Spectroscopy and Data Analytics For The Early Detection of Red Blotch Viral Infection in Grapevines

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Challenges of Grapevine Red Blotch Virus

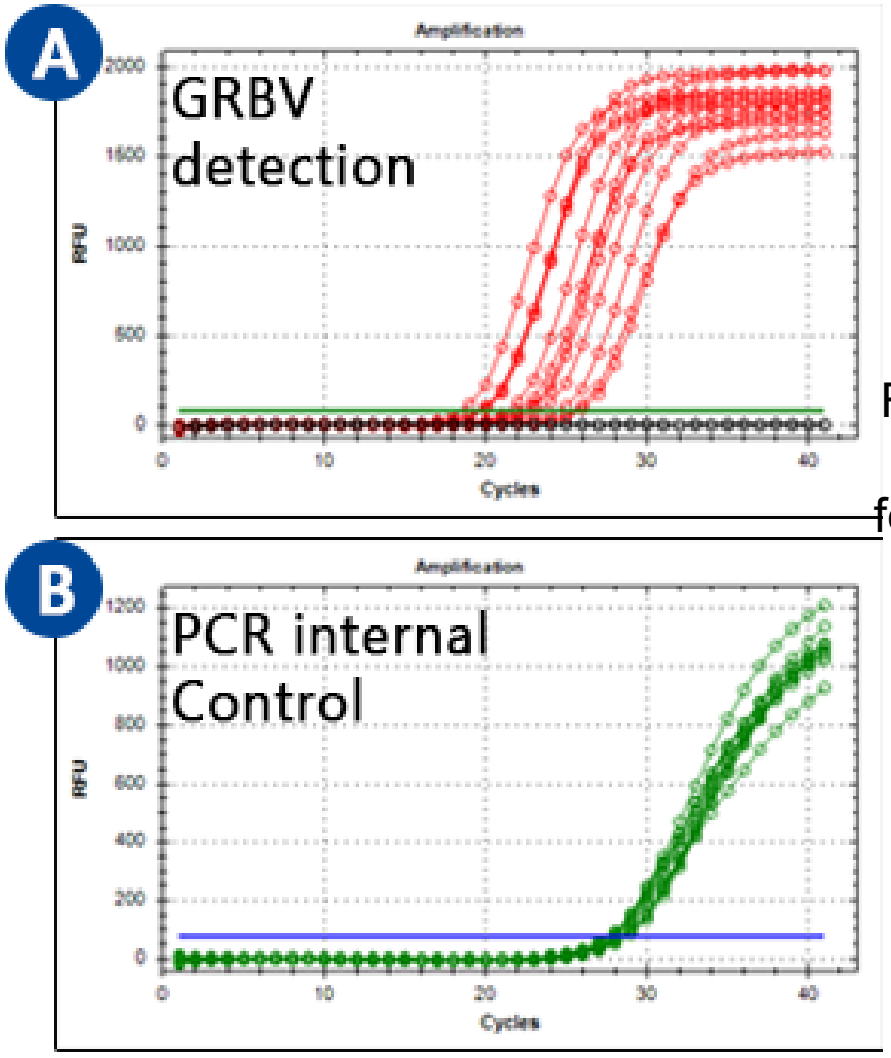
Grapevine red blotch virus (GRBV) infection

Red berry crops White berry crops

- Reduce 35 – 40 % berries yield
- Reduce berries sugar and their skin anthocyanin content
- Similar visual appearances as in leafroll disease but these features are only visible in late seasons (early fall)

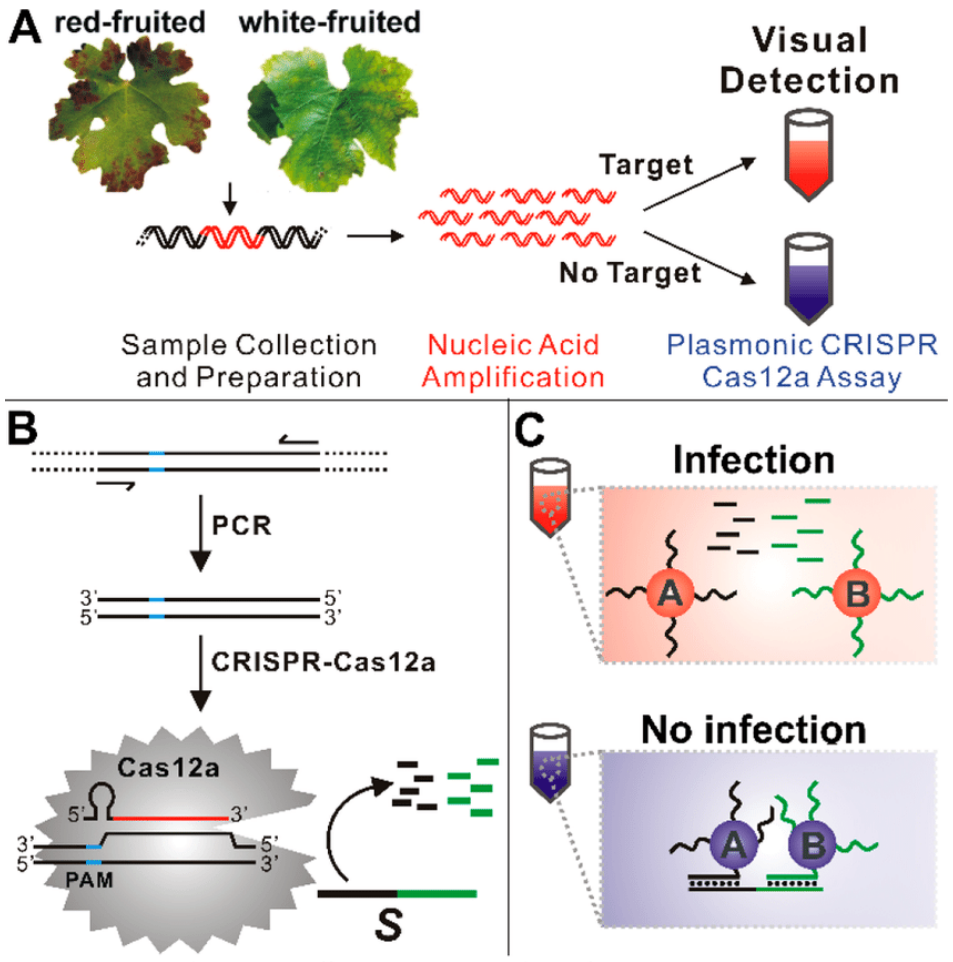
Methods of Detection

Real time PCR or PCR combined with electrophoresis

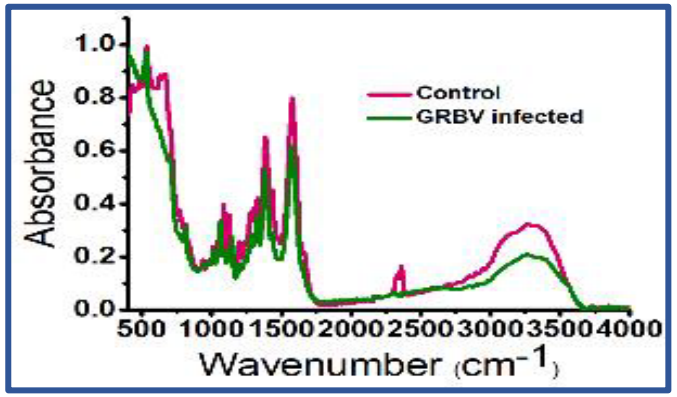


Requires purified DNA from plant samples, followed by RT-PCR or PCR with molecular grade reagents and environment

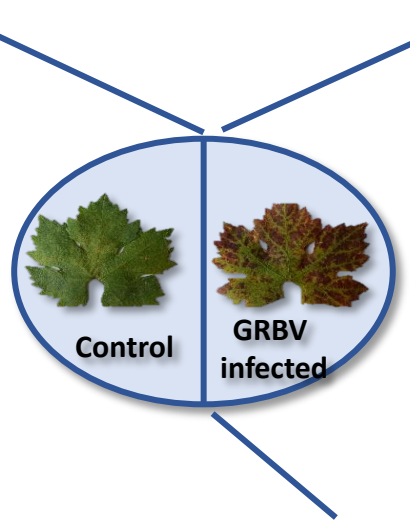
Variations on a PCR approach for visual detection

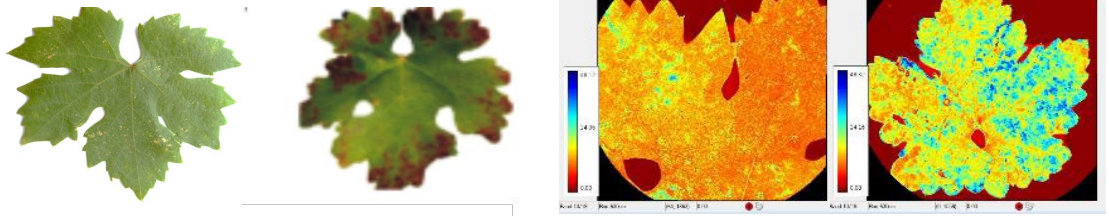


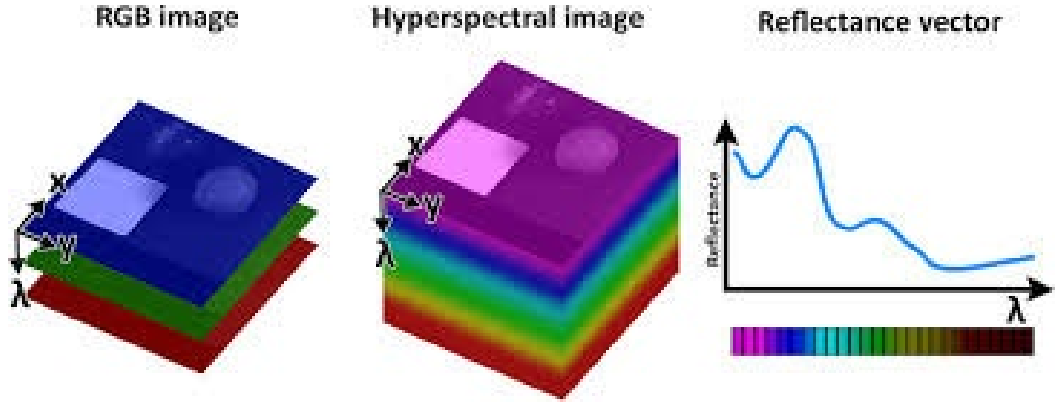
Spectroscopy and Imaging Approaches for Detection



Hand Held Devices







FTIR Spectroscopy
Mid-IR Wavelength = 2500 – 25000 nm

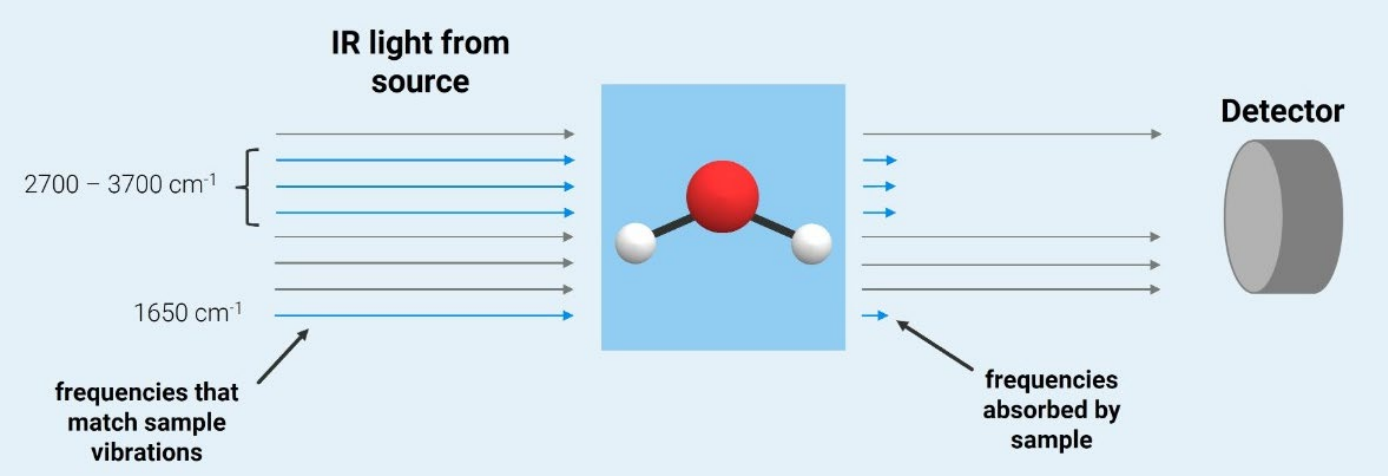
Vis-NIR Spectroscopy
Wavelength = 400 – 1100 nm

RGB Imaging (Vis)
Wavelength=445- 575 nm

Hyperspectral Imaging (Vis-NIR)
Wavelength = 400 – 1000 nm

IR Spectroscopy for Red Blotch Detection- FTIR and Potential of NIR

Primer on IR Spectroscopy and Detection of Red Blotch Infections



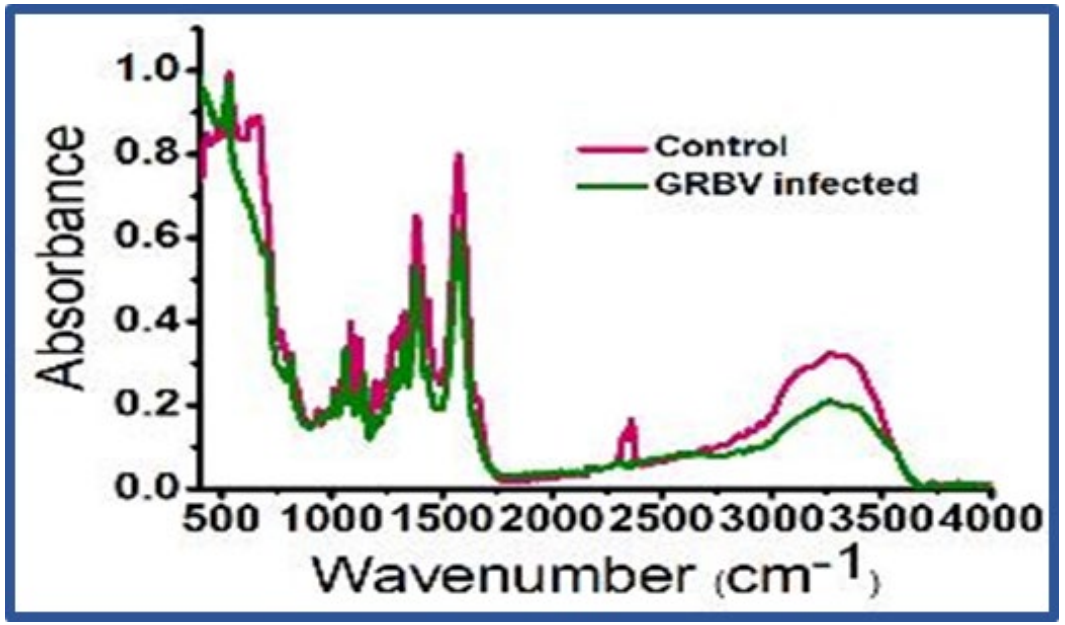
	FTIR	Visible- NIR
Sensitivity	High resolution (defined bands and strong absorption	Broad Bands
Functional Groups	Large Diversity of Groups (-C-O, O-H, C-C, N-H, C-N, and others)	Limited to O-H; C-H, N-H but in combination with visible region can detect pigments
Penetration Depth	Limited and Requires Sample Preparation	>3 mm (780-1600 nm) and field deployable (no sample preparation)

FTIR (Mid-IR Region) Spectroscopy for Red Blotch Detection

Compositional analysis of water extracts using FTIR

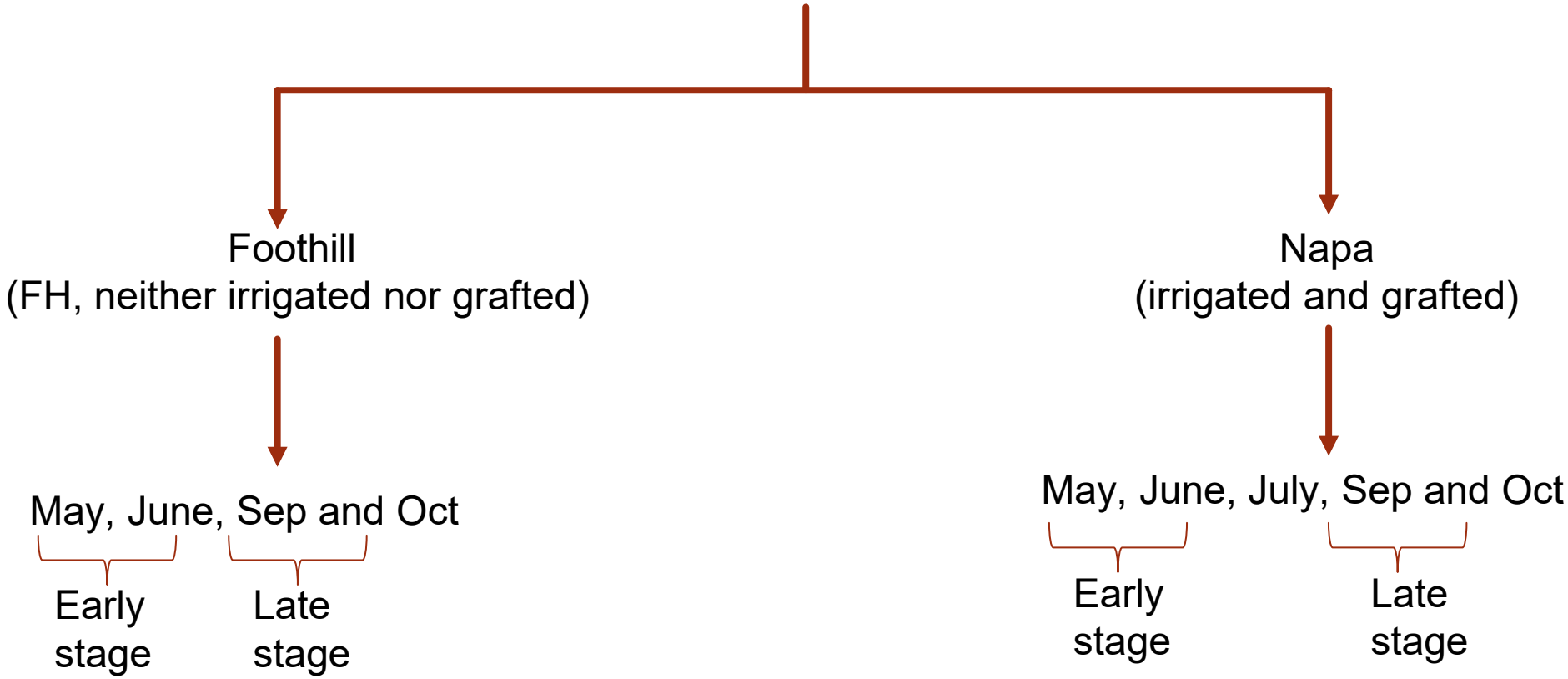
Benchtop IR Measurement

Handheld IR device

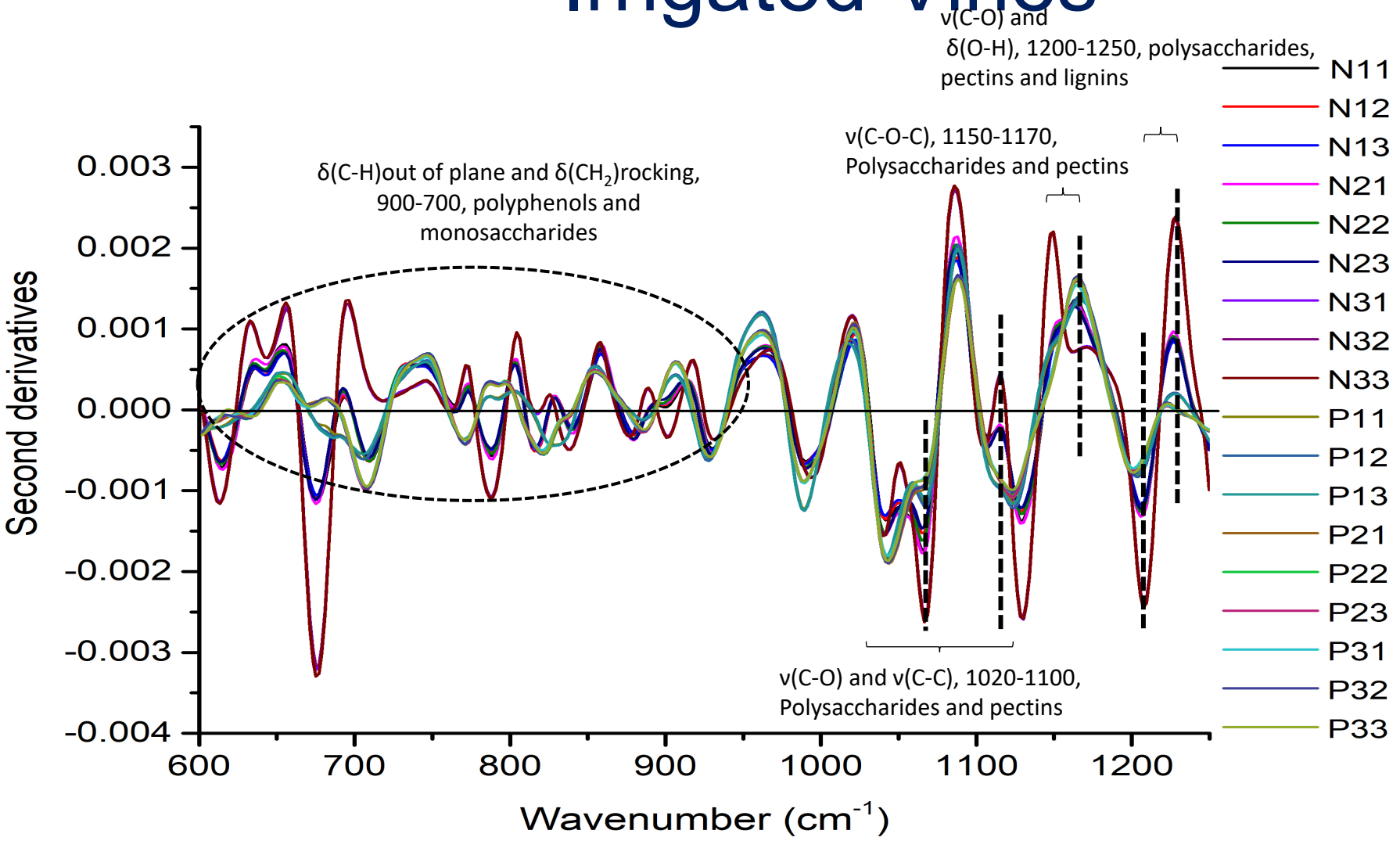


Experimental Plan

FTIR spectra of water extract of leaves

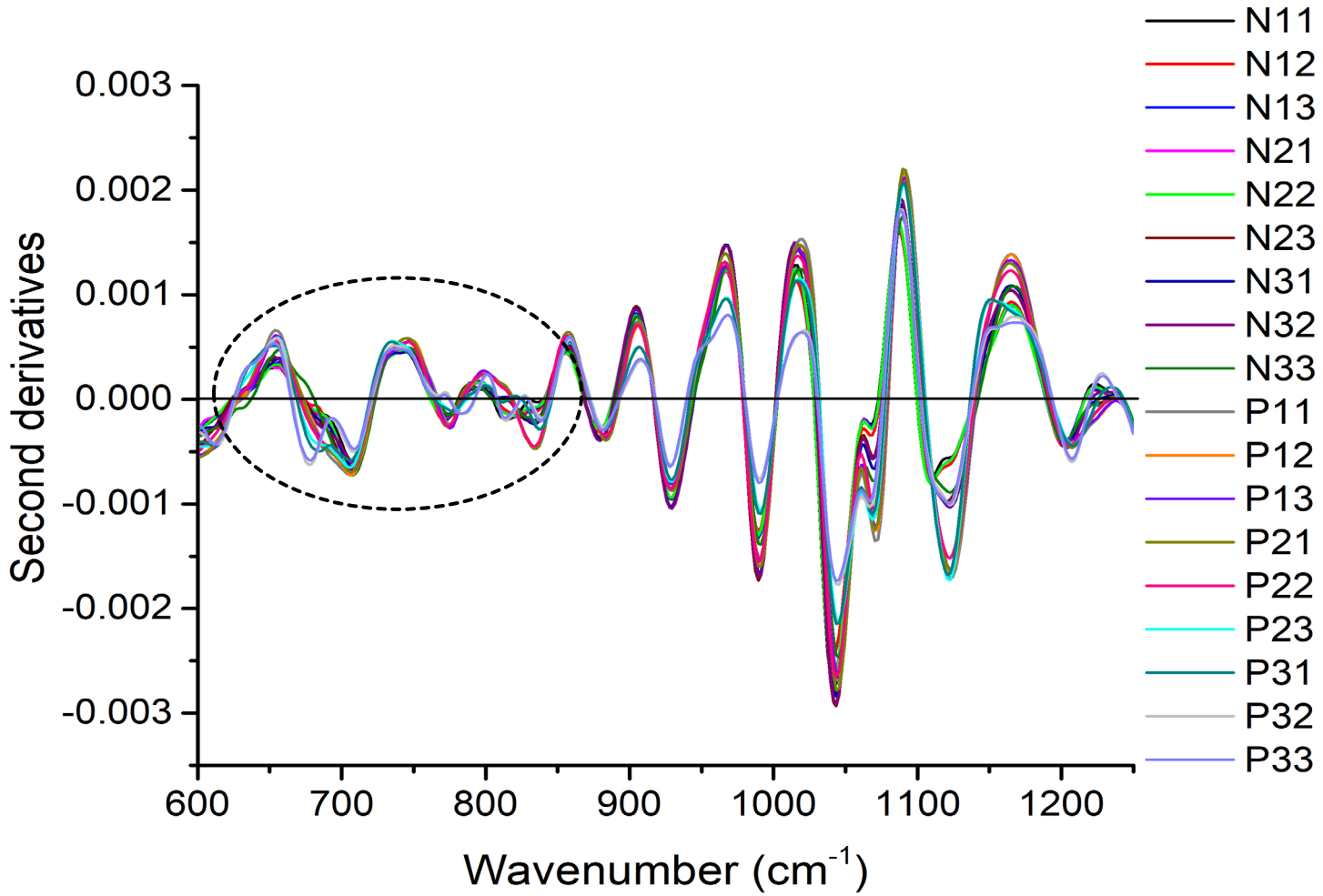


Early Season Changes in the Spectral Features of Infected (P) vs Non-Infected Vines (N)- Non Irrigated Vines



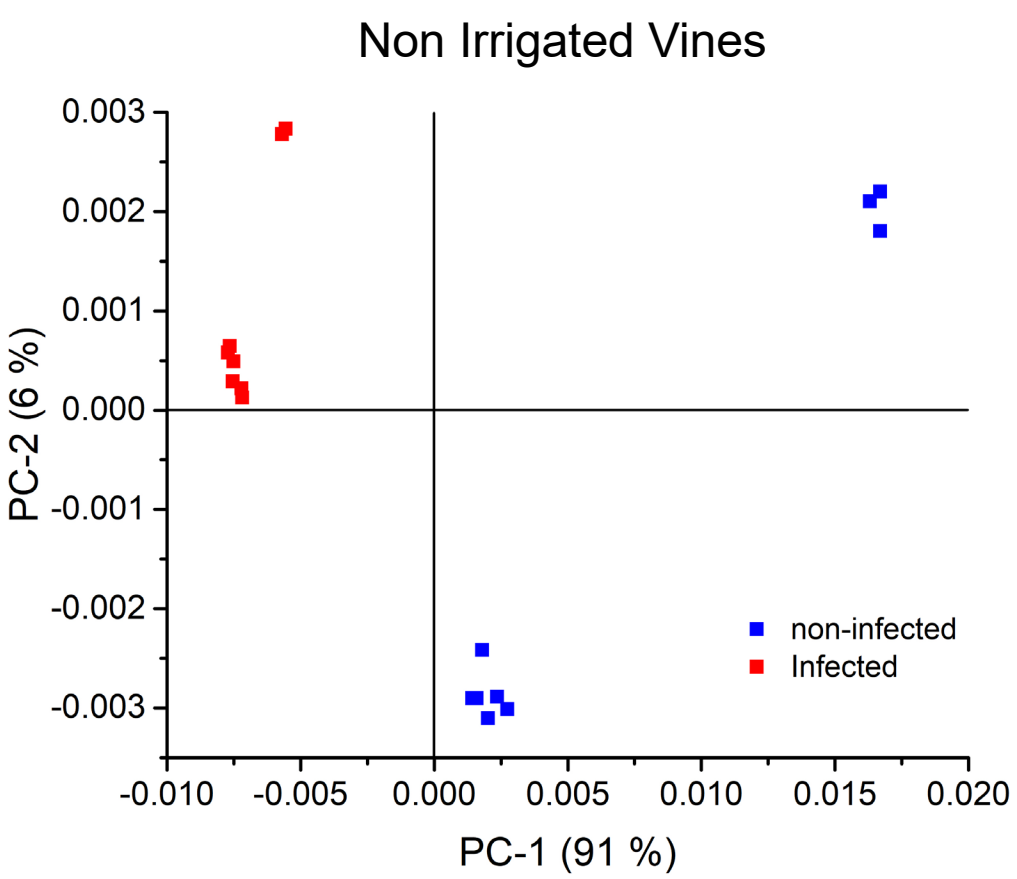
Second derivative of FTIR absorbance of infected and non-infected leaves collected during shoot and leaf growth (April-May)

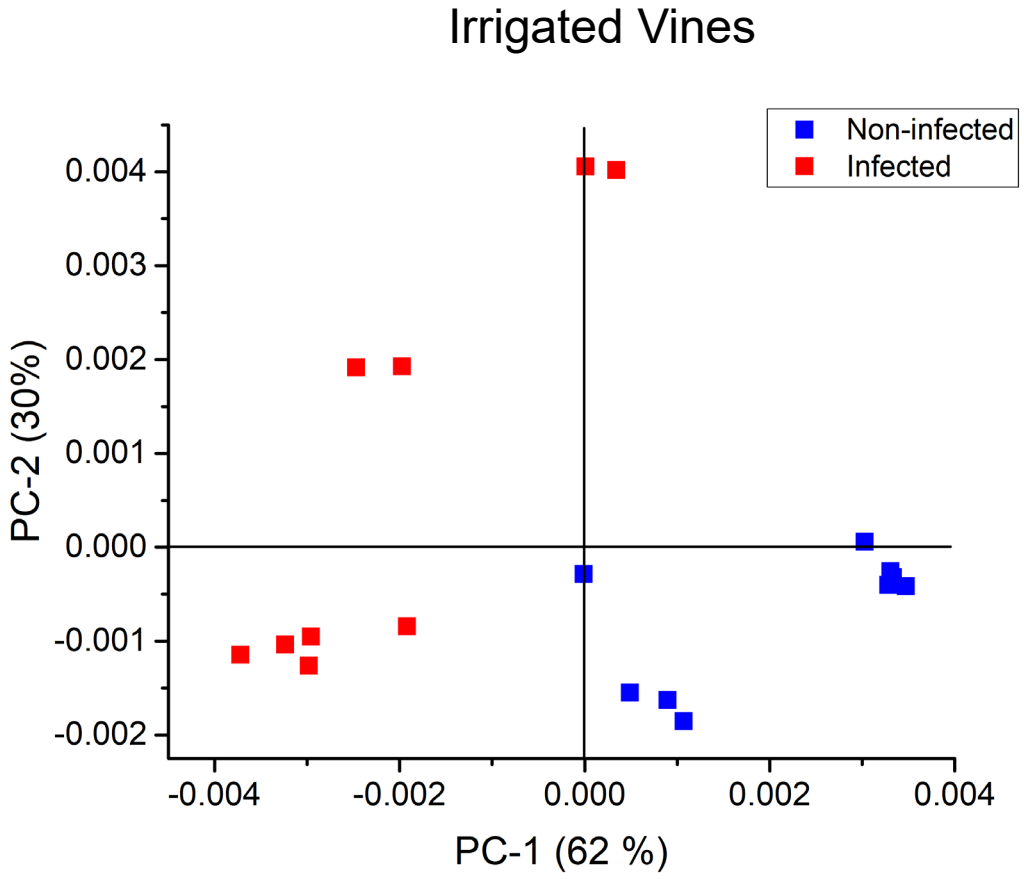
Early Season Changes in the Spectral Features of Infected (P) vs Non-Infected Vines (N)- Irrigated Vines



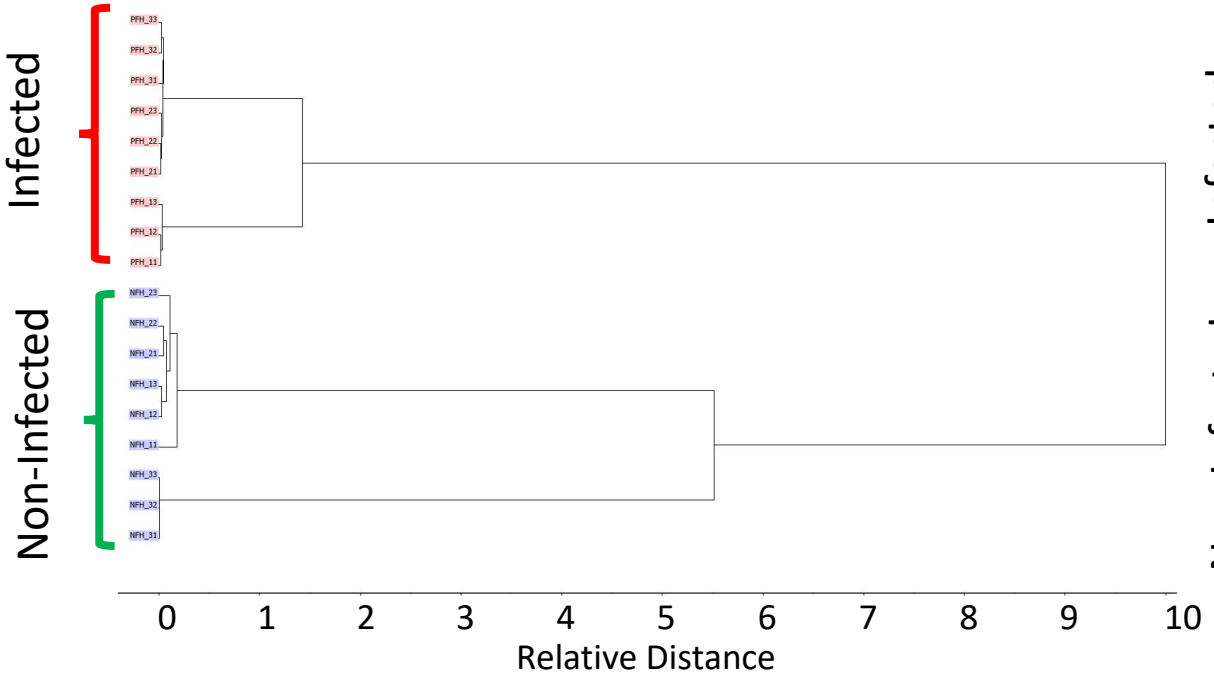
Second derivative of FTIR absorbance of infected and non-infected leaves collected in May from Irrigated Vines

PCA Analysis of Spectral Data (Early Season)

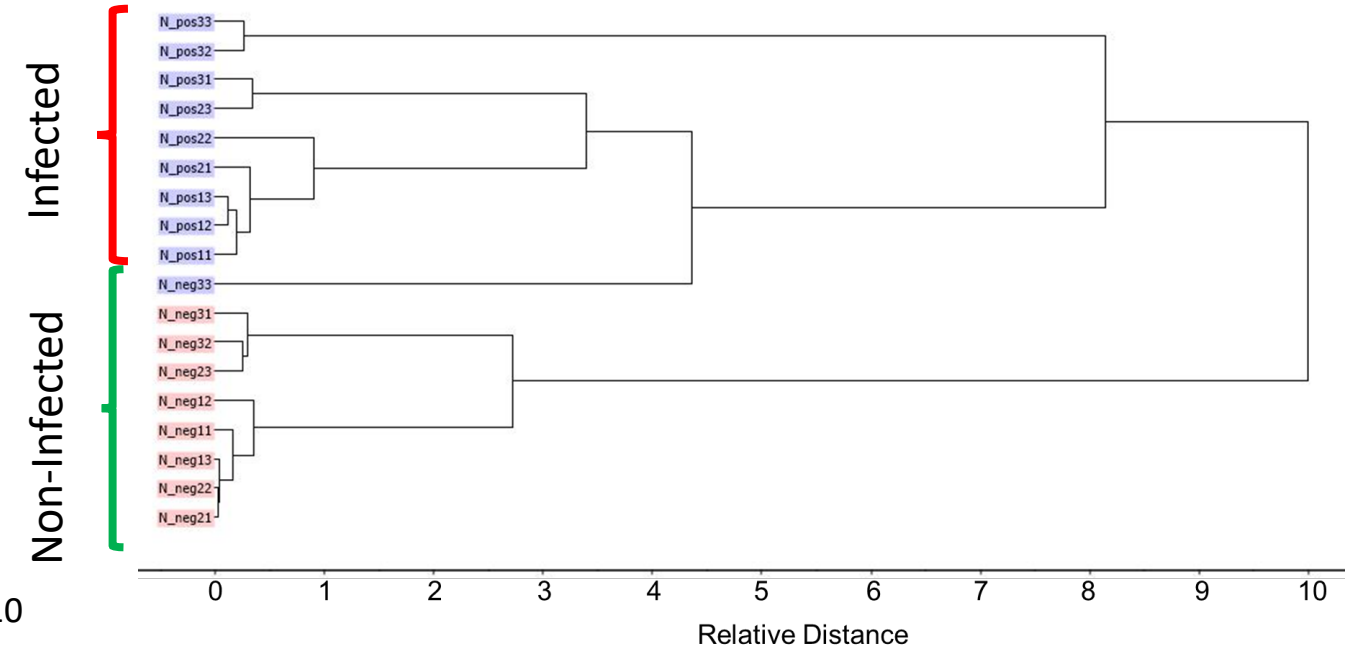




Hierarchical Clustering for Infected vs Non-Infected Vines (Early Season)



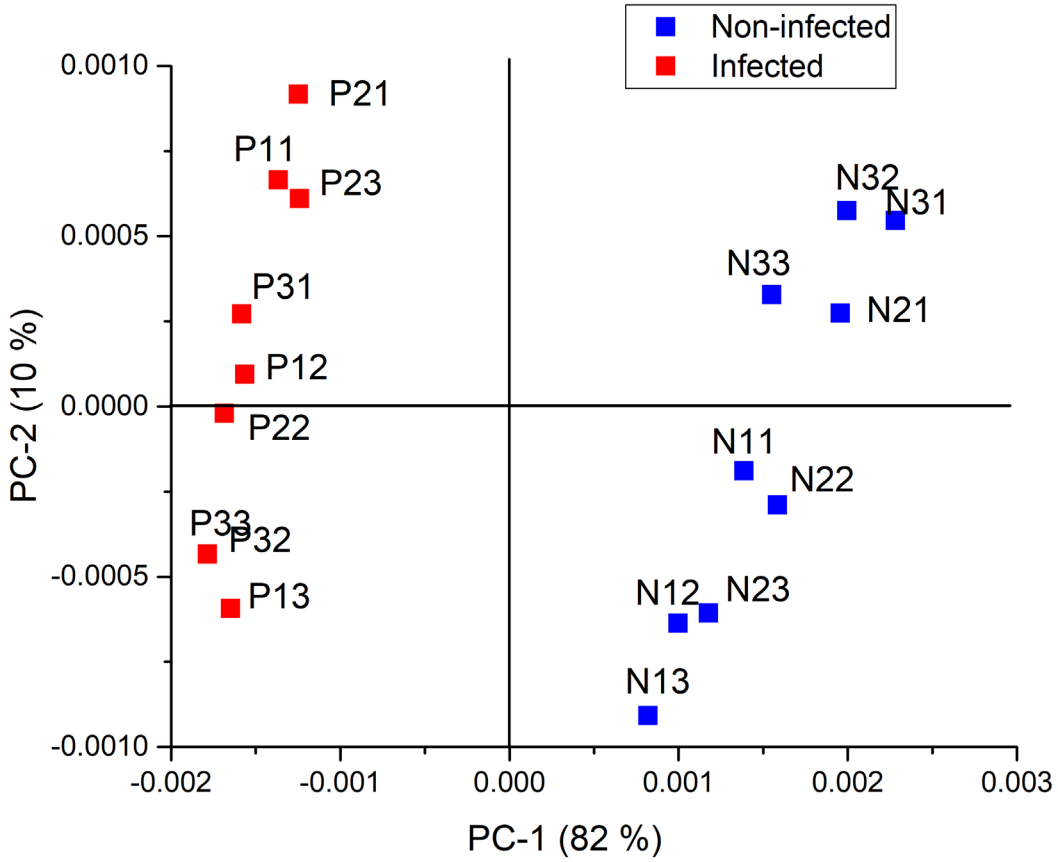
Hierarchical median-linkage clustering- Non Irrigated Vines



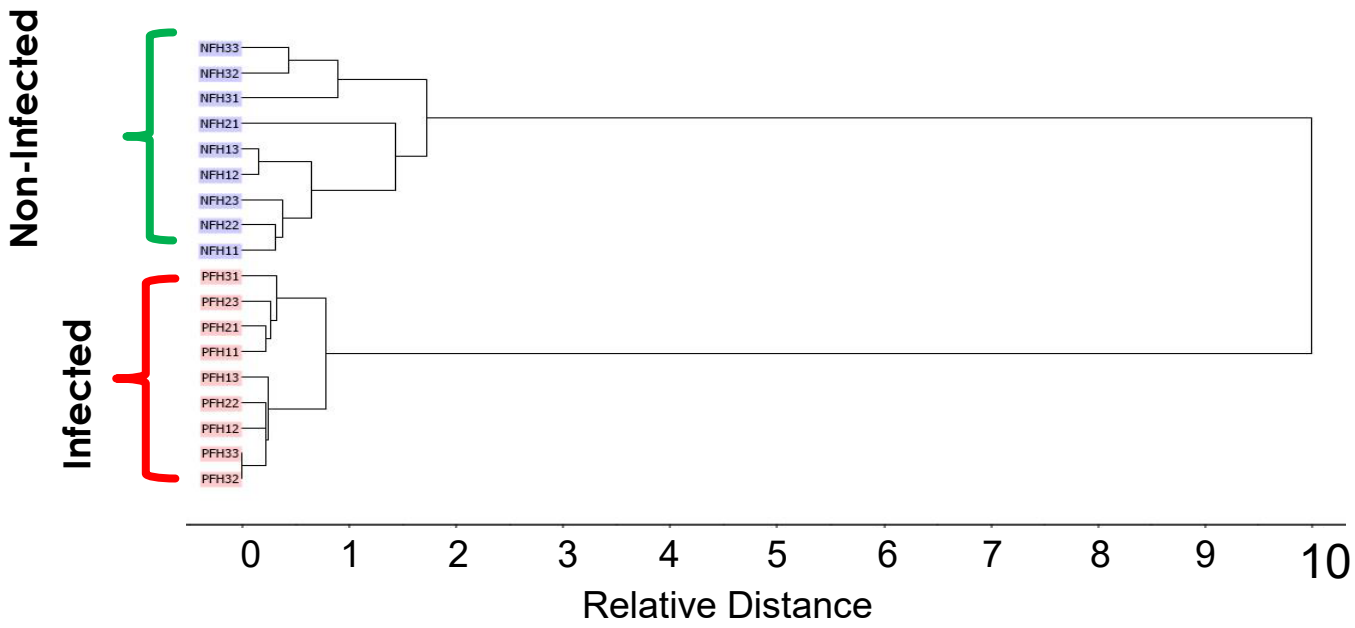
Hierarchical median-linkage clustering – Irrigated Vines

Early Season (June) PCA and Cluster Analysis of Spectral Data

PCA Analysis

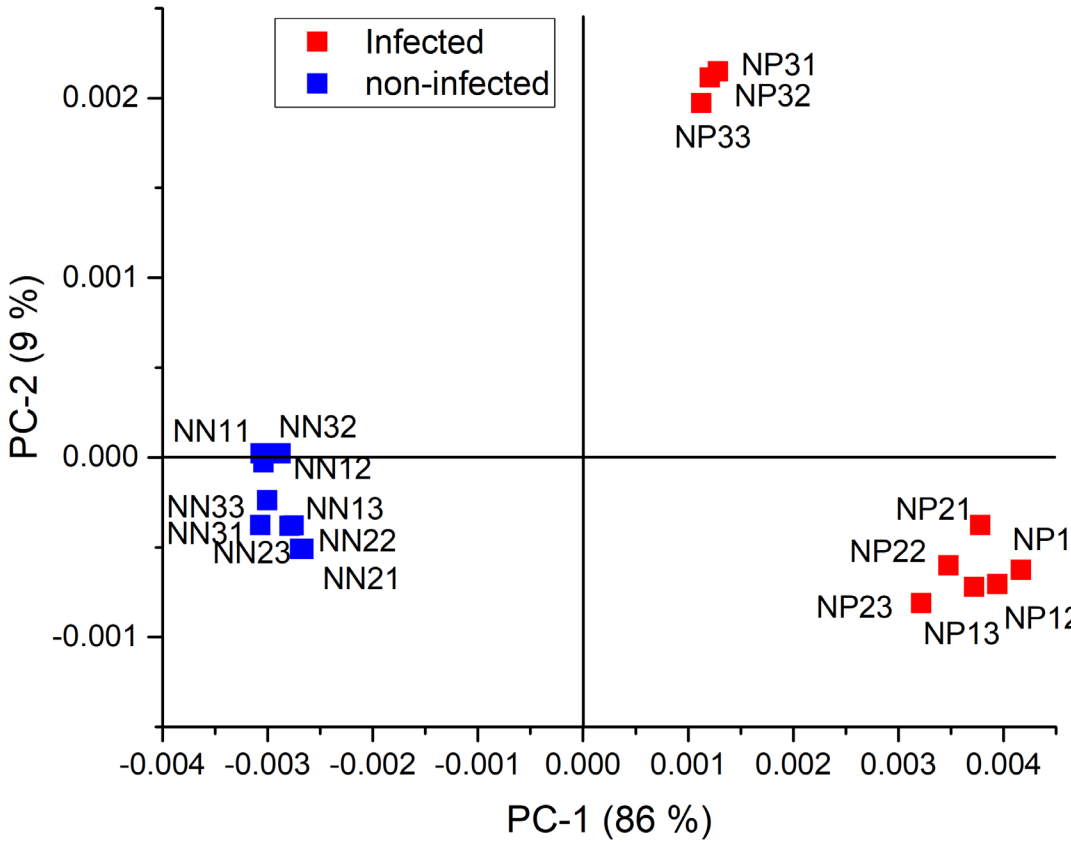


Hierarchical Median-Linkage Clustering

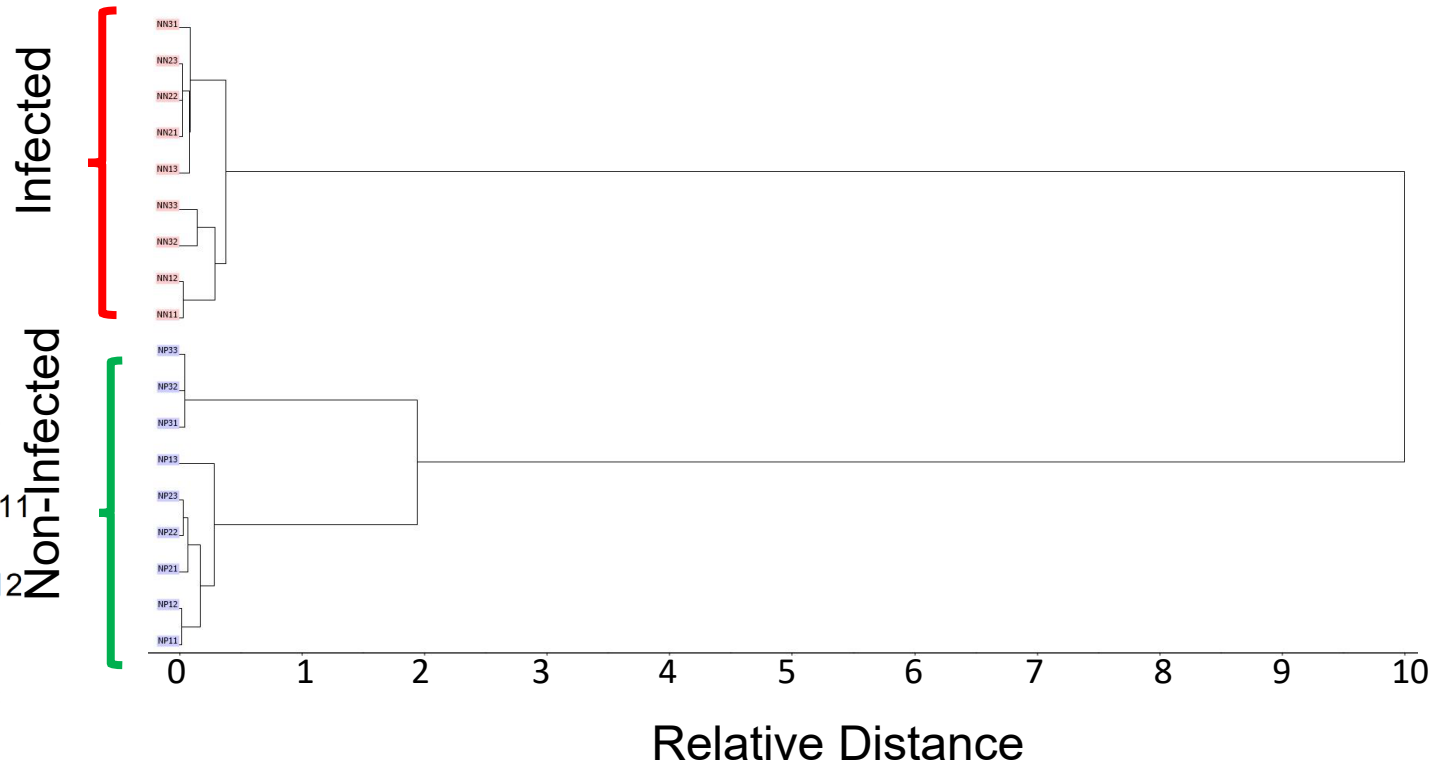


PCA Analysis of Spectral Data (Late Stages, Irrigated Vines)

PCA Analysis



Hierarchical Median-Linkage Clustering

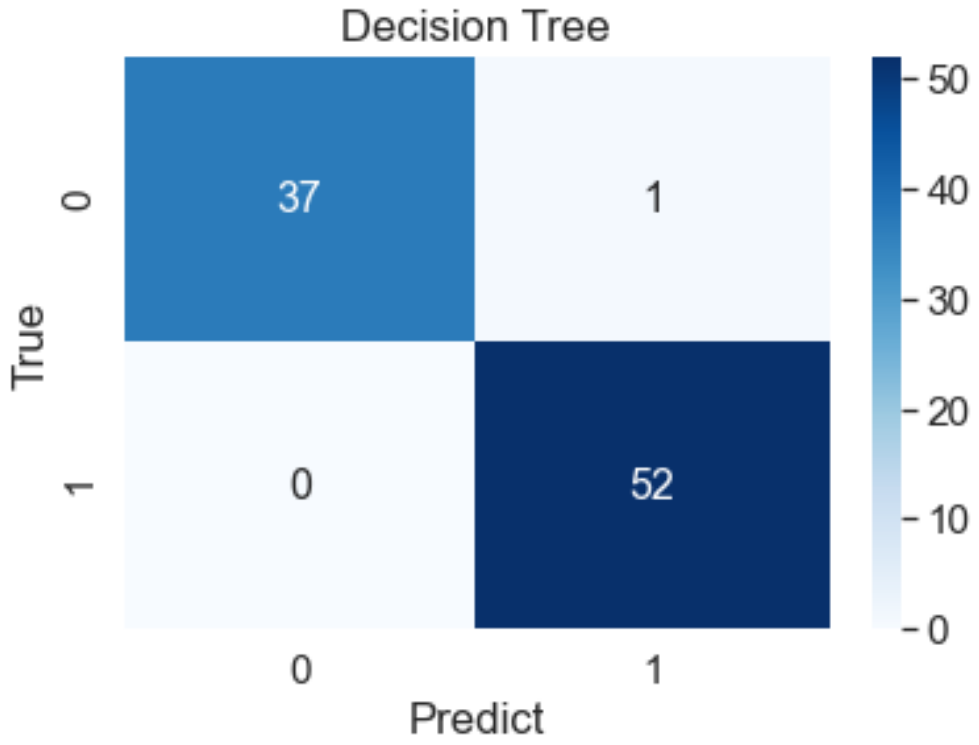


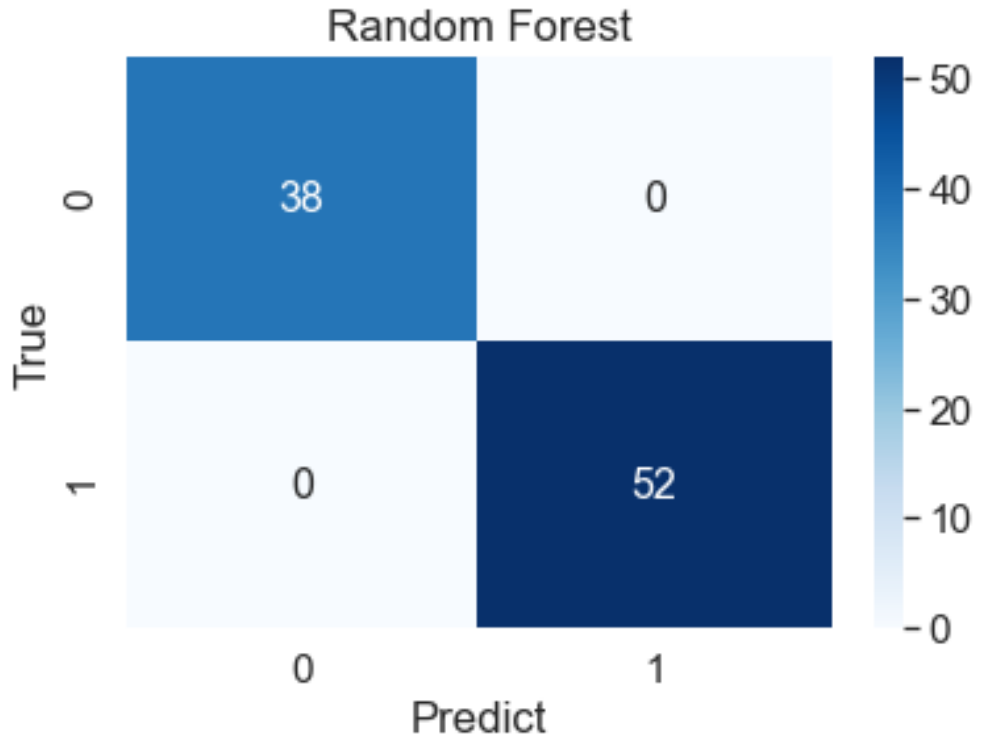
Machine Learning Models (Supervised Learning) for Detection

Train and Test Split = 70 : 30, random stratified split

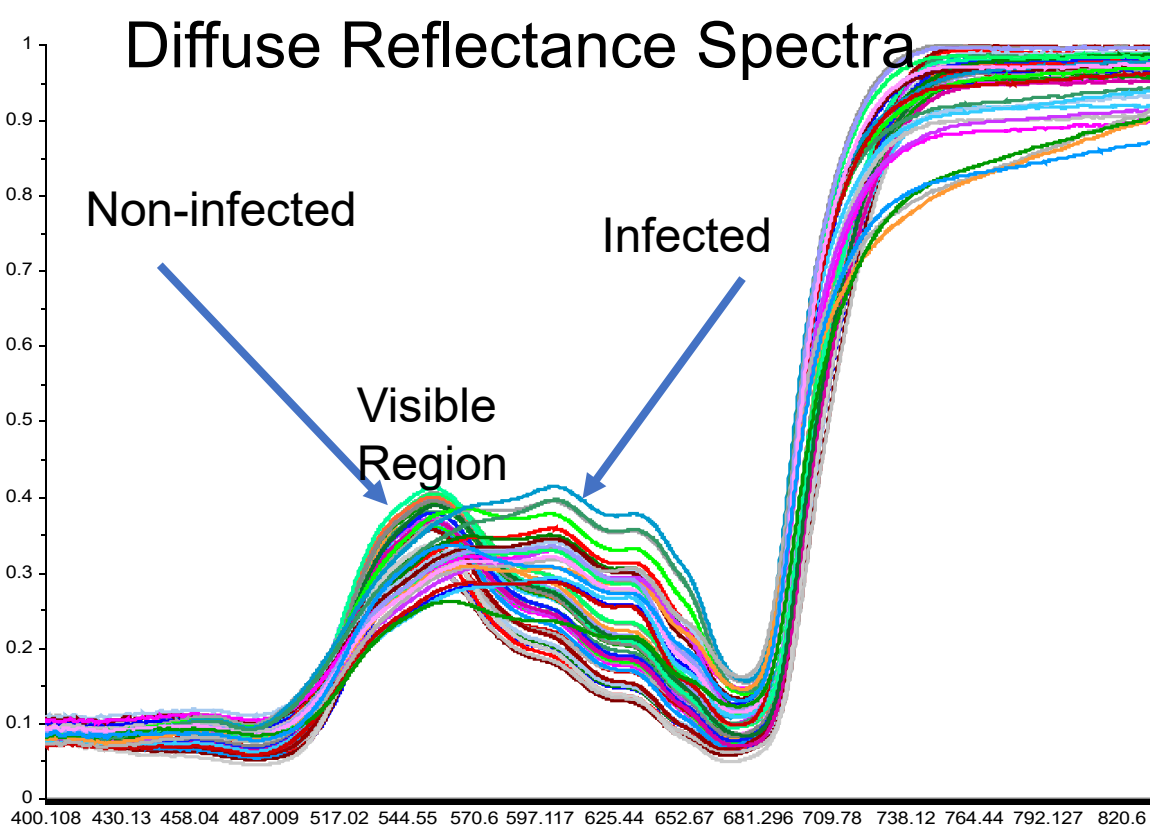
Number of run and folds for cross-validation = 100 and 5

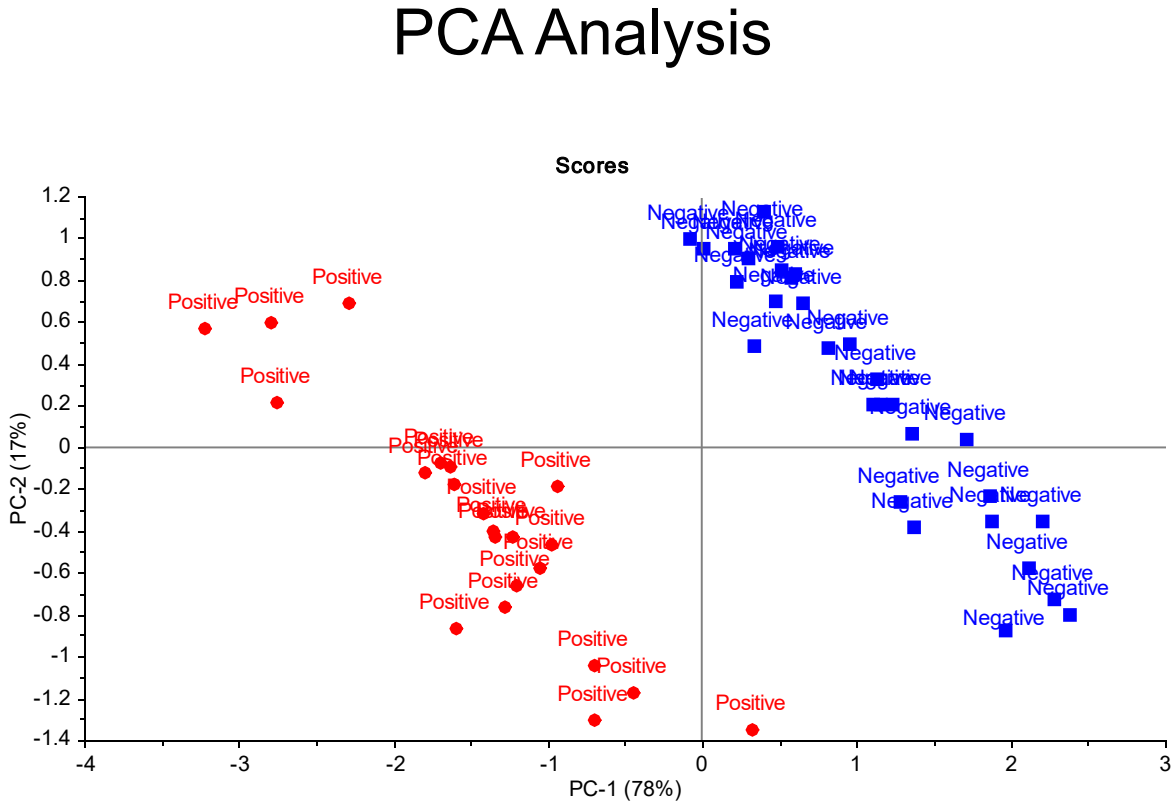
Prediction Using Decision Tree and Random Forest Models





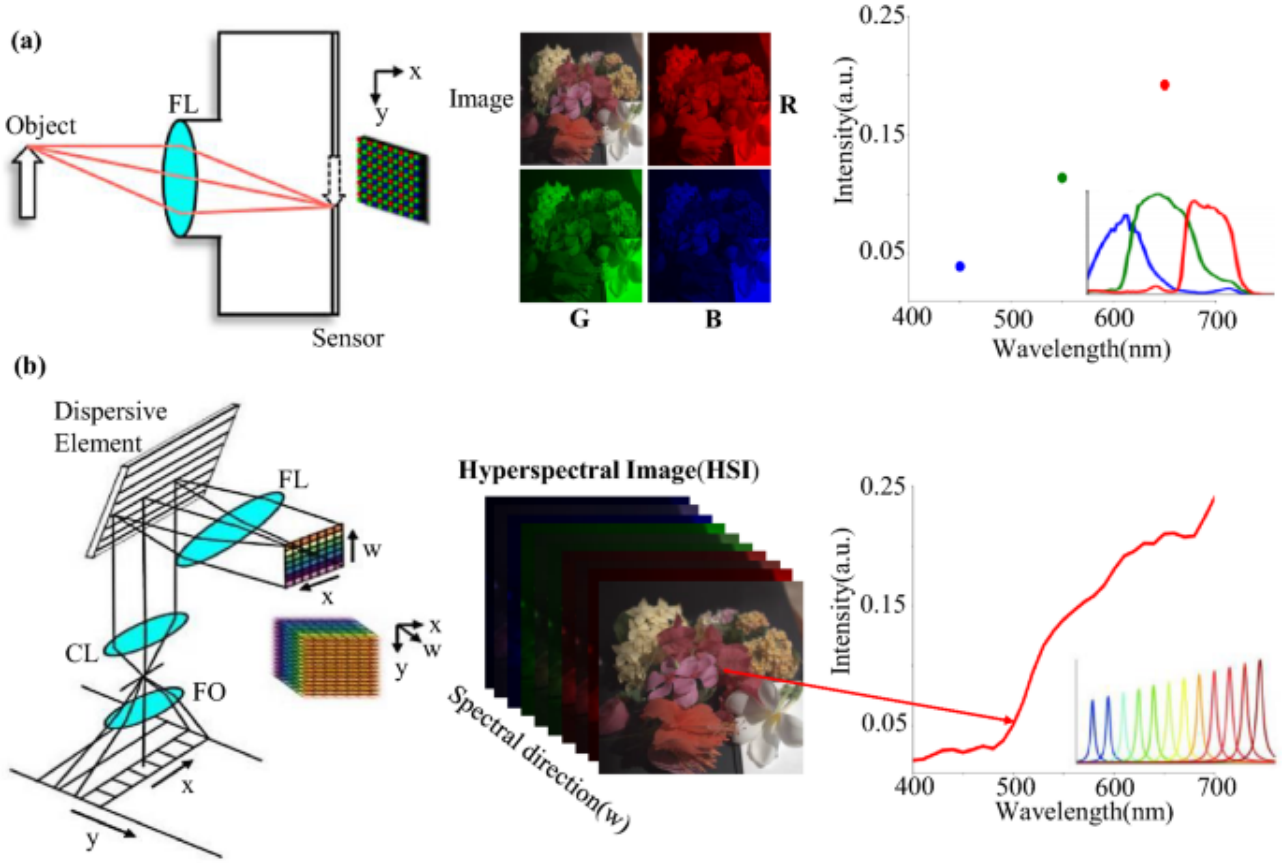
Potential in Field Measurements using Portable vis-NIR Spectroscopy (Late Season)





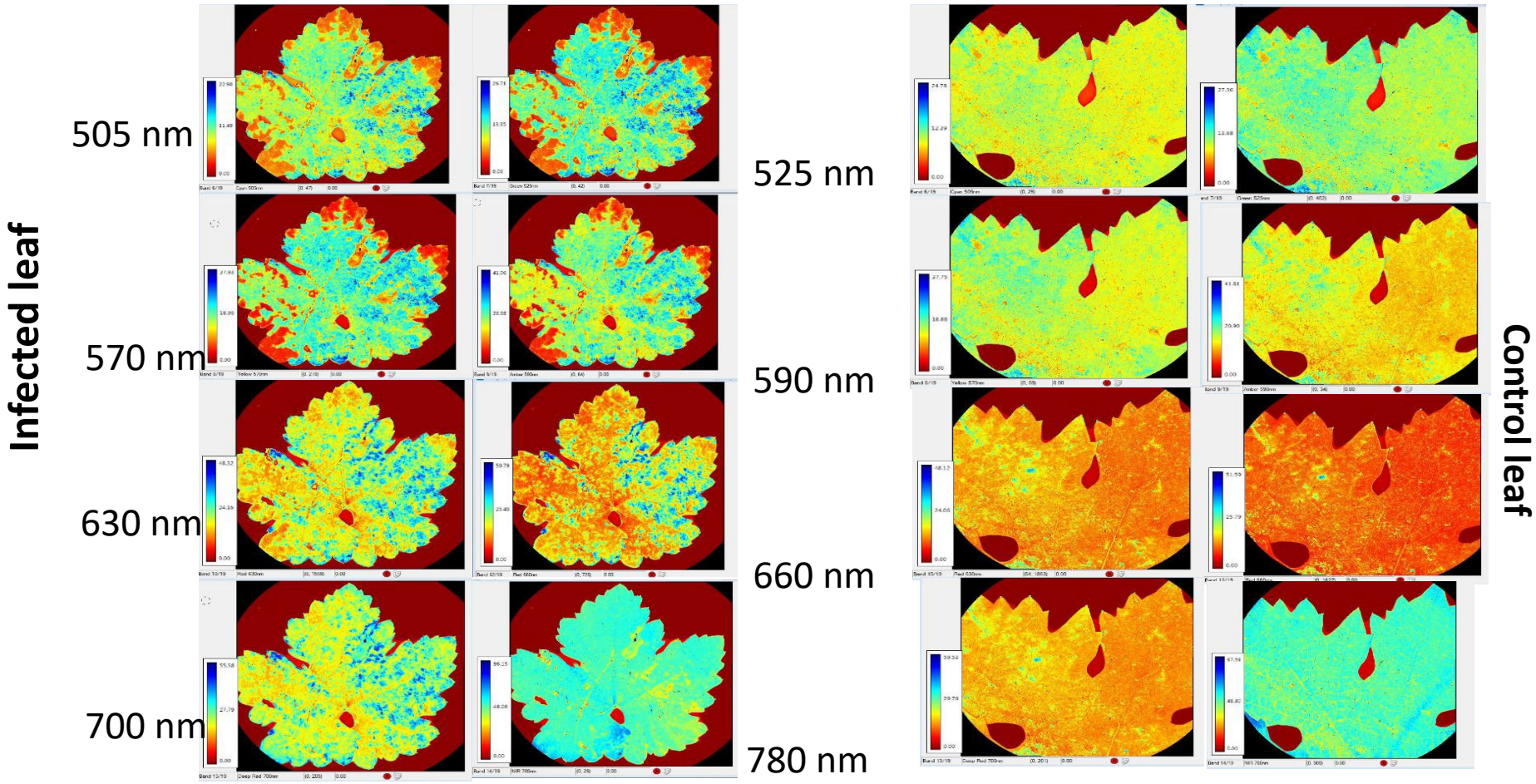
Hyperspectral and RGB Imaging

RGB and Hyperspectral Imaging

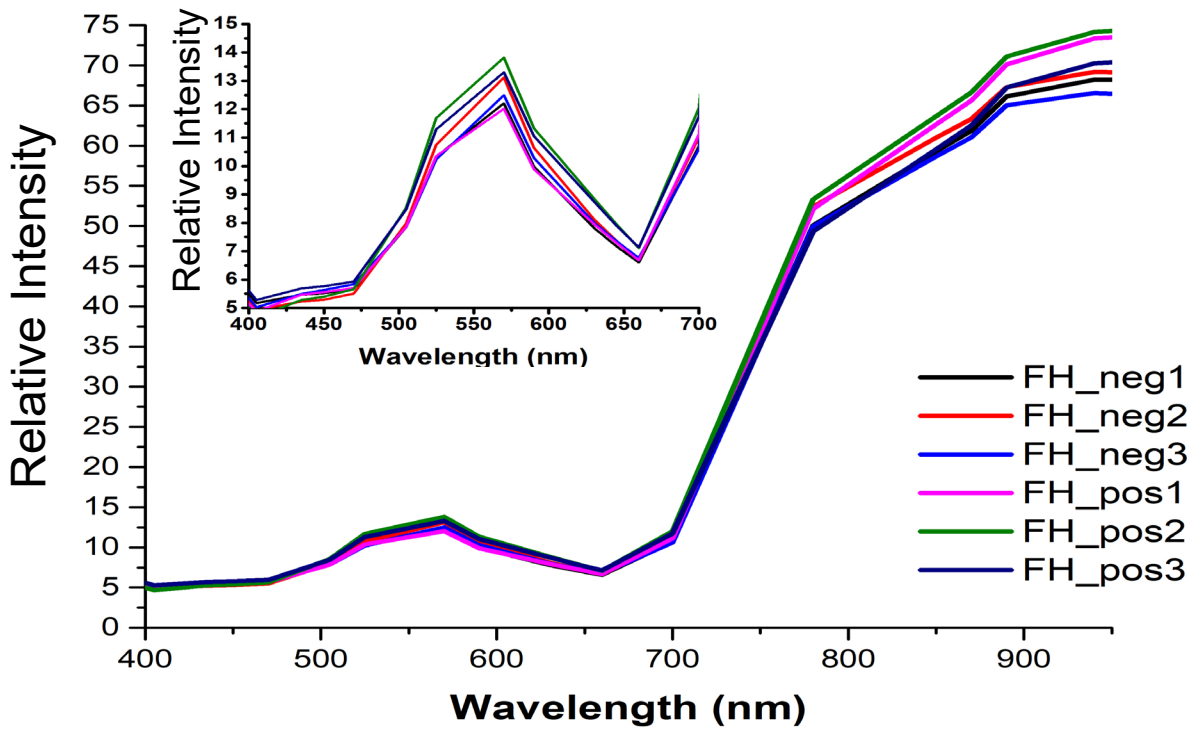


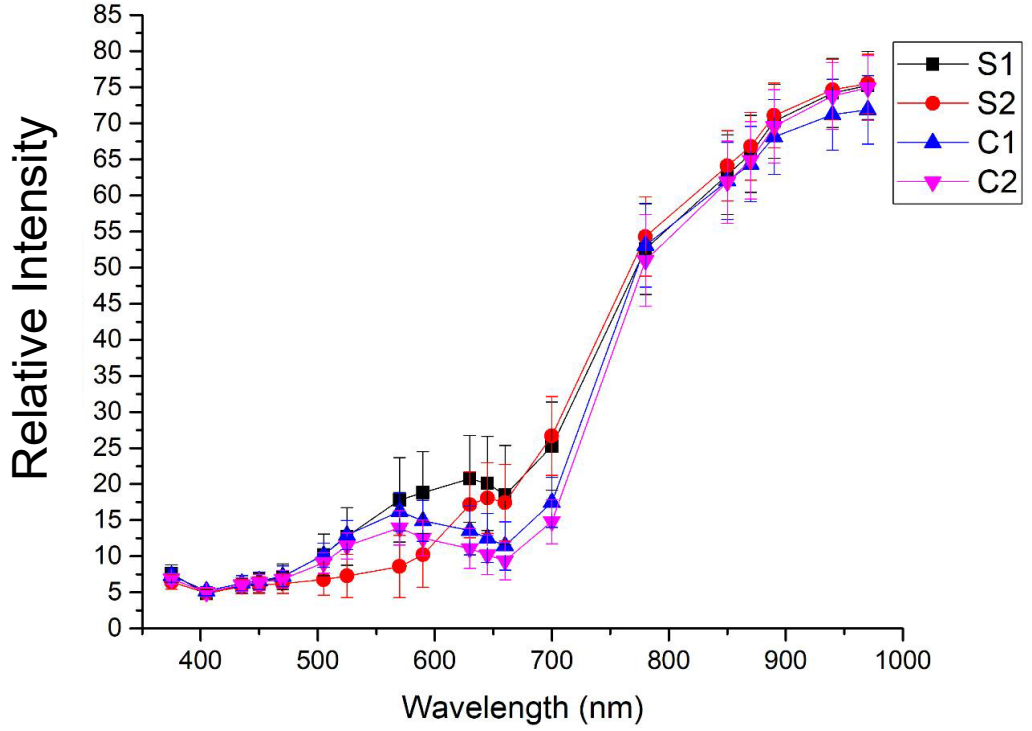
	Hyperspectral Imaging (Vis-NIR)	RGB(Visible)
Penetration Depth	~2-3 mm (in 800-1000 nm)	~0.5 mm
Functional Properties	Pigments and diverse chemical features	Pigments and limited chemical features
Cost	Relatively High	Low

Hyperspectral Images of infected and non infected leaves (Late Season)



Differences in Spectral Features- Early vs Late Stage Features

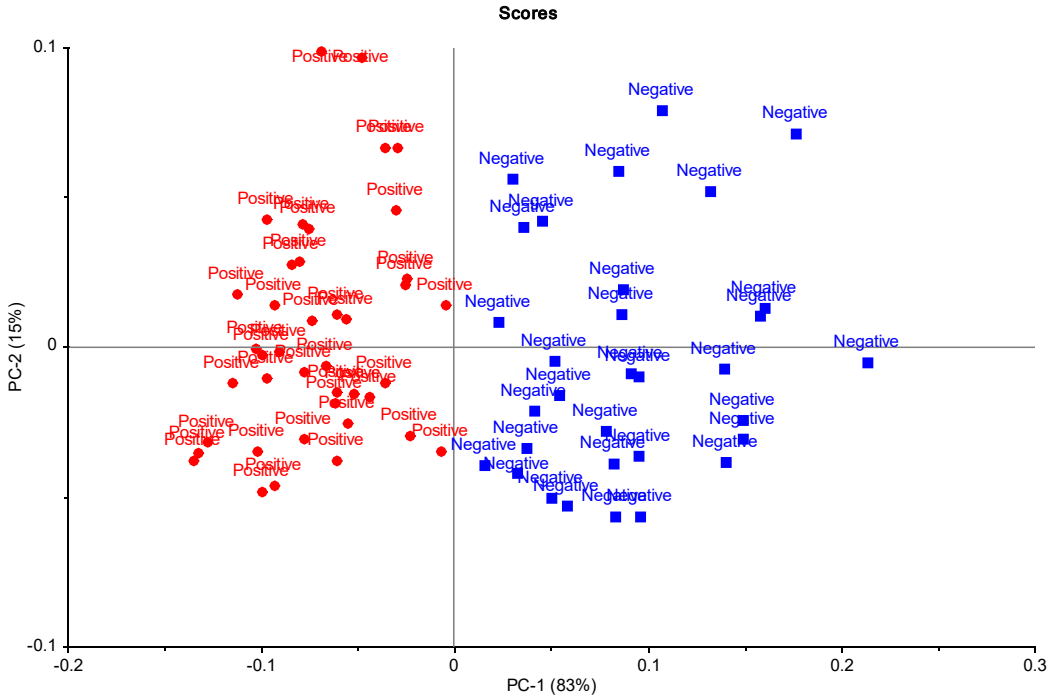




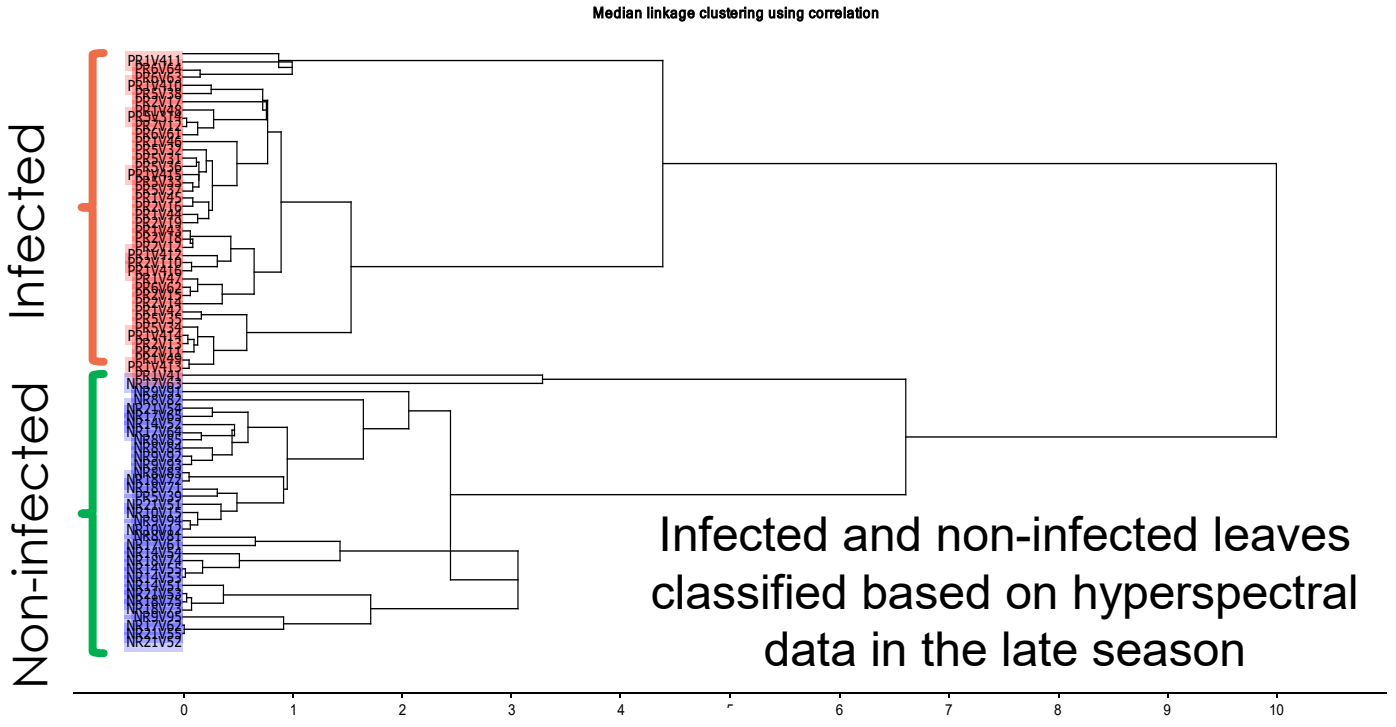
Spectral Features of Hyperspectral Images

Hyperspectral Imaging Based Discrimination between Infected and Non-Infected Vines

PCA Analysis

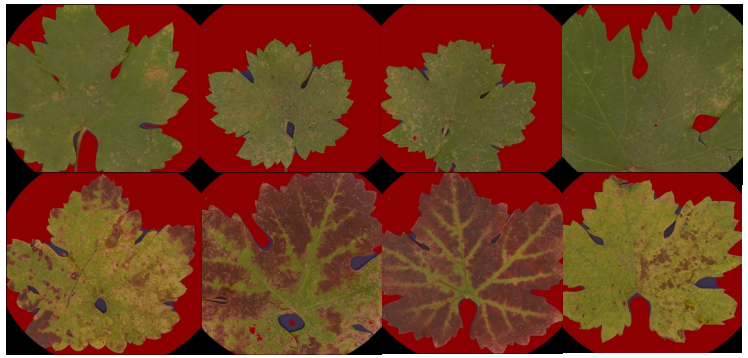


Hierarchical Median-Linkage Clustering



Infected and non-infected leaves classified based on hyperspectral data in the late season

Potential of RGB Imaging with Data Analytics



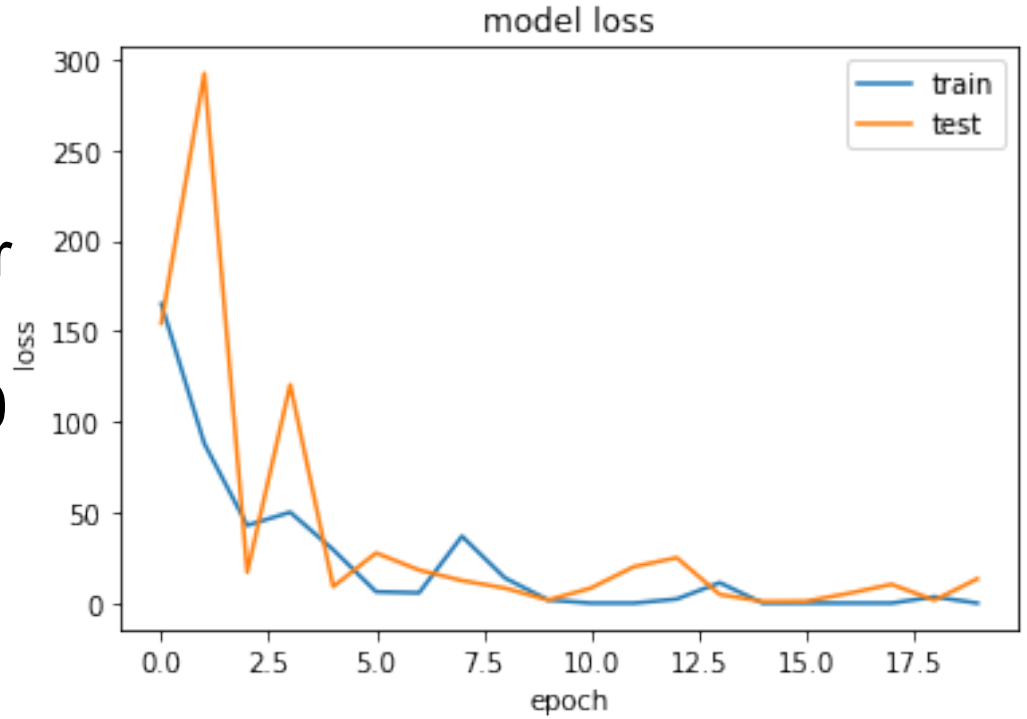
Input (RGB images)

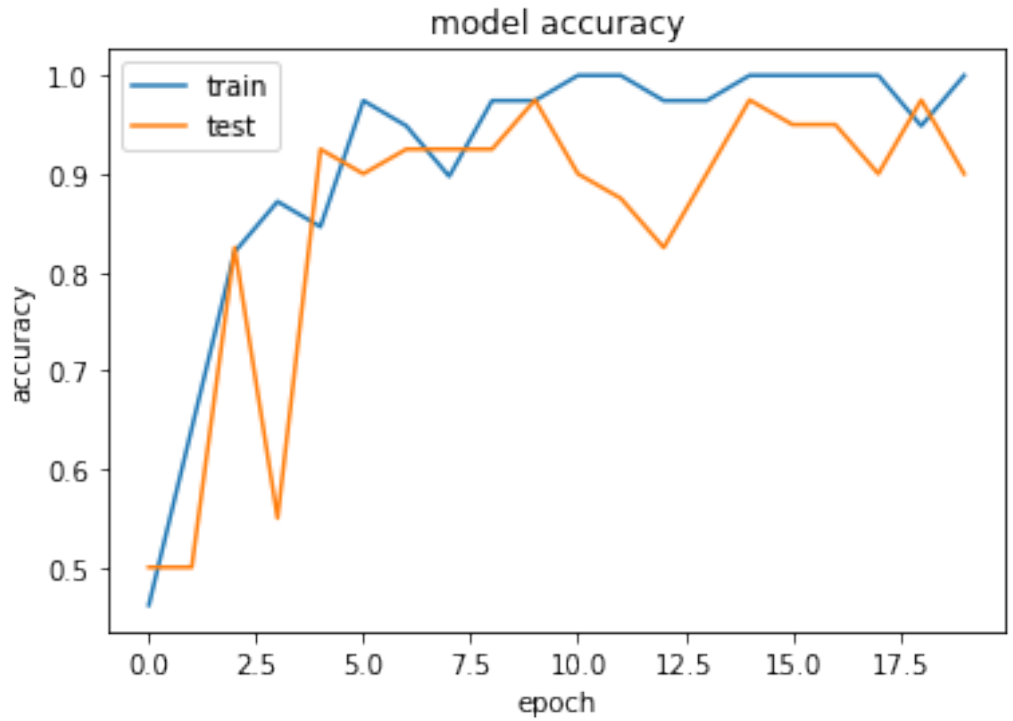
Deep convolutional neural network (CNN)

Fresh leaves | Infected leaves

Output

Model result after 20 epoch = accuracy: 0.9000





Key Learnings

- Mid- IR spectroscopy can detect red blotch virus infection in the early season
- Combination of spectroscopy and machine learning models can improve detection accuracy and enable automation
- NIR, hyperspectral and RGB imaging has a potential for late season detection of viral infection, potentially due to changes in the pigment content
- Evaluation of expanded NIR region (400-2500 nm) needs further evaluation
- Irrigation status and other nutrient stresses can influence the spectral features and thus training models with appropriate conditions is important

Thanks