Practical measures for reducing the risk and impact of lettuce fusarium wilt

Dr Tim O’Neill, ADAS
14 December 2017
Fusarium diseases in the UK

**Established**
- Narcissus – basal rot
- Pinks – wilt
- Cyclamen – wilt
- Tomato – wilt

**Emerging (Europe)**
- Rocket – wilt
- Strawberry – wilt
- Gerbera - wilt

**New**
- Basil – wilt (1997)
- Tomato – FCRR (1999)
- Pepper – fruit rot (2000)
- Lettuce – wilt (2017)
Overview

1. Potential lessons from other crops
2. Lettuce fusarium wilt – what we know
3. Identification and disease monitoring
4. Minimising risk and managing the disease
   (a) Seed health
   (b) Sanitation and hygiene
   (c) Soil features affecting wilt
   (d) Soil disinfestation
   (e) Fungicides, biofungicides & cultural control
5. Integrated management
6. Future prospects
1. Potential lessons from other Fusarium diseases

Narcissus basal rot

Pinks/ carnations

Cyclamen

Tomato

Hebe

Pepper
Fusarium wilt of column stocks

*Fusarium oxysporum f.sp mathiolae*

**Biology**
- Seed-borne
- Persists in soil
- Saprophytic
- Worse in hot weather

**Management (2017)**
- Seed health
- Soil disinfestation
- Less intensive cropping
- Manage debris
- More tolerant cultivars
# Management measures for some important Fusarium diseases

<table>
<thead>
<tr>
<th>Measure</th>
<th>Nar</th>
<th>Pink</th>
<th>Cyc</th>
<th>Tom</th>
<th>Heb</th>
<th>Pep</th>
<th>Sto</th>
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</thead>
<tbody>
<tr>
<td>Seed/stock health</td>
<td>√</td>
<td>√</td>
<td>?</td>
<td>?</td>
<td>√</td>
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<tr>
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<td>X</td>
<td>X</td>
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<td>Resistance/tolerance</td>
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<td>?</td>
<td>X</td>
<td>√</td>
<td>X</td>
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<td>√</td>
<td>X</td>
<td>√</td>
<td>√</td>
<td>X</td>
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<tr>
<td>Soil amendments</td>
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<td>X</td>
<td>√</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>?</td>
</tr>
<tr>
<td>Soil disinfestation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>√</td>
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<tr>
<td>GH env. control</td>
<td>X</td>
<td>X</td>
<td>√</td>
<td>X</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>

- Key management tool

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Lessons - Disinfectants

- Good activity from several products
- Clean surfaces first (peat, debris)
- Cannot use on soil/growing media
- Follow label carefully (e.g. temperature)
- Contact time
- Identify high risk areas
- Persistence in foot/wheel dips
Disinfectant tests - Fusarium

• Products from different chemical groups tested in laboratory bioassays

• Efficacy tested against fusarium spores and mycelium (+/- peat)

• Tested at full label rate and half rate

• Treatment durations of 5 min and 30 min

• Swab tests on treated surfaces

Ref: O’Neill, 2007 (PC 213); Wedgwood, 2015
# Disinfectants vs Fusarium spores

<table>
<thead>
<tr>
<th>Rep</th>
<th>0</th>
<th>5m</th>
<th>30m</th>
<th>1/2 rate</th>
<th>5m</th>
<th>30m</th>
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<tr>
<td>1</td>
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</tbody>
</table>

**Control**

- **NaOCl**
- **Unifect G**
- **Vitafect**

![Image 1](image1.png)

![Image 2](image2.png)

![Image 3](image3.png)

![Image 4](image4.png)

[ADAS Logo]
Disinfectant efficacy vs **Fusarium** spores*

<table>
<thead>
<tr>
<th>Product</th>
<th>Half rate</th>
<th></th>
<th></th>
<th>Full rate</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>5 mins</td>
<td>30 mins</td>
<td>5 mins</td>
<td>30 mins</td>
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</tr>
<tr>
<td>Jet 5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Citrox P</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Disolite</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>FAM30</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Hydrocare</td>
<td>100</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Virkon S</td>
<td>20</td>
<td>0</td>
<td>20</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Unifect G</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Menno Florades</td>
<td>100</td>
<td>100</td>
<td>80</td>
<td>40</td>
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<tr>
<td>Domestos EGK</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</table>

*Macrocondia + microcondia

Ref: E Wedgwood
Disinfectant efficacy vs *Fusarium mycelium*

<table>
<thead>
<tr>
<th>Product</th>
<th>Half rate</th>
<th>Full rate</th>
<th>Full rate (+ peat)</th>
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<tbody>
<tr>
<td></td>
<td>5</td>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>Jet 5</td>
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<td>90</td>
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</tr>
<tr>
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</tr>
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<td>Disolite</td>
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<td>0</td>
</tr>
<tr>
<td>FAM30</td>
<td>100</td>
<td>100</td>
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</tr>
<tr>
<td>Hydrocare</td>
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<tr>
<td>Virkon S</td>
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<tr>
<td>Unifect G</td>
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<td>0</td>
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<td>Menno Florades</td>
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<tr>
<td>Domestos EGK</td>
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*Mycelium in paper disc*

Ref: E Wedgewood
Recovery of Fusarium* after disinfection of different surfaces

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Glass</th>
<th>Plastic</th>
<th>Aluminium</th>
<th>Concrete</th>
<th>WGC</th>
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<tr>
<td>Water (control)</td>
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<td>5</td>
<td>5</td>
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<td>Virkon S</td>
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<td>5</td>
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<tr>
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<td>Menno Florades</td>
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<td>Domestos</td>
<td>0</td>
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</tbody>
</table>

*Mycelium + 3 spore types

Ref: E Wedgwood
# Effect of hot water treatments on Fusarium chlamydospores

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Warm</th>
<th>HWT</th>
<th>No. plates (of 5) with Fusarium growth</th>
</tr>
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<tbody>
<tr>
<td>1. Control</td>
<td>-</td>
<td>3h, 18°C</td>
<td>5</td>
</tr>
<tr>
<td>2. Std</td>
<td>-</td>
<td>3h, 44°C</td>
<td>5</td>
</tr>
<tr>
<td>3. Std +</td>
<td>-</td>
<td>4h, 44°C</td>
<td>5</td>
</tr>
<tr>
<td>4. Pre warm</td>
<td>30°C</td>
<td>3h, 18°C</td>
<td>5</td>
</tr>
<tr>
<td>5.</td>
<td>30°C</td>
<td>3h, 46°C</td>
<td>5</td>
</tr>
<tr>
<td>6.</td>
<td>30°C</td>
<td>3h, 47°C</td>
<td>5</td>
</tr>
<tr>
<td>7.</td>
<td>30°C</td>
<td>3h, 47.5°C</td>
<td>5</td>
</tr>
<tr>
<td>8.</td>
<td>30°C</td>
<td>3h, 48°C</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>2h, 44°C</td>
<td>1h, 47°C</td>
<td>5</td>
</tr>
</tbody>
</table>

Ref: BOF 61a
Effect of disinfectants and a wetter in HWT* on Fusarium chlamydospores

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. plates (of 5) with Fusarium growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Water (control)</td>
<td>5</td>
</tr>
<tr>
<td>2. Harvest Wash (Clo2)</td>
<td>5</td>
</tr>
<tr>
<td>3. Citric acid</td>
<td>5</td>
</tr>
<tr>
<td>4. Silwett L-77 (wetter)</td>
<td>5</td>
</tr>
<tr>
<td>5. FAM30 (iodophor)</td>
<td>0</td>
</tr>
<tr>
<td>6. Water (18°C)</td>
<td>5</td>
</tr>
</tbody>
</table>

*3h at 44.4°C

Ref: BOF 61a
Disinfectants summary

• Easy to kill spores (<5 min)
• Difficult to kill mycelium (longer exposure better)
• Disolite and Unifect G most effective (equivalent products available)
• Peat reduced product activity (see also BOF 77)
Lessons - Biofungicides

Effect of Serenade ASO and T-34 Biocontrol on pepper fusarium fruit rot - 2016

% fruit affected

<table>
<thead>
<tr>
<th></th>
<th>Unt</th>
<th>Ser</th>
<th>T34</th>
<th>Unt</th>
<th>Ser</th>
<th>T34</th>
<th>Unt</th>
<th>Ser</th>
<th>T34</th>
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<td>Harvest 1</td>
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<tr>
<td>Harvest 2</td>
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<td></td>
<td></td>
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<tr>
<td>Harvest 3</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Lessons - Fungicides, biofungicides and soil amendments - 2012
Fusarium wilt of stocks – Evaluation of fungicides and biofungicides

Ref: O’Neill & Mason (2014)
Fusarium wilt of stocks – Evaluation of soil treatments

Severity (0 – 5)

UnT  PW + Tri  PW + Pre  Mu  Mu + Tri  Mu + Pre  Bar  Bar + Tri  Bar + Pre

* Significant reduction

Ref: O’Neill & Mason (2014)
2. Lettuce fusarium wilt – what we know

Fusarium oxysporum f.sp. lactucae

History

• Japan – 1955 (race 1,2,3)
• California – 1990 (race 1)
• Europe (Italy) – 2001 (race 1)
• Portugal – 2004 (race 1)
• Netherlands – 2015 (race 4)
• France – 2016
• UK – 2017 (race 4)
Symptoms

• Leaf wilt/yellowing
• Orange to dark streaks in petiole & crown (vascular system)
• Stunted growth
• Rotting tap root
• Hollow stem
• Plant collapse
Crops affected

**Lettuce**

- Butterhead
- Romaine (Cos)
- Oak leaf
- Batavia
- Iceberg (Crisphead)
- Lamb’s lettuce (possibly)
Symptomless hosts

• Spinach
• Broccoli
• Cauliflower
• Wilt resistant lettuce
What is the effect of planting different crops after a fusarium wilt outbreak?

Here is a table showing the symptoms and infection rates for various crops:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Symptoms in Crop</th>
<th>Roots infected (0%)</th>
<th>Vascular infection (%)</th>
<th>Quantity of Fusarium (cfu/g cortex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lettuce</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crisphead (S)</td>
<td>V</td>
<td>100</td>
<td>71</td>
<td>1,312</td>
</tr>
<tr>
<td>Batavia (R)</td>
<td>X</td>
<td>100</td>
<td>71</td>
<td>576</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinach</td>
<td>X</td>
<td>50</td>
<td>50</td>
<td>12</td>
</tr>
<tr>
<td>Broccoli</td>
<td>X</td>
<td>53</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

Ref: Scott et al, 2014
Key features of lettuce fusarium wilt

- Host-specific
- Vascular wilt disease
- 3 spores types
- Soil temperature greatly affects disease severity
- Long survival in soil (years)
- Saprophytic stage
- Seed-borne
- Major gene resistance
- 4 races identified on lettuce

Scott et al. 2010
Survival of Fusarium (FOM) in crop debris in soil at levels sufficient to cause Fusarium wilt in stocks - 2007

% plants developing wilt

Ref: PC 213a
Proposed life-cycle

Infested soil → Local spread → Next crop infected

Trays/equipment → Latent infection → Debris/dirt → New race evolves (soil) → Seed
3. Identification and disease monitoring

- Botrytis
- Downy mildew
- Bacterial leaf rot
- Sclerotinia
- Phoma leaf spot
- Phoma basal rot
- Pythium sp.
Lettuce fusarium wilt
Monitoring and testing

- Inspect crops carefully & regularly
- Send plants for testing if uncertain of cause
- Remove suspect plants & soil (bag *in situ*)
- Prompt identification and action reduces build-up in soil
- Measuring soil inoculum?
Measuring *Fusarium oxysporum* in soil

1. Bioassay

2. Selective nutrient agar (e.g. Komada’s)

3. DNA extraction and PCR
   (+/- ; quantification; community structure)

PCR test for detection of Fol race 1 on lettuce seed published
4. Minimising risk and managing the disease

a) Seed health
   - Seed production
   - Seed testing
   - Seed treatment

   What is being done?
   What can be done?

b) Sanitation and hygiene
   - Propagation & production

c) Soil features affecting wilt

d) Soil disinfestation

e) Fungicides, biofungicides and cultural control
4a) Occurrence of *Fusarium oxysporum* on lettuce seed in Italy - 2004

27 commercial seed lots examined (500-1500/lot)

Direct test

9 lots affected

Wash in 1% NaOCl

1 lot (1 seed) affected

3/16 isolates caused *Fusarium* wilt following root dip inoculation (1x10^6 spores/ml); symptoms after 8d at 20-30°C.

Ref: Garibaldi *et al.*, 2004
4b) Sanitation and hygiene - aims

- Stop movement of *Fusarium oxysporum* f.sp. *lactucae* (*Fol*) onto site; minimise movement on site.
- Minimise amount of Fusarium in local environment
  - Measures to avoid soil movement (wash + disinfect)
  - Maintain procedures even when no crop/symptoms
Sanitation and hygiene

• Nursery hygiene protocol
  Trays, equipment, visitors

• Crop disposal
  ➢ Prompt ID and removal
  ➢ Leaves, blocks, roots
  ➢ Propane burner?

• Disinfection
  ➢ Temperature, exposure

• Special attention
  ➢ Unusual/trial varieties
## 4c) How soil features affect risk of fusarium wilt

- **Pathogen presence & level**: ***
- **Soil temperature**: **
- **Depth of fusarium in soil**: *
- **Soil structure**: *
- **Soil microbial community**: ?
- **Soil type/chemistry**: ?
- **Soil physical features**: ?
Pathogen presence and level

- Fusarium wilt in Hebe

No. plants affected (12 weeks)

Ref: O’Neill, 2009 (HNS 146)
Soil temperature

Fusarium wilt of stocks

Lethal temperatures

![Graph showing growth (mm/day) vs. temperature (degrees C) for different strains of fungi, with lethal temperatures indicated for various pathogens such as Virus (TMV), Some bacteria, Verticillium, Sclerotinia, Phytophthora, and Pythium.]
Effect of temperature on growth of *F. oxysporum* f.sp. *lactucae* (race 1 isolate)

Ref: Scott et al., 2010
Effect of soil temperature at planting on lettuce fusarium wilt - Arizona

<table>
<thead>
<tr>
<th>Temperature at 10cm depth (°C)</th>
<th>Plants wilted or dead (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crisphead</td>
</tr>
<tr>
<td>13.9</td>
<td>1.3</td>
</tr>
<tr>
<td>15.0</td>
<td>23.0</td>
</tr>
<tr>
<td>25.6</td>
<td>94.0</td>
</tr>
</tbody>
</table>

- Belgium observation – infection can occur at 15°C

Ref: Matheron, 2015
Effect of soil temperature on lettuce fusarium wilt – Italy
Number of days to reach DI 90 (0-100 scale)

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>Batavia de serra</th>
<th>Romana velvet</th>
<th>Batavia</th>
<th>Lollo Rosso</th>
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<tbody>
<tr>
<td></td>
<td>HS</td>
<td>S</td>
<td>PR</td>
<td>‘R’</td>
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<tr>
<td>10</td>
<td>&gt;100</td>
<td>&gt;100</td>
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<td>25</td>
<td>15-20</td>
<td>23-32</td>
<td>&gt;100</td>
<td>&gt;100</td>
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<td>30</td>
<td>8-10</td>
<td>12-20</td>
<td>36-40</td>
<td>&gt;100</td>
</tr>
</tbody>
</table>

Soil infested at 1x10⁶ cfu/ml

Ref: Gullino et al., 2015
Effect of temperature and inoculum level – lettuce fusarium wilt - Italy

Number of days to reach severe wilt (disease susceptible variety)

Ref: Gullino et al., 2015
Soil depth and disease

- 0 cm: Pythium, Sclerotinia
- 10 cm: Rhizoctonia, Phytophthora
- 20 cm: Rhizoctonia, Phytophthora
- 30 cm: Fusarium, Verticillium
- 40 cm: Fusarium, Verticillium
Effect of soil structure

- Cloddy soil under gutter
- Fusarium wilt under gutter
- Wetter soils
4d) Soil disinfestation

**Physical**
- Sheet steam
- Vacuum steam
- Steam plough
- Sandwich steaming

**Chemical**
- Dazomet
Pathogen reduction – Soil steaming
(Norfolk site)

• Spaded to 35 cm
• Steamed for 10 hours (with thermal fleece)
• Left covered overnight
• Planted after 2-3 days
Temperatures achieved - sheet steaming (Norfolk)

- Heat front travels down the soil profile, fairly slowly
- Rate of heat loss increases when sheet removed (22h)
# Sheet steaming and depth - % kill

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Fus in stem</th>
<th>Fus in root</th>
<th>Sclerotinia</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>94</td>
<td>94</td>
<td>100</td>
</tr>
<tr>
<td>10 – 15</td>
<td>92</td>
<td>98</td>
<td>100</td>
</tr>
<tr>
<td>20 - 25</td>
<td>94</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>30 - 35</td>
<td>92</td>
<td>88</td>
<td>99</td>
</tr>
</tbody>
</table>
Sheet steaming - Suffolk

- Soil type: medium sandy loam
- Cultivation: spaded to 35 cm, without crumbler bar
- % moisture: 44% FC
- Month treated: September
- Area treated: 400 m$^2$ (40 m x 10 m)
- Steamed for 12 h, left covered overnight
Sheet steaming and depth: temperatures achieved in bay 2

The graph shows the temperature (°C) over time (hours) for different depths (3.5 cm, 13.5 cm, 23.5 cm, 33.5 cm). The temperatures peak at different times, with the 3.5 cm depth reaching the highest temperature first.
**Sheet steaming and depth - % kill**

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Fus in stem</th>
<th>Fus in roots</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 5</td>
<td>30</td>
<td>81</td>
</tr>
<tr>
<td>10 – 15</td>
<td>67</td>
<td>96</td>
</tr>
<tr>
<td>20 – 25</td>
<td>23</td>
<td>59</td>
</tr>
<tr>
<td>30 – 35</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

Reduced kill, especially in woody stems, when the soil temperatures are lower
Vacuum steaming

Temperatures achieved with vacuum steaming

1. 5h steam. 120 m² strip adjacent to inner glasshouse wall. Temperature probes inserted 30 cm from tubes.
2. As above, adjacent strip.
3. As above, adjacent strip, but probes directly over vacuum tubes.
4. 5 ¼ h steam. Probes 30 cm from tube. Boiler tripped after 15 mins.
5. 5 ½ h steam (boiler OK), with double suction. Probes 30 cm from tubes.
7. 3 ¼ h steam. Probes 30 cm from tube. Warm soil either side from previous steams.

<table>
<thead>
<tr>
<th>Run</th>
<th>Approx. max. temperature (inlet end) at each depth (cm)</th>
<th>Best location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.5</td>
<td>13.5</td>
</tr>
<tr>
<td>1</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>2</td>
<td>98</td>
<td>88</td>
</tr>
<tr>
<td>3</td>
<td>98</td>
<td>90</td>
</tr>
<tr>
<td>4</td>
<td><strong>98</strong></td>
<td><strong>98</strong></td>
</tr>
<tr>
<td>5</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>6</td>
<td><strong>98</strong></td>
<td><strong>98</strong></td>
</tr>
<tr>
<td>7</td>
<td><strong>98</strong></td>
<td><strong>98</strong></td>
</tr>
</tbody>
</table>
Steam plough - Norfolk

- Steam injected at 31 cm depth
- Travels at 10.3 metres/hour
- Requires constant attendance
- Soil covered by 4 m sheet (for around 23 mins at any one point)
Max temp at each depth very similar to sheet steam
# Steam plough and depth: % kill

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Fus in stem</th>
<th>Fus in roots</th>
<th>Sclerotinia</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 5</td>
<td>94</td>
<td>94</td>
<td>97</td>
</tr>
<tr>
<td>10 – 15</td>
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<td>92</td>
<td>100</td>
</tr>
<tr>
<td>20 – 25</td>
<td>98</td>
<td>98</td>
<td>100</td>
</tr>
<tr>
<td>30 – 35</td>
<td>98</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
The Company: Möschle-Seifert-Dämpftechnik

Specialist for steaming technology and systems

Products: Steaming Technology and Systems
For use in:
- Horticulture
- Agriculture
- Viniculture, Industry, etc.

Experience: More than 60 years in the market
One of the world’s leading suppliers

Customers: More than 3,000 customers worldwide

Partners:
- Barel BV, Niederlande
- IMANTS BV, Niederlande
- Josef Zeyer GmbH, Deutschland
- Clemens GmbH Co.KG, Deutschland

Michael Seifert  email: info@moeschle.de
Fully automated steaming robot with sting hood for depth and surface steaming.

Advantages: Energy exposure can be increased to up to 120 kg steam per m²/h and only half of the regular steaming time is needed.
Sandwich Steaming

Fully automated systems

Hydraulic lowering of the sting hood.
Chemical fumigants

• Basamid
Evaluation of Basamid (dazomet) for fusarium wilt in stocks
Control of Fusarium in stem pieces (firm vs soft) with Basamid*

<table>
<thead>
<tr>
<th>Depth in soil (cm)</th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Firm</td>
<td>Soft</td>
</tr>
<tr>
<td>0</td>
<td>78</td>
<td>82</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>15</td>
<td>12</td>
<td>54</td>
</tr>
<tr>
<td>30</td>
<td>5</td>
<td>-</td>
</tr>
</tbody>
</table>

*76g/m2; LDPE cover
Ref: PC 249
4e) Fungicides, biofungicides, and cultural control

Arizona

Products equivalent to Cercobin, Switch & Signum applied at seeding:

- No suppression of fusarium wilt in crisphead lettuce

Netherlands

Several fungicides and biofungicides tested:

- No reduction of infection

Ref: Matheron, 2015
Cultural control

• Resistant/tolerant varieties
• Hydroponic systems
  - NFT, float system
• Manage soil temperature
  - Shade screen?
  - Whitewash?
  - White plastic over soil?
• Non-host (in summer)
  - Pak choi
  - Other?
  - Fallow
5. Integrated management of fusarium wilt
An example - stocks

- Harvest by pulling
- Remove crop debris
- Nursery hygiene - foot dip
- Prepare for soil treatment
- Soil disinfestation
- Care to avoid recontamination
- Biological amendment?
- Clean seed/
- Inspect crop regularly
- Remove infected plants
- Post-plant fungicide dip

(Pre plant fungicide dip)
# Integrated management of lettuce fusarium wilt - likely components and their importance

<table>
<thead>
<tr>
<th>Component</th>
<th>Now</th>
<th>Medium term</th>
<th>Long term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed health</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Tolerant/resistant varieties</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Fungicides</td>
<td>In prop?</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Biofungicides</td>
<td>In prop?</td>
<td>(✓)</td>
<td>(✓)</td>
</tr>
<tr>
<td>Sanitation (crop debris)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Disinfection/burner</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Soil amendments</td>
<td>X</td>
<td>(✓)</td>
<td>(✓)</td>
</tr>
<tr>
<td>Soil disinfection</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>Cultural control</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

- Key management tool
Key control measures - summary

- Rigorous hygiene protocol
- Remove all plant remains
- Grow resistant varieties (esp. when soil warm)
- Regular crop inspections (+ action)
- Isolate affected areas
- Soil disinfection
- Consider non-host break crops
- Consider hydroponics/temp. control
- Consider fallow in summer
6. Future prospects – relevant research

• Seed companies – lists of resistant varieties

• AHDB -Technical Review of lettuce fusarium wilt

• Soil Biology & Soil Health Partnership (2017 – 2021)

• Biological products & methods
Acknowledgments

- AHDB
- David Stokes, Horticulture Consultant
- Ruth D’urban-Jackson, ADAS
- Michael Seifert, MSD