A NEW TOOL FOR UNDERSTANDING TREE STRESS

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Urban trees have it rough. They face a myriad of challenges that have become an all too familiar part of our landscape: compacted soil, road salts, limited rooting space and excessive heat, in addition to a growing list of invasive pests and diseases that limit tree growth, establishment and survival. At the same time, we are witnessing and experiencing the effects of climate change in our lives and in our landscapes, with extreme weather, drought, flooding and changes in heat and growing degree days impacting the way we manage and maintain our urban forests.

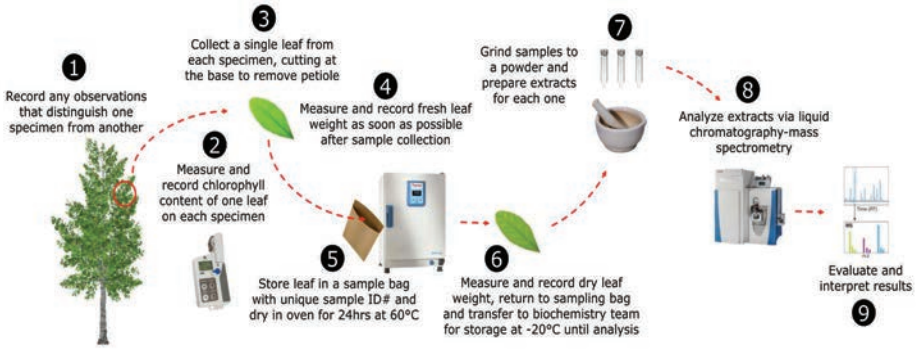
Although some of these impacts may be identified through visual cues, like leaf chlorosis, wilting, early senescence, flaking bark, branch dieback or limited growth, the effects of biotic and abiotic stressors can often take time to present, particularly in such large and long-lived organisms as trees. Given their tendency to decline slowly, our urban trees are often stressed and struggling well before we can see it, leaving diagnosis, management and mitigation consistently one step behind where we'd like it to be.

We currently understand tree stress from the outside looking in, identifying those characteristic signs and symptoms of biotic and abiotic stresses only once they present at the tree level, and when our trees are struggling or already in decline. To proactively manage the health of our urban forests, we need to be able to identify and understand not only when stress has occurred, but more importantly, the progressive and adaptive process through which trees respond to and manage the early stages of stress - before the impact of these stressors manifest in the canopy, stem and branches. By adopting a new perspective and applying cutting-edge analytical technology, we can get a better understanding of how a tree is responding to stress in real time, by considering the inner workings of its biology. A tree's innate biochemistry, referred to as its metabolome, can be used to characterize the dynamics of tree health as well as monitor, manage and maintain our urban forests for the future.

Metabolomics is the technical approach used to study the metabolome. It aims to provide a comprehensive profile of all detectable biochemicals in an organism. Metabolomics began in the 1940s, and like many technologies, was applied to human medical research first - to identify the biochemical fingerprints in bodily fluids in healthy versus diseased states. The technology has now reached the point where we can analyze and interpret metabolomic profiles of many different types of plants, including our urban trees.

Metabolomics is an incredibly powerful tool for understanding trees. Fewer than 10 leaf samples can be used to generate vast amounts of information detailing the complex inner workings of trees. This information shows how trees respond to a diverse and ever evolving range of environmental conditions, including what the root system is experiencing, as even below ground stresses can be reflected in the biochemical profile of the canopy.

Metabolomic analysis gives us the unique opportunity not just to understand tree stress from the inside out but to utilize and apply that understanding to detect, diagnose and



deploy interventions even before visible tell-tale signs of tree stress are observed. For example, if a certain species of tree is consistently found to increase the production of a particular biochemical under low water conditions, then that biochemical may likely be an indicator of drought. Even before the leaves start to wilt, dry out and fall away, this biochemical marker could be used to detect the early stages of drought stress in living leaf tissue. The severity and extent of the stress can even be determined by measuring the relative concentration of the biochemical at a particular point in time. It's possible that the biochemical might reach a critical threshold, at which point tree health and performance are observed to decline or that management and mitigation are most effective before a certain threshold is reached.

Several biochemical indicators common to plant stress responses have been identified in trees, such as an increase in phenolics metabolism in response to drought. However, metabolomics can also readily identify species-specific responses that may be the key to certain mechanisms of stress tolerance. Ultimately, metabolomic analysis provides us with detailed insight into a tree's internal, adaptive processes as well as an opportunity to align our own thinking and management with that of the tree's response.

Since 2021, researchers at Vineland Research and Innovation Centre have been building a library of data, collecting over 2,500 individual leaf tissue samples to characterize the metabolomes of various tree species subjected to drought and rapid flooding conditions. Using this information, we are working to identify, characterize and understand biochemical indicators of tree stress, how these indicators vary from species to species and how this data might be used to manage trees in the landscape.

As with any tool, it's how we use it that will determine its impact. In the hands of urban foresters, nursery managers, arborists and tree specialists, metabolomic analysis has the potential to change the way we understand and diagnose tree stress - promoting the transition of urban tree management from an inherently responsive approach to a proactive one.

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