Optical sensors for the adaptation of nitrogen fertilizer rates to crop needs

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Intensive sustainable crop production - example nitrogen fertilization -

[Graph showing the relationship between nitrogen supply and crop yield, with economic optimum yield indicated.]
Yield response of winter wheat to increasing N rates on different fields

- The same yield being obtained at different N rates
N fertilizer demand can be calculated from crop N demand minus N supply from the soil.
**Fertilizer application in several N dressings**

- N rates are adaptable to actual weather conditions and crop growth
- N fertilizer application close to N uptake of the crop reduces the loss potential and increases the nitrogen fertilizer use efficiency
- Plant analysis can be used to determine the nutritional demand of the crop

![Graph showing N uptake and fertilizer application strategies]
N-Tester and ImageIT– Yara’s plant analysis tools for efficient N fertilizer management field by field
N-Tester™
The N-Tester values correlate well with the chlorophyll and nitrogen content of crop leaves.

Example: processing tomato

Example: table grapes
The Yara N-Tester shows the N supply of crops

Results from Gianquinto et al. (2004) for processing tomato in Italy

-> The N-Tester clearly shows different crop N status at increasing N application rates and growth stages
The N-Tester can be calibrated for N fertilizer recommendation

- The N-Tester calibration requires trials in order to establish critical N-Tester values which indicate optimum crop N supply.

- If the measured value is below the critical value, additional N fertilizer is required in order to enable optimum crop development.

- The critical value is specific for each crop, variety and growth stage.
N-Tester – a tool for in-season N recommendations

- Handy chlorophyll meter giving instantaneous recommendations for optimum N fertilizer rates on the field
- Recommendation schemes developed in field trials for various crops, crop varieties and growth stages

Example: Cereals, Germany
In-season plant analysis enable the grower to meet the optimum N fertilizer rate

Yield, t ha\(^{-1}\)

<table>
<thead>
<tr>
<th>Applied N rate acc. to chlorophyll measurement (YARA N-Tester)</th>
</tr>
</thead>
<tbody>
<tr>
<td>89</td>
</tr>
<tr>
<td>181</td>
</tr>
<tr>
<td>227</td>
</tr>
</tbody>
</table>

N Fertilization, kg N ha\(^{-1}\)

<table>
<thead>
<tr>
<th>N Fertilization, kg N ha(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>150</td>
</tr>
<tr>
<td>200</td>
</tr>
<tr>
<td>250</td>
</tr>
<tr>
<td>300</td>
</tr>
<tr>
<td>350</td>
</tr>
</tbody>
</table>

Economic optimum N rate, kg ha\(^{-1}\)

103
178
209
ImageIT
Image IT

Smartphone with camera and internet access

Acquire and transmit images

Process images and generate response

Central server

Display response
Image Processing Chain – Overview

- Raw image
- (optional) Resize to VGA
- Classify leaf pixels
- Filter noisy areas
- Count leaf pixels

Repeat for $n$ images

- Percentage leaf cover

Empirical relationship
- Growth stage
- Percentage of brown leaves
- Variety (?)

- Fresh matter, N-Uptake

Agronomic calibration

- N-Recommendation
Classification

Calculate Green - Red

Thresholding

Noise reduction and smoothing

Percentage leaf cover

Final result
N-Uptake Calculation – Example (OSR)

Predict N-uptake from:
- percentage leaf cover
- growth stage
- estimated fraction of brown leaves
- variety (?)

Example: OSR after winter (February 2007 and 2008) on 4 sites
## Number of Images in Database

### ...by crop:

<table>
<thead>
<tr>
<th>Crop</th>
<th>No. of images</th>
</tr>
</thead>
<tbody>
<tr>
<td>corn/maize</td>
<td>1641</td>
</tr>
<tr>
<td>oats</td>
<td>560</td>
</tr>
<tr>
<td>potatoe</td>
<td>351</td>
</tr>
<tr>
<td>spinach</td>
<td>196</td>
</tr>
<tr>
<td>spring barley</td>
<td>560</td>
</tr>
<tr>
<td>winter barley</td>
<td>4208</td>
</tr>
<tr>
<td>oilseed rape</td>
<td>12024</td>
</tr>
<tr>
<td>winter wheat</td>
<td>25251</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>44791</strong></td>
</tr>
</tbody>
</table>

### ...by year:

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of images</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>1045</td>
</tr>
<tr>
<td>2005</td>
<td>2469</td>
</tr>
<tr>
<td>2006</td>
<td>7541</td>
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<tr>
<td>2007</td>
<td>12048</td>
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<td>2008</td>
<td>5395</td>
</tr>
<tr>
<td>2009</td>
<td>8775</td>
</tr>
<tr>
<td>2010</td>
<td>4092</td>
</tr>
<tr>
<td>2011</td>
<td>3426</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>44791</strong></td>
</tr>
</tbody>
</table>
Oilseed Rape

Options for N-uptake estimation:

1. Measured in autumn ($N_a$)
   \[ N\text{-Uptake} = N_a \]

2. Measured in autumn ($N_a$) & spring ($N_s$)
   \[ \text{if } N_a < N_s \text{ then } N\text{-Uptake} = N_s \]
   \[ \text{if } N_a > N_s \text{ then } N\text{-Uptake} = \frac{(N_a + N_s)}{2} \]

3. Measured in spring ($N_s$) only
   \[ N\text{-Uptake} = \frac{N_s}{(1 - 0.5 \times f_B)} \]
   where $f_B$: fraction of brown leaves

Correction for mineralisation potential

<table>
<thead>
<tr>
<th>Level</th>
<th>Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>low</td>
<td>+10...15 kg/ha</td>
</tr>
<tr>
<td>medium</td>
<td>±0 kg/ha</td>
</tr>
<tr>
<td>high</td>
<td>-10...20 kg/ha</td>
</tr>
</tbody>
</table>
N recommendation

- Sulphur Plus
- All Yara Products

Analysis Results:

Your oilseed rape crop has currently taken up 30 kg N/ha. The green fresh matter is about 5.4 t/ha. Yara recommends a total N-application of 210 kg N/ha. This result has been obtained from 4 out of 4 images.

Valid Photos: 4/4

Yara Recommends

Sulphur Plus (29.0% + 2% SO3) is a quality product for oilseed rape where higher rates of sulphur are required.
Heterogeneous fields are the rule – Precision farming takes in-field-variability into account
N-Sensor® - variable rate N fertilization

- Plant nutrition know-how & sophisticated hardware
  - Detection of the nutritional status of crops on-the-go
  - Development based on an agronomic concept for site-specific plant nutrition
  - Crop and growth stage specific fertilization algorithms (developed in field trials)
  - Powerful sensor hardware
    - Great distance from sensor to crop, oblique view, large footprint
    - Optimized vegetation indices for reliable N status discrimination in dense crop stands
N-Sensor® & N-Sensor® ALS: Key Technology for Precision Farming

Crop scanning and fertilizer application on-the-go

**N-Sensor®**
- launched 1999
- passive system
- needs daylight
- 8-10 hours per day

**N-Sensor® ALS**
- launched 2005
- active system
- own light source
- 24 hours per day

Measurement → Calculation of N fertilizer demand → N application

Research Centre Hanninghof – JJa - 2014-05-27
Light reflectance from crop canopies gives information on the crop's N nutrition status

N status of crops can be measured by analysing spectral reflectance data
N-Sensor® detects areas of different N supply and adjusts N fertilizer rates accordingly.

Winter Barley, N-Sensor measurement and N application on the 25th of May 1999
Source: AgriCon, Germany
Effects of N-Sensor® based variable rate N application (field trials, on-farm research)

- Yield increase 3-7%
- N savings up to 14%
- Improved N balance up to 30 kg N/ha
- Reduced risk of crop lodging 50-100%
- Improved combine performance 12 – 20%
- Enhanced and more even protein content
Thank you for your attention!

Questions?