From Vines to Ecosystems: Ecological Effects of Grapevine Leafroll Disease

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Abstract

So far, 102 viral entities are known in grapevine, this being considered one of the most affected crops by various types of viruses. As a vegetatively propagated woody species, it is a model plant for studying virus-plant interactions both under controlled and field conditions. Assessing the effects of a viral disease is not easy because a plant can be simultaneously infected with several viruses, and, in addition, it can be subjected to different abiotic and biotic stress factors at the same time. Grapevine leafroll disease (GLD), caused by a complex of grapevine leafroll-associated viruses (GLRaVs), is among the most widespread and economically damaging viral diseases of grapevine. Six positive-sense RNA viruses belonging to family Closteroviridae are associated with grapevine leafroll-associated viruses (GLRaVs): 4 viruses of genus Ampelovirus (GLRaV-1, GLRaV-3, GLRaV-4, and GLRaV-13), 1 virus of genus Closterovirus (GLRaV- 2), and 1 virus of genus Velarvirus (GLRaV-7). Of the 6 leafroll associated viruses, GLRaV-3 is the most prevalent in all grapevine growing countries of the world, and most associated to leafroll effects, together with GLRaV-1. While its physiological and yield impacts are well recognized, the broader ecological implications for vineyard ecosystems remain poorly understood. This review integrates traditional literature analysis with bibliometric approaches to synthesize current knowledge on GLRaV occurrence, diversity, host responses, epidemiology, diagnostics, and management. Data from 729 peer-reviewed articles were categorized into six research clusters: global occurrence and first reports, viral diversity and characterization, host–pathogen interactions, epidemiology and vector dynamics, effects on vine physiology and fruit composition, and diagnostic and management strategies. Our findings highlight GLRaVs as dynamic pathogens shaped by genetic variability, human-mediated plant trade, and ecological interactions with vectors and vineyard biodiversity. Knowledge gaps persist regarding mixed infections, underexplored viticultural regions, ecological impacts, and sustainable management. Future work should prioritize high-resolution genomics, multiomics approaches, improved diagnostics, ecological studies, and innovative management tools. By framing GLD not only as an agronomic but also as an ecological challenge, this review provides a foundation for more holistic strategies to safeguard vineyard health and productivity.

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