Fruit tree canker (*Neonectria ditissima*) and related diseases

Roland W. S. Weber

ESTEBURG Centre, Jork (Germany)

Dept. of Food Science, Aarhus University, Årslev

Fruktseminar, Drammen (15 March 2017)
1. Introduction to Northern Germany
2. Biology of *N. ditissima*
3. Spread within the tree
4. Control of *N. ditissima*
5. *N. ditissima* infections of nursery trees
6. Look-alikes of canker
7. Fruit rots due to *N. ditissima*
The Lower Elbe region

650 tree fruit farms (family-run)

<table>
<thead>
<tr>
<th>Type</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree fruit</td>
<td>11,000 ha</td>
</tr>
<tr>
<td>Total</td>
<td>15,000 ha</td>
</tr>
</tbody>
</table>

Integrated production 88%
Organic production 12%
ESTEBURG
Fruit Research and Advisory Centre

Applied research
- Funded by regional government and by research grants
- Fruit Research Station OVA Jork
  - Founded 1934

Advisory service
- Funded by the fruit farmers
- Integrated Production
- Organic production
  - Founded 1929

Training and Education
- School of Fruit Production
- Further training and education
- Supervision of student projects, undergraduate and Ph.D. research
  - Founded 1890s

Kernefrugt Temadag (31 Jan. 2017)
Roland W. S. Weber
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Climatic gradient within Northern Germany

Altenbruch 837 mm
Oberndorf 801 mm
Stade 778 mm
Moorende 726 mm
Hoopte 667 mm
# Taxonomic history of the apple canker fungus

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>19th century</td>
<td>included in <em>Nectria ditissima</em></td>
</tr>
<tr>
<td>1901</td>
<td><em>Nectria galligena</em> separated from <em>N. ditissima</em></td>
</tr>
<tr>
<td>1995</td>
<td>re-named <em>Neonectria galligena</em></td>
</tr>
<tr>
<td>2006</td>
<td>re-united with <em>Neonectria ditissima</em></td>
</tr>
</tbody>
</table>
Stages of *Neonectria ditissima*

**Summer spores**
*Cylindrocarpon*

**Winter spores**
*Neonectria*
Factors affecting the severity of canker

1. Inoculum (spores)
2. Wounds as points of entry
3. Susceptibility of apple varieties
4. Infection conditions
Inoculum and wounds throughout the year

- Ascospore release
- Production of conidia

- Pruning wounds
- Frost cracks
- Bud break
- Growth cracks
- Fruit/leaf drop
- Hail damage
- Fruit picking
- Leaf scars

Critical phase

Susceptibility of wounds

Leaf scars

- about 48 h

Pruning wounds

- about 7 days within the growing season
- about 3 weeks outside the growing season

How many spores per wound?

50-100 conidia or ascospores per wound produce good infections
Susceptibility and callus formation

‘Nicoter’ (highly susceptible)

‘Elstar’ (relatively robust)

29 March 2014
## Susceptibility of varieties to canker

<table>
<thead>
<tr>
<th>very high</th>
<th>high</th>
<th>moderate</th>
<th>low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civni (Rubens)</td>
<td>Cox Orange</td>
<td>Collina</td>
<td>Aroma</td>
</tr>
<tr>
<td>Nicoter (Kanzi)</td>
<td>Discovery</td>
<td>Gravenstein</td>
<td>Boskoop</td>
</tr>
<tr>
<td></td>
<td>Gala</td>
<td>Rubinola</td>
<td>Elstar</td>
</tr>
<tr>
<td>Gloster</td>
<td></td>
<td>Braeburn</td>
<td>Jonagold</td>
</tr>
<tr>
<td>Ingrid Marie</td>
<td></td>
<td></td>
<td>Pinova</td>
</tr>
<tr>
<td>James Grieve</td>
<td></td>
<td></td>
<td>Santana</td>
</tr>
<tr>
<td>Julyred</td>
<td></td>
<td></td>
<td>Topaz</td>
</tr>
<tr>
<td>Summerred</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wellant</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There is no fully resistant apple variety as yet
Effect of N fertilisation on tree and canker growth

I – non-fertilised  
II – light N fertilisation  
III – heavy N fertilisation

Bark inoculation with *N. ditissima* on 1 Aug. 1962  
Data from Saure (1963)

**Leaf N content**

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>N content [% dry matter]</td>
<td>2.3</td>
<td>2.9</td>
<td>3.0</td>
</tr>
</tbody>
</table>

**Bark N content**

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>N content [% dry matter]</td>
<td>0.7</td>
<td>0.8</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Canker growth**

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canker extension [mm]</td>
<td>1.5</td>
<td>1.6</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Data from Saure (1963)
Effect of root pruning on tree and canker growth

A – root pruning (3x)
B – untreated
C – additional N fertilisation

Bark inoculation with *N. ditissima* on 1 Aug. 1962
Data from Saure (1963)

Leaf N content

Long-shoot growth

Canker growth

<table>
<thead>
<tr>
<th>N content [% dry matter]</th>
<th>Long-shoot length [cm]</th>
<th>Canker extension [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
<td>A</td>
</tr>
<tr>
<td>B</td>
<td>2.5</td>
<td>B</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>C</td>
</tr>
<tr>
<td>A</td>
<td>40</td>
<td>A</td>
</tr>
<tr>
<td>B</td>
<td>45</td>
<td>B</td>
</tr>
<tr>
<td>C</td>
<td>50</td>
<td>C</td>
</tr>
<tr>
<td>A</td>
<td>15</td>
<td>A</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
<td>B</td>
</tr>
<tr>
<td>C</td>
<td>25</td>
<td>C</td>
</tr>
</tbody>
</table>

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Roland W. S. Weber
Canker may also occur on pear trees

Easily confused with

- fire blight (*Erwinia amylovora*)
- bacterial blossom blast (*Pseudomonas syringae*)

Severe incidence of pear canker in Northern Germany 2016
Infection conditions

Leaf scars (Latorre et al. 2002)
- wetness required:
  - 24 h at 10°C
  - 10 h at 15°C
  - 2 h at 20°C
- minimum temperature 5°C

Other wounds
- no surface wetness required?
- minimum temperature 1°C
Appearance of symptoms in a susceptible variety

<table>
<thead>
<tr>
<th>Infection in</th>
<th>Wilting of individual leaves</th>
<th>Visible canker lesion with conidia</th>
<th>Appearance of first perithecia</th>
</tr>
</thead>
<tbody>
<tr>
<td>autumn</td>
<td>around bloom</td>
<td>May / June</td>
<td>autumn or later</td>
</tr>
<tr>
<td>spring</td>
<td>after bloom</td>
<td>June / July</td>
<td>following year</td>
</tr>
</tbody>
</table>

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3. **Spread within the tree**
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Uneven distribution of *N. ditissima* in apple trees

Canker lesions are often unevenly distributed:
- many trees without canker
- a few trees with numerous lesions

**Systemic growth**: Favoured theory since Hartig (1889). Brown streaks as proof

**Splash dispersal of conidia** within a tree: More plausible
Xylem frost damage and *N. ditissima* lesions on ‘Nicoter’

Each lesion due to a separate infection event

Xylem staining due to frost damage

→ no sign of systemic growth of *N. ditissima*
Both symptoms appear at the same time (flowering)
‘Nicoter’ trees planted in late April 2011

Canker lesions in June 2011

Isolation of fungi from the entire tree canopy
How far does *N. ditissima* spread? (25 Nov. 2011)

Bark lesion visible from outside
Spread within the wood
N. ditissima vs. xylem frost damage (19 Aug. 2011)

N. ditissima spreads within the previous year’s wood (i.e. just inside the outermost growth ring)

• preferably in tissue pre-damaged by xylem frost
Multiple infection of growth cracks

‘Nicoter’ orchard, planted in autumn 2008

Initially no canker problems

Summer 2011: no canker pruning, no fungicide measures (transition integrated → organic production)

Feb. 2012: canker in crotches

48% → 78% damaged trees (Feb. → Dec. 2012)

2.8 trunk lesions per tree (Dec. 2012); no interconnections between lesions
How did this happen?

1. Canker in trunk extension (May/June 2011)

2. Rainfall (June/July)

3. Growth cracks (July 2011)

4. Conidia running off along the trunk

5. Wood infections without bark necroses
What happened then?

Attempts at pruning wounds on trunk were mostly unsuccessful

• Re-colonisation of the bark from locally infected wood
• ‘Systemic growth’ on a local scale

The end: uprooting of all trees after 4 years (Dec. 2012)
Summary: Distribution within the tree

1. Each canker lesion visible from the outside is the result of an individual infection event. Conidia facilitate spread within trees!

2. Infection is initially confined to the bark. ‘Nicoter’ bark has only a weak barrier function.
   → Canker pruning is essential throughout the growing season! (emphasis on autumn/winter and first part of growing season)

3. Once the previous year’s xylem has been reached, a rapid vertical spread is possible.

4. Xylem frost damage may facilitate vertical spread. ‘Nicoter’ is highly susceptible to xylem frost.

5. It is unclear how the fungus gets out again after long-distance growth in xylem.
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Copper fungicides (Cu hydroxide) in comparison

<table>
<thead>
<tr>
<th>Compound</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cuprozin WP</td>
<td>450 g Cu kg⁻¹</td>
</tr>
<tr>
<td>Funguran progress</td>
<td>350 g Cu kg⁻¹</td>
</tr>
<tr>
<td>Cuprozin progress</td>
<td>250 g Cu l⁻¹</td>
</tr>
</tbody>
</table>

All compounds applied at 1 kg or 1 l ha⁻¹ m⁻¹ canopy height
Trial details

Date of planting  autumn 2007
Plantation  3.5 m x 1 m
Canopy height  2.5 m

4 repeats of 10 trees each

Beginning of leaf fall: Captan applied in all treatments

Copper applications (500 l water ha\(^{-1}\) m\(^{-1}\) canopy height):

<table>
<thead>
<tr>
<th>Date</th>
<th>Leaf Fall Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 Nov. 09</td>
<td>30-50% leaf fall</td>
</tr>
<tr>
<td>01 Dec. 09</td>
<td>98% leaf fall</td>
</tr>
<tr>
<td>23 Feb. 10</td>
<td>dormancy</td>
</tr>
<tr>
<td>08 Nov. 10</td>
<td>50-60% leaf fall</td>
</tr>
<tr>
<td>22 Nov. 10</td>
<td>95-98% leaf fall</td>
</tr>
<tr>
<td>27 Jan. 11</td>
<td>dormancy</td>
</tr>
</tbody>
</table>

Regular and careful canker pruning throughout the experiment in all plots!
Control of apple canker on ‘Kanzi’
(18 March 2010 - 7 Nov. 2011)


Cu ha$^{-1}$ year$^{-1}$ in 3 applications (2.5 m canopy ht.)
Summary: copper treatments

1. Pruning without chemicals is insufficient to grow Kanzi in Northern Germany
2. Leaf-scar infections are an important entry route
3. Cu hydroxide more effective than Cu oxychloride
4. At least 2 (with ‘Nicoter’ 3) treatments with Cu hydroxide in autumn/winter
5. New Cu compounds are promising, especially Funguran progress (reduction of copper input)
6. Future work: painting of tree trunks with Cu fungicides in order to reduce Cu input into environment
Which chemical treatments in Norway?

Specific chemical treatments necessary only at / after leaf fall

1. Nordox 75 WG has a high efficacy against canker

**Two-year trial set up in the course of ‘Friske Tre’ project**

- Variety ‘Nicoter’, planted spring 2013
- Sprays with Cu fungicides in two seasons so far:
  - 2015 season: 3 Dec., 28 Dec., 1 March
- Evaluation of twig canker during subsequent growing seasons
- Thorough canker pruning in all variants (incl. untreated control)
Difficult conditions in autumn 2015
First results with Nordox 75 WG in N. Germany

Cumulative two-year results of the „FriskeTre“ trial

- Control: 3 infected twigs per tree
- Cuprozin WP 1.0 kg: 1 infected twig
- Funguran prog. 1.0 kg: 0.5 infected twig
- Nordox 75 WG 0.6 kg: 0.5 infected twig

Maximum levels:
- Germany 3 kg ha\(^{-1}\) year\(^{-1}\)
- Norway 4 kg ha\(^{-1}\) year\(^{-1}\)

Cu ha\(^{-1}\) year\(^{-1}\) in 3 applications (2.5 m canopy ht.)
Which chemical treatments in Norway?

Specific chemical treatments necessary only at / after leaf fall

1. Nordox 75 WG has a high efficacy against canker → registration?

2. Delan WG expected to be effective at leaf-fall, but no depot properties

3. Topsin (thiophanate-methyl): controversial results, negative effect on leaf decomposition

4. Calcium hydroxide: limited and uncertain efficacy
Summary: Control of apple canker

Cu treatments in autumn and winter

Fresh wounds during infection periods

Wet and mild weather during autumn

High infection pressure due to adjacent orchards

Successful production

Canker pruning every 4-6 weeks during the season

Winter frost damage

Excessive nitrogen fertilisation
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2011: Problems with ‘Nicoter’ trees from a nursery

Trees delivered and planted on 27/28 April 2011
Survey on 19 Aug. 2011 (10 trees per symbol)

Uprooting of both orchards in Nov. 2011
2012: Re-planting of orchard B – with ‘Nicoter’!

Trees delivered and planted in April 2012
Survey on 13 Nov. 2012 (10 trees per symbol)

Trunk canker
Canker on lateral branches
Healthy tree
Molecular biological evidence for nursery infections

McCracken et al. (2003)

The population of *N. ditissima* on the trunk of freshly planted trees at various locations of the British Isles

- differed from the surrounding established orchards
- but correlated with the nursery of origin

In contrast, *N. ditissima* from twig cankers on the same trees was similar to surrounding orchards

**Conclusion**: Trunk cankers were introduced from nursery infections, twig cankers arose from local inoculum
The Norwegian experience

Contaminations at grafting may lead to canker at graft union

Susceptible varieties affected: ‘Discovery’, ‘Summerred’ and ‘Julyred’

Emergence of canker within 12 months of explanting
Factors favouring nursery infections

1. Excessive N fertilisation to promote lush growth
2. Treatments with copper chelates in autumn to induce leaf fall (but not winter hardiness)
3. Pruning during wet weather
4. Grafting of contaminated material
Latent infections in ‘Topaz’

Bark strip (surface-sterilised)

Bark segments

Incubation

Symptoms similar to collar rot caused by *Phytophthora* spp.
N. ditissima as the cause of latent infections

1. Robust varieties affected
2. Sudden outbreak of necrosis around the entire trunk
3. No callus formation
   → de novo infections by spores unlikely
   → contamination during grafting more likely
Summary: Nursery infections

1. Trees may be contaminated by *N. ditissima* in nurseries

2. Infections become visible within the first season (e.g. ‘Nicoter’) or within 2-3 years in less susceptible varieties

3. Farmers should check the incidence of canker after the first growing season!

4. Subsequent development of canker is dependent on infection potential of the orchard and on susceptibility of varieties
Successful production of healthy nursery trees depends on several factors:

- **Cu treatments in autumn and winter**: +
- **Fresh wounds during infection periods**: -
- **Wet and mild weather during winter**: -
- **High infection pressure due to adjacent orchards**: -
- **Canker pruning every 4-6 weeks during the season**: +
- **Winter frost damage**: -
- **Excessive nitrogen fertilisation**: -
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Dead twigs are a niche for other fungi

*Neonectria*  *Diplodia*  *Phomopsis*

*Diplodia seriata*, cause of black summer rot
Necrotic lesions on tree bark: → „paper bark“, encapsulation

Infections by *P. syringae* at low temp. (<10°C) and high humidity (e.g. cold-storage of nursery trees prior to planting)

Spring plantings suffer greatest damage (up to 25% of trees)

No further symptom development as from end of June
Measures against *P. syringae*

1. Store nursery trees outdoors
2. If cold-room storage is inevitable, avoid water splash onto twigs
3. Diagnosis: Rule out *E. amylovora* and *N. ditissima*
4. Delay pruning of affected twigs until encapsulation has occurred
5. Only strongly affected trees need to be replaced
6. There are no effective spray measures
7. No further development of symptoms in the following season
Fireblight

1. Most important bacterial disease of Rosaceae
2. Optimum conditions at >18°C and high humidity (e.g. thunderstorm)
3. Flowers and wounds are the most important entry points
4. Bacterial slime
5. Spread by wind and pollinating insects
6. Overwintering as bark necroses (canker)
Host range

Quince (*Cydonia oblonga*)
> Pear (*Pyrus communis*)
> Apple (*Malus domestica*)

Alternative hosts:
*Crataegus* (whitethorn)
*Cotoneaster*
*Sorbus* (mountain ash)
others

10 yr old pear orchard

*Crataegus*
Fireblight: Infection cycle
Overwintering canker on pear (‘Kondo’), 17 Dec. 2013
Cankers caused by *Neofabraea* spp.

*N. perennans* und *N. alba* cause weak cankers on cut ends of twigs.
**Gloeosporium-like fungi**

- *Neofabraea perennans* (T)
- *Pezicula perennans* (T)
- *Cryptosporiopsis curvispora* (A)
- *Gloeosporium perennans* (A)

- *Neofabraea alba* (T)
- *Pezicula alba* (T)
- *Phlyctema vagabunda* (A)
- *Gloeosporium album* (A)

- *Glomerella acutata* (T)
  - [Glomerella cingulata] (T)
- *Colletotrichum acutatum* (A)
- [Glloeosporium fructigenum] (A)
Gloeosporium-like fungi

Damage due to storage rots: in organic production 10-25%, sometimes more (e.g. 90% in IP in 1968)

60-80% of all storage rots due to ‘Gloeosporium’

Gloeosporium-type rots more common in poorly pigmented fruit from 2\textsuperscript{nd} / 3\textsuperscript{rd} picking

Relative importance in Northern Germany:

- *Neofabr. perennans* 70-75%
- *Neofabraea alba* 20-25%
- *Colletotr. acutatum* <5%

\begin{column}
\begin{itemize}
  \item *N. alba* dominant in S. Germany and S. Europe
  \item *C. acutatum* common in Scandinavia
\end{itemize}
\end{column}

Apple cultivars may differ in their spectrum of storage rots (reasons unknown)
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Blossom-end rot on 5 July 2014 after artificial infection at flowering
Occurrence of Nectria blossom-end rot on ‘Nicoter’

**Orchard 1**

- ‘Nicoter’
- ‘Braeburn’

**Orchard 2**

Survey:
16 Aug. 2012

- N. ditissima
- Botrytis
- Others

<table>
<thead>
<tr>
<th>Apples with blossom-end rot [%]</th>
<th>‘Nicoter’</th>
<th>‘Braeburn’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orchard 1</td>
<td>4.5</td>
<td>1.2</td>
</tr>
<tr>
<td>Orchard 2</td>
<td>5.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Storage rot
caused by *N. ditissima* infections shortly before harvest

Advanced rot in cold-storage

Separation of diseased tissue
Fruit rots caused by *N. ditissima*

1. Infections during wet weather at flowering (blossom-end rot) or during 4-6 weeks before harvest (storage rot)
2. Latent phase of several weeks on the tree or in storage
3. Infections caused by conidia
4. Both rots are most frequent on fruits from trees affected by cankers

Canker pruning will control both fruit rots
Control of *Neonectria ditissima* on apple

1. No planting of susceptible varieties downwind of a heavily infected old orchard

2. Careful observation of trees within the first growing season; immediate removal of trees with trunk canker

3. Regular visual control and pruning of bark lesions before the fungus gets into the xylem or produces conidia

4. No pruning during wet weather

5. Removal of all pruning material from the orchards

6. Chemical control during leaf fall in autumn (if possible)
Publications

