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Water relations in plants to address current challenges for plants

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Gas exchange and Minimum Conductance Reveal Leaf Growth Plasticity Under Contrasting Vapor Pressure Deficit in *Quercus ilex*

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Abstract:

Vapor pressure deficit (VPD) has emerged as a key parameter influencing plant transpiration and ecosystem productivity. Elevated VPD values can reduce vegetation growth, accelerate forest decline, decrease crop yields, increase wildfire risk, and alter water and carbon cycling within ecosystems. Despite these recent advances in understanding the impact of VPD on vegetation productivity, its effects on plant physiological processes remain poorly understood. Thus, the aim of this study is to assess the physiological plasticity of leaves when growing under contrasting VPD conditions. Specifically, we evaluated three key physiological parameters: net assimilation rate (A_N), which reflects photosynthetic carbon uptake; stomatal conductance (g_s), which regulates leaf gas exchange and water loss through stomata; and minimum conductance (g_{min}), which represents the residual water loss through the cuticle and incompletely closed stomata. These traits are critical for understanding plant water and carbon balance under varying atmospheric demand. To achieve this objective, we constructed two cubic growth chambers measuring 1 × 1 × 1 m. In the first chamber, air with outdoor Mediterranean summer conditions (VPD up to 8kPa) was introduced, whereas in the second chamber, humid air was supplied, reducing VPD to maximum values of 3 kPa. We selected 3-year-old plants of *Quercus ilex,* a paradigmatic oak species of the Mediterranean landscape. Plants were pruned, and fifteen individuals were placed in each chamber in mid-summer 2025. After leaf growth and maturation inside each chamber, leaf A_N, g_s and g_{min} were measured. Leaf stomatal density was also assessed in 5 plants from each chamber. Results showed that plants grown under low VPD exhibited significantly higher A_N (17.7 ± 0.7 µmol m^{-2} s^{-1}) compared to those under high

VPD (13.8 ± 1.0 µmol m^{-2} s^{-1}; $P < 0.01$). Similarly, g_s and g_{min} were markedly higher under low VPD (530 ± 20 and 5.9 ± 0.6 mmol m^{-2} s^{-1}, respectively) than under high VPD (313 ± 16 and 3.5 ± 0.2 mmol m^{-2} s^{-1}; $P < 0.0001$). Stomatal density was also significantly higher ($P < 0.05$) in plants grown under low VPD, with values of 453 ± 28 and 595 ± 55 stomata mm^{-2} for high and low VPD chambers, respectively. Our findings demonstrate that *Q. ilex* exhibits substantial physiological plasticity in response to contrasting VPD growth conditions. Higher photosynthetic rates and conductances under low VPD indicate enhanced carbon assimilation and water flux when atmospheric demand is reduced. Importantly, the increased stomatal density observed under low VPD likely contributes to these responses by providing a greater number of pores for gas exchange, thereby promoting higher g_s and *A*. This anatomical adjustment may also explain the elevated g_{min} under low VPD, as more stomata—even when partially closed—can increase residual water loss. Conversely, under high VPD, the marked reduction in g_s and g_{min}, together with lower stomatal density, suggests a coordinated strategy to limit water loss, which may help prevent excessive dehydration but at the cost of reduced photosynthesis. These results highlight the interplay between anatomical and physiological traits in mediating water conservation and carbon gain, and suggest that VPD-driven shifts in stomatal density and related parameters could play a critical role in the resilience of Mediterranean species under future climate scenarios.

Keywords: Atmospheric drought, Climate Change Resilience, Drought Adaptation, Gas Exchange, Water Balance, Water Loss.

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