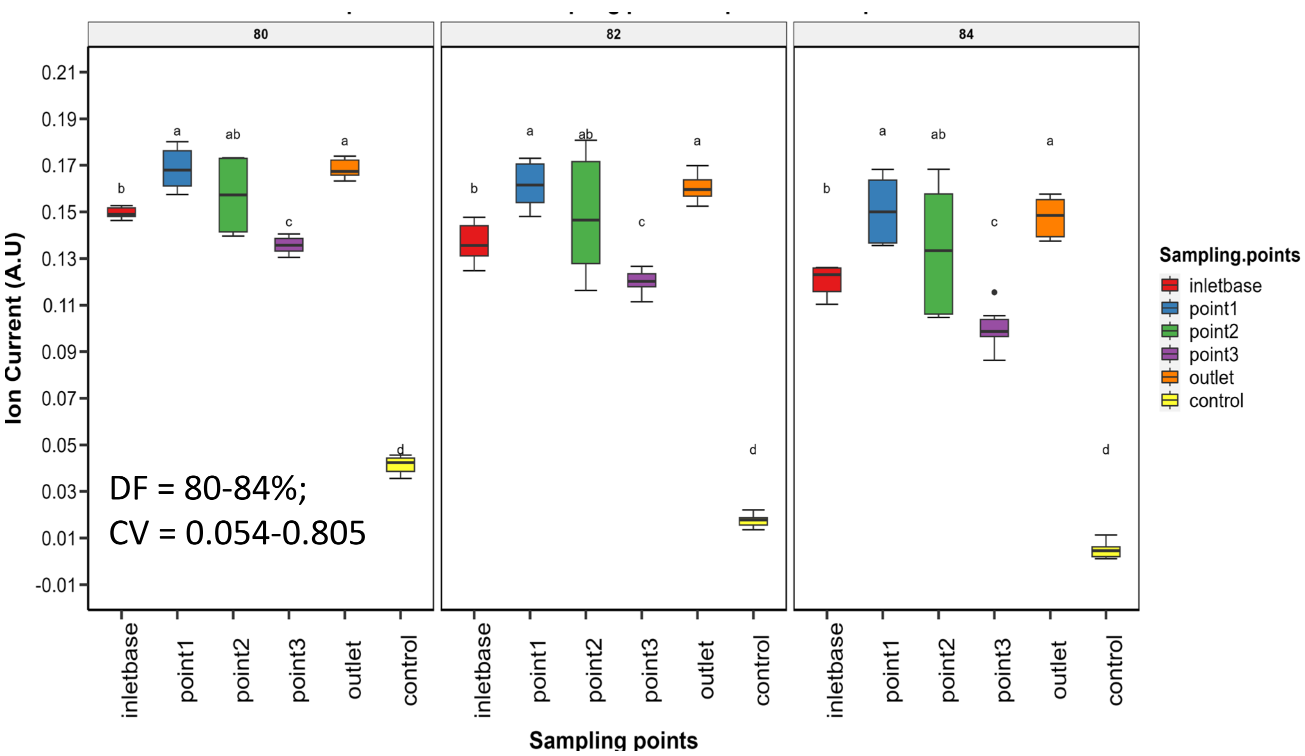
Control

Background VOCs in Storage

Preliminary sample collection for VOCs		
Storage type	Rate (ml/min)	Sampling point(s)
Bulk	375	5 (3 points on the pile surface, 1 at the air inlet duct, and 1 at air exit from pile)

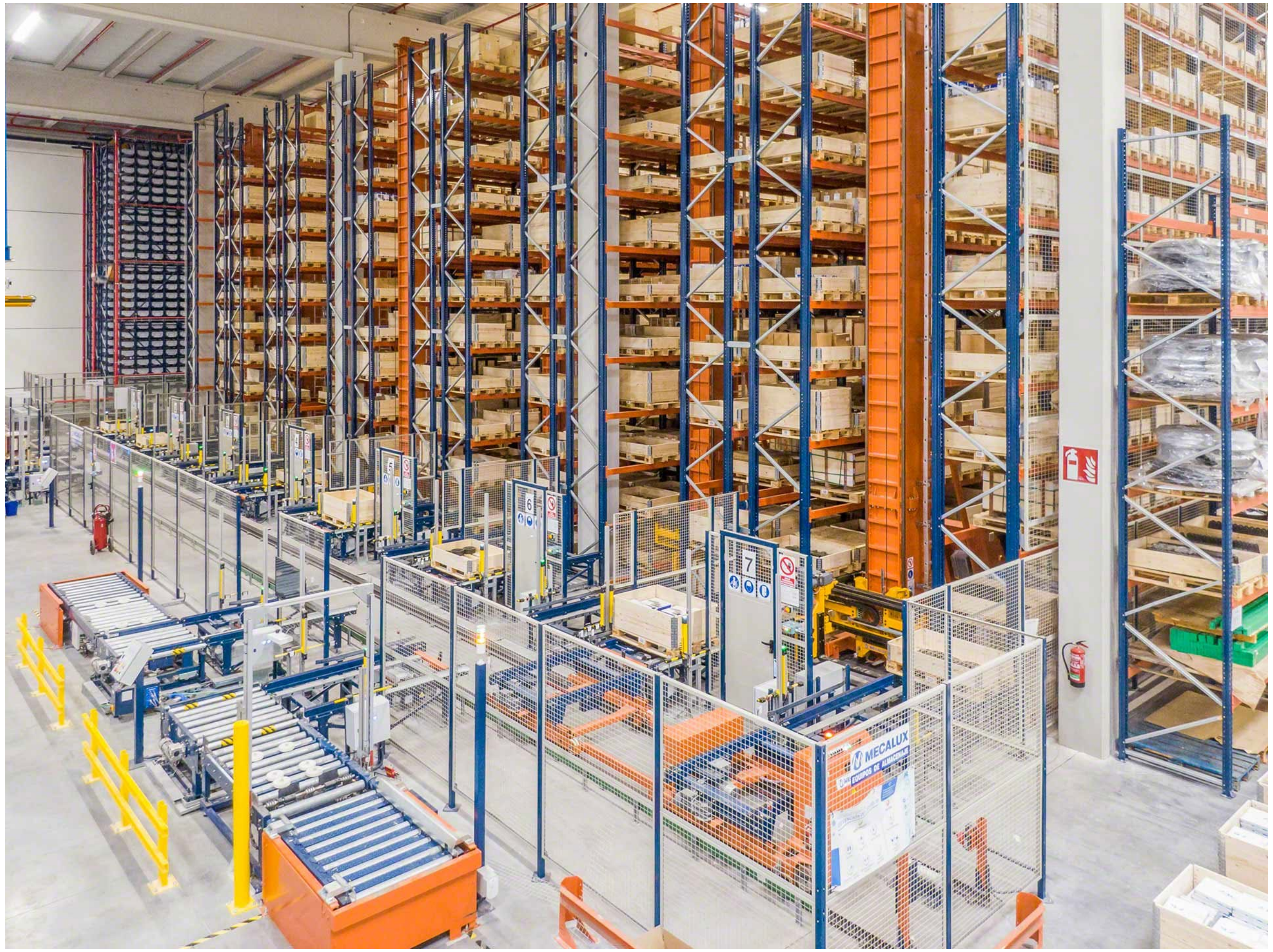


Comparison of VOC profiles between sampling points in the bulk storage

Automated Bulk Storage Facility

- Automation and sensing technologies for better crop management

https://www.viastore.com/systems/en-us/warehouse-and-material-flow-solutions/cold-storage-warehouse



https://www.mecalux.com/blog/advantages-of-automated-storage-and-retrieval-systems

Summary

- Can sensing and associated technologies assist in crop improvement and precision management programs in potato?
  - ✓ **Simple** and **rapid** techniques can be valuable.
  - ✓ Important to establish **cause-effect relationship** by studying or understanding crop science/physiology. e.g. Potato
  - ✓ **Optimizing** data acquisition and **establishing** data processing pipelines takes time.
  - ✓ Valuable when integrated with **weather data.**

- Sensing technologies, robotics, and automation will **advance with time**.
  - ✓ Not necessarily for agriculture.
  - ✓ **AI/machine learning** techniques will also get better to **aid in human decisions**.

Acknowledgments

Breeders & Collaborators:

Dr. Brenda Schroeder
Dr. Dennis Johnson
Dr. Jake Bauer
Dr. Lav Khot
Dr. Mark Pavek
Dr. Rick Knowles
Dr. Sagar Sathuvalli
Mr. Scott Mattinson
Dr. Yongsheng Si

College of Agricultural, Human, & Natural Resource Sciences
Washington State University

EMERGING RESEARCH ISSUES in Washington Agriculture

WSDA 100 YEARS Specialty Crop Block Grant Program

USDA United States Department of Agriculture National Institute of Food and Agriculture

Thank you!!!