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NIR-Spectroscopy to estimate soil nitrogen supply

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Abstract

The aim of this study is to establish the applicability of NIR-spectroscopy as a rapid method for an accurate estimation of N-potentials in agricultural soils. Furthermore, the usefulness of this method to determine other important soil parameters was tested. Three subsequent N-uptakes of by oat in rye grass in pot trials conducted with 106 soils were used to define short-term or long-term N-potentials. Using NIR-spectra (3850-10000 cm^{-1}), models were calculated to predict N-potentials and other soil-parameters (i.e. clay). The results demonstrate that the prediction of short-term N-potentials by NIRS-models is inadequate (R^2=0.33), whereas models for long-term N-potentials are good (R^2=0.77). In addition, valuable information concerning the N-turnover as N_t, C_{org} or soil texture (i.e. clay, silt) (R^2=0.91) can be obtained. NIR-spectroscopy is a useful tool to estimate long-term soil nitrogen supply.

Introduction

Owing to the rapid progress in data-processing during the last decade, the use of NIR-spectroscopy in chemical, biological or agricultural sciences has been enhanced. Referring to agriculture, NIR-spectroscopy is used for the rapid analysis of the quality of forages, rape seed or cereals. The subject of this study was to prove the applicability of NIR-spectroscopy for the fast and accurate determination of N-potentials in agricultural soils.

Materials and methods

Pot trial

From 1997 to 1999 four subsequent pot experiments were conducted with 106 soils representing a wide range of different composition and origin (Table 1).

Table 1. Soil characteristics

Parameter	Range	Parameter	Range
clay (%)	6 – 42	C_{org} (%)	0.59 – 4.24
silt (%)	9 – 79	N_t (%)	0.07 – 0.46
sand (%)	3 – 84	C/N	7.7 – 12.7
pH ($CaCl_2$)	4.7 – 7.5		

Owing to the broad origin (fields and long-term fertilising experiments) of the samples the NO_3-N-content of the soils differed considerably. Its influence on the N-potential was excluded with the first pot trial (08/97-10/97) (Figure 1) (results not shown). On soil samples, taken after the 1st trial (10/97), NIR-spectra were taken. The total N-uptake was defined as the criteria for the total N-potential, divided into short-term N-potential (i.e. N-uptake 3/98 – 6/98) and long-term N-potential (i.e. N-uptake 7/98 – 6/99), respectively (Figure 1).

Methods

NIR-spectra were obtained by using the Bruker/Vector 22N system (Bruker©, Ettlingen, Germany) equipped with a PbS detector. For the NIR-spectroscopy, soils samples (10/97) were sieved (2 mm) and dried (40°C, 24 h). Scanning was performed from 3850 – 10000 cm^{-1} (λ = 1000 – 2600 nm), 64 scans per sample, data were collected every 8 cm^{-1}. Five measurements were averaged to calculate a mean NIR-spectra. From all NIR-spectra, models for the N-potentials and other soil characteristics were developed based on the Partial Least Square regression and cross validation using Opus/Quant2-Software (Bruker©). Further, several standard methods as EUF-extraction (Nemeth, 1982) or determination of microbial biomass (Anderson and Domsch, 1978) were carried out and the data were also included with the N-potentials in regression equation to describe N-potentials.

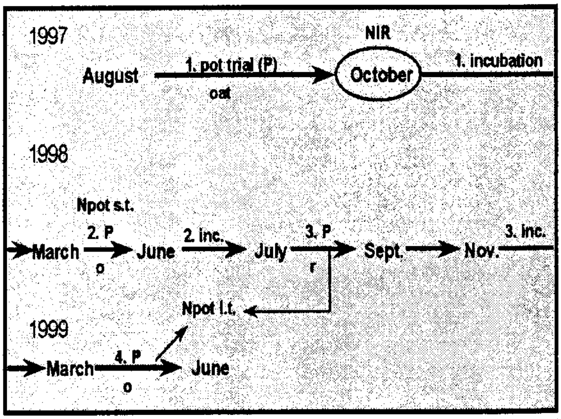

Figure 1. Course of pot experiments (P) and soil incubation periods (inc.), 1997 to 1999 (o = oat, r = rye grass), Npot s.t. = short-term N-potential, Npot l.t. =long-term N-potential

Results

The long-term N-potential was accurately predicted by the NIR-models (R^2=77 %), where as the prediction for the short-term N-potential was inadequate (Table 2). For the long-term N-potential the proportional mean prediction error was approx. 12 %. The total N-uptake was also well represented by the NIR-spectra.

Table 2. Results of cross-validation of the NIRS-models for the N-potentials (n=106).

	Range	R^2 (%)	PE (%)
Npot s.t.	0.4-4.2 mg N/100g d.s.	34	30
Npot l.t.	1.1-7.1 mg N/100g d.s.	77	12
Npot total	2.5-11.1 mg N/100g d.s.	63	15

(PE = Ø prediction error)

Compared to the other tested methods for the evaluation of long-term and total N-potentials, the NIR-models showed the highest regression coefficient together with the lowest prediction error (Table 3).

Table 3. Regression coefficients and mean prediction errors of NIRS-models compared to models calculated with results of conventional methods (n=106).

		R^2 (%)	PE (%)
Npot l.t.	• NIRS	77	12
	• Norg (EUF)	66	14
	• N_t	71	13
	• microb.biomass	58	18
Npot total	• NIRS	63	15
	• Norg (EUF)	55	17
	• N_t	53	17
	• microb.biomass	50	18

Beside the development of prediction-models for N-potentials by the means of NIR-spectroscopy, the NIR-spectra were also computed for important soil parameters such as C_{org}, N_t and soil texture (Table 4). Especially for C_{org}, N_t, clay, and silt the prediction is very accurate. For sand, the regression coefficient is also very high, but the model has an inadequate prediction error.

Table 4. Results of cross-validation of the NIRS-models for soil texture and organic matter content.

Parameter	R^2 (%)	PE (%)
Clay (%)	91	11
silt (%)	91	15
Sand (%)	89	35
C_{org} (%)	90	12
N_t(%)	90	11

The presented NIR-models are based on cross-validations, i.e. all 106 samples were entered into the regression. The general applicability of NIR-prediction for C_{org} and N_t has been established by a validation with test samples (n=42, R^2=80 %, PE =9 %) (data not presented). The relation between N-potentials and N_t is quite close (Table 3), therefore NIR-spectroscopy is likely to work on the prediction of N-potentials. A conclusive evidence will only be possible by the conduction of further pot experiments with unknown test-samples.

By the means of adequate NIRS-models, information on important soil characteristics and on details of the N-cycle can be obtained by NIR-spectroscopy as an easy and rapid method for analysis.

Discussion

Only few information is available on the use of NIR-spectroscopy for the prediction of N-potentials. Börjesson *et al.* (1999) described the successful use of NIRS to predict the N-uptake on unfertilised plots, whereas Reeves *et al.* (1999) found no relationship between NIR-spectra and potential N-mineralisation in agricultural soils. Both studies dealt with soils taken from plots only at few locations. In our study, the locations were scattered over a broad area. This indicates, that NIR-spectroscopy can be generally used to predict long-term N-potentials in soils. The presented results possibly enable the classification of arable soils into different levels of N-potentials. However, the N-potential was measured through pot trials, the realisation of the potentials in field depends on environmental factors as climate or soil cultivation, for example, and has yet not been taken into consideration. To apply our results to agricultural practice, further field experiments on different soils conducted over several years are required.

The NIR-spectroscopy has already been demonstrated as an accurate method to obtain valuable information on soil texture and organic matter (Stenberg *et al.*, 1995), especially of soils of homogeneous origin (Ben-Dor *et al.*, 1995). These results have been confirmed by our studies with soils of very different origin and composition.

The stability of NIR-models over several years has not yet been demonstrated (Börjesson *et al.*, 1999). To establish a general applicability of NIR-spectroscopy for the determination of soil characteristics and N-potentials in agricultural soils further investigations are necessary.

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