OPTIMA

THIS PROJECT HAS RECEIVED FUNDING FROM THE **EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME** UNDER GRANT AGREEMENT N. 773718

Novel sensing and machine learning techniques for in field disease detection

Workshop on Adoption of Digital Technology for Data Generation for the efficacy evaluation of Plant Protection Products - 2022-06-27/29 - Ede (NL)

Gerrit Polder, Wageningen University & Research

Wageningen University & Research

- A university plus R&D organisation for innovation in the agrifood sector.
- Working with industry, governmental authorities and other knowledge institutes
- 6.500 employees
- 12.000 students
- 100 countries
- 65 researchers on Agro Food Robotics

- Gerrit Polder
- 30 years at Wageningen University & Research.
- Senior scientist computer vision for plant phenotyping
- Background: Electronics/Applied Physics.
- PhD on Spectral Imaging

OPTimised **I**ntegrated Pest **MA**nagement

for precise detection and control of plant diseases in perennial crops and open-field vegetables

An EU research project (Horizon 2020 framework)
1 September 2018 – 30 June 2022

5 Main Objectives

OPTIMA

- **Optimize** plant disease prediction models and **develop** advanced early disease detection methods.
- Evaluate and screen biological and synthetic PPPs and assess plant and pathogen resistance mechanisms for **successful disease control.**
- Enhance and develop **innovative** precision spraying technologies.
- Test and evaluate the proposed **new IPM elements** under field conditions.
- Assess health, environmental and socioeconomic impacts and risks of the proposed **IPM system**.

- Early disease detection methods can be utilised as a tool to measure the effect of plant protection products.
- This presentation describes research on disease detection systems, for different crops and diseases, based on colour and spectral imaging and deep learning techniques to precisely localise and quantify infections, as applied in the OPTIMA project.

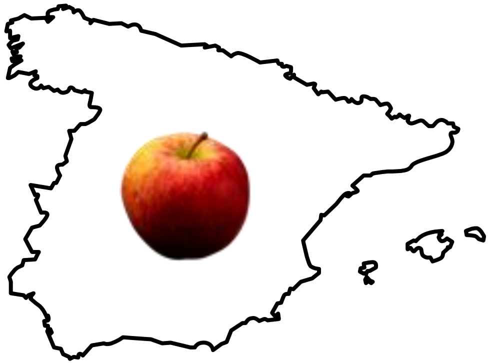
Field contexts where OPTIMA activities will be carried out :

FRANCE

Crop: carrots in open field

Disease: *Alternaria leaf blight*

SPAIN



Crop: apple orchards

Disease: *Apple scab*

ITALY

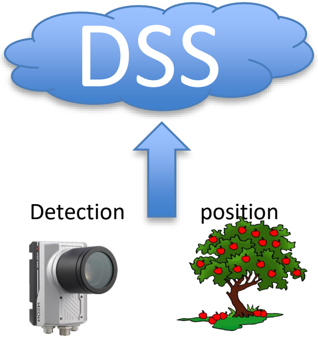
Crop: vineyards

Disease: *Grape downy mildew*

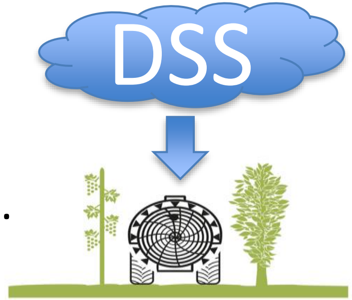
EDS DSS system overview

A camera based early detection system for scab in apple orchards.

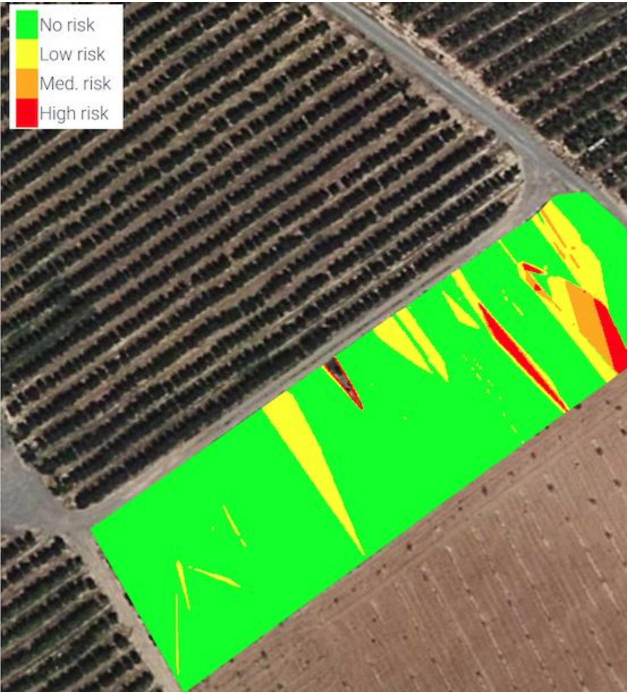
Detections are sent along with location information to a decision support system in the cloud.



The decision support system will advice on spraying actions.



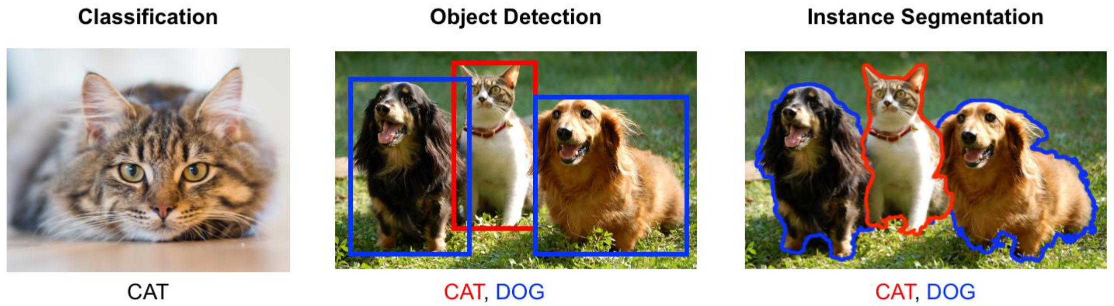
DSS Prescription Maps



Early detection system approach

- RGB Imaging
  - Smart Camera
  - Deep Learning
- Spectral Imaging
  - Traditional machine learning
  - Deep learning

Deep Learning Approach



- Classification (EfficientNet-B5)
  - Healthy/diseased
  - One hit, probability = confidence
- Detection (YOLO-V5)
  - Multiple spots in one image
- Fancy new thing (EfficientNet-B0):
  - Classification on image patches

Downy mildew in grapes:

- Dataset 2019 + Dataset 2020 (IDS Ca
  - Training dataset:
  - Validation dataset: 5
  - Test dataset: 4

Images taken automatically from a moving platform

- Data from Greece and Italy
- Diseased spots were annotated by UN exp
- Three crop cultivars (Barbera, Moscato, Agl
- Dataset 2021 (EDS Field campai Italy, 700

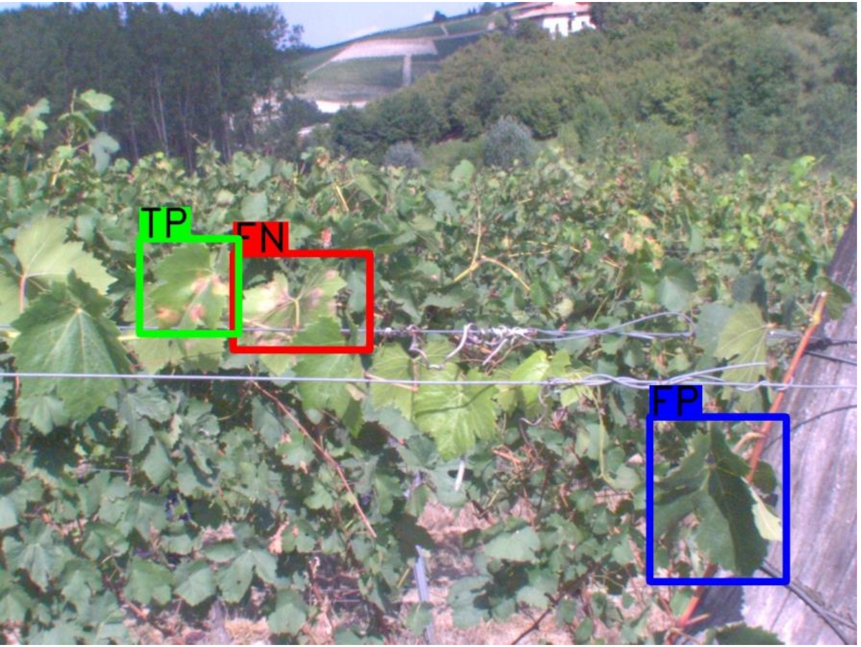
Images taken in a 'controlled' way

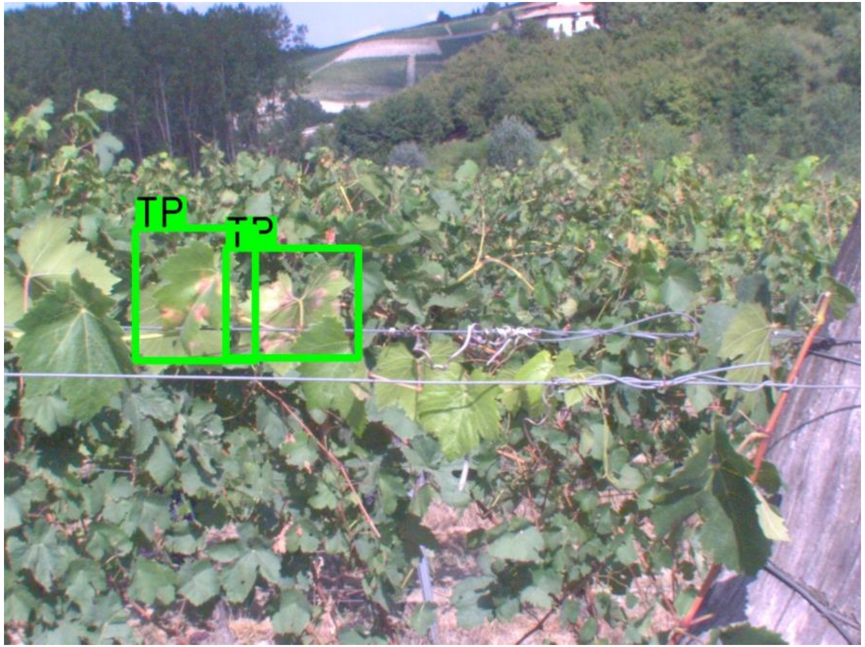
Training dataset:	235	(77%)
Validation dataset:	35	(11.5%)
Test dataset:	35	(11.5%)

Downy mildew in grapes:

OPTIMA

- Detections original and after retraining on 2021 data





Downy mildew in grapes:

- EI
-

F1-score decreased from 86% and 67% on 2019/2020 data due to different image acquisi[...]

More annotated data with more variation will increase this score

Ground-truth				
Downy-Mildew	47	58		
Healthy	118	-**	-	
Total	165	-**	-**	
Precision	28.5%			*F1-score* 34.8%

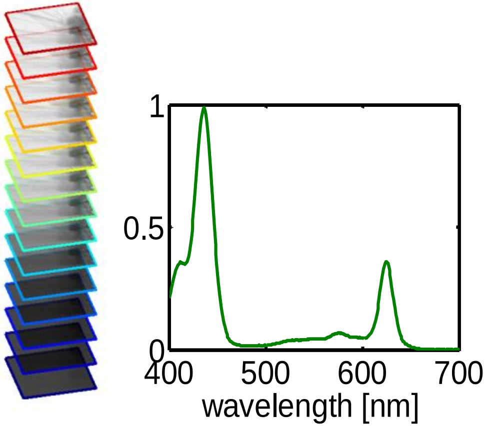
Original

Total	79	-**	-**	
Precision	77.2%			*F1-score* 66.3%

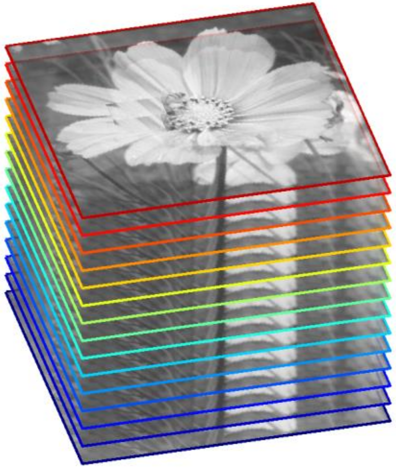
Retrained on 2021

Spectral Imaging

Spectroscopy



Spectral Imaging / Imaging Spectroscopy

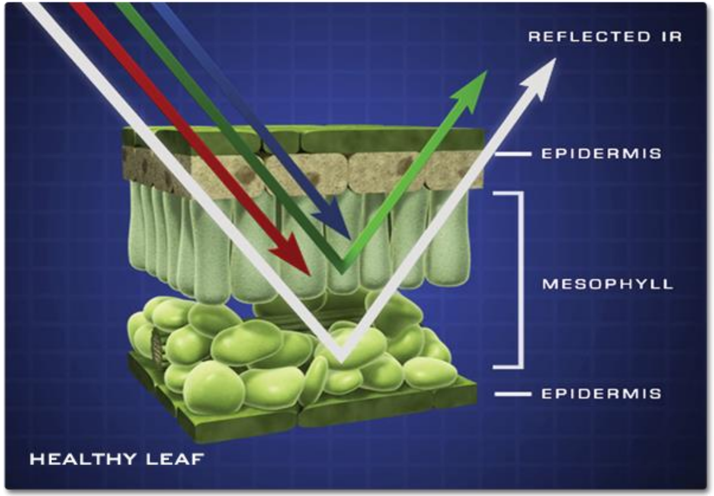


Imaging

Spectral Imaging

- Why Spectral Imaging?
  - Imaging access plant structure
  - Spectroscopy provides chemical composition
    - VIS (400-700 nm): pigments
    - NIR (700 – 2500 nm): moisture and internal structure of plant leaves

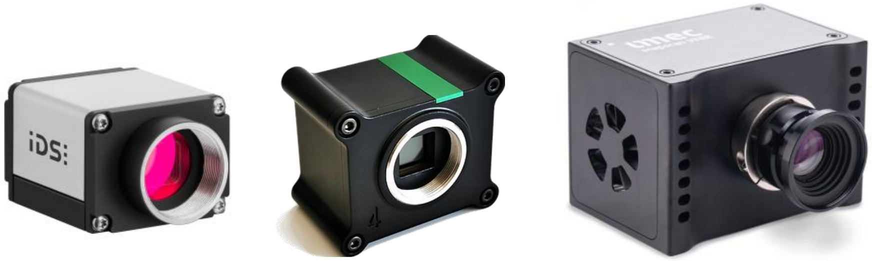
@Humboldt state University

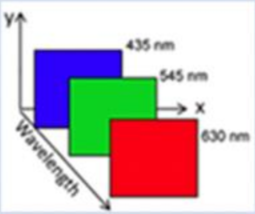


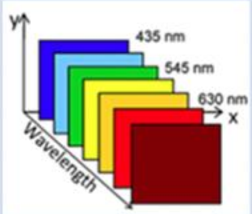
- *Mishra, Puneet, et al. "Close range hyperspectral imaging of plants: A review." Biosystems Engineering 164 (2017): 49-67.*

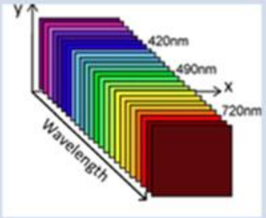
Spectral Imaging

- Camera types
- Spectral/spatial resolution





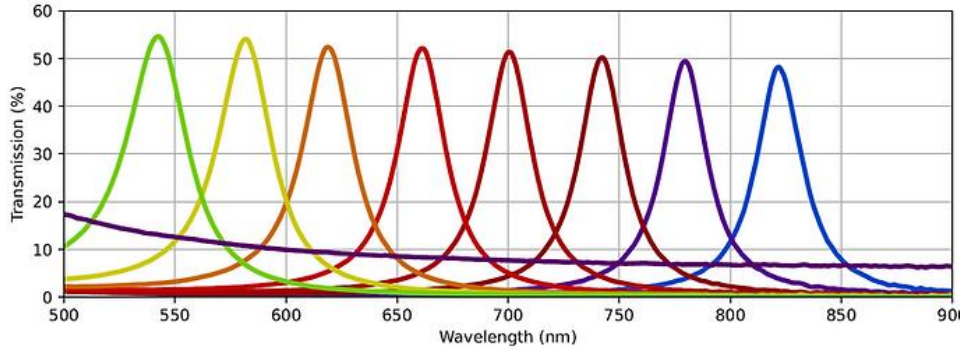




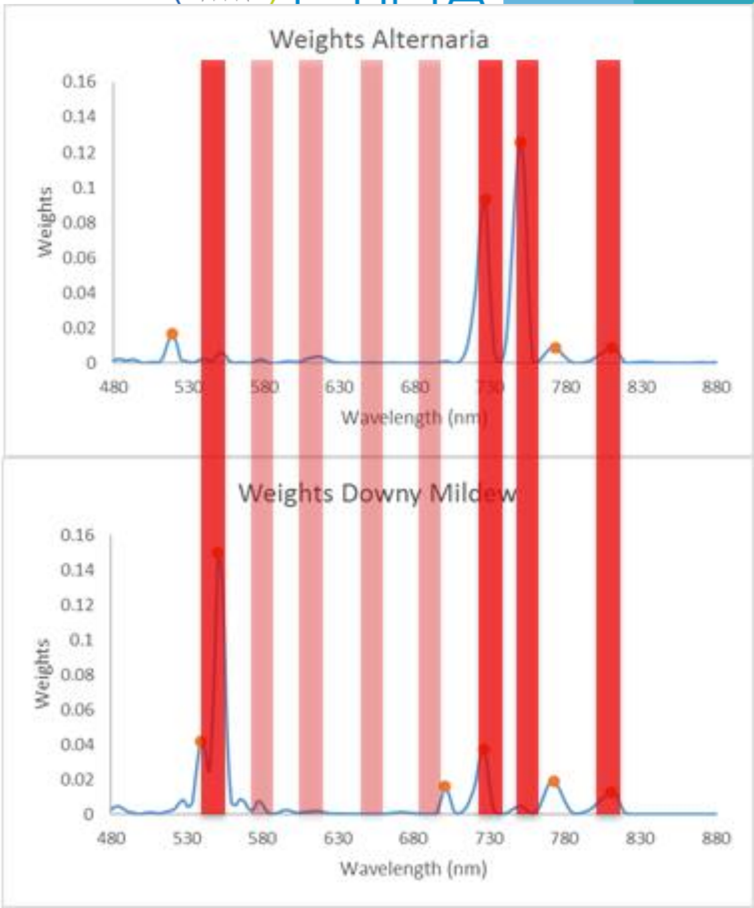
High spectral but zero spatial info	High Spatial but very low spectral info	High spatial and moderate spectral info	High spatial AND spectral info
Fast	Fast	Fast	Slow

Source: (http://www.spectricon.com/spectral-imaging/)

Spectral Camera Selection



- SILIOS CMS-V 4
  - 8 wavelength MS Camera
  - 682 x 682 resolution



Multispectral DL Dataset

- Performed on annotated Apple Scab data.
- Spectral Images converted into false color using three most discriminating Wavelengths (545 nm, 743 nm, 824 nm).
- RGB Yolo Ne... o...

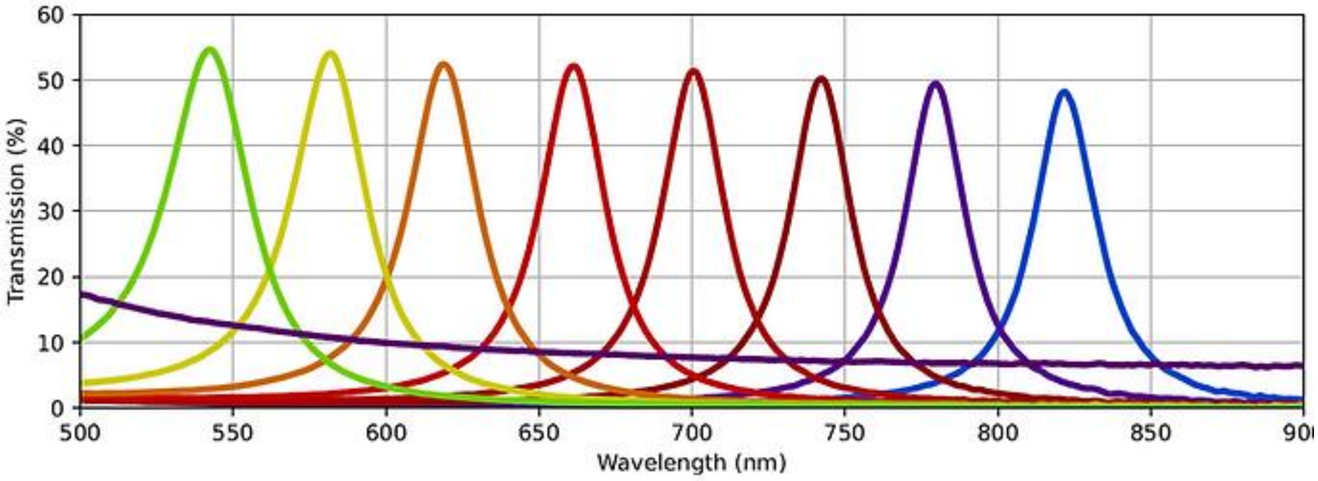
But our camera has 8 bands

Ground-tr				
Apple scab				
Healthy				
Total				
Precision	100.0%			76.9%

YOLOv5 multispectral image analysis

- Research question:

  What is the effect on the YOLOv5 performance when using images with more channels (6 and 9) compared to using 3-channel images?



YOLOv5 multispectral network

- Standard YOLOv5 network from Ultralytics: https://github.com/ultralytics/yolov5
- Dataloader added that can process the multichannel images (basically by stacking multiple 3-channel images into a bigger image tensor)
- Transfer-learning: duplicate the COCO weights of the first network layer (for the number of image channels):
  - 3 channel image: 1x
  - 6 channel image: 2x
  - 9 channel image: 3x

Image visualized - RGB

Image visualized – SegN image

Result of Segmentation network based on 9 band spectral Image data

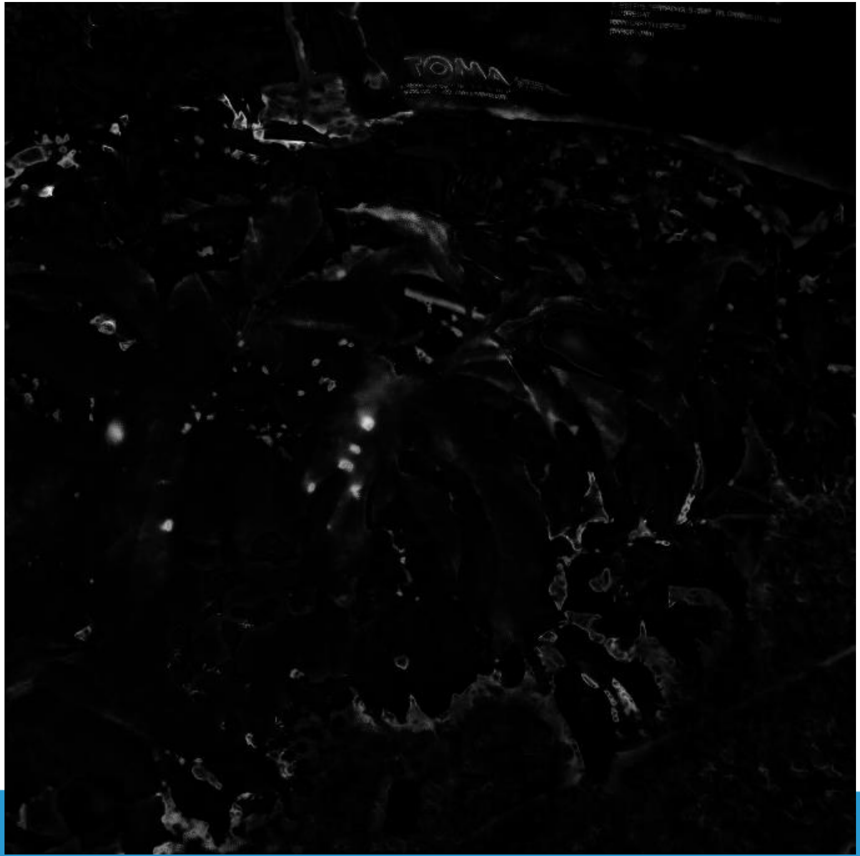


Image visualized – MS image 7,3,1

Image visualized – MS image 7,3 + SegN

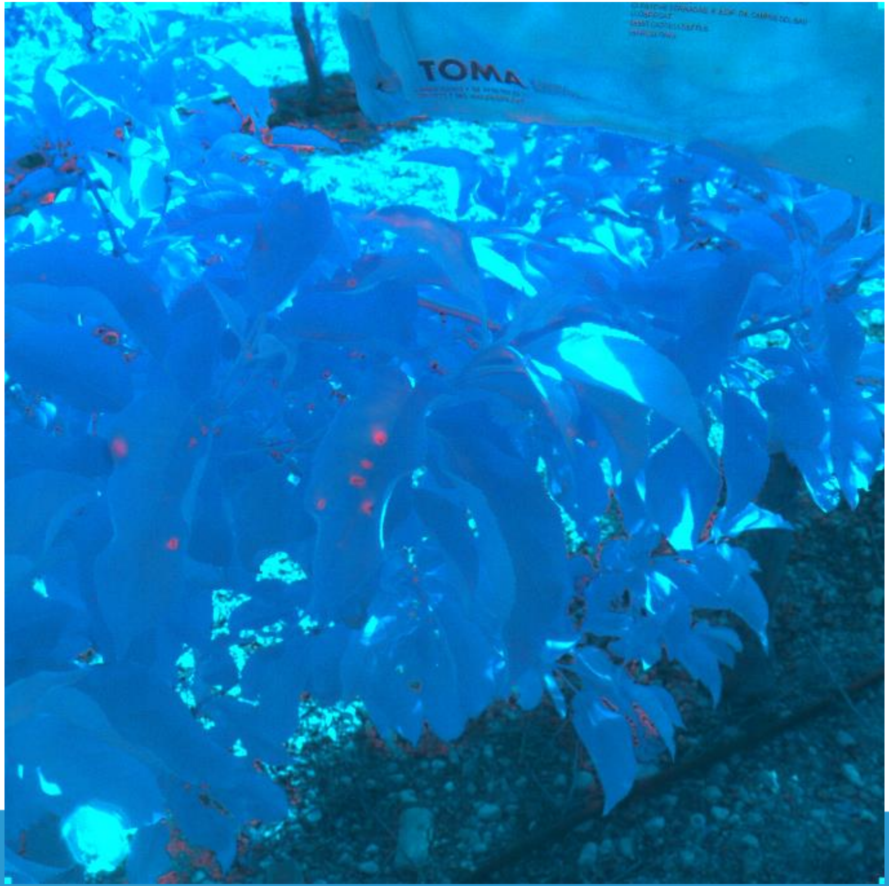


Image visualized – MS image 7,3,1,5,2,6

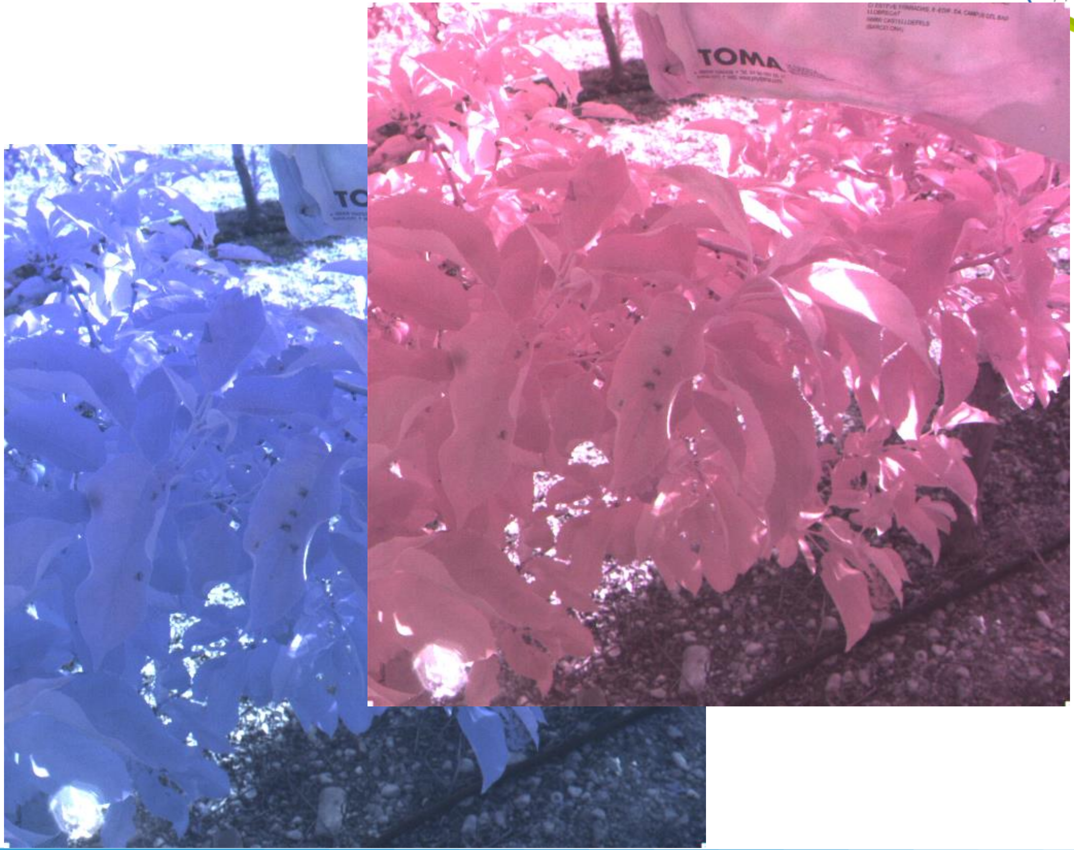


Image visualized – MS image

7,3,1,5,2,6,8,4,0

Preliminary results show that although symptoms are better visible in MS, classification performance is not significantly better

Take home message

- Disease detection as used in integrated pest management, can be utilised as a tool to measure the effect of plant protection products.
- Data is the key.
  variation/annotation/pretraining
- More bands that are beneficial require a much larger annotated MS dataset.

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time for questions

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