

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

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# 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)
- Stocks – wilt (2003)
- Hebe – wilt (2005)
- Lettuce – wilt (2017)

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# 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

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# 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

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# Management measures for some important Fusarium diseases

| Measure | Nar | Pink | Cyc | Tom | Heb | Pep | Sto |
|---|---|---|---|---|---|---|---|
| Seed/stock health | √ | **√** | **?** | **?** | **√** | **?** | **?** |
| Sanitation | √ | √ | **√** | √ | √ | √ | **√** |
| Disinfection | √ | √ | **√** | √ | √ | √ | √ |
| Rotation | **√** | √ | X | X | X | X | X |
| Resistance/tolerance | √ | **?** | X | **√** | X | √ | √ |
| Fungicides | √ | **√** | **√** | X | √ | √ | X |
| Biofungicides | **?** | **?** | **?** | √ | √ | **√** | X |
| Soil amendments | X | X | **√** | X | X | X | **?** |
| Soil disinfestation | X | X | X | X | X | X | **√** |
| GH env. control | X | X | √ | X | √ | **√** | √ |

**□** - Key management tool

# 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

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# Disinfectant tests - Fusarium

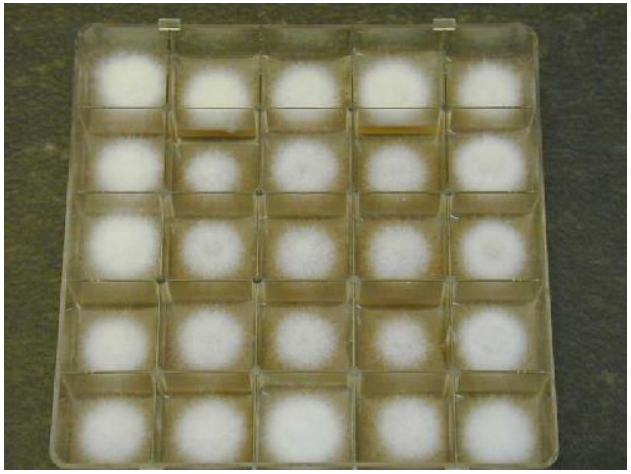
- Products from different chemical groups tested in laboratory bioassays
- Efficacy tested against fusarium spores and mycelium (+/- peat)
- Tested at full label rate and half rate
- Treatment durations of 5 min and 30 min
- Swab tests on treated surfaces

Ref: O'Neill, 2007 (PC 213); Wedgwood, 2015

# Disinfectants vs Fusarium spores

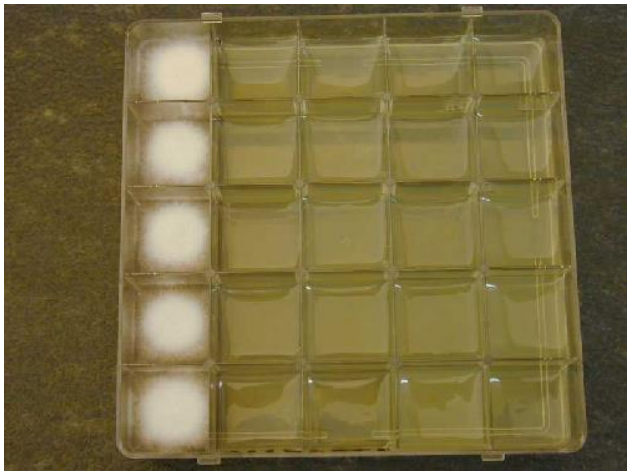
| | | Rec | | $^1/_2$ rate | |
|---|---|---|---|---|---|
| Rep | 0 | 5m | 30m | 5m | 30m |
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |

**Control**



**NaOCl**

**Unifect G**



**Vitafect**

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# Disinfectant efficacy vs **Fusarium spores***

% wells with growth

| Product | Half rate | | Full rate | |
|---|---|---|---|---|
| | 5 mins | 30 mins | 5 mins | 30 mins |
| Jet 5 | 0 | 0 | 0 | 0 |
| Citrox P | 0 | 0 | 0 | 0 |
| Disolite | 0 | 0 | 0 | 0 |
| FAM30 | 0 | 0 | 0 | 0 |
| Hydrocare | 100 | 10 | 0 | 0 |
| Virkon S | 20 | 0 | 20 | 0 |
| Unifect G | 0 | 0 | 0 | 0 |
| Menno Florades | 100 | 100 | 80 | 40 |
| Domestos EGK | 0 | 0 | 0 | 0 |

*Macrocondia + microcondia

Ref: E Wedgwood

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# Disinfectant efficacy vs **Fusarium mycelium***

% wells with growth

| Product | Half rate | | Full rate | | Full rate (+ peat) | |
|---|---|---|---|---|---|---|
| | 5 | 30 | 5 | 30 | 5 | 30 |
| Jet 5 | 100 | 90 | 100 | 40 | 100 | 100 |
| Citrox P | 100 | 100 | 100 | 100 | 100 | 90 |
| Disolite | 0 | 0 | 0 | 0 | 0 | 0 |
| FAM30 | 100 | 100 | 100 | 100 | 100 | 100 |
| Hydrocare | 100 | 100 | 100 | 100 | 100 | 80 |
| Virkon S | 100 | 100 | 100 | 100 | 100 | 100 |
| Unifect G | 0 | 0 | 0 | 0 | 0 | 0 |
| Menno Florades | 100 | 100 | 100 | 100 | 100 | 100 |
| Domestos EGK | 0 | 0 | 0 | 0 | 0 | 0 |

*Mycelium in paper disc

Ref: E Wedgewood

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# Recovery of Fusarium* after disinfection of different surfaces

No. of swabs (of 5) with Fusarium

| Treatment | Glass | Plastic | Aluminium | Concrete | WGC |
|---|---|---|---|---|---|
| Water (control) | 5 | 5 | 5 | 5 | 5 |
| Jet 5 | 5 | 1 | 5 | 5 | 5 |
| Citrox P | 5 | 5 | 5 | 5 | 5 |
| Disolite | 0 | 0 | 0 | 0 | 0 |
| FAM30 | 5 | 5 | 5 | 5 | 5 |
| Hydrocare | 5 | 5 | 5 | 5 | 5 |
| Virkon S | 5 | 5 | 5 | 5 | 5 |
| Unifect G | 0 | 0 | 1 | 0 | 0 |
| Menno Florades | 5 | 5 | 5 | 5 | 5 |
| Domestos | 0 | 5 | 5 | 5 | 5 |

*Mycelium + 3 spore types

Ref: E Wedgwood

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# Effect of hot water treatments on Fusarium chlamydospores

| Treatment | Warm | HWT | No. plates (of 5) with Fusarium growth |
|---|---|---|---|
| 1. Control | - | 3h, 18°C | 5 |
| 2. Std | - | 3h, 44°C | 5 |
| 3. Std + | - | 4h, 44°C | 5 |
| 4. Pre warm | 30°C | 3h, 18°C | 5 |
| 5. | 30°C | 3h, 46°C | 5 |
| 6. | 30°C | 3h, 47°C | 5 |
| 7. | 30°C | 3h, 47.5°C | 5 |
| 8. | 30°C | 3h, 48°C | 5 |
| 9 | 2h, 44°C | 1h, 47°C | 5 |

Ref: BOF 61a

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# Effect of disinfectants and a wetter in HWT* on Fusarium chlamydospores

| Treatment | No. plates (of 5) with Fusarium growth |
|---|---|
| 1. Water (control) | 5 |
| 2. Harvest Wash (Clo2) | 5 |
| 3. Citric acid | 5 |
| 4. Silwett L-77 (wetter) | 5 |
| 5. FAM30 (iodophor) | 0 |
| 6. Water (18°C) | 5 |

*3h at 44.4°C

Ref: BOF 61a

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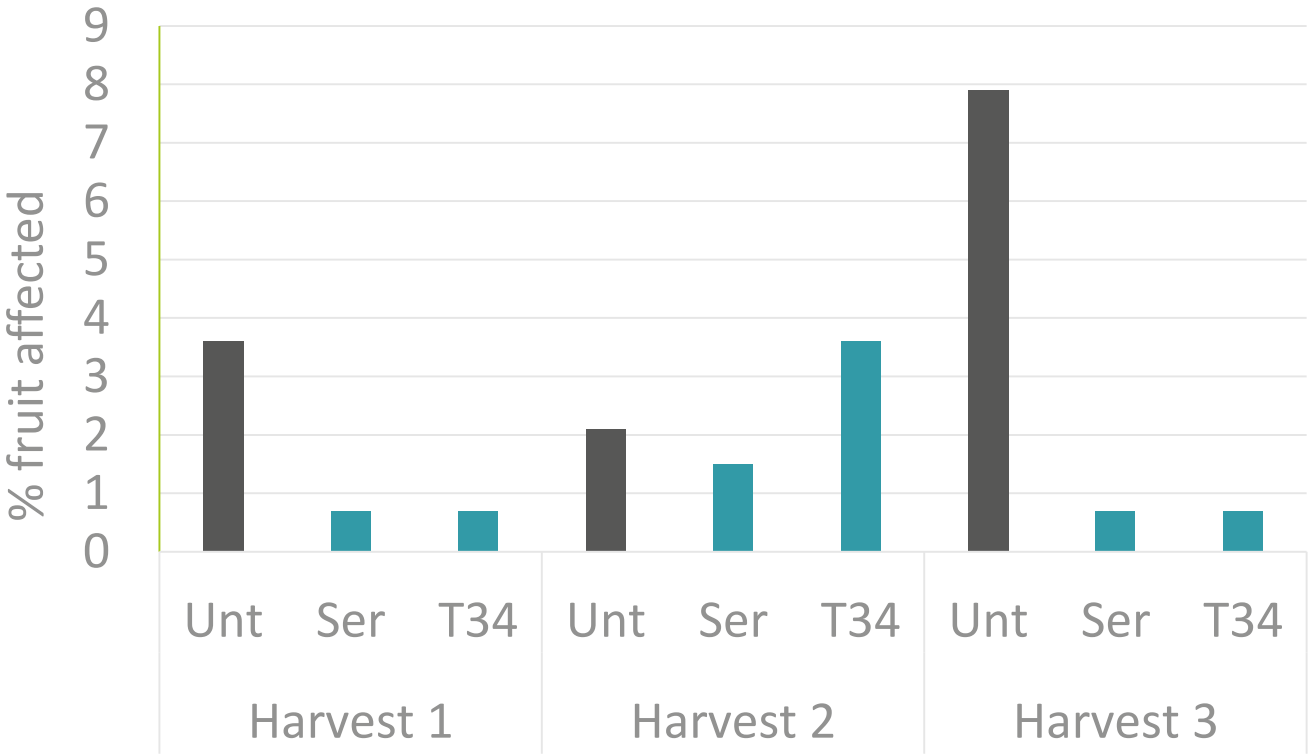
# Disinfectants summary

- 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)

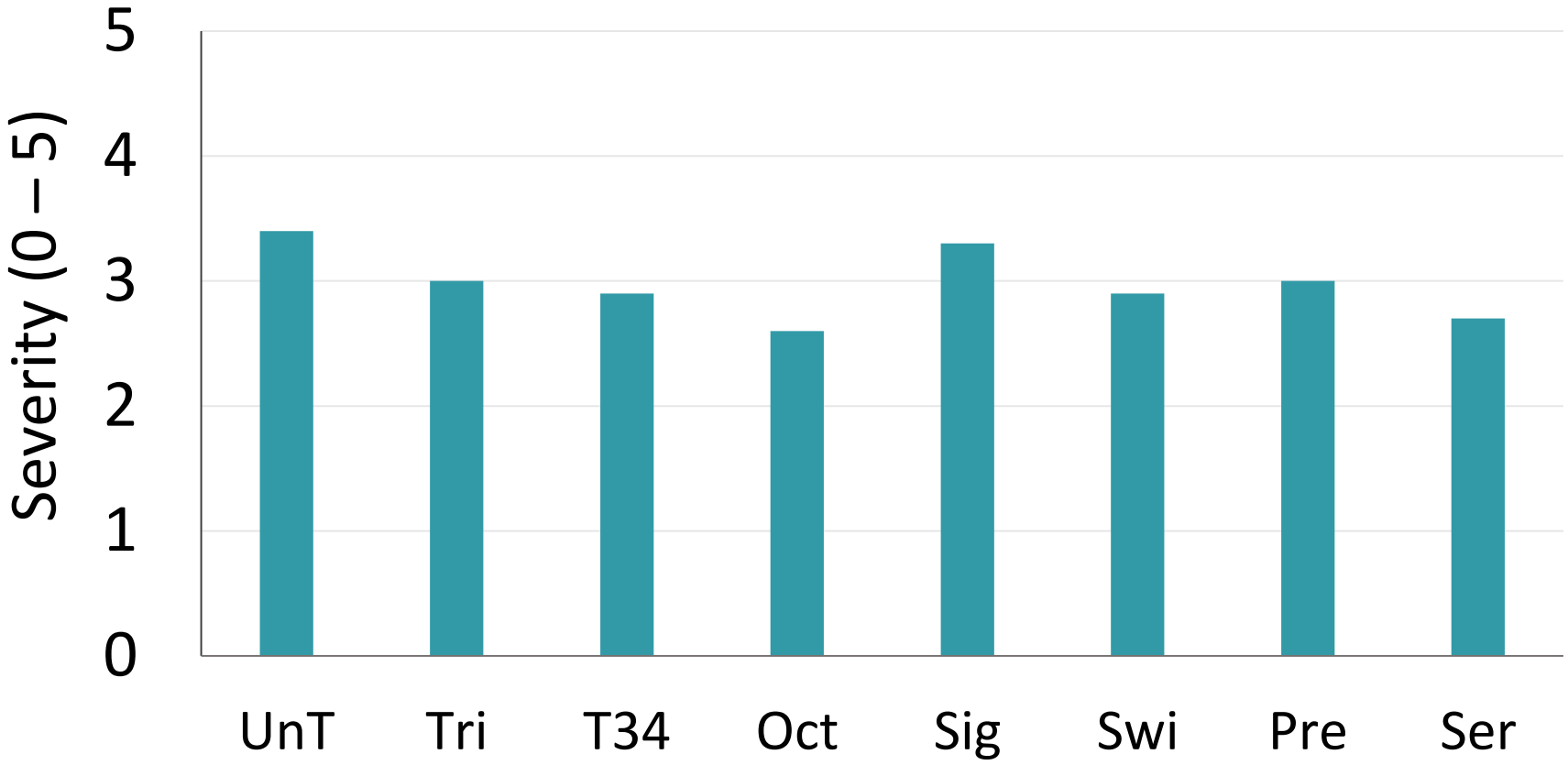
# Lessons - Biofungicides

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



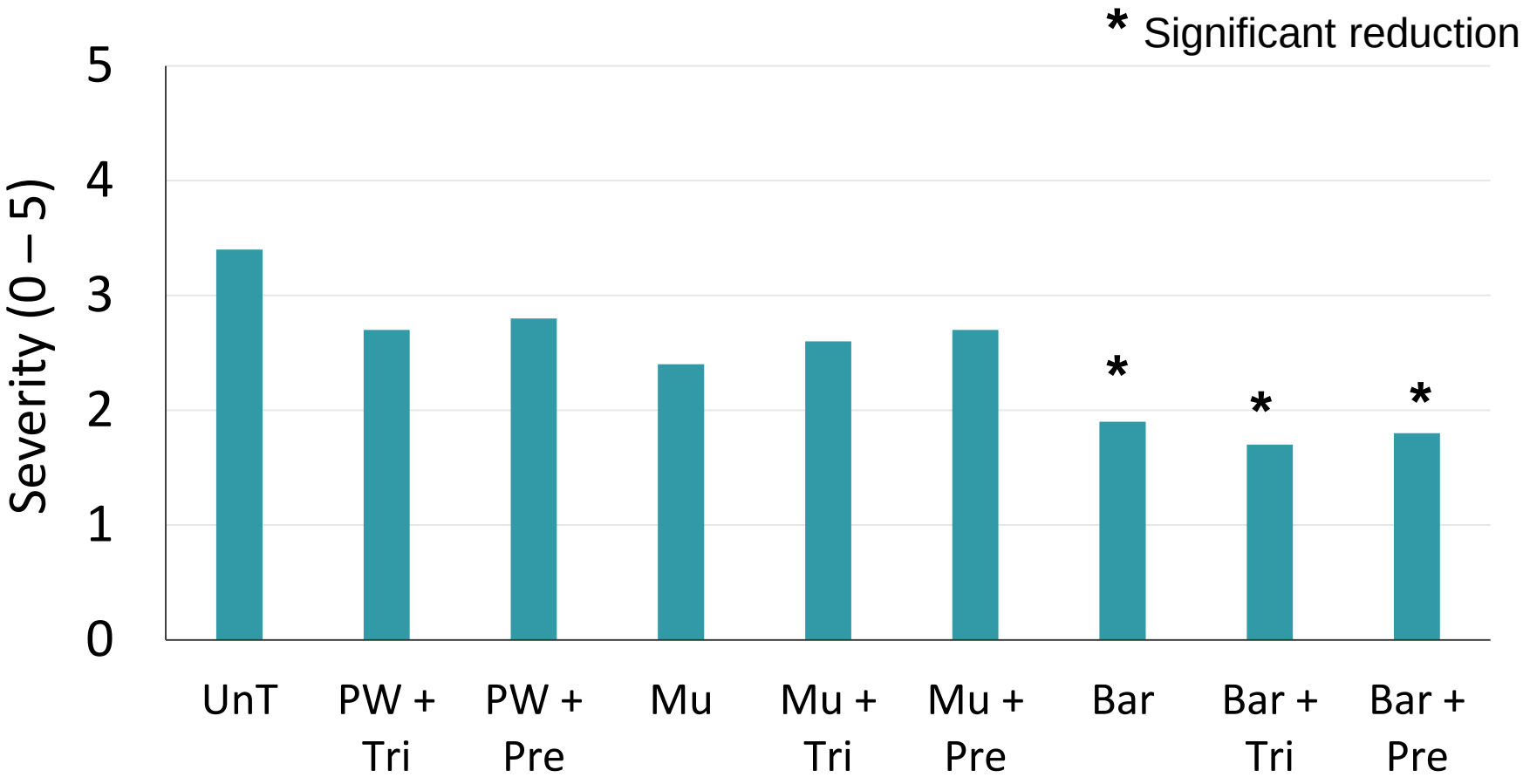

# Lessons - Fungicides, biofungicides and soil amendments - 2012

# Fusarium wilt of stocks – Evaluation of fungicides and biofungicides




Ref: O'Neill & Mason (2014)

# Fusarium wilt of stocks – Evaluation of soil treatments




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?

| Crop | Symptoms in Crop | Roots infected (0%) | Vascular infection (%) | Quantity of Fusarium (cfu/g cortex ) |
|---|---|---|---|---|
| **Lettuce** | | | | |
| Crisphead (S) | √ | 100 | 71 | 1,312 |
| Batavia (R) | X | 100 | 71 | 576 |
| **Other** | | | | |
| Spinach | X | 50 | 50 | 12 |
| Broccoli | X | 53 | 0 | 3 |

Ref: Scott et al, 2014

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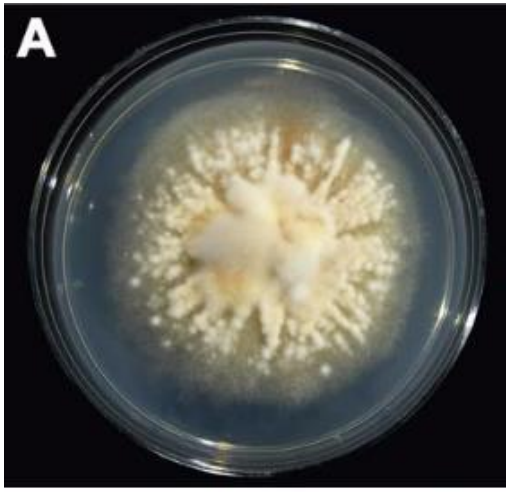
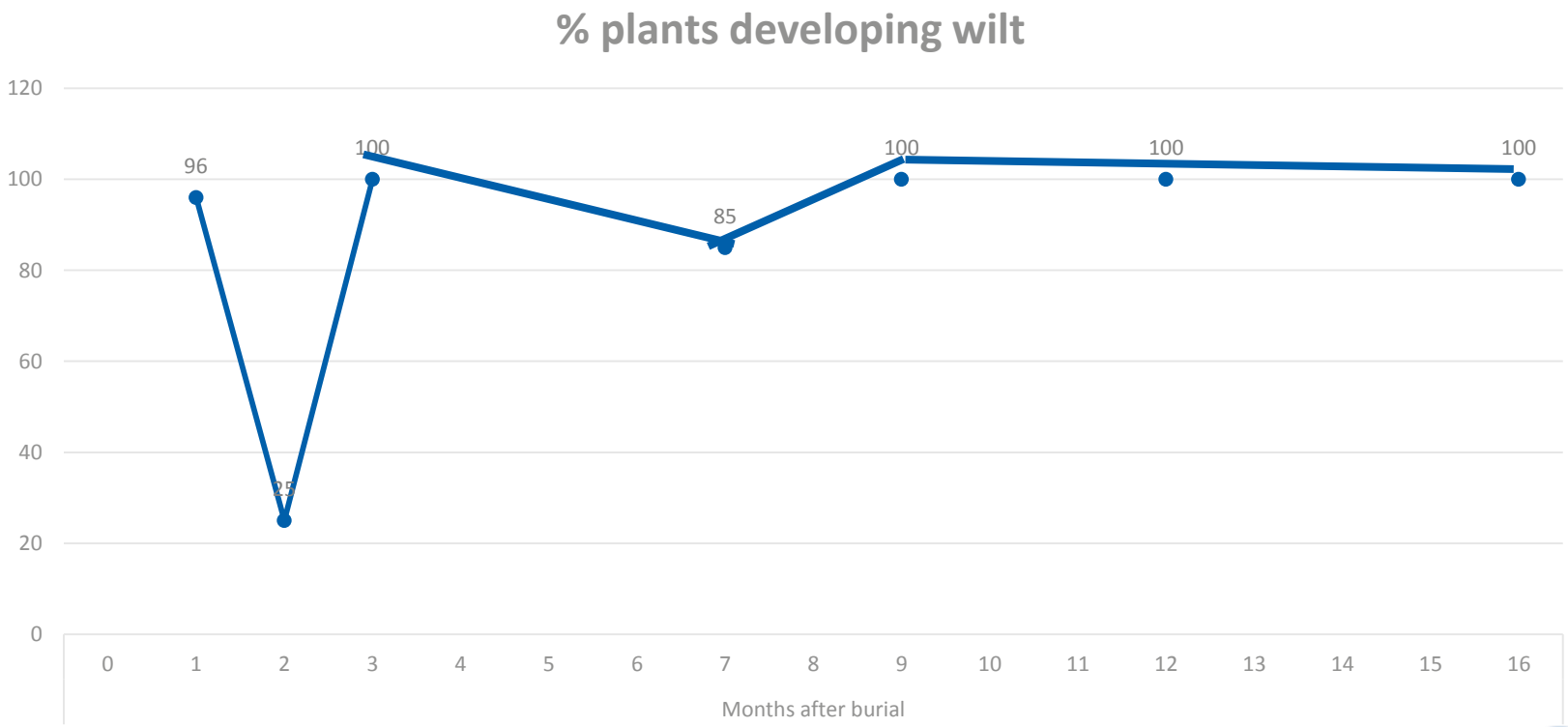
# Key features of lettuce fusarium wilt




Scott *et al*. 2010

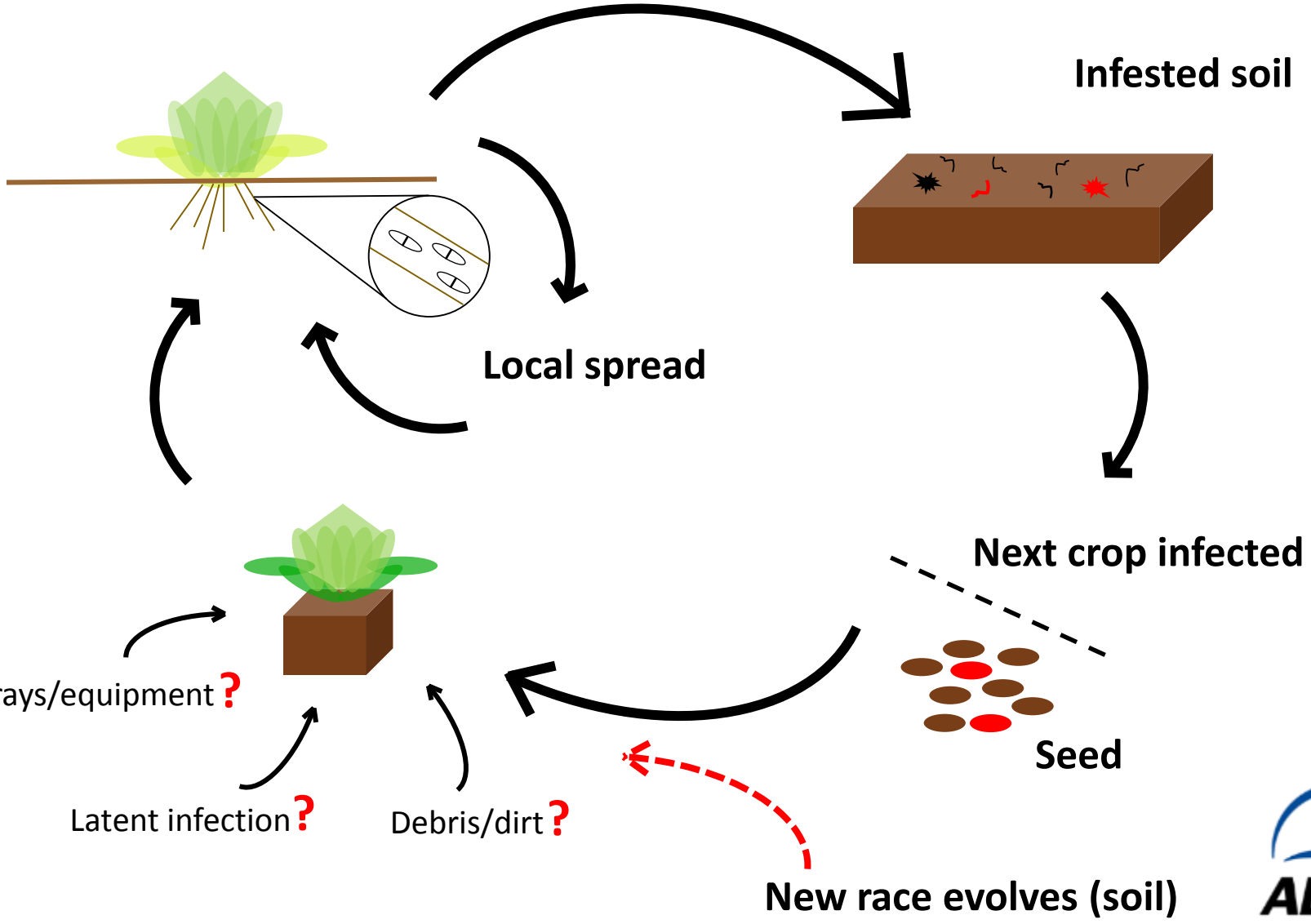
- Host-specific
- Vascular wilt disease
- 3 spores types
- Soil temperature greatly affects disease severity
- Long survival in soil (years)
- Saprophytic stage
- Seed-borne
- Major gene resistance
- 4 races identified on lettuce

# Survival of Fusarium (FOM) in crop debris in soil at levels sufficient to cause Fusarium wilt in stocks - 2007




Ref: PC 213a

# Proposed life-cycle



# 3. Identification and disease monitoring

Botrytis

Downy mildew

Bacterial leaf rot

Sclerotinia

Phoma
leaf spot

Phoma
basal rot

Pythium sp.

# Lettuce fusarium wilt

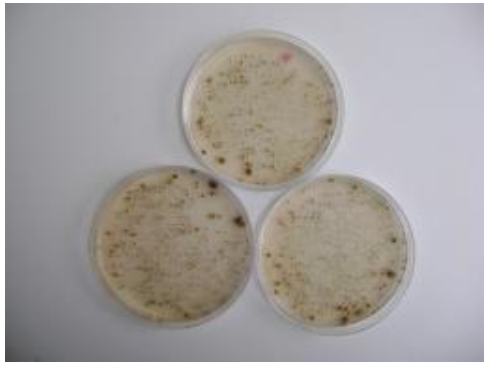





# Monitoring and testing

- 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

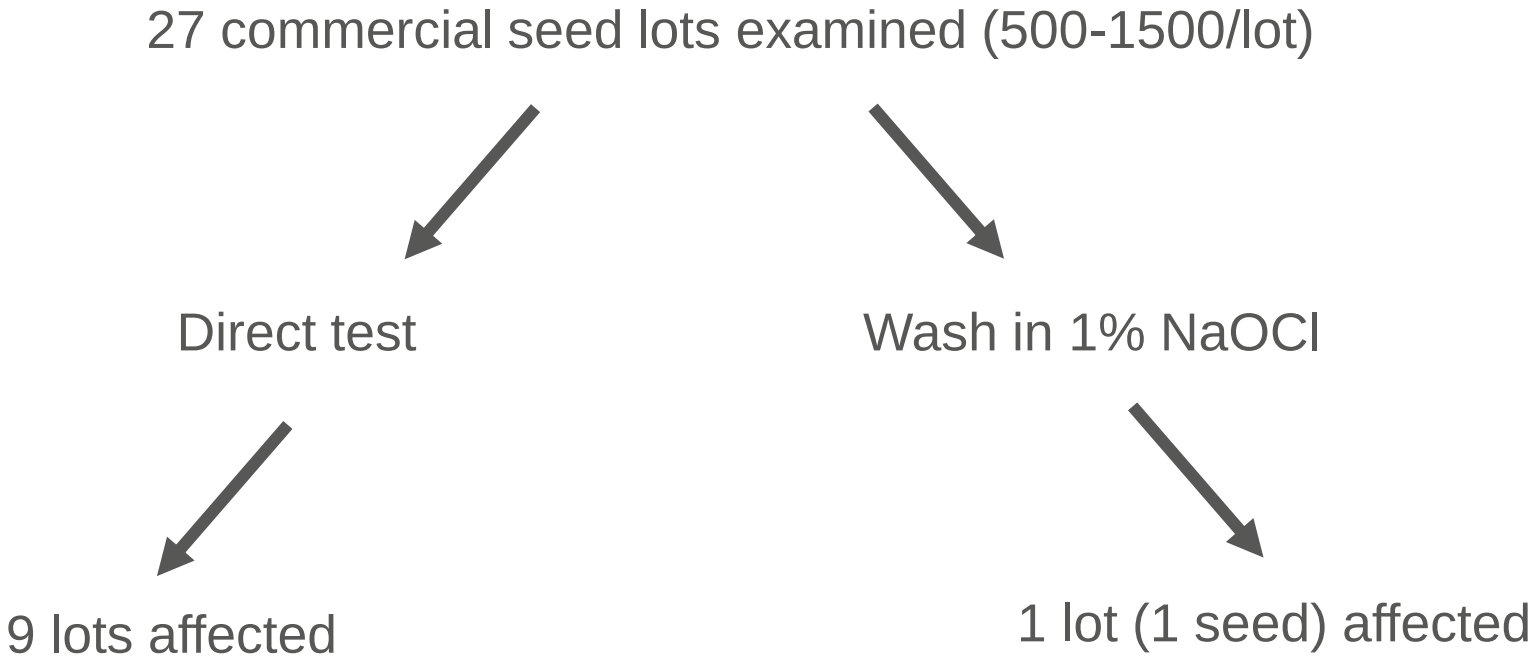
- Propagation & production

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




3/16 isolates caused Fusarium wilt following root dip inoculation ($1x10^6$ spores/ml); symptoms after 8d at 20-30$^{o}$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

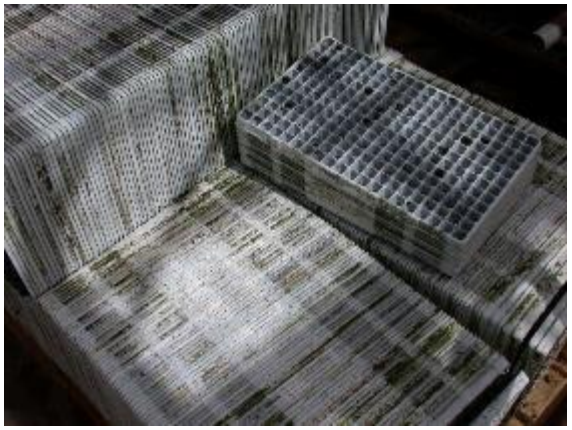
- ➢ Measures to avoid soil movement (wash + disinfect)
- ➢ Maintain procedures even when no crop/symptoms

# 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



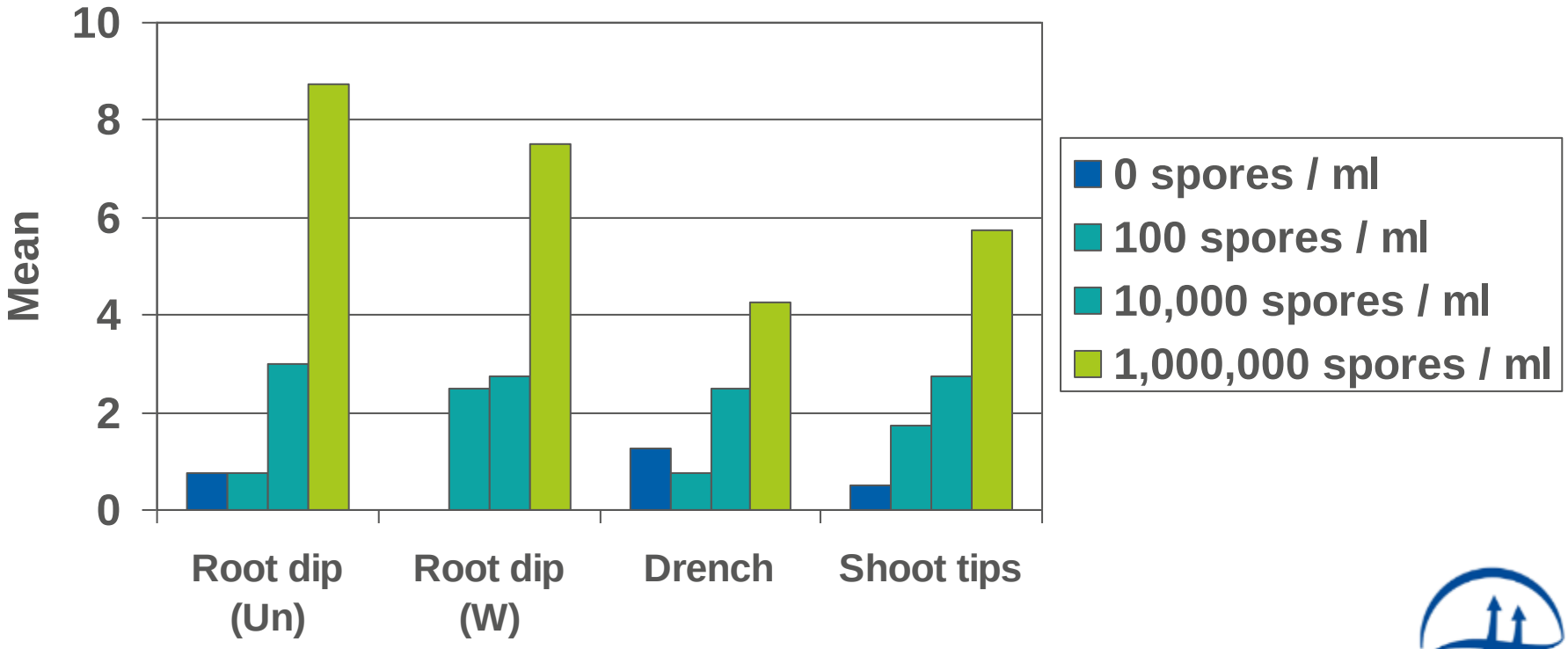
# 4c) How soil features affect risk of fusarium wilt

- 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)

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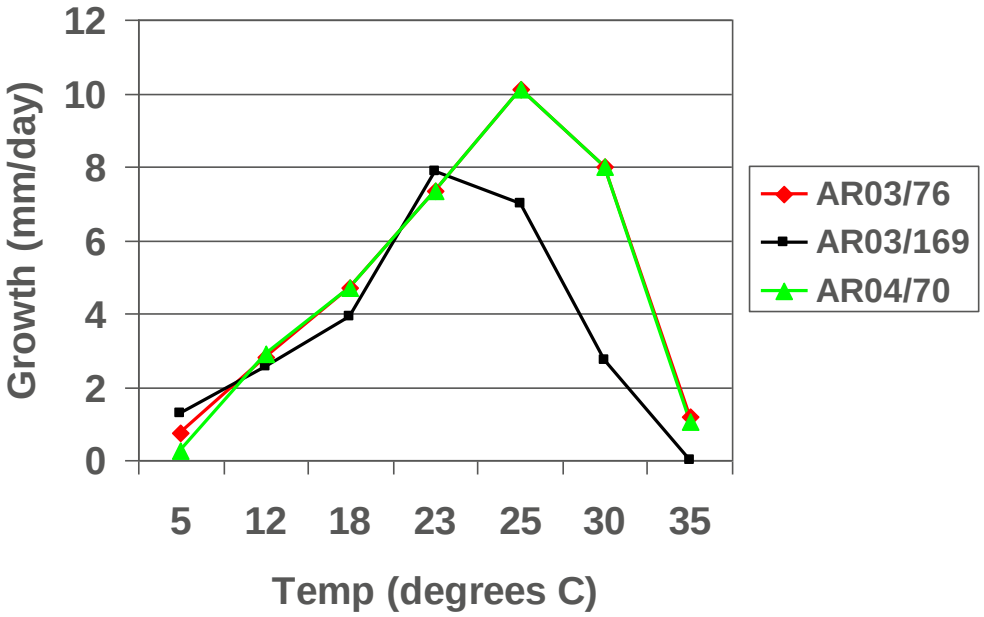
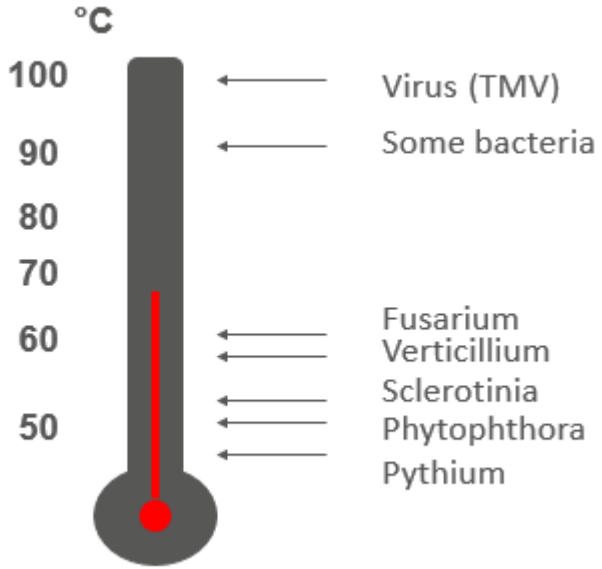
# Soil temperature

## Fusarium wilt of stocks




## Lethal temperatures

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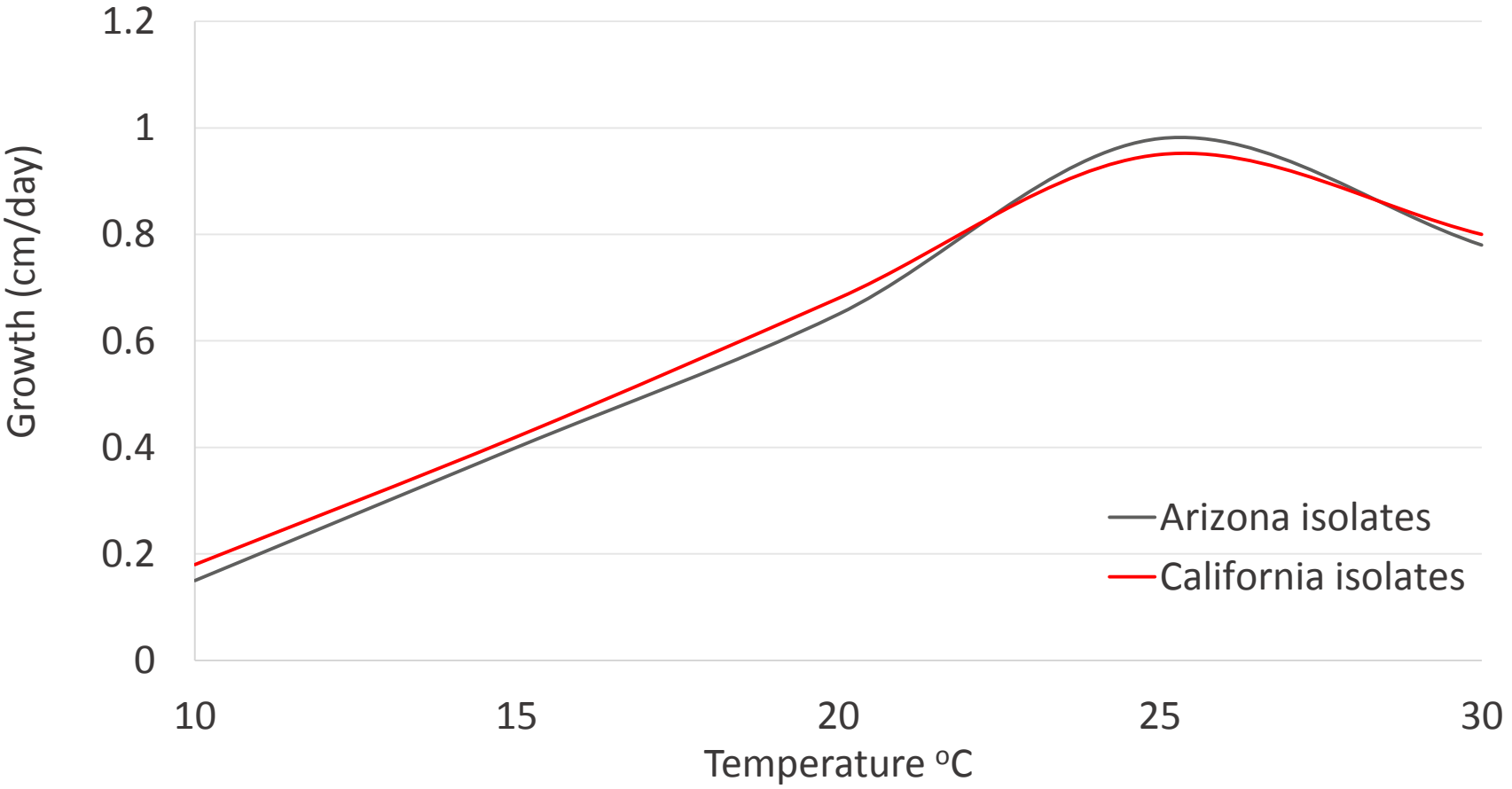
# Effect of temperature on growth of *F.oxysporum* f.sp. *lactucae* (race 1 isolate)




Ref: Scott et al., 2010

# Effect of soil temperature at planting on lettuce fusarium wilt - Arizona

| Temperature at 10cm depth (°c) | Plants wilted or dead (%) | |
|---|---|---|
| | **Crisphead** | **Romaine** |
| 13.9 | 1.3 | 0.2 |
| 15.0 | 23.0 | 0.7 |
| 25.6 | 94.0 | 34.0 |

- 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)

| Temp (°C) | Batavia de serra | Romana velvet | Batavia | Lollo Rosso |
|---|---|---|---|---|
| | **HS** | **S** | **PR** | **'R'** |
| 10 | >100 | >100 | >100 | >100 |
| 15 | >100 | >100 | >100 | >100 |
| 20 | 25 | >100 | >100 | >100 |
| 25 | 15-20 | 23-32 | >100 | >100 |
| 30 | 8-10 | 12-20 | 36-40 | >100 |

Soil infested at $1x10^6$ cfu/ml

Ref: Gullino et al., 2015

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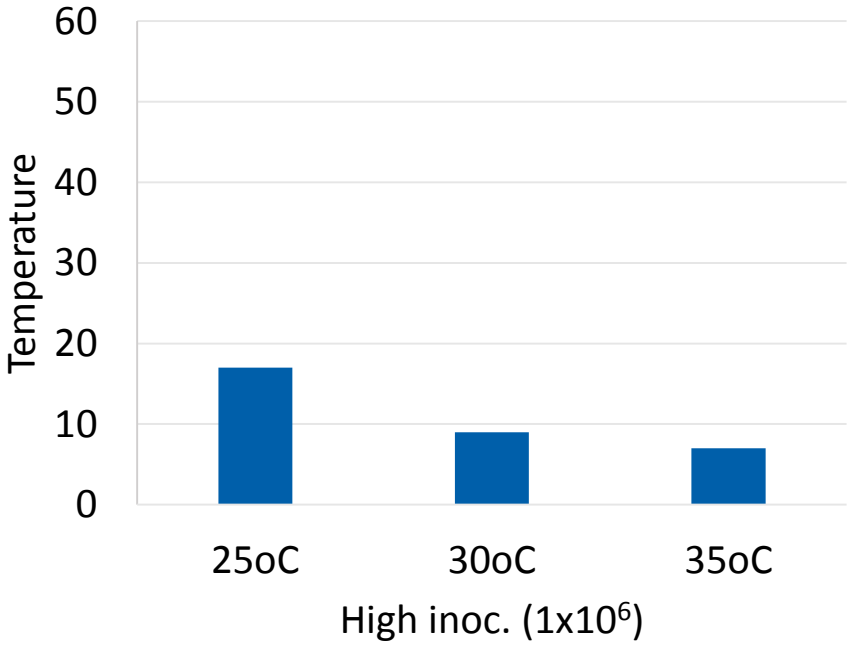
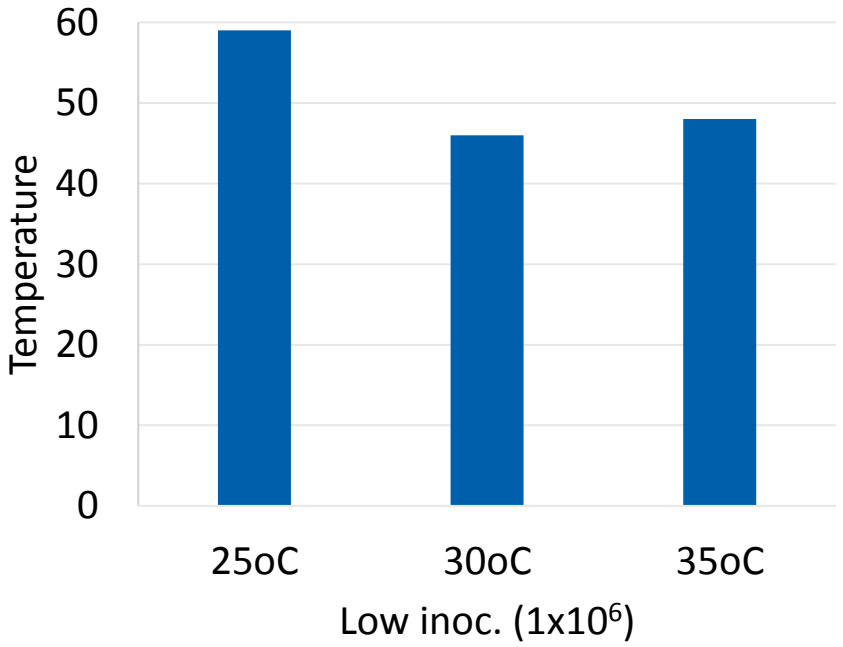
# Effect of temperature and inoculum level – lettuce fusarium wilt - Italy

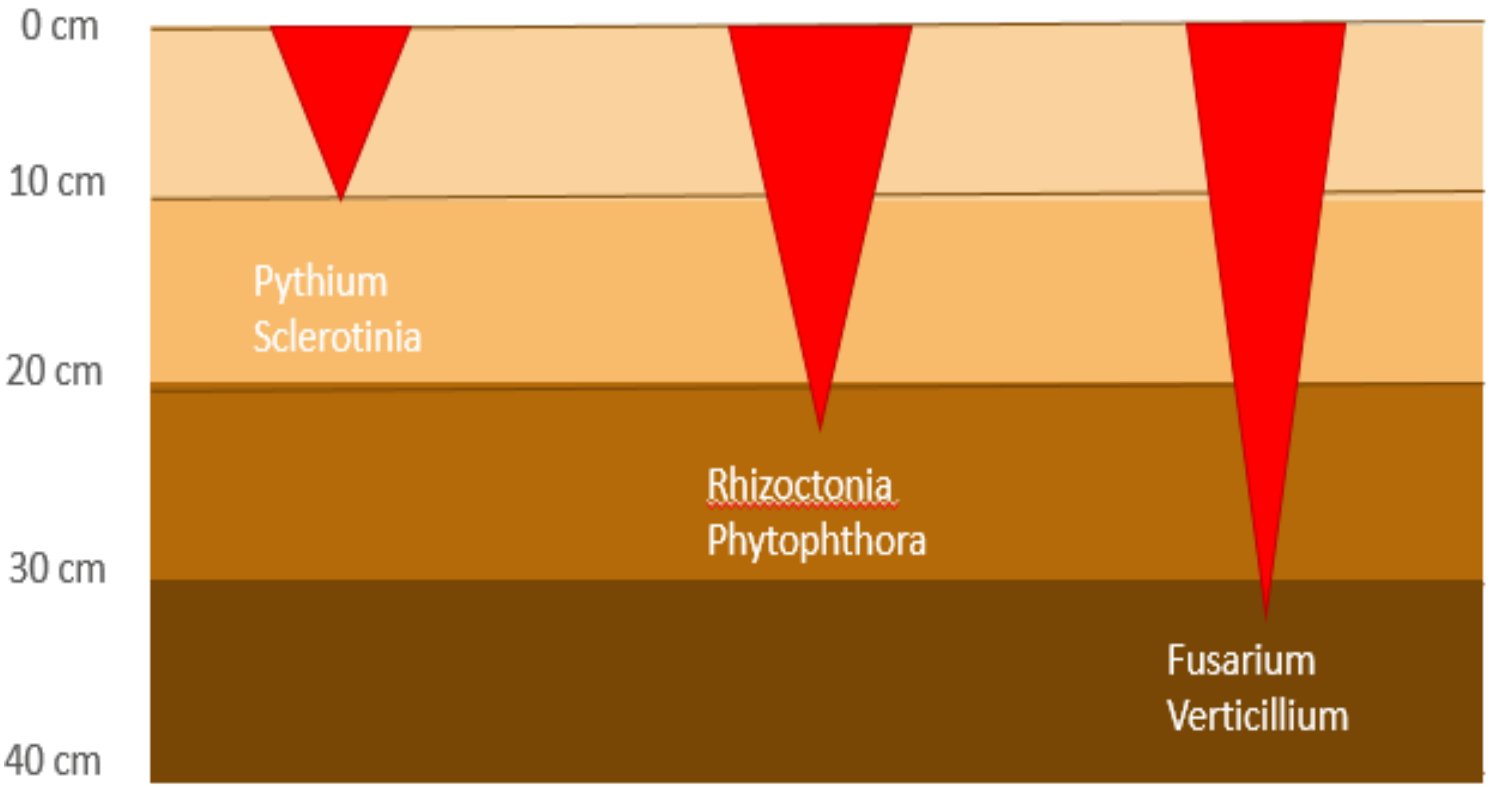
Number of days to reach severe wilt (disease susceptible variety)




Ref: Gullino et al., 2015

# Soil depth and disease



# 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

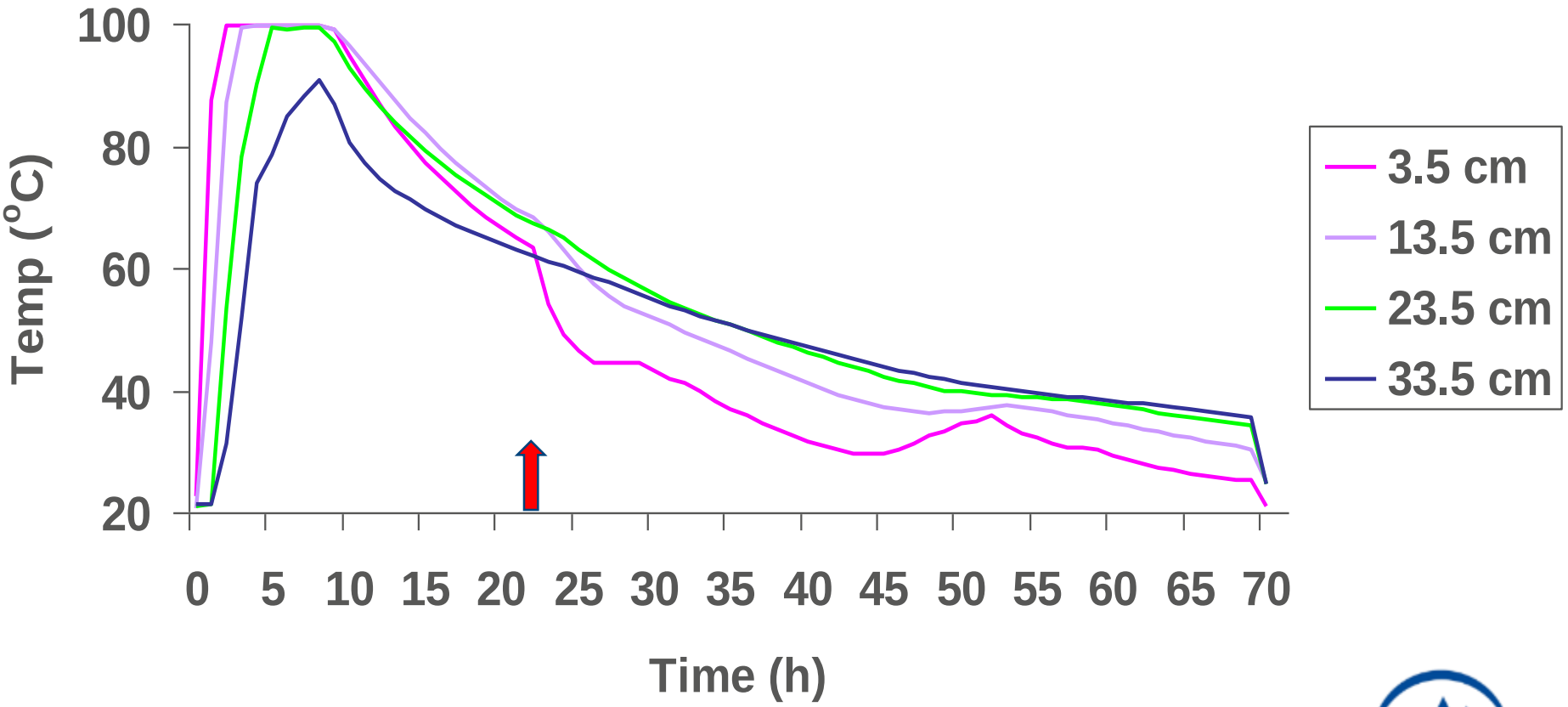
Dazomet

# 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)

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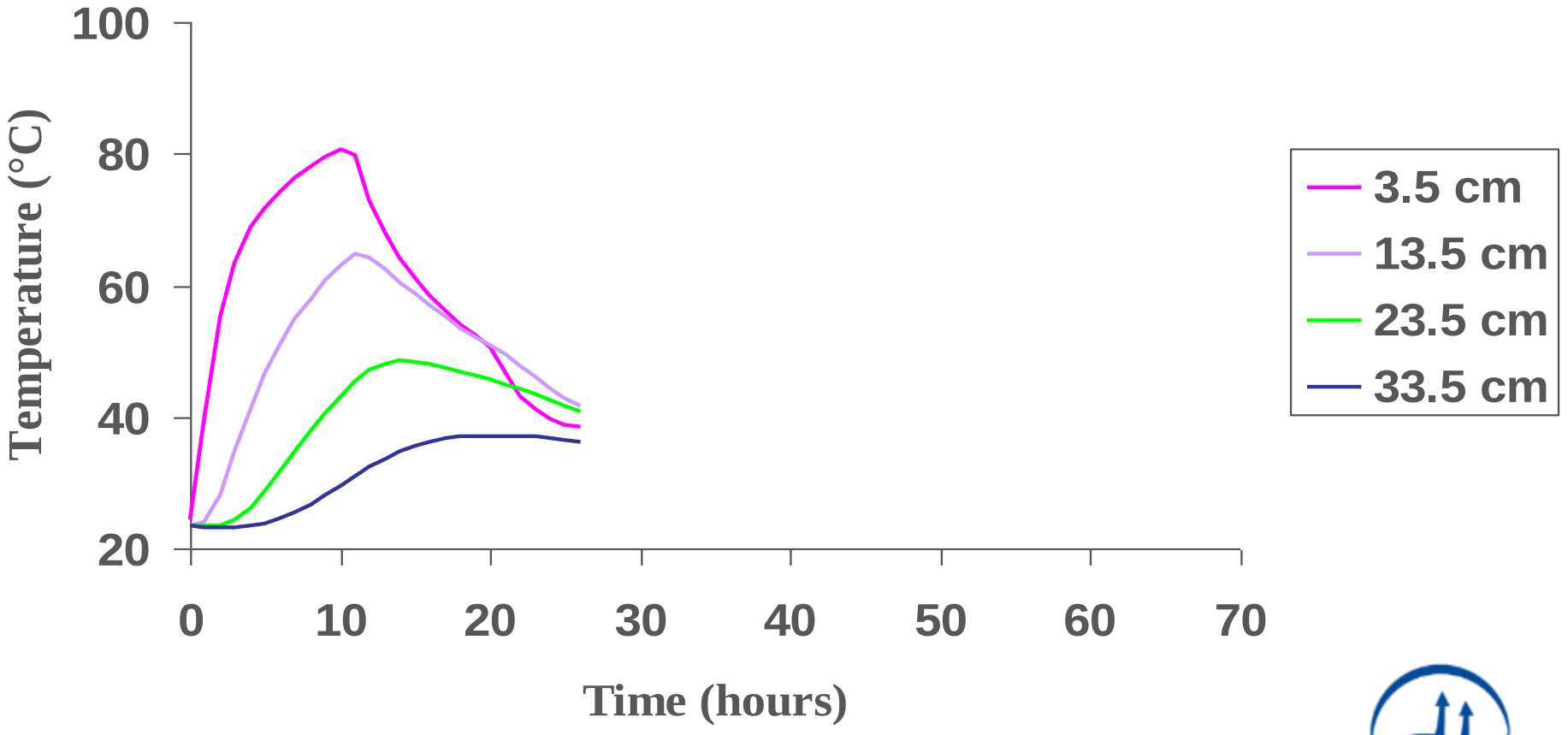
# Sheet steaming and depth - % kill

| Depth (cm) | Fus in stem | Fus in root | Sclerotinia |
|---|---|---|---|
| 0-5 | 94 | 94 | 100 |
| 10 – 15 | 92 | 98 | 100 |
| 20 - 25 | 94 | 100 | 100 |
| 30 - 35 | 92 | 88 | 99 |

# 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

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# Sheet steaming and depth - % kill

| Depth (cm) | Fus in stem | Fus in roots |
|---|---|---|
| 0 – 5 | 30 | 81 |
| 10 – 15 | 67 | 96 |
| 20 – 25 | 23 | 59 |
| 30 – 35 | 2 | 8 |

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

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# Vacuum steaming

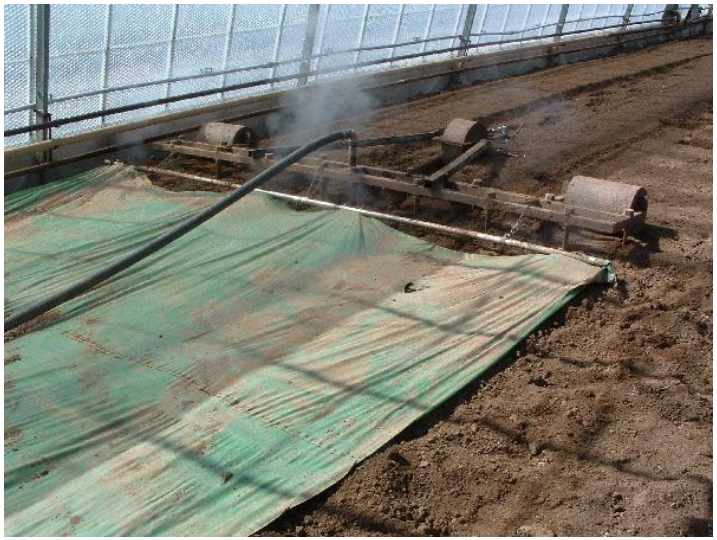
## Temperatures achieved with vacuum steaming

1. 5h steam. 120 $m^2$ 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.
6. 6 ¼ h steam. Probes 30 cm from tube. Double suction. Boiler problem – low pressure.
7. 3 ¼ h steam. Probes 30 cm from tube. Warm soil either side from previous steams.

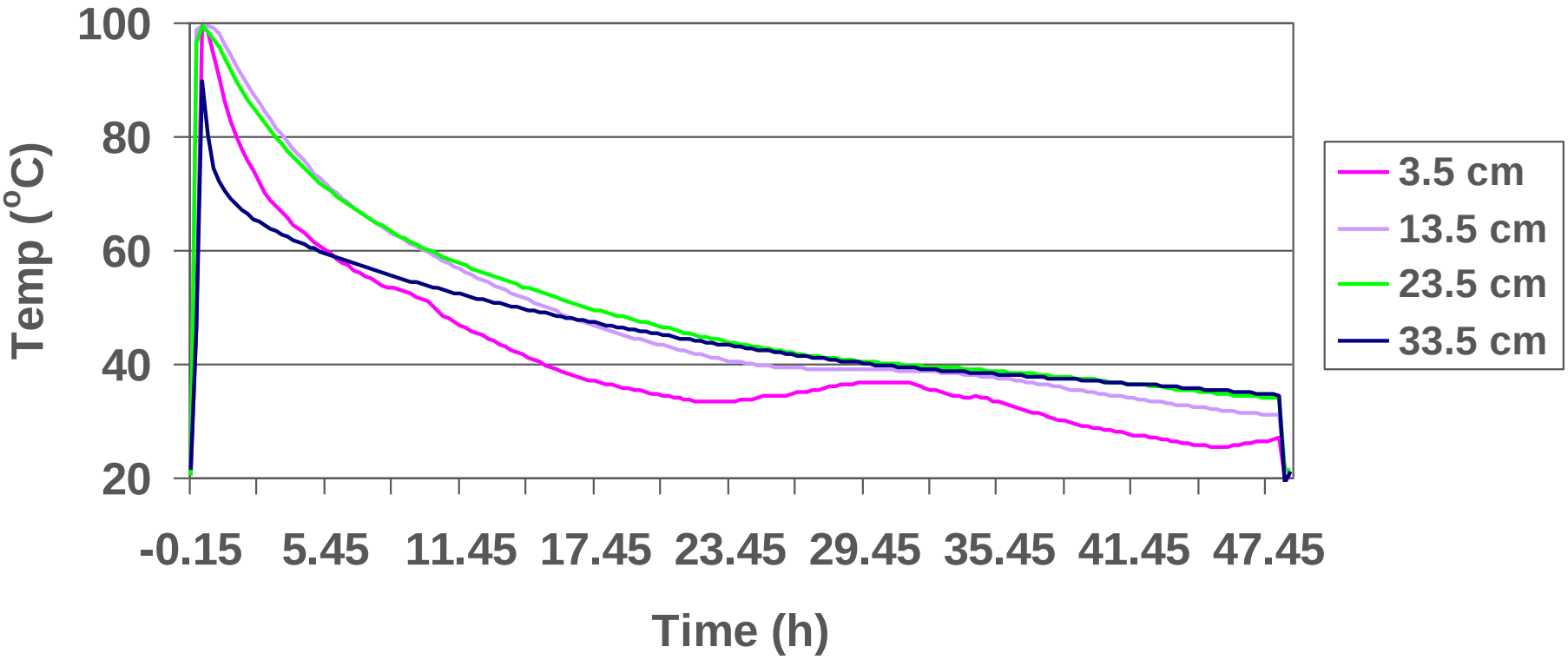
| Run | Approx. max. temperature (inlet end) at each depth (cm) | | | | Best location | | |
|---|---|---|---|---|---|---|---|
| | 3.5 | 13.5 | 23.5 | 33.5 | Inlet | Mid | Far-end |
| 1. | 98 | 98 | 70 | 50 | √ | | |
| 2. | 98 | 88 | 52 | 40 | | √ | |
| 3. | 98 | 90 | 52 | 42 | | | √ |
| 4. | **98** | **98** | **98** | **80** | | √ | |
| 5. | 98 | 98 | 90 | 55 | | √ | |
| 6. | **98** | **98** | **98** | **95** | √ | | |
| 7. | **98** | **98** | **96** | **94** | | | √ |

# 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)



# Steam plough




Max temp at each depth very similar to sheet steam

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# Steam plough and depth: % kill

| Depth (cm) | Fus in stem | Fus in roots | Sclerotinia |
|---|---|---|---|
| 0 – 5 | 94 | 94 | 97 |
| 10 – 15 | 90 | 92 | 100 |
| 20 – 25 | 98 | 98 | 100 |
| 30 – 35 | 98 | 100 | 100 |

# **The Company:** Möschle-Seifert-Dämpftechnik

Specialist for steaming technology and systems


| | |
|---|---|
| **Products:** | Steaming Technology and Systems<br>For use in : - Horticulture<br>- Agriculture<br>- Viniculture, Industry, etc. |
| **Experience:** | More than 60 years in the market<br>One of the world's leading suppliers |
| **Customers:** | More than 3.000 customers wordwide |
| **Partners:** | Barel BV, Niederlande<br>IMANTS BV, Niederlande<br>Josef Zeyer GmbH, Deutschland<br>Clemens GmbH Co.KG, Deutschland |

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# Sandwich Steaming

Fully automated systems

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


ADAS

# Control of Fusarium in stem pieces (firm vs soft) with Basamid*

| Depth in soil (cm) | Site 1 | | Site 2 |
|---|---|---|---|
| | Firm | Soft | |
| 0 | 78 | 82 | 100 |
| 5 | - | - | 90 |
| 15 | 12 | 54 | 86 |
| 30 | 5 | - | 80 |

*76g/m2; LDPE cover

Ref: PC 249

ADAS

# 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

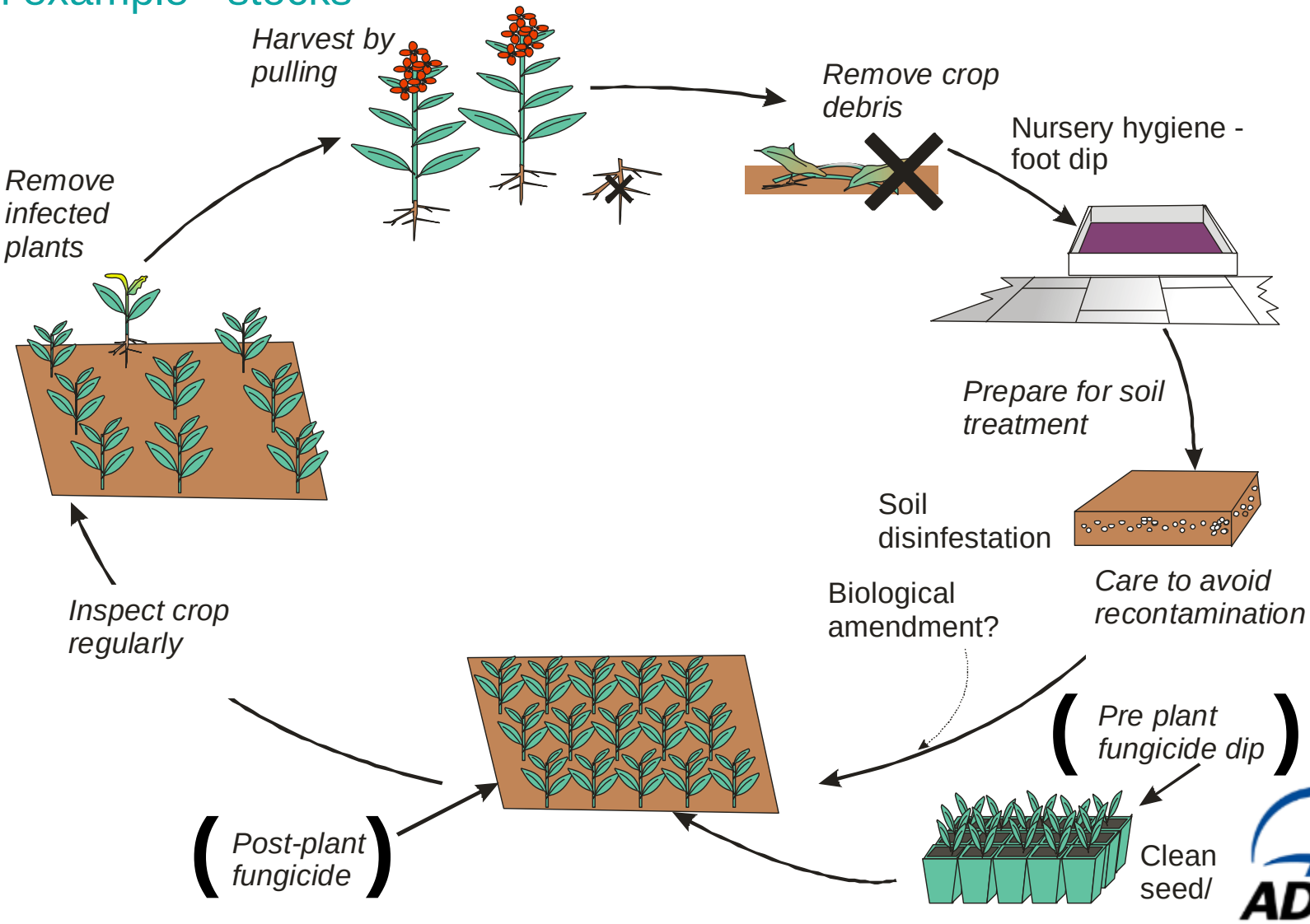
Ref: Matheron, 2015

# 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



# Integrated management of lettuce fusarium wilt - likely components and their importance

| Component | Now | Medium term | Long term |
|---|---|---|---|
| Seed health | √ | √ | √ |
| Tolerant/resistant varieties | √ | √ | √ |
| Fungicides | In prop? | X | X |
| Biofungicides | In prop? | (√) | (√) |
| Sanitation (crop debris) | √ | √ | √ |
| Disinfection/burner | √ | √ | √ |
| Soil amendments | X | (√) | (√) |
| Soil disinfestation | √ | √ | X |
| Cultural control | √ | √ | √ |

- 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 disinfestation
- 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

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