EGU22-10182
https://doi.org/10.5194/egusphere-egu22-10182
EGU General Assembly 2022

Using image spectroscopy to assess the genetic and environmental controls governing tree chemical defense responses to an irruptive herbivore

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Genetics, in concert with environmental factors, affect plant chemical defenses, and thereby plant susceptibility to pests, pathogens, and ultimately mortality. Plant resource allocation strategies in response to stress play important roles in balancing trade-offs and coordinating non-structural carbohydrate (NSC) investment between critical functions such as growth, storage, and chemical defense. Yet stress-induced growth-storage-defense (GSD) dynamics and their consequences for tree function *in situ* in the face of severe insect defoliation events are lacking. While vegetation model simulations have suggested that incorporating these dynamics will vastly impact our ability to predict outbreak "hotspots" and ultimately outbreak trajectories, we lack sufficient empirical studies describing herbivore-induced GSD relationships. Improving our predictive capabilities of tree-insect dynamics at the landscape level requires accurate quantification of plant defense dynamics in relationship to growth and storage, which can be accomplished using image spectroscopy.

To gain a more robust understanding of genetically-driven variation in NSC-chemical defense relationships—and the link to susceptibility or resilience in the face of invasive insect outbreak events—we leveraged a current *Lymantria dispar* outbreak occurring in an aspen (*Populus tremuloides*) common garden in Arlington, Wisconsin, USA comprised of 519 genotypes collected along a latitudinal gradient across Wisconsin. We measured shifts in the metabolome of targeted genotypes with known dissimilarity in phenolic glycosides and condensed tannin concentrations, the former being biologically active in defense against *L. dispar*. Targeted and untargeted metabolomics were used to assess shifts in leaf chemistry throughout the outbreak and whole-tree NSCs were measured concurrently. To evaluate the utility of imaging spectroscopy to quantify stress-induced chemical variation, remote sensing data were acquired concurrently using airborne and UAV-based HySpex and LiDAR sensors along with leaf-level reflectance measurements.

During the 2021 growing season, hyperspectral imagery shows distinct changes in foliar traits spatially and among genotypes over the course of the defoliation and during foliar reflush. LiDAR data illustrate discontinuous temporal patterns of defoliation during the event, likely due to spatial patterns of egg mass distribution rather than differences among genotypes. The leaf spectral

dissimilarity analysis across all bands shows greater spectral variation among genotypes after defoliation than before defoliation. However, untargeted metabolomics indicates that leaf phytochemical profiles are more homogeneous following the outbreak, largely due to the enhanced production of phenolic glycosides. This suggests that other primary metabolites may be responsible for explaining a higher proportion of the spectral variation. Analysis of NSC dynamics is ongoing, but we expect to see differential shifts in tissue-specific NSC pools (specifically, starch) in response to herbivory, which are likely to be related to foliar defensive chemistry both prior to and following the defoliation event.