Measuring Crop Plant Quality in the Field

INTRODUCTION

For the short period between harvesting and the next sowing, plant breeders need rapid, cost-effective and meaningful analytical techniques to be able to develop crop plants with improved quality. The advances achieved obtained in, for example, the dry matter content of forage grass, the oil content of oilseed rape and the protein content of feed barley depend directly on the intensity of selection from a starting material which consists of thousands of foundation stocks. Instead of conventional „wet chemical“ analytical procedures, spectroscopy in the near infrared (NIRS) has proved to be successful for this purpose and can now be transferred from the laboratory to the field as a consequence of newly developed instruments.

Fig.1 MMS NIR

Fig.2 Forage harvester from the company Haldrup (Denmark).

THE METHOD

The water content of field crops determines their stability during storage, partially characterizes their nutritional value and is also a crucial factor in fixing their trading price. Water is the constituent which can be most easily determined in the near infrared While other constituents of economic importance such as protein, oil and carbohydrates display lower absorptivity in the near infrared , their contents can nonetheless be determined with high analytical precision by a single, non-destructive measurement of freshly harvested grains and seeds.

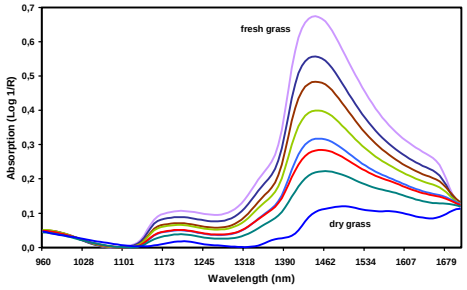


Fig.3 Absorption spectra of grass with different levels of moisture.

THE SYSTEM

On the basis of the equipment devised and the chemometric research carried out by Norris in the USA, spectroscopy in the near infrared (NIR) has now made its way into plant cultivation. So far, however, the current status of the NIRS instrument technology has limited this analytical procedure to stationary use in the laboratory. The availability of diode arrays for the spectral range of the near infrared now makes it possible to the use NIRS directly on agricultural harvest machines. The company Carl Zeiss, the Danish agricultural engineering company Haldrup and the Institute of Crop and Grassland Science of the German Federal Agricultural Research Center have jointly developed a forage harvester for trial plots which allows NIRS measurements on representative samples of the crop during harvesting. The **CORONA NIR** sensor module installed in the harvester is based on the **MMS-NIR** 1.7 diode array spectrometer (Fig. 1) and has been specially designed for the rough conditions of field use.
The particular benefits of the **CORONA NIR** result from the high measuring speed of the **MMS-NIR** 1.7, its high temperature stability, small size and total insensitivity to vibrations and shock. These features clearly distinguish this unit from the NIR measuring instruments used in the laboratory which are unsuitable for mobile use in the rough conditions of field cropping, not only because of their slow measuring speed but also because of their moving, shock-sensitive gratings or filter wheels required for the dispersion of polychromatic light. In the summer of 1999, the first Haldrup forage harvesters of the new „NIRS harvest line“ for such forage plants as grass and clover were purchased by the German plant breeding companies Deutsche Saatveredelung (DSV) and Norddeutsche Pflanzenzucht (NPZ) and tested in the field (Fig. 2). The chemometric calibration of the sensor in field conditions is being continued together with these plant breeding companies. In addition, a combine harvester equipped with a **CORONA NIR** will be available for such grain crops as cereals, oil seeds and grain legumes for the first time in the year 2000.
The integration of NIR diode array spectrometers in agricultural combine harvesters will initially increase the efficacy of plant breeding and testing aimed at creating cultivars with improved properties. In addition, it should not be overlooked that this type of „mobile analysis” can also be transferred to practical agriculture where a wide variety of approaches to so-called „precision farming” are increasingly being tested. Thus, the NIR diode array spectrometers could one day make an effective contribution to quality assurance in environmentally compatible plant production.

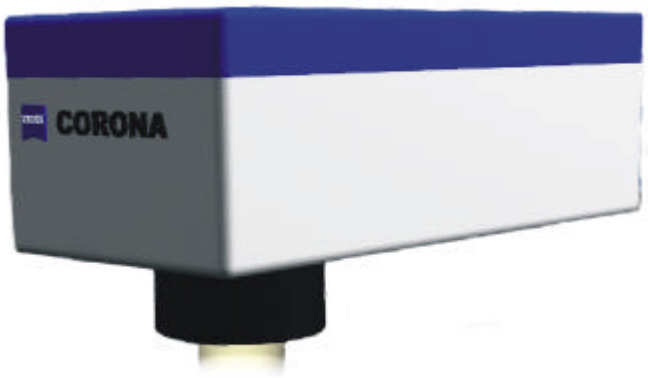
Autors:
Dr. Christian Paul and Michael Rode work at the Institute of Crop and Grassland Science of the German Federal Agricultural Research Center (FAL), Bundesallee 50 in 38116 Braunschweig/Germany.

Carl Zeiss
Spektralsensorik

D-07740 Jena
Telefon: (03641)64 2838
Telefax: (03641)64 2485
E-Mail: info.spektralsensorik@zeiss.de
Internet: http:// www.zeiss.de

CORA - Software Package for Agriculture and Food

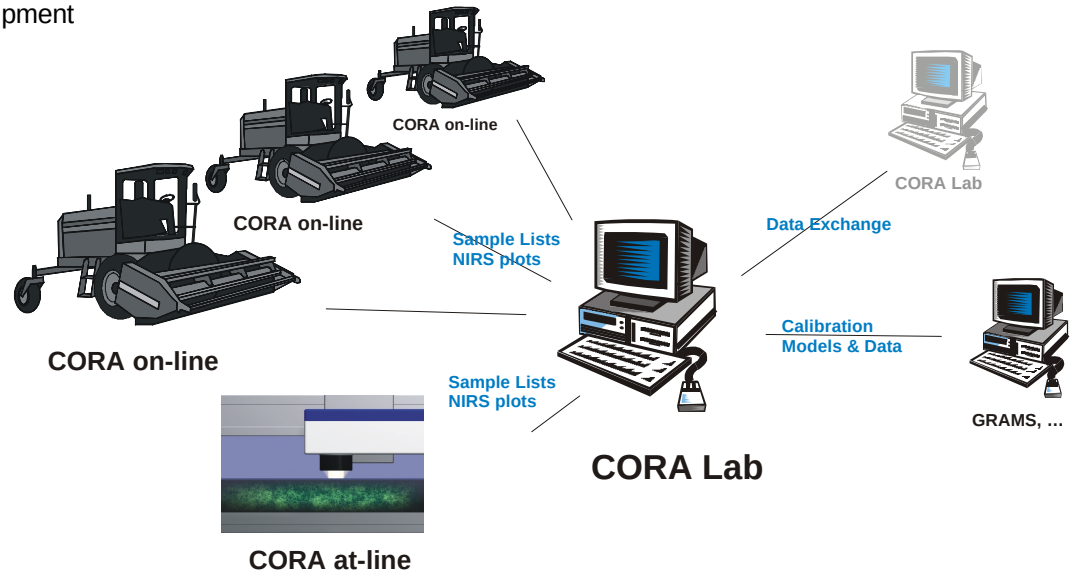
CORA is a software program package specially designed for the requirements of agriculture and food processing. Its great ease of operation, data security, data base administration, spectral manager and the possibility of integrating a great variety of data make this package a top-of-the-line option in on-line, routine and field analysis. Applications include monitoring GPS coordinates, specimen temperature and different chemometric calibration models.



CORONA sensor unit

Benefits

- New open software concept
- Dual use: On-line and At-line
- Extensive sample list management
- Customizable operation, measurement, prediction and output
- Multiple and expandable support of third-party external equipment



Configuration for agriculture fields

Distributor US/Canada

ATECH

45 John Street #908
New York, NY 10038-3706
Phone: 212.393.9540
Fax: 212.393.9538
email: info@analyze.com

ZEISS

Dual use On-line and At-line

- One touch / automatic operation
- Active (switchable) display
- Easy-to-read results & status indicators
- Scrollable plot list
- Multiple level password protection
- Sample list management and processing
- Future customizable options ....

Sample Lists - the central data collections

ASCII sample lists hold all information

- Origin: Station, Operator and Software
- Measurement and Operation
- Additional Measuring Devices
- Prediction & Evaluation
- Output Specifications
- Plot File Names and Prediction Results

Sample lists can be...

- Generated automatically in on-line mode
- Checked and post-processed
- Edited and transferred
- Prepared at-line for on-line measurements
- Customized (header tags)

Spectra Manager

- Management and processing of spectra
- Visualization of spectra
- Generation of filters for elimination of outliers

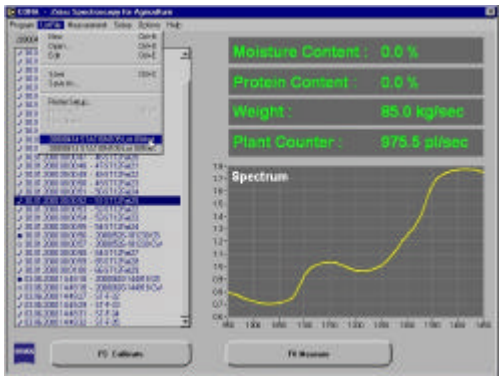
Customizing the Data Evaluation

- Selection of calibration to be applied, produced from different analytical packages (GRAMS, ...)
- Enable / Disable prediction
- Specification of several prediction values (results, residuals ..) to be used as measurements results for selected data output

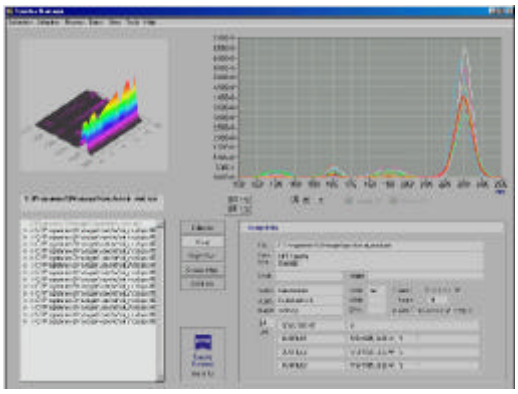
Customizing the Data Output

Selectable data output options including:

- Configurable ASCII tables
- RS 232 on-line uni-directional data stream (string format customizable)



Sample list



Spectra Manager

Measurement & Operation settings

- Spectrometer settings, interpolation and averaging
- Adjustments for outlier detection & removal
- Measurement trigger mode: wire, keyboard, touch screen, time
- Operational options include:timed, manual or automatic calibration, active control of sample processing equipment via dig. I/O

Setting up the Measuring Station

- Identification of measuring station and operator
- Assignment, activation and setup of additional measuring devices on this local station, e.g.. Scales, Plant counter, Barcode readers, Grain counters .....

Carl Zeiss
Spectral Sensors

D-07740 Jena
Telefon: ++49 364164 33 85
Telefax: ++49 364164 24 85
E-Mail: info.spektralsensorik@zeiss.de
Internet: http://www.zeiss.de/spectral

Near Infrared Spectroscopy (NIRS) Methods for the Assessment of Quality in Fresh Forages

Michael Rode, Christian Paul

Institute for Grassland and Forage Research
Federal Research Centre for Agriculture
Bundesallee 50
D - 38116 Braunschweig
Germany

Overview

- Instrumentation
- Material
- Calibration Examples
- Prospects

Instrumentation

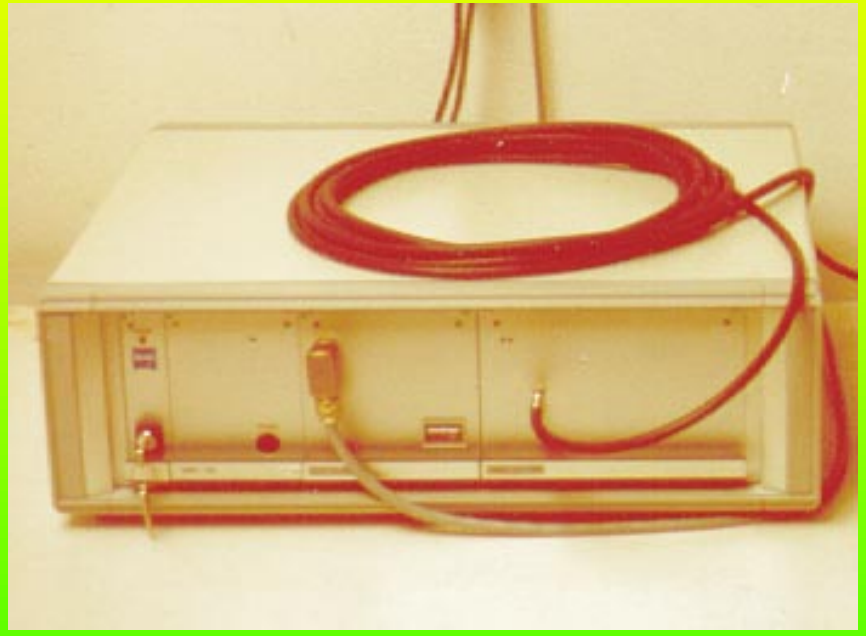
NIRSystems 6500

- Diffuse Reflectance / (Transmittance)
- Wavelength range: 400 - 2500 nm
- Scans per second: 1 Scan
- Resolution: 2 nm
- Wavelength accuracy: +/- 0,5 nm

Infratec Meat Analyzer

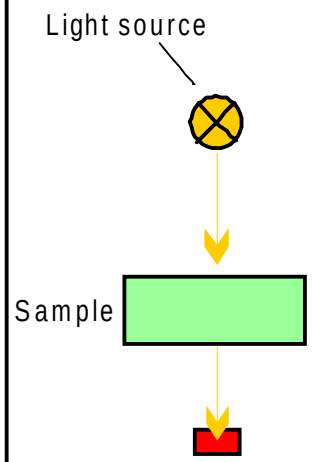
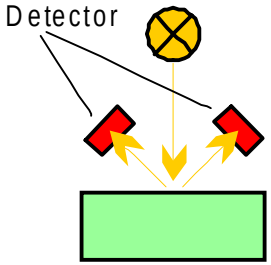
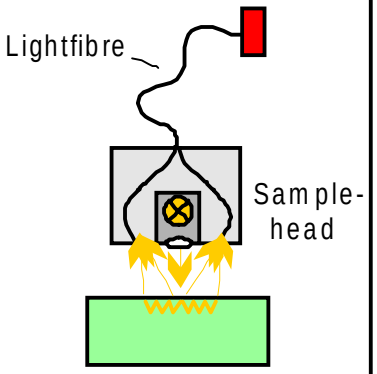
- Transmittance
- Wavelength range:
  850 - 1050 nm
- Scans per second:
  1 Scan
- Resolution:
  2 nm

Zeiss MMS-NIR 1.7



- Diffuse Reflectance / (Transmittance)
- Wavelength range: 945 - 1700 nm
- Scans per second: 100 Scans
- Resolution: 6 nm
- Wavelength accuracy: +/- 0,6 nm

Instruments / Sampling methods

	Diffuse Transmission	Diffuse Reflection	Transflection with Lightfibre
Construction-principle			
Detector :	Si	Si + PbS	InGaAs
λ- Range (nm) :	800-1050	400-2500	900-1700 (900-2500)
Area (cm²) :	3	5	5
Scans / sec :	~ 1	~ 1	~ 100

Material

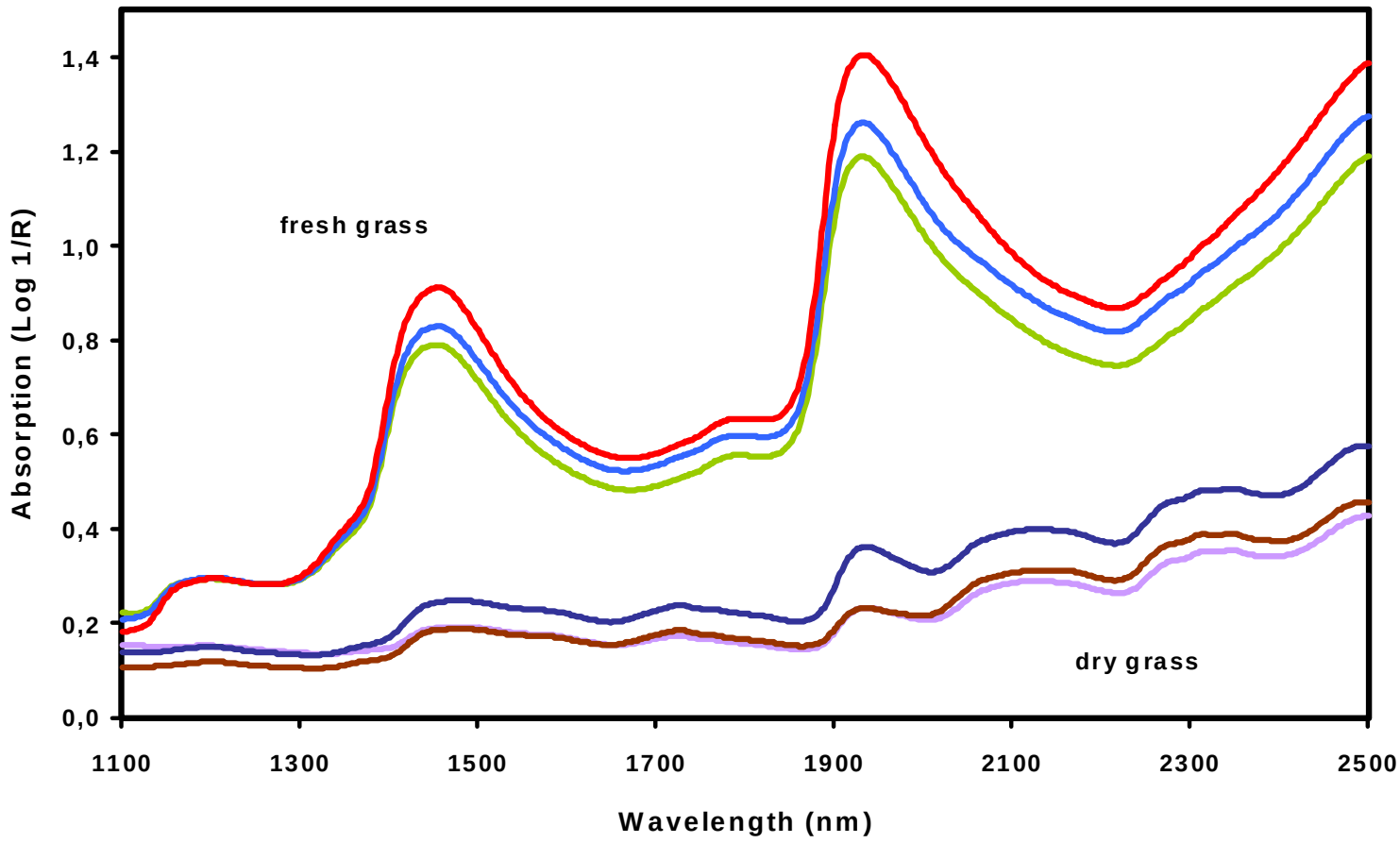
Grasses and Legumes

- Grasses
  - Lolium perenne
  - Lolium multiflorum
  - Dactylis glomerata
  - Festuca arundinacea

- Legumes
  - Trifolium repens
  - Trifolium pratense
  - Medicago sativa
  - Lotus corniculatus
  - Galega orientalis

Calibration Examples

Spectral Differences between Dry and Fresh Grass Samples



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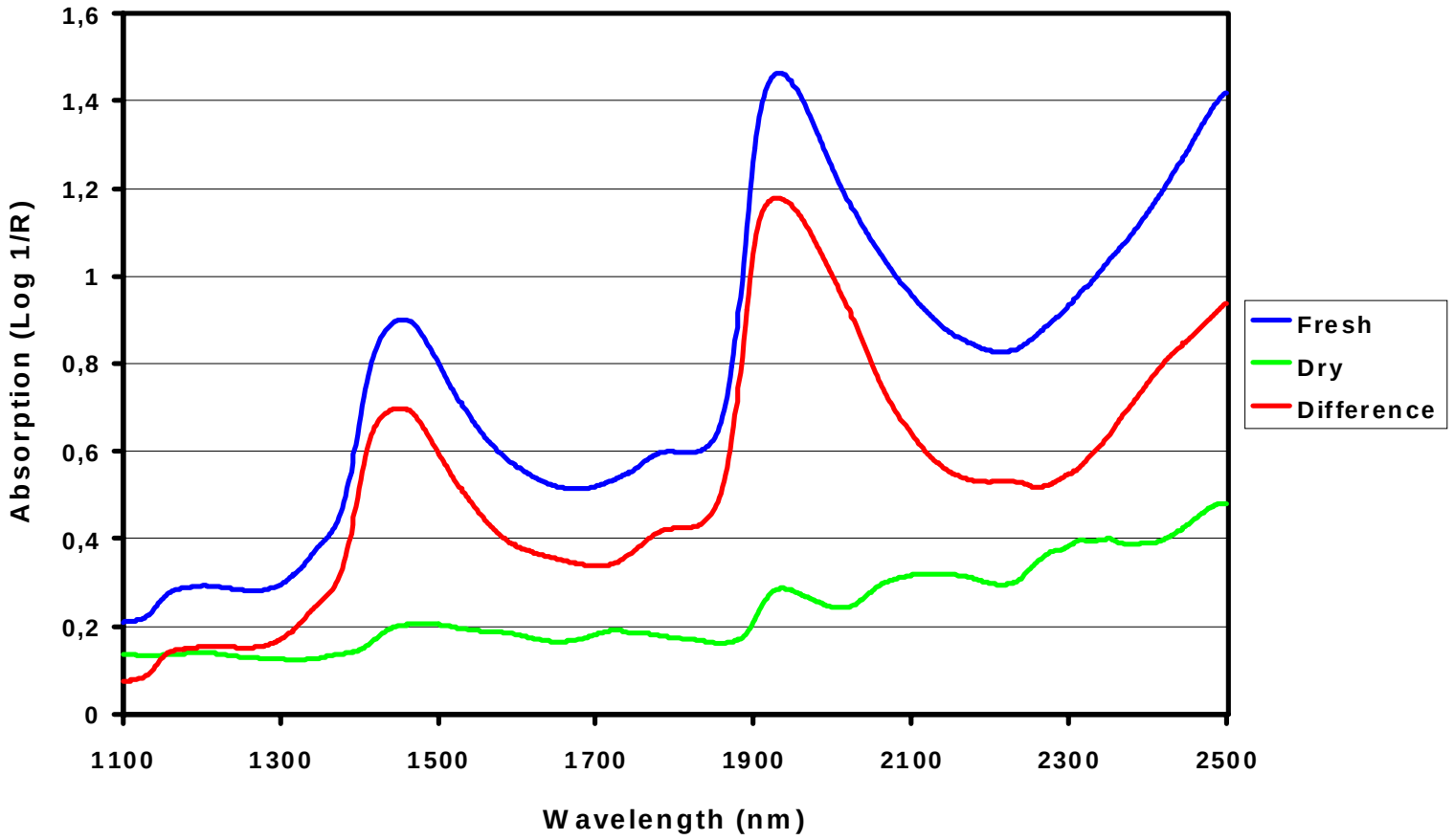
Bundesallee 50, D - 38116 Braunschweig, Germany

Difference Spectrum of Fresh vs. Dry Grass



Chemometric Software

- WinISI II V1.0
  - Global Calibrations
    - Regression types
      - Partial Least Squares (PLS)
      - Principle Component (PCR)
      - Step-up
      - Modified Stepwise (MSR)
    - Cross Validation
  - Local Calibrations
  - Neural Networks

Examples of Calibrations for Fresh and Dry Grasses (NIRSystems and ZEISS)

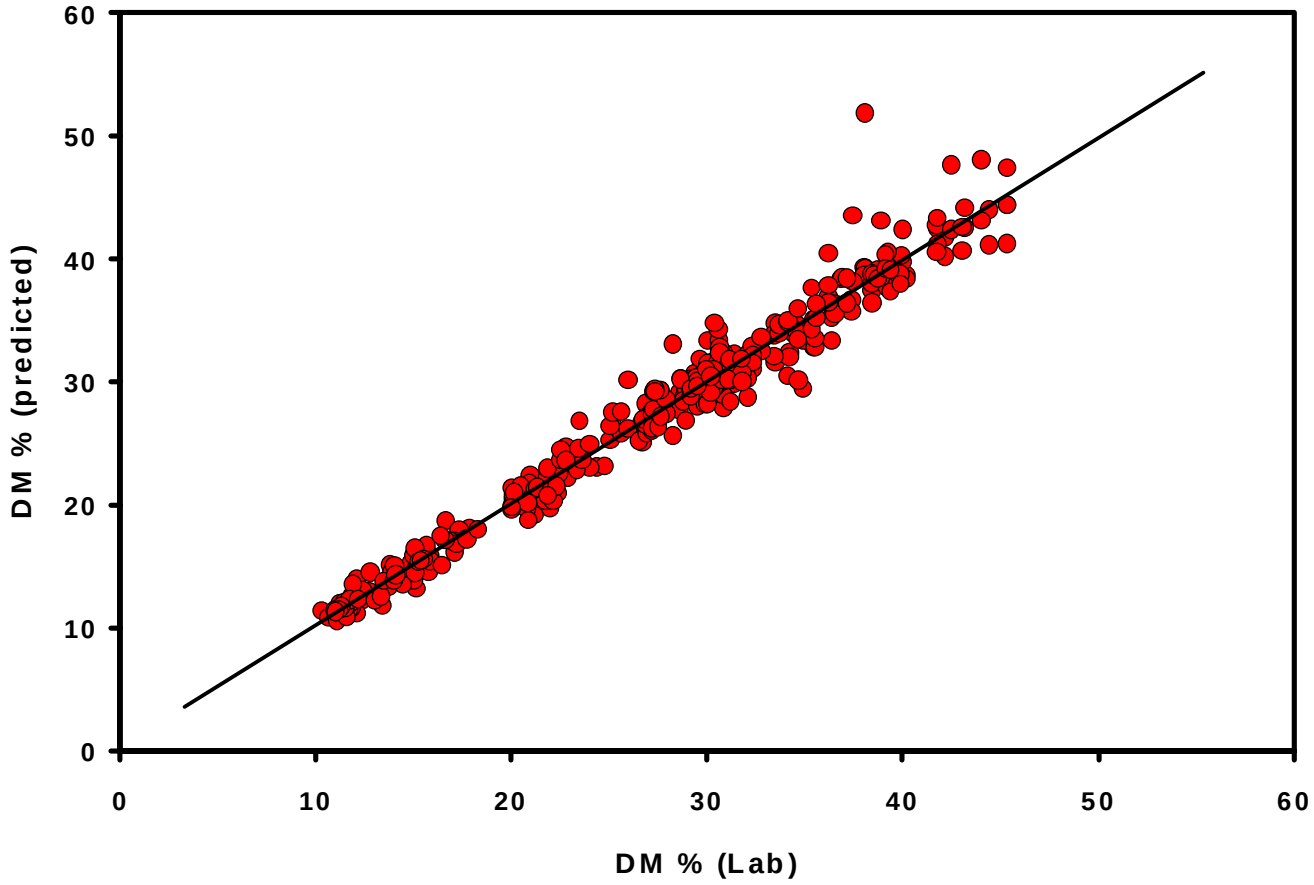
- Calibrations on the NIRSystems 6500
  - Calibration Results with Fresh Forages
  - Comparison of Calibrations with Dry Samples on NIRSystems 6500 vs. ZEISS MMS-NIR 1.7

- Calibrating the portable ZEISS MMS-NIR 1.7
  - Regression Analysis of NIR Absorption vs. Dry Matter Concentration in Fresh Grass on NIRSystems 6500 vs. ZEISS MMS-NIR 1.7

Selection of Fresh Forage Calibrations on the NIRSystems 6500: Results

- Dry Matter DM %
  - Standard Error (SE): 1,13
  - R^2: 0,99
- Crude Protein CP (% of DM)
  - SE: 1,56
  - R^2: 0,92
- Water Soluble Carbohydrates WSC (% of DM)
  - SE: 0,88
  - R^2: 0,94

Dry Matter Calibration of Fresh Forages (NIRSystems 6500)



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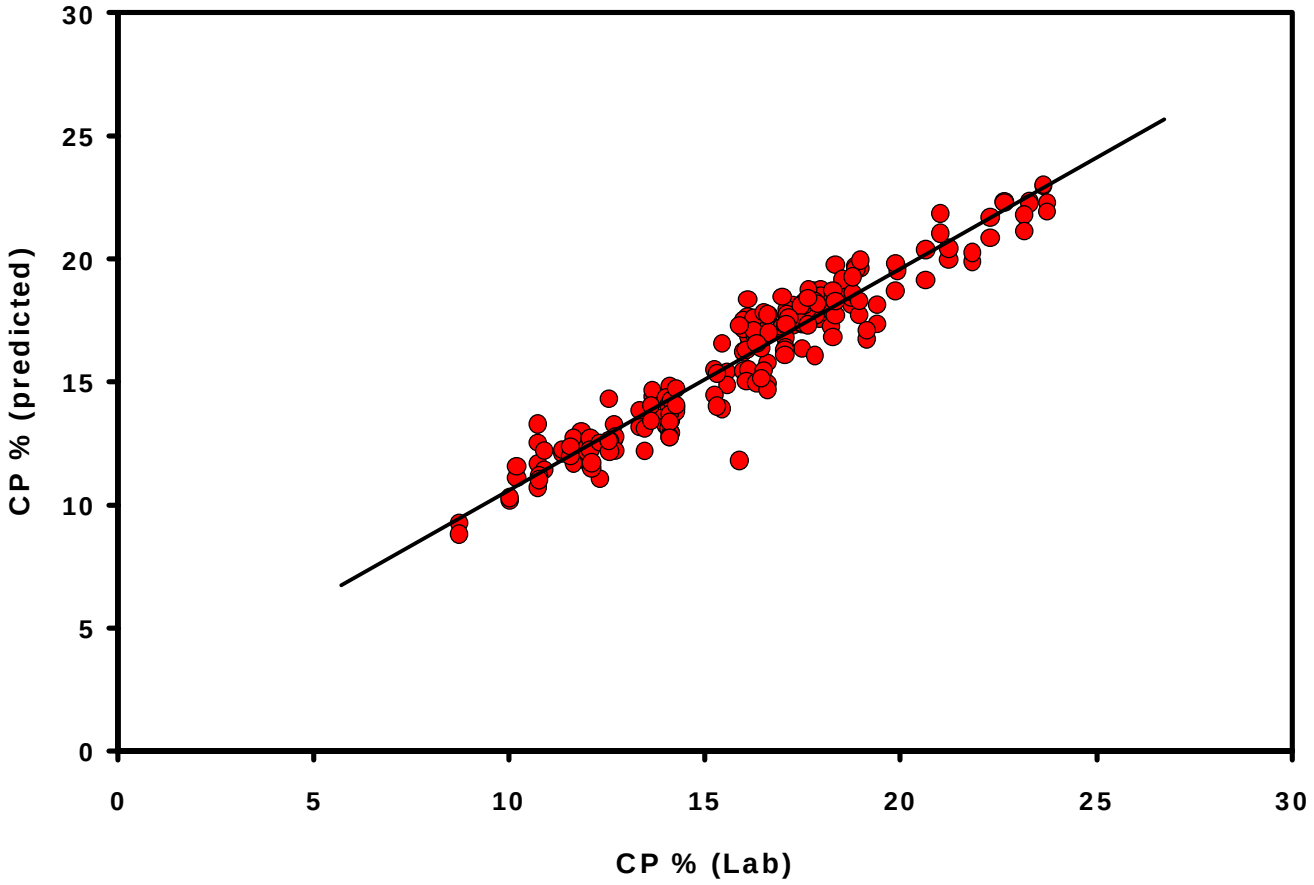
Protein Calibration of Fresh Forages (NIRSystems 6500)



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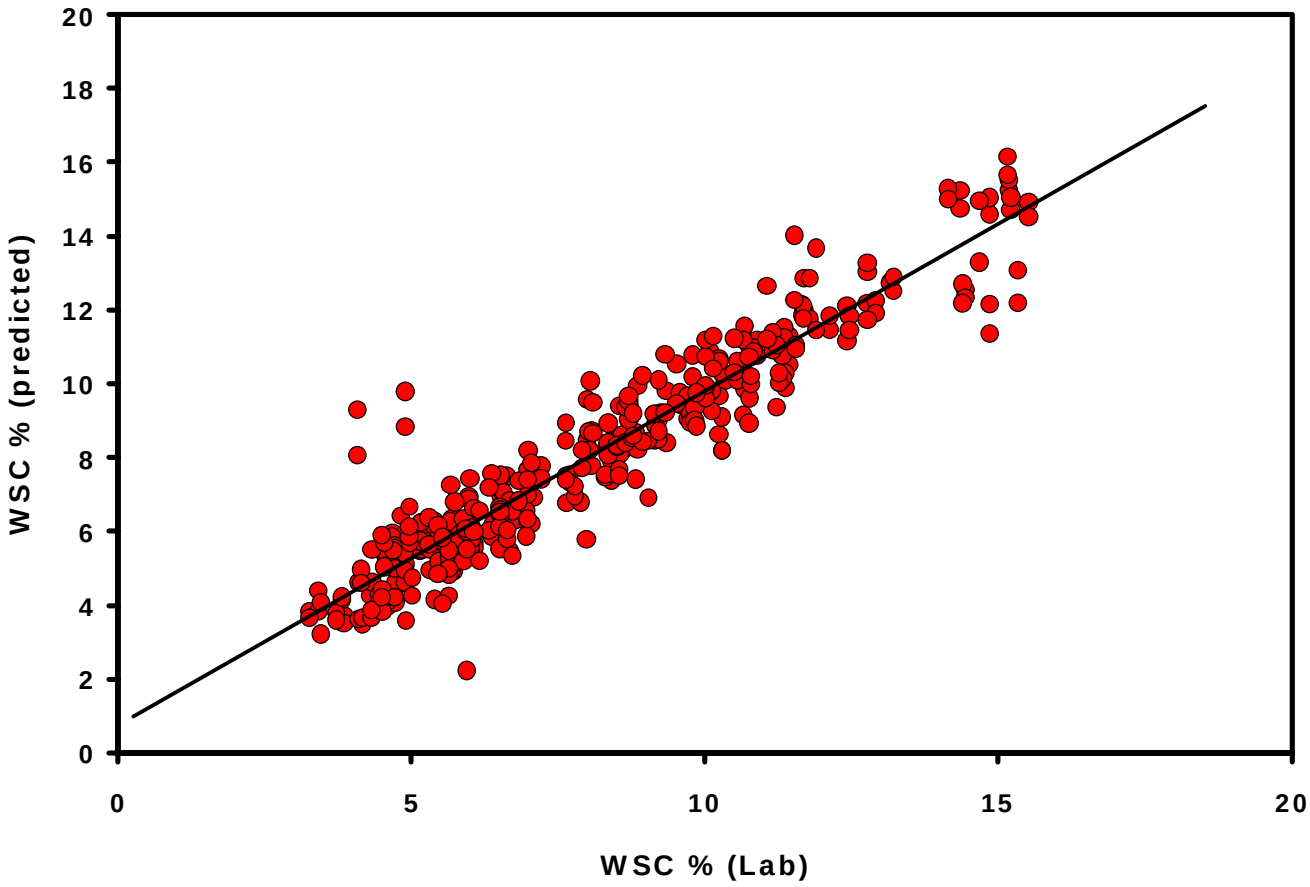
Carbohydrate Calibration of Fresh Forages (NIRSystems 6500)



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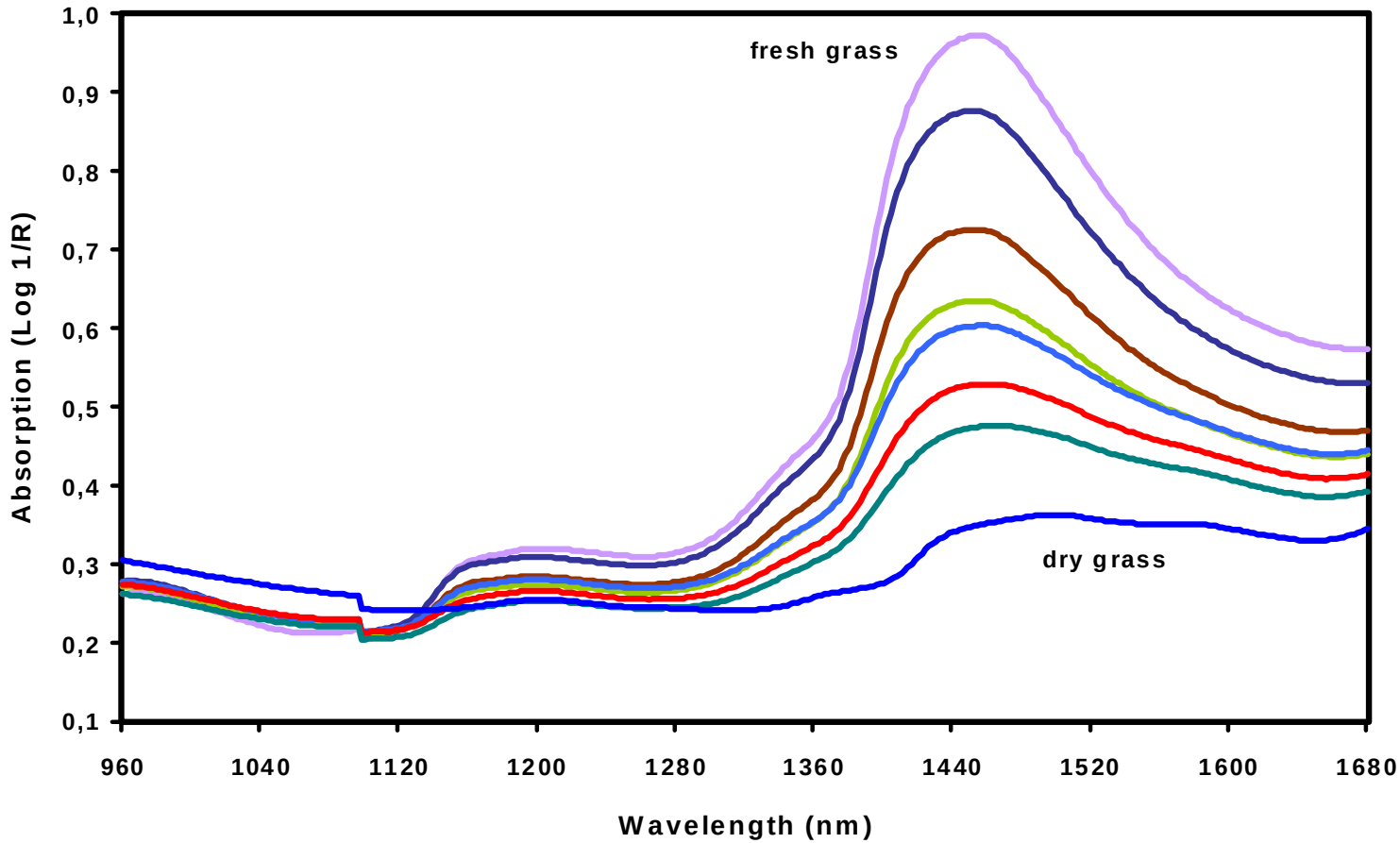
Calibration Comparison of Dry Samples on the NIRSystems and the ZEISS

Equalized Wavelength Range 958-1678 nm			NIRSystems 6500		ZEISS MMS-NIR	
Constituent	n (6500/MMS)	Range (%)	Terms	SE	Terms	SE
Dry Matter	94 / 97	93,8 - 98,7	5	0,43	7	0,46
Crude Protein	92 / 94	8,7 - 23,7	8	0,52	8	0,57
Crude Ash	65 / 64	7,6 - 12,6	6	0,61	5	0,67
Crude Fibre	94 / 94	16,7 - 34,1	8	0,99	8	1,22
WSC	194 / 193	3,3 - 15,5	12	0,63	10	0,87
EULOS	93 / 93	116,5 - 388,3	8	15,99	8	19,21

Spectra of Fresh Grass with Different Dry Matter on the NIRSystems 6500



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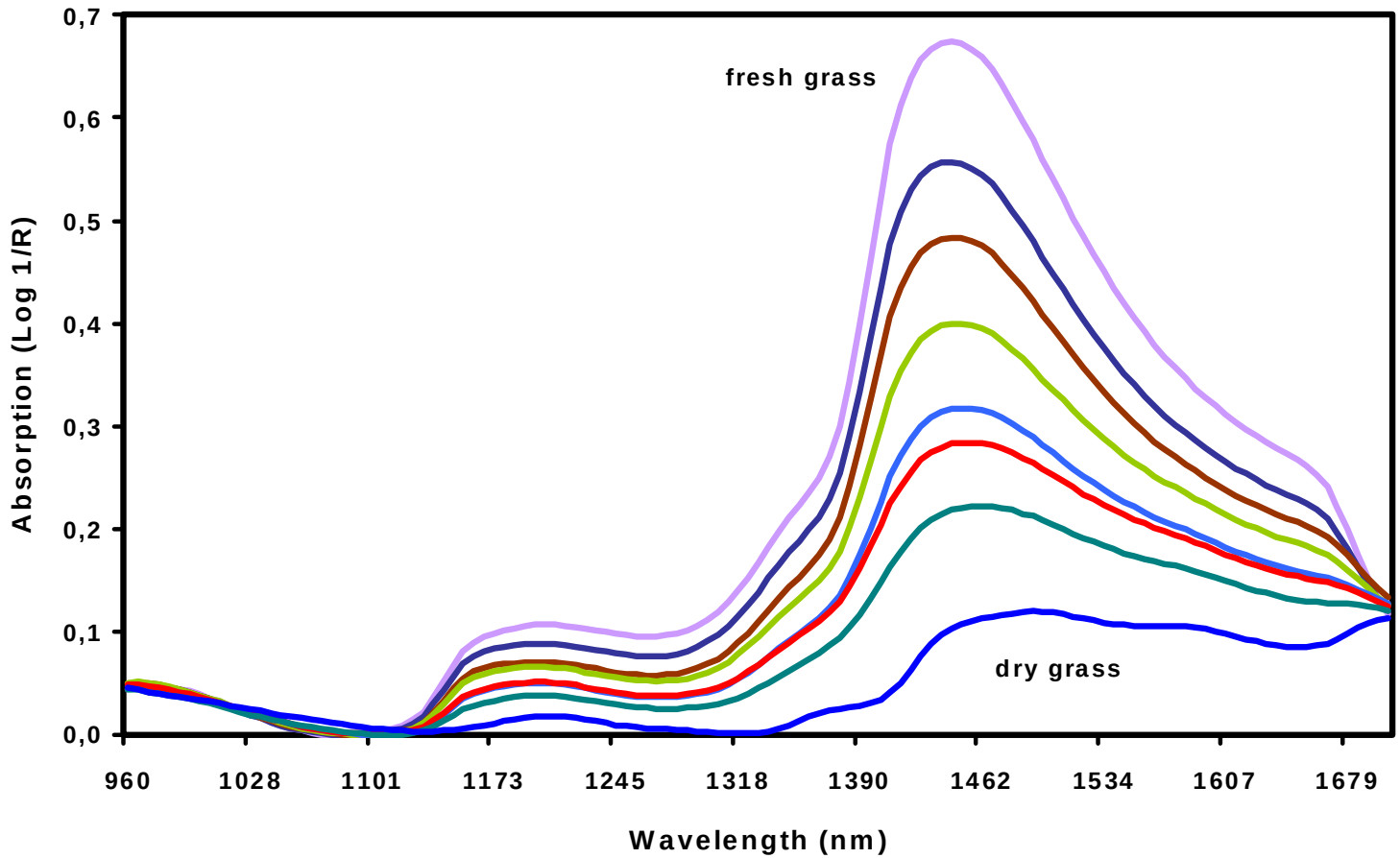
Bundesallee 50, D - 38116 Braunschweig, Germany

Spectra of Fresh Grass with Different Dry Matter on the ZEISS MMS-NIR 1.7



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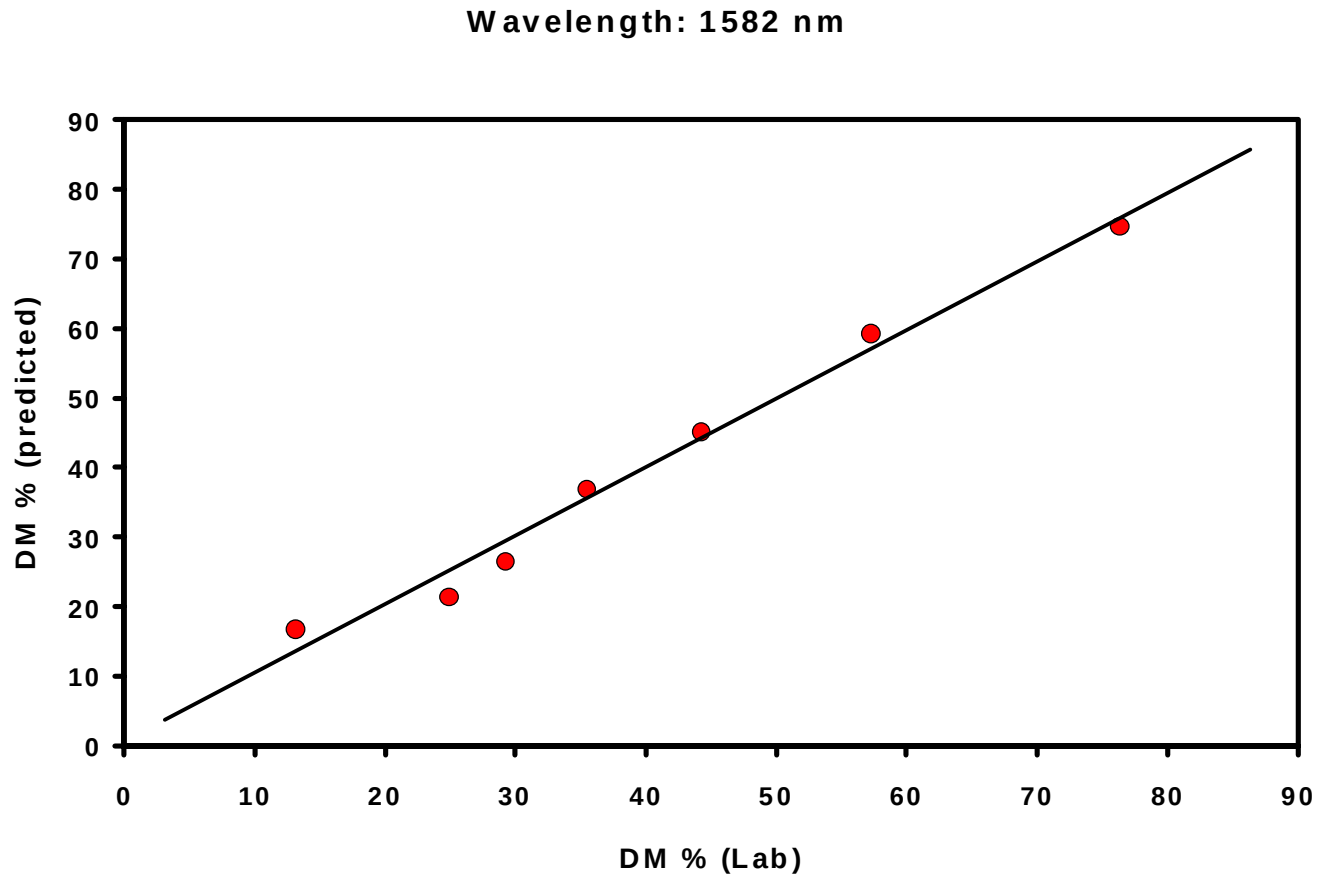
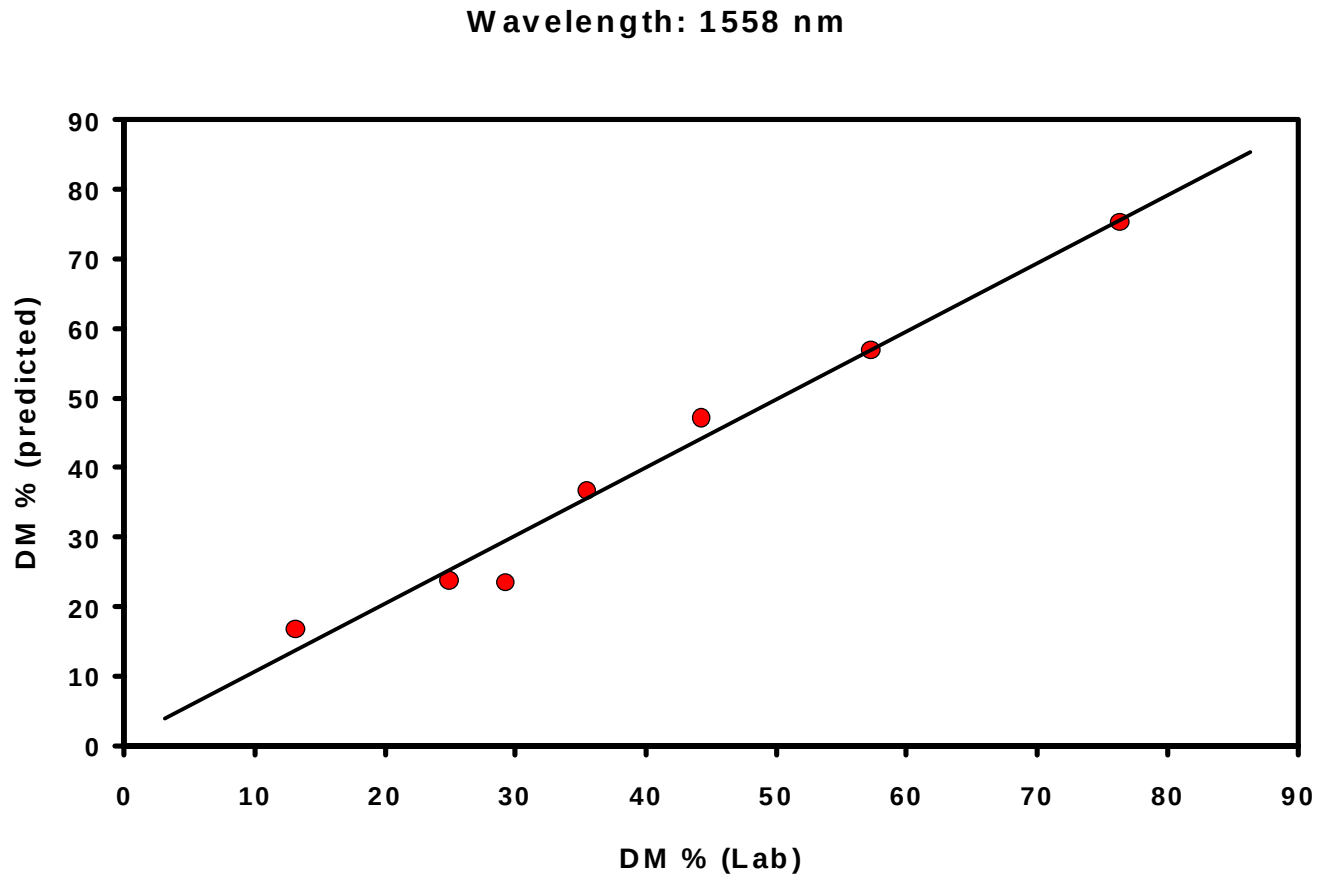
Dry Matter 1 - Term - Regression (NIRSystems 6500)



Dry Matter 1 - Term - Regression (ZEISS MMS-NIR 1.7)



Institute for Grassland and Forage Research (FAL)
Bundesallee 50, D - 38116 Braunschweig, Germany

Prospects

Measurement and Data Handling

- Construction of Instruments
  - Modular Construction
  - Portability / Ruggedness
  - Miniaturization
  - Data Point Standardization
- Sample Presentation
  - in line / on line
  - Reflectance / Transmittance
  - Size of Measurement Area

Measurement and Data Handling

- Standard Data Format
- Transferability of Spectra
- Identification Routines
- Quantification Routines