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Title: Identification of stress in plants via femtosecond laser-induced fluorescence and steady-state absorption spectroscopy

Abstract
Plants are known to respond to the conditions of their environment, such as improved growth upon exposure to fertilizers or inhibited health upon uptake of heavy metals. There has been recent interest in using plants as biosensors for tracking nuclear proliferation activities; however, differentiating the response of heavy metals from nuclear materials such as uranium (U) has not been explored in detail. One potential method to identify stress in-field is through plants' optical properties, such as chlorophyll fluorescence (ChlF). Therefore, it is of interest to understand how ChlF changes in response to different stresses. In our recent study, we expose 50-day mature Arabidopsis thaliana to four different environmental conditions: healthy (control), drought, Pb-contaminated water, and U-contaminated water. We extract the plant pigments via polar solvent extraction every 24 h from 0 h to 120 h after exposure. Fs-laser induced fluorescence (fs-LIF) is recorded to identify time-dependent signatures, which may be unique to the environment of the plant. We further perform steady-state absorption spectroscopy to measure how the pigment concentrations (such as [Chl] and carotenoids or [Car]) change, which is known to provide information on the plant's response to stress. We find that a decrease in the fs-LIF lifetime of Chl is observed for all three stress conditions at 24 h after initial exposure; however, the most significant decrease is noted at 48 h. Furthermore, we find that the drought condition shows an increase in [Chl]:[Car] compared to the control at 24 hours, but decreases and remains stable from 48 hours to 120 hours. Less fluctuation in [Chl]:[Car] is observed for the heavy metal conditions. This result may be related to the function of Car under drought stress compared to heavy metal stress. While our preliminary results show promise, future work is needed to explore potential signatures in-vivo.