Using Nitrogen as a tool for building optimal cereal crops for high yields and the right quality

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ADAS UK Ltd, UK
UK Wheat yield & N rates
Estimating *bio-physical potential* cereal yields

... based on *Yields of Farmed Species* (2005) Chapter 11: ‘Wheat’

Conversion
- Radiation: 1.4 t/TJ
- Water: 5.5 t/ha/100mm

60% = ~20 t/ha grain

@ 85% DM
NEW World Record Yield*, 2015

- **Grain cv. Reflection**: 16.5 t/ha
  - @ 15% MC & 11.5% protein
  - Grain N ‘offtake’ 282 kg/ha

- **Incident Solar Radiation**: 36 TJ/ha

- **Summer Water Supply**: 470 mm
  - 200 mm summer rain
  - 270 mm soil water

- **Nitrogen Fertiliser**: 330 kg/ha
  - plus soil N (after OSR)

- **ESTIMATED POTENTIAL**: 21.0 t/ha
  
  _Yield achieved_: 79% of potential

* Whether this or a very similar yield by Rod Smith, Beal Farm, Haggerston, Northumberland will be accepted by the Guinness Book of Records remains to be seen.
<table>
<thead>
<tr>
<th><strong>Benchmark</strong></th>
<th><strong>Entry</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ears / m²</td>
<td>460</td>
</tr>
<tr>
<td>Grains / ear</td>
<td>48</td>
</tr>
<tr>
<td>TGW @ 15% MC</td>
<td>50</td>
</tr>
<tr>
<td>Sp Wt, kg/hl</td>
<td>NA</td>
</tr>
<tr>
<td>Grain protein %</td>
<td>11.6</td>
</tr>
<tr>
<td>Biomass, t/ha</td>
<td>18.4</td>
</tr>
<tr>
<td>Harvest Index</td>
<td>51%</td>
</tr>
<tr>
<td>N ‘uptake’, kg/ha</td>
<td>279</td>
</tr>
<tr>
<td><strong>Yield, t/ha (rank)</strong></td>
<td><strong>11.0</strong></td>
</tr>
<tr>
<td><strong>Yield % Potential</strong></td>
<td><strong>79% (2nd)</strong></td>
</tr>
</tbody>
</table>
Theory of Crop N requirement

Estimating N requirement

• Traditional: Fertiliser Manual (RB209)
  • Look up tables
  • Accounts for Soil N Supply & soil type

• Newer: N Management Guide for wheat
  • Account for greater yield potential of new varieties
  • Greater price volatility
  • Adjust for local conditions
  • Simpler SNS index tables
  • Detailed soil N measurement instructions
Calculating N fertiliser rates

Fertiliser Requirement & Manure

Crop yield \times N \% \quad \text{Crop demand}

Soil Supply

Crop N Demand (kg/ha) - SNS (kg/ha)

Fertiliser N requirement (kg/ha) =

Fertiliser recovery (\%) =

Prediction e.g.110

Calculate kg/ha:

\frac{225 – 110}{60\%} = 190

www.adas.uk
Crop fertiliser N requirement

Crop fertiliser N requirement = \frac{\text{Crop N demand} - \text{soil N supply}}{\text{Fertiliser N recovery}}
Crop N Demand

• **Rule of thumb**
  - nabim Groups 1&2: 25 kg N/t
  - nabim Groups 3&4: 23 kg N/t

• Detailed calculation
  \[ \text{N harvest index} = \text{grain yield (t/ha)} \times \text{grain N (kg/t)} \]

  **Farm average over years**
  - = 0.7 or 70%
  - From farm protein average for feed varieties over years
Crop fertiliser N requirement

Crop fertiliser N requirement = \frac{\text{Crop N demand} - \text{soil N supply}}{\text{Fertiliser N recovery}}
Soil N Supply (SNS)

Measured Soil N Supply

Crop N uptake near harvest without applied N = ‘Harvested SNS’
Used here as definitive measure of SNS

SMN
nitrate & ammonium

mineralisable N

Autumn or Spring

At harvest (no N applied)
Estimating SNS

Field Assessment Method (FAM)

- Look up tables
- Soil type
- Over winter rainfall
- Previous Crop
- Previous manuring
Estimating SNS

When to measure soil mineral N (SMN)?

- where SNS uncertain & possibly high (>160 kg/ha)
- on deep retentive (clay / silt) soils in low rainfall areas,
- as part of a wider monitoring approach applied to large areas across a farm, especially new blocks of land.
Best practice for measuring SNS

- Autumn sampling
  - Better than spring sampling, except shallow soils
  - 0-60cm … as good as 0-90cm

- Spring sampling
  - 0-90cm best
  - mineralisation analysis helps

- Sample handling & storage
  - Don’t freeze, don’t mix, keep cool
  - SMN increases with storage … *get samples to lab quickly*
How to estimate crop N: Cereals

• Count shoots before GS31
  • 500 shoots/m²: 5-15 kg N/ha
  • 1000 shoots/m²: 15-30 kg N/ha
  • 1500 shoots/m²: 25-50 kg N/ha

• Fraction of soil covered by crop
  • Third: 10 kg N/ha
  • Half: 30 kg N/ha
  • Two thirds: 60 kg N/ha

• Digital photo (wheat)
  • 30 kg N/ha per unit of GAI
  • Upload I photo on www.pgrplus.basf.com
Wide range of crop N contents

GAI 0.3 ≈ 10 kg N/ha

GAI 0.9 ≈ 30 kg N/ha

GAI 2.0 ≈ 60 kg N/ha

GAI 3.2 ≈ 90 kg N/ha
Crop fertiliser N requirement

Crop fertiliser N requirement =  

\[ \text{Crop N demand} - \text{soil N supply} \]

\[ \frac{\text{Fertiliser N recovery}}{60\%} \]
Steps in N Management Guidelines

Annual N Management Cycle

- **Steps M-V:** Schedule & Adjust N Applications
  Manures

- **Steps A-D:** Judge Crop N Demand
  Expected yield x 23 kg/t N

- **Steps J-L:** Calculate Crop N Requirement
  (Demand – Supply)
  Fertiliser recovery

- **Steps E-I:** Judge Soil N Supply
  Previous crop, soil type & SMN analysis.

- **Step W:** Monitor Success
  N use, Yield, Grain N%, Lodging.
Monitor & Review ... *vital for good management*

- **N errors are inevitable**
  - They are usually unseen
  - Small errors seldom matter
  - Beware of big errors
  - Errors can accumulate
    - if not corrected
    - not light or shallow soils

- Checklist provided
  - Key check is grain protein

- Action
  - Double-check odd fields
  - Adjust strategy gradually.

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**Table 16. Check-list for an example field**

<table>
<thead>
<tr>
<th>Check</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did you use more or less N than intended?</td>
<td>less</td>
</tr>
<tr>
<td>How did N use compare with Table 12?</td>
<td>same</td>
</tr>
<tr>
<td>How do grain prices compare to those budgeted?</td>
<td>more</td>
</tr>
<tr>
<td>How did N prices compare to those budgeted?</td>
<td>less</td>
</tr>
<tr>
<td>Colour of crop in late May?</td>
<td>pale</td>
</tr>
<tr>
<td>Estimated weed infestation in May?</td>
<td>little</td>
</tr>
<tr>
<td>Crop height and lodging, ignoring overlaps?</td>
<td>short</td>
</tr>
<tr>
<td>Was grain yield more, or less, than expected?</td>
<td>more</td>
</tr>
<tr>
<td>Was grain protein of feed varieties?</td>
<td>11%</td>
</tr>
<tr>
<td>What about other grain analyses?</td>
<td>normal</td>
</tr>
<tr>
<td>Summary position of ticks</td>
<td></td>
</tr>
<tr>
<td>Likely difference from optimum N use</td>
<td></td>
</tr>
</tbody>
</table>

![Checklist Image](image.png)
Use grain protein to indicate success

Rules of thumb:
- 11% optimum for feed
- 10% – 50 kg N/ha short
- 12% - 50 kg N/ha over
- NB Danish protein is less
Bread varieties: extra N for protein

9 HGCA trials

HGCA Project Report 400
Monitoring ear N – results

Ear N at 1.9% indicates 13% grain protein

Big Variability
- Mainly due to sampling limitations
- May be reduced by modelling
- Conclusion: Ear analysis best used by cooperatives for regional policy.
Varietal differences in N requirement (5 years)

Four groups:
- L-Y L-O
  - Old cvs
- M-Y H-O
  - New bread cvs
- H-Y H-O
  - New feed cvs
- H-Y L-O
  - Mariboss & Triticale

Mean optimum grain yield, t/ha vs. Mean N optimum, kg/ha

Regression line: $y = 10.3x + 44$, $R^2 = 0.48$
Grain Protein

R² = 0.47, omitting old cvs
Within-field variation: Auto-N
Within-field variation: Auto-N

- Large variation in optimum N
- Differences of 100-200 kg N/ha
- In some fields, N optimum can be partly explained by variations in:
  - SNS
  - crop N demand (yield)
Summary – Winter Wheat

• Record yielding crops usually have high biomass and many ears
• Will need early N to maximise tillering & shoot retention, and late N to delay senescence and prolong grain filling
• Fertiliser requirement depends on: crop N requirement, SNS, fertiliser recovery
• Possible that > 300 kg N/ha needed when yield potential high
  • Don’t apply more than 100 kg N/ha in one split
  • Allow 2-3 weeks between splits
  • Include tillering application and a late one (GS33-39)
• Principles apply for estimating intra-field variation of fertiliser
• Varietal differences in N requirement
  • Higher yielding varieties generally had higher N requirement
  • Grenado, Mariboss & Hereford had good yields and low N optima
  • Low grain protein indicates low N requirement
Winter Barley
Introduction

- Farm winter barley record: **12.2 t/ha**
  - Scottish Borders, 1989
- UK 2015 >13 t/ha
- Trial yields > **12 t/ha** for winter barley and > **10 t/ha** for spring barley
- Winter barley N rate: 141 kg N/ha
- Spring barley N rate: 102 kg N/ha
Increase seeds/m$^2$ to maximise yield
Maximise light interception between plant emergence & flowering

More light intercepted increases grains/m²

Losing GAI 5 weeks after ear emergence NOT important
Optimum N timing & rate for winter barley

• RB209 recommends 25-30% N applied before early stem extension

• Current practice for 30-40% N applied before early stem extension

• RB209 may underestimate the N requirement of high yielding modern varieties
Review of historic data

N Timing

• 25 experiments (2004–12)

• “More than 30% of the total N applied before 1\textsuperscript{st} April vs 30% or less of the total N applied before 1\textsuperscript{st} April”

• “More than 50% of the total N applied before 1\textsuperscript{st} April vs 30% or less of the total N applied before 1\textsuperscript{st} April”
## N timing experiment – HM 2015

<table>
<thead>
<tr>
<th>Total</th>
<th>Autumn</th>
<th>1st split GS 25-29</th>
<th>2nd split GS30</th>
<th>3rd split GS31</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosemaund High Mowthorpe</td>
<td>30/10/14</td>
<td>27/02/15</td>
<td>26/03/15</td>
<td>13/04/15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2/10/14</td>
<td>08/03/15</td>
<td>11/04/15</td>
<td>02/05/15</td>
<td></td>
</tr>
<tr>
<td>1) RB209</td>
<td>0</td>
<td>40</td>
<td>0</td>
<td>170</td>
<td>210</td>
</tr>
<tr>
<td>2) Medium</td>
<td>0</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>210</td>
</tr>
<tr>
<td>3) Early</td>
<td>0</td>
<td>130</td>
<td>80</td>
<td>0</td>
<td>210</td>
</tr>
<tr>
<td>4) Autumn</td>
<td>30</td>
<td>100</td>
<td>80</td>
<td>0</td>
<td>210</td>
</tr>
</tbody>
</table>

### Varieties

- **Volume:** Hybrid
- **SY Venture:** 2-row malting
- **KWS Meridian:** 6-row feed
- **KWS Cassia:** 2 row feed

SMN: 29 kg/ha;  AAN: 24 kg/ha
N timing yields (HM 2015)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) RB209</td>
<td>9.11</td>
</tr>
<tr>
<td>2) Medium</td>
<td>9.15</td>
</tr>
<tr>
<td>3) Early</td>
<td>9.33</td>
</tr>
<tr>
<td>4) Autumn</td>
<td>9.27</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment</th>
<th>P</th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>N Timing</td>
<td>0.031</td>
<td>0.165</td>
</tr>
<tr>
<td>Variety</td>
<td>&lt;0.001</td>
<td>0.165</td>
</tr>
<tr>
<td>N Timing x Variety</td>
<td>0.062</td>
<td>0.329</td>
</tr>
</tbody>
</table>
Crop height

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) RB209</td>
<td>98.2</td>
</tr>
<tr>
<td>2) Medium</td>
<td>108.1</td>
</tr>
<tr>
<td>3) Early</td>
<td>111.8</td>
</tr>
<tr>
<td>4) Autumn</td>
<td>110.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment</th>
<th>$P$</th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>N Timing</td>
<td>&lt;0.001</td>
<td>1.498</td>
</tr>
<tr>
<td>Variety</td>
<td>&lt;0.001</td>
<td>2.631</td>
</tr>
<tr>
<td>N Timing x Variety</td>
<td>0.015</td>
<td>4.70</td>
</tr>
</tbody>
</table>
Straw yield

- Treatment Straw Biomass (t/ha)
  - 1) RB209 4.06
  - 2) Medium 4.67
  - 3) Early 5.07
  - 4) Autumn 4.87

- Treatment P LSD
  - N Timing 0.031 0.261
  - Variety <0.001 0.261
  - N Timing x Variety 0.109 0.522
Disease

The diagram shows the percentage of flag leaf area affected by different diseases across various stages of development:

- **Rhynchosporium**
- **Net Blotch**
- **Brown Rust**
- **Necrotic Flecking**

The stages are indicated by different colors:

- **RB209**
- **Medium**
- **Early**
- **Autumn**

The y-axis represents the percentage of flag leaf area affected, ranging from 0 to 3.5 percent. The x-axis lists the diseases.
Physiological effects of early N

- More shoots/m² in April/May
- No improvement in maintaining tiller number
- Significantly greater GAI in April & May
- Significantly more light interception GS37 & GS57
Effect of earlier N on winter barley

Early N

RB209
Effect of earlier N on grain N%
N rate experiments

6 N rates: 0 – 360kg/ha

Varieties:
- Volume (Hybrid)
- Venture (2-row malting)
- Cassia (2-row feed)
- Meridian (6-row feed)
- Maris Otter (2-row malting ‘old’ Intro 1966)
- Pastoral (2-row malting ‘old’ Listed 1989)
N rate experiment (HM 2015)

- **Variety Optimum N rate (kg/ha) Yield at Optimum (t/ha)**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Optimum N rate (kg/ha)</th>
<th>Yield at Optimum (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>182</td>
<td>8.94</td>
</tr>
<tr>
<td>SY Venture</td>
<td>212</td>
<td>9.15</td>
</tr>
<tr>
<td>KWS Meridian</td>
<td>314</td>
<td>10.22</td>
</tr>
<tr>
<td>KWS Cassia</td>
<td>214</td>
<td>9.12</td>
</tr>
<tr>
<td>Pastoral</td>
<td>210</td>
<td>8.59</td>
</tr>
<tr>
<td>Maris Otter</td>
<td>169</td>
<td>7.14</td>
</tr>
</tbody>
</table>

- **Treatment**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>P</th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety</td>
<td>&lt;0.001</td>
<td>0.251</td>
</tr>
<tr>
<td>N Rate</td>
<td>&lt;0.001</td>
<td>0.251</td>
</tr>
<tr>
<td>Variety x N Rate</td>
<td>&lt;0.001</td>
<td>0.6147</td>
</tr>
</tbody>
</table>

**Notes:**
- **Volume:** Variety Optimum N rate and Yield at Optimum are shown.
- **SY Venture:** Similar trend as Volume but with slightly higher yield.
- **KWS Meridian:** Optimum N rate is the highest, yielding the highest at Optimum.
- **KWS Cassia:** Optimum N rate is also high, but yield is slightly lower than KWS Meridian.
- **Pastoral:** Optimum N rate and yield are moderate.
- **Maris Otter:** Optimum N rate is the lowest, yielding the lowest at Optimum.
Rate trial yield (RM 2015)

<table>
<thead>
<tr>
<th>Variety</th>
<th>Optimum N rate (kg/ha)</th>
<th>Yield at Optimum (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>241</td>
<td>12.59</td>
</tr>
<tr>
<td>SY Venture</td>
<td>246</td>
<td>11.58</td>
</tr>
<tr>
<td>KWS Meridian</td>
<td>272</td>
<td>11.95</td>
</tr>
<tr>
<td>KWS Cassia</td>
<td>226</td>
<td>11.02</td>
</tr>
<tr>
<td>Pastoral</td>
<td>248</td>
<td>10.80</td>
</tr>
<tr>
<td>Maris Otter</td>
<td>169</td>
<td>9.32</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment</th>
<th>P</th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety</td>
<td>&lt;0.001</td>
<td>0.358</td>
</tr>
<tr>
<td>N Rate</td>
<td>&lt;0.001</td>
<td>0.358</td>
</tr>
<tr>
<td>Variety x N Rate</td>
<td>0.017</td>
<td>0.877</td>
</tr>
</tbody>
</table>
Optimum N rate

- Crops with yield potential of >8t/ha require more N than recommended by RB209
- Additional 27 kg N/ha required for each tonne above 8t/ha

\[ y = 26.653x - 209.43 \]
\[ R^2 = 0.6953 \]
Conclusions – Winter Barley

• 0.5t/ha yield benefit from applying 50% of N before stem extension.
  • 10cm taller and at 1-2 t/ha more straw
  • But greater lodging risk
• Earlier N reduces grain N% by 0.1%
• Each additional 1t/ha over 8t/ha requires +27kg/ha N
• >12 t/ha possible for winter barley
Thank You

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