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Unlocking the Underground Network of New York Vineyards

Research at Cornell University Explores Arbuscular Mycorrhizal Fungi and Predictive Soil Modeling for Sustainable Viticulture

By Philip O'Dell

Beneath the scenic rolling hills and expansive vineyards of the Finger Lakes region lies a complex biological ecosystem needed for plant survival and agricultural sustainability. While agricultural research has historically focused on above-ground plant development, contemporary viticulture increasingly examines the subterranean dynamics of root systems and soil microbiology.

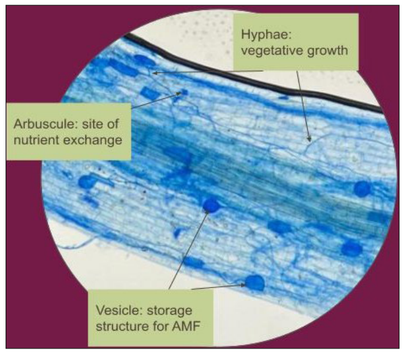
At Cornell University, researcher Hannah Frank, a doctoral candidate in the School of Integrative Plant Science, leads research into the soil fungi that inhabit regional vineyard soils and their potential to enhance grapevine health, nutrient acquisition, and climate resilience.

Despite some frequent mix-ups, she is not related to the iconic Dr. Konstantin Frank winemaking dynasty.

Operating within Cornell's viticulture research program led by Professor Justine Vanden Heuvel, Frank's doctoral research focuses specifically on arbuscular mycorrhizal fungi (AMF). Derived from Greek roots where *myco* signifies fungus and *rhizal* denotes root, mycorrhizal fungi form symbiotic relationships with about 85% of land plant species. Evolutionary biology suggests these relationships were pivotal during the transition of aquatic plants to terrestrial environments, providing early plant life with physical stability and nutrient uptake mechanisms prior to the evolution of complex root structures.



Hannah Frank is a doctoral candidate and researcher at Cornell University. (Photo: Provided)



The structures of an arbuscular mycorrhizal fungus inside a grapevine root that has been cleared of pigment and stained with blue ink. (Photo: Provided)

The Microscopic Dynamics of AMF Symbiosis

AMF derives its name from microscopic, tree-like structures called arbuscules formed within the cortical cells of host plant roots. These specialized structures serve as the primary exchange site between the fungus and host plant. Lacking photosynthetic capabilities, fungi rely on the host plant for carbon energy and carbohydrates. In return, extensive fungal hyphae extend far beyond the root zone, absorbing water and essential soil mineral nutrients, such as phosphorus, before delivering them back to the host plant.

Rather than passive conduits, plant roots operate as dynamic organs essential for long-term health. In perennial viticulture systems, root vitality directly dictates vine vigor and stress tolerance.

Frank's work investigates the environmental mechanisms driving naturally occurring populations of these beneficial fungi across regional vineyards, seeking to provide growers with practical insights to optimize natural soil biology.

Regional Fieldwork and Predictive Soil Modeling

To evaluate natural fungal colonization under commercial conditions, Frank established a regional field study sampling across ten commercial vineyards spanning diverse soil profiles in the Finger Lakes, ranging from Branchport on Keuka Lake to Skaneateles Lake. Throughout the growing season, field evaluation involves collecting soil and root samples, tracking vine growth, and measuring harvest weights across commercial blocks.



A vineyard floor is in full bloom with natural vegetation in July. (Photo: Provided)



A view of Cayuga Lake from a vineyard. (Photo: Provided)

A central objective of Frank's research addresses the surge of commercial biological supplements entering agricultural markets. In recent years, commercial mycorrhizal inoculants are widely promoted to enhance crop performance. However, applying commercial inoculants represents a notable expense for growers without guaranteed returns. Evaluating whether native fungal populations are already adequate traditionally requires complex laboratory extraction and microscopic staining procedures inaccessible to commercial operations.

To resolve this challenge, Frank is developing a mathematical predictive model designed to estimate native mycorrhizal abundance in grapevine roots without direct laboratory testing. The model integrates site-specific parameters, including physical and chemical soil properties, nutrient levels, and local weather patterns. By utilizing Network for Environment and Weather Applications (NEWA) data, growers can reliably forecast native fungal quantity, enabling informed management decisions prior to purchasing commercial additives or taking cultural steps to alter soil biology.

Efficacy of Commercial Inoculants and Agricultural Policy

Preliminary findings from Frank's vineyard trials indicate mixed effects regarding commercial fungal inoculants. Evidence demonstrates that introducing commercial inoculants does not produce significant changes or increases in root fungal populations within Finger Lakes vineyard soils. This may be because fungal communities are well-adapted to local soil conditions, outcompeting or rendering supplementary inoculants redundant.

These findings highlight broader questions surrounding scientific research and agricultural policy. As research funding increasingly shifts toward private-sector commercialization, product development is heavily prioritized. However, Frank's findings demonstrate that agricultural solutions do not always require manufactured commercial products. Instead, effective soil management often stems from adjusted cultural practices, such as under-vine cover cropping and targeted soil conservation.



Hannah Frank demonstrates her soil sampling methods in a teaching vineyard. (Photo: Provided)



Riesling grapes are ready to harvest starting in late September. (Photo: Provided)

Advanced Molecular and Anatomical Research

Beyond field-level modeling, Frank's research incorporates advanced laboratory methodologies. Visualizing fungal structures within dense grapevine roots requires a specialized clearing and staining protocol utilizing low-toxicity mixtures of household vinegar and blue ink, followed by mounting slides under a compound microscope.

To examine fungal diversity at the genetic level, Frank utilizes polymerase chain reaction (PCR) assays and DNA sequencing to determine whether fungal species diversity influences overall plant benefit. In collaboration with Penn State University, Frank utilizes high-resolution laser imaging called laser ablation tomography to examine grapevine anatomical adaptations during nutrient stress.

Focusing on phosphorus—an essential plant macronutrient—the research evaluates how grapevines balance carbon energy budgets during nutrient deficiencies. Under phosphorus stress, vines face energetic trade-offs: either spending energy modifying internal root diameter or allocating photosynthetic carbon to feed surrounding fungal networks in exchange for increased nutrient foraging. Clarifying these metabolic shifts helps determine when plants rely on symbiotic fungal partners versus internal physiological stress mechanisms.

Climate Resilience and Sustainable Viticulture

The broader implications of subterranean fungal dynamics carry strong significance for climate change adaptation. Vineyard management in New York state faces increasing vulnerability from weather volatility, including unseasonal winter warmth, late spring freezes, and extreme rainfall events interspersed with drought.

Robust root systems and established mycorrhizal networks enhance plant resilience by enabling vines to access deeper soil moisture during dry periods, Frank said.

"There is evidence of AMF alleviating salt stress in salinized soils, helping with both drought stress and excess water risk, priming immune response for disease resistance," Frank said.

Sustainable management practices, such as under-vine cover crops, can stabilize topsoil and prevent erosion during heavy precipitation events. Frank's research aligns with international initiatives such as the Society for the Protection of Underground Networks (SPUN), which maps global mycorrhizal networks to understand how agricultural practices affect soil carbon storage capacity. Illuminating subterranean fungal dynamics provides vital scientific groundwork for promoting resilient and sustainable viticulture.