

# XVII HISPANO-PORTUGUESE INTERNATIONAL SYMPOSIUM ON WATER RELATIONS

PAMPLONA  
FEBRUARY 25-27th, 2026



**XVII Spanish-Portuguese Symposium**  
**on Plant Water Relations**

*Water relations in plants to address current  
challenges for plants*

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### Differential response of stem CO<sub>2</sub> efflux to soil and stem temperature in two Mediterranean oaks with contrasting water use strategy

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#### Abstract:

Determining the origin of stem CO<sub>2</sub> efflux and its contribution to the overall forest carbon balance is challenging. Not all the CO<sub>2</sub> produced by respiration in woody tissues is emitted directly to the atmosphere, but dissolved and transported within the xylem. Furthermore, the CO<sub>2</sub> respired within the soil can be transported upwards and contribute to the CO<sub>2</sub> efflux measured at the tree stem. In order to disentangle this complex process, we have developed an automated system to quantify and trace the metabolic origin of stem CO<sub>2</sub> efflux. This system is composed by dynamic steady-state stem chambers where the CO<sub>2</sub> efflux and its isotopic fingerprint (<sup>13</sup>C and <sup>18</sup>O) are measured in real time together with environmental variables (photosynthetic active radiation, vapor pressure deficit, and soil, stem, and air temperature). Complementarily, we performed independent incubation trials of stem and soil samples, as a reference for the response to temperature when stem and soils are isolated from the soil-plant system. In the present study, we compared two oak species with contrasting traits that are extensively distributed across the Iberian Peninsula, *Quercus ilex* subsp. *rotundifolia* and *Quercus faginea*. While the evergreen *Quercus ilex* has a water-saver strategy with greater stomatal conductance regulation, the deciduous *Quercus faginea* can reach high transpiration rates even under stress conditions. Given that the CO<sub>2</sub> transport across and beyond the stem depends on xylem sap velocity and morphology of woody tissues, we



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hypothesize that both the magnitude and isotope signal of stem CO<sub>2</sub> efflux will differ between species as well as its relationship with ambient variables. Incubation trials showed no significant differences between species in the temperature response curve of CO<sub>2</sub> efflux in isolated stems, resulting in a common temperature coefficient  $Q_{10}$ , consistent with the expected temperature response of gross respiration rates ( $Q_{10}=2.28$ ). Conversely, soil CO<sub>2</sub> efflux showed a steeper response to temperature ( $Q_{10}=3.44$ ), and within the range reported in the literature for temperate soils. In the steady-state chamber experiment, stem temperature was generally a better predictor of stem CO<sub>2</sub> efflux than air or soil temperature. During night-time, the response to stem temperature was very similar to the curve derived from incubation experiments. Conversely, during day-time the response was less steep, suggesting that CO<sub>2</sub> refixation, together with transpiration flow, tends to reduce net stem CO<sub>2</sub> efflux. This interpretation was also supported by the less negative <sup>13</sup>C values in emitted CO<sub>2</sub> during day-time, consistent with carbon discrimination during CO<sub>2</sub> refixation. Incipient soil drying (soil water potential <0.3 MPa) also caused a flattening of the response curve, but with an opposite offset in the two species: stem CO<sub>2</sub> efflux increased for *Q. ilex*, but decreased for *Q. faginea*. On top of that, when soil was warmer than the stem we observed higher stem CO<sub>2</sub> efflux than predicted from incubation experiments. This divergence increased proportionally to the ratio between soil and stem temperatures. In those particular cases, stem CO<sub>2</sub> efflux was better explained by the soil  $Q_{10}$  than using predicting models for stem respiration, suggesting a contribution of soil-derived CO<sub>2</sub>. This interpretation is further supported by a differential isotopic response, both in <sup>13</sup>C and <sup>18</sup>O, indicating a shift in CO<sub>2</sub> source. Overall, our results indicate that net stem CO<sub>2</sub> efflux is highly sensitive to changes in transpiration rates and bark photosynthesis, which in turn are affected by both soil water content and light condition. The different behaviour of the two species could be partly explained by their distinct water use strategies. The difference between soil and stem temperature can be useful to define the periods when soil versus stem CO<sub>2</sub> production dominates the stem CO<sub>2</sub> efflux. Our findings have strong implications for the interpretation and modelling of carbon fluxes along the soil-tree-atmosphere continuum.

**Keywords:** Stem respiration, Soil respiration, Stable isotopes, Gas Exchange, *Quercus ilex*, *Quercus faginea*, Holm oak, Portuguese oak