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Development of a non-contacting method for the determination of the plant water status

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Abstract

The influence of irrigation on the spectral signature in the visible light, NIR and SWIR was investigated in laboratory and field experiments with wheat plants. First results of droughted and well-watered wheat show that the differentiation of the spectral signatures in water-absorption bands in the SWIR increases with drought stress. In a laboratory experiment, the best correlation of water potential to reflectance was found at wavelengths of 1450 to 2000 nm. Field measurements show a strong dependency of the reflectance on the zenith-view angle, the field of view and the weather conditions. It could not yet been clarified whether it is possible to determine the water status independent of the biomass status.

Introduction

The importance of spectral signature studies for describing drought stress and crop biomass is well established. The reflectance characteristics of crops depend on tissue optical properties, canopy biophysical attributes, soil reflectance, illumination conditions, viewing geometry and abiotic stresses. Water is, in addition to nitrogen, the most important yield-determining factor for crops. A determination of the water content of crops for site-specific crop management, which does not require direct physical contact, could improve existing fertilising and irrigation systems.

Several authors have shown that wavelengths in the SWIR may be correlated with the water status of plants (Bowman, 1989; Carter, 1991; Kleman and Fagerlund, 1987). Correlations of the water status with wavelengths in the visible light or NIR (Kleman and Fagerlund, 1987; Penuelas *et al.*, 1997) were pointed out as well. The combination of NIR and SWIR was proposed for the detection of the relative water content (Hunt, Rock and Nobel, 1987; Hunt and Rock, 1989). Frequently the water status of plants is closely correlated with the biomass. Independent relationships have not yet been demonstrated and were sought in this study. The results may contribute to the development of a non-contacting online water-status sensor.

Material and methods

Canopy reflectance was measured with a GER 3700 hyper-spectral spectroradiometer (Geophysical & Environmental Research Corp., Millbrook, NY, USA), ranging from 330 to 2500 nm. A fiber optic was used for the measurements. Reference measurements were done using a spectralon white standard. In the laboratory, drought was established by withholding watering, and comparing it with a control treatment that was optimally watered. The spectral signature and the water status (water potential) of wheat were measured parallel. The water potentials were determined with a pressure bomb (PMS, Corvallis, OR, USA).

Results

Figure 1 shows the results of a growth chamber experiment with spring wheat. Droughted and well-watered plants were measured under artificial light with daylight characteristics at differing zenith-view angles (Nadir, 15°, 30°) as well as parallel and sideways from the plantation rows. Watering was stopped on April 20th in order to generate drought. From April 26th the reflectance showed an increasing differentiation between droughted and non-droughted plants. This is most clearly visible at about 2000 nm, but also at about 1450 nm and at the chlorophyll absorption band in the red range.

In another experiment wheat plants in pots were spectrally recorded in a photo room, using the light of a 1000-watt halogen headlamp with day-light characteristics. The experiment contained five stress treatments and one control treatment with four replications. Wavelengths and indices used were based on literature findings. Again, the best correlation was found at 1450, 2000, and 700 nm. The NDVI also correlated with the water potentials, but less strongly (Figure 2).

In field experiments (data not shown) under perfect weather conditions and for relatively short periods of time, the reflectance of the reference (Lambert reflector) almost linearly increased prior to the highest sun position and decreased after the highest sun position. Under such conditions, the reference measurement for the target measurement can be linearly interpolated. Due to the measurement principle with the spectralon as absolute reference, problems are already caused at only slightly changed weather conditions, because of the time interval between reference and target measurements. The field measurements taken so far showed further problems with small measurement areas, with impact of the soil or of crop rows.

Discussion

The results from the laboratory experiments showed that wavebands at around 1450 and 2000 nm can most reliably be used to spectrally determine the water status in plants. Nonetheless, changes in the water status correlated to changes in biomass in all experiments. Wavelengths characterizing changes in the water status independent of biomass changes could not be distinguished in these experiments. Further experimentation is now on-going to eventually demonstrate relationships between reflectance and water status changes independent of biomass changes.

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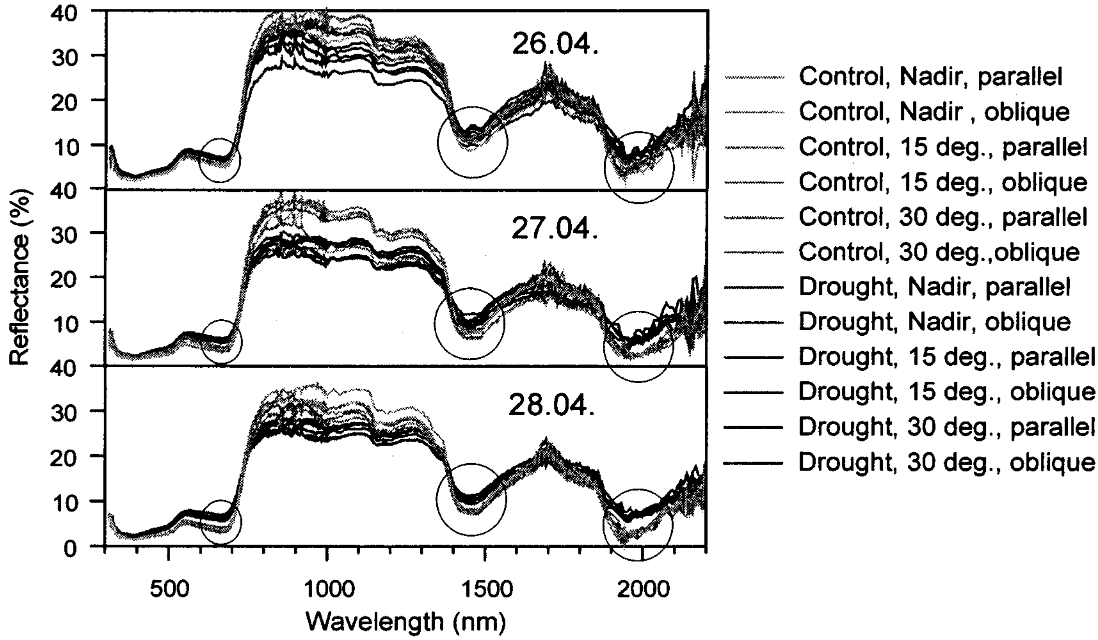

Figure 1. Reflectance of spring wheat at different drought levels. The impact of the zenith-view angle on the reflectance is shown. The reflectance increases with increasing zenith-view angle.

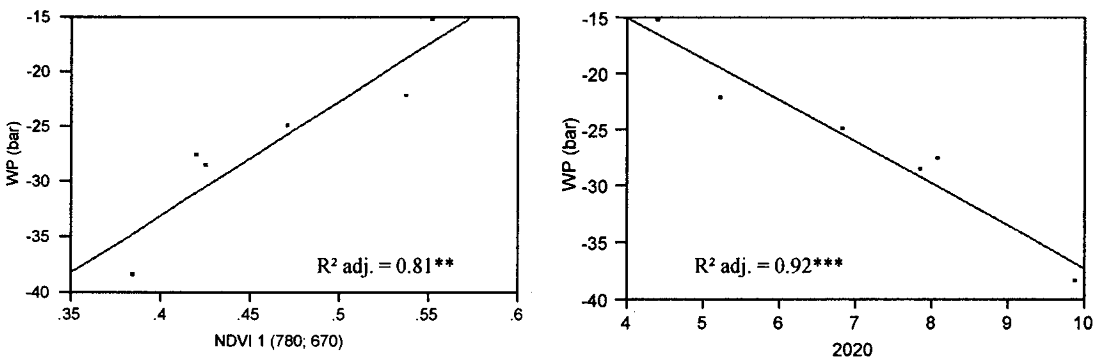

Figure 2. NDVI and reflectance at 2020 nm of wheat from different drought treatments. R^2 adjusted of linear fits of water potentials with NDVI values and reflectance are given. WP = water potential.