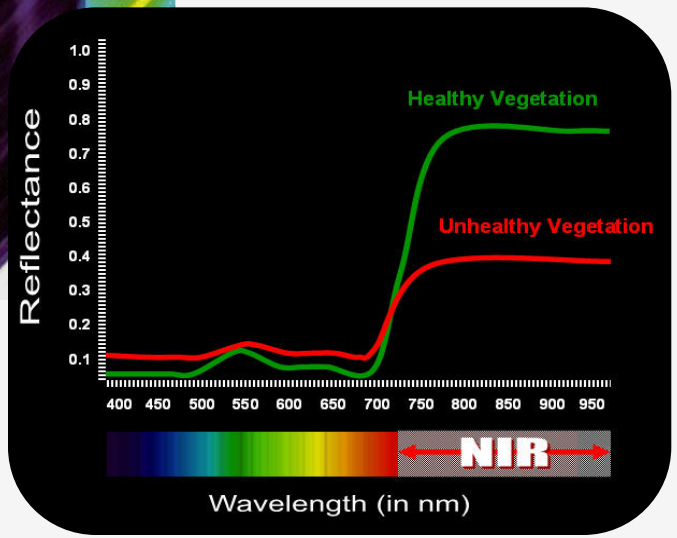
Hyperspectral Remote Sensing in Detection of Biotic and Abiotic Stresses in Plants for Precision Agriculture



Keshav D Singh (Postdoc);

Christian Nansen (P.I.);

Robert Starnes (Pilot);

Elvira De Lange (Postdoc);

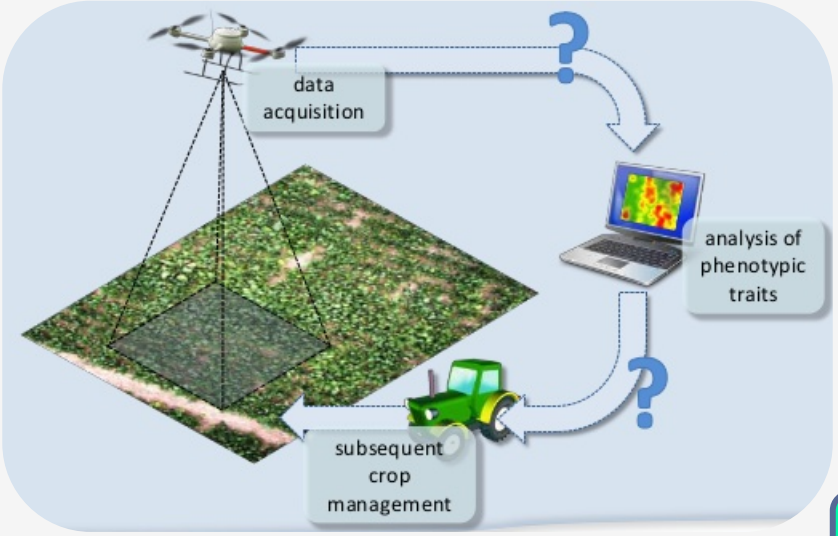
UC Davis, CA

UCDAVIS
COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

Agriculture Plants/Trees

Change in Spectral Signature

Hyperspectral Imaging



Infestation/Disease/Wilt

Biotic/Abiotic Stress

Vegetation starts Damaging

Pest Management

Pesticides Spray

Crops Management/ Precision Agriculture

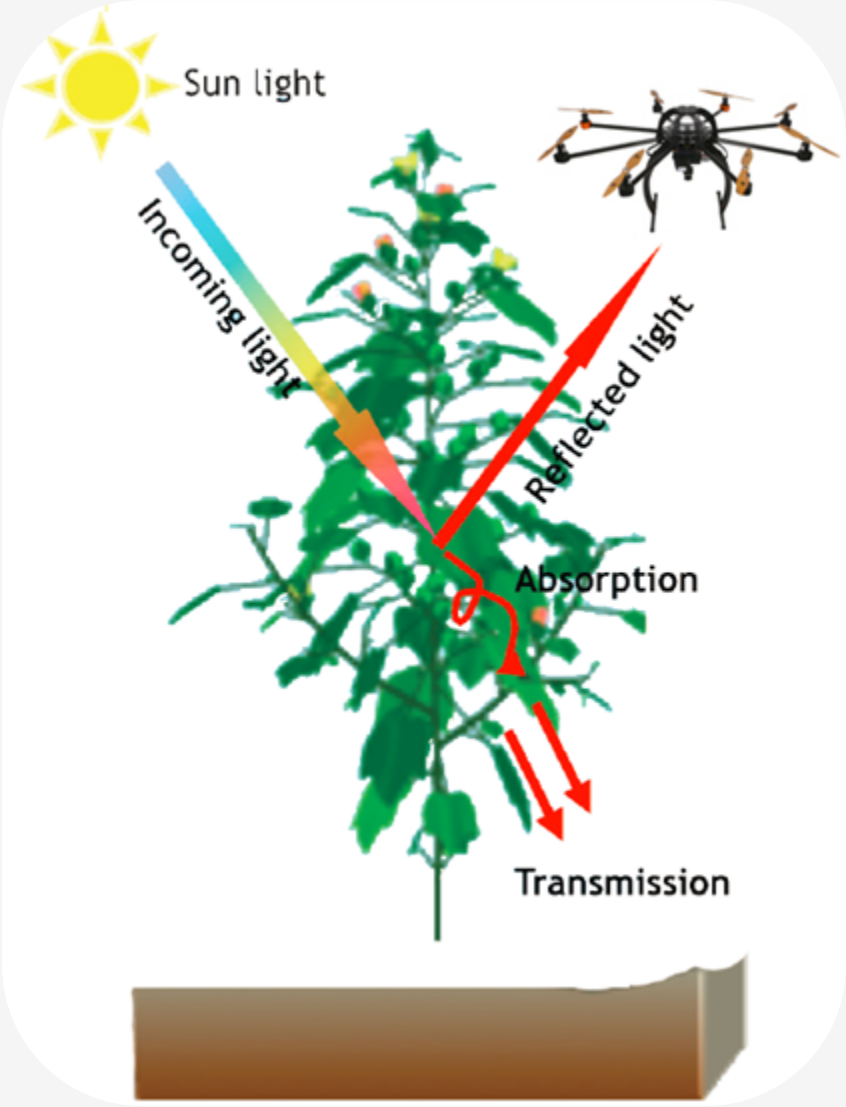
Hyperspectral Imaging (HSI):

- Imaging and Spectroscopy
- Hundreds of narrow spectral bands to address subtle information

Advantages:

- Non-destructive
- Low cost
- Less time

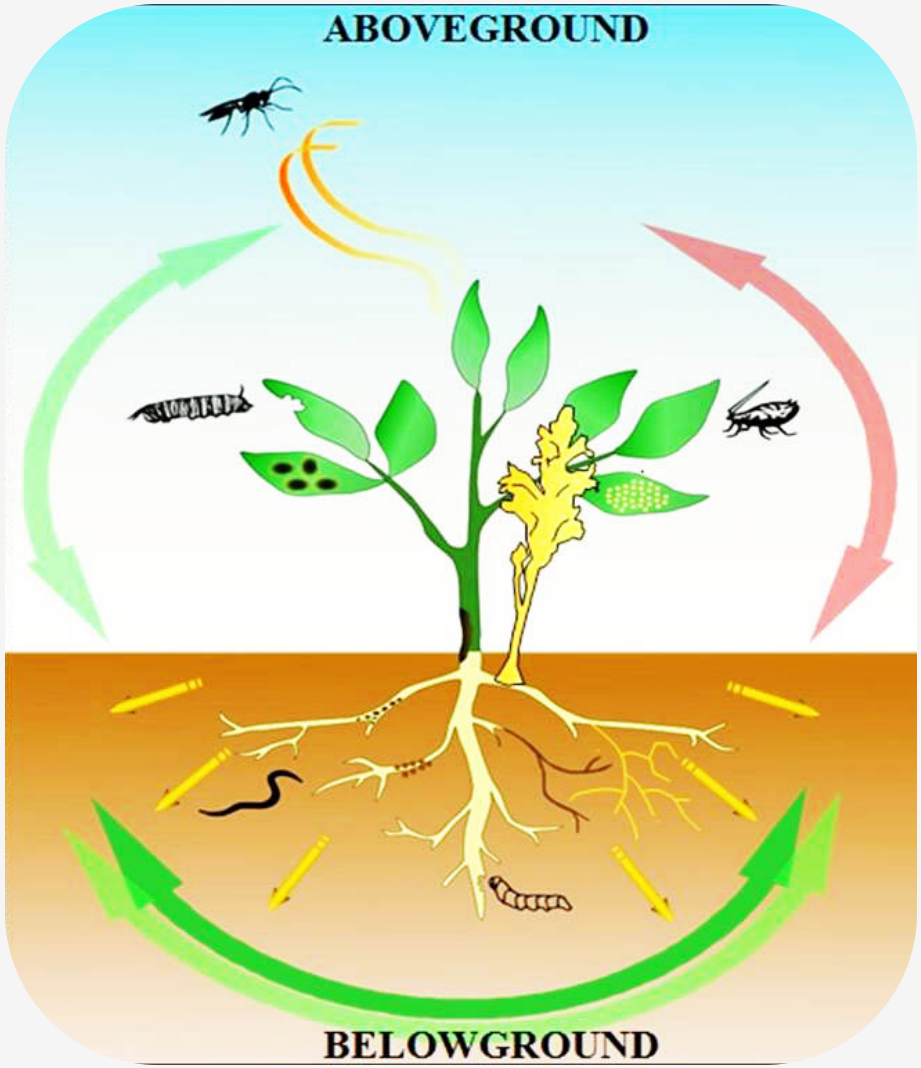
Imaging Spectroscopy: Interaction between the electromagnetic radiation and contact material



Ref: @Basics of Crop Sensing, ANR-1398

Plant-Biotic Interaction:

- Infestation/Pests
- Fertilizers/Nutrients



Infestation causes:

- **Bacteria**
- **Fungus**
- **Virus**
- **Insect pests:** Whiteflys, Mealybugs, Aphids, Spidermites, Nematodes)

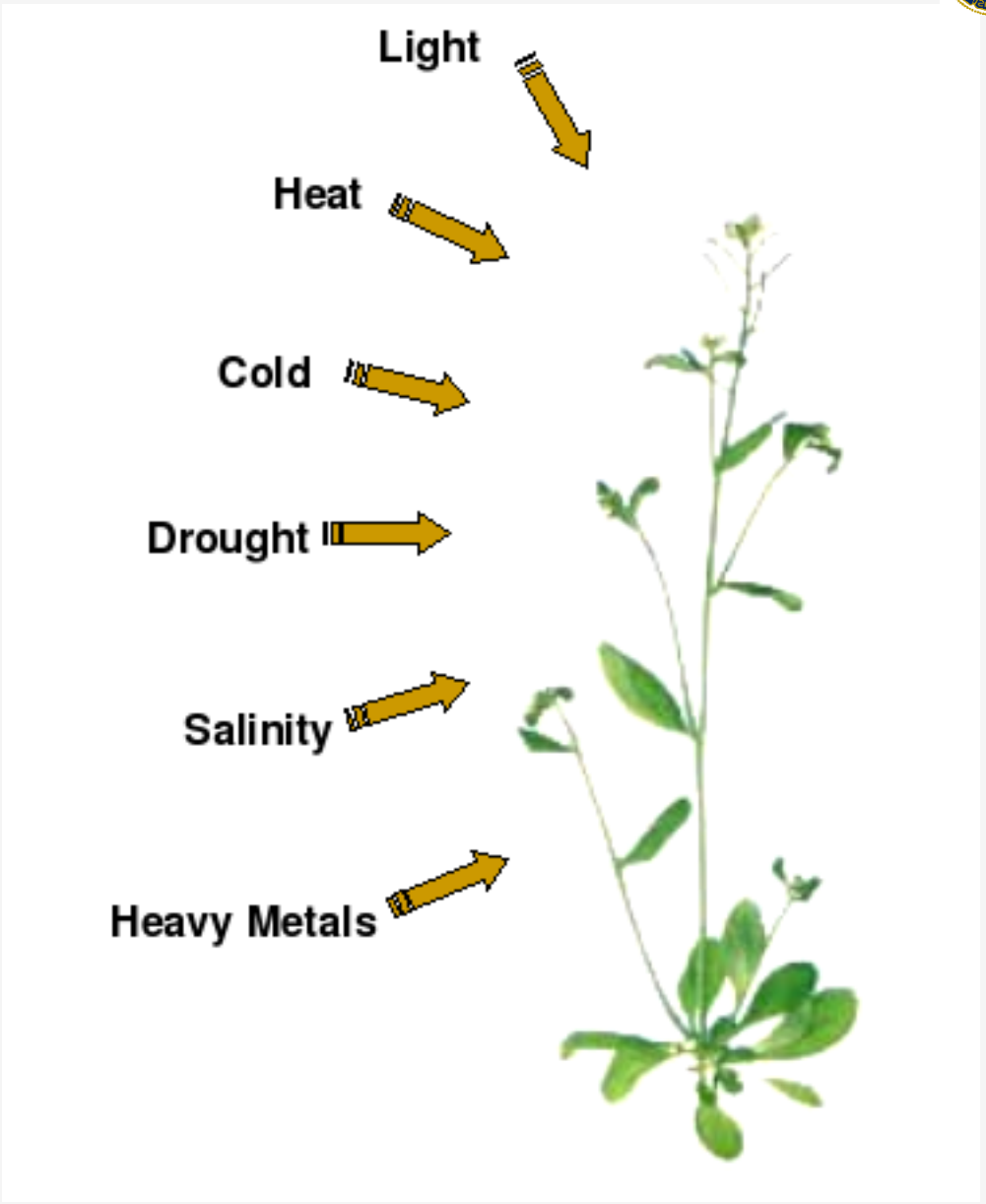
Fertilizer/Nutrients:

- **Nitrogen (N)**
- **Phosphorus (P)**
- **Potassium (K)**

Ref: @Estación Experimental del Zaidín (CSIC), Spain

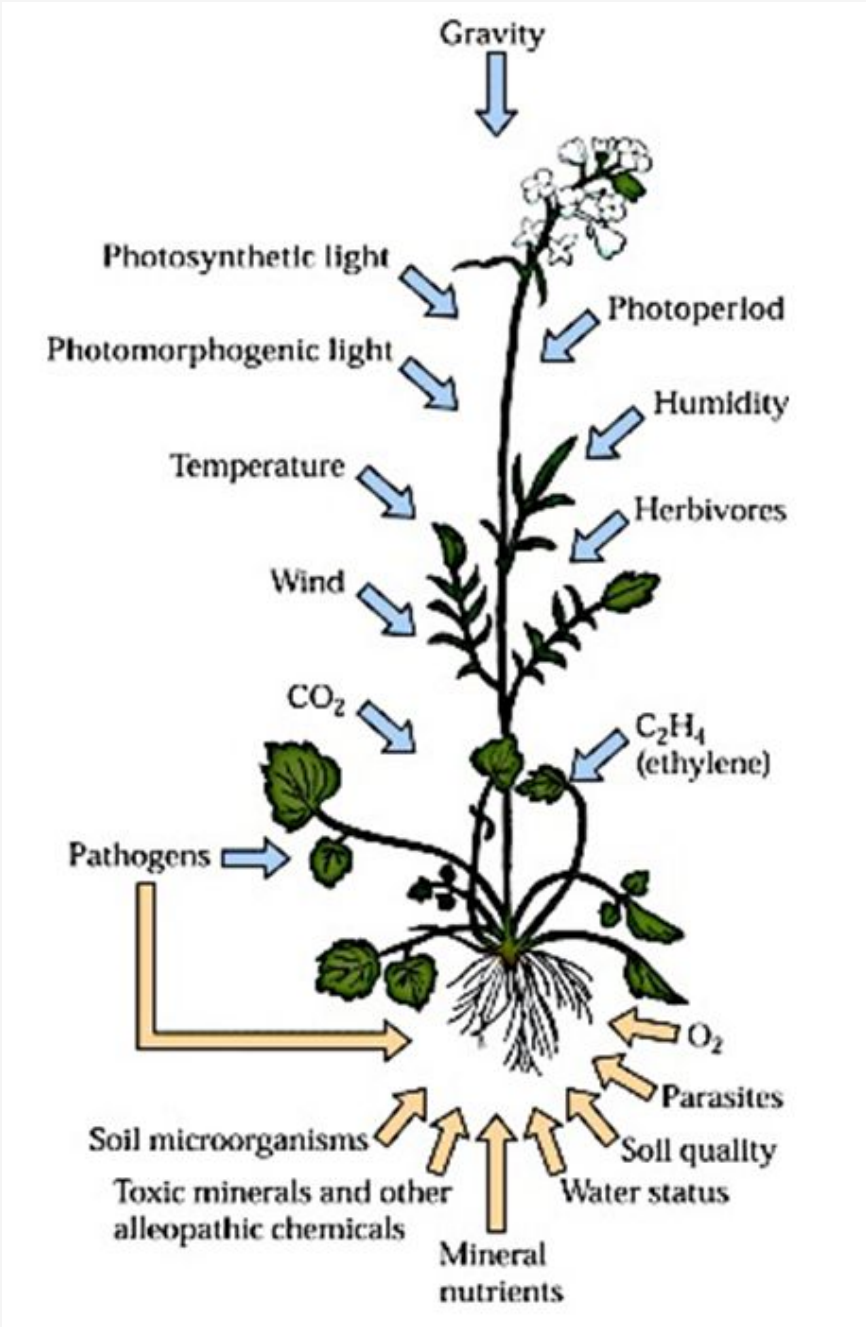
Plant-Abiotic Interaction:

- Drought (water deficit),
- Excessive watering (water-logging/flooding),
- Extreme temperatures (cold, frost and heat)
- Salinity (sodicity)
- Mineral (metal and metalloid) toxicity



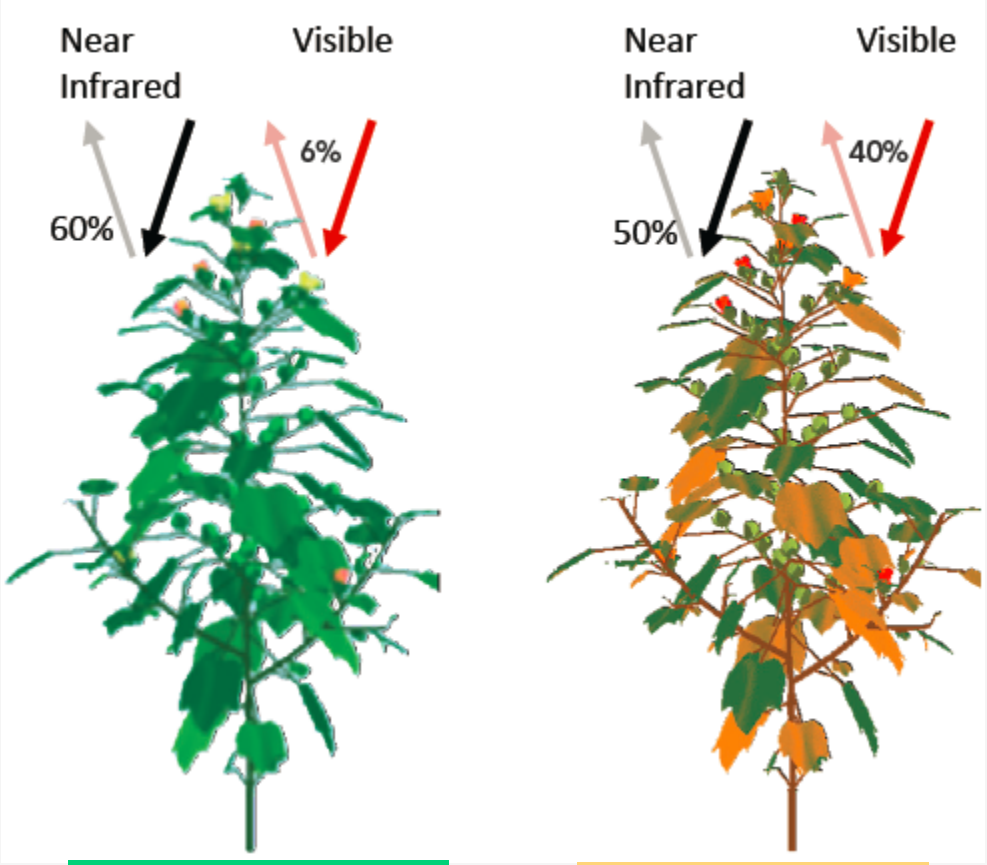
Combined biotic and abiotic environmental stress factors:

Healthy **Stressed**



Crop health via Reflectance profiling:

- Vegetation stress identification and monitoring
- Detection of crop responses to biotic and abiotic stressors

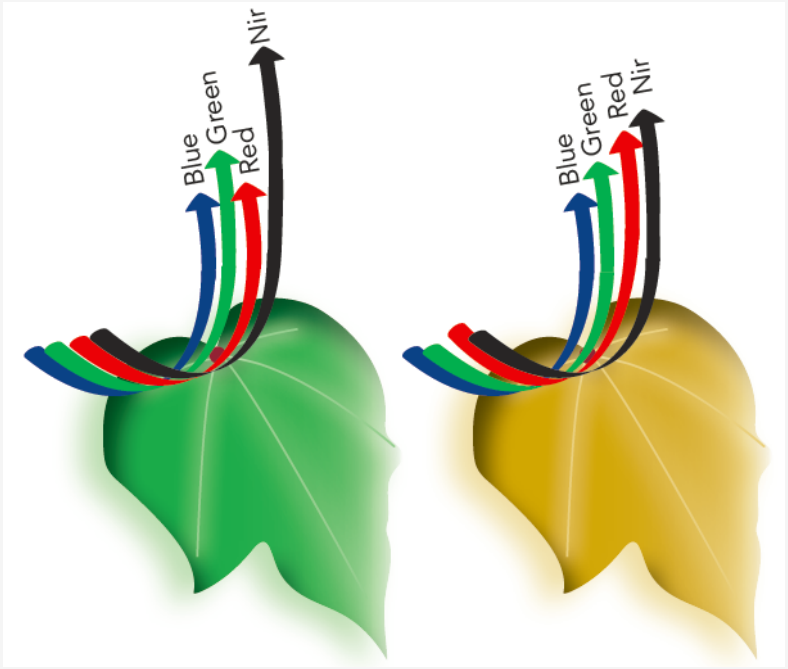


Healthy (high biomass)

Unhealthy (low biomass)

Healthy

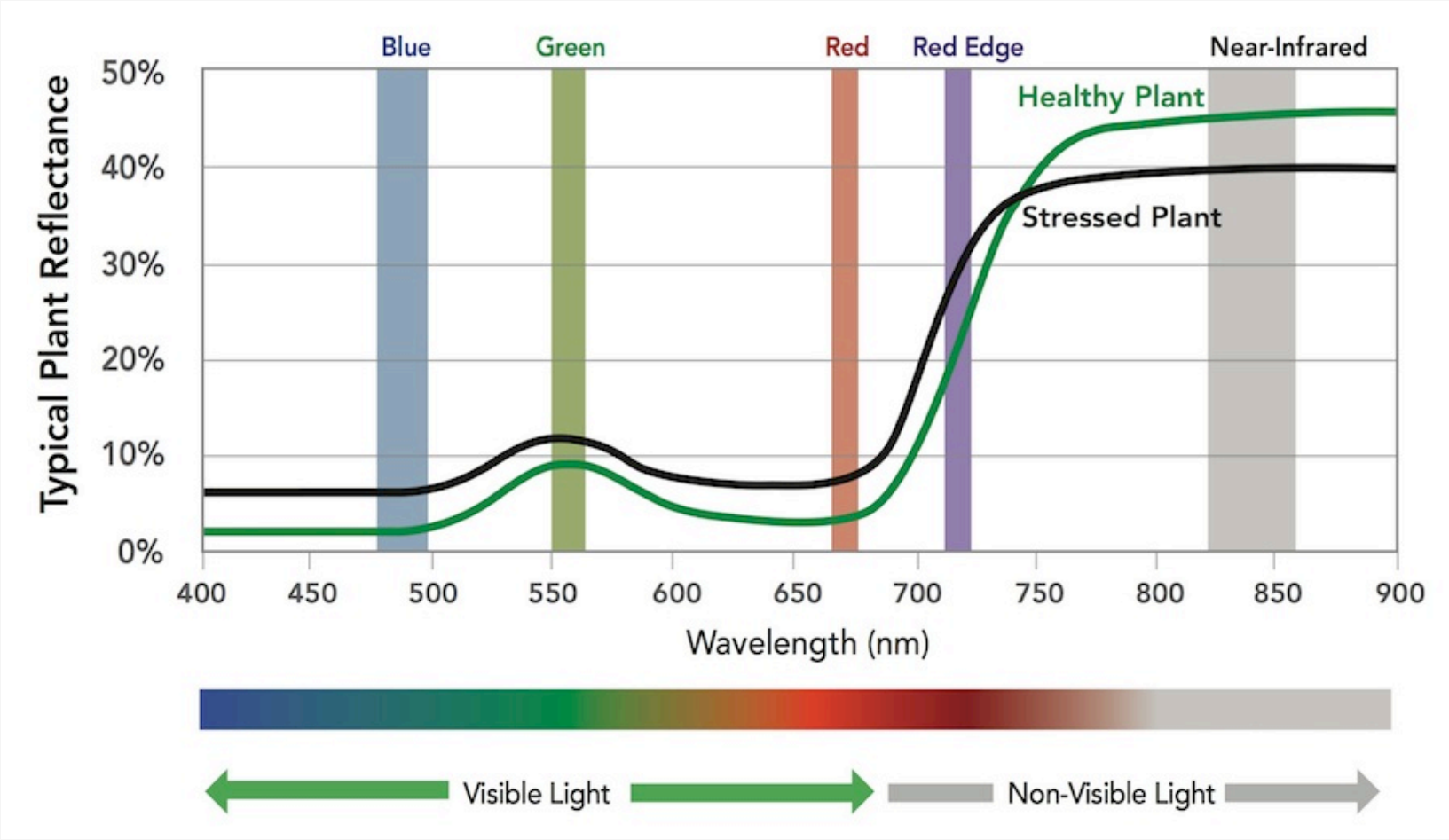
Stressed



Ref: @Basics of Crop Sensing, ANR-1398

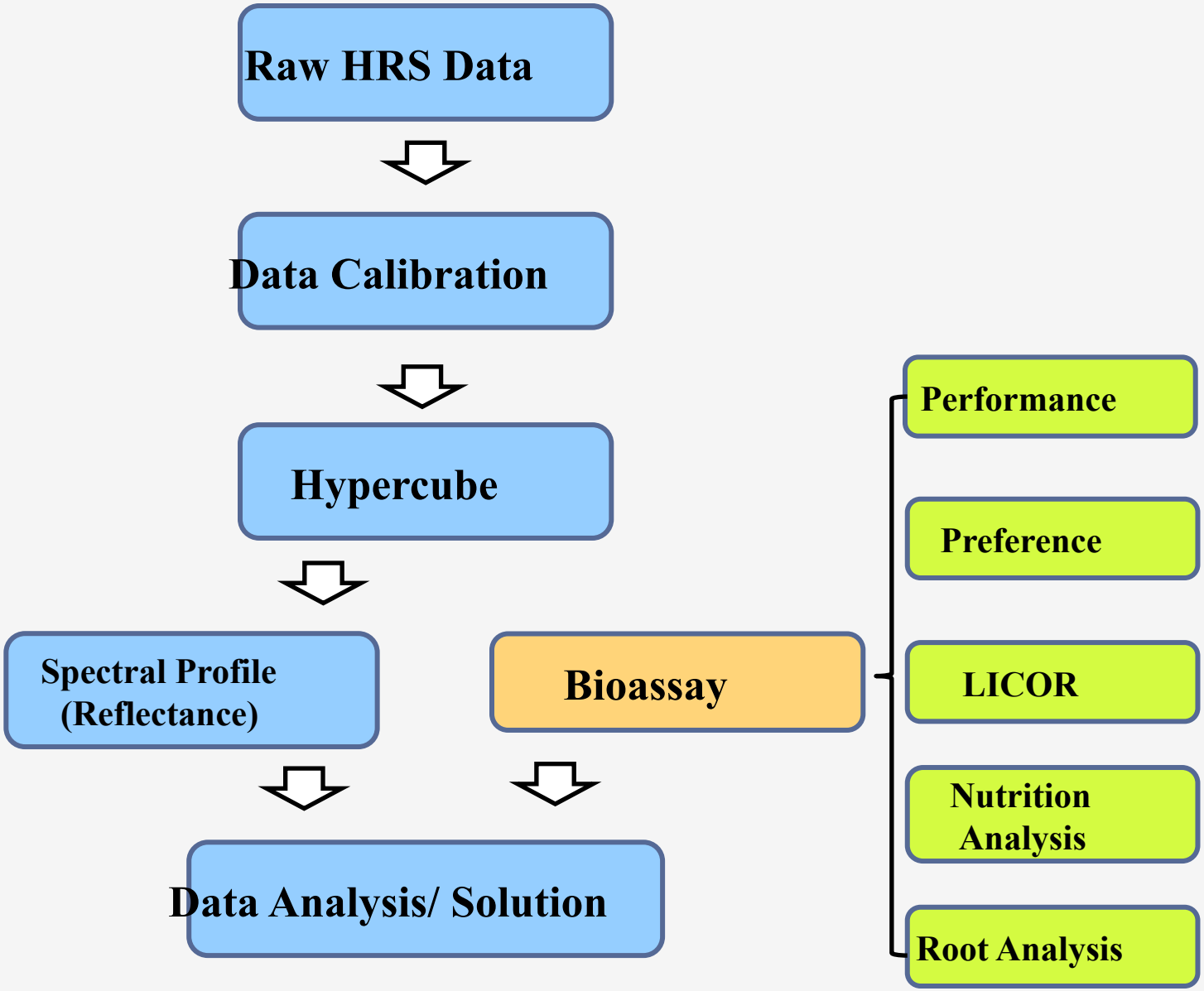
Reflectance profiling:

Healthy vs. Unhealthy/Stressed Plants (chlorophyll content or plant health)



Plants reflect **Green** light and absorb all other colors (**Blue**, **Red** etc.)

Processing and Analysis Steps:



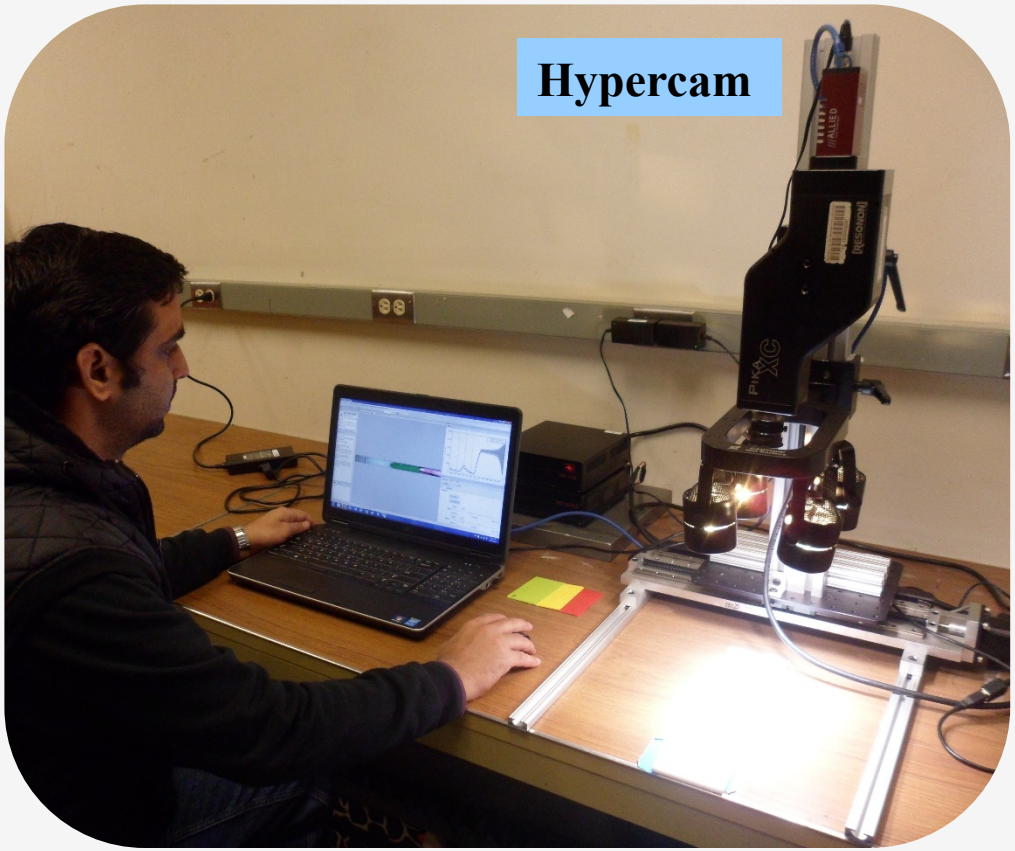
Benchtop Hyperspectral Camera:

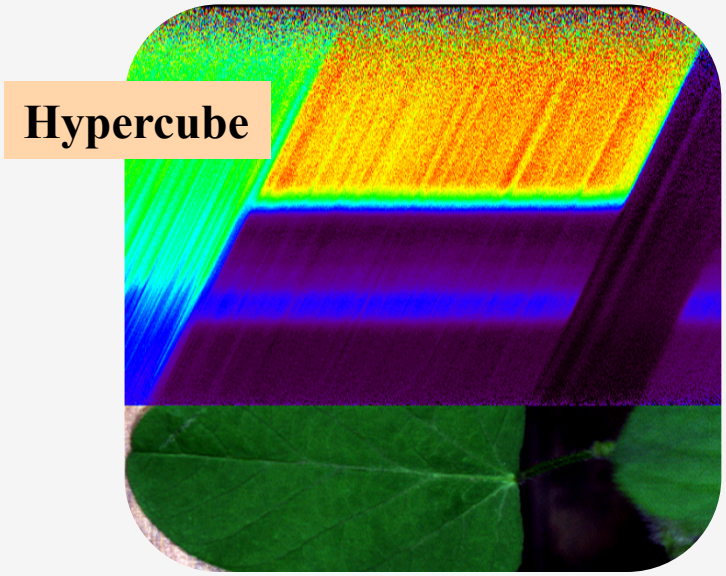
Sensor Type: Push-broom line scanning

Spectral bands: 240

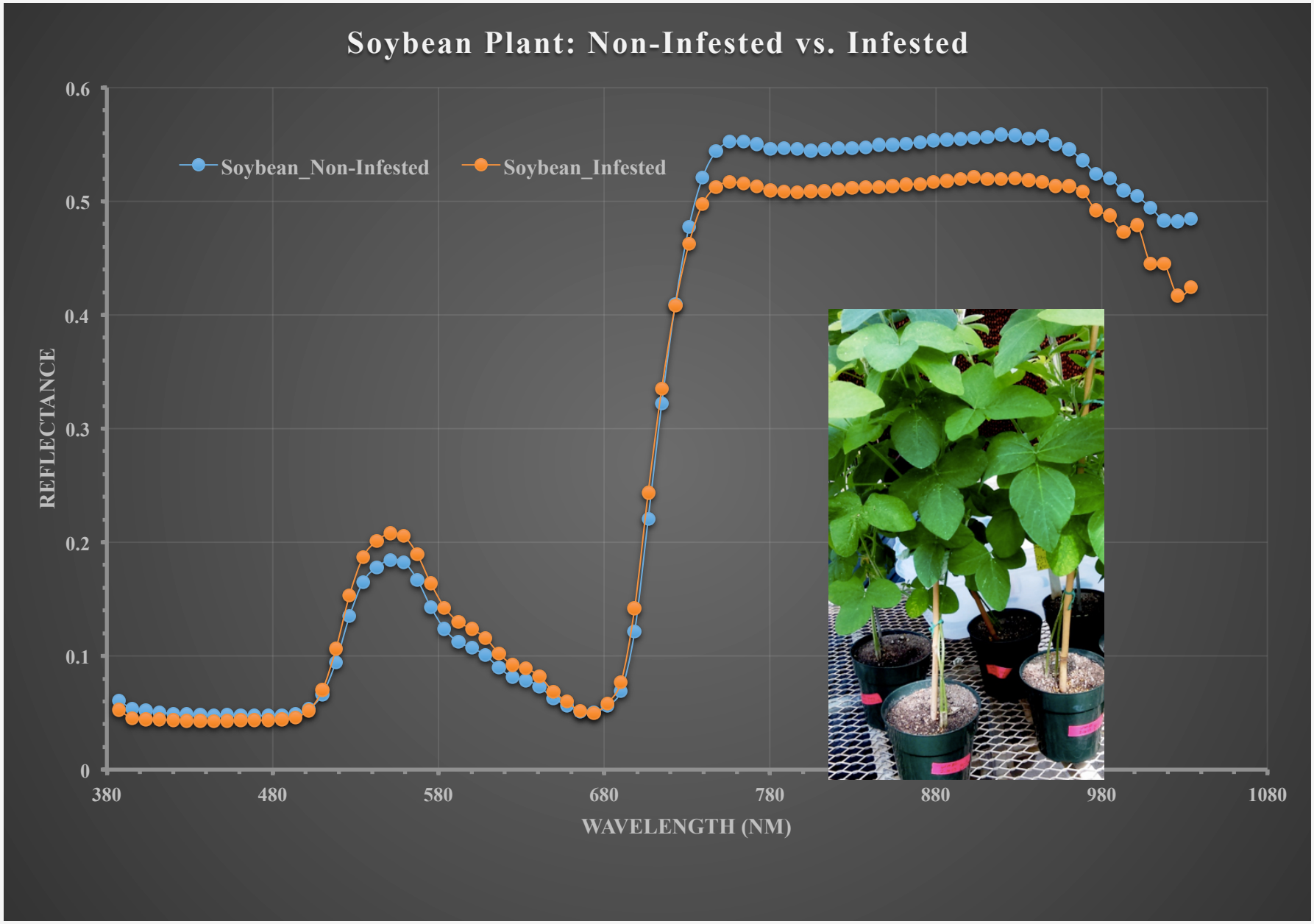
Range: 380-1035nm

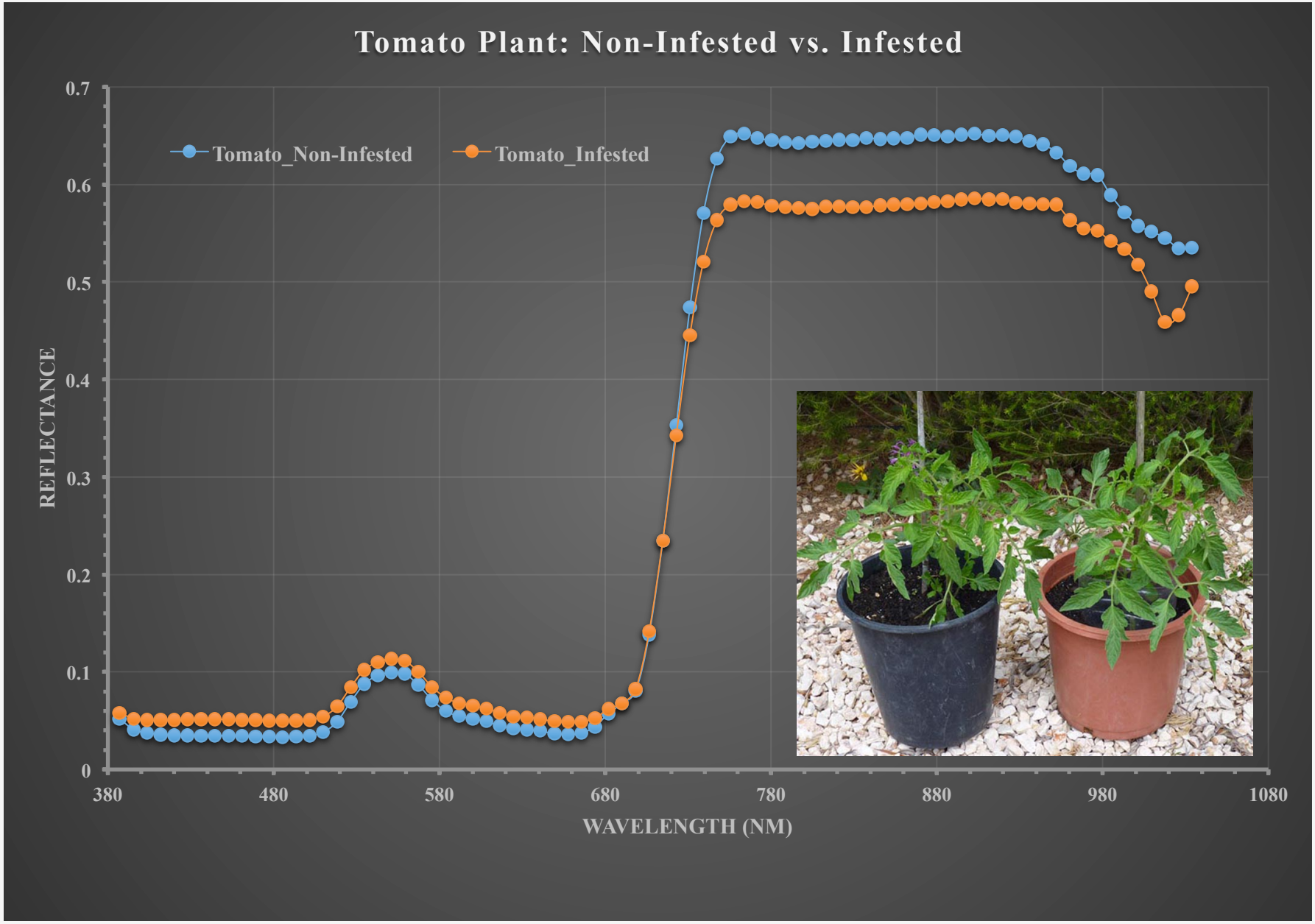
Spectral resolution: 2.75 nm





Ref: @Nansen Lab., UC Davis


Soybean Plant: Non-Infested vs. Infested
Soybean_Non-Infested
Soybean_Infested
REFLECTANCE
0.6
0.5
0.4
0.3
0.2
0.1
0
380
480
580
680
780
880
980
1080
WAVELENGTH (NM)


Tomato Plant: Non-Infested vs. Infested
Tomato_Non-Infested
Tomato_Infested
REFLECTANCE
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
380
480
580
680
780
880
980
1080
WAVELENGTH (NM)

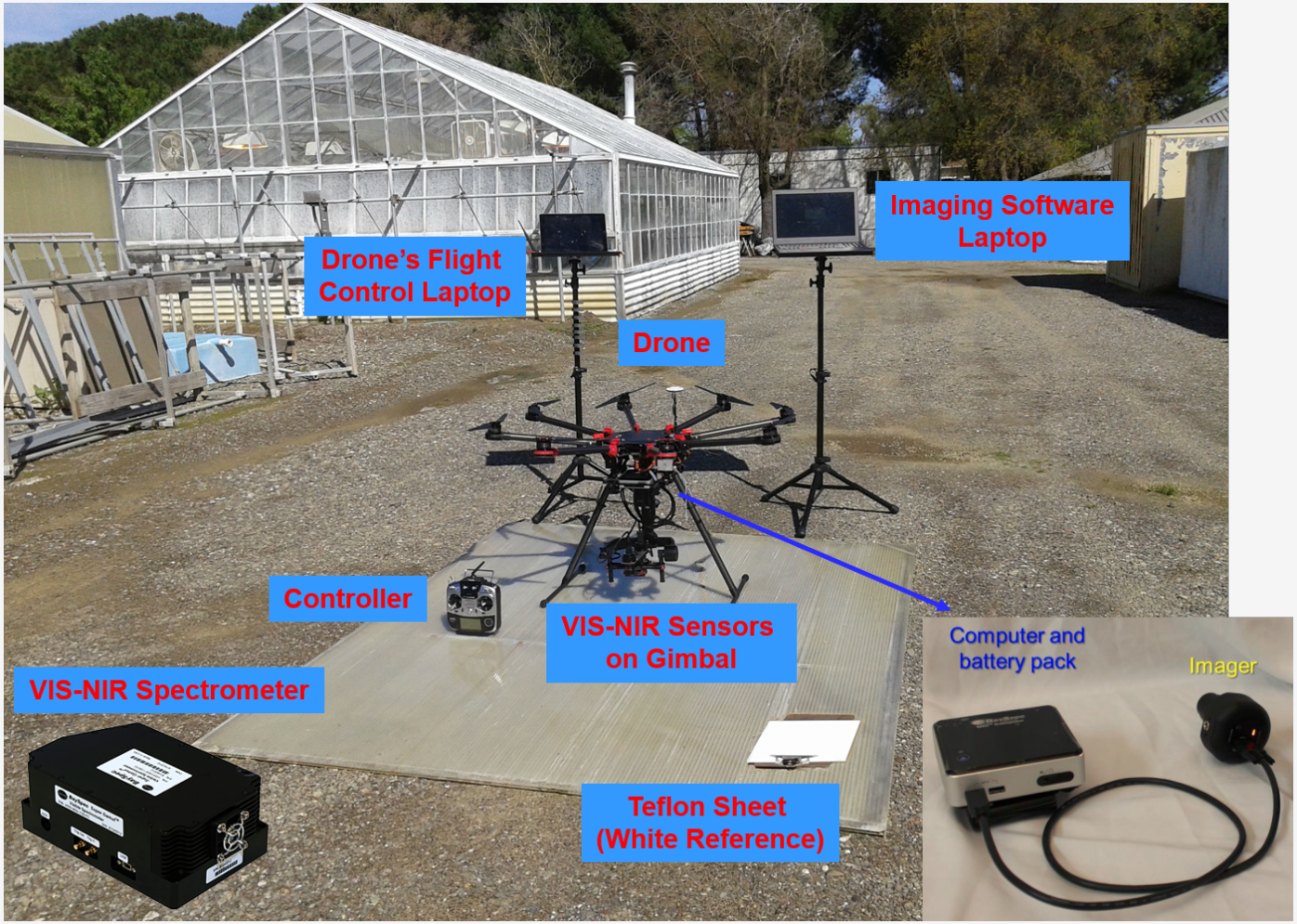
Unmanned Aircraft Systems (UAS) overview:

Drone/UAV: S1000 Premium Octocopter

Hyperspectral Imager: OCI-D1000 (Push-broom frame scanning)

Wavelength: 470-980nm

Spectral bands:116



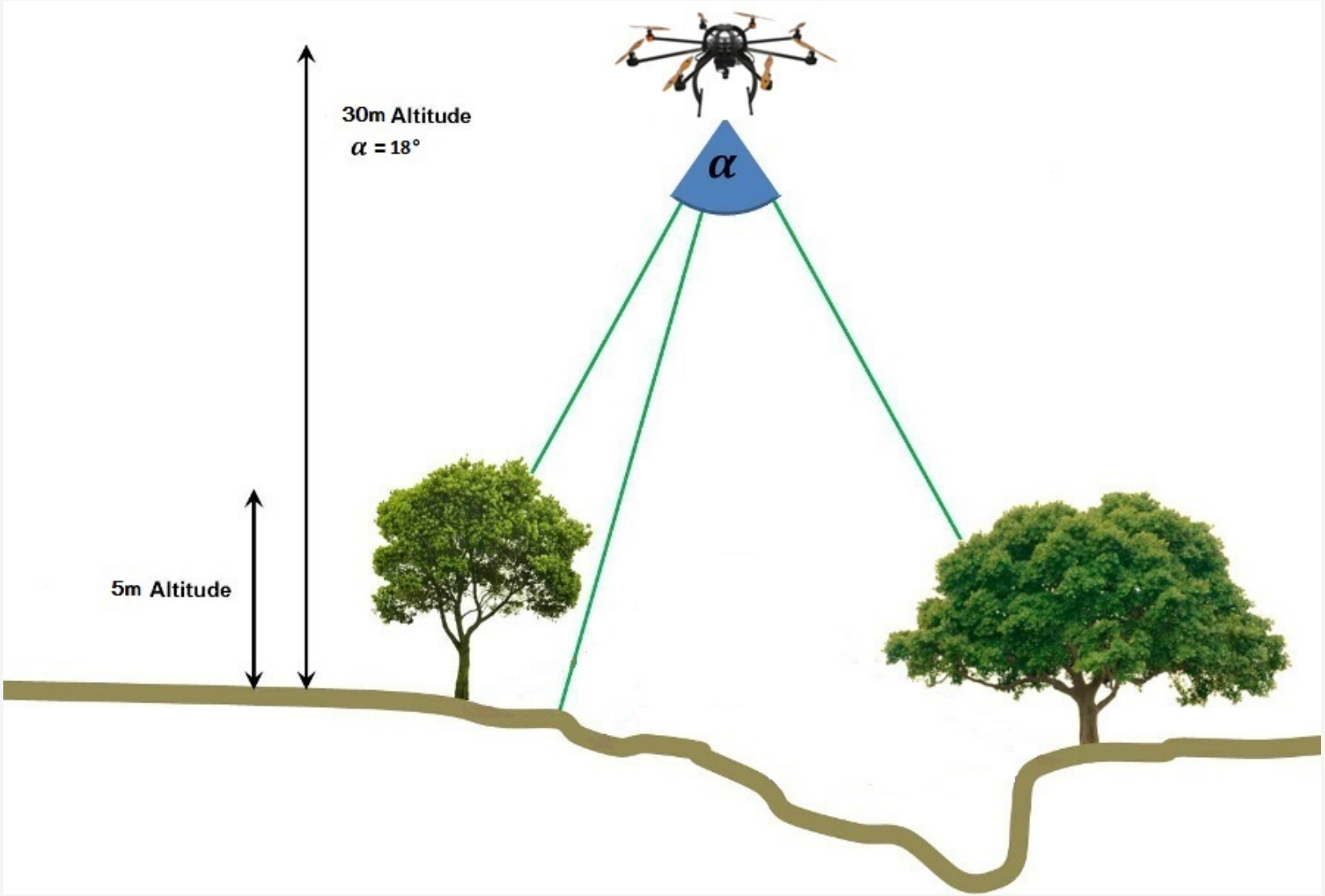
Almond Trees Field Study using UAS

Field Trip-1

Nichols Farm, CA

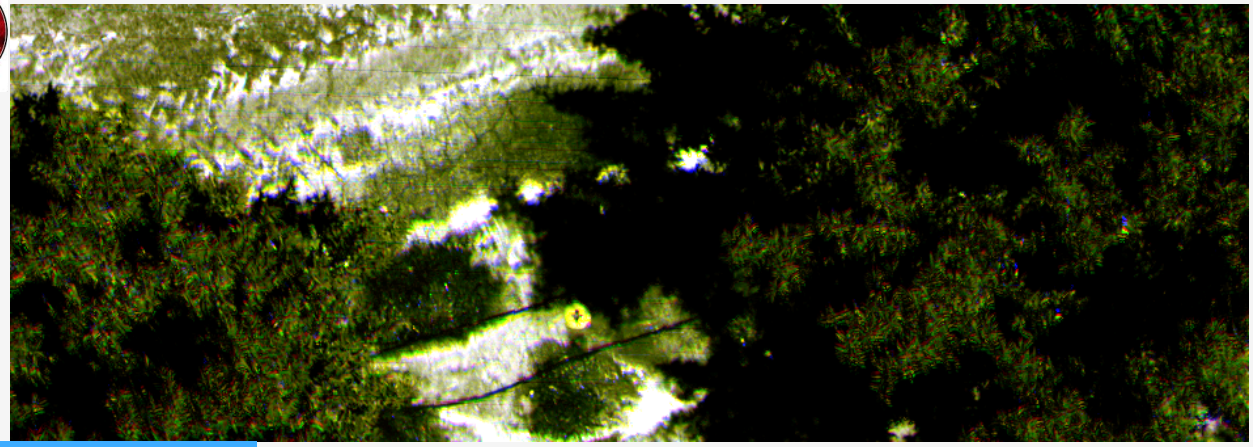
UAV Images Affect:

- Multiple scattering ground reflectance
- Atmospheric conditions



Field Flight with UAV:

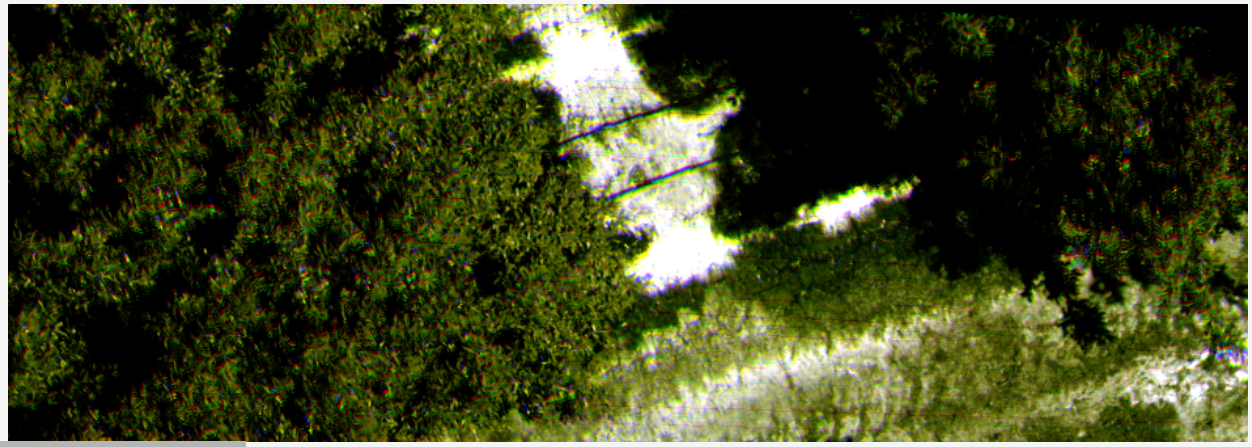
- Healthy spots
- Potential disease hotspots



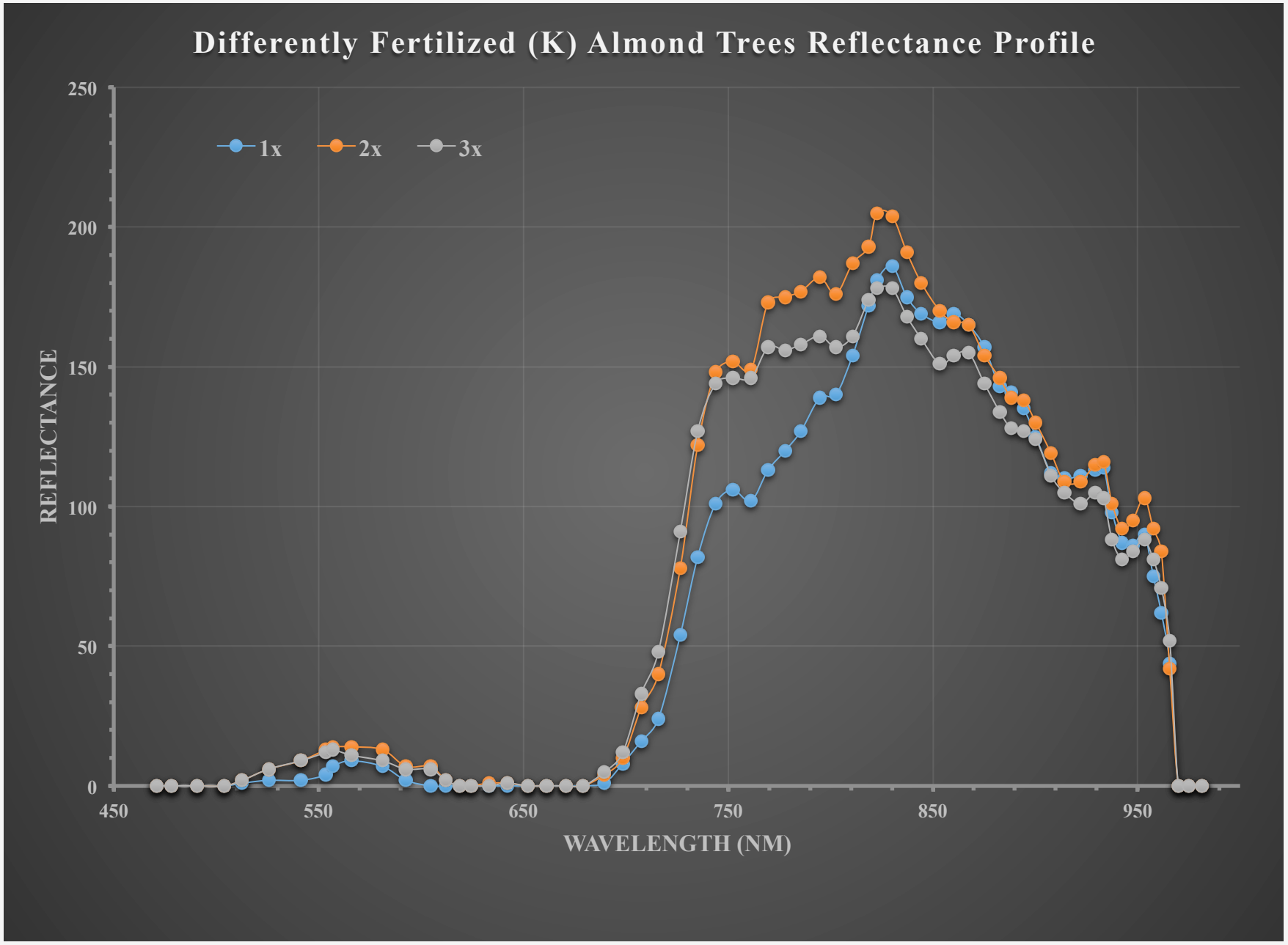
Hyperspectral images of Almond trees subjected to different levels of "K" fertilization

1x- Treatment

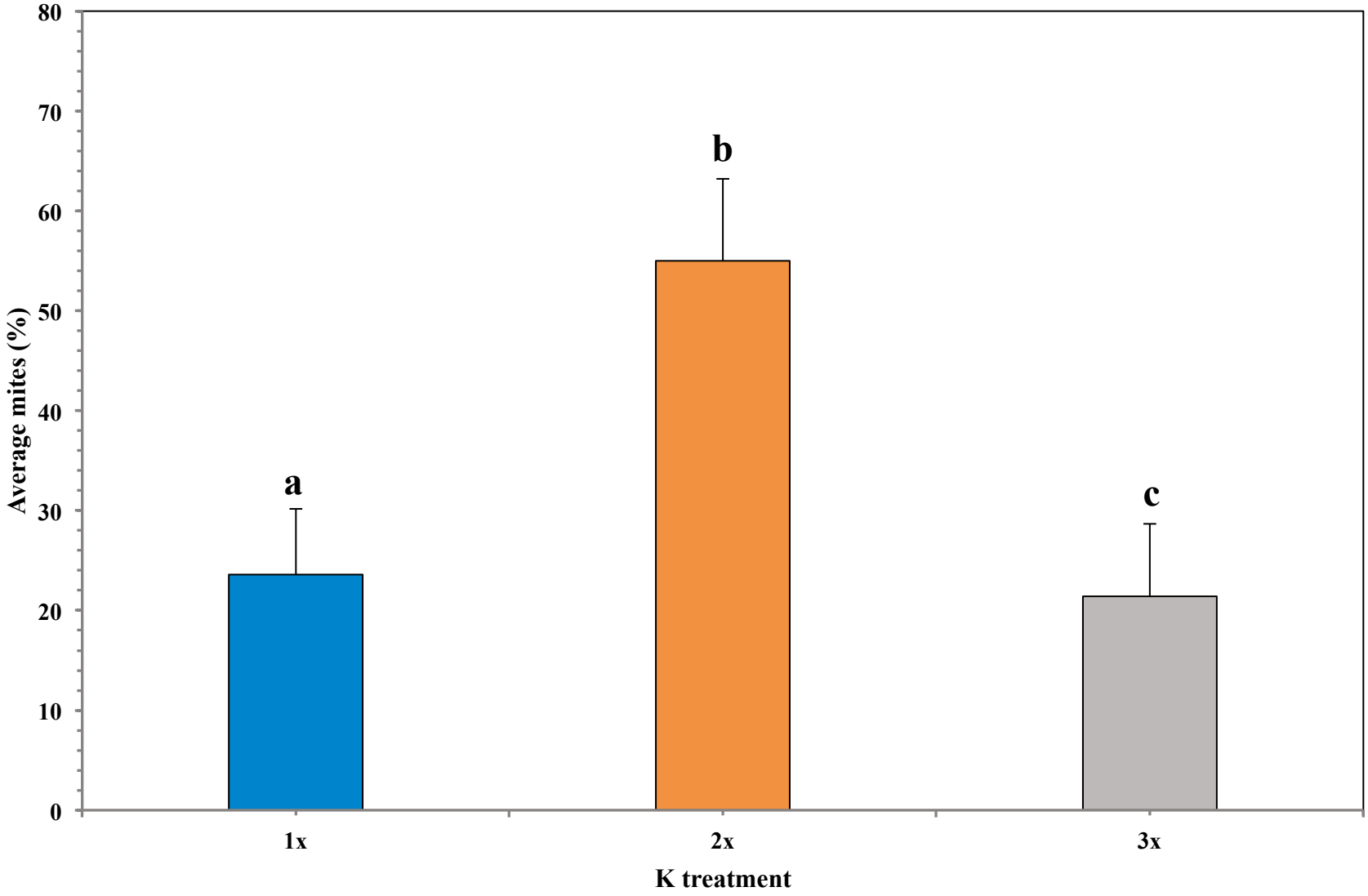
2x- Treatment



3x- Treatment

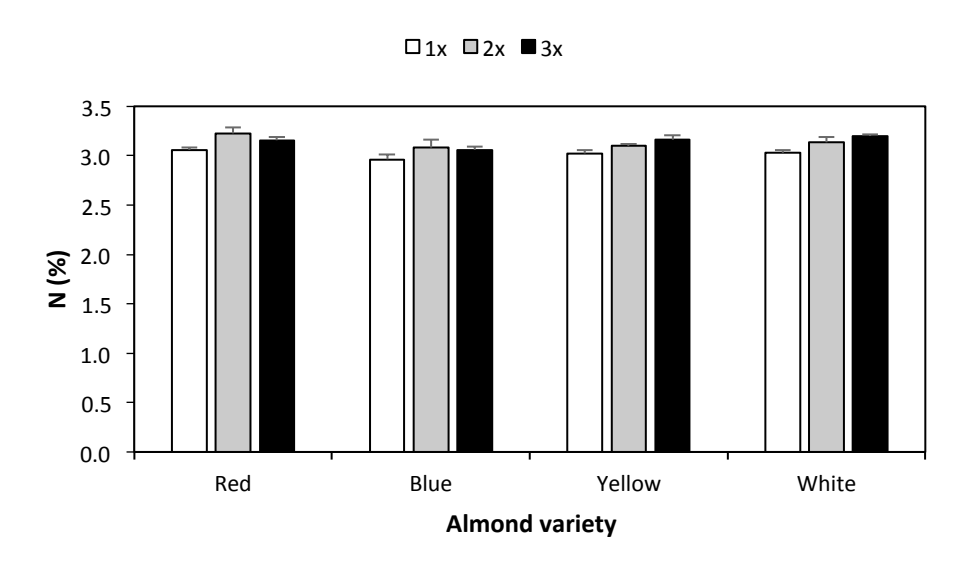

Differently Fertilized (K) Almond Trees Reflectance Profile
1x
2x
3x
250
200
150
100
50
0
REFLECTANCE
450
550
650
750
850
950
WAVELENGTH (NM)

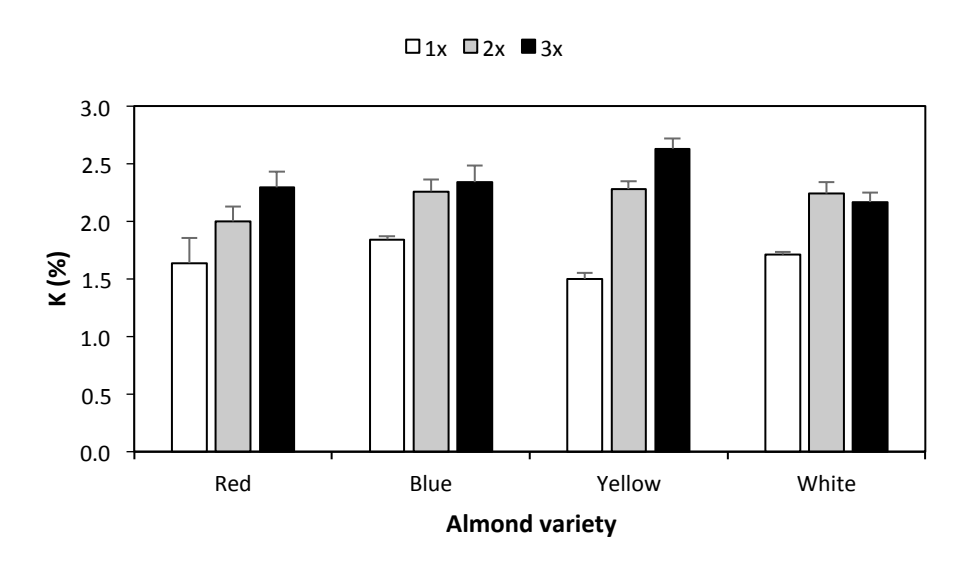
Mite three-choice bioassay: b>a≈c



Ref: @Nansen Lab., UC Davis

Macro-elements Analysis:



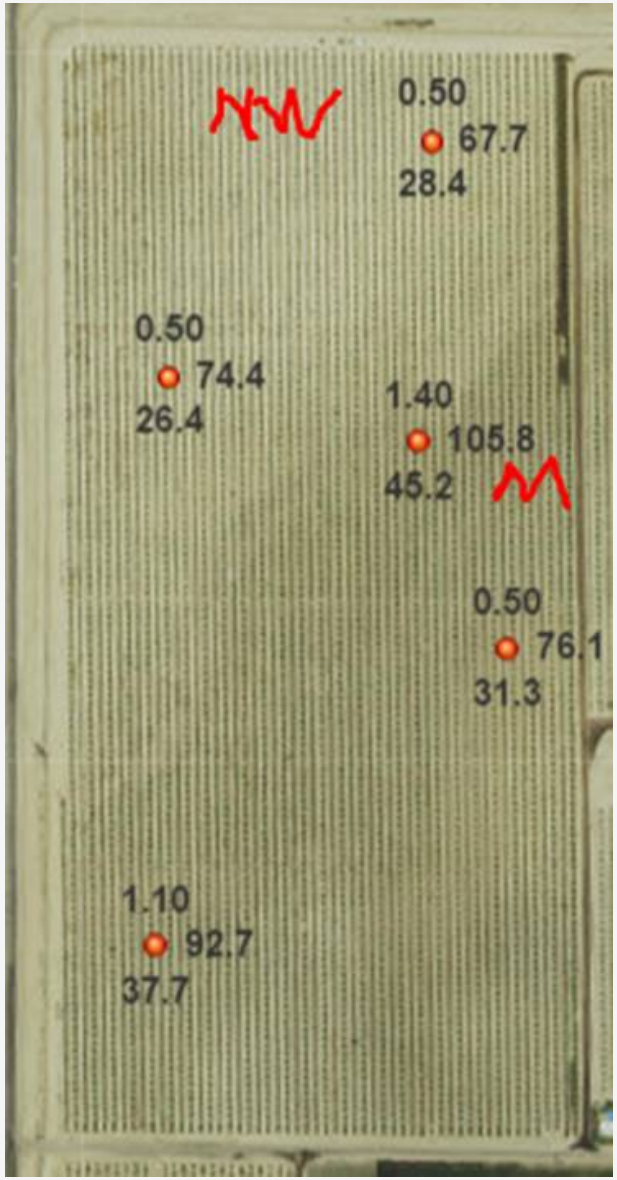


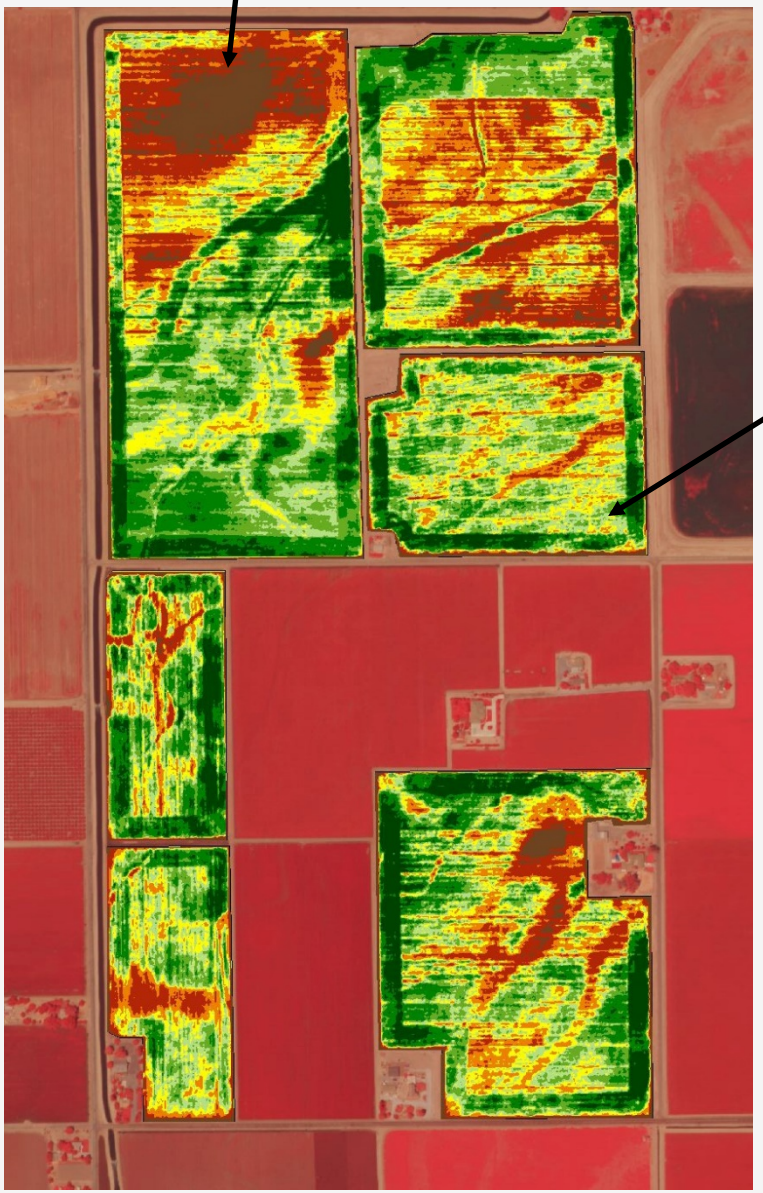
Ref: @Nansen Lab., UC Davis

Field Trip-2

Nichols Farm, CA

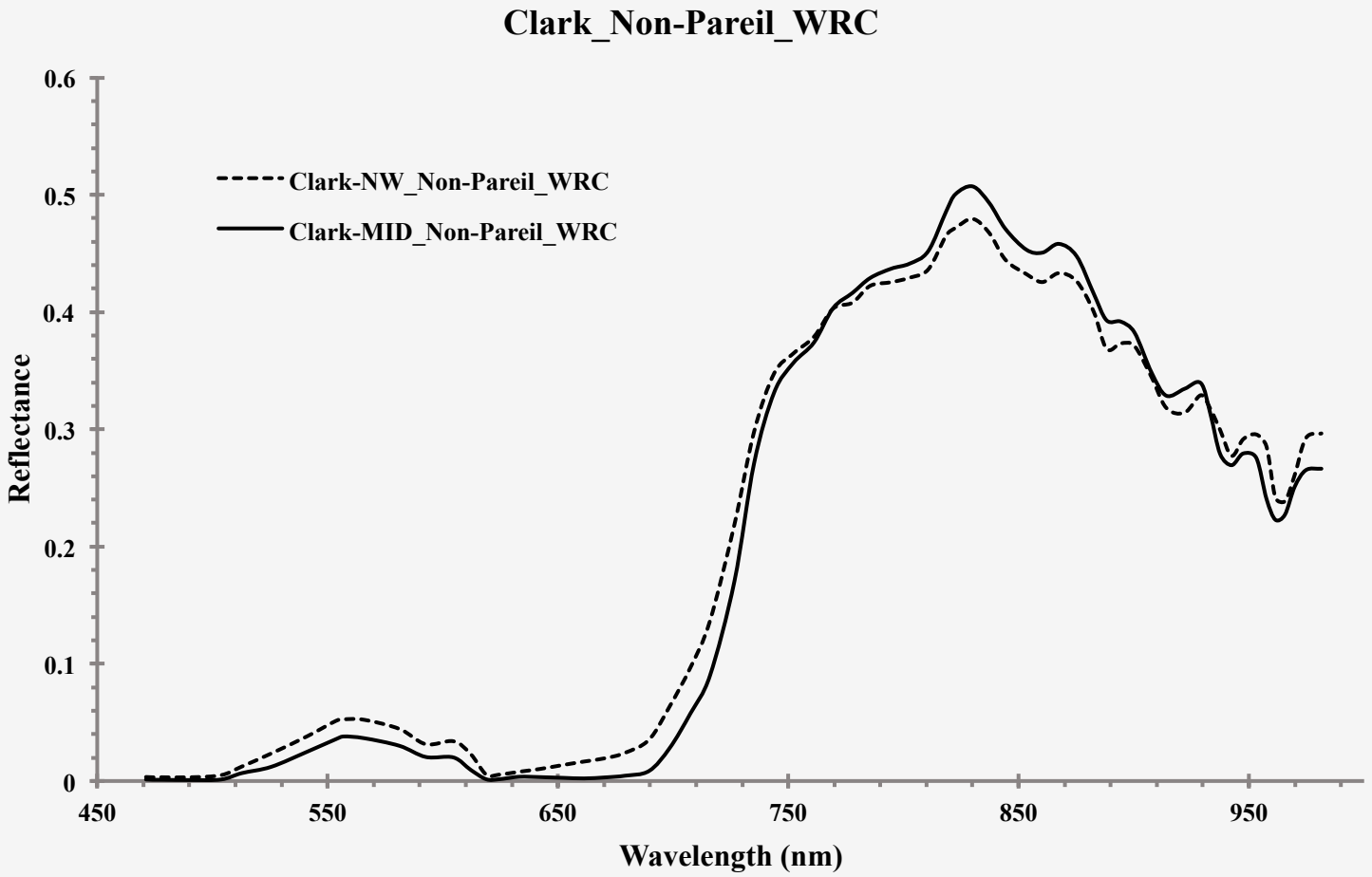
Field Infrared Data:



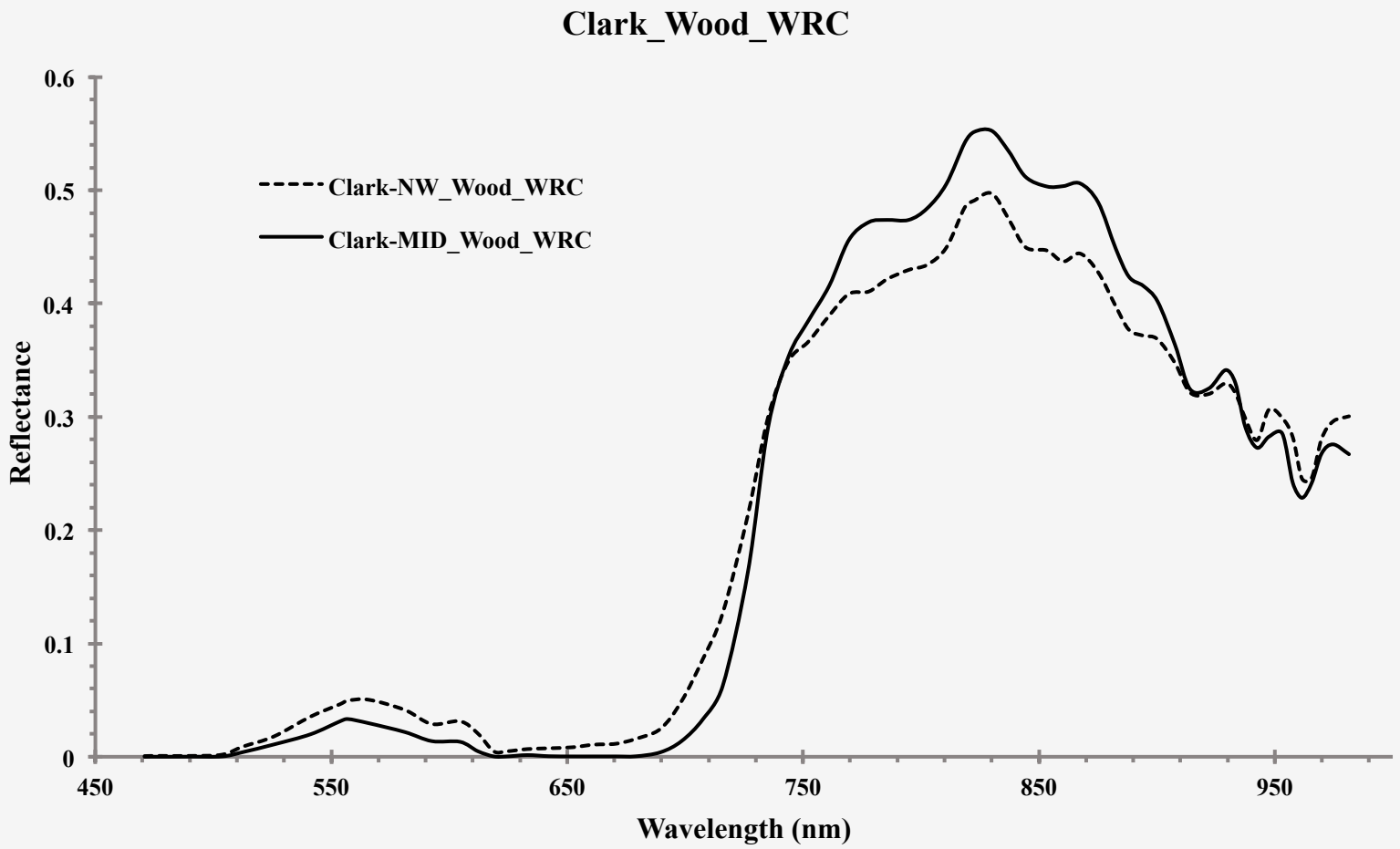


Courtesy: Nichols Farm, CA

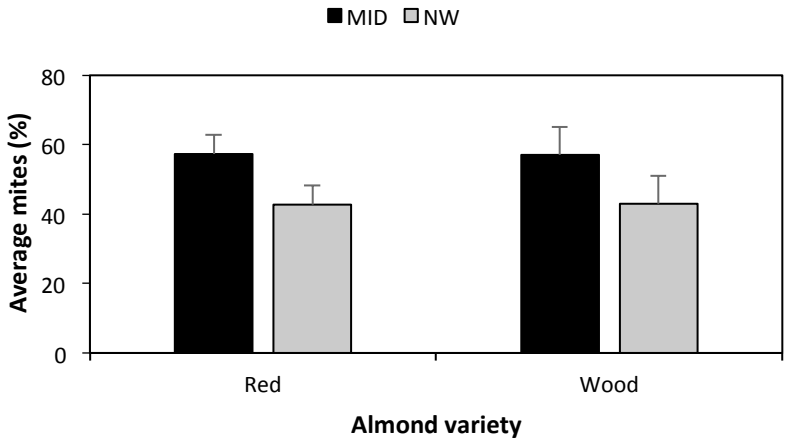
Reflectance variation in Non-Pareil/ Red (Clark-NW vs. Clark-MID):

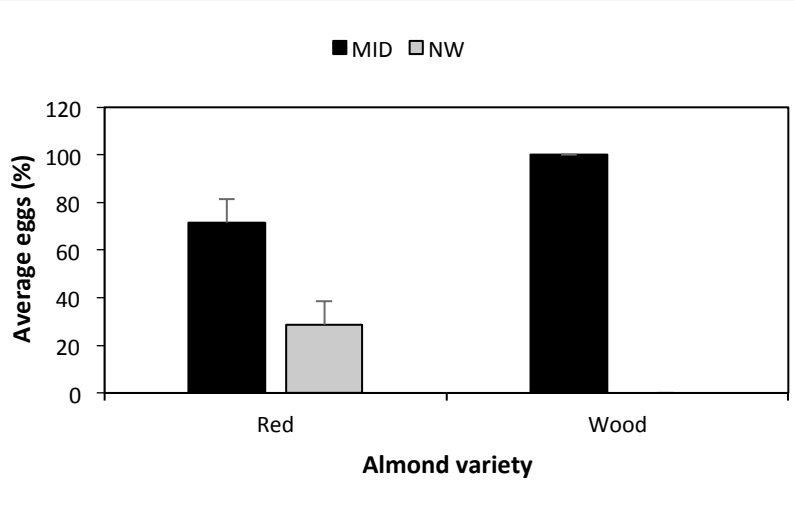


Reflectance variation in Wood (Clark-NW and Clark-MID):

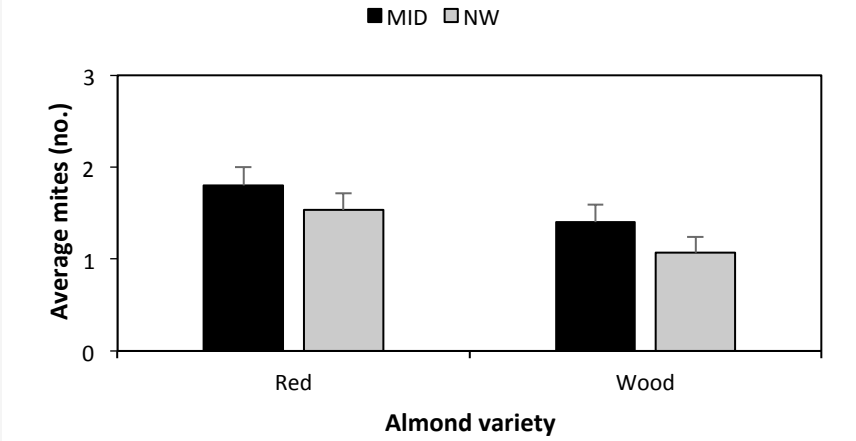


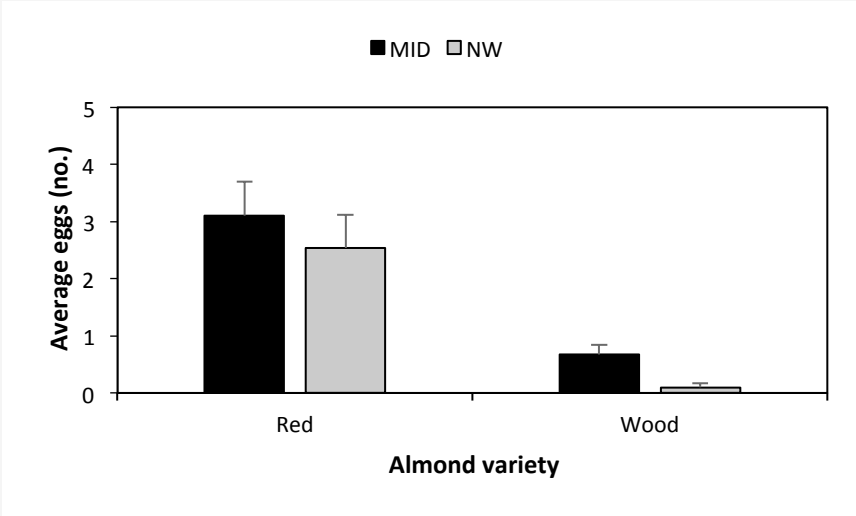
Mite two-choice bioassays:





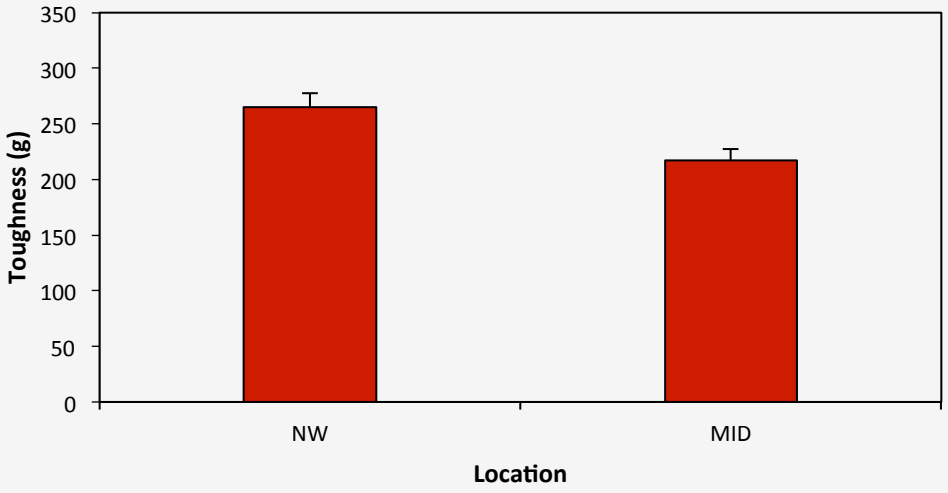
Mite performance bioassay:



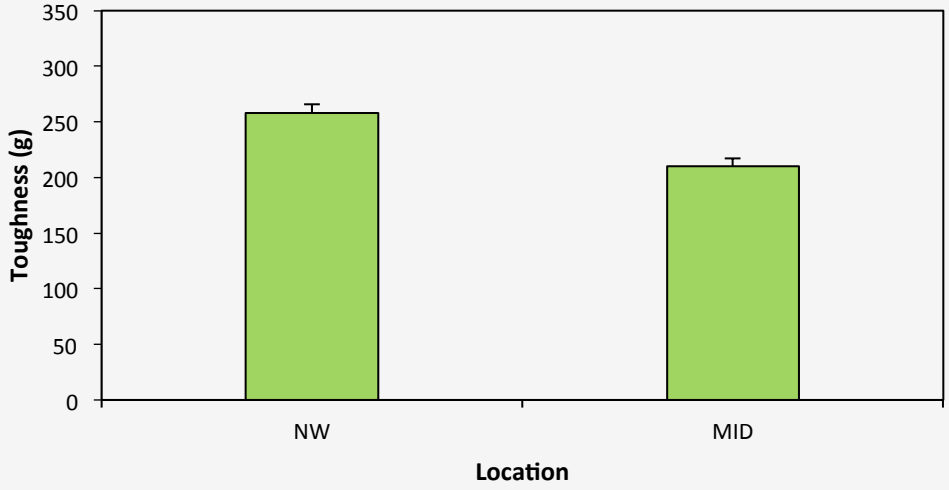


Ref: @Nansen Lab., UC Davis

Leaf toughness Non-Pareil

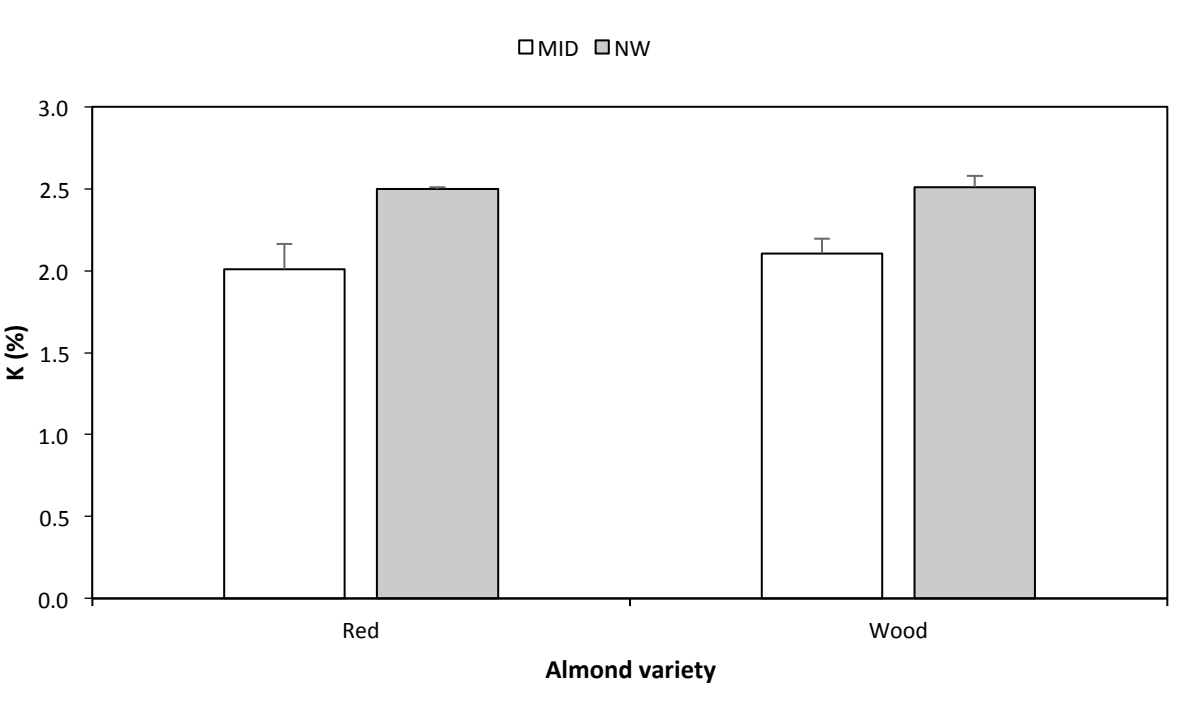


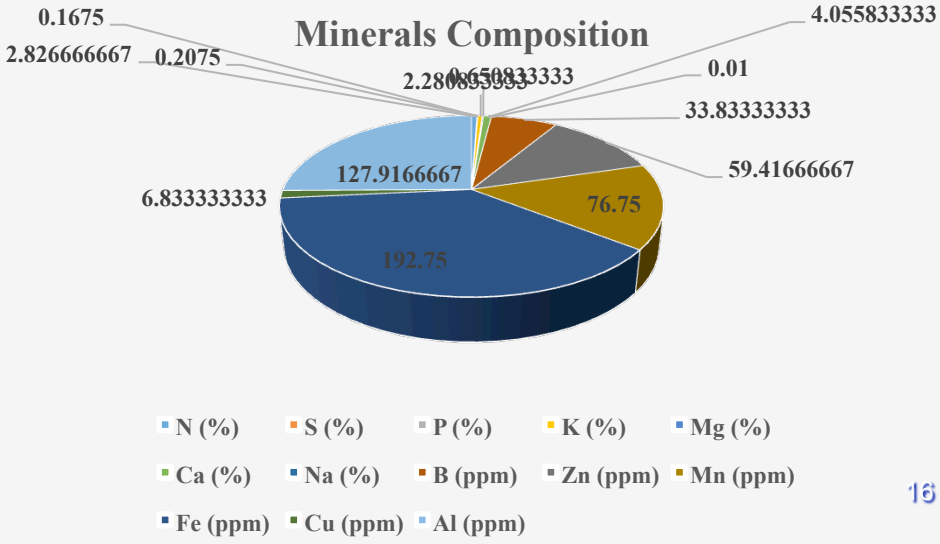
Leaf toughness Wood Colony



Ref: @Nansen Lab., UC Davis

Macro-elements Analysis:



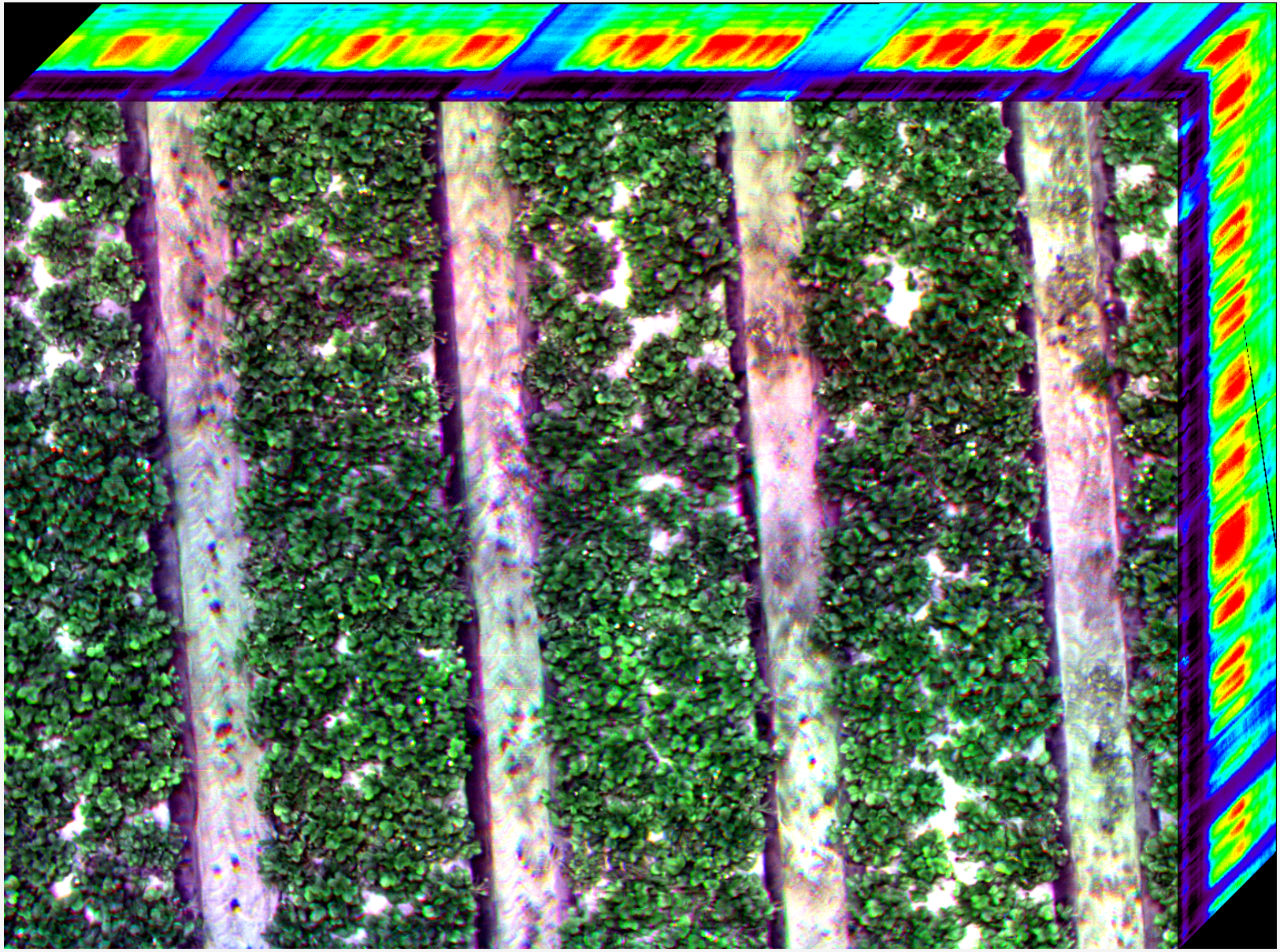


Ref: @Nansen Lab., UC Davis

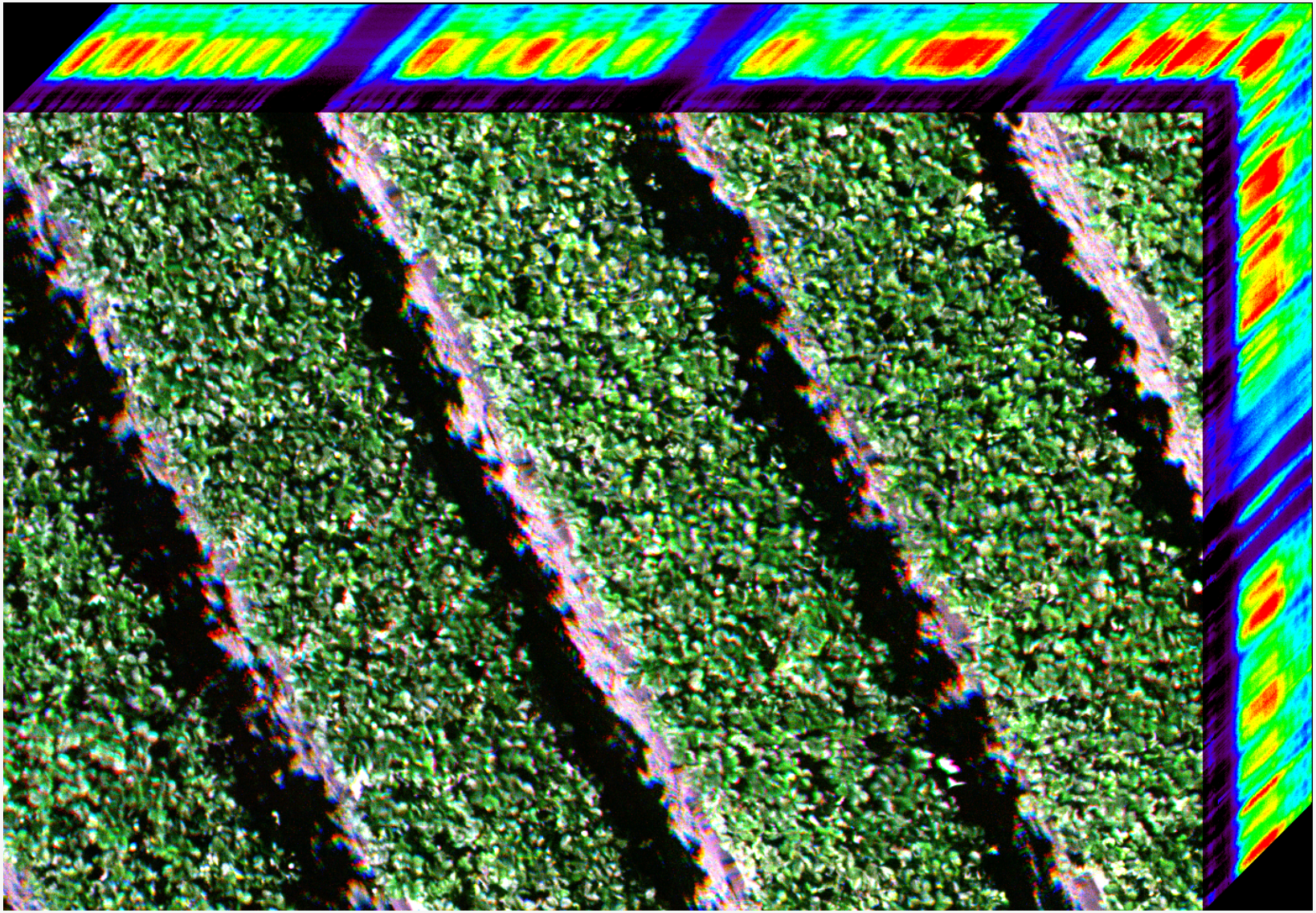
Strawberry Field Trip-1

Santa Maria, CA

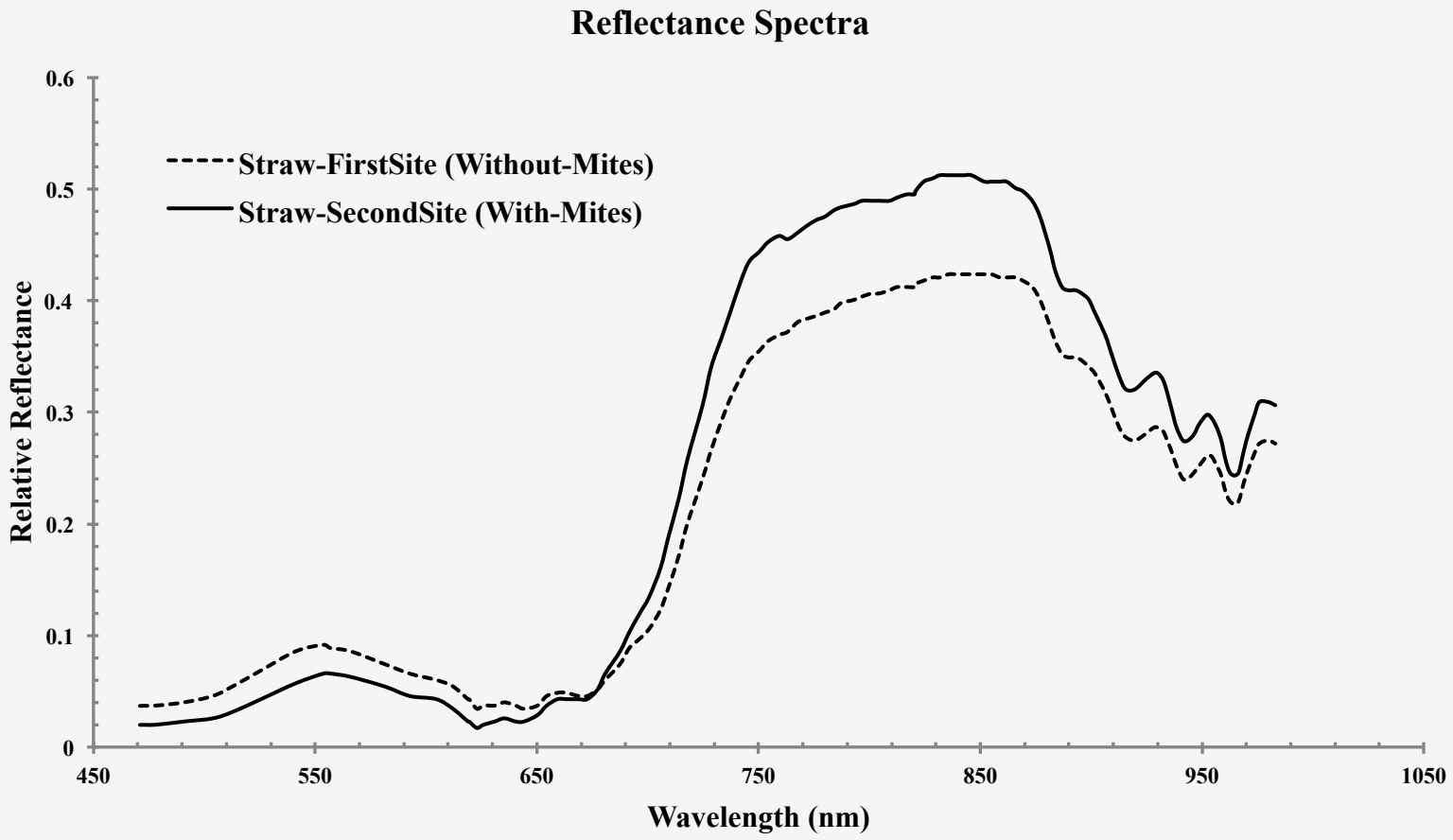
Strawberry hypercube (without-mites):



Strawberry hypercube (with-mites):

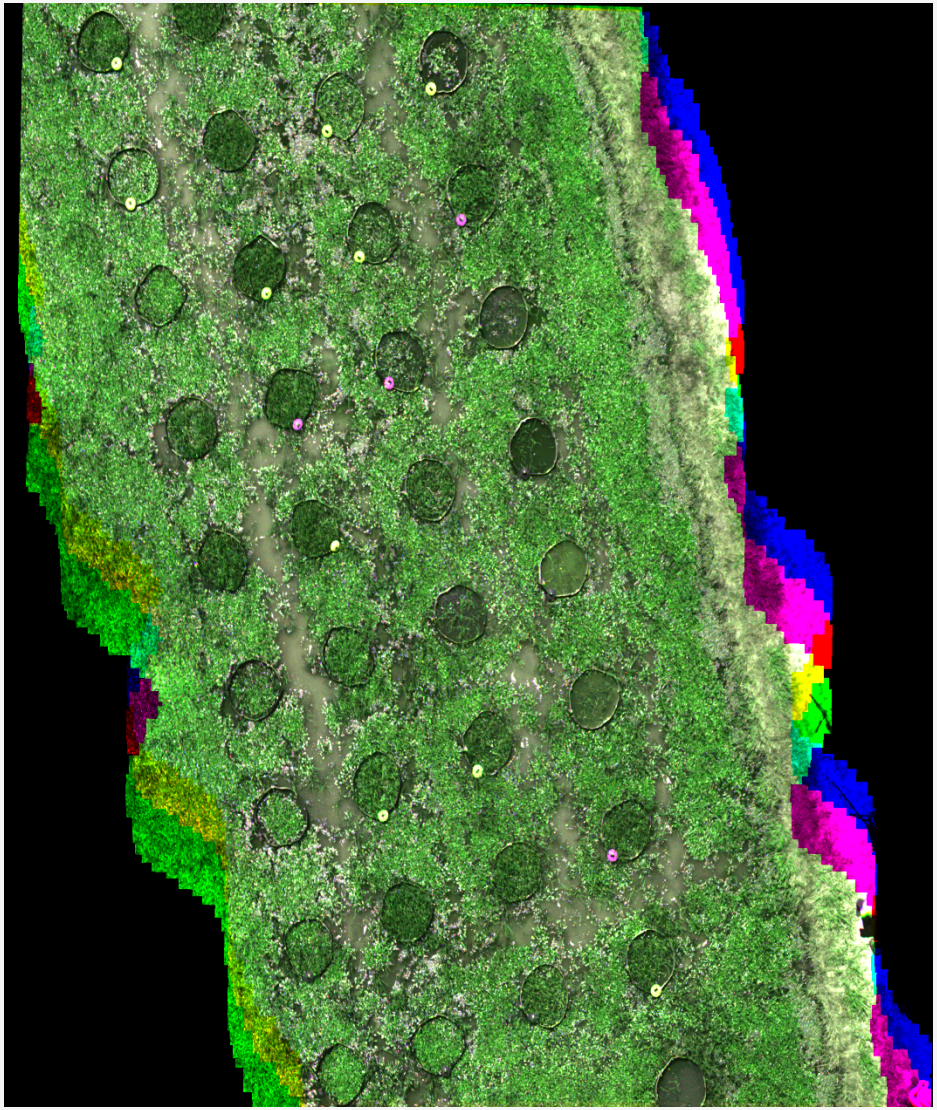


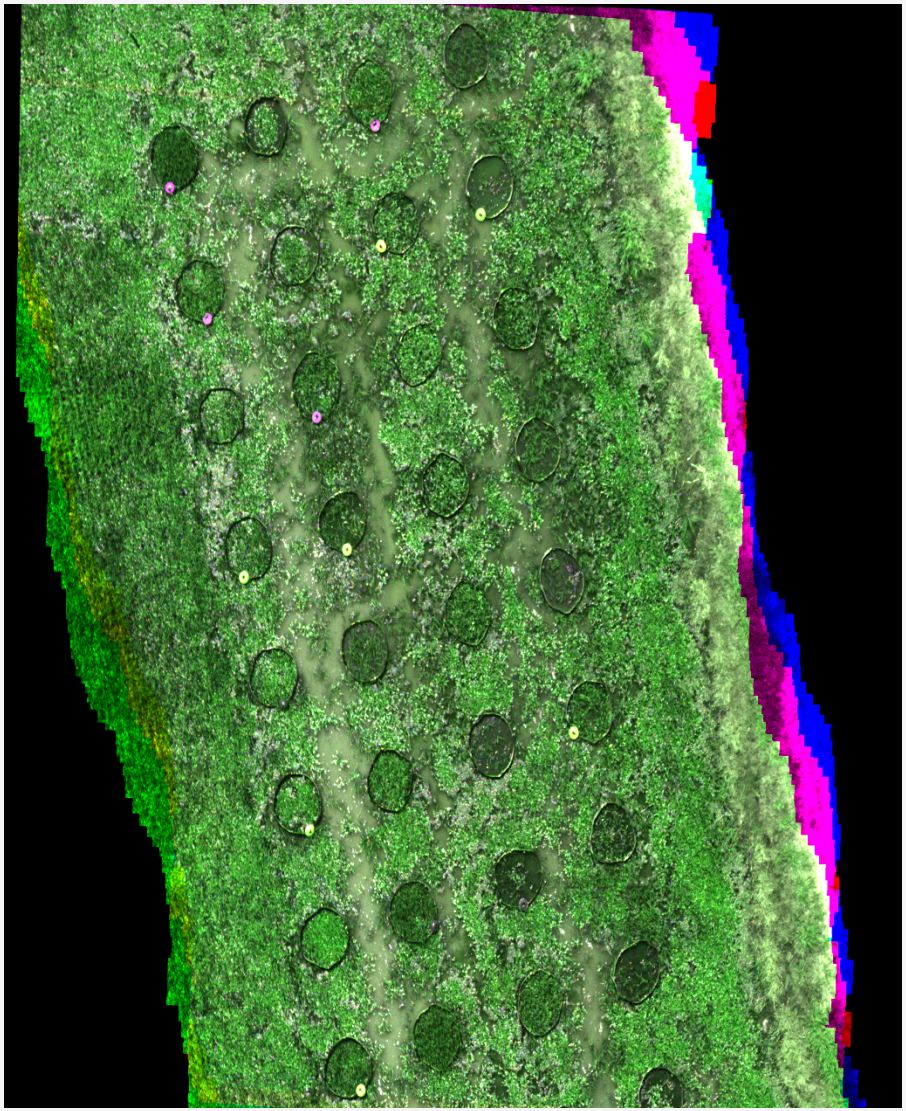
Reflectance variation in Strawberry Field:



Rice field treatment plots: Rice varieties (M-202 & M-206)

Four Weevils' Density treatment (Control, Low, Medium, High)



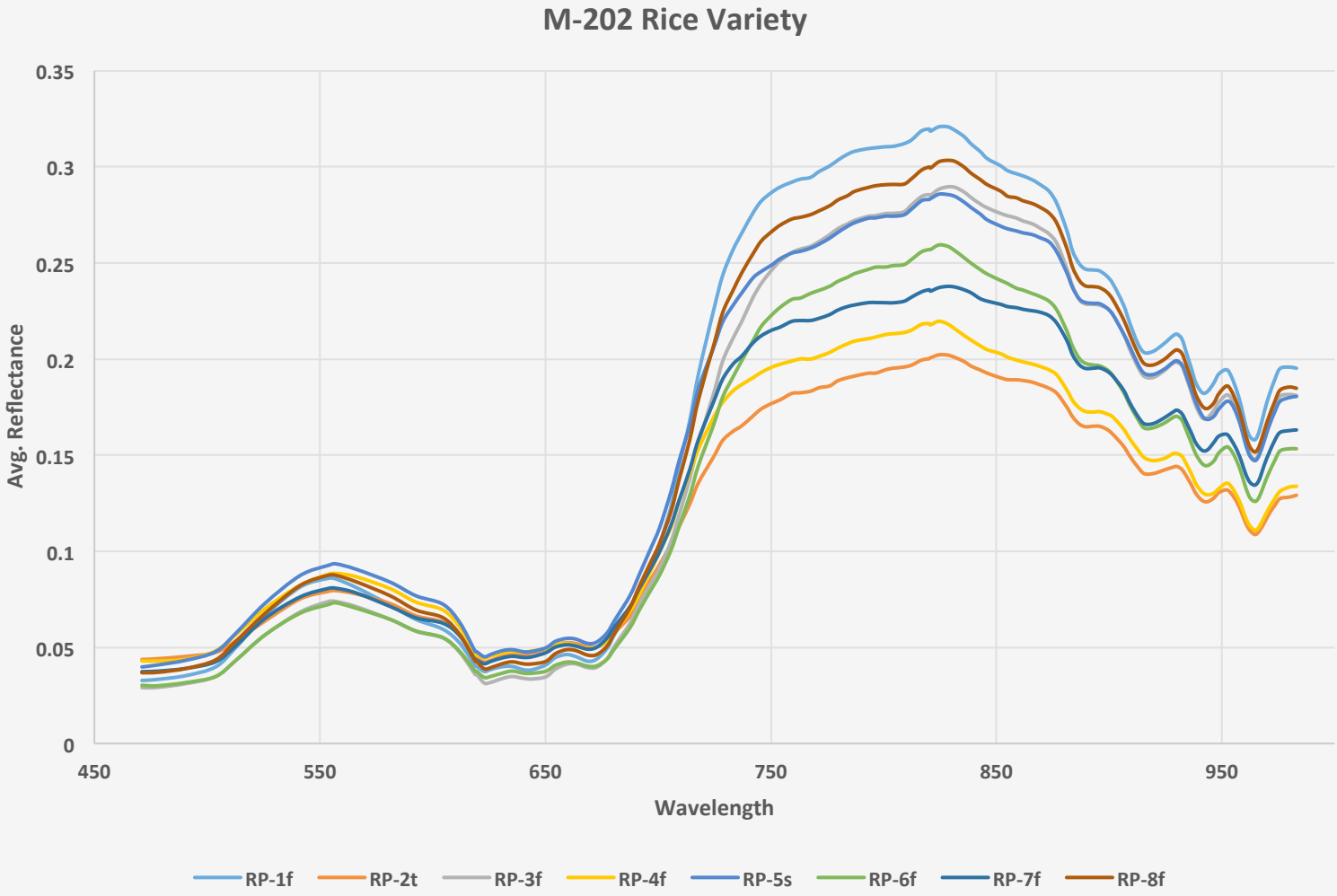


First 8 rows

Last 8 rows

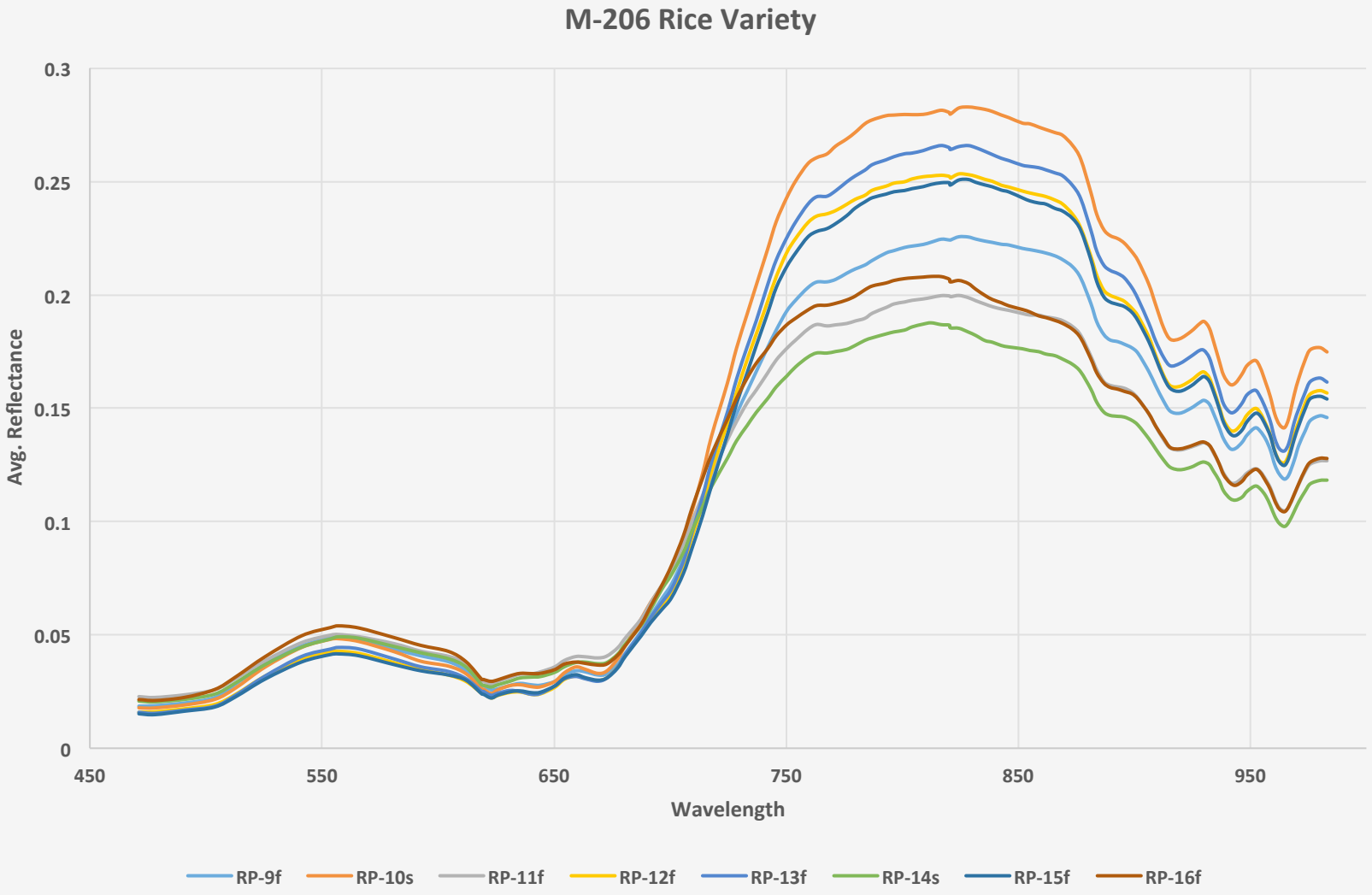
Yuba City, CA

Reflectance variation w.r.t. weevils' density within M-202 rice variety:



The two factors analysis of variance (ANOVA) with replication (two) was used to evaluate whether significant differences exist between treatments

Reflectance variation w.r.t. weevils' density within M-206 rice variety:

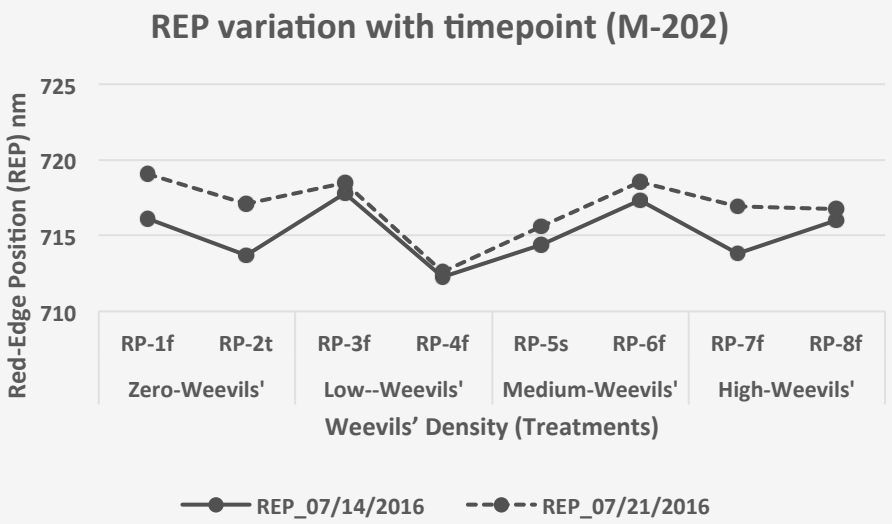


The Reflectance differences are due to variation in weevils' density over each treatment.

Red-Edge Positions (REPs) of M-202 rice variety :

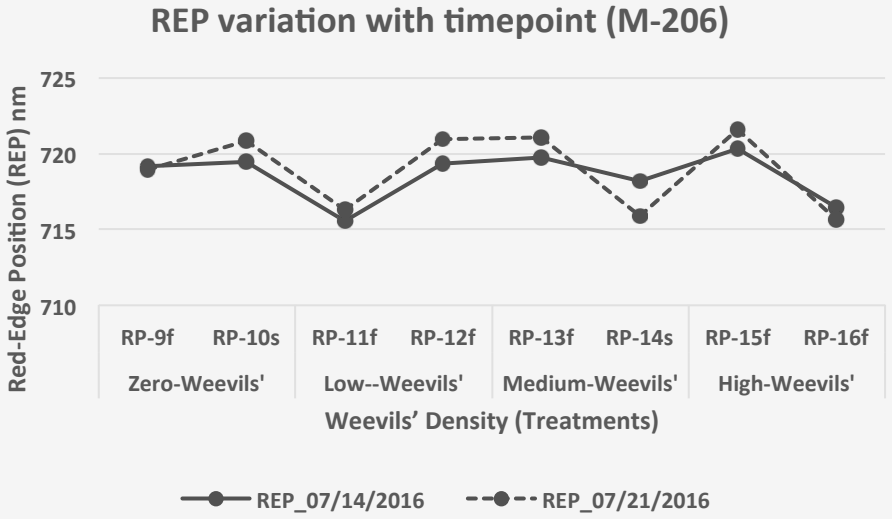
REP = [700 + 40(RRE − R700)/(R740 − R700)] nm;

where, **RRE** = (R670 + R780)/2



Red-Edge Positions (REPs) of M-206 rice variety :

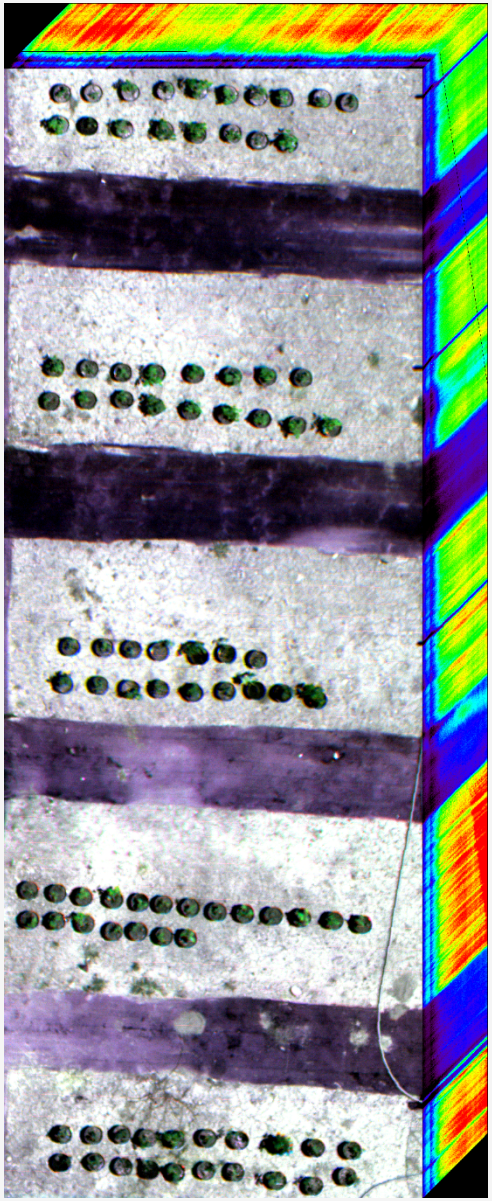
Changes in leaf chlorophyll content cause shifts in the REP to shorter and longer wavelengths for low and high chlorophyll contents, respectively.



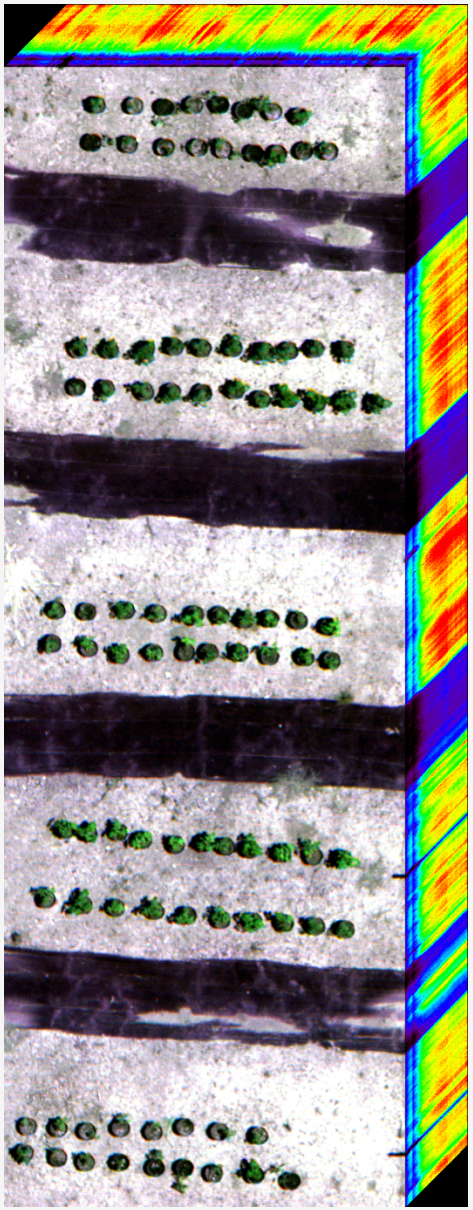
Tomato Plants: Orchard Park, UC Davis, CA

10 different treatments with sterile/non-sterile soil types:

- **Sterilized** (Orange, Blue, Green, Brown, Red)
- **Non-sterilized** (Red/gray, Brown/gray, Green/gray, Orange/gray, Blue/gray)

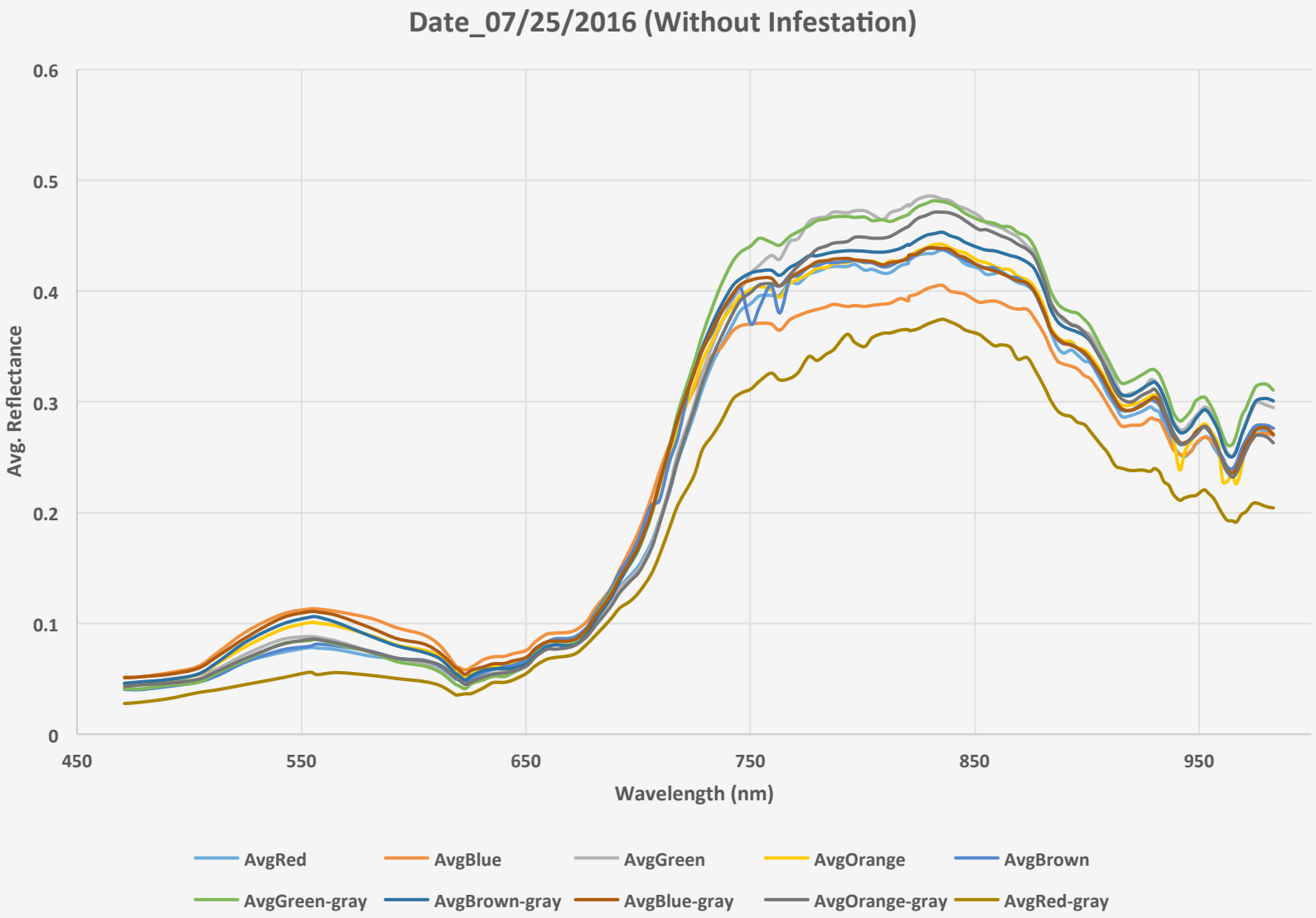


First 5 rows

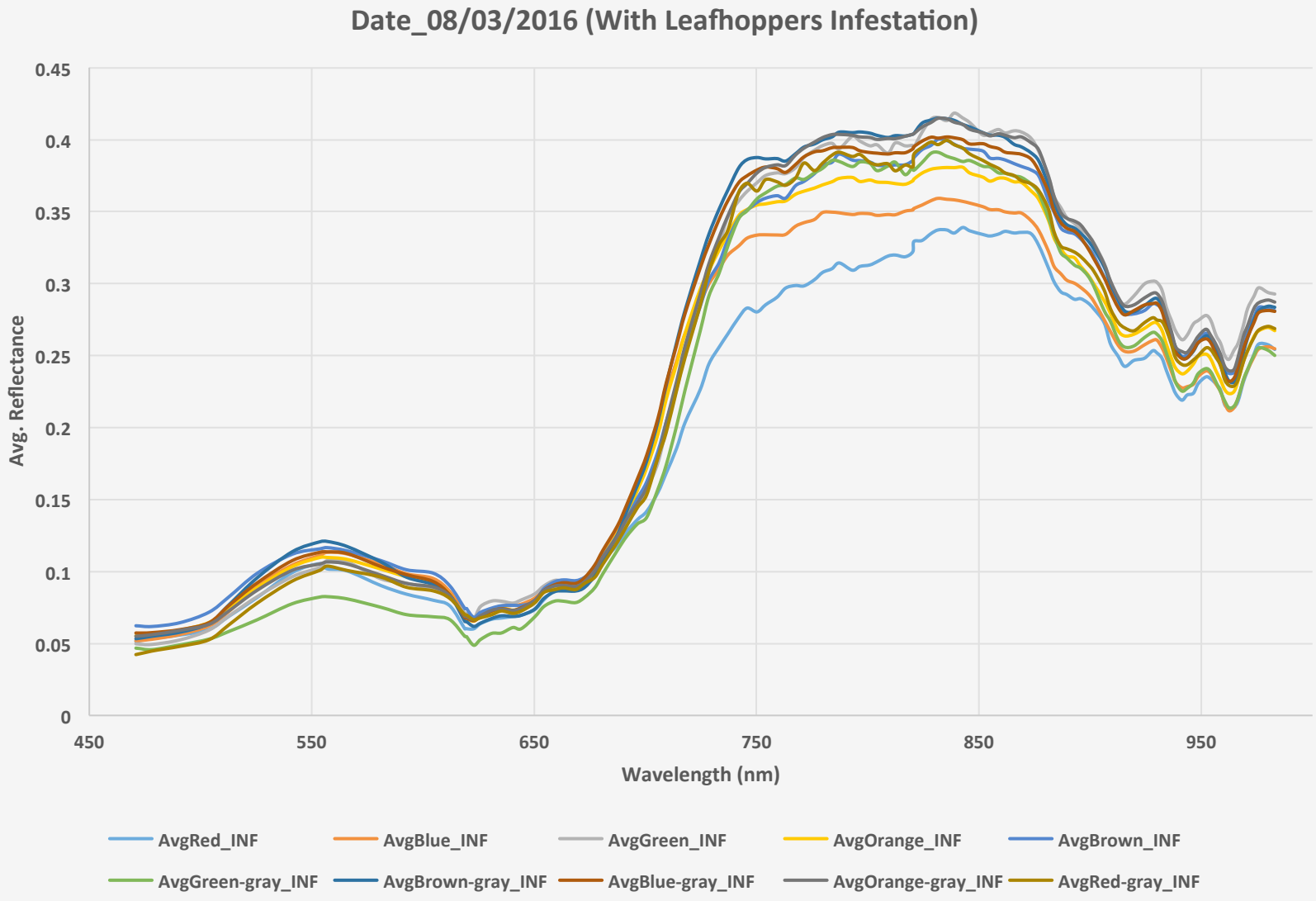


Last 5 rows

Reflectance variation within all treatments without infestation:

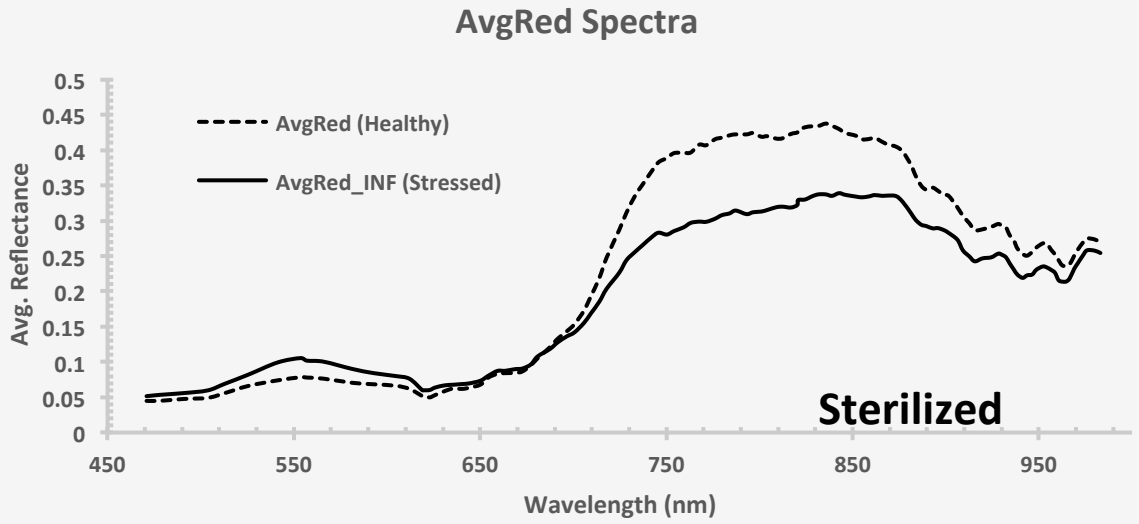


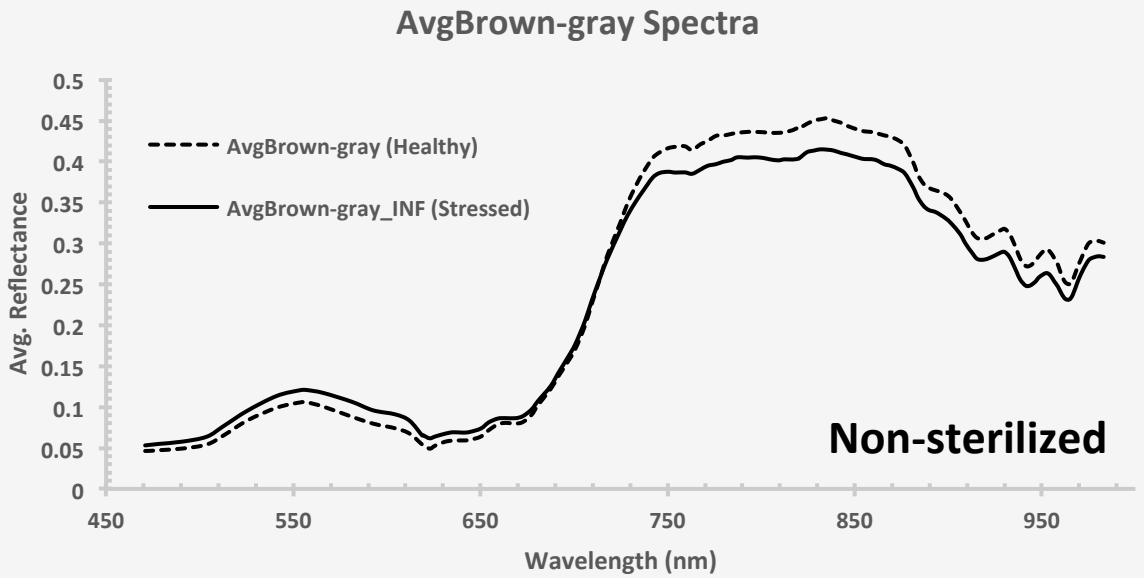
Reflectance variation within all treatments after infestation:



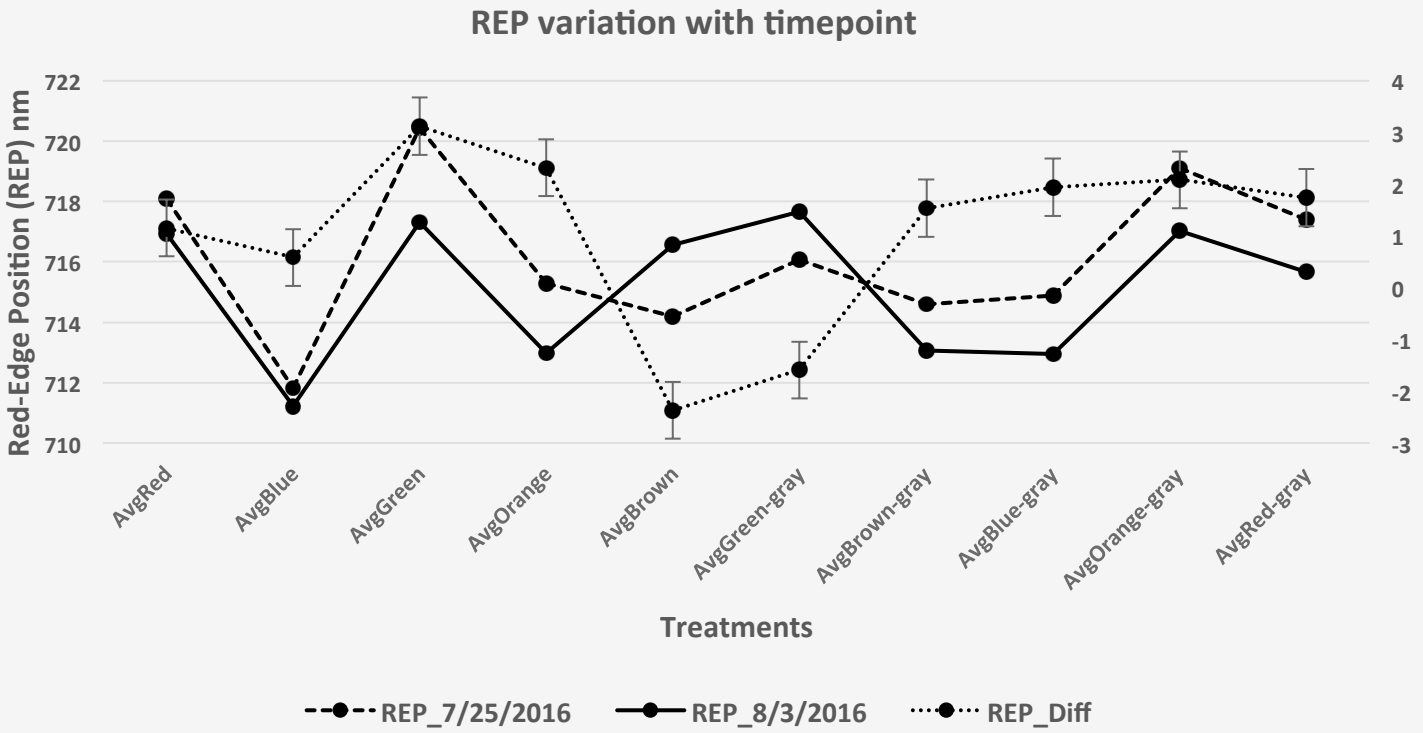
Reflectance comparison before and after infestation (Date_07/25/2016 vs. Date_08/03/2016):

- Narrowband hyperspectral vegetation indices are used to get chlorophyll content and carotenoids concentration.
- The reflectance variation between the two dates as a consequence of exposure to leafhoppers (non-infected vs. infected)
- It estimates smaller changes in vegetation health to differentiate sterile/non-sterile treatments of with and without infestation.





REPs variation with and without infestation (Date_07/25/2016 vs. Date_08/03/2016):



- The REPs are sensitive to changes in chlorophyll concentration.
- Green treatment is highly preferred by leafhopper followed by Orange, Orange-gray, Blue-gray, Red gray, Brown-gray, Red, Blue, Green-gray to Brown treatment, as least preferred.

Conclusions:

- Reflectance spectra indicate significant differences
- Early detection of infection & diseases, before wilt or pest outbreaks
- Field area covered by stress plants
- Yield and seed quality of crops

- **Advantages:**

It reduces,

- ➢ Fertilization and Pesticide spray time
- ➢ Cost of spray
- ➢ Poisonousness in our biosphere (organic farming)
- ➢ Crops destruction

Hyperspectral Remote Sensing: "A way to sustainable agroecosystem study for precision agriculture"

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Thank you