Rapid treatment monitoring by field spectroscopy

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Abstract

Remote sensing has been widely used for farming applications. Historically satellites dominate this technique. Terrestrial platforms can carry spectral sensors as well enabling real-time estimations for crop yield, pest and disease occurrence and much more. Field spectroscopy is a technique that can provide biochemical measurements without wet chemistry using the solar spectrum and the reflectance spectrum of an object. An imaging spectrometer can provide physiological information with a ground pixel size of a few centimeters. This tool can help organic farming researchers and farmers better understand the biochemical components of their fields without any destructive analysis. The availability of such field techniques and the growing interest in food quality and field monitoring have speeded up the technology transfer process. This paper gives a short overview of techniques and presents an ongoing research for the rapid monitoring of organic foliar fertilizer treatments.

Introduction

This paper presents an ongoing research and technological perspective on applying high- and low-resolution field spectroscopy for the rapid monitoring of grain quality (protein) of fertilized organic spelt. We used two field spectrometers, the Minolta SPAD 502 Chlorophyll Meter that is a small hand-held spectrometer which measures light at 650 and 940 nm absorbed by single leaves and gives a non-destructive estimate of plant Chl and Nitrogen (N) status and the FieldSpec® 4 Wide-Res spectrometer (ASD/Panalytical) with a spectral resolution of 3 nm and 30 nm between 400 and 2500 nm (2151 spectral channels).

The wavelengths of SPAD Meter (650 nm, 940 nm) were selected to calculate vegetation indices that were reported to be suitable for grain protein estimation. We followed a hybrid model because the SPAD measurements were made on in-season canopy leaves and the FieldSpec measurements on grains in laboratory. The grain protein content was compared to SPAD and FieldSpec measurements in case of four foliar fertilizers for two different farms in Hungary.

Material and methods

Vegetation indices are significant indicators for agriculture activities. The NDVI (Normalized Difference Vegetation Index) has been successfully used in the last four decades (Rouse at el. 1973).Traditional vegetation indices are calculated from two relatively broad (100 nm) spectral bands. Imaging systems offered new perspectives and methodological approaches for precision farming in Hungary (Fekete et al. 2004, Baranyai and Firtha 1997, Láng et al. 2000,Felföldi et al. 2001, Tamás 2001, Németh et al. 2004, Jung et al. 2006). We calculated the following vegetation indices: Normalized Difference Vegetation Index (NDVI, Rouse et al. 1973), Ratio Vegetation Index (RVI, Jordan 1969) and Difference Vegetation Index (DVI, Tucker 1979)

In 2013 on-farm field experiments have been started on different organic fields in Hungary to evaluate the effect of natural foliar fertilizer applications on spelt crop quality and yield. Four combinations of foliar applications and a control field were compared in order to monitor the efficacy of the treatments. Products used in the experiments are all substances intended to increase grain yields and quality and are available in trade. The following parameters were analyzed: grain quality (protein-, gluten-, moisture content and falling number), and foliar SPAD chlorophyll content of treated and control plants. Chlorophyll concentration correlates with foliar N concentration which is often a limitation factor of crop productivity (Evans 1989, Yoder and Pettigrew-Crosby 1995). The aim of the SPAD measurements was to see if the leaf total chlorophyll content can be related to the grain quality, using the four foliar fertilization treatments. In some cases leaf greenness was influenced by the foliar fertilizer applications, but in most cases the treatments did not

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enhanced the postharvest quality of the crop. A direct connection between SPAD results and grain quality measurements could not be detected.

Field spectroscopy was conducted on one of the field trials, in order to test spectral information for crop quality differences between the four foliar treatments. The test measurement also allowed a comparison of the field remote sensing technique with the point measurements of SPAD.

Results

For statistical evaluation R.2.14.0 was applied. For measuring differences between group means and their associated procedures Anova and Tukey HSD post-test were applied. There was no significant difference between the grain quality of the treatments. Similarly, SPAD measurements of the treatments did not show significant difference. Moreover, correlation could not be detected between SPAD data and grain protein content.

Based on the concept that the field spectrometer can provide the same wavelengths that the SPAD meter uses, two wavelengths (650 nm, 940 nm) were selected to calculate vegetation indices. The results of Apan et al. (2006) say that the most significant spectral bands for grain protein prediction (measured in in-season canopy), in descending order are: 710-754nm, 890-960nm, 1020-1055nm, 662-680nm, 545-580nm, and few wavelengths in the SWIR (over 1000 nm).

We followed a hybrid model because the SPAD measurements were made in in-season canopy as well and the region of 662-680nm and 890-960nm fit best to the spectral sensibility of SPAD. Comparing the values of vegetation indices and protein contents it can be observed that the three indices do not show common tendencies with the protein measurements.

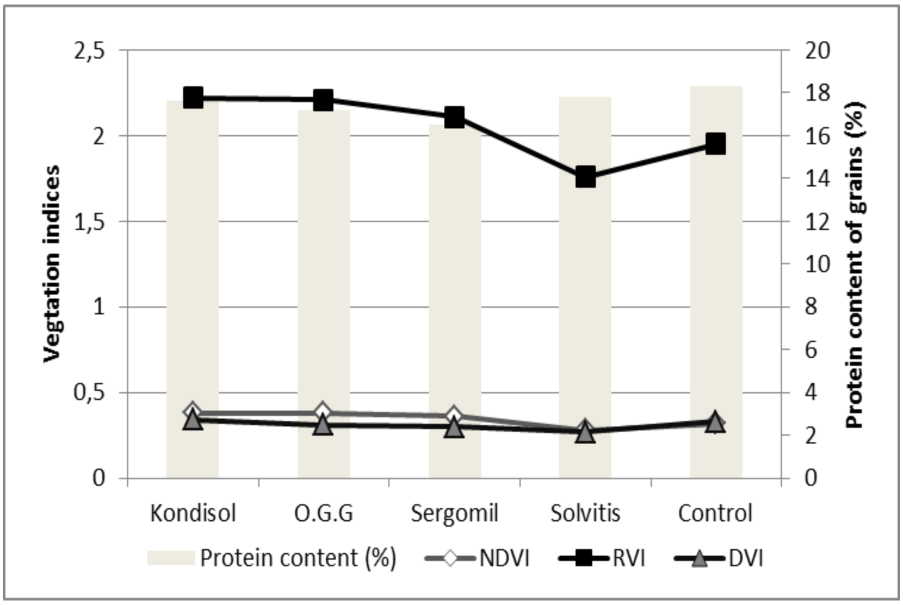

Fig.1. Comparison of the vegetation indices with the average protein content of grains in Csárdaszállás, Hungary.

Conclusions

Based on present statistical data there is no reason to assume that significant grain quality differences occurred between foliar fertilizer treatments. Further measurements are needed to verify preliminary data. Spectral nutrient analyses need to be compared to wet chemistry results. The preliminary results presented here suggest that field spectroscopy might have a good potential for the rapid analysis of crop quality. However, it is necessary to test both point and image spectrometry further. Using proximal sensing, we will continue to compare the spectral information of red-edge parameters with SPAD measurement and grain quality measures in order to detect plant Chl content and forecast crop quality in real-time under organic farming conditions. For developing sound models of organic foliar fertilizers' effects on organic spelt quality we need more SPAD- and grain quality measurements. Our aim is to proceed with the trials in order to introduce remote sensing techniques into the forecasting of organic crop quality.

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