Abstract

Hyperspectral imaging phenomenology of genetically engineered plant sentinels

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Public areas such as schools and malls often have few or no preventative measures in place to deal with chemical hazards. Their distributed layout and numerous entrances make them difficult to monitor using conventional methods. A recently developed alternative uses genetically engineered plants that display a visible reaction to chemical inducers in their environment. These plants, called bio-sensors or plant sentinels, are designed to cease chlorophyll production and rapidly turn white in the presence of an inducer [Antunes, et al, 2006]. Figure 1 shows bio-sensors de-greening over a 48 hour period. The plants used in this project have been designed to respond to several types of inducers, including environmental pollutants such as zinc.

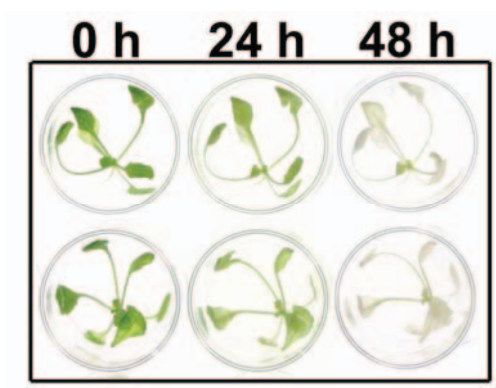

Figure 1. Bio-sensors de-greening over a 48 hr period [Simmons, et al, 2009]

Bio-sensors are ideal for use in public areas like transportation centers, malls and schools. Multiple bio-sensors could be included in the landscaping and design of a public space. They require no more maintenance than the common houseplant and are easily distributed. Their reaction is highly visible and recognizable.

Quick identification of the presence of a hazardous chemical is vital to the prevention of harm to people or property. With first generation bio-sensor technology, a visible change in the plant is apparent after a day and can be remotely sensed within a couple of hours [Shaw, et al, 2007]. Future generations of the bio-sensor plant technology are expected to reduce the reaction time to minutes or even seconds. Our project is investigating if the narrow spectral resolution and broad spectral coverage of a hyperspectral imaging system will lead to quicker detection of the plant response than possible using visible imagery alone. A faster response time would increase the likelihood of identifying the hazard. This paper investigates the phenomenological changes that appear in the bio-sensor spectrum over the course of de-greening. Also considered are the spectral effects of common sources of plant stress on the bio-sensors which could lead to false alarms.

First, spectral data of de-greening bio-sensors were collected in a laboratory environment using imaging spectrometers. Measurements were made of the bio-sensors at the time of exposure to the inducer and approximately every six hours after. This data helped describe the speed at which the bio-sensors de-green and what type of spectral changes occurred as the plants whiten. Several stressed bio-sensors were also measured. The plant sentinels were exposed to draught, over fertilization and a slightly acidic pH level independently of one another. Figure 2 is a plot of the reflectance spectra gathered from such stressed plants.

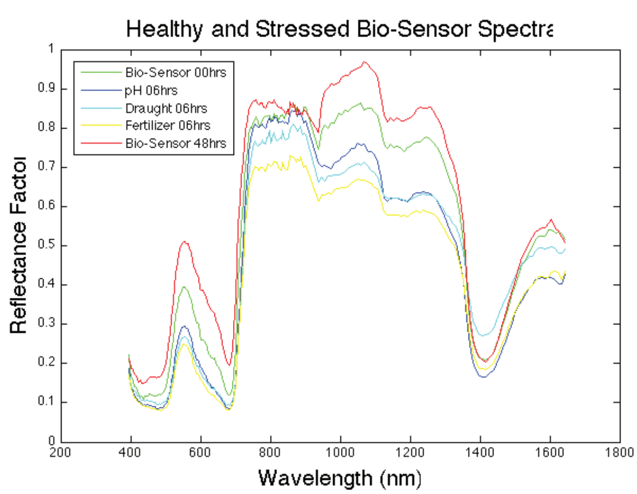

Figure 2. Spectral reflectance plot of bio-sensors under different stressors

A model of the bio-sensors deployed in front of a school was created using the Digital Imaging and Remote Sensing Image Generation (DIRSIG) simulation tool. Figure 3 is an overview of the scene created. The reflectance spectra shown in Figure 2 were applied to plant models placed in this scene which is a region of the DIRSIG MegaScene [Ientilucci and Brown, 2003]. DIRSIG was then used to simulate hyperspectral imaging of the bio-sensors under different illumination conditions. The resulting radiance images allow for further investigation into the effects of illumination on the hyperspectral phenomenology of de-greening, green and stressed bio-sensors. The paper will expand on the optimal ways of measuring differences between these spectra with a spectral imager. In particular we consider the effects of the atmospheric transmission and illumination conditions.

Figure 3. DIRSIG generated RGB image showing bio-sensors left and right of entrance

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