Raman spectroscopy as a rapid plant phenotyping technique for detecting plant stress responses and identifying drought tolerant plant genotypes

Narangerel Altangerel and Philip Hemmer
Texas A&M University

Development of a phenotyping platform capable of non-invasive biochemical sensing could offer researchers, breeders, and producers a tool for precise response detection. In particular, the ability to measure plant stress in vivo responses is becoming increasingly important. In this work, a Raman spectroscopic technique is developed for high-throughput stress phenotyping of plants. We demonstrated for the first time, the early (within 48 hours) in vivo detection of plant stress responses (Fig 1). Coleus (Plectranthus scutellarioides) plants were subjected to four common abiotic stress conditions, individually: high soil salinity, drought, chilling exposure, and light saturation. Plants were examined post stress induction in vivo where changes in the concentration levels of the reactive oxygen scavenging pigments were observed by Raman microscopic and remote spectroscopic systems. The molecular concentration changes were further validated by commonly accepted chemical extraction (destructive) methods. Raman spectroscopy also allows simultaneous interrogation of various pigments in plants. For example we found a unique negative correlation in concentration levels of anthocyanins and carotenoids which clearly indicates that plant stress response is fine-tuned to protect against stress-induced damages (Fig.2). Furthermore, we were able to detect the drought tolerance levels among 5 genotypes of maize plants: 3 inbreds and 2 mutants. The maize (Zea Mays) plays a critical role in feeding humans and livestock around the world and a wide array of industrial application. The use of Raman spectroscopy allowed us to screen drought tolerance rates between not only genetically different inbreds but also mutants, which are genetically identical save for one gene. This precision spectroscopic technique holds promise for the future development of high throughput screening for plant phenotyping and for the quantification of biologically or commercially relevant molecules such as antioxidants and pigments.

Fig 1. A simultaneous and in vivo detection of anthocyanins and carotenoids which are reactive oxygen scavenging pigments by the Raman technique.

Fig 2. [A] The bar distributions for the fit coefficients for carotenoids (brown), chemically extracted value for carotenoids (mg/g dry weight) (grey) as functions of durations of the abiotic stresses; [B] The bar distributions for the fit coefficients for anthocyanins (violet), chemically extracted value for anthocyanins (mg/g dry weight)(black) as functions of durations of the abiotic stresses.