3rd European Conference on Xylella fastidiosa and XF-ACTORS final meeting

A Model and Image based Investigation of *Xylella fastidiosa* Dynamics

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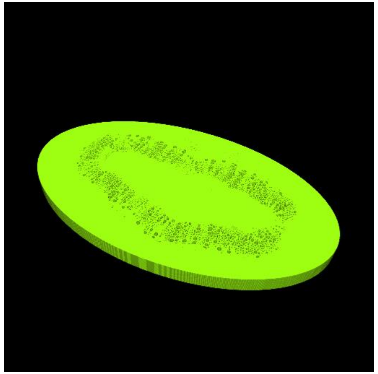


MOTIVATION

- *Xylella* causes disease symptoms by forming biofilms.
- Biofilms act to restrict flow of water in host xylem.
- Mechanisms of resistance are still not well understood.

HYPOTHESES:

Differences in xylem geometry contribute to reduce the impact of *X. fastidiosa* biofilm development on hydraulic conductivity in resistant compared with susceptible olive cultivars.

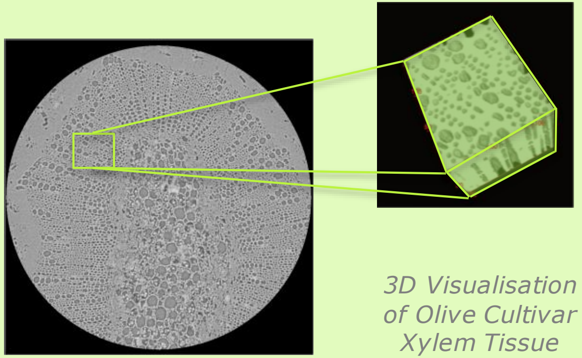
In particular, we hypothesise that resistant cultivars have larger diameter vessels than susceptible cultivars.

3D Visualisation of Xylem Vessels

OBJECTIVES

XCT IMAGING

- 3D X-ray Computed Tomography (XCT): used to visualise xylem vessels.
- We measure differences in aspects of xylem geometry between resistant and susceptible cultivars.

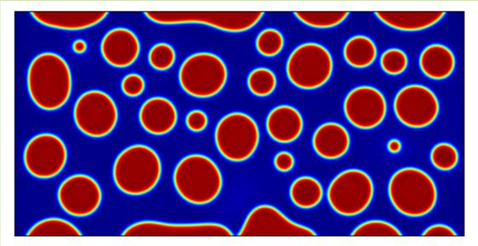


3D Visualisation of Olive Cultivar Xylem Tissue Networks

MATHEMATICAL MODEL

- A model will be developed to describe *X. fastidiosa* biofilm.
- The models aim to capture biofilm structure, development, organisation and growth.

Simulation of Biofilm Aggregation



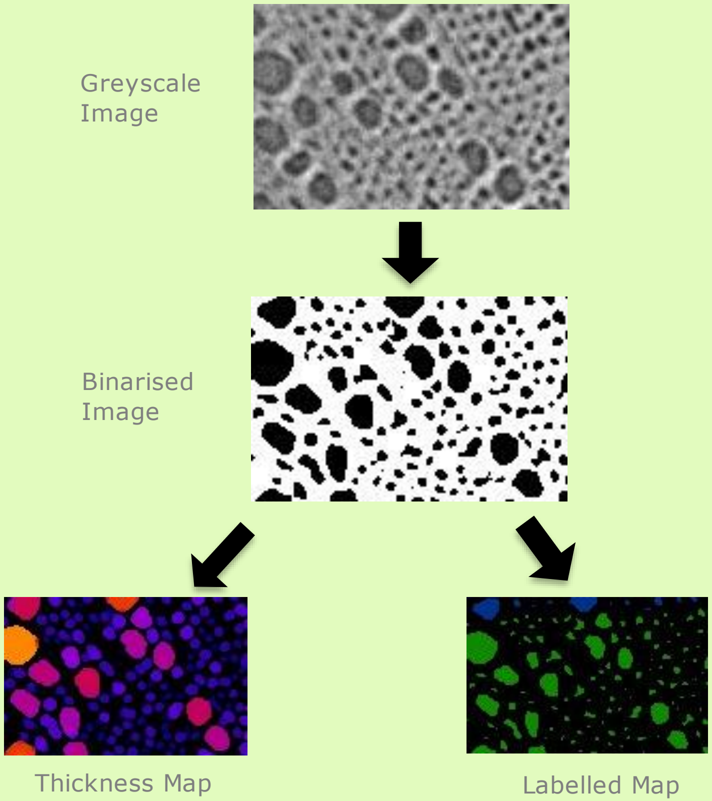
METHODS – XCT IMAGING

Cultivars Scanned

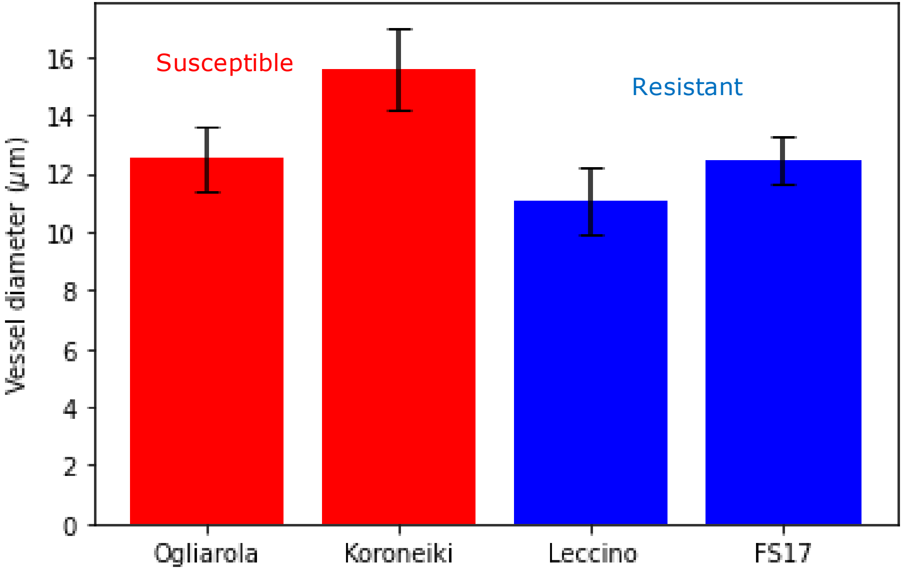
Susceptible	Resistant
Ogliarola	Leccino
Koroneiki	FS17

- We develop a custom image processing workflow to analyse xylem networks.
- We quantify vessel diameters which correspond with hydraulic conductivity.
- Obtained xylem networks will also aid model parametrisation and will form the spatial domain for simulations.

Image Analysis Workflow



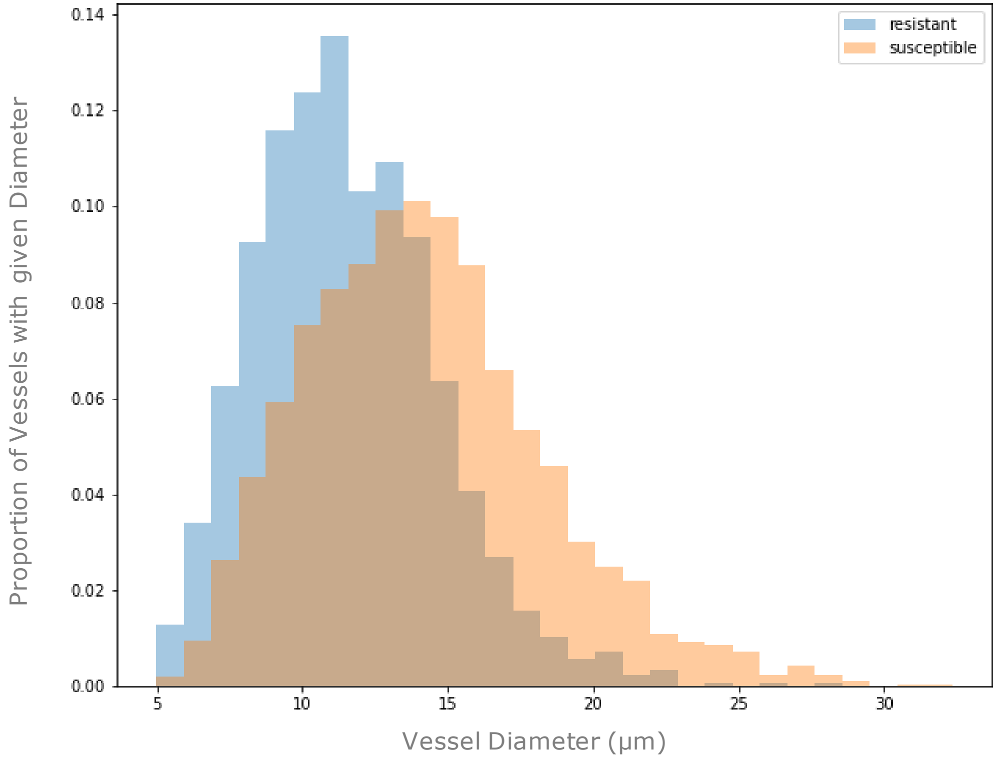
PRELIMINARY RESULTS AND OUTLOOK: CT MEASUREMENTS



Preliminary Results:

- There was no statistically significant difference ($p = 0.062$, 1 way ANOVA) between cultivar mean vessel diameters.

PRELIMINARY RESULTS AND OUTLOOK: CT MEASUREMENTS



Preliminary Results:

- There was no statistically significant difference ($p = 0.062$, 1 way ANOVA) between cultivar mean vessel diameters.
- However, if we look at the individual vessels, we see there is a difference in the distribution of diameters.
- Susceptible cultivars have larger vessel diameters than resistant ones.

Outlook:

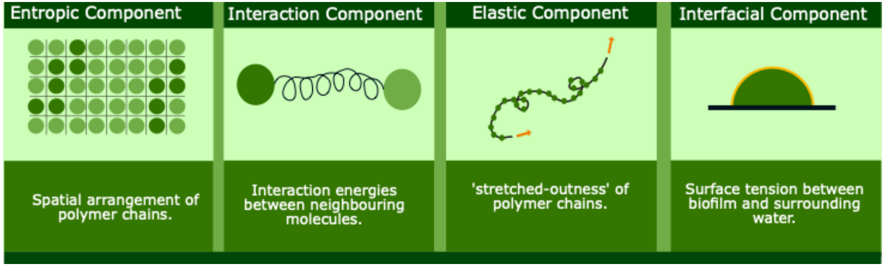
- Unexpected result - investigate other morphological features between resistant and susceptible cultivars (connectivity).

METHODS – MATHEMATICAL MODEL

- Biofilm – bacteria enclosed in extracellular polymeric substance (EPS) molecules - dominant component in determining 3D structure.

- Thus, we approximate the biofilm as a water-polymer mixture, capturing biofilm structure based on physiochemical first principles.

Physiochemical Components of Hydrogels



ORGANISATION

Model Equations

GROWTH

1 $$\partial_t \phi + \nabla \cdot \left(\phi \left[\boldsymbol{u} - \frac{\phi(1-\phi)^2}{\zeta} \nabla \mu \right] \right) = \boxed{s}$$

Biofilm phase conservation equation – describes transport and formation of biofilm phase (ϕ)

2 $$\mu = \partial_\phi f - \kappa \nabla^2 \phi$$

Biofilm chemical potential (μ)– Energetic description of how biofilm spatially organises (f, κ)

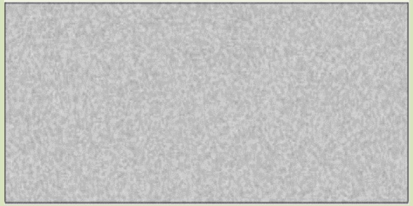
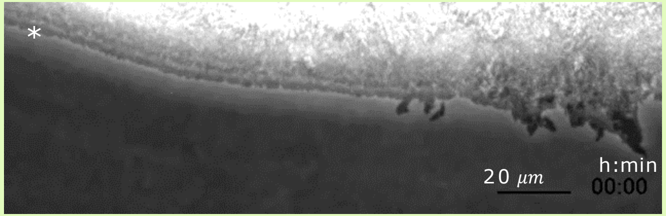
3 $$\nabla \cdot \eta \nabla \boldsymbol{u} - \nabla p = \phi \nabla \mu$$

Stokes flow – Momentum of bulk fluid flow $(\boldsymbol{u})$ considering chemical (μ) and pressure (p) potentials

4 $$-\nabla \cdot \boldsymbol{u} = 0$$

Divergence free – Implies a balance between mass conservation

PRELIMINARY RESULTS AND OUTLOOK: BIOFILM MODEL

	ORGANISATION	GROWTH
MODEL SIMULATIONS		
ACTUAL *XYLELLA* BIOFILMS		

Preliminary Results:

- Model simulations are able to capture spatial organisation with just the polymer physics.

Outlook:

- Accurate parametrisation of growth source term is still required.

- The model will later be applied to XCT-based geometries from susceptible and resistant olive cultivars.

*Experimental results from: http://web.pppmb.cals.cornell.edu/hoch/movies/ - Leonardo de la Fuente

Zenodo Poster

CONCLUSIONS AND ACKNOWLEDGEMENTS

Conclusion:

- CT results show that vessels from our samples of resistant cultivars have on average smaller, and more similar diameter than those from samples of susceptible cultivars.
- Model simulations are able to capture spatial organisation with just the polymer physics.

Future Work:

- Investigate additional morphological features between resistant and susceptible cultivars.
- Apply model to XCT-based geometries from susceptible and resistant olive cultivars to capture any differences in disease development.

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UKRI Natural Environment Research Council

INSPIRE

UK Centre for Ecology & Hydrology

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