**UtahState UNIVERSITY**
Crop Physiology Lab

Wheat Stress and Reflectance:
Ground Cover, Chlorophyll, and Nitrogen

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Introduction:

Vegetation reflectance indices can be used to identify plant health and separate plant growth from spectral contaminants, such as the soil. Leaf transmittance and reflectance were compared with plant canopy reflectance to determine the usefulness of using reflectance to detect nitrogen stress in spring wheat (*Triticum aestivum* cv. Westbred 936).
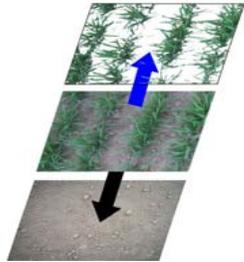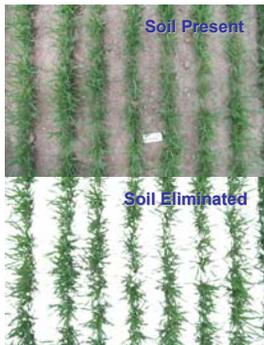
Materials and Methods:

- Wheat plants were grown hydroponically at seven nitrogen levels.
- At heading, the reflectance and transmittance of the upper two or three leaves of each plant were measured.
- Chlorophyll was extracted in DMSO from each leaf, and reflectance and transmittance were compared to leaf chlorophyll content by wavelength.
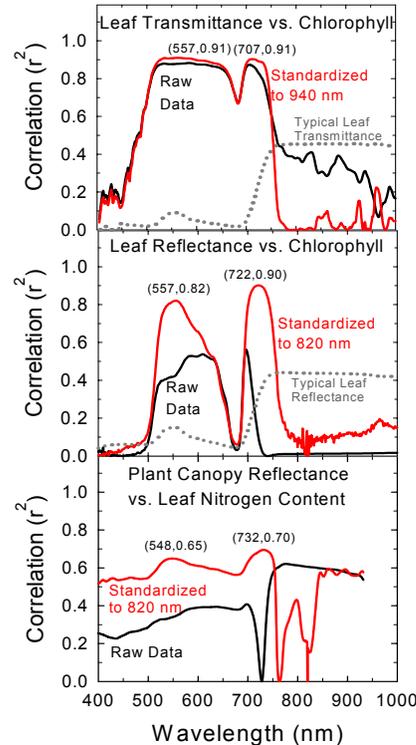
- Wheat was grown in small field plots under two nitrogen levels.
- Reflectance measurements were made with a narrowband spectrometer (2 nm resolution; 0.3 nm sampling interval) in the 400-1000 nm range.
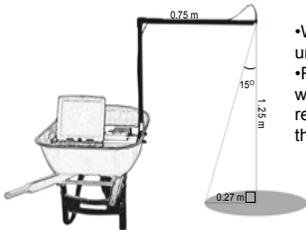
- Ground cover was estimated by taking digital photographs over each sample point. Soil was removed from the images, and ground cover was calculated as the percentage of green pixels.
- Reflectance indices were compared with ground cover estimates and SPAD-502 chlorophyll readings to determine useful methods for detecting stress.
- Reflectance from field plots was compared with ICP tissue analysis to determine which wavelengths correlated best with tissue nutrient concentration.
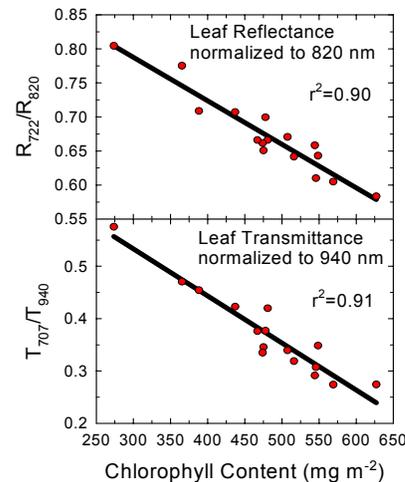
Soil Present

Soil Eliminated

Results: Plant Health

Leaf Transmittance vs. Chlorophyll
(557,0.91) (707,0.91)
Raw Data
Standardized to 940 nm
Typical Leaf Transmittance

Leaf Reflectance vs. Chlorophyll
(557,0.82) (722,0.90)
Raw Data
Standardized to 820 nm
Typical Leaf Reflectance

Plant Canopy Reflectance vs. Leaf Nitrogen Content
(548,0.65) (732,0.70)
Standardized to 820 nm
Raw Data

Wavelength (nm)

- Leaf transmittance and reflectance of green and far-red radiation correlated well with tissue chlorophyll concentrations.
- Normalized and raw transmittance data showed similar correlation to chlorophyll content by wavelength.
- Raw reflectance data showed significantly lower correlation than normalized data and different peak correlation wavelengths.

- The regions of the spectrum that had the highest correlation with nitrogen content were similar to the leaf reflectance regions that correlated most closely with chlorophyll content.
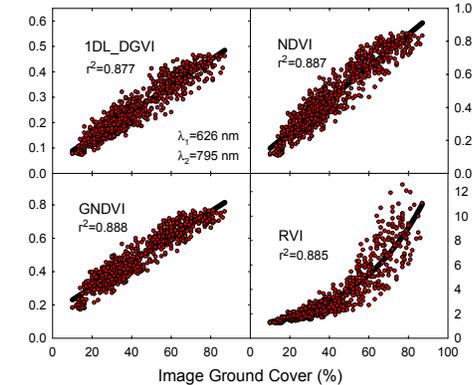
Leaf Reflectance normalized to 820 nm
R_{722}/R_{820}
$r^2 = 0.90$

Leaf Transmittance normalized to 940 nm
T_{707}/T_{940}
$r^2 = 0.91$

Chlorophyll Content (mg m^{-2})

Examples of the leaf reflectance and transmittance wavelengths that correlated highest with leaf chlorophyll content.

Results: Ground Cover

Name	Vegetation Index	Reference	r^2	Relationship
Ratio Vegetation Index	$RVI = \dfrac{NIR}{RED}$	(Jordan, 1969)	0.884	Exponential
Normalized Difference Vegetation Index	$NDVI = \dfrac{(NIR - RED)}{(NIR + RED)}$	(Rouse et al., 1973)	0.886	Linear
Difference Vegetation Index	$DVI = NIR - RED$	(Tucker, 1979)	0.870	Linear
First-order derivative green vegetation index using zero baseline	$1DZ\_DGVI = \sum_{\lambda_1}^{\lambda_n}\|\rho'(\lambda_i)\|\Delta\lambda_i$	(Elvidge and Chen, 1995)	0.877	Linear
First-order derivative green vegetation index using local baseline	$1DL\_DGVI = \sum_{\lambda_1}^{\lambda_n}\|\rho'(\lambda_i) - \rho'(\lambda_1)\|\Delta\lambda_i$	(Elvidge and Chen, 1995)	0.877	Linear
Green Normalized Difference Vegetation Index	$GNDVI = \dfrac{(NIR - GREEN)}{(NIR + GREEN)}$	(Gitelson and Merzlyak, 1998)	0.889	Linear
Yellowness Index	$YI \propto \dfrac{R(\lambda_{-1}) - 2R(\lambda_0) + R(\lambda_{+1})}{\Delta\lambda^2}$	(Adams et al., 1999)	0.189	

1DL_DGVI $r^2 = 0.877$ $\lambda_1 = 626$ nm $\lambda_2 = 795$ nm
NDVI $r^2 = 0.887$
GNDVI $r^2 = 0.888$
RVI $r^2 = 0.885$
Image Ground Cover (%)

Examples of ground cover data compared to spectral indices.

Conclusions:

- Leaf reflectance characteristics can be identified in field situations, even with the low signal-to-noise due to incomplete vegetative cover and soil effects.
- Reflectance measurements can be used to determine chlorophyll, and thus nitrogen, content.
- Even simple vegetation indices correlate well with ground cover images. Both methods can be used to eliminate the effects of a homogeneous soil to determine ground cover.

References
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