Clubroot in Germany and Europe

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Outline

• Relevance of clubroot in Europe

• Clubroot control:
  - Integrated Pest Management
  - Host resistance

• Monitoring and resistance management

• Pathogen variation
Clubroot in European Oilseed Rape

Market share of CR Cultivars in % (NPZ)
EU 2012: 2% cert. seed sales

Infestation:
- Light
- Medium to heavy

Source: S. Goertz, NPZ Lembke
**Integrated Control of Clubroot**

**Most relevant:**

- Avoid increase and spread of inoculum
- If clubroot is present, resistant crucifers only every 4-5th year
- Use of resistant cultivar while keeping wide rotation
- Increase of soil pH-value

- Control of cruciferous weeds, *regrowth* and *volunteers* (also in subsequent crops)

- **Hygiene:** Prevent spread of contaminated soil (machinery, animals, erosion, water run off, visitors) and infected roots

- Winter oilseed rape: *Late sowing* helps to escape the disease

- Grow resistant cultivar only upon confirmed incidence to prolong its efficacy

- If resistant cultivar is infected: No OSR cultivation until broader resistance in adapted cultivars is available
Experiences from public advisors ...

- Some farmers mix seeds from resistant cultivars with seeds from susceptible cultivars

- Use of farm-saved seeds from hybrid cultivars, 25% susceptible plants

   → Risk of pathogen propagation!
Prevention of Pathogen Multiplication in Volunteers

- In summer resting spores are present already after 1 week post emergence in volunteer plants (temperature!)
- Prevent multiplication by early destruction of volunteers: Shallow disk or glyphosate or both
- Reduction of symptoms after both treatments when applied 7 dpi
- First indications of reduced resting spore viability after early treatment

Data: N. Zamani-Noor, JKI Braunschweig
Breeding: Traditional Resistance Sources

**Brassica napus**: Swedes (‘Wilhelmsburger’), fodder rape (‘Nevin’),
Race-specific resistance

**B. oleracea**: Some kale cultivars, white cabbage, broccoli,
Race-specific and broad-spectrum resistance

**B. rapa**: Stubble turnips
Race-specific resistance

**Raphanus sativus**: Many cultivars show different levels of resistance
Broad spectrum resistance?
Interspecific transfer

B. oleracea (CC) → X ← B. rapa (AA)

Synthetic Amphihaploid (AC)

ACC

Back cross

B. napus (AACC)

AAC

Chromosome doubling

Back cross

Embryo rescue
Clubroot resistant cultivars

- *B. napus* 'Wilhelmsburger' x *B. oleracea*
  Cabbage cultivars 'Acadie', 'Richelain' (St.Jean-sur-Richelieu, Canada)

- *B. rapa* (turnip) x *B. oleracea* → Synthetic *B. napus*
  'Mendel' (NPZ Lembke), 'Tosca' (SW Seeds), 'Invitation' (Swede, SCRI), new releases

- *B. rapa* (turnip) x *B. oleracea*
  'Clapton', 'Kilafur' etc. (Syngenta Seeds)
Mapping of Clubroot Resistance Genes in *B. napus*

(Werner et al. 2008, TAG)
# Resistance Genetics in Different Crucifers

<table>
<thead>
<tr>
<th>Species</th>
<th>Chromosome</th>
<th>QTL</th>
<th>Race-specificity</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>B. rapa</em></td>
<td>A1</td>
<td>Crr2</td>
<td>Race-specific</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>CRc</td>
<td>Race-specific</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A3</td>
<td>CRa, CRb, Crr3, CRk</td>
<td>Many races</td>
<td>Closely linked or identical, dominant</td>
</tr>
<tr>
<td></td>
<td>A8</td>
<td>Crr1</td>
<td>Few races</td>
<td>Co-dominant</td>
</tr>
<tr>
<td><em>B. oleracea</em></td>
<td>C2</td>
<td>PbBo-Anju1</td>
<td>?</td>
<td>Major locus</td>
</tr>
<tr>
<td></td>
<td>(LG 1)</td>
<td>PbBo-1</td>
<td>Broad-spectrum</td>
<td>Identical with PbBo-Anju1?</td>
</tr>
<tr>
<td><em>B. napus</em></td>
<td>A3</td>
<td>PbBn-01:07-1, PbBn-1-1, PbBn-k-2</td>
<td>Few races</td>
<td>Closely linked or identical genes</td>
</tr>
<tr>
<td></td>
<td>A8</td>
<td>PbBn-01:07.2, PbBn-1.2</td>
<td>Few races</td>
<td>Closely linked or identical genes</td>
</tr>
<tr>
<td></td>
<td>C9</td>
<td>PbBn-e4x04</td>
<td>Race-specific</td>
<td></td>
</tr>
<tr>
<td><em>Raphanus sativus</em></td>
<td>(LG1)</td>
<td>Crs1</td>
<td>?</td>
<td>Major locus, syntenic to A03 locus?</td>
</tr>
</tbody>
</table>

Cloning of *RPB1* from Arabidopsis (Rehn, Siemens et al.)

- *RPB1* confers race-specific resistance to isolate e
- Locus is present in a few ecotypes: Tsu-0, RLD, Ze-0
- No homologous allele in susceptible ecotypes
- Two *RPB1*-like genes in close vicinity (*RPB1a, RPB1b*)
- Based on sequence analysis: Membrane-bound protein, no LRR-kinase

Clubroot reaction of Col-0 (A, susceptible) and transgenic Col-0 expressing *RPB1* (B, resistant) against isolate e3.
Breeding of cv. "Mendel"

1987: Kale ECD-15 (CC) x Stubble turnip ECD-04 (AA)

Synthetic *B. napus* 15/04 (AACC) x *B. napus* ‘Falcon’

Selection of resistant DH-line in greenhouse and field

2001: Approval of ‘Mendel’ in Germany (UK: 2000)
(1 dominant, race-specific resistance gene)

Foto: U. Preiss, Bad Kreuznach
Yield effects of clubroot resistance

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Clubroot Reaction</th>
<th>Seed Yield</th>
<th>Seeding Rate</th>
<th>Plants/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mendel H</td>
<td>res</td>
<td>100 rel.</td>
<td>43,0 dt/ha</td>
<td>4,1 TKW g</td>
</tr>
<tr>
<td>Talent H</td>
<td>sus</td>
<td>53 rel.</td>
<td>23,0 dt/ha</td>
<td>3,5 TKW g</td>
</tr>
<tr>
<td>Tosca L</td>
<td>res</td>
<td>77 rel.</td>
<td>33,0 dt/ha</td>
<td>3,3 TKW g</td>
</tr>
<tr>
<td>Express L</td>
<td>sus</td>
<td>35 rel.</td>
<td>15,0 dt/ha</td>
<td>3,4 TKW g</td>
</tr>
</tbody>
</table>

Source: W. Sauermann 2012 („Bauernblatt“), data from an official trial in Schleswig-Holstein in 2002

In 2011: Two official cultivar trials in SI-H affected by clubroot, yield loss of susceptible cultivars between 15 to 40% compared to „Mendel“
From 'Mendel' to 'Mendelson'

'Mendelson: Same resistance, better agronomy

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Pb Schiphorst</th>
<th>Pb Löstrup</th>
<th>Pb NPZ18</th>
<th>Pb Kiesow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mendel</td>
<td>res</td>
<td>res</td>
<td>res</td>
<td>sus</td>
</tr>
<tr>
<td>Mendelson</td>
<td>res</td>
<td>res</td>
<td>res</td>
<td>sus</td>
</tr>
<tr>
<td>Granaat</td>
<td>sus</td>
<td>sus</td>
<td>sus</td>
<td>sus</td>
</tr>
</tbody>
</table>

New CR *B. napus* cultivars in the market:
- Mendelson, Cracker (NPZ)
- SY Alister (Syngenta Seeds)
- Andromeda (Limagrain)
### Outlook on next generation of resistant *B. napus*

<table>
<thead>
<tr>
<th><em>P. brassicae</em> Isolate</th>
<th>Origin</th>
<th>Mendel</th>
<th>NPZ-CR21</th>
<th>Chinese Cabbage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leduc</td>
<td>CA (Edmonton)</td>
<td>67</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>Wusterhusen</td>
<td>D (Meck.-Pomerania)</td>
<td>98</td>
<td>92</td>
<td>100</td>
</tr>
<tr>
<td>Dersekw</td>
<td>D (Meck.-Pomerania)</td>
<td>73</td>
<td>21</td>
<td>100</td>
</tr>
<tr>
<td>b</td>
<td>D (Westphalia)</td>
<td>10</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>Pol4</td>
<td>PL (Silesia)</td>
<td>71</td>
<td>16</td>
<td>100</td>
</tr>
<tr>
<td>k</td>
<td>D (Schleswig)</td>
<td>63</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>HRO1</td>
<td>D (Rostock)</td>
<td>27</td>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td>Schwaan</td>
<td>D (Meck.-Pomerania)</td>
<td>71</td>
<td>31</td>
<td>100</td>
</tr>
<tr>
<td>N19</td>
<td>D (Schl.-Holstein)</td>
<td>67</td>
<td>7</td>
<td>100</td>
</tr>
<tr>
<td>SS2</td>
<td>F (Brittany)</td>
<td>0</td>
<td>0</td>
<td>98</td>
</tr>
<tr>
<td>L1</td>
<td>D (Schl.-Holstein)</td>
<td>67</td>
<td>42</td>
<td>100</td>
</tr>
<tr>
<td>CZ1</td>
<td>CZ (NE Bohemia)</td>
<td>77</td>
<td>24</td>
<td>100</td>
</tr>
<tr>
<td>Qsch</td>
<td>D (Saarland)</td>
<td>39</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Vissch1</td>
<td>D (Schl.-Holstein)</td>
<td>3</td>
<td>0</td>
<td>99</td>
</tr>
<tr>
<td>BB1</td>
<td>UK (Scotland)</td>
<td>3</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>WY1</td>
<td>UK (Scotland)</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td><strong>Mean:</strong></td>
<td><strong>46</strong></td>
<td><strong>18</strong></td>
<td></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
Monitoring for virulent isolates on 'Mendel'

- On demand

- Official advisors

- Advisors of NPZ breeding company or Rapool GmbH

Exclude infected volunteers:

- Check identity of infected plants with 'Mendel'- specific markers

- Confirm virulence of local isolate on 'Mendel' in greenhouse assay
Clubroot Incidences in German 'Mendel' Crops

- = Clubroot on susceptible OSR
- = Clubroot also on 'Mendel'

Clubroot on 'Mendel' outside of Germany:

Some cases in Poland, a few cases in the UK, none in France, Sweden?
Unbiased monitoring in *B. napus* crops


- Soil samples from crops, all cultivars, independent of previous disease reports
- Test for presence of *P. brassicae* in Bioassay using soil samples
- 16% of 453 samples were tested positive for *P. brassicae* (red dots)
- 'Mendel' resistant against 97% of local isolates

(Data from U. Preiss, DLR-RNH Bad Kreuznach)
Characterization of pathogen variation

Two different attempts in Germany:

- Pathogenicity testing using different tester sets, JKI Quedlinburg and Limagrain, W. Lüders (poster)

- Molecular differentiation of Pb isolates, B. Strehlow University Rostock, separation of isolates from Northern Germany vs South-Western isolates

- INRA France: Ongoing project (pathogenicity)

- Poland: See posters from Kaczmarek et al. and Niemann et al.
Clubroot research in France

- CETIOM: Monitoring for clubroot incidences, online questionnaire

- INRA: Coordination and execution of different research projects on clubroot
  - Mapping and use of quantitative resistance in *Brassica* breeding (*napus, oleracea*)
  - Study the molecular basis of quantitative resistance in Arabidopsis
  - Metabolomics of clubroot disease
Summary

- Clubroot is of increasing relevance for oilseed rape in Europe
- Resistant cultivars have a central role in integrated clubroot control
- Resistance sources are present in *Brassica* gene pool
- Race-specific effects of resistance loci are of key relevance for breeding
- So far, occurrence of compatible pathotypes remains locally
- Incidences of compatible isolates on resistant cultivars are getting slowly more frequent and widespread
Acknowledgements

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- Field consultants of NPZ, Rapool and Saaten-Union
- Public advisors: Margit Nagel, Pflanzenschutzdienst Greifswald, M-V, Uwe Preiss, DLR-RLP Bad Kreuznach

Thank you for your attention!
Clubroot Disease (Plasmodiophora brassicae)

**Conditions** needed for clubroot disease:

- Soil-pH < 7
- Soil moisture > 60% soil water capacity
- Soil temperature > 12-16°C
- Inoculum load > 1000 resting spores per plant
- Young roots with root hairs of Crucifer hosts

**Multiplication:** 100,000 fold increase per generation (<6 weeks)

**Longevity** of resting spores: 20 years, half life time 3.6 years

**Spread**s with soil (machinery, erosion, animals, drain water, seed potatoes) or infected transplants, no seed transmission

**Ca. 10% of cropping area of crucifers world wide is infested, yield losses up to 100%**
Use of Quantitative Clubroot Resistance?

- All known clubroot resistance loci show qualitative or quantitative reactions depending on *P. brassicae* isolate and/or environmental conditions.

- Race-specificity is the major issue, broadness!

- Specific combining effects of certain resistance loci have been described.

Selection of resistance loci should be based on knowledge of their specific effects.