Utilizing precision technologies for crop health and yield monitoring to promote sustainable strawberry production

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USDA-ARS, CSUMB and UC Davis




Funding:

- USDA-ARS Areawide Pest Management Program
- USDA-NIFA Methyl Bromide Transition Grant Program
- California Strawberry Commission
- California Department of Pesticide Regulation

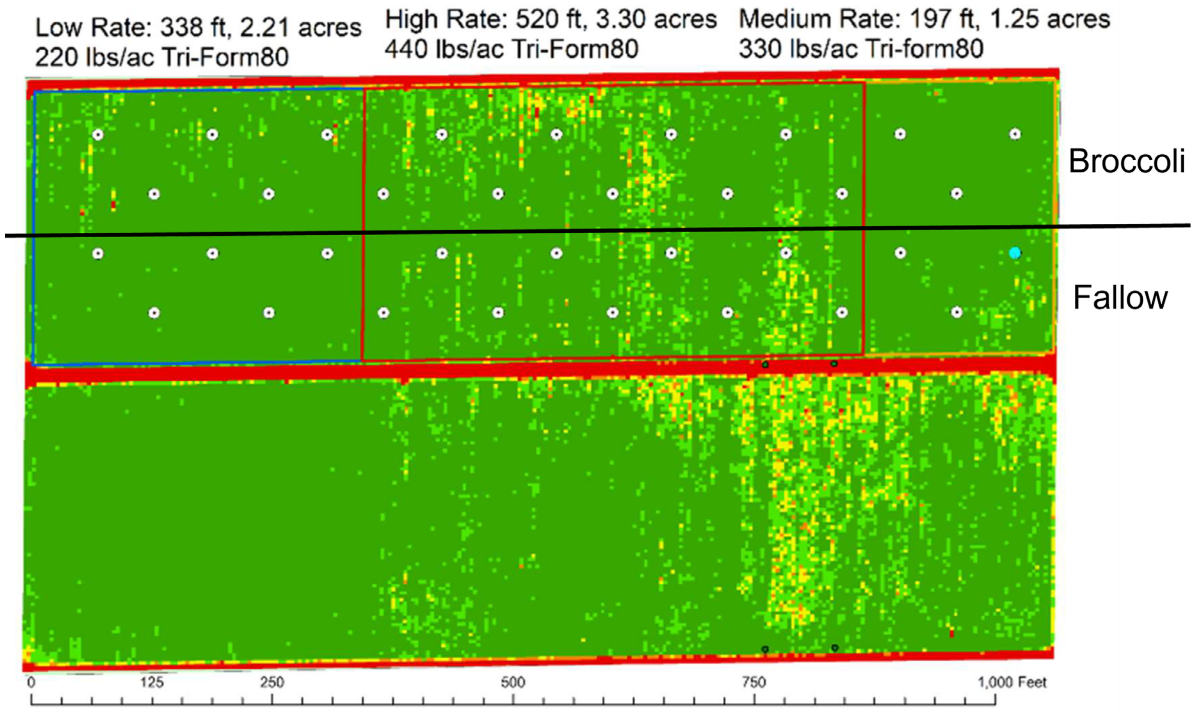
Project Objectives

- Develop site specific pathogen management program based on risk
- Make tools available to the grower community that improve crop management
  - Reduction in fumigant use while maintaining yield
  - Improved capabilities for pathogen detection and quantification in soil
  - Drone flights to evaluate plant vigor and identify problem areas
  - Look for correlations between vegetation index (crop vigor) and yield
  - Develop models to predict crop yield

Risk Assessment

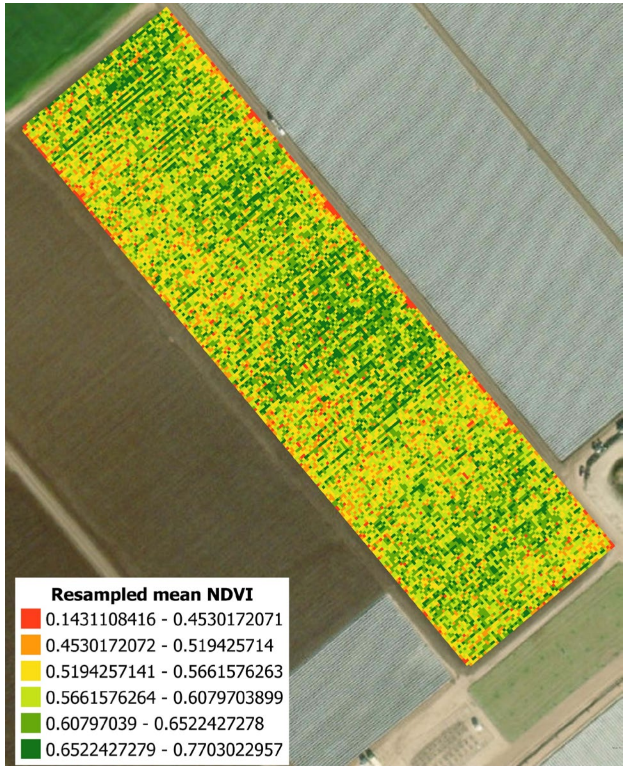
Quantification of soilborne pathogens

- Molecular diagnostic assays developed for:
  - Verticillium wilt
  - Fusarium wilt (strawberry and lettuce)
  - Macrophomina (strawberry)
- Detect the pathogen in plant material
- Quantify pathogen in the soil

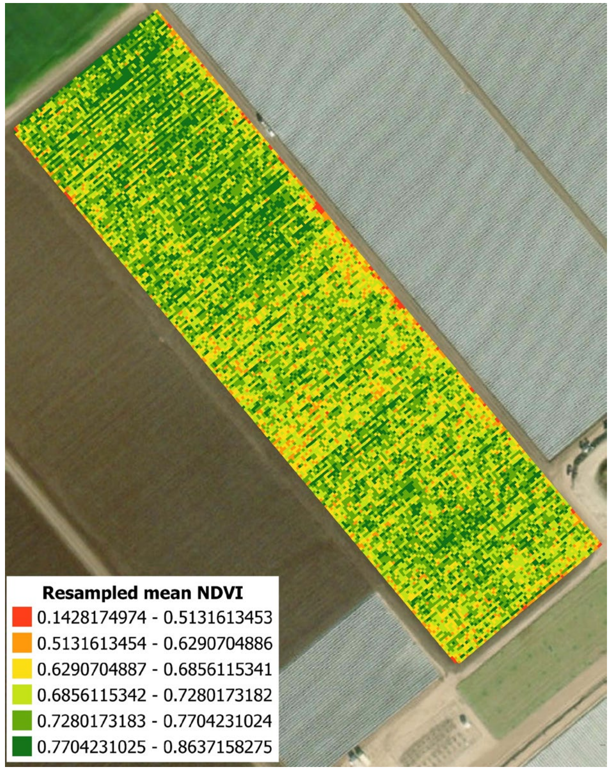


Drone Flights to Assess Plant Vigor

- Evaluate plant health throughout the season
  - Weekly drone flights to collect data for calculating vegetation indices



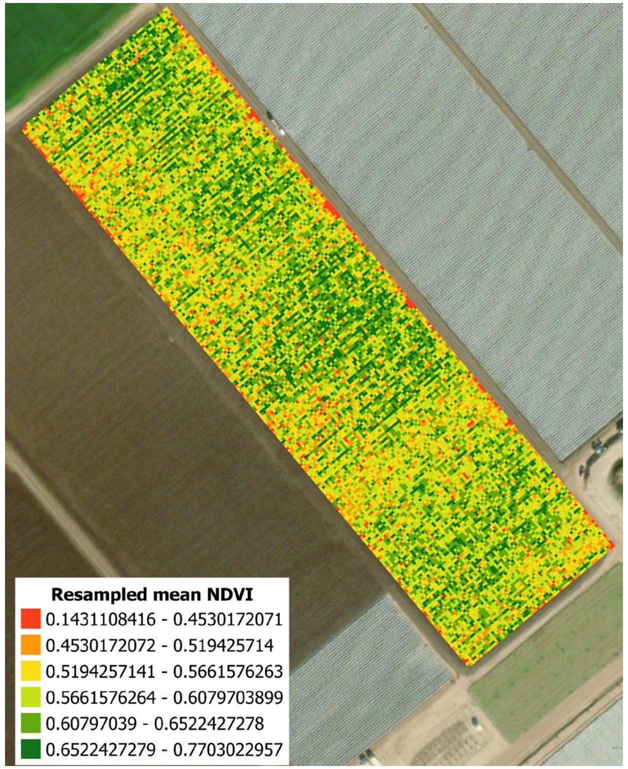
June 7



July 19

Drone Flights to Assess Plant Vigor

- Evaluate plant health throughout the season
  - Weekly drone flights to collect data for calculating vegetation indices

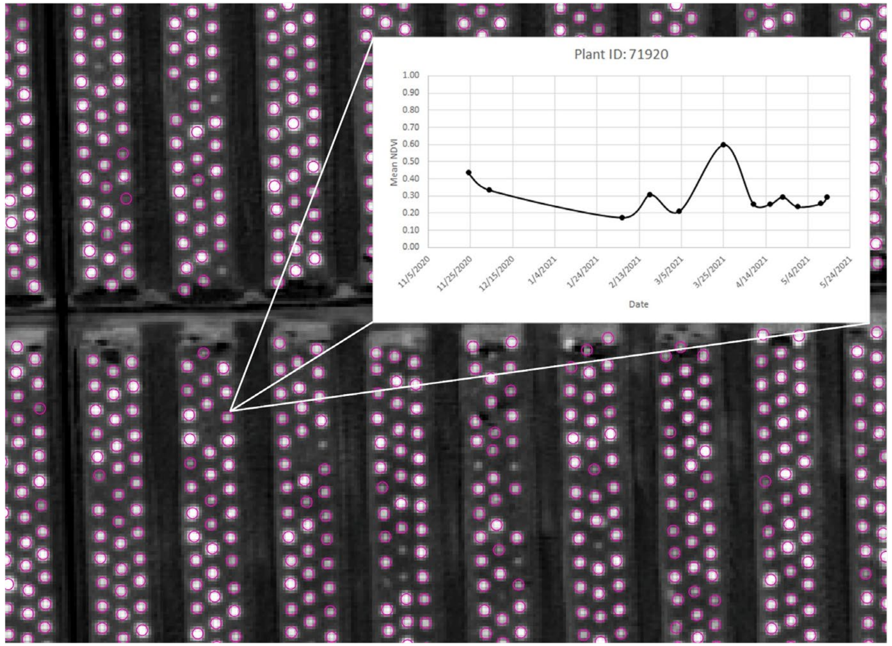


June 7

July 19

Remote Sensing Data Collection

Follow NDVI of individual plant over time



Note intensity of the signal in the image for this diseased plant is less than adjacent plants

M. Hang, F. Melton

Precision Yield Data Collection

- Evaluate plant health throughout the season
- Quantify yield

Precision Evaluation of Yield "i-carrito" components

Load cells

GPS antenna

Electronics box
- Microcontroller
- GPS receiver
- Accelerometer
- Storage
- Bluetooth.

S. Vougioukas

Weekly Cumulative Yield Map

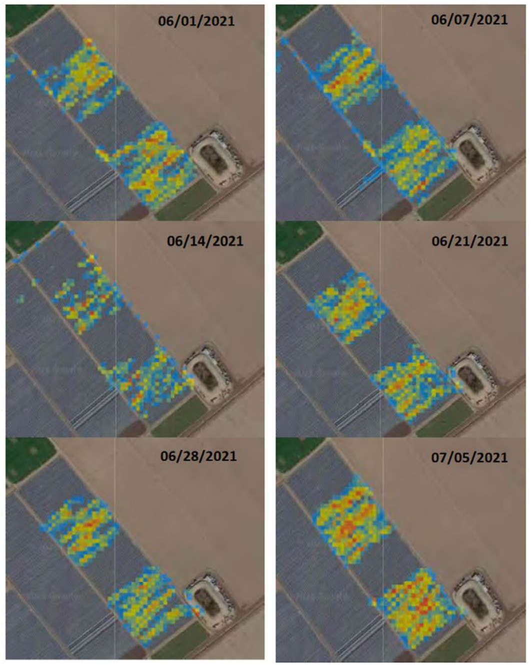


Figure 15. Weekly cumulative yield map throughout the strawberry season 20/21 at Spence Ranch field Salinas gained from early June until early of July 2021.

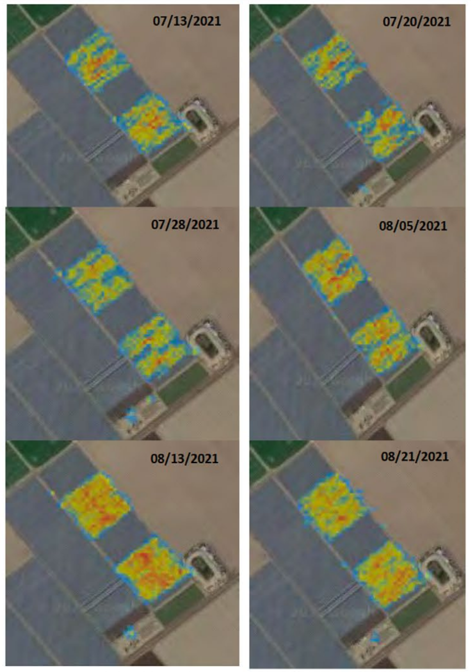


Figure 16. Weekly cumulative yield map throughout the strawberry season 20/21 at Spence Ranch field in Salinas gained from early July until late of August 2021.

Developing Yield Prediction Models

- Evaluate plant health throughout the season
- Quantify yield
- Develop yield prediction model

Agkit Sensor System

Video Cameras

Right camera view

Agkit

Left camera view

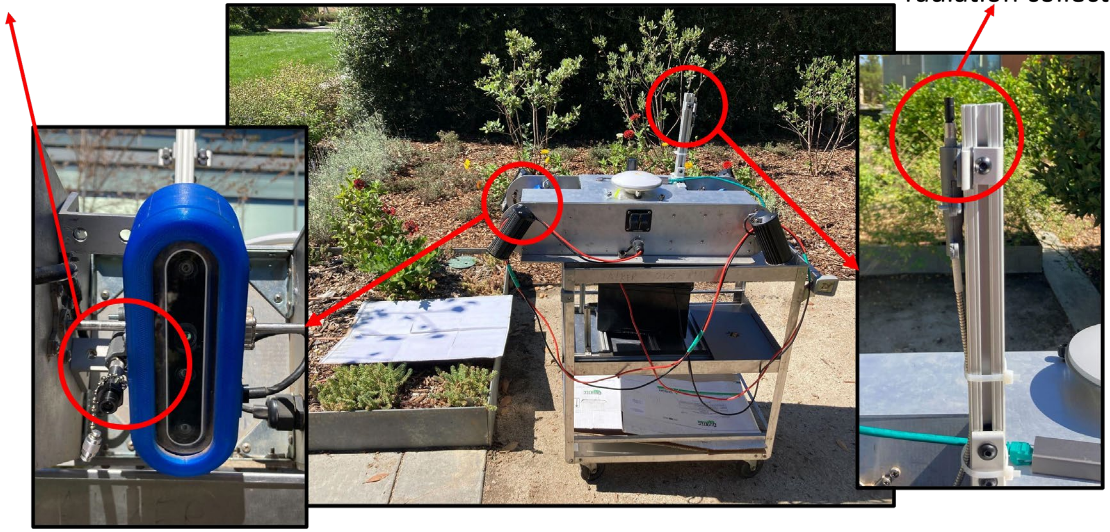
Mason Earles – UC Davis

Agkit Sensor System

Spectrometer Integration

Spectrometer for plant radiation collection

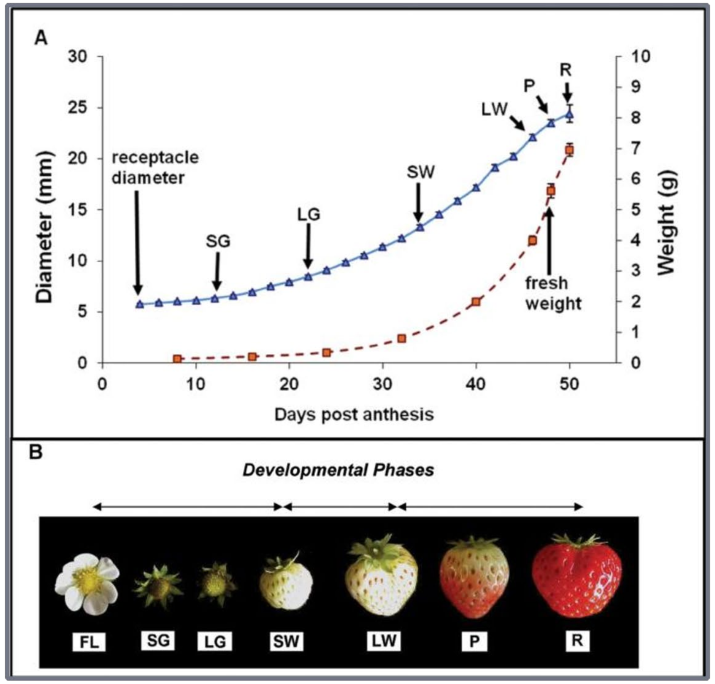
Spectrometer for sun radiation collection



Troy Magney – UC Davis

Developing Yield Prediction Models

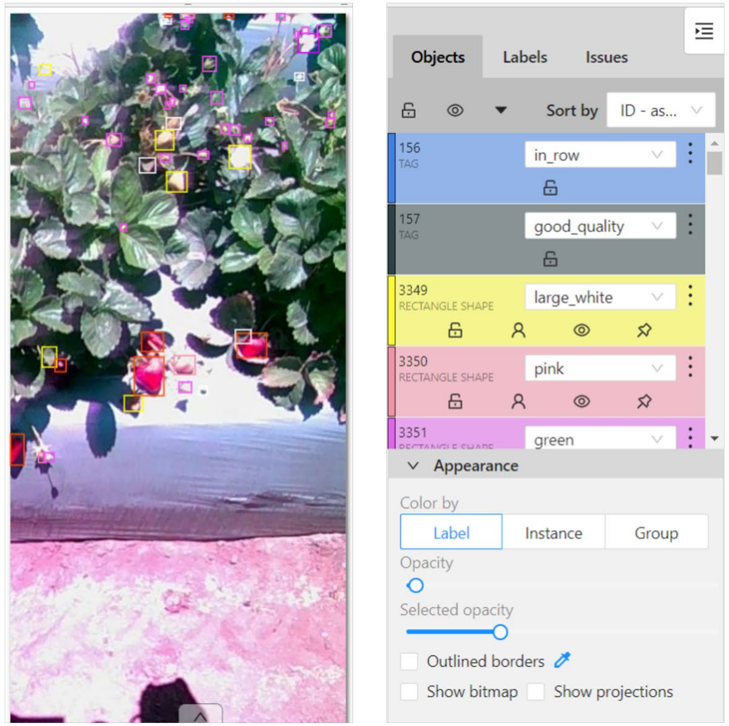
Data Annotation for Model Training



Symons et al. - https://doi.org/10.1093/jxb/ers147

Based on different maturity stages, We have annotated the imagery with 6 classes:

- Red
- Pink
- Green
- Large White
- Small White
- Flower

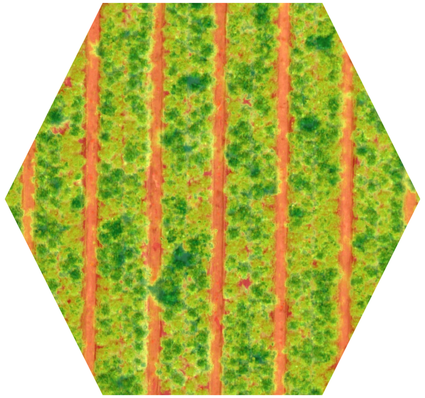


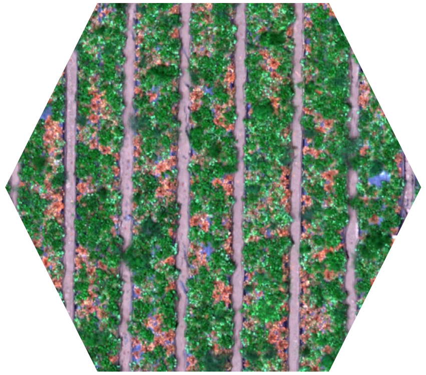
Annotation process

Mason Earles – UC Davis

Additional Types of Data Analysis we are Working Toward

- Develop site specific fumigation strategy that reduces fumigant use but maintains yield
- Look for relationship between pathogen inoculum density and disease severity – and how this impacts yield
- Look for relationships between vegetation indices and yield
- Develop predictive model for yield using imagery from Agkit
- With higher resolution reflectance data collected by Agkit look for other vegetation indices that better reflect plant health and yield





Advancing Plant Health Monitoring with Drones

Jon Detka, PhD

Postdoctoral Researcher, WATRS Lab

NASA USDA Cal State Monterey Bay

Current Research

Site-specific soil pest management in strawberry and vegetable cropping systems using crop rotation and a needs-based variable rate fumigation strategy

Project Goal: Develop a multi-tactic site-specific management program to reduce soilborne pathogens.

Research Goal: Develop drone-based monitoring approaches for early disease detection and link to estimated yield.

AI-related Research Questions

Can we use deep-learning image analytics to map fieldwide plant health?

Can we use machine learning to estimate disease prevalence and impact on yield?

USDA UCCE UC DAVIS UNIVERSITY OF CALIFORNIA UCR TriCal INC. Cal State Monterey Bay NASA

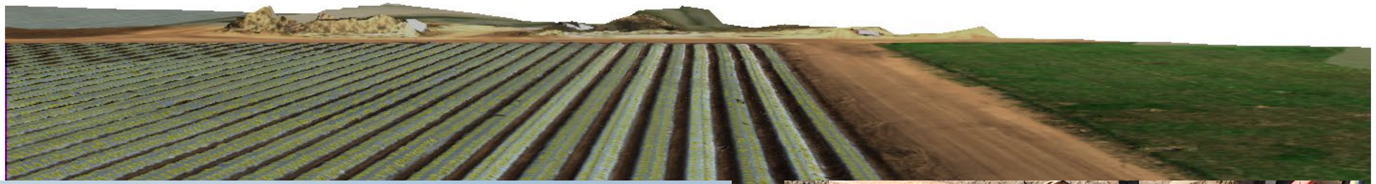
From Holes to Harvest

A Drone-Based Approach to Strawberry Canopy Positioning and Yield Estimation

Transplant holes mark the **initial positions** of plants.

Foundational for tracking plant growth, health, and productivity over time.

1. Generate imagery
    - multispectral imagery
    - 3-D digital surface
2. Calculate spectral index
    - Near Infrared – Blue
3. Mask Furrow and Bed
4. Isolate potential holes
5. Compare to deep-learning approach



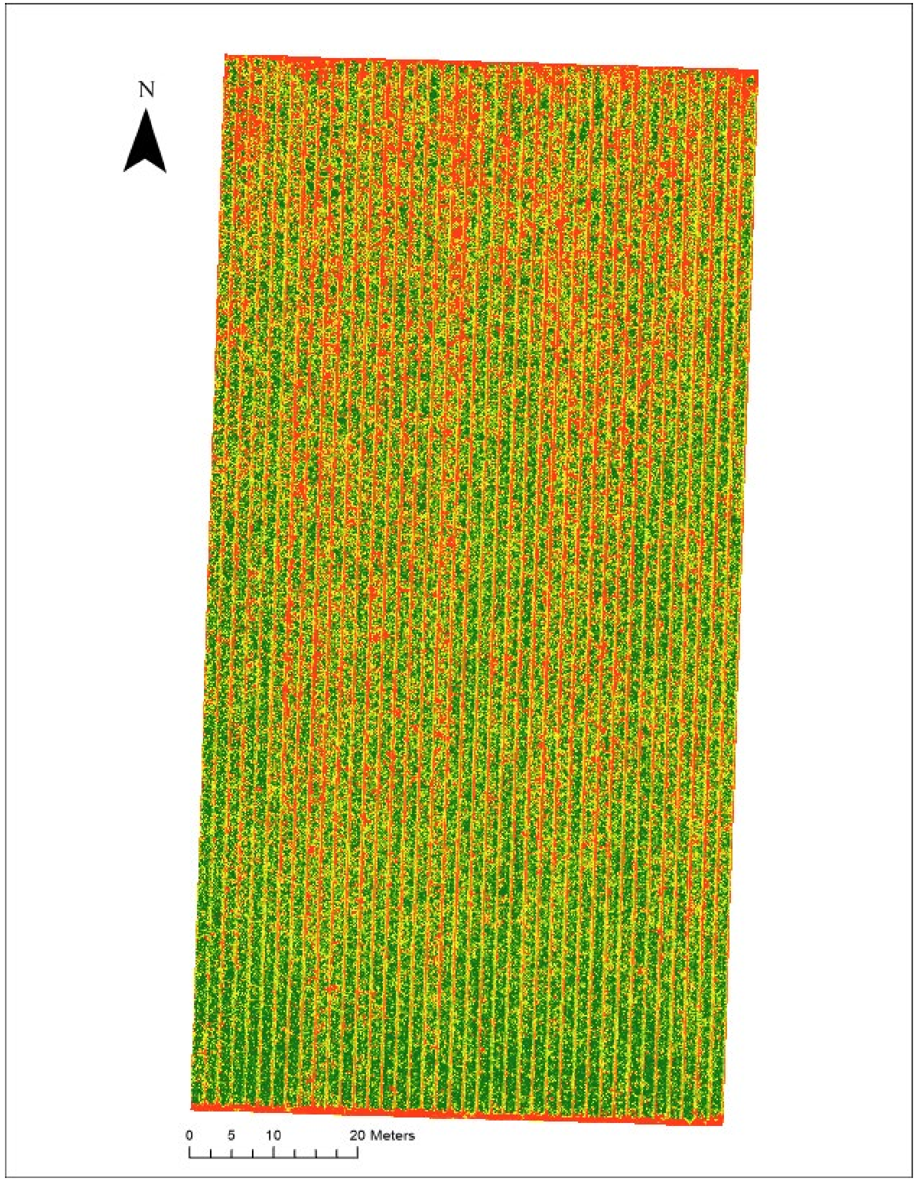
Towards an automated plant health classification and yield estimation

1. Can we create an automated rapid classification method for strawberry canopy health status at field scale?

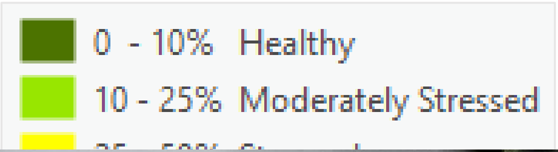
2. Can we make predictions about peak disease prevalence using changes in plant health?

- Oxnard, CA. ; 2 Acre Field,
  - 50k plants, short-day variety
  - Flights: 12/7/22 - 6/20/23
  - Continuous Crop
  - *Persistent M. phaseolina*

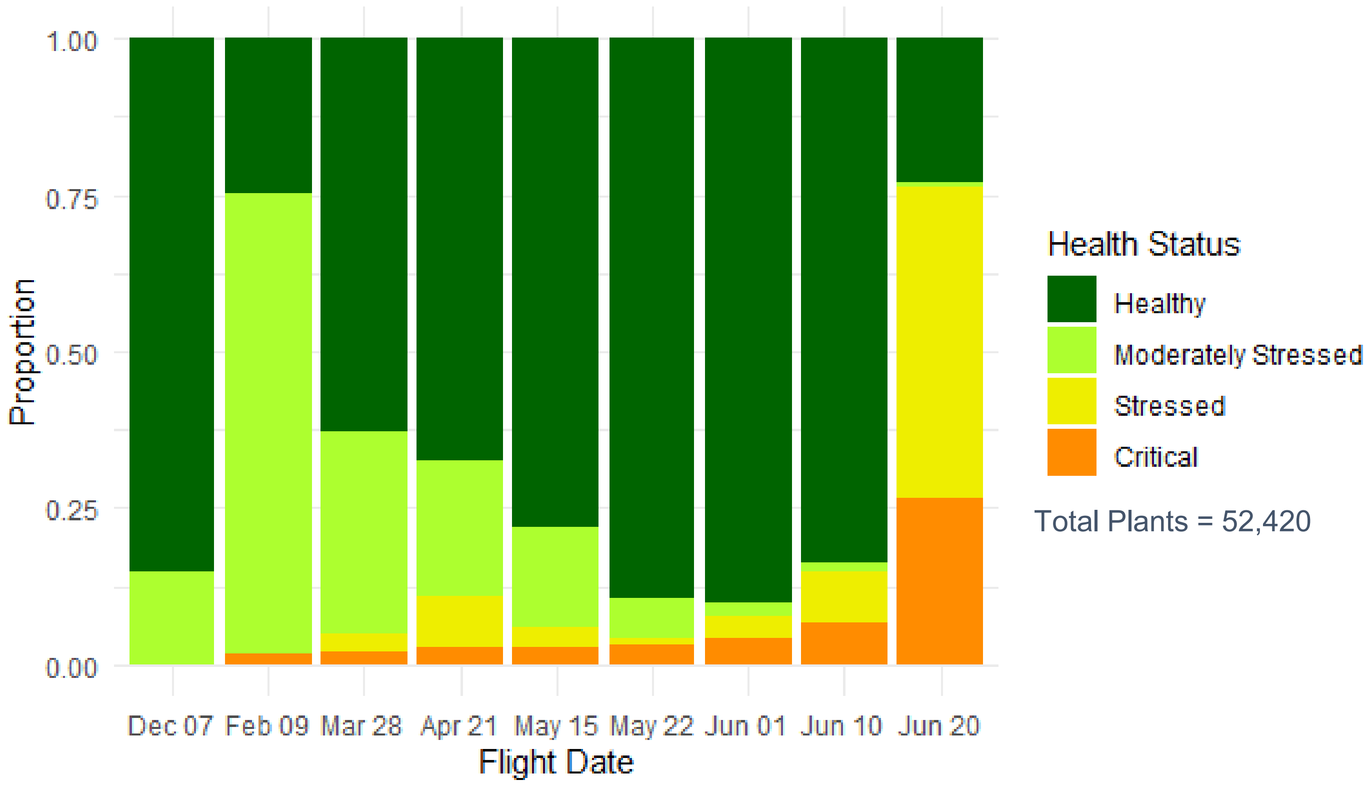
$$NDRE = \frac{NIR - Red\ Edge}{NIR + Red\ Edge}$$



Toward an automated rapid classification method for strawberry canopy health status at field scale.



Preliminary Results – Canopy Health Status



Estimating peak disease prevalence using changes in plant health

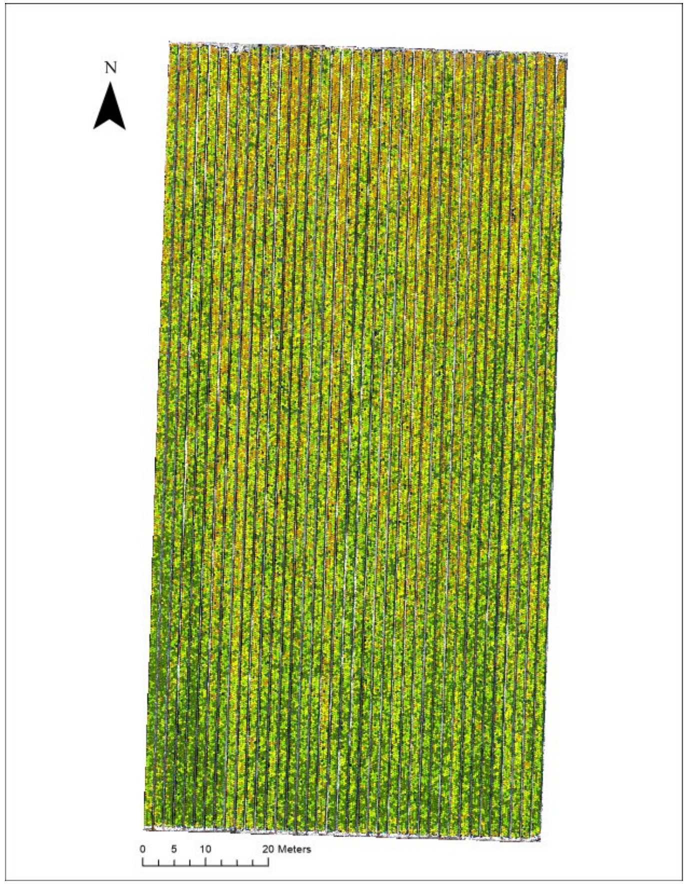
Approach: Predict end-of-season plant status given prior time windows.

Time Windows

- **Early to mid-season growth** (Feb 9 – Apr 21)
- **Peak growth and fruiting** (Apr 21 – May 15)
- **Emerging health challenges** (May 15- Jun 1)
- **Extensive disease symptoms** (Jun 1 – Jun 10)

Model Input Features

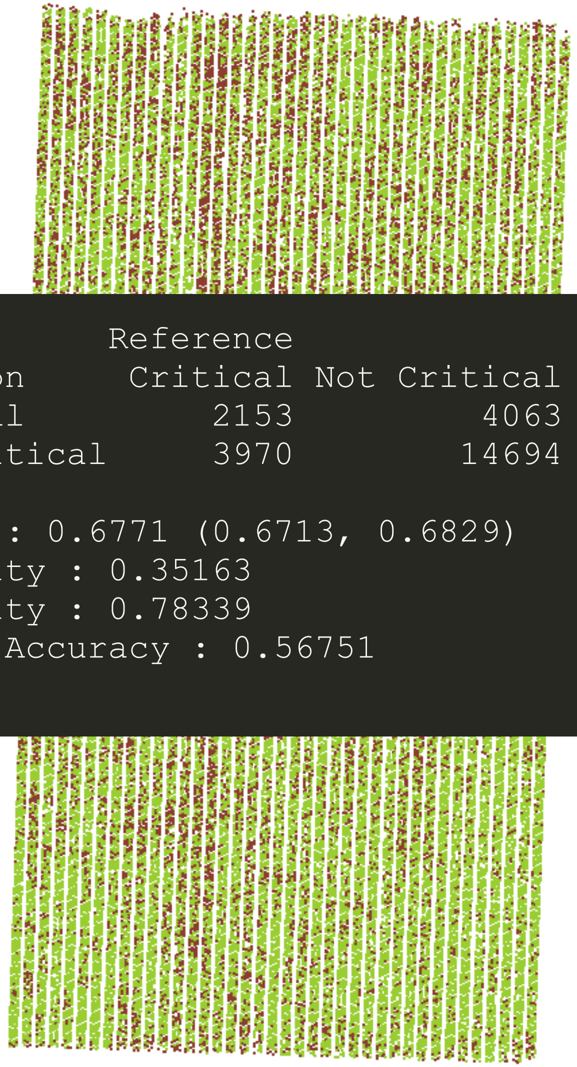
- **% Dieback and % Growth - Change Over Time**
- **Distance to Nearest Unhealthy Neighbors**



Make predictions about peak disease prevalence using changes in plant health.

Apr 21 - May 15

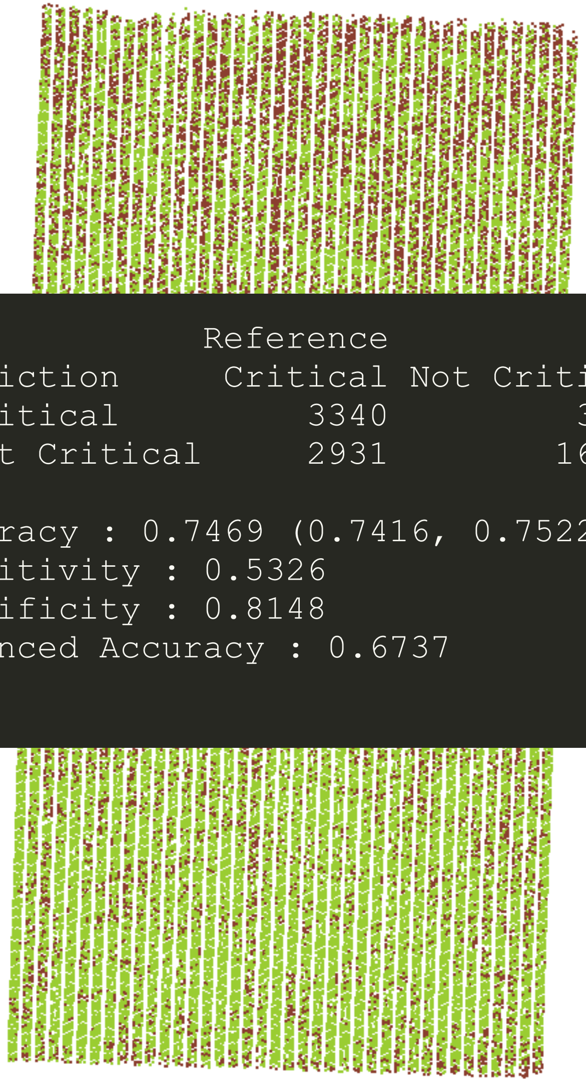
Predicted Critical Plants



```
                 Reference
Prediction      Critical Not Critical
  Critical          2153         4063
  Not Critical      3970        14694

Accuracy : 0.6771 (0.6713, 0.6829)
Sensitivity : 0.35163
Specificity : 0.78339
Balanced Accuracy : 0.56751
```

May 15 - Jun 1

Predicted Critical Plants



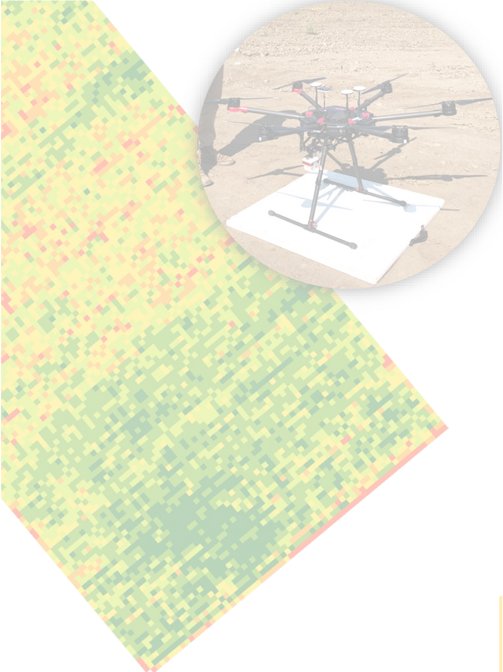
```
                 Reference
Prediction      Critical Not Critical
  Critical          3340         3666
  Not Critical      2931        16127

Accuracy : 0.7469 (0.7416, 0.7522)
Sensitivity : 0.5326
Specificity : 0.8148
Balanced Accuracy : 0.6737
```

Actual Critical Plants 6/20

Insight & Next Steps

- Promising approach for identifying healthy plants mid- and late-season.
- Refine identification of critical diseased cases.
- **Next steps**
  - Survey and analyze day-neutral growing regions.
  - Explore the utility of other spectral features to identify plant stress.
  - Estimate plant health impact on yield.
  - Examine the efficacy of variable rate fumigation.

Implementation and assessment of variable-rate fumigation in strawberry fields through precision tools



Objective:

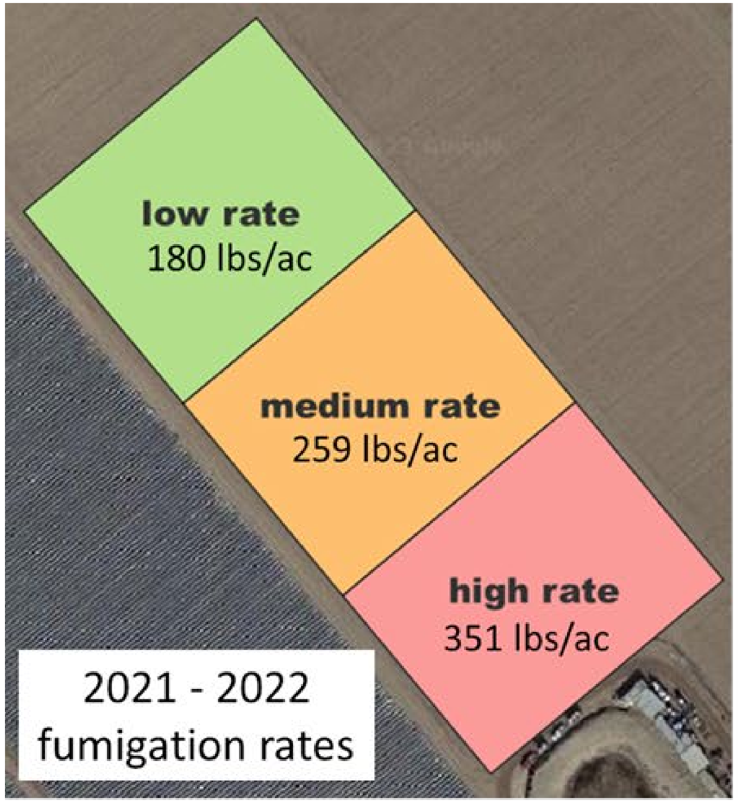
- ➢ assess the viability of using variable rate fumigation in strawberry production

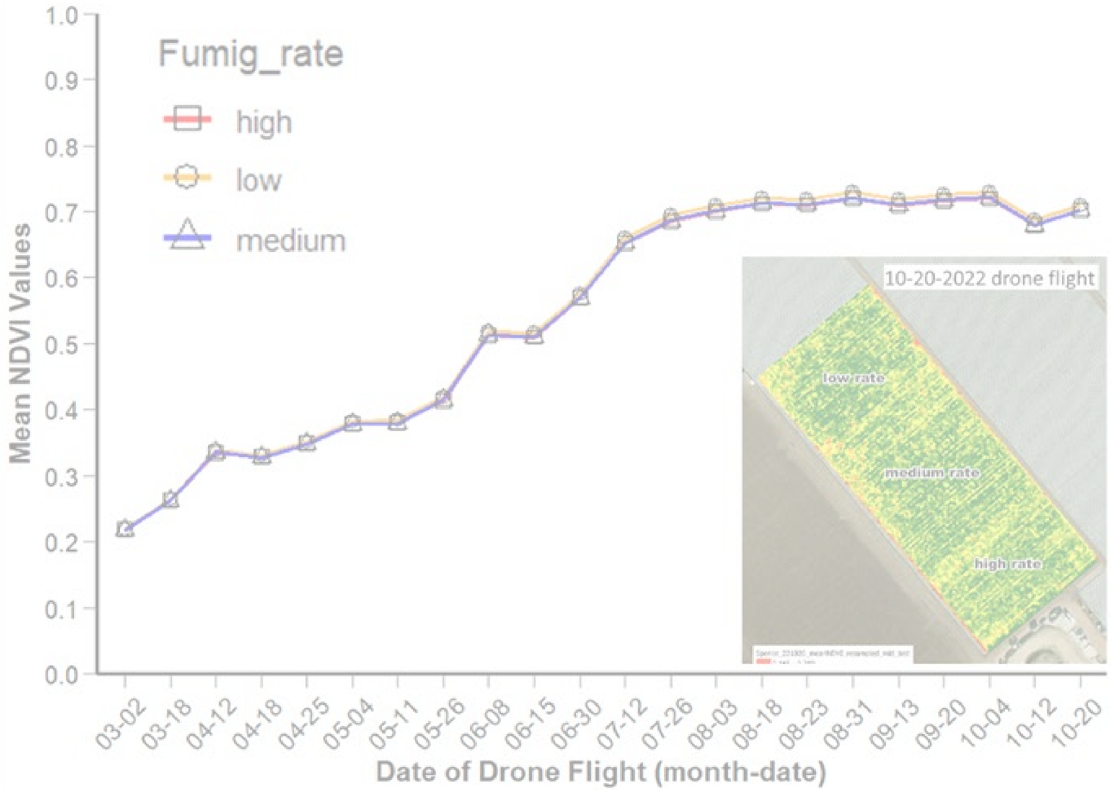
On-farm experiments in Salinas and Oxnard between 2020 -2024

Field	Season	Stawberry variety	Panting date	Fumigant	Fumigation method	Fumigation rates (lbs/ac)	
Salinas Field 1	2020-2021	Cabrillo	11-Nov	Tri-Form 80	Broadcast	low	220
						medium	330
						high	440
	2022-2023	Cabrillo	12-Nov	Pic-Clor 60 EC	Drip	low	220
						medium	330
						high	417
Salinas Field 2	2021-2022	Cabrillo	10-Nov	Pic-Clor 60 EC	Drip	low	180
						medium	259
						high	351
	2023-2024	Cabrillo	13-Nov	Pic-Clor 60 EC	Drip	medium	330
						high	417
Oxnard Field	2022-2023	Fronteras	1-Oct	Tri-Clor	Broadcast	low	250
						medium	300
						high	350
	2023-2024	Fronteras	1-Oct	Tri-Clor	Broadcast	low	250
						medium	300
						high	350

Salinas field 2: 2021-2022 season || F. Martin, S. Fennimore, and team

Application of reduced fumigation rates in areas with lower pest pressure did not appear to impact crop health and yield.

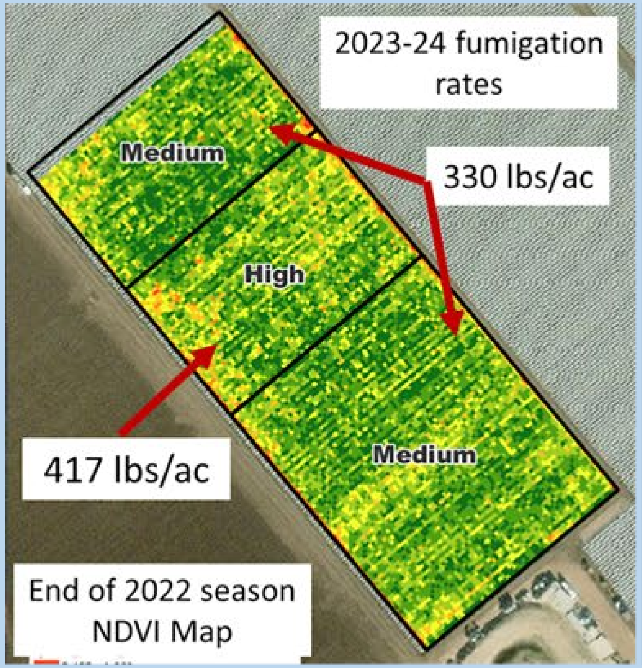


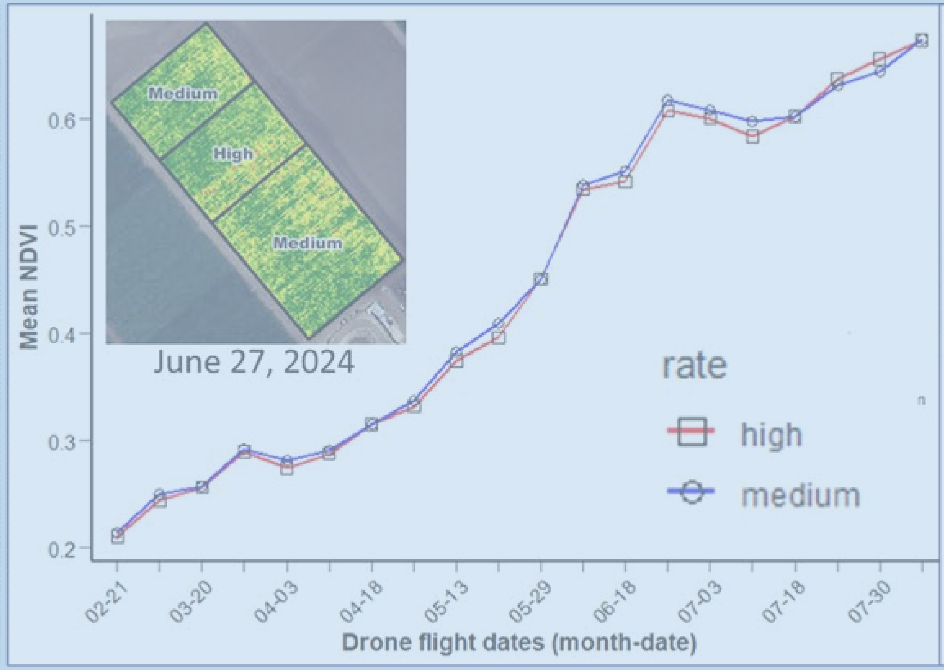


Results

Salinas field 2: 2023-2024 season || F. Martin, S. Fennimore, and team

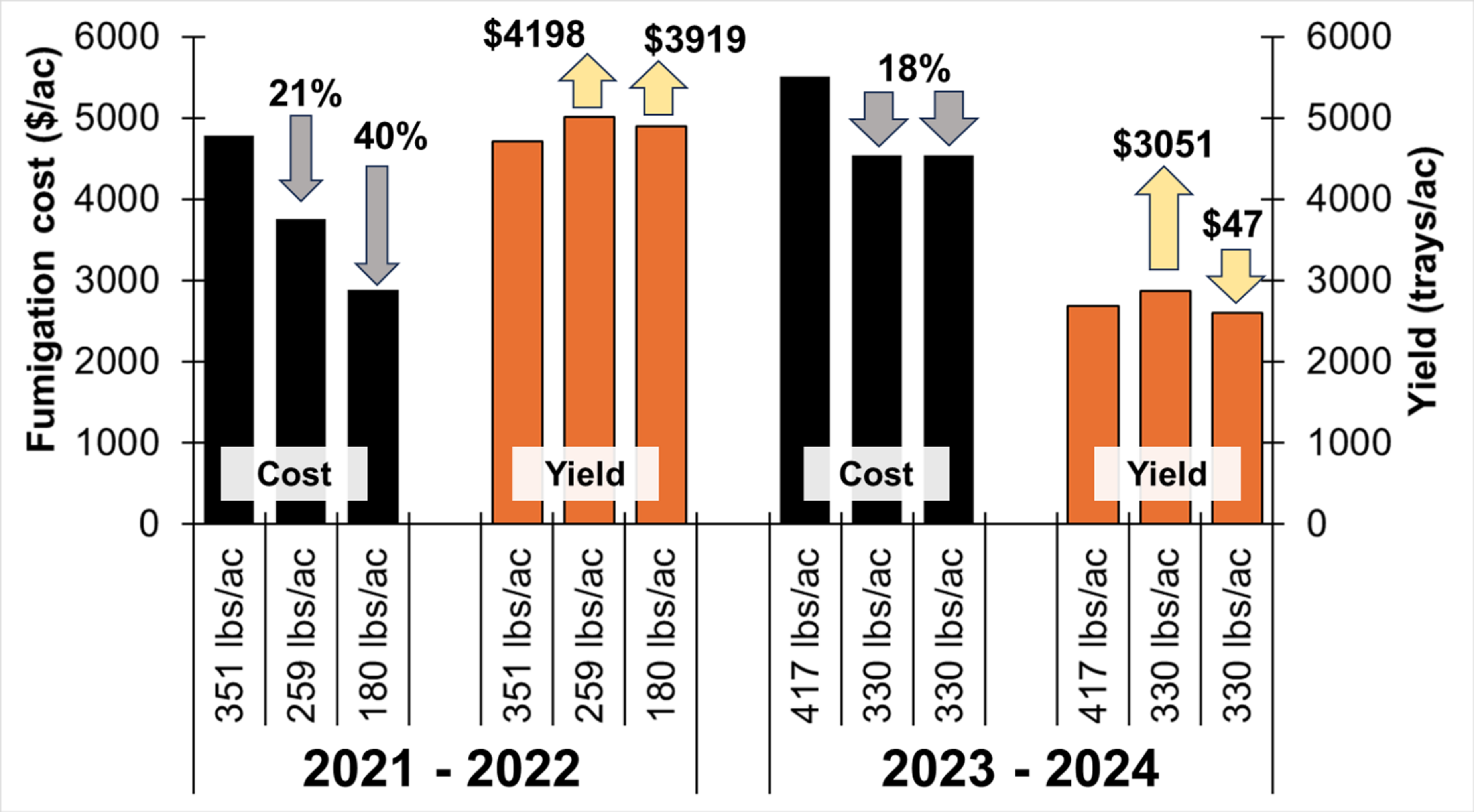
Consistent patterns: No significant difference in mean NDVI and yield between plots with 'medium' and 'high' fumigation rates





Results

Reduced fumigation rates in areas with historically lower pest pressure help reduce fumigation cost without compromising yield



Will variable rate fumigation perform as good as a standard uniform rate?

Pest pressure “risk”	Standard: Uniform rate	Variable rate fumigation
High risk	30 gal/ac	30 gal/ac
Low risk	30 gal/ac	20 gal/ac

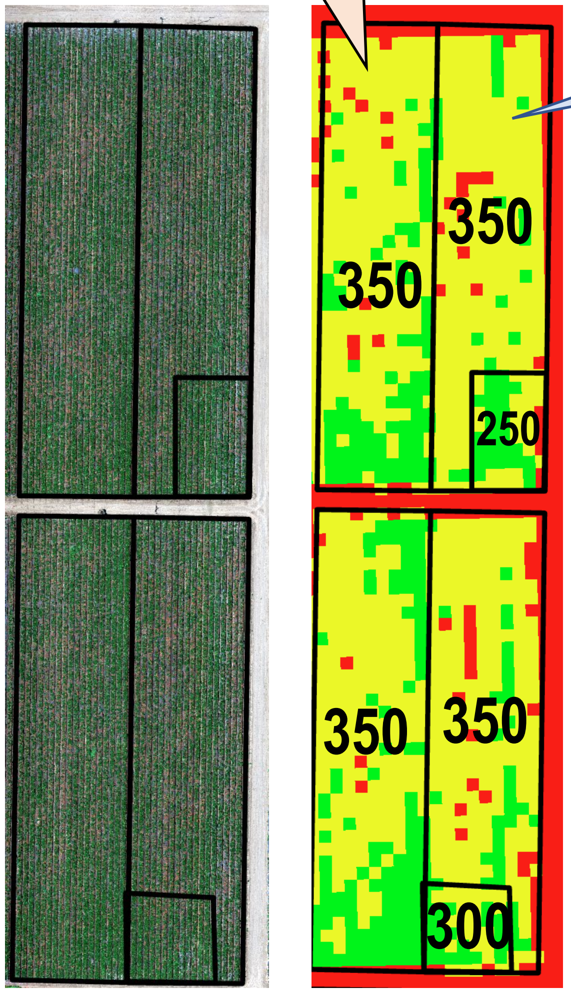
Oxnard field : 2022-2023 season || O. Daugovish, A. Putman, C. Greer, and team

Standard rate

RGB NDVI

Block 1

Block 2



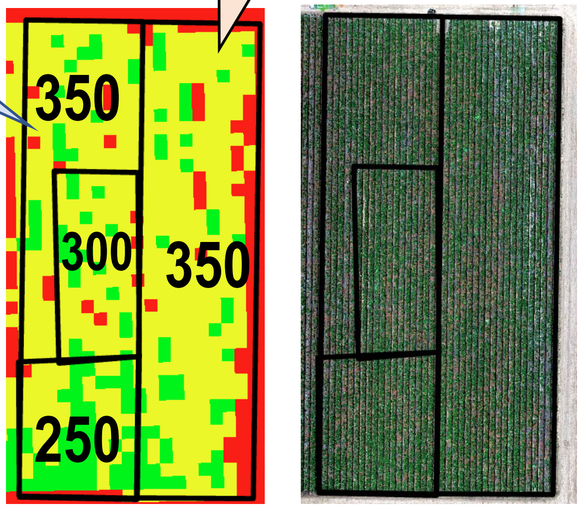
Variable rate
'Prescription map"

Standard
VS
Variable rate

Standard rate

NDVI RGB

Block 3

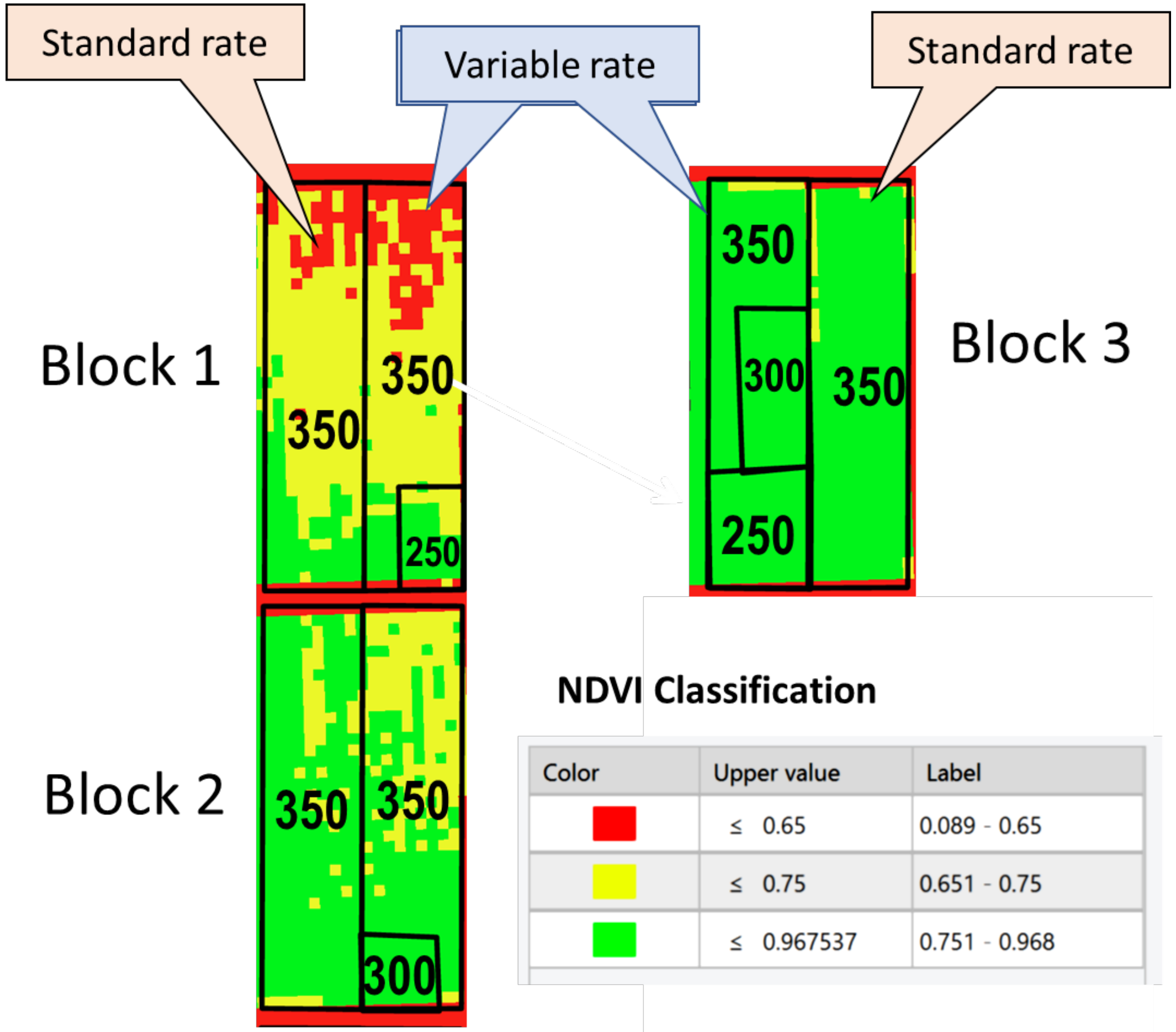


NDVI Classification

Color	Upper value	Label
Red	≤ 0.45	0.042 - 0.45
Yellow	≤ 0.6	0.451 - 0.6
Green	≤ 0.860611	0.601 - 0.861

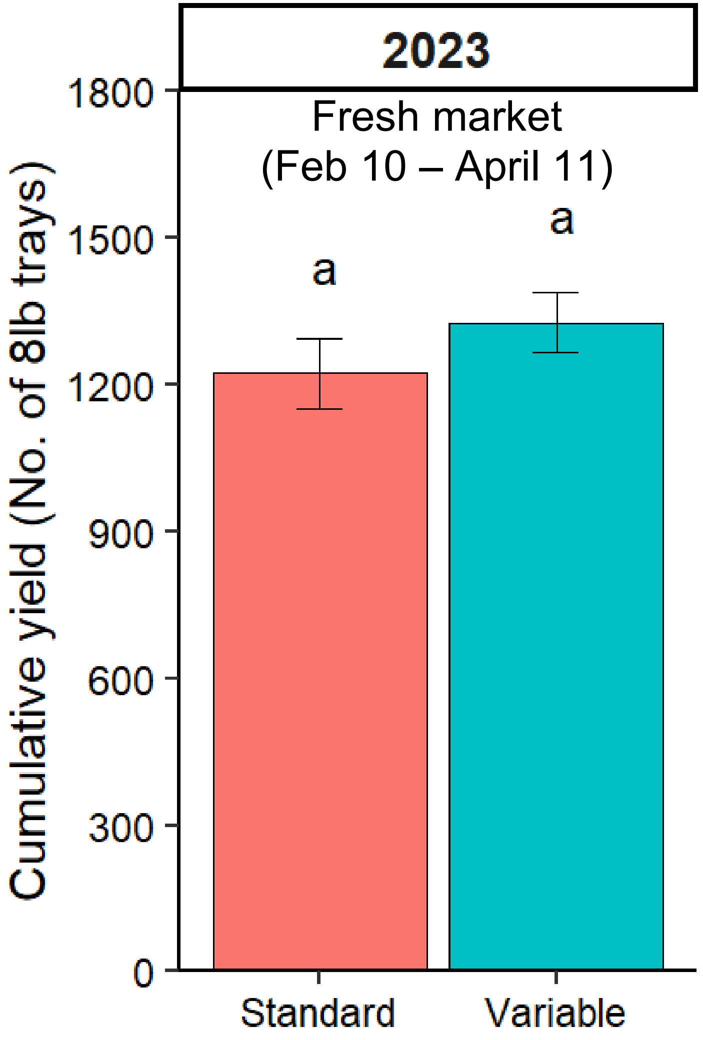
Standard VS Variable rate: Implementation of variable rate fumigation did not significantly impact crop health and did not compromise yield

End-of-season NDVI (July 2023)

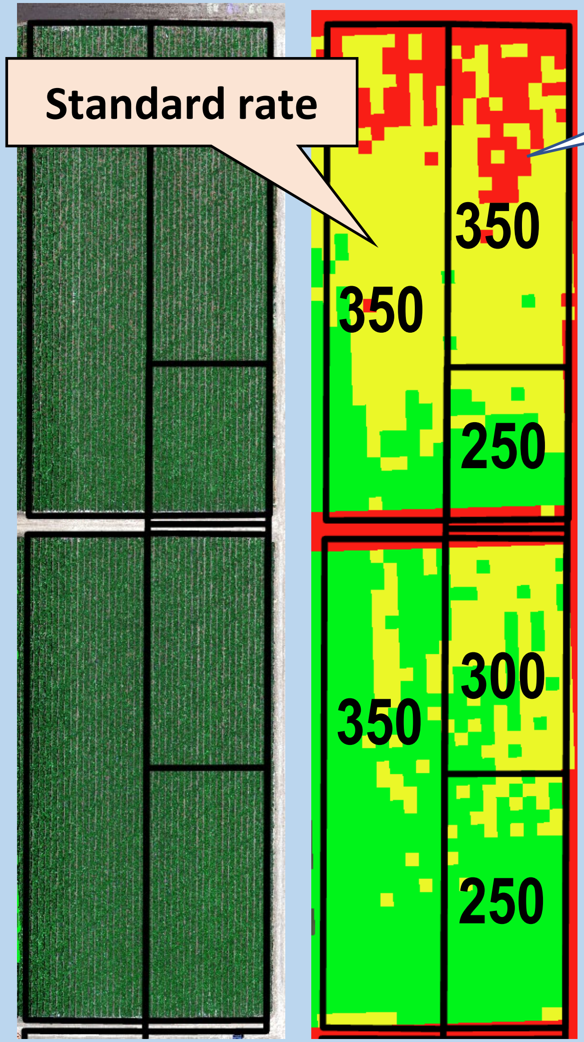


NDVI Classification

Color	Upper value	Label
Red	≤ 0.65	0.089 - 0.65
Yellow	≤ 0.75	0.651 - 0.75
Green	≤ 0.967537	0.751 - 0.968

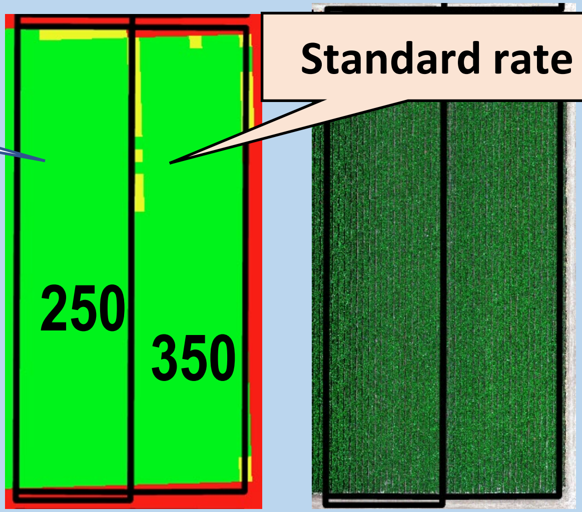


Oxnard field : 2023-2024 season || O. Daugovish, A. Putman, C. Greer, and team



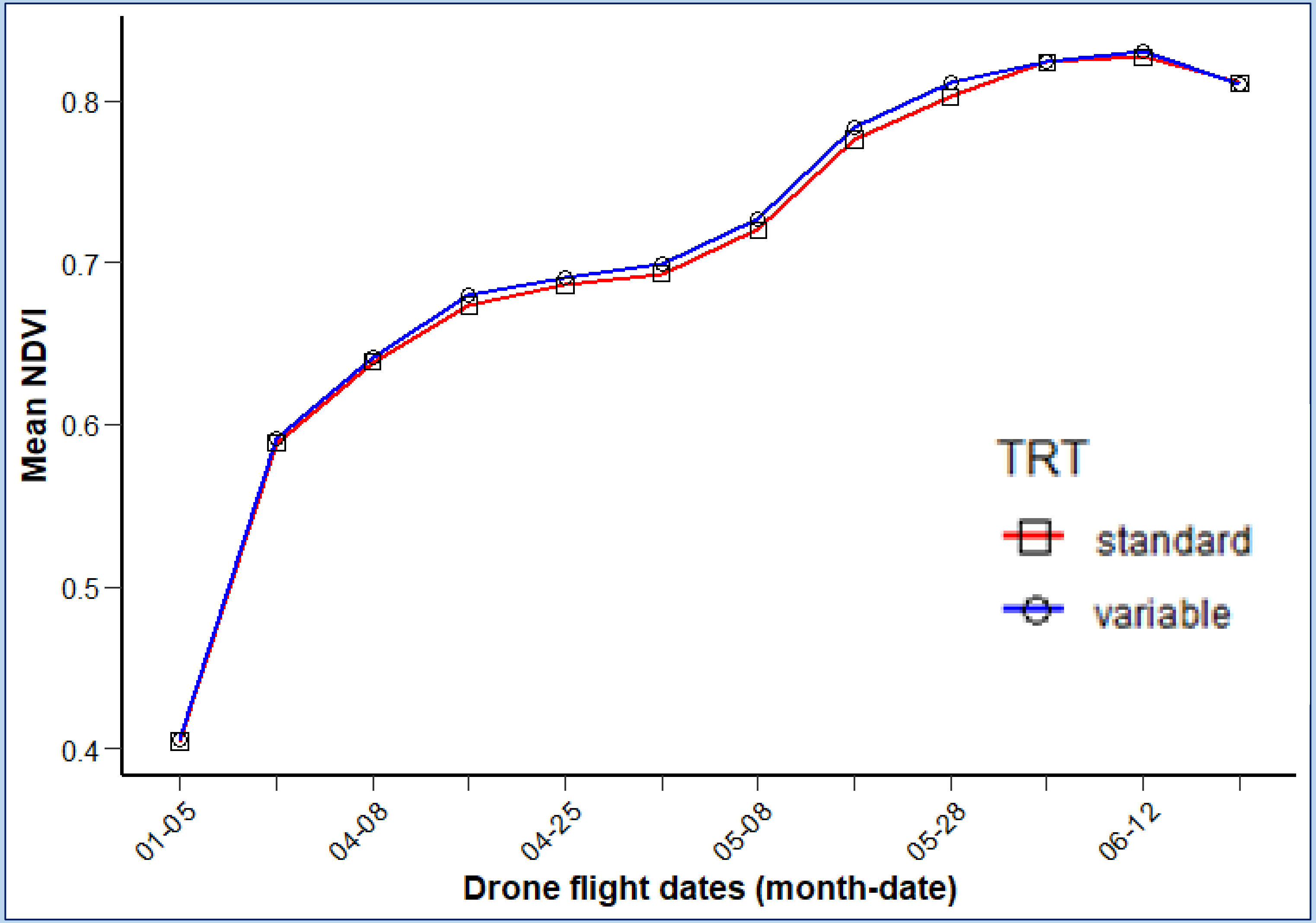
Variable rate
"Prescription map"

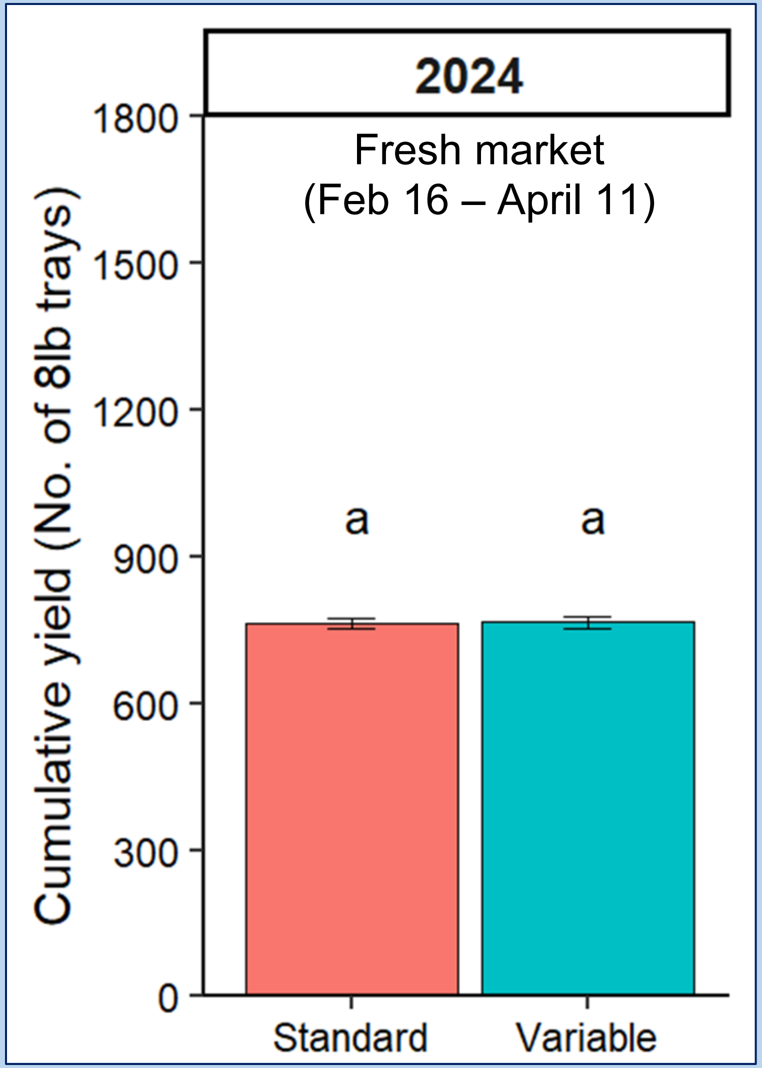
Standard
VS
Variable rate



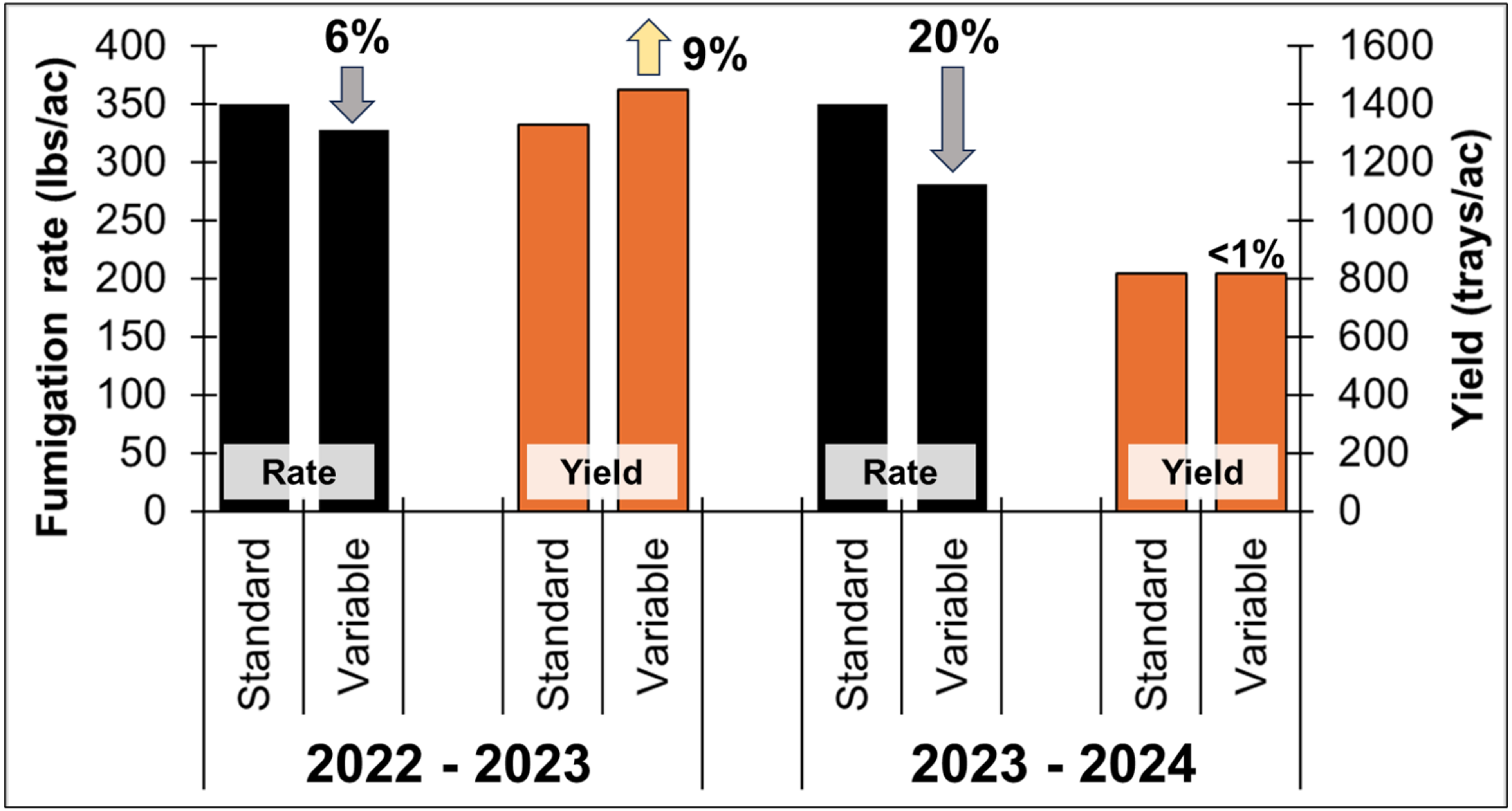
Color	Upper value	Label
Red	≤ 0.65	0.089 - 0.65
Yellow	≤ 0.75	0.651 - 0.75
Green	≤ 0.967537	0.751 - 0.968

Standard VS Variable rate: Implementation of variable rate fumigation did not significantly impact crop health and did not compromise yield





Variable rate fumigation is a viable tactic for reducing the quantity of fumigant applied maintaining crop yield



Key Findings:

- Ability to map out areas where plant collapse occurred within a field
- Prediction of areas where plant collapse is likely to occur
- Application of reduced fumigation rates in areas with historically lower pest pressure reduces fumigant use and associated costs without compromising yield
- Current data suggests that variable rate fumigation is a viable tool in strawberry production

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