STEREO: Agriculture and vegetation at a local scale

Early detection of biotic stress in fruit orchards using statistically-based hyperspectral analysis

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Objectives

Stress-induced variability

Determine if *Venturia inaequalis* infected leaves could be differentiated from healthy leaves by measuring their hyperspectral reflectance spectra

- At which developmental stage ?
- At which wavelength ?

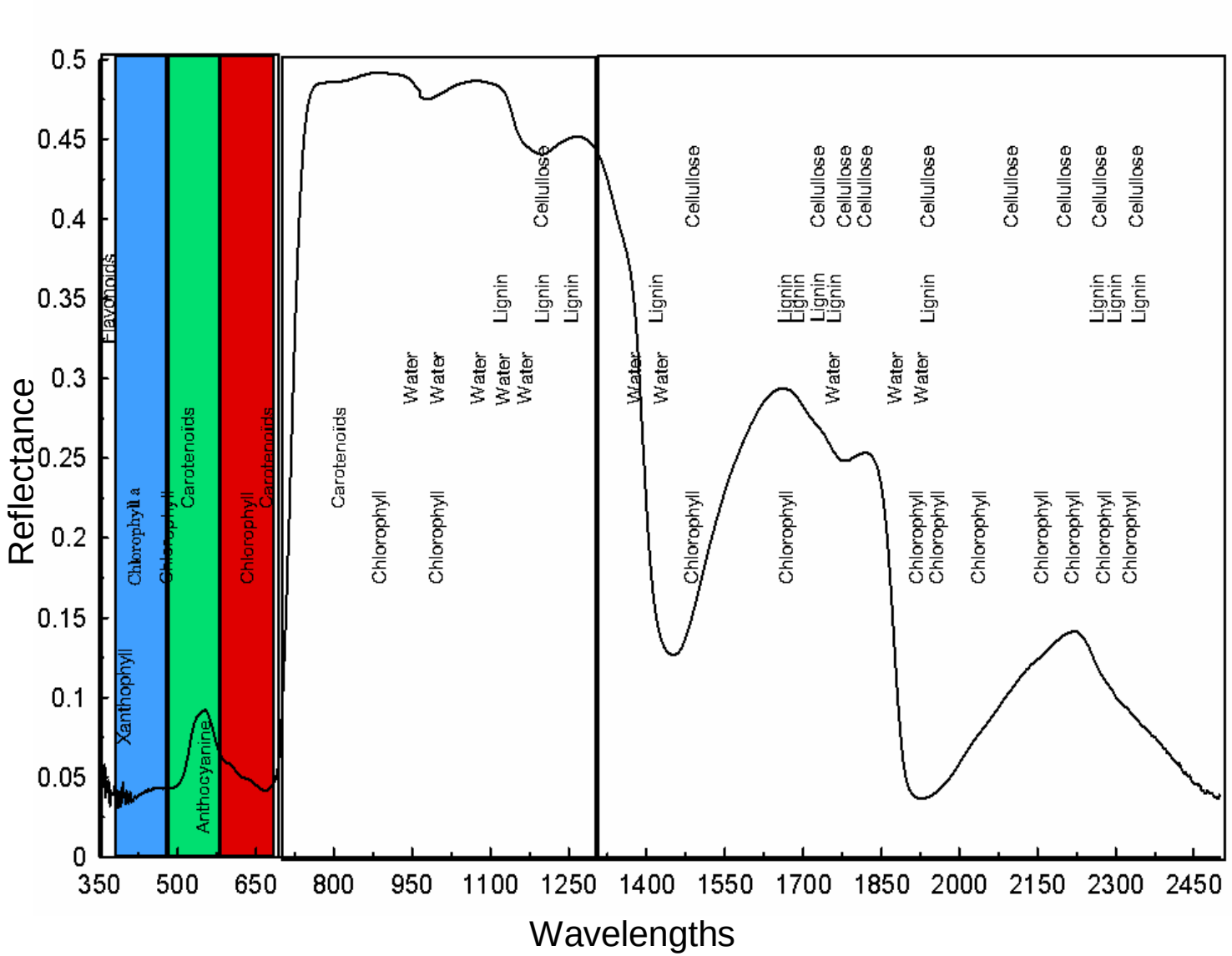
Phenological-induced variability

Determine if physiological changes in healthy leaves could be detected during the first days of development by measuring their hyperspectral reflectance spectra

- Link to physiological knowledge ?

Vegetation spectrum

Vegetation spectrum



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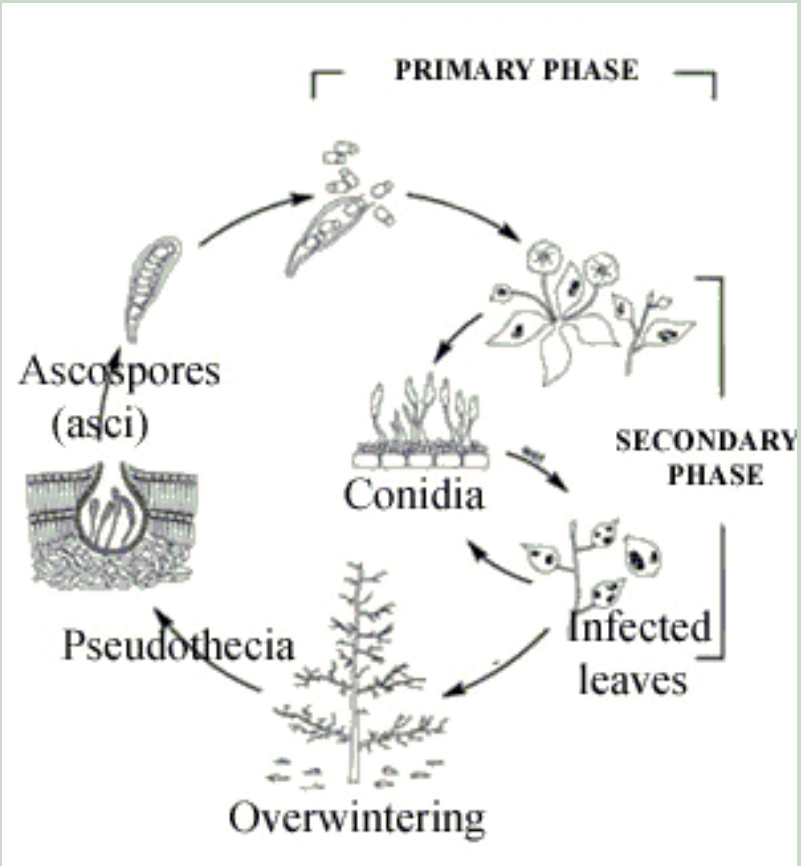
Apple scab disease cycle

Apple scab disease

Scab stress manifests in different stadia



Wayne F. Wilcox, 2005

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Vegetative Material

Cultivars

In vitro cloned cultivars	
Susceptible to scab	‘Braeburn’
Resistant to scab	‘Rewena’

Number of plants & measurements				
Infected	10 plants /cultivar	2 leaves /plant	2 measurements /leaf	Total: 40
Placebo	10 plants /cultivar	2 leaves /plant	2 measurements /leaf	Total: 40
Control	10 plants /cultivar	2 leaves /plant	2 measurements /leaf	Total: 40

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Methods

Objectives ⟶ Methods

Problem	• High dimensionality of the hyperspectral dataset (too many variables: 350-2500 nm) • Data not normally distributed
Solution	Logistic Discriminant Analysis (LDA) Tree-Based Modeling (TBM)

This research
Detection of differences between hyperspectral reflectance spectra of healthy and infected leaves using LDA and TBM

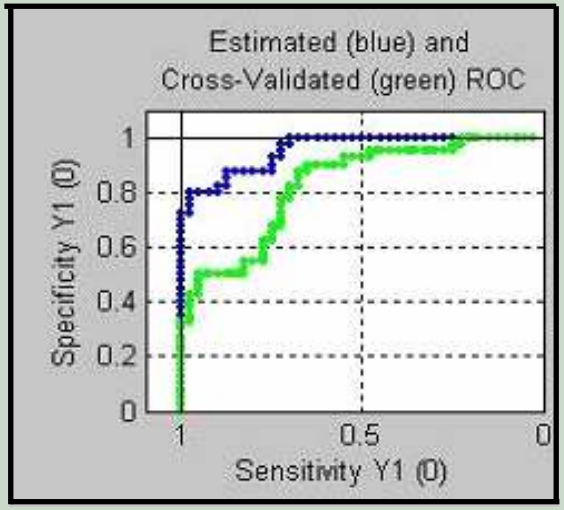
Logistic regression

Logistic regression

- Normal distribution not required
- Binary response variables stressed (0), healthy (1)

Step1 : Analysis at each wavelength (350-2500nm)

Step2 : Discriminatory performance (ROC-curve)



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Discriminatory performance

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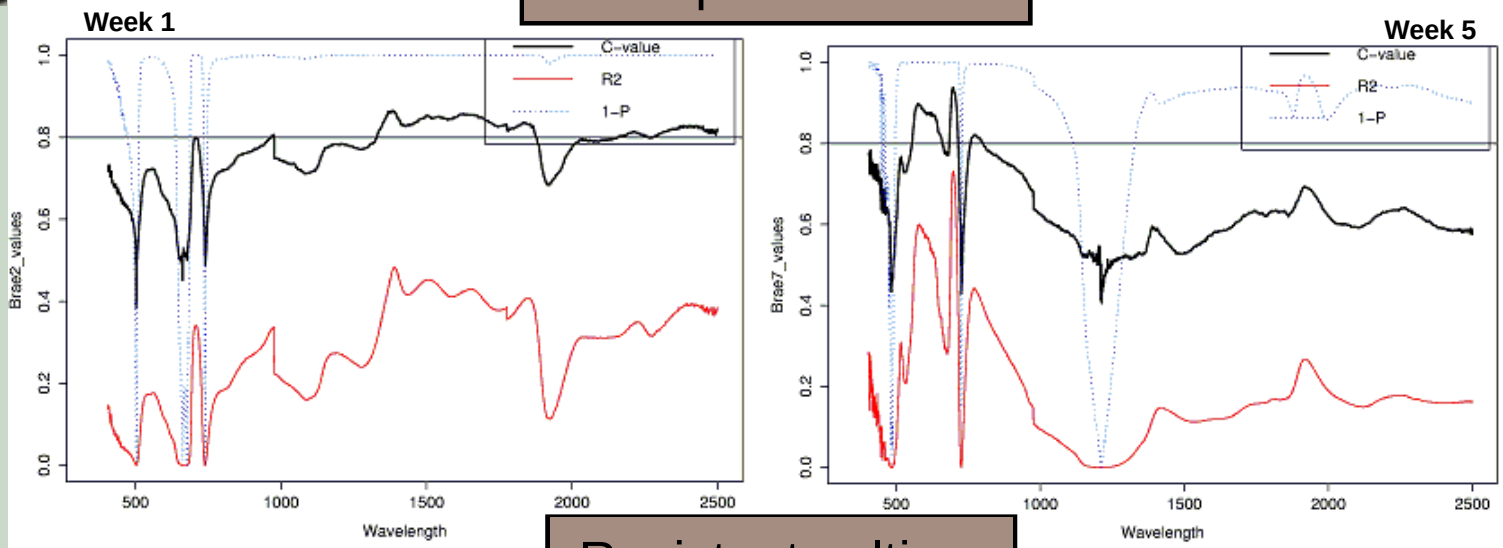
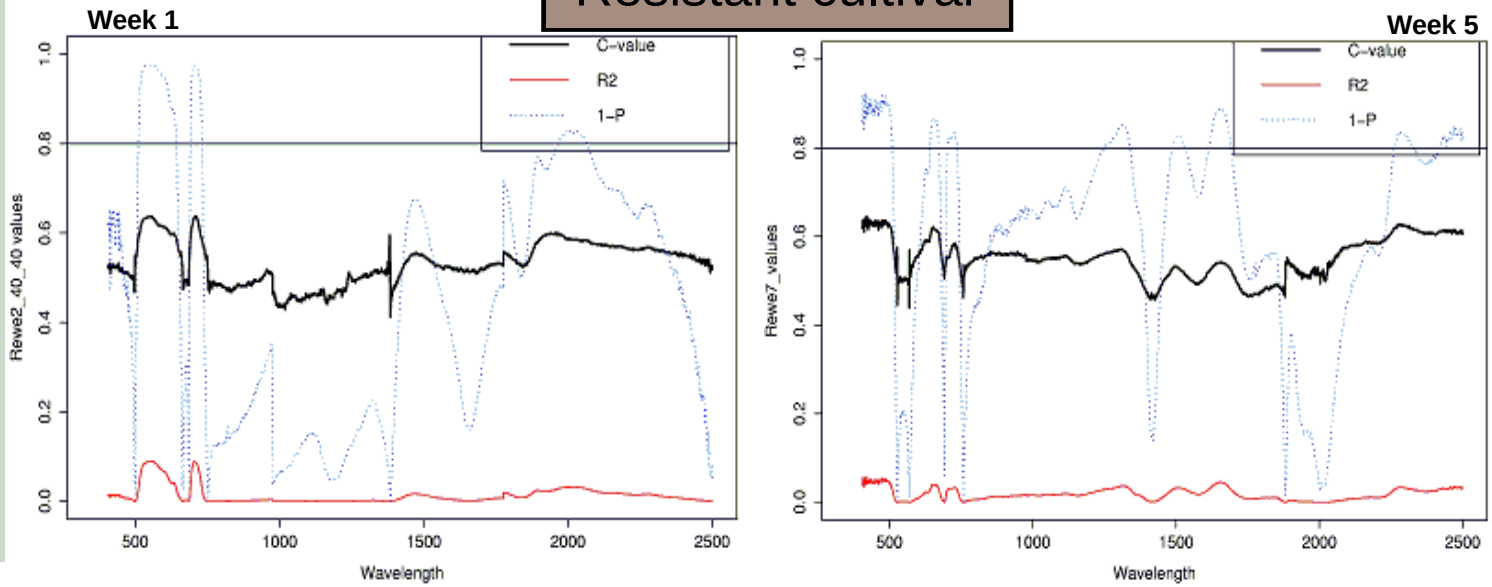
Logistic regression

Susceptible cultivar



Resistant cultivar



Tree-Based Modeling

Tree-based modeling

- Normal distribution not required
- Dimension reduction of high dimensionality

Step 1 : Define decision rules

Step 2 : Selection of splits - impurity criterion Gini index

Step 3 : Stopping rule - cost-complexity pruning, 10 x CV

Step 4 : Plurality rule

Step 5 : Accuracy - κ-values & correctness values

Results : Tree-based modeling

Braeburn : SUSCEPTIBLE CULTIVAR

Tree-Based Modeling

Day	Full TBM	CORRECT	κ	Pruned TBM	CORRECT	κ	1 WVL	CORRECT	κ
10	2447	0.87	0.72	2447	0.87	0.72	**2447**	**0.87**	**0.72**
14	1615+513	0.90	0.78	1615+513	0.90	0.78	**1615**	**0.85**	**0.70**
18	840	0.99	0.97	840	0.99	0.97	**840**	**0.99**	**0.97**
21	784+512	0.94	0.88	784+512	0.94	0.88	**784**	**0.92**	**0.85**
26	698	0.99	0.97	698	0.99	0.97	**698**	**0.99**	**0.97**
31	701+1433	0.94	0.88	701	0.93	0.85	**701**	**0.93**	**0.85**

Rewena : RESISTENT CULTIVAR

Tree-Based Modeling

Day	Full TBM	CORRECT	κ	Pruned TBM	CORRECT	κ	1 WVL	CORRECT	κ
10	531+741+1777+1397+697+581	0.88	0.75	531	0.59	0.18	**531**	**0.59**	**0.18**
14	401+1903	0.83	0.65	401	0.78	0.55	**401**	**0.78**	**0.55**
18	767	0.83	0.65	767	0.83	0.65	**767**	**0.83**	**0.65**
21	976+401	0.84	0.68	976+401	0.84	0.68	**976**	**0.75**	**0.50**
26	699+454+405+1594	0.91	0.83	699+454	0.81	0.63	**699**	**0.71**	**0.43**
31	2439+1938+414+410	0.91	0.83	2439+1938	0.79	0.58	**2439**	**0.69**	**0.38**

Logistic regression ~ TBM

Discriminatory performance

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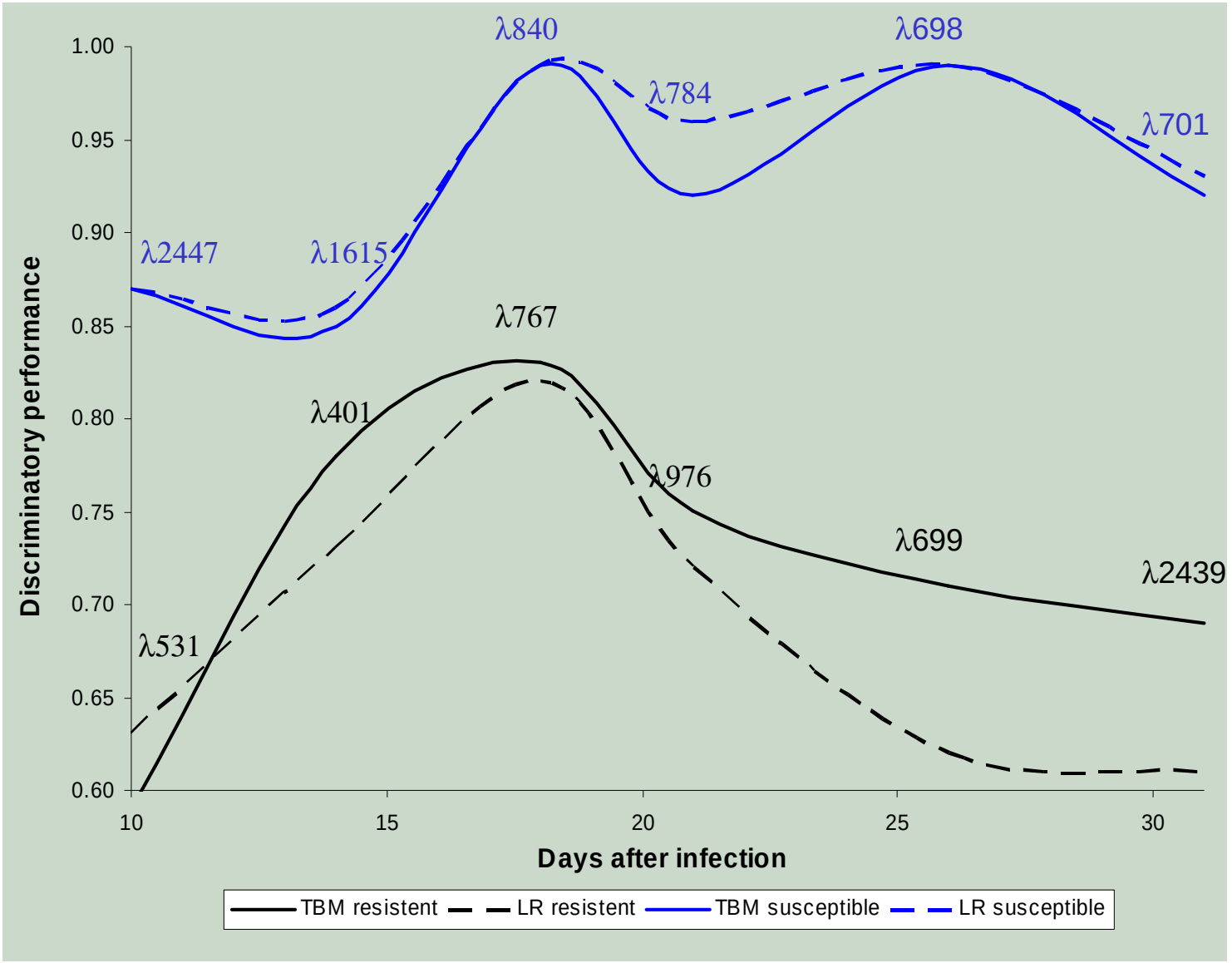


Conclusions – Stress Detection

Conclusions

Immediately after infection

- Susceptible cultivars: 1500nm –1800nm, 2450 nm

Two weeks after infection

- Susceptible cultivars: 700nm – 850 nm
- Resistant cultivars : 970nm, 1650nm

30 days after infection

- Susceptible cultivars: 550-715 nm, ~1500 nm

Phenological variability

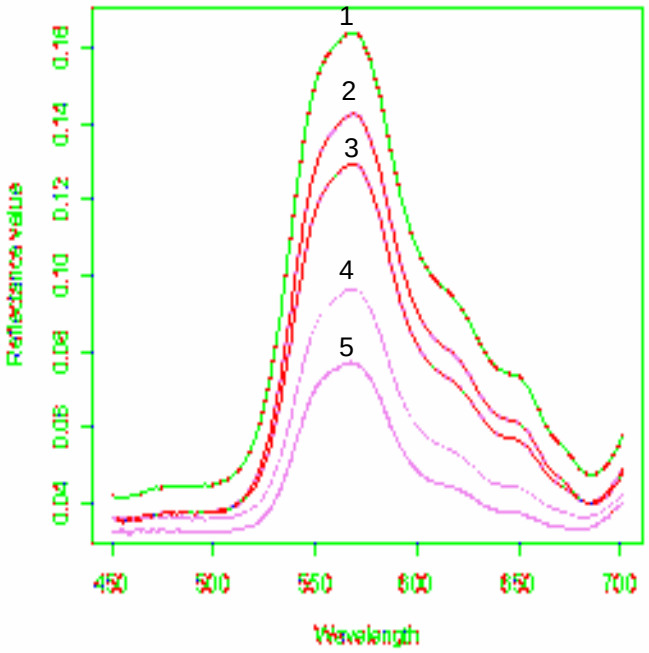
Phenological variability

- Causality of the results of the scab experiment ?
- Normal growth process ⟷ Stressed
- Ontogenic resistance ?
- Test TBM on dataset of which the physiological changes are well-known

↺ feed-back physiological knowledge

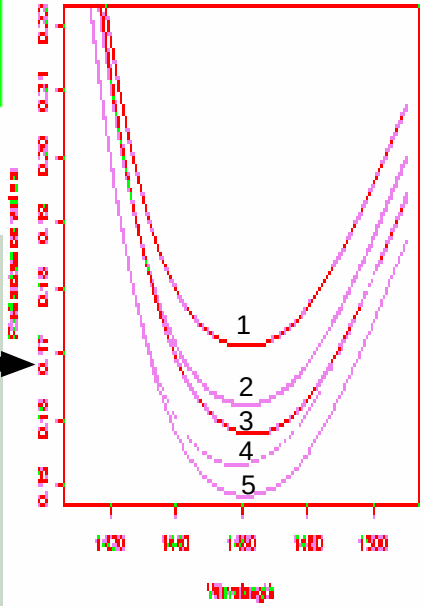
Phenological variability

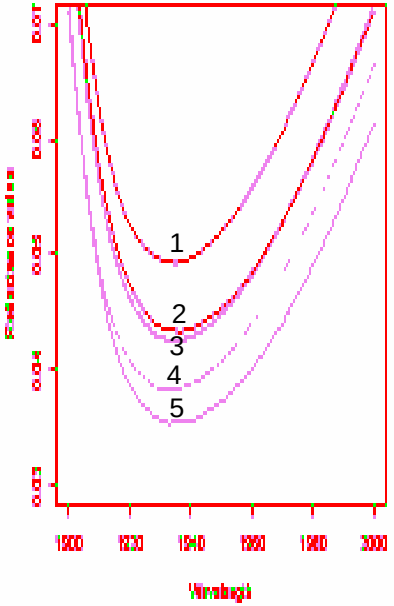
Tree-based modeling



VIS region dominated by pigment amounts

1450 nm and 1940 nm main water absorption bands





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Tree-based modeling

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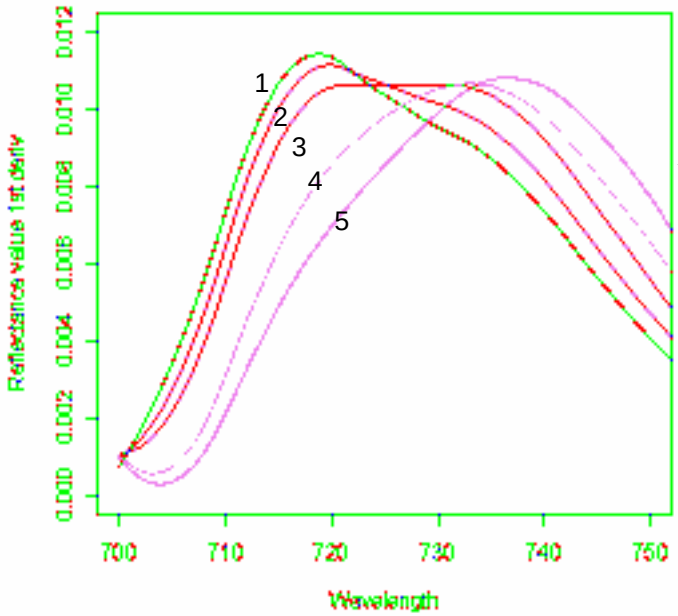
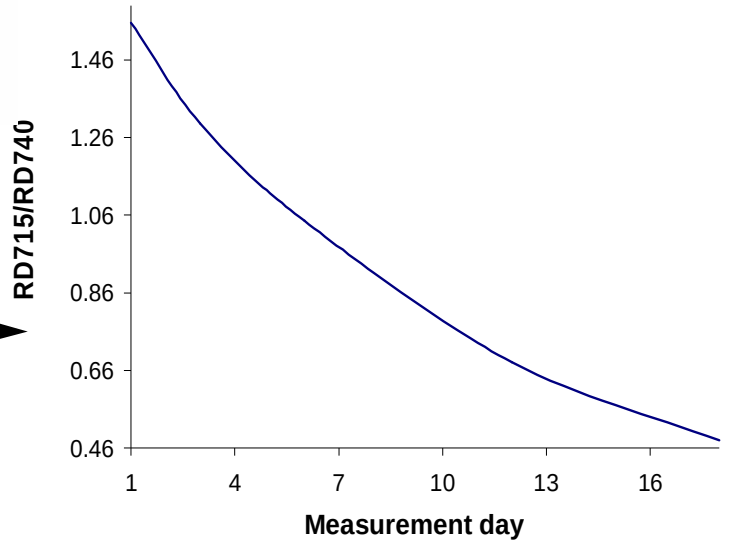
Red edge characteristics



Red Edge Inflection Point (REIP)

1st derivative reflectance values in red edge region

First derivative ratio of $\lambda_{715\ nm}$ and $\lambda_{740\ nm}$



Phenological variability

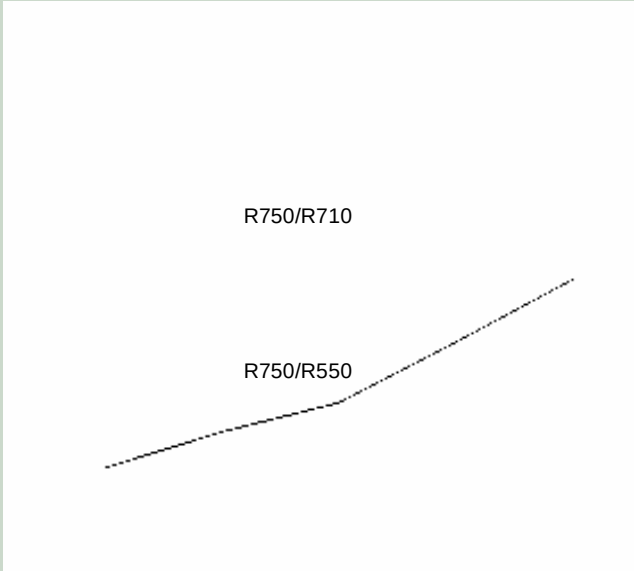
Physiological feed-back

REIP shifts to longer wavelengths

→[Chl] ↗ (absorption feature around 670nm broadened)

Feed-back **chlorophyll-related indices :**

(Zarco-Tejada *et al*., 2001)



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Conclusions

Conclusions - Phenology

Feed-back physiological knowledge

- Pigment concentration increases during first days after leaf development
- Results of TBM can be explained by physiological knowledge

TBM

- TBM was succesful in detecting effects of physiological changes in plants using hyperspectral data

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For further information

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