Use of reflectance measurements for the early detection of N, P, Mg, and Fe deficiencies in *Zea mays* L.

Simone Graeff[1], Wilhelm Claupein[1] and Sven Schubert[2]

[1]Institute of Crop Farming and Grassland Research (340)
University of Hohenheim, Fruwirthstr. 23, 70593 Stuttgart, Germany

[2]Institute of Plant Nutrition, Interdisciplinary Research Center (IFZ)
Justus Liebig University, Heinrich-Buff-Ring 26-32, 35392 Gießen, Germany

Introduction

Mineral deficiencies can seriously reduce crop yield and economic returns to farmers. Reflectance measurements may provide inexpensive and fast estimates of the mineral status of plants. The use of spectral measurements to sense immediate changes in crop physiology and metabolism may allow timely correction of stress problems before irreversible damage occurs.

This study was conducted to examine specific changes of leaf reflectance of corn due to nutrient deficiencies.

Material and Methods

During the 1998 and 1999 growing seasons (May-August) reflectance spectra were collected from the 4th leaf of corn (*Zea mays* L. cv. Arsenal) deficient in N, P, Mg and Fe. Scanning was performed with a digital, light-sensitive, high-spatial- resolution LEICA S1 PRO camera in conjunction with a light source (HRI-TS 400 W/D; ~ 150 W m^{-2}) of total daylight spectrum. Using long-pass filters active in different wavelength ranges, total daylight spectrum was split into various wavelength ranges (Fig. 1 a-c).

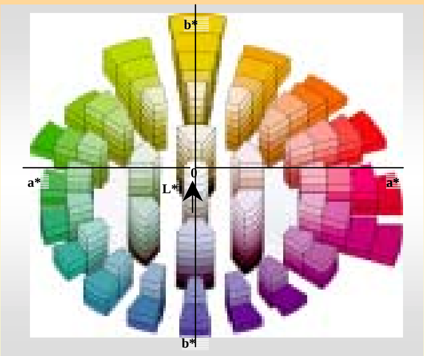
Fig. 1a: LEICA S1 PRO

Fig. 1b: Leaf scan

Fig. 1c: Measuring Technique

Commercial long-pass filters were used to split the total spectrum into various wavelength ranges. Scans were performed of the fourth leaf for each plant over a period of 4 w. Leaf scans were analyzed with the Software ADOBE® Photoshop 5.0 in the L*a*b*-color system. All experiments were carried out as completely randomized block design with 3 replications. Analysis of variance was performed for all data for (α=0,05) using the general linear model procedures of Jandel Scientific Sigma. Stat 2.0.

Fig. 2: L*a*b*-color system; (CIE,1976)



The L*a*b*-color system is a three-dimensional system (Fig. 2). The x-axis represents the parameter a* which describes the green/ red percentage of the color. The y-axis represents the parameter b* which describes the yellow/ blue percentage of the color. L* stands for the lightness of a color and is represented on the z-axis. Nutrient deficiencies were identified by splitting the scans into a*- and b*-parameters in different wavelength ranges.

Results

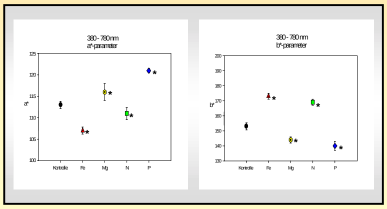
Fig. 3 presents a scan of the 4th leaf of different nutrient deficient plants. The scan was carried out without filters and can be compared to the normal view of the human eye. No visible differences in the color of the leaves, nor any typical deficiency symptoms were detectable.

Fig. 3: Optical comparison of induced nutrient deficiencies

Scans were separated into different wavelength ranges and split into the L*a*b*-system. Fig. 4 shows the results for the parameters a* and b* in the wavelength range 380 - 780 nm.

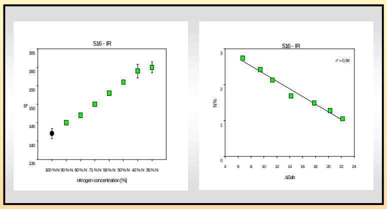
All nutrient deficiencies showed significant changes compared to the control and significant differences relative to other examined nutrient deficiencies.

Fig. 4: Effect of nutrient deficiencies on parameters a* and b* for the wavelength range 380 - 780 nm



As shown in Fig. 5a (left) a linear relationship was found between nitrogen concentration and the b*-parameter. Fig. 5b (right) shows the correlation results for nitrogen deficiency in the wavelength range 516 - IR. Using this correlation it not only seems to be possible to detect and identify a nutrient deficiency, but also to quantify the amount of nutrient requirement.

Fig. 5: Relationship between nitrogen concentration and the b*-parameter



Conclusion

Reflectance measurements appear to be a powerful non-destructive technique with a great potential for monitoring plant nutrient deficiency. The results indicate that reflectance changes in the early stage of a nutrient deficiency were mainly related to structural changes within the leaves (Graeff et. al, 2001).
However, the use of spectral properties as a tool in nutrient deficiency diagnostics requires further understanding of the relationship between spectral properties, nutrient concentration, and structural changes in plant tissues.

Graeff, S., Steffens, D., Schuber, S. (2001): Use of reflectance measurements for the early detection of N, P, Mg, and Fe deficiencies in *Zea mays* L. J. Plant Nutr. Soil Sci. 164, 445-450