11th International Workshop on Grapevine Trunk Diseases July 7-12, 2019. Penticton, British Columbia, Canada

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Exploring the hydraulic failure hypothesis on esca leaf symptom formation.

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Plant vascular disorders are almost invariably identified by conspicuous leaf scorch symptoms but the exact mechanisms driving leaf symptoms remains unknown. Two of the main hypotheses, presence of air embolism or tyloses/gels, rely on the disruption of xylem integrity but they still need to be investigated. In this study we explore the xylem integrity in esca symptomatic leaves of naturally fieldinfected grapevines (V. vinifera cv. Sauvignon) using traditional light microscopy and non-invasive, in vivo imaging via x-ray microtomography (microCT). This method allows for the visualization and quantification of embolism and vessel functionality in esca symptomatic leaf petioles and midribs. We survey annual stems and leaves using qPCR to determine if two of the main pathogen species associated with esca, Phaeomoniella chlamydospora and Phaeoacremonium minimum, were present in these annual organs. Our results demonstrated that symptomatic leaves are not associated with air embolized xylem conduits. In symptomatic leaves, high percentages of xylem vessels were not functional due to nongaseous embolisms formed by gels and/or tyloses. However, the severity of esca leaf symptoms was not correlated to the proportion of non-functional vessels. P. chlamydospora and P. minimum were undetected in the vine's distal organs confirming that the symptoms and vascular occlusions likely occur at a distance from the pathogen niche. Studying xylem water transport and vessel integrity during esca pathogenesis is fundamental and critically important if we are to understand esca etiology. Our observations inform new perspectives on esca symptom expression where two of the underlying hypotheses (elicitor/toxin and hydraulic failure) are not necessarily mutually exclusive