Discriminating NPK Stress in Barley by Spatial Reflectance at Sub-Leaf Scale

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Abstract

Non-destructive stress diagnostics are essential optimising variable nutrient application with a minimal environmental load. Nitrogen, phosphorous and potassium stress at canopy scale are primary characterised as non-specific symptoms due to the varying levels of chlorophyll in the leaves. Chlorophyll is predominantly influencing the characteristics for each of the three target symptoms. Hence it will be almost impossible spectrally to discriminate N, P and K stress at canopy scale. Therefore it is essential to include spatial information at sub-leaf scale in order to reach discrimination abilities of N, P and K stress symptoms.

This paper introduces a methodology potentially able to discriminate between N, P and K stress symptoms by identifying the most significant characteristics at the plant separating each of the three stress symptoms. The methodology was tested in a spring barley crop.

Equipment
The equipment used was a Zeiss monolithic miniature spectrometer (MMS 1) NIR enhanced. It is an OEM (Original Equipment Manufacture) device and a tec5 company multi operating spectrometer system. The spectrometer system consists of a light source (12V/100W tungsten halogen lamp), which is controlled by a photodiode sensor, and optical components of the spectrometer. The optical components consisted of a body made of UBK 7 glass with aberration corrected grating. The Zeiss MMS 1 NIR was the sensor. The claimed detection range of the sensor was 306 -1132 nm in 2 nm broad bands (Zeiss company, 1999), however, the wavelength range used was 450-1000 nm.

N, P and K Stress Symptoms Establishment
Clear visible stress symptoms of N, P and K respectively were established under glasshouse conditions in an inactive media (perlite) applied with sufficient amount of essential nutrients (micro and macro) with the exception of the respectively target nutrient stress components (N, P and K). Three replicates in time were carried out and ten sub-samples for each nutrient stress symptom (N, P and K stress) were established. Control plants, applied with all essential nutrients and in sufficient amounts, were further established.

Data Acquisition and Analysis
Directed Sampling Technique (DST) was carried out on each plant at three different growth stages. The principle of the DST is to measure the light absorption from several spatial specified areas at a plant and relate the spectral information according to the spatial information.
Each leaf on the barley plant was measured at the top, mid and bottom. This acquisition of data was carried out at three early growth stages (12-13, 21-24, and 26-29 BBCH scale). Soft independent modelling of class analogy (SIMCA) was used to identify the most significant locations on the plant for N, P, K deficiency and Control condition discrimination. Partial least squares regression (Dummy PLS2 also known as PLS-DISCRIMination) was used to separate the significant discrimination spectra identified through SIMCA.

Results
The significant locations with respective growth stages for N, P, K deficiency and Control condition discrimination are illustrated in Figure 1.

![Figure 1: Significant discrimination locations on a barley plant for Nitrogen, Phosphorous and Potassium deficiency and control condition. GS is the growth stage in BBCH scale.](image)

The discrimination results from the four conditions are illustrated through the PLS2 score plots in Figure 2.

![Figure 2: Partial Least Square Regression 2 from locations shown in Figure 1 in the spectral range 450 – 1000 nm, full cross validation was used. A: Step 1, spectra from control plants (C) and spectra from phosphorus stress (P) could be identified and discriminated. B: Step 2, it was possible to discriminate between nitrogen (N) and potassium (K) stressed plants after excluding control plants and phosphorus stressed plants.](image)

Control spectra and phosphorus deficiency spectra could be separated through PLS2 step 1 (Figure 2, A) and nitrogen and potassium deficiency spectra could be separated in step 2 (Figure 2, B)

Conclusion
The results show that inclusion of the plant’s spatial information together with hyper spectral information enables discrimination of N, P, K deficiency and Control condition.