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Rapid Monitoring of Organic Foliar Fertilizer Treatments on Organic Spelt by a Portable SPAD 502 Chlorophyll Meter and Field Spectroscopy

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Abstract: Remote sensing techniques are widely used for farming applications but are less widespread in the organic sector. This technique offers great perspective for organic farms as field scale spectroscopy could provide rapid monitoring of nutrient imbalances or stresses and the efficiency of organic foliar fertilizer treatments. Foliar fertilization may have a major influence on grain quality and can increase grain protein content for optimum yield quality. Remote sensing tools can help researchers and organic farmers better understand the biochemical, physiological or morphological activity of their fields without invasive or destructive analysis. Remotely sensed data could provide opportunities to manage grain harvest differently and maximize productivity. In this study we introduce a monitoring approach for spelt grain quality influenced by foliar fertilizers and using spectral methods to forecast grain protein content. This approach has three main components. (1) Leaf Nitrogen content. which is supposed to be significantly correlated with the leaf total Chlorophyll (Chl) concentration measured by a Soil–Plant Analysis Development (SPAD) 502 Chlorophyll Meter. (2) The relationship between leaf total Chl content and grain protein of spelt observed with and without foliar fertilizers. (3) The relationship between protein content data and reflectance spectra measured with field spectrometer. Preliminary results show that hand-held techniques (SPAD 502 Chlorophyll Meter and FieldSpec® 4 Wide-Res - spectrometer) provide useful auxiliary data for organic crop management. One of our objectives is to decrease time and budget currently needed for destructive chemical analysis and increase the accuracy of on-site and quasi-real-time analysis of major constitutes such as protein or Chl.

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1 Introduction

This paper presents an ongoing research on applying field spectroscopy and Soil–Plant Analysis Development (SPAD)-502 Chlorophyll Meter for the rapid monitoring of Chlorophyll (Chl) content and grain quality of fertilized organic spelt. We used a Minolta SPAD 502 Chlorophyll Meter that is a small hand-held spectrometer which measures light (650 and 940 nm) absorbed by single leaves and gives a non-destructive estimate of plant Chl and Nitrogen (N) status (WOOD ET AL., 1993; LEMAIRE AND SALETTE, 1984; LEMAIRE ET AL., 2008). The measuring area of SPAD 502 Chlorophyll Meter is 2 mm x 3 mm. Leaf nitrogen concentration is related to photosynthetic capacity and this relationship can be used to predict the N content of leaf (JACQUEMOUD AND BARET, 1990) by means of SPAD 502 Chlorophyll Meter. We have chosen spelt as our test plant to study the efficiency of four organic foliar fertilizers. Spelt (Triticum aestivum ssp. spelta) is genetically closely related to wheat (ABDEL-AAL & HUCL, 2005) and an interesting and promising crop for organic farming. This domesticated hulled wheat was one of the major feed and food grains in ancient Europe. In the last years the interest in organic farming towards hulled wheat has increased due to the low-input needed for its cultivation, its special stress resistance and quality output (AN ET AL., 2005; CAMPBELL, 1997). Spelt may contain higher levels of protein and minerals than wheat depending on the genotype (ABDEL-AAL & HUCL, 2005). We used in our research organic foliar fertilizers to test their effects on the nutritional quality of spelt. In order to upscale SPAD measurements to field scale we also conducted field spectroscopy using FieldSpec® 4 Wide-Res spectrometer to analyse the correlations of the two spectral data.

2 Methods and materials

2.1 Experimental design

The data were obtained from 2 field experiments in Hungary. We tested four different foliar fertilizers (Organic Green Gold, Kondisol, Solvitis Cu, Sergomil L-60) used on organic spelt in the growing seasons 2013. All products are available in trade in Hungary. Organic Green Gold (O.G.G.) contains living microorganisms and algae[1]. Kondisol includes a moist solution extract from peat- and earthworm humus mixture [2]. Solvitis Cu [2] and Sergomil L-60 are liquid, microelement and Cu contained foliar fertilizers [3]. The experiment was undertaken in Hungary at Csárdaszállás (N 45º51’42.38” E 20º56’52.22”) and Földes (N 47º16’09.30” E 21º23’07.30”). The experimental treatments were arranged in a complete block design. Each plot was 1 ha. Products used in our experiments are all available in trade. Crops were sown in the period 15-23 October 2012. The Minolta SPAD 502 Chlorophyll Meter was used in the period 20–29 May 2013, 1-2 weeks after the treatments. Twenty random readings were taken in each plot on the flag leaf of 20 plants. One day before the harvesting, 3 microplots (0.25 m2 each) in each treatment were hand-harvested for grain quality measurements. Four protein contents measurements were performed in each plot.

2.2 Tools for rapid measurements

We used the Mininfra Scan-T Plus grain analyser which applies high quality infrared optics and special sample presentation systems and allows the whole grain, flour and feed measurements [4].

The SPAD 502 Chlorophyll Meter is a widespread tool for rapid testing in the field. From a spectroscopic point of view it is an active sensor with minimalistic spectral resolution since it uses two LED-s at 650 and 940 nm. The detector is a common silicon array that converts the signals into readable digital values.

Additionally to the field SPAD leaf measurements the treated seed (from the same parcels) were measured with a field spectrometer of ASD/Panalytical under laboratory conditions in order to test the comparability of SPAD related information to diffuse reflectance data. SPAD measures the transmission signals of the leaf tissue while the spectrometer detects the reflectance of seed surfaces.

A FieldSpec® 4 Wide-Res spectrometer (ASD/Panalytical) was used. The available spectral range was 350 - 2500 nm with a sampling interval of 1.4 nm at 350 - 1000 nm and 2 nm at 1000 - 2500 nm. The spectral resolution is 3 nm at 700 nm and 30 nm at 1400/2100 nm. It has a 25 degree full conical angle fiber optic cable. Noise equivalent delta radiance (NeΔL) for standard 1.5 m fiber optic cable is 1.0 x 10-9 W cm-2 nm-1 sr-1 at 700 nm, 1.2 10-9 W cm-2 nm-1 sr-1 at 1400 nm, and 1.9 10-9 W cm-2 nm-1 sr-1 at 2100 nm. Stray light is in VNIR 0.02%, in SWIR 1 and 2 0.01%. Wavelength reproducibility is 0.1 nm and wavelength accuracy is 0.5 nm. For the calibrated reference panels, the absolute hemispherical-conical reflectance factor (SCHAEPMAN-STRUB ET AL., 2006) values were defined. The calibration of the panels was performed with a standard from the U.S. National Institute of Standards and Technology (NIST), serial number 2044a-01-15. The (hemispherical-conical) absolute reflectance was determined by use of a Perkin-Elmer Lambda 19 UV-VIS-NIR spectrometer (serial number: 1260) equipped with a 150 mm PTFE (Polytetrafluoroethylene) sphere (certified by National Metrology Institute of Germany (PTB) Braunschweig, Calibration PTB 4.52-0208). The size of the calibrated reference panels was 300x300mm.

The proximal seed detection was carried out using a special optical head called contact probe to set a minimum distance between seeds and optical fiber. Artificial intern light source was used with the following specifications: 12-18 VDC. 6.5 W. light source Halogen bulb. color Temperature 2901 +/- 10º% K and with a spot size of 10 mm.

2.3 Statistical analysis and 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.

Box plots in Figure 1 and Figure 2 display differences between Chl and protein contents for treatments and median for SPAD readings and the deviation from the means. In Figure 3 and

Figure 4 the deviation of SPAD readings and protein contents from the Control plots are demonstrated in order to detect any correlation between SPAD and protein content data. 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.

Földes, Hungary

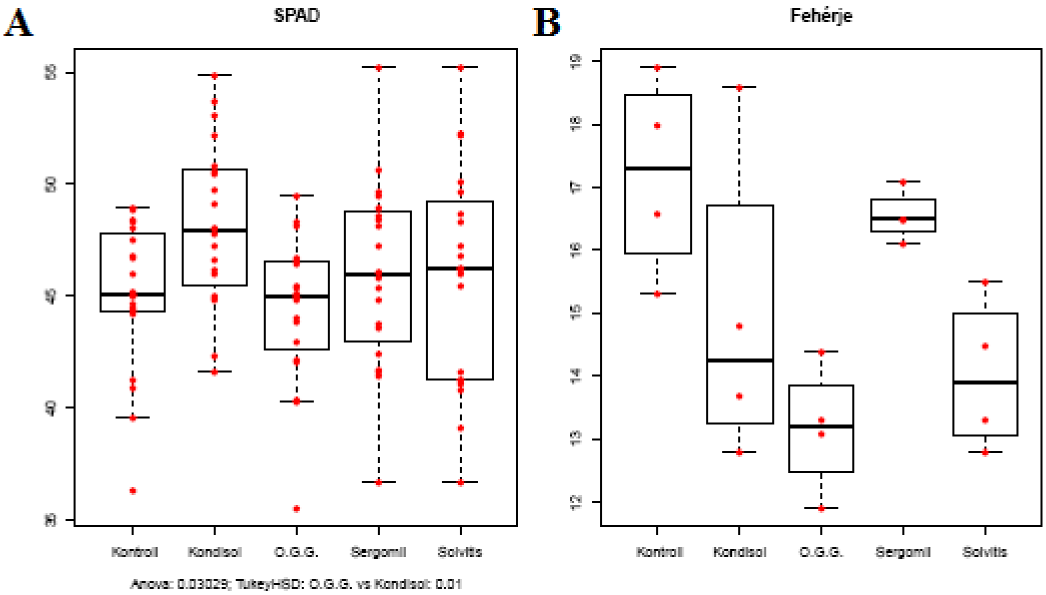

Fig.1. (A) Box plots of Minolta SPAD readings show the differences between the Chl content of leaves. (B) Box plots of protein measurements show the differences between the protein content of treated grains.

Csárdaszállás, Hungary

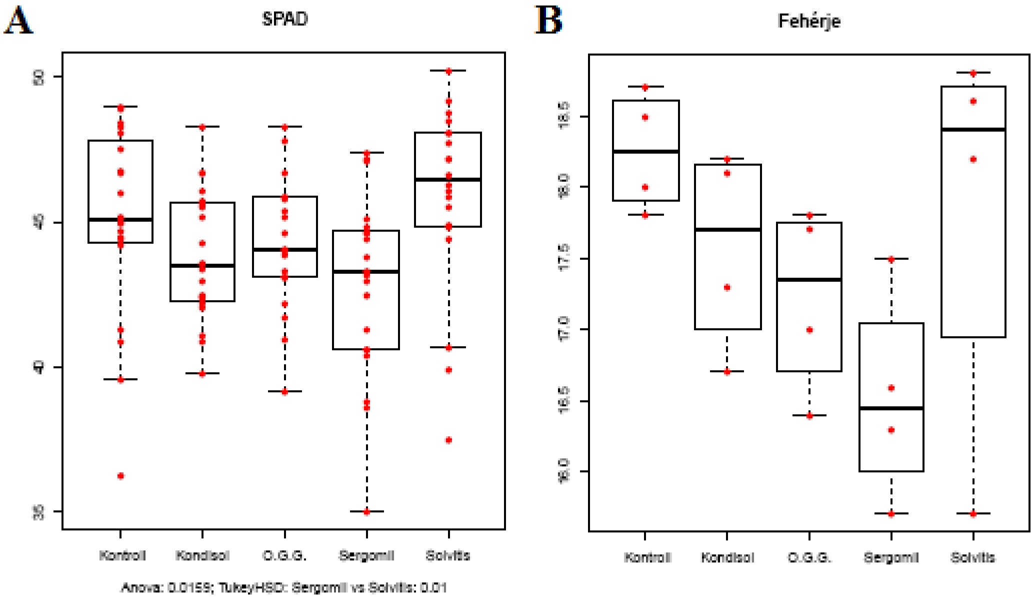

Fig.2. (A) Box plots of Minolta SPAD readings show the differences between the Chl content of leaves. (B) Box plots of protein measurements show the differences between the protein content of treated grains.

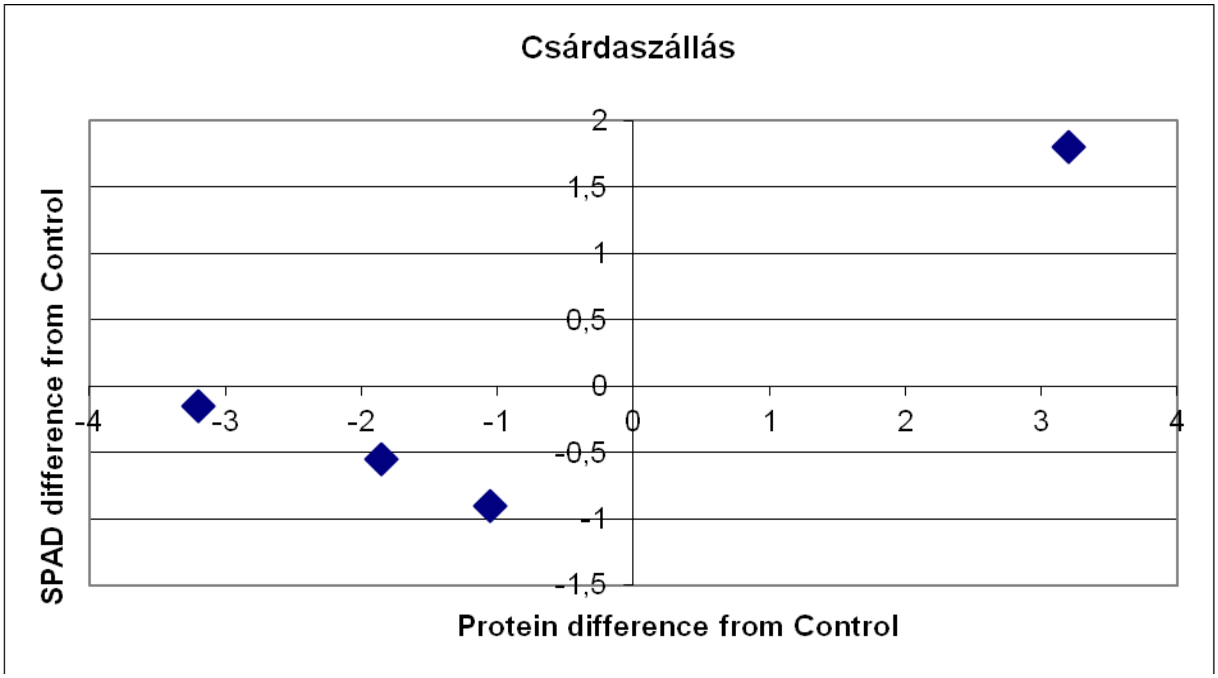

Fig.3. Chl and protein deviation from the Control plot

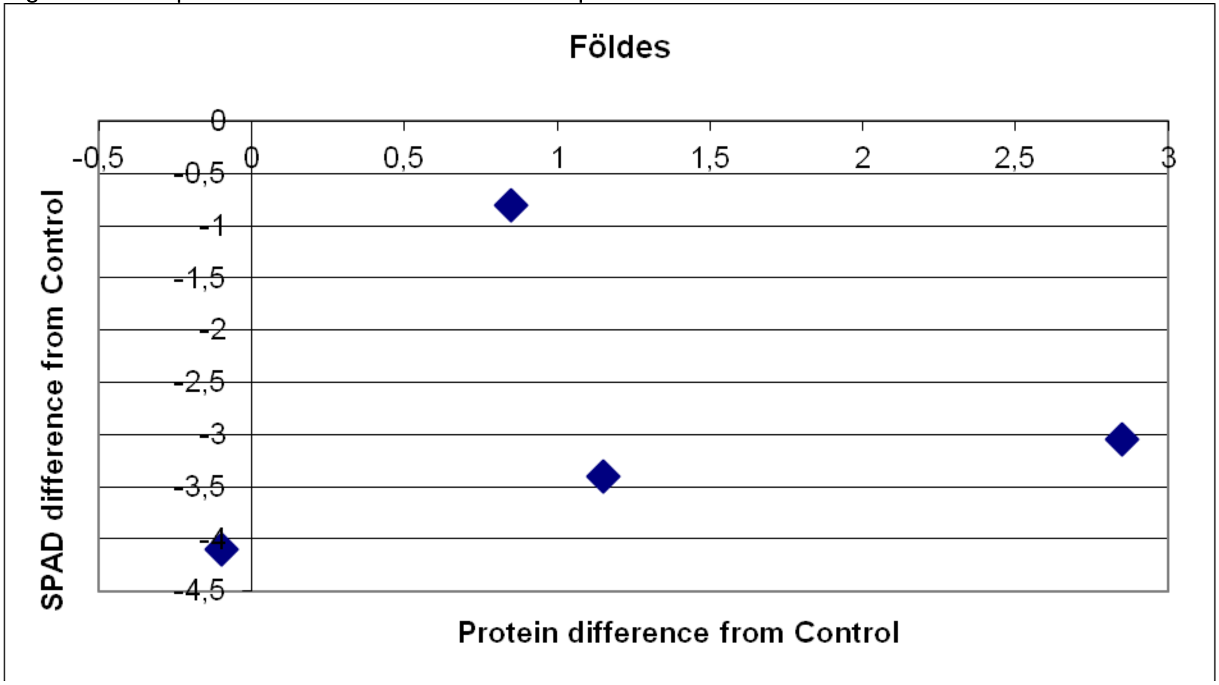

Fig.4. Chl and protein deviation from the Control plot

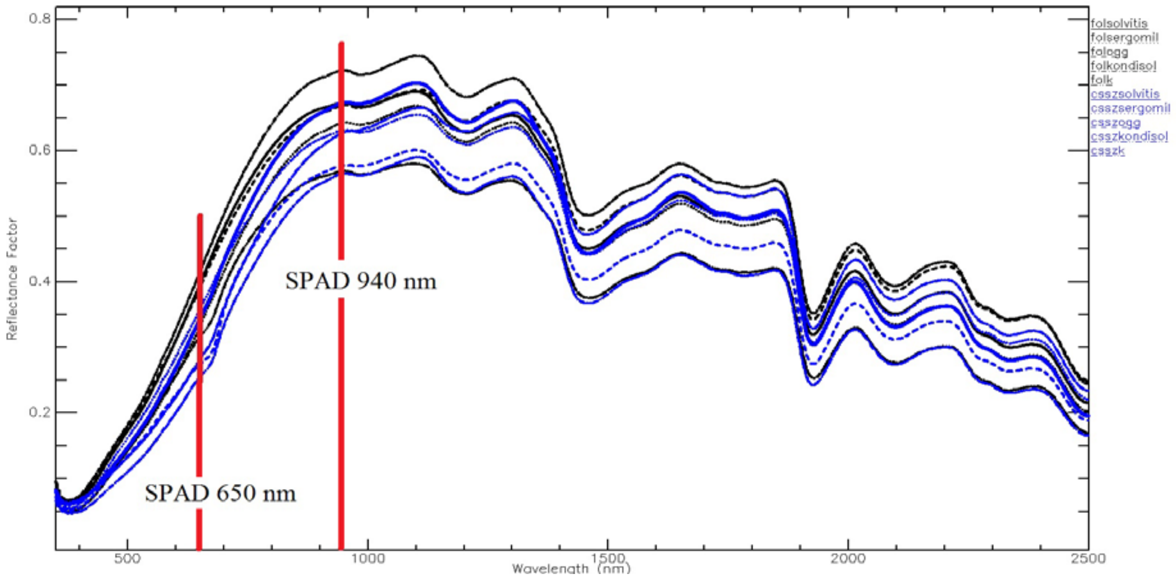

Fig.5. Spectra of treated grains and the detection channels of SPAD compared to a full reflectance spectrum

Figure 5 shows the relation between the spectral sampling points (650 nm, 940 nm) of SPAD device and the FieldSpec spectrometer.

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 follow 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.

The following vegetation indices were calculated

Tab.1. Vegetation indices used for grain protein prediction in our study

Abbrivation	Name	Vegetation index formula	Source
NDVI	Normalized Difference Vegetation Index	$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$	Rouse et al. 1973
RVI	Ratio Vegetation Index	$RVI = \frac{NIR}{RED}$	Jordan. 1969
DVI	Difference Vegetation Index	$DVI = NIR - RED$	Tucker. 1979

Tab.2. Vegetation indices values for 4 treatments on two different on-farm sites

	Földes					Csárdaszállás				
Index	Control	Kondisol	O.G.G	Sergomil	Solvitis	Control	Kondisol	O.G.G	Sergomil	Solvitis
NDVI	0.29	0.27	0.26	0.32	0.26	0.38	0.38	0.36	0.28	0.32

RVI	1.80	1.74	1.71	1.93	1.70	2.22	2.21	2.11	1.76	1.95
DVI	0.25	0.31	0.28	0.31	0.28	0.34	0.31	0.30	0.27	0.33

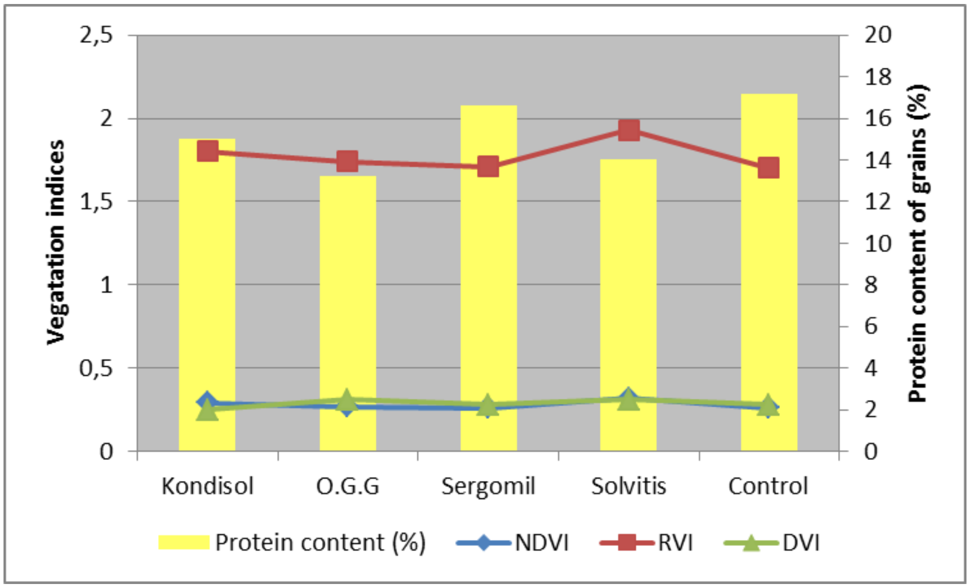

Fig.6. Comparison the vegetation indices with the average protein content of grains in Földes, Hungary.

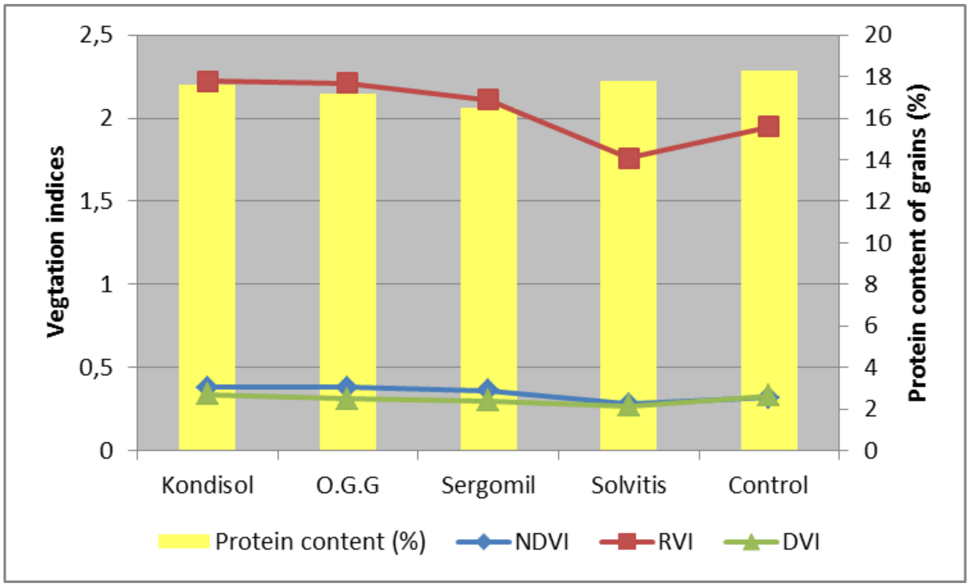

Fig.7. Comparison the vegetation indices with the average protein content of grains in Csárdaszállás, Hungary.

The vegetation indices used in our study are presented in Table 2. 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.

2.4 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, in 2014 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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