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Review Finds Grapevine Hairy Root Cultures Have Become a Practical Tool for Vineyard Research

The system offers a faster, genetically stable way to study genes, pathogens and stilbene production, despite no full grapevine regeneration.

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A review published Thursday in the South African Journal of Enology and Viticulture says grapevine hairy root cultures are becoming a practical research tool for studying genes, plant disease, and valuable grape compounds, and could open new paths for biotechnology in vineyards and wine-related research.

The paper, by Sasha Tietz, Philip Young, and Melané Vivier of Stellenbosch University and the South African Grape and Wine Research Institute, examines how these root cultures have been used in grapevine and where the method may go next. The authors describe hairy root cultures as a fast-growing and genetically stable system that can be created in tissue culture after infection by Rhizobium rhizogenes, a bacterium formerly known as Agrobacterium rhizogenes.

Hairy root syndrome is a plant disease, but the biological process behind it has also become a laboratory tool. According to the review, the bacterium inserts genes into the plant genome, triggering the growth of so-called hairy roots. In controlled culture, those roots can then be used as a stable experimental system. The authors say that more than 500 plant species have produced hairy root cultures to date, including grapevine, and that researchers have tested more than 50 Vitis genotypes.

The review brings together earlier work on how to establish and refine the system in grapevine. That includes tests of different Vitis species, different plant tissues and tissue ages, bacterial strains, infection methods, co-cultivation times, growth media, and reporter genes used to confirm successful transformation. The paper lists several reporter systems that have been used, including nptII, hptII, GUS, gfp, DsRed, and siRUBY.

In grapevine research, the authors say, hairy root cultures have already shown clear value in several areas. One is the functional characterization of genes in the phenylpropanoid pathway, which is important in plant defense and in the production of secondary metabolites. Another is stilbene bioproduction. Stilbenes are compounds that include resveratrol and related molecules found in grapevine. The system has also been used to study root-pathogen interactions, and more recently it has been combined with CRISPR gene-editing approaches.

That combination is one reason the review points to broader opportunities ahead. A stable root-based system can give researchers a faster way to test gene function before moving to more complex plant studies. In a crop like grapevine, where breeding and transformation can take time, that may help narrow down which targets are most promising for further work.

The authors also note an important limit. In several plant species, whole plants have been regenerated from hairy roots, but that has not yet been reported in grapevine. Even so, researchers have been able to build composite and micro-grafted plants in which untransformed shoots grow on hairy roots. That means the system can still be used to study how modified roots affect the rest of the plant, even without full regeneration.

The paper is a review rather than a single experimental report, so it does not claim a new breakthrough on its own. Its contribution is to map the field and show where methods have become solid enough to support wider use. The authors say methodological improvements in producing grapevine hairy roots now provide room for applications that have been demonstrated in other species but remain largely unexplored in grapevine.

Those possible next uses include phytoremediation, larger-scale bioreactor production, recombinant protein production, studies of root interactions with symbiotic organisms, and the use of hairy roots as a model in grapevine breeding approaches. Each of those would require further testing in grapevine, and the review presents them as opportunities rather than established outcomes.

The work may matter beyond basic plant biology because grapevine is the base crop for wine production, and root health, disease response, and metabolite pathways are central issues for the industry. A more reliable and faster research model could help scientists screen genes tied to stress response, pathogen resistance, and the production of compounds that are important in grape development. If those tools continue to advance, they could support future work on vineyard resilience and grape improvement, with possible downstream effects for wine production and related beverage research.

The review comes from a journal focused on enology and viticulture, underscoring the link between laboratory methods and agricultural use in vineyards. While the study does not argue that hairy root cultures are ready to replace field or whole-plant work, it presents them as a strong complement to those approaches. The authors' central point is that grapevine hairy root cultures have moved past proof of concept in several areas and now offer a broader platform for gene studies, biotechnology, and root-focused research.

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