Tree-ring anatomy and carbon isotope ratio reveal direct and legacy effects of climate on xylem formation in Mediterranean Pinus pinea

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Xylem anatomy

Tells us about the xylem **structure**
Different cell features provide information on different processes:
• Lumen size -> cell enlargement
• Cell wall thickness -> wall thickening

Stable isotopes

Tell us about the xylem **chemical composition**

$^{13}\text{C}/^{12}\text{C}$ isotope ratio in xylem provides information on:
• Carbon assimilation at leaf level
• Carbon transfer from leaf to xylem
• Processes that control plant–atmosphere exchanges

... we used them in the same study
What resolution?

Multiple rings

Ring
What resolution?

Intra-ring, early / latewood separation

Intra-ring, in continuum

From continuous information we can get discrete data
Species and study area

*Pinus pinea* (L.) Umbrella pine or Italian stone pine

- Castelvolturno Natural Reserve
- Close to the Tyrrhenian seashore
- Arenosols with low water holding capacity
- Artificial 60 years old plantation
- Tree diameter 40 ± 11 cm, height 14 ± 1 m
Research hypotheses

1) Xylem anatomy is affected by water availability throughout the growing season, and lumen size is the most affected parameter

2) Xylem isotopic composition is related to precipitation in the growing season
Xylem anatomy

- 10 trees: Cross sections (12 μm thick) of 30 rings (1984 to 2013)
- Images taken with digital camera
- Processed with ROXAS, >700,000 tracheids

Lab: TESAF department (Padua)

Carbon isotope

- 5 trees: Cellulose extraction for 30 rings (1984 to 2013)
- Continuous-flow isotope ratio mass spectrometry
- Calculation of $\delta^{13}$C relative to the Vienna Pee Dee Belemnite standard

Lab: IRMS-SUN (Caserta)
What resolution should we use, analyzing Mediterranean trees?
Methods: resolution

Isotopes: earlywood / latewood split
Anatomy: in continuum

<table>
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<th>Parameters</th>
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<tr>
<td>$\delta^{13}\text{C}$</td>
<td>on EW and LW</td>
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<td>Cell number</td>
<td>on EW and LW</td>
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**Methods: resolution**

**Parameters**

- $\delta^{13}C$ on EW and LW
- Cell number on EW and LW
- Lumen and cell diam on 10+5 sectors
- Cell-wall thickness on 10+5 sectors
Statistical methods

1. Inter-relationships among parameters

2. Correlations between parameter and climate 30-year time series

Daily weather records from Grazzanise meteorological station, 10 km from the study area
Earlywood (blue) and latewood (red) parameters clearly separated.

Cell size and number separated from cell-wall thickness and $\delta^{13}C$. 

Inter-relationships between parameters.
Cell enlargement is highly sensitive to water availability.

Strong positive correlation along the growing season.
Under water shortage, trees close stomata

Increased δ^{13}C in leaves

Negative relation between precipitation and δ^{13}C

If recently absorbed carbon goes in the wood, we should see this signal in the ring
Climate-$\delta^{13}$C relationships

We see this in earlywood, but not in latewood!

Where we see correlations with temperature many months before
Summing-up

Earlywood and latewood parameters are independent to each other
Summing-up

Earlywood and latewood parameters are independent to each other

Research hypotheses
1) Xylem anatomy is affected by water availability in the growing season, and lumen size is the most affected parameter

Direct influence of precipitation on xylem structure
Summing-up

Earlywood and latewood parameters are independent to each other

Research hypotheses

2) Xylem isotopic composition is related to precipitation in the growing season

Direct and legacy influence of climate on xylem chemical composition
Thanks for your kind attention!

Daniele CASTAGNERI,
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Tree-ring anatomy and carbon isotope ratio show both direct and legacy effects of climate on bimodal xylem formation in *Pinus pinea*

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Received January 16, 2018; accepted March 16, 2018; published online April 24, 2018; handling Editor Lucas Cermusak