Imaging Canopies to Detect Stress Using a Portable Spectrometer

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Abstract:

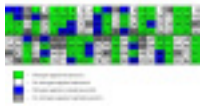
We conducted field studies in Idaho and Utah to determine canopy spectral differences between nitrogen-stressed, water-stressed, and healthy winter wheat. Spectrometer reflectance measurements made with a portable spectrometer correlated with plant health and seed yield (highest $r^2 = 0.68$). Derivative spectra provided a method for differentiating water-stress from nitrogen deficiency in test plots.

Introduction:

Plant reflectance and image characteristics have been used for many years to determine ground cover, water status, yield, and other plant growth parameters. Advances in portable spectrometers, digital photography, software, and high-resolution satellite imagery continue to improve the speed, portability, scope, and cost-effectiveness of stress detection. Here we report preliminary results from the use of a portable narrow-band spectrometer to differentiate between nitrogen- and water-stress in wheat.

Materials and Methods:

Randomized plots of spring wheat (*Triticum aestivum* cv. Westbred 936) were subjected to two levels (0 and 120 kg ha^{-1}) of soil nitrogen on a silt loam soil in Logan, Utah. We induced water stress on the outside plots using the line source technique. Canopy reflectance was measured between May 19, 2001 and July 2, 2001 using a StellarNet portable spectrometer with a two-meter fiber optic cable and sensor. The sensor was suspended over the plots with a small (d = 2 cm) pole to minimize shadows. The spectra were analyzed using the normalized difference vegetation index (NDVI) and derivative indices of the green (500-550 nm) and red/far-red (670-770) regions of the spectrum.



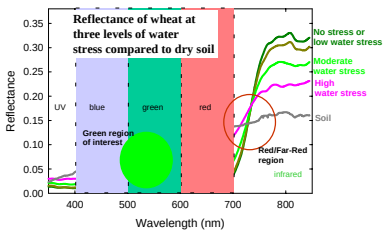


Figure 1. The effect of water stress on canopy reflectance.

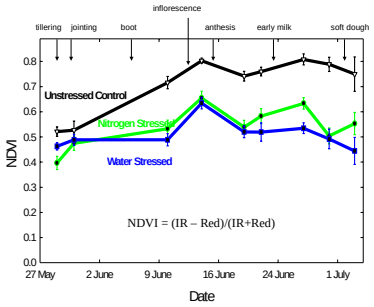


Figure 3. Broadband reflectance indices, such as NDVI, have been used for many years to estimate ground cover and plant health. NDVI was calculated from StellarNet spectrometer reflectance measurements. Bars are standard error of the mean.

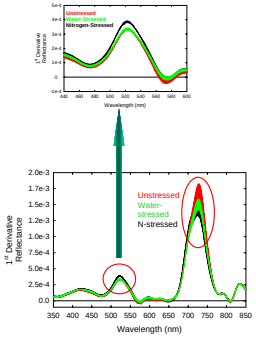


Figure 4. An increased slope of reflectance in the green region can signal nitrogen stress, and a decrease in the slope of reflectance at the red/far-red edge without accompanied increase in the green suggests water stress.

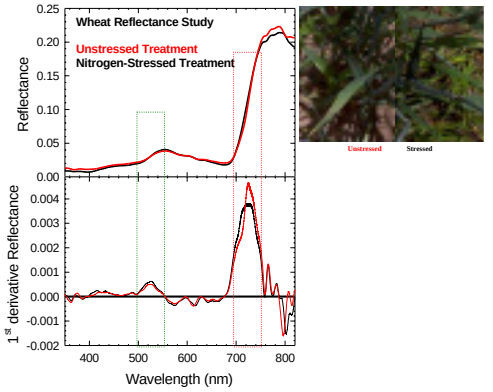


Figure 5. Derivative spectra can emphasize subtle spectral differences.

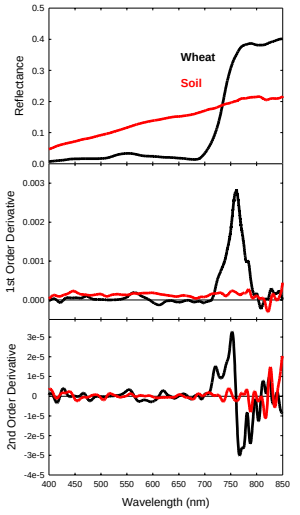


Figure 6. Derivative spectra also minimize the effect of the soil background.

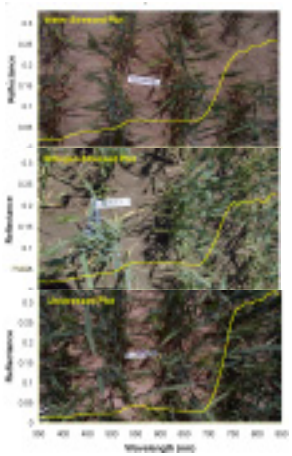


Figure 2. Plant canopies reflect more light in the green and infrared regions of the spectrum. Reflectance in these regions can be used to identify stress.

Conclusions:

- Both broad- and narrow-band indices can be used to detect stress in plants. However, it is difficult to differentiate types of stress using broad-band indices.
- Water-stressed canopies have lower reflectance slope than healthy canopies in the red/far-red region; nitrogen-stressed canopies differ mostly in the green region.
- Reflectance derivatives of narrow-band measurements in the green and red regions can help differentiate between water- and nitrogen-stress.
- Inexpensive spectrometers can be used as portable field stress-detection devices.
- Spectrometers can provide a ground-truth for multispectral satellite or aerial images.

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References:

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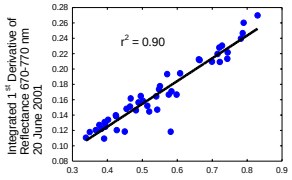

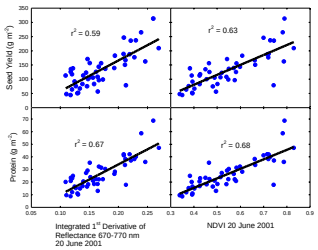

Figures 7 and 8. Derivative reflectance in the red/far-red region was highly correlated with NDVI. Both indices had similar correlations to yield and protein.

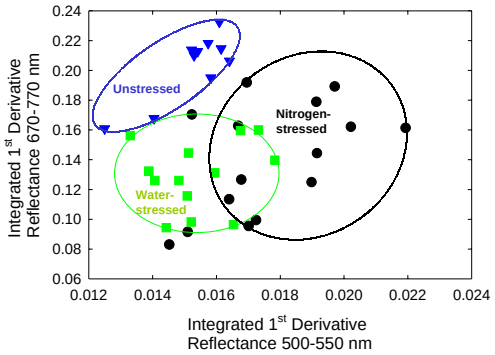

Figure 9. Water-stress can identified by lower slope of reflectance in the red/far-red region, and nitrogen-stress can be identified by higher slope of reflectance in the green.