The Effects of Drought and Heat Stress Combination on Arabidopsis Plants: A Metabolomics Analysis

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This study revealed a new type of plant defense response induced by the combination of drought and heat stress.

Introduction

This study examines the response of Arabidopsis plants to two environmental stresses, low water availability and extreme temperatures, and their combination. The combination of drought and heat stress has been shown to have a significantly higher harmful effect on the growth and productivity of crops and other plants compared to each of the different stresses applied individually. Consequently, resistance to these two stresses is a target for plant breeding. A comprehensive metabolomics analysis using gas chromatography-mass spectrometry (GC-MS) and chemometric analyses was performed to identify metabolites and metabolic pathways unique to the combined stress treatment.

Methods

Arabidopsis plants were grown under controlled conditions. Heat stress was induced by raising the temperature in the growth chamber from 21-22oC to 38oC for six hours. Drought was caused by withdrawing water from plants until they reached a relative water content of 70%-75%. A combination of drought and heat stress was accomplished by subjecting drought-stressed plants to a heat stress treatment. Experiments were performed in triplicates and repeated at least three times. Leaves were harvested and polar metabolites extracted and derivatized. GC-MS analysis was performed using a Thermo Scientific DSQ GC-MS that was used in full scan mode at a scan range of 50-600 m/z. Thermo Scientific SIEVE and Umetrics SIMCA-P+ software were used for data analysis.

Preliminary results

The metabolic response of Arabidopsis plants to a combination of drought and heat stress was distinct from that of plants subjected to drought or heat stress alone as evidenced by principal component and partial least squares analyses (PCA, PLS respectively). Over 650 masses unique to the combined stress were uncovered for further identification. Metabolites that were unique to the combined stress treatment were identified based on retention time and comparison with reference spectra in mass spectral libraries. The unique response of plants to the combined stresses was characterized by enhanced respiration, suppressed photosynthesis, induction of particular defense and metabolic responses, and the accumulation of sucrose and other sugars. Interestingly, the osmoprotectant proline accumulated in plants subjected to drought alone, but did not accumulate in plants subjected to the combination of drought and heat stress. These results suggest that sucrose may replace proline as an osmoprotectant in the combined stress condition. This study highlights the plasticity of the plant metabolome and its ability to effectively respond to complex natural environmental conditions.