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Spectral detection of nitrogen status, biomass and yield of field-grown maize plants

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Abstract

On-the go measurements of biomass and nitrogen uptake allow to optimise fertilising strategies in heterogeneous fields. We evaluated the potential to non-destructively detect biomass and nitrogen uptake in maize with a tractor-based sensor. The measurements were conducted in 1.5 m wide strips on both sides of the tractor. To create a range of biomass and differences in nitrogen status, five N-fertilizing and three seeding rates were applied. Measurements were conducted seven times between 5-leaf-stage and ripeness. Nitrogen-uptake could remarkably well be detected with $R^2 = 0,85$. The results show a good correlation of about $R^2 = 0,80$ between REIP (red edge reflection point) and the final yield for all measurements.

Keywords: nitrogen uptake, proximal sensing, yield estimation

Introduction

Precision farming can increase yield, reduce fertilizer input and pollution by avoiding partial over-fertilization. Therefore the nitrogen status should be estimated, the biomass and yield be determined. Spectral measurements are a suitable tool to estimate these parameter. We examined how well they can be estimated in maize with a tractor based field spectrometer.

Materials and methods

The experiment was carried out in the south-east of Germany in 2002. The experimental field was about 4 ha in size and contained 52 plots which were 15 m wide and about 40 m long. The sowing rate was varied at 6, 10, and 14 plants per m² and the N-rate consisted of 5 treatments (25, 70, 120, 170 and 220 kg/ha). 25 kg N were applied at sowing, the remainder was applied at May 5 as N-fertilizer stabilised with a nitrification inhibitor.

Figure 1. Field sensor in front of the tractor.

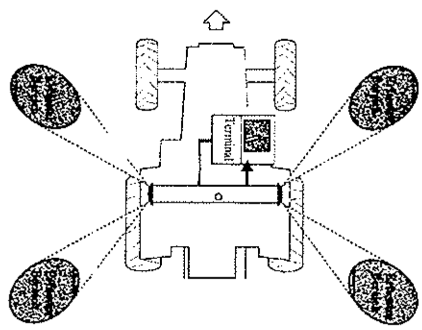

Figure 2. Sensing area with four ellipsoids, each about 2 m² in size.

The spectral measurements were conducted with a two channel spectrometer at five wavelengths using a modified Hydro-N Sensor (Fig. 1). It consists of a four fibre optics to measure the canopy reflection (Fig. 2) and a second spectrometer to measure the radiance. Measurements were done at 550, 670, 700, 740 and 780 nm and three spectral indices were calculated, namely red edge inflection point (REIP), infrared green ratio (G/IR) and red infrared ratio (700/780). The measurements were performed at 2 m above the canopy. Spectral indices were compared with destructive harvests of biomass, N-content and yield. Measurements were conducted seven times between the 5-leaf-stage and ripeness. Biomass was destructively measured exactly in the same area as the measurements were done in June 20 (5-leaf-stage), July 1 (6-leaf-stage), July 22 (8-leaf-stage) and the harvest was at September 16.

Results and discussion

N-concentration was moderately well determined (Fig. 3). High coefficients of determination for quadratic relationships were obtained between biomass, yield, N-uptake, and reflection indices (Figures 4-6).

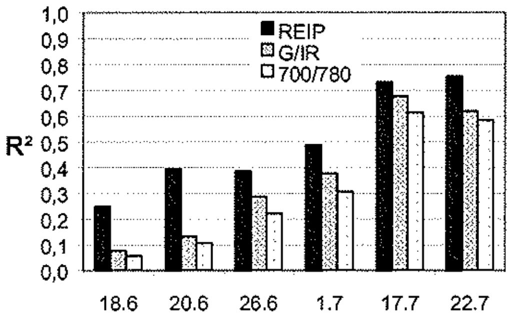

Figure 3. Coefficients of determination between concentration and reflection indices.

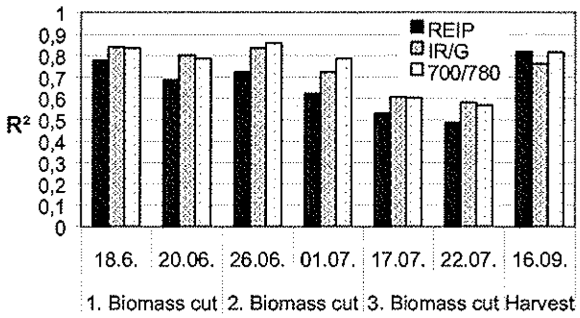

Figure 4. Coefficients of determination between biomass and reflection indices.

Measurements were probably influenced by soil reflectance at the 5-leaf-stage and by flowering at the 8-leaf-stage. Yield estimations with REIP were hardly influenced. N-uptake was consistently very well predicted.

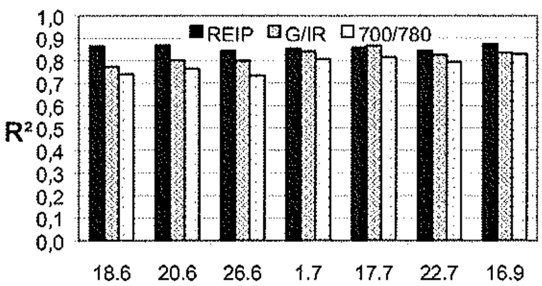

Figure 5. Coefficients of determination between N-uptake and reflection indices.

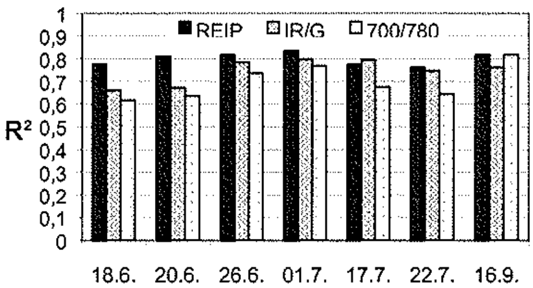

Figure 6. Coefficients of determination between yield and reflection indices.

Conclusion

The results show that nitrogen status, nitrogen uptake and yield can be detected already at an early stage by spectral measurements. The results suggest that nitrogen fertilisers could potentially more specifically and rationally be applied to maize crops.