Genotypic differences in nitrogen efficiency of oilseed rape

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Definition of genotypic nitrogen efficiency

Nitrogen efficiency is the capacity of a genotype to produce a higher yield (grain, biomass, sugar, protein) than the mean of the population under conditions of limited N supply.
Field experiments investigating N efficiency traits

Field experiments Göttingen 1997-2004

investigating 36 oilseed rape lines and DH lines

Grain yield without N fertilization (t ha\(^{-1}\))

Grain yield at 240 kg N ha\(^{-1}\) (t ha\(^{-1}\))

1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0

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Grain yield without N fertilization (t ha\(^{-1}\))
Grain yield without N fertilization

N efficiency of the cultivars investigated

Mean grain yield at low N supply relative to the standard genotype „Capitol“
Field experiments Göttingen 1997-2004
Rape Ideotypes Differing in Nitrogen Efficiency (from Wiesler)

"Traditional" Ideotype
- High N uptake until beginning of flowering, low N uptake during the reproductive growth phase
- Incomplete N retranslocation from senescent leaves into seeds
- High N fertilizer demand
- Large N balance surpluses

Improved "traditional" Ideotype
- High N uptake until beginning of flowering, low N uptake during the reproductive growth phase
- Improved N retranslocation from senescent leaves into seeds
- Reduced N fertilizer demand
- Reduced N balance surpluses

"Alternative" Ideotype
- Lower N uptake until beginning of flowering, maintenance of N uptake during and after flowering
- Delayed N retranslocation from senescent leaves into seeds
- Reduced N fertilizer demand
- Reduced N balance surpluses
Seed yield, N uptake, and N utilization of 12 oilseed rape cultivars at low and high N supply* in 1999

Horst et al., OECD 2003

** Low N: no N fertilization  High N: 223 kg ha\(^{-1}\) fertilizer N
Correlation coefficients between grain yield and various N efficiency traits of 12 oilseed rape cultivars at low and high N supply.

Field experiment in Göttingen 1999. Wiesler et al., IPNC 2001

<table>
<thead>
<tr>
<th></th>
<th>Linear correlation coefficients</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Low N</td>
<td>High N</td>
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<tr>
<td><strong>N uptake</strong></td>
<td></td>
<td></td>
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<tr>
<td>Maturity</td>
<td>0.89***</td>
<td>0.50</td>
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<tr>
<td>Beginning of Flowering</td>
<td>-0.43</td>
<td></td>
<td>0.68*</td>
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<tr>
<td>Beginning of Flowering - Maturity</td>
<td>0.82***</td>
<td>-0.46</td>
<td></td>
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<td><strong>N utilization</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Grain dry weight/total shoot N</td>
<td>0.06</td>
<td></td>
<td>0.66*</td>
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<tr>
<td><strong>Nitrogen harvest index</strong></td>
<td>0.10</td>
<td></td>
<td>0.37</td>
</tr>
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Rape Ideotypes Differing in Nitrogen Efficiency (from Wiesler)

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⇒ High N fertilizer demand
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Why was the N translocation to the seeds only of low importance?

Nitrogen harvest index (kg N kg\(^{-1}\) shoot-N)

Low N: 0.86 (0.83-0.89)  
High N: 0.82 (0.80-0.85)

F-test:  
N: *  
Cult: **  
N x Cult: ns

Field experiment Göttingen 1999; Behrens, 2002
Cumulative N losses through leaf shedding during reproductive growth at different N supplies.

Mean of two cultivars. Field experiment 1999. from Behrens, 2002

![Graph showing cumulative N losses through leaf shedding over weeks after beginning of flowering with different N supplies.](image_url)
Nitrogen losses through leaf shedding during the reproductive growth stage of 12 oilseed-rape cultivars at medium and high N supply.

from Behrens, 2002

F-test: N supply **; Cultivar ***; N supply x Cultivar n.s.
LSD N supply: 1.1; LSD Cultivar: 3.5
Shoot N uptake during the reproductive growth stage of 12 oilseed-rape cultivars at low (no N fertilization) and high N supply (223 kg ha⁻¹).

Behrens et al., UFOP-Schriften 2003
Root-length densities during the vegetation period determined with mini-rhizotrones in the 0.9 m deep soil layer under two oilseed rape cultivars at low and high N supply. Behrens et al., UFOP-Schriften 2003
Illustration of the compartment method for measuring root growth and nitrate uptake in the field. Kamh et al., JPNSS 2005
Root growth and nitrate-N depletion in the compartments at flowering of two oilseed-rape cultivars. Kamh et al., JPNSS 2005
The N-efficient cultivar Apex has a higher light interception after flowering at low N supply

Ulas and Wiesler, unpubl.

Diagram showing the intercepted radiation in global radiation [%] for Apex and Capitol under N0 and N2 conditions, with key stages of growth marked: Beginning of shooting, Beginning of flowering, End of flowering, and Maturity.
Chlorophyll concentration and photosynthetic activity of individual leaves of two oilseed rape cultivars at the end of flowering 2001.

Ulas and Wiesler, unpubl.

4 plants per N treatment and cultivar, all main stem leaves, PAR 1000 µmol m\(^{-2}\) s\(^{-1}\)
Genotypic differences in stay-green under N-deficiency in short-term nutrient solution experiments

NPZ-1 (N-efficient)

NPZ-2 (N-inefficient)
SPAD loss of aging leaves induced by N deficiency. Genotypic differences of oilseed rape in „stay green“

*Nutrient solution experiment* Schulte auf‘m Erley et al., *Physiol. Plant.* 2007

![Graph showing SPAD values over days and grain yield](image)

- 0.1 mM N
- 2 mM N

- Days after start of treatment
- SPAD value
- Grain yield [t ha\(^{-1}\)]

$r = 0.98^{***}$
Possible relationships

- Leaf senescence
- Grain yield
- Root activity

Diagram showing the relationship between leaf senescence, grain yield, and root activity.
Hypothesis for delayed leaf senescence

Better root growth/root activity

Higher cytokinin production

Delayed senescence of older leaves

Experimental approaches

• Dissecting the relationship between root activity, N uptake and leaf senescence
• Exploring genotypic variation in root activity
**Hypothesis for yield penalty due to enhanced senescence**

- Delayed senescence of older leaves
- Higher C assimilation and assimilate transport
- Higher reproductive yield and N uptake

**Experimental approaches**

- Dissecting the importance of C and N export from leaves and root N uptake for reproductive growth
- Exploring genotypic variation in leaf senescence
Thanks to:

Franz Wiesler
Torsten Behrens
Walter Horst
Mahmoud Kamh
Abdullah Ulas