Hochschule Geisenheim University

Management of plant health in hydroponic systems

Summer School

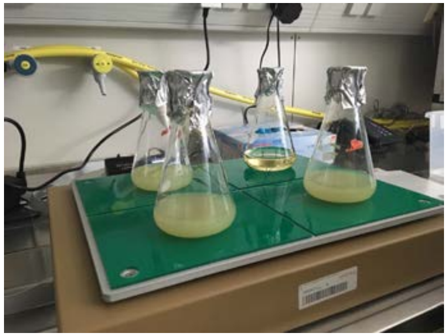
Greenhouse Hydroponics

Ada Linkies, Phd Biology

27 September 2019

Who is talking?

- Dipl.- Ing. horticulture (Geisenheim)
- PhD in molecular biology, plant physiology at Freiburg University
- since 2013: department of Crop Protection Hochschule Geisenheim (head Prof. Annette Reineke)
- since April 2019: *mikroPraep*- fungicidal activity of *Lysobacter enzymogenes* against plant pathogens on diverse crops



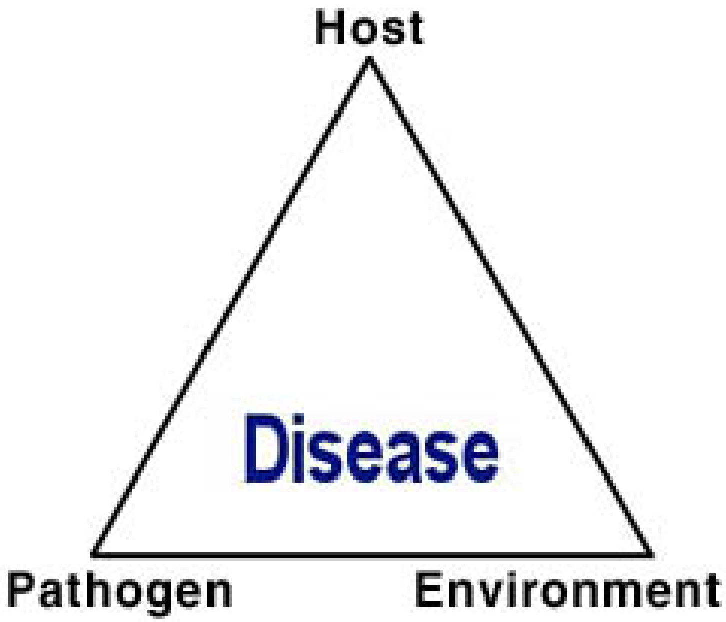
What is the lecture about?

Management of plant health in hydroponic systems

focus on pathogens (virus, fungi, bacteria)

- Which pathogens are mainly present in hydroponic systems?
- What are the origins of plant diseases in hydroponic systems?
- What influences pathogen infection, survival & distribution in hydroponic systems?
- Which methods can be applied to reduce pathogen occurence in hydroponic systems?

Several pests and pathogens are present in greenhouse production



Disease outbreak depends on pathogen presence, susceptible host plant and favorable environmental conditions.

www.apsnet.org

Which diseases are relevant in hydroponic systems?

All diseases that are relevant in greenhouse production

(depending on crop species and environmental conditions)!

Which diseases play a **particular role in hydroponic systems**?

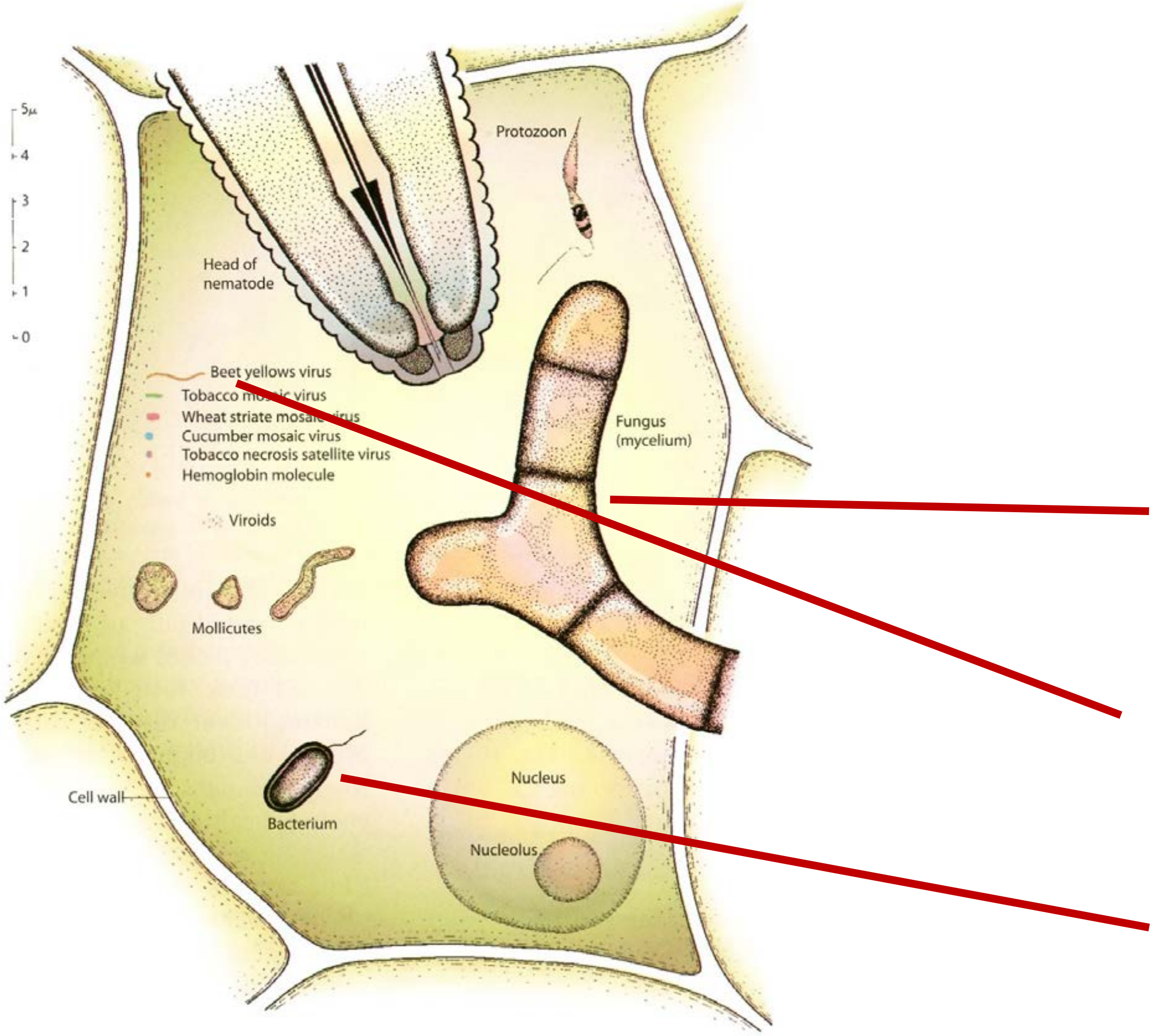
Diseases related to root- diseases and humid environment!

Occurence of pests and pathogens in greenhouse production

Some pests are vectors for viral diseases!

www.umweltbundesamt.de; www.apsnet.org; https://pnwhandbooks.org

Occurence of pathogens in greenhouse production and hydroponic systems



fungus

virus

bacterium

Pathogens with a special relevance in hydroponic systems

Viruses

- cucumber green mottle mosaic virus, tomato mosaic virus, tabac mosaic virus, cucumber mosaic virus, melon necrotic spot virus, lettuce infectious virus

Bacteria (occasionally)

- in tomatoes *Clavibacter michiganensis* spp. *michiganensis, Pseudomonas corrugata* and *Ralstonia solanacearum*

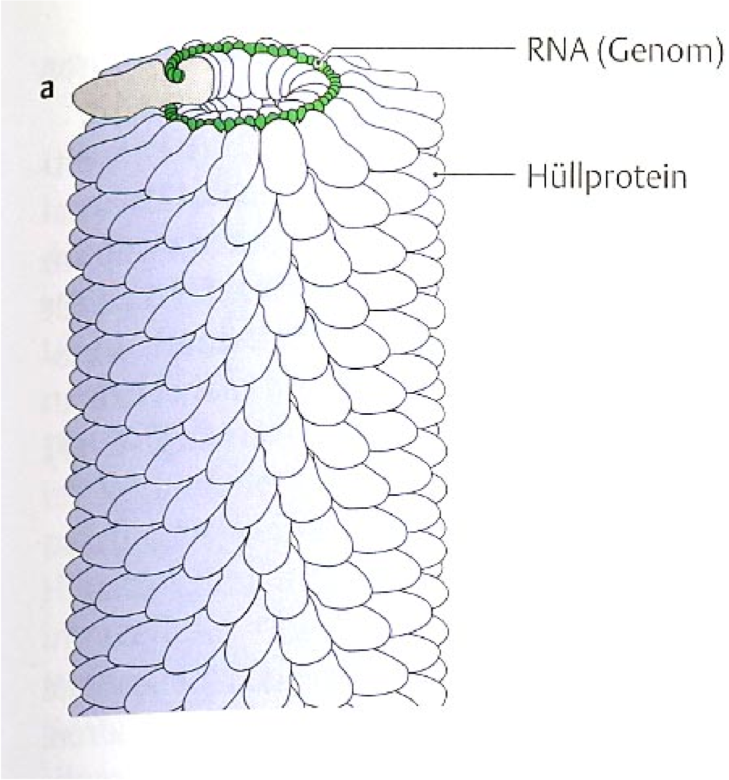
Fungi/Oomycetes (`water moulds´)

- *Phytophthora spp.*
- *Pythium* spp.
- *Fusarium* spp.
- *Olpidium brassicae* (vectors tobacco necrosis virus and lettuce big vein),

  O. radicale (vectors melon necrotic spot virus)
- *Verticillium* spp., *Thielaviopsis* sp., *Rhizoctonia* sp.

Characteristics of viral pathogens

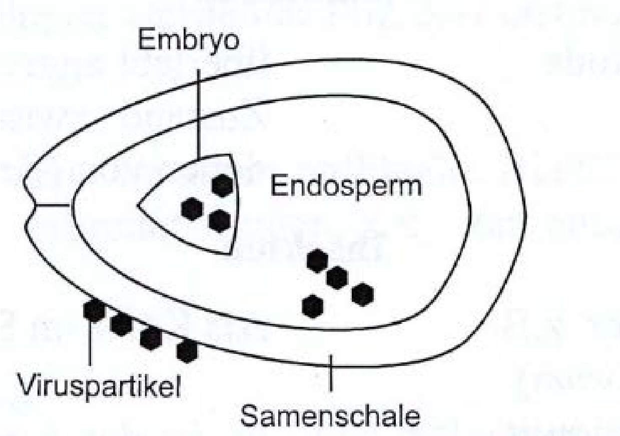
- smallest pathogens, 20-2000 nm
- simple structure: DNA/RNA- genome and protein coat (and lipids)
- no own metabolism
- no living organisms
- need host/vector for reproduction and long-term survival

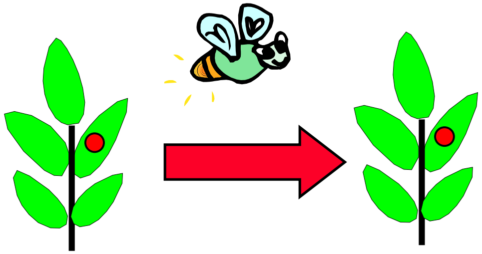


Tomato Mosaic Virus; www.apsnet.org

Transmission/distribution/survival of viral pathogens

- vectors: mainly insects (i.e. aphids, thrips etc.), plants, fungi (e.g. *Olpidium* sp.)
- distribution also through pollen and seeds (15% of all viruses)
- soil, water, plant debris: at least short term survival

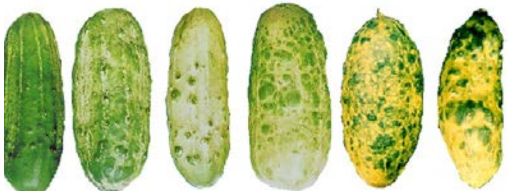




Poehling, 4th edition

Occurence and symptoms of viral diseases in the greenhouse

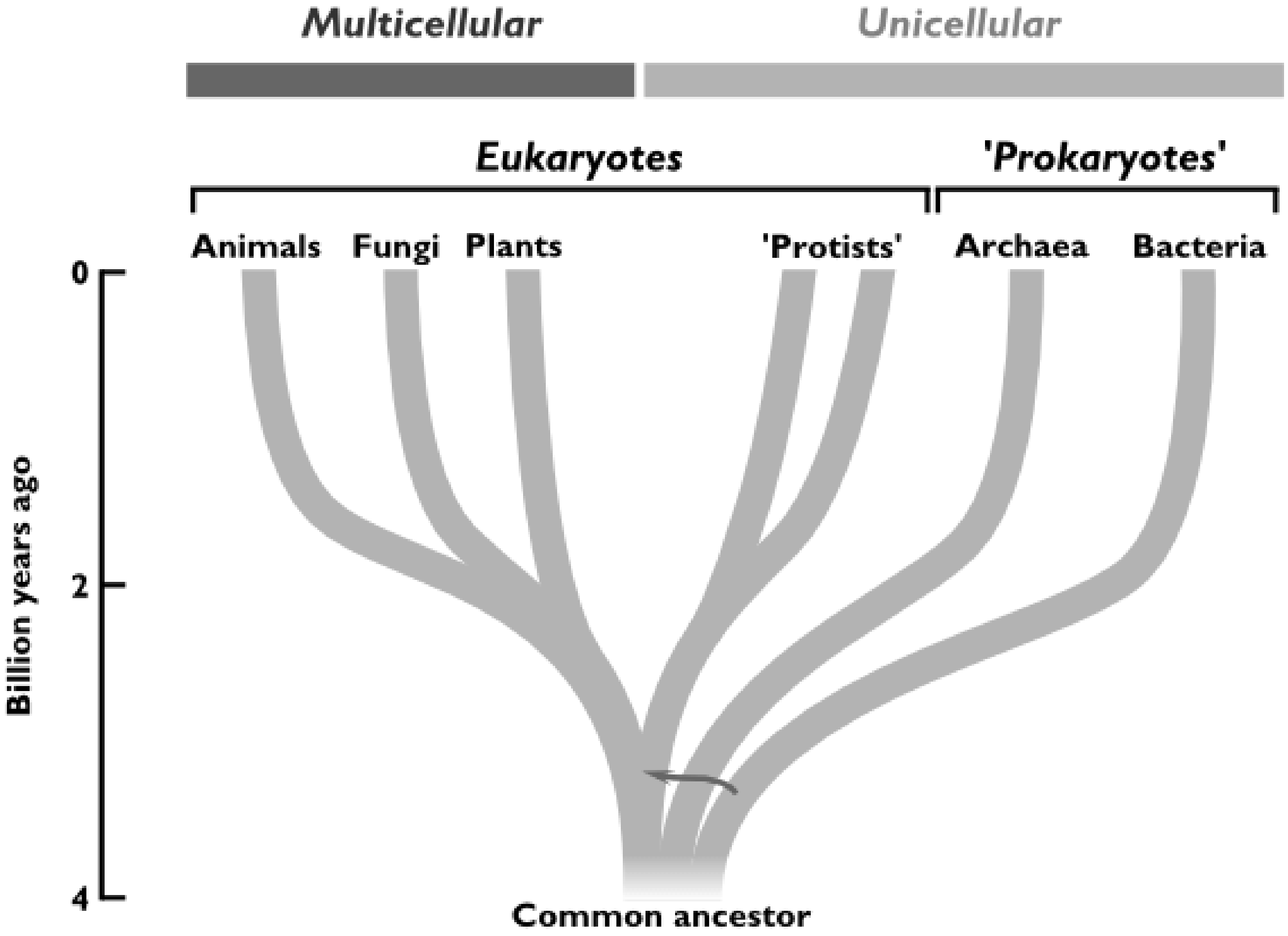
- broad range of viral diseases and symptoms
- problem: latency without symptoms!



Cucumber Mosaic Virus (CMV); broad host range; transmitted by aphids and seeds; apsnet.org

Tobacco Necrosis Virus (TNV); broad host range; transmitted by *Olpidium brassiceae*; apsnet.org

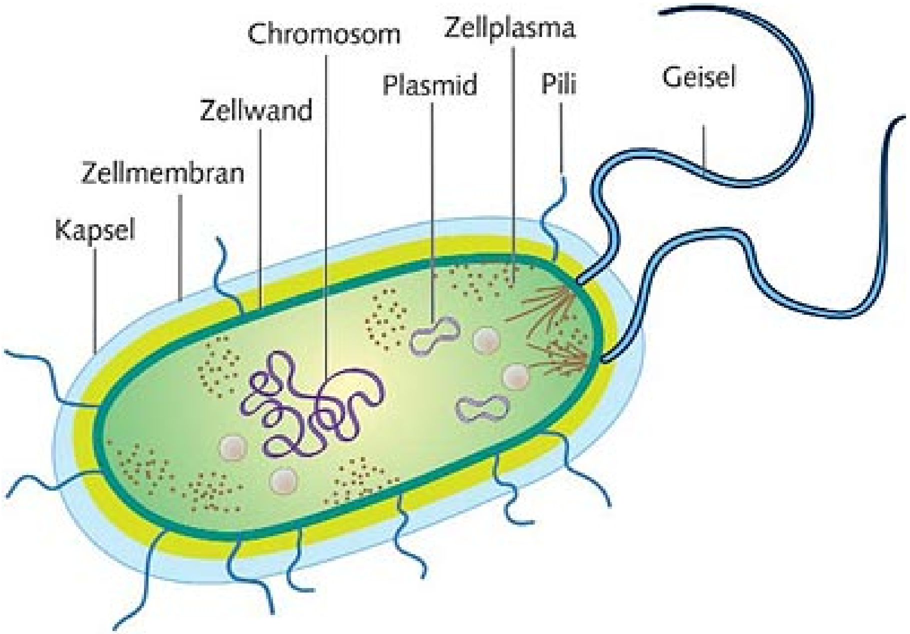
Characteristics of bacterial plant pathogens



www.researchgate.net

Characterisitics of bacterial plant pathogens

- simple cell structure
- cell- wall (gram- positive and gram- negative)
- some species: flagella for active distribution in humid environment
- motion towards attractant (root)

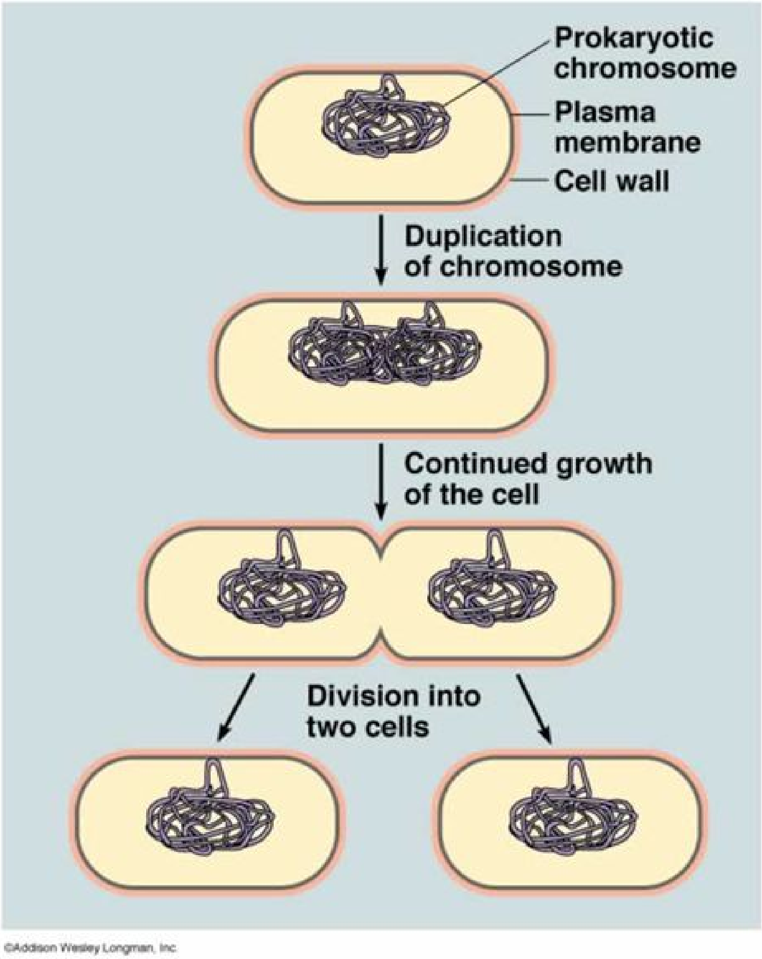


Schema Bakterium

www.bode-science-center.de

Transmission, distribution and survival of plant pathogenic bacteria

- bacterial division
- exponential growth (epidemics!)
- survival as single cells: soil, plant parts, seeds, water
- some species: endospores (long- term survival)



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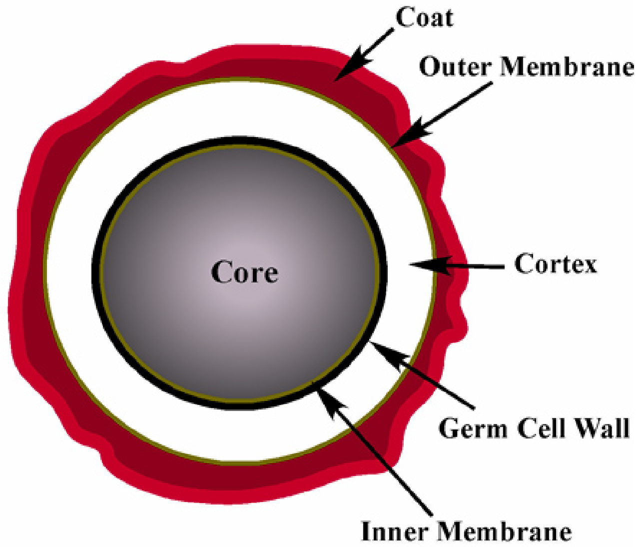


www.micro.cornell.edu

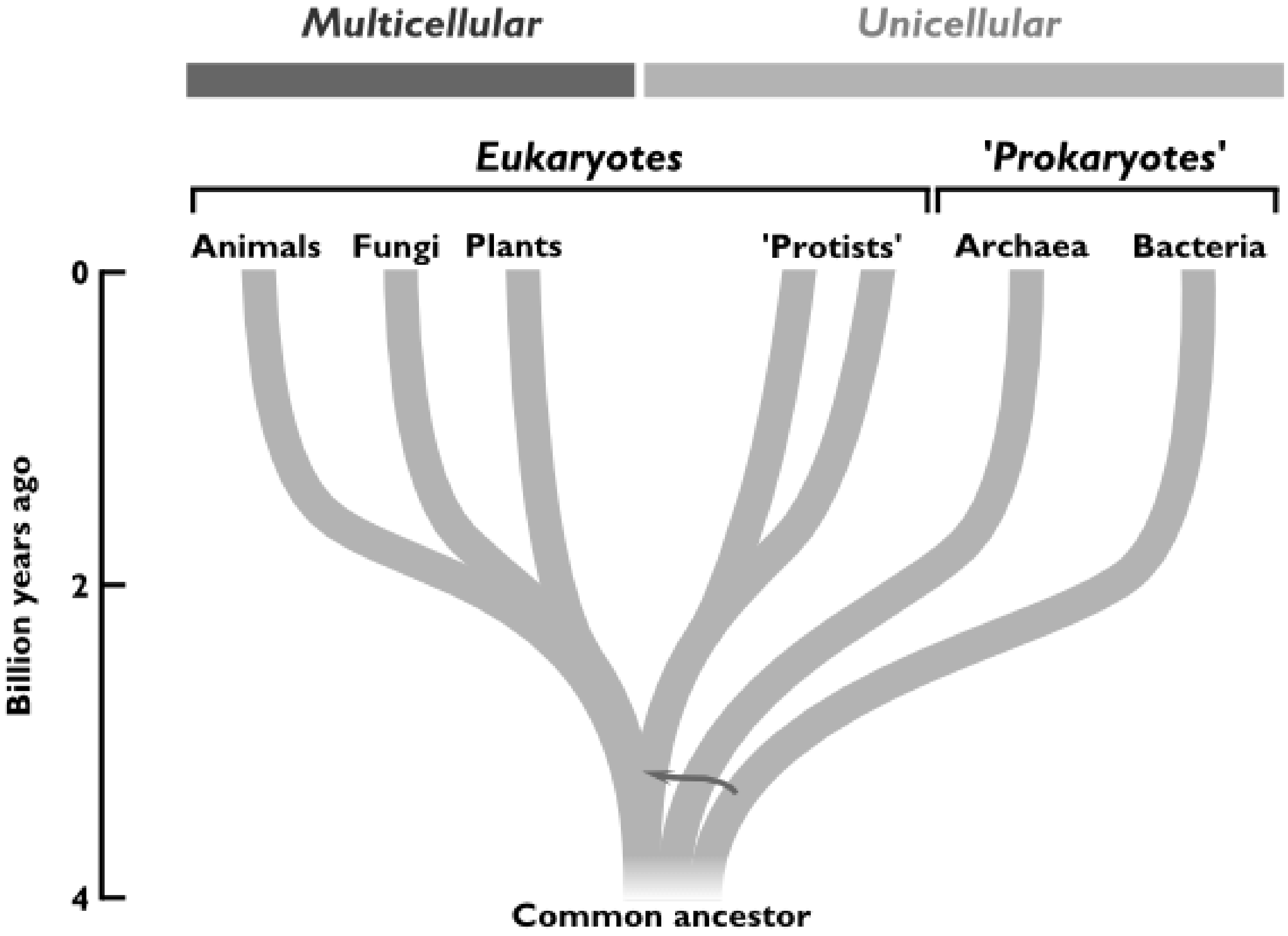
Occurence and symptoms of bacterial plant diseases in the greenhouse

- spots, wilting, soft rot, plant death
- partly seed transmittable
- only preventive control possible

Clavibacter michiganensis ssp. *michiganensis*; quarantaine organism; koppertbio.de

Xanthomonas hortorum pv. *pelargonii*; host specific;

Characteristics of fungal plant pathogens



www.researchgate.net

Fungi: most relevant group (highest damage) of plant pathogens

- many species (1.5 – 4 million)

- high epidemic potential
  - high reproduction rate
  - efficient distribution by spores
  - strong persistance and high survival rate (plant debris, seed, soil, water)

- environmental conditions can influence disease outbreak (leaf wetness, temperature etc.)

Botrytis (very broad host range)

Pathogens with a special relevance in hydroponic systems

Fungi/Oomycetes (`water moulds´)

- *Phytophthora spp.*
- *Pythium* spp.
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Bacteria (occasionally)

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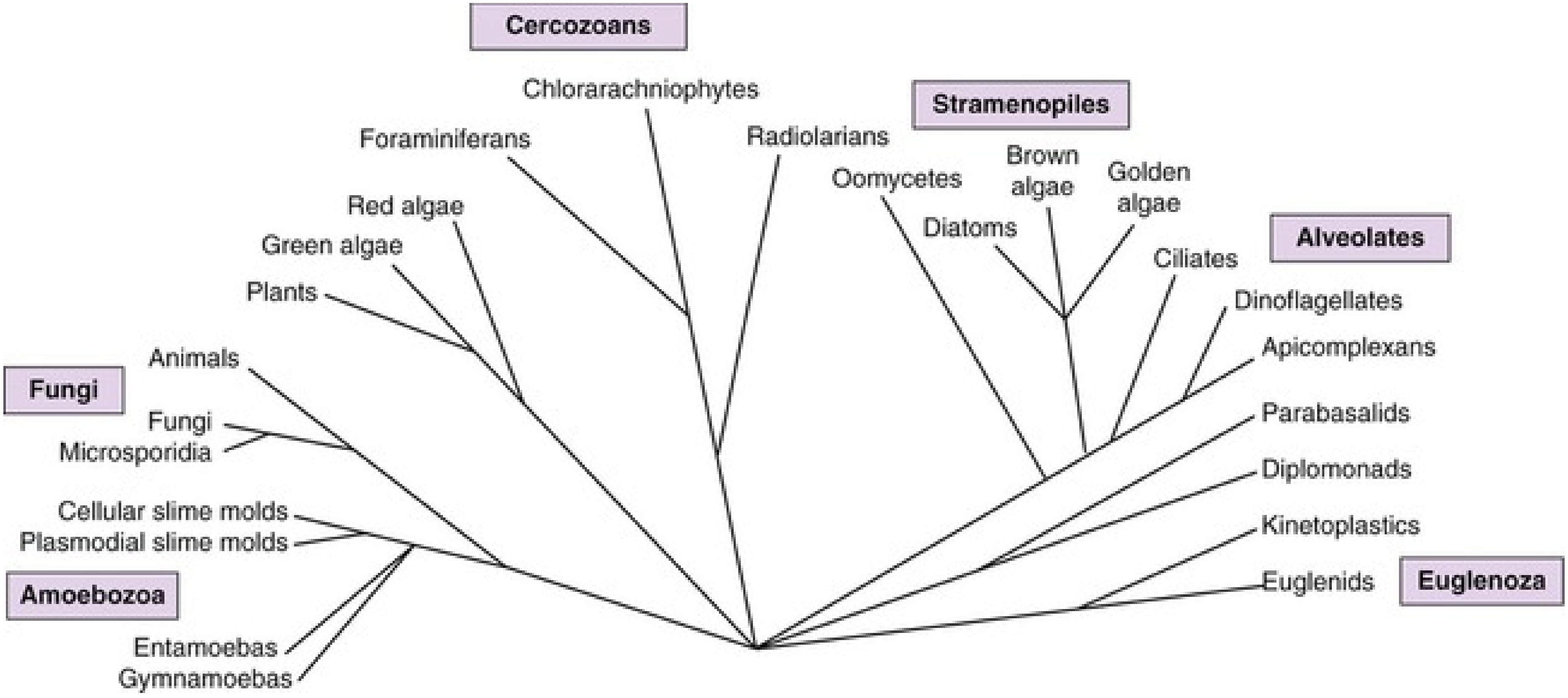
Oomycetes (water moulds) are no fungi.

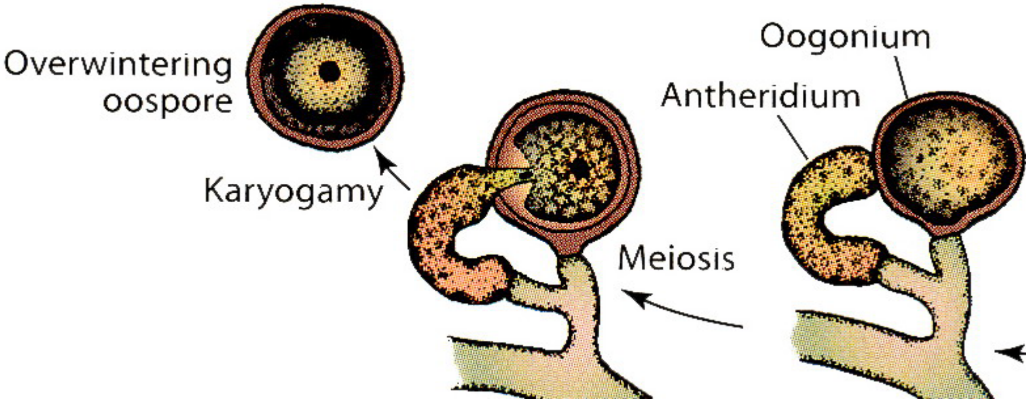


www.researchgate.com

Oomycetes in hydroponic systems

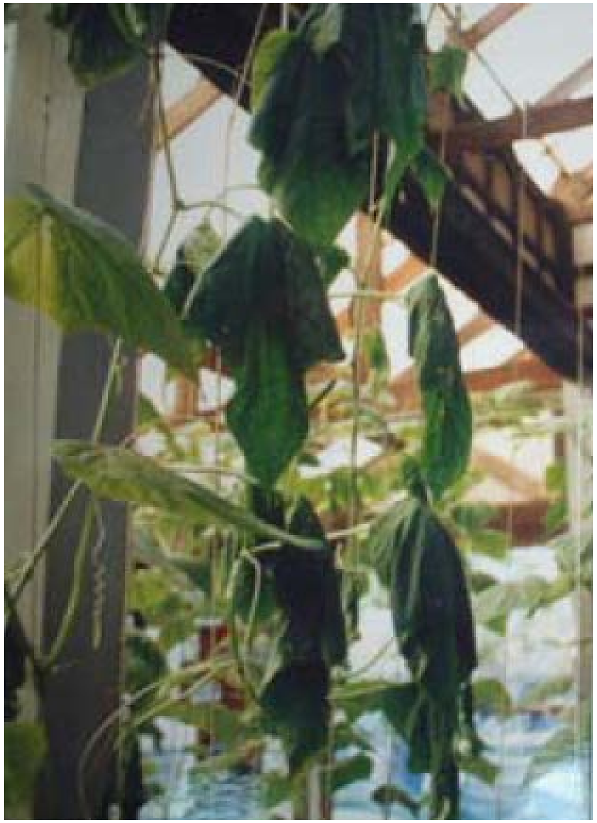
- ***Pythium* spp.**
- ***Phytophthora* spp.**

- closely related to algae
- cell wall made of cellulose
- well adapted to humid/aquatic environment
- easily spread due to mobile spores (zoospores in sporangia)

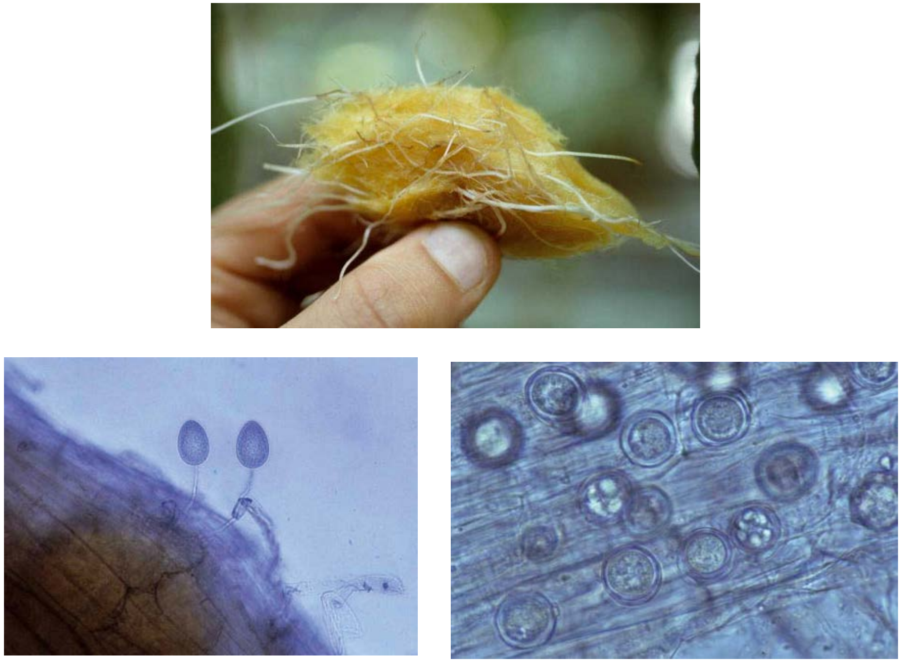


apsnet.org

Oomycetes in hydroponic systems



Pythium aphanidermatum on cucumber in NFT; Koohakan et al. (2008)



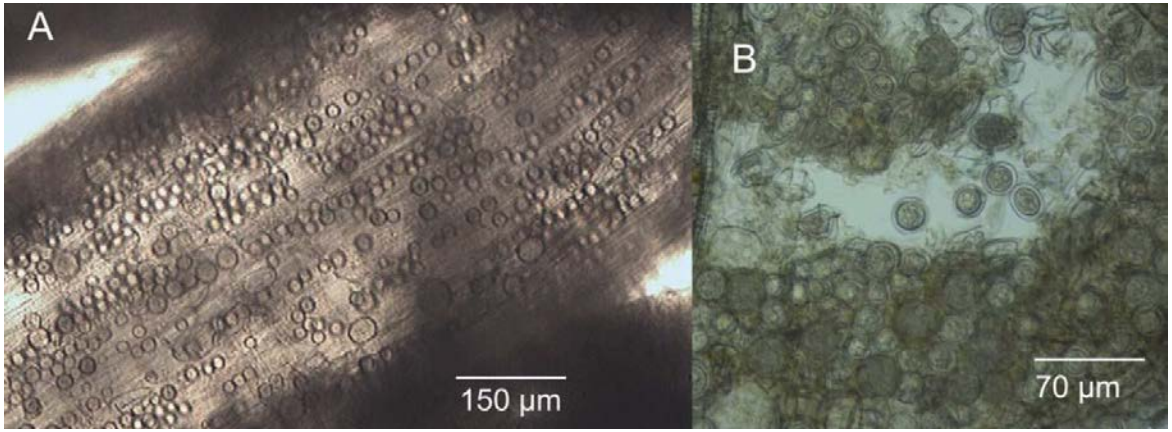
First symptoms necrotic roots;
Phytophthora cryptogea zoosporangia;
Pythium aphanidermatum oospores in roots
(Vallance et al., 2011)

Oomycetes in hydroponic systems

Pythium root rot on basil plants;
David de Villiers, Cornell University

Olpidium spp. in hydroponic systems

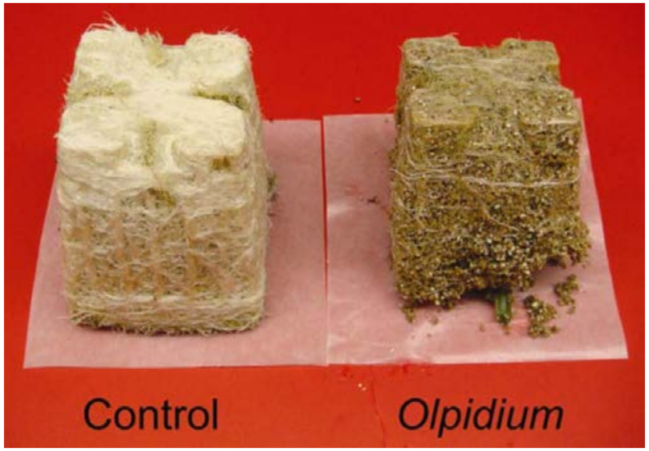
- true fungi
- prefer aquatic environment: sporangia with flagelled zoospores
- resting spores survive > 20 years



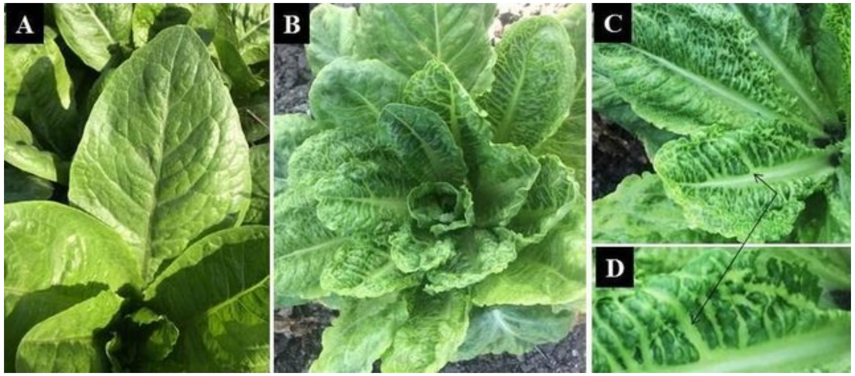
Sporangia (A) and resting spores (B) in cantaloupe (Stanghellini et al., 2010)

Olpidium spp. in hydroponic systems

- root decay by fungal pathogen
- main damage as vectors for plant viruses
- lettuce big vain virus (LBVV), TNV on pepper, cucumber and tomato



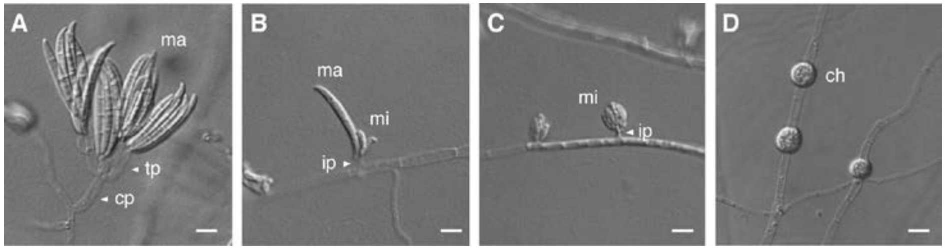
Healthy and diseased roots of cantaloupe (Stanghellini et al., 2010)



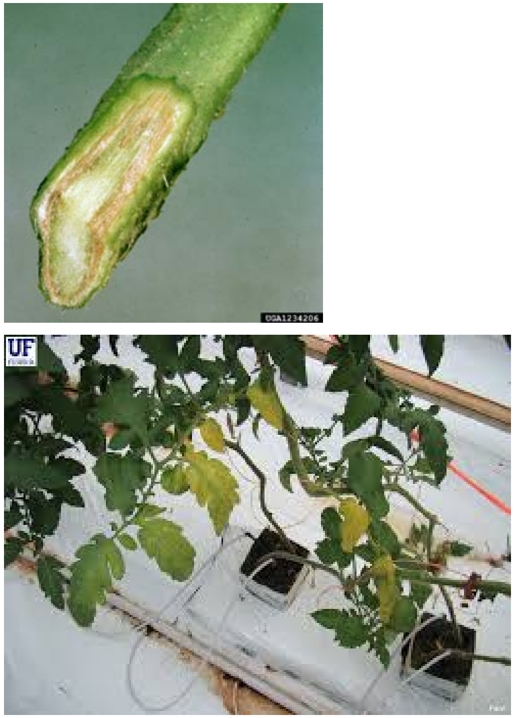
Ketta, 2017; symptoms on lettuce

Fusarium spp. in hydroponic systems

- true fungi (ascomycete)
- vegetative and generative spores highly abundant
- spores easily transmitted in the water
- persistant spores, esp. chlamodospores, survive several years



ma: macroconidia; mi: microconidia; ch: chlamydospores (https://projects.ncsu.edu)

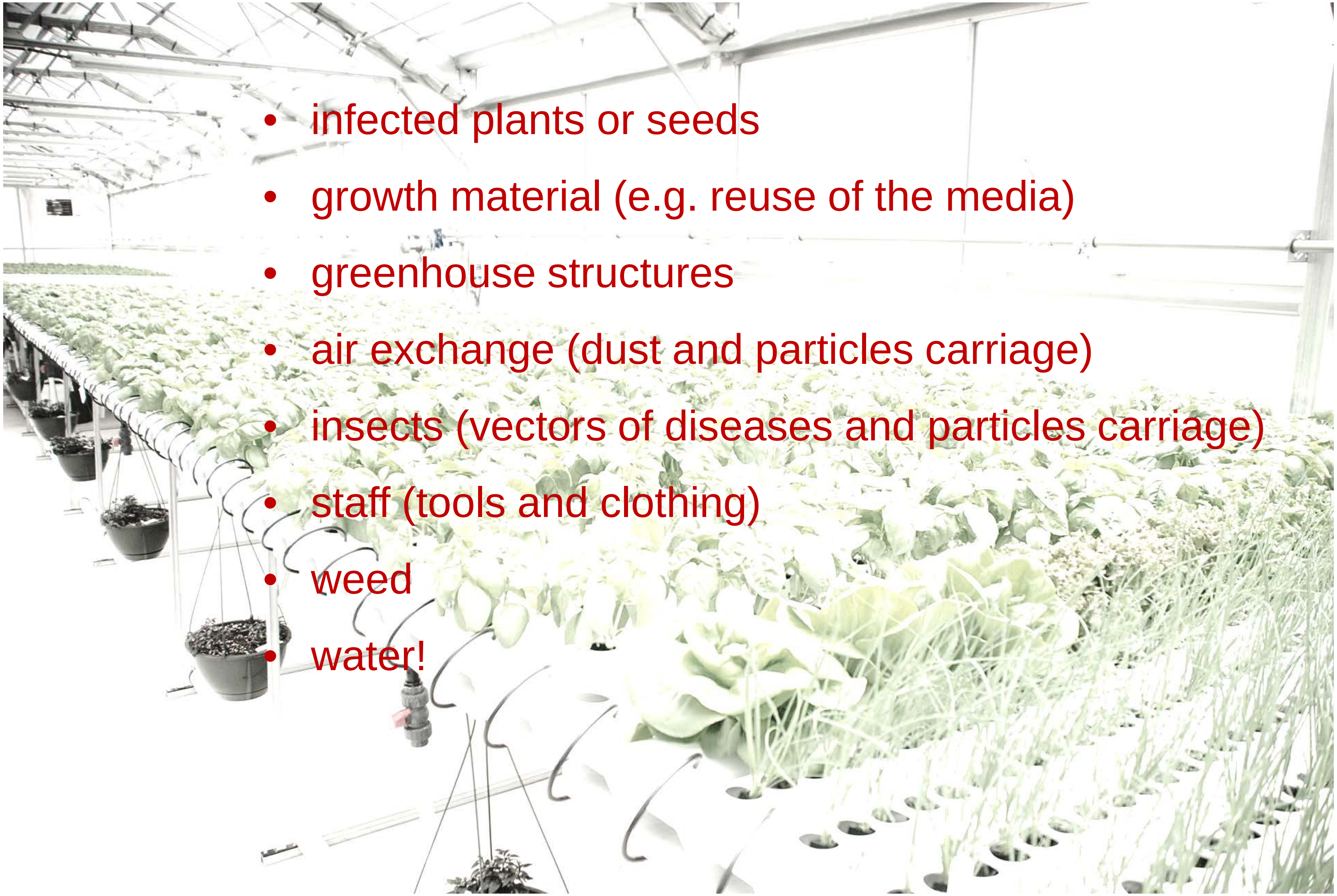


Fusarium oxysporum f.sp. *lycoversici* on tomato plants (https://projects.ncsu.edu)

What are potential origins of disease in hydroponic systems?

www.rimolgreenhouses.com

What are potential origins of disease in hydroponic systems?



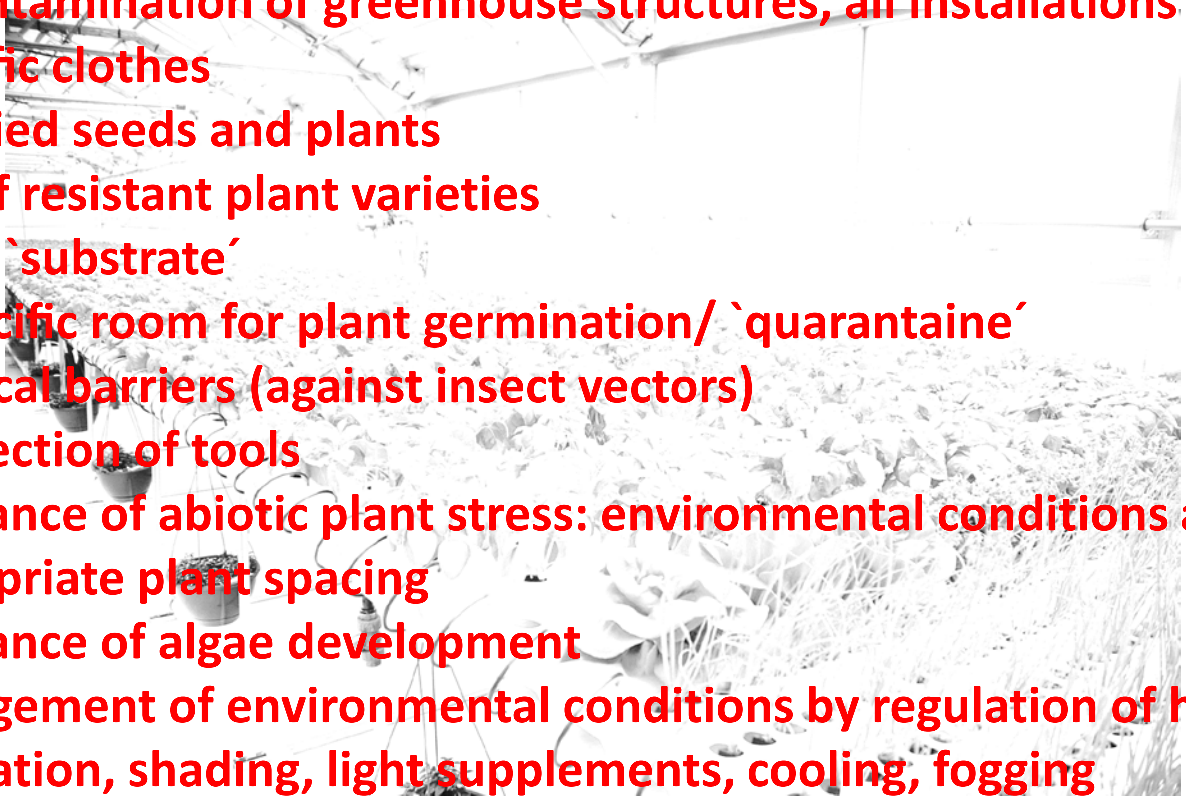
- infected plants or seeds
- growth material (e.g. reuse of the media)
- greenhouse structures
- air exchange (dust and particles carriage)
- insects (vectors of diseases and particles carriage)
- staff (tools and clothing)
- weed
- water!

Preventive measures against diseases in hydroponic systems

How to avoid the entry, infection and distribution of pathogens into your hydroponic system?

Preventive measures against diseases in hydroponic systems

How to avoid the entry, infection and distribution of pathogens into your hydroponic system?



- **plant debris removal**
- **decontamination of greenhouse structures, all installations and supplies (pot**
- **specific clothes**
- **certified seeds and plants**
- **use of resistant plant varieties**
- **clean `substrate´**
- **a specific room for plant germination/ `quarantaine´**
- **physical barriers (against insect vectors)**
- **disinfection of tools**
- **avoidance of abiotic plant stress: environmental conditions and fertilization**
- **appropriate plant spacing**
- **avoidance of algae development**
- **management of environmental conditions by regulation of heat (air/nutrient ventilation, shading, light supplements, cooling, fogging**
- **water disnfection!**

Examples for appropriate greenhouse hygiene

Fig. 10. Thrips exclusion screening. Porchlike addition at end of greenhouse provides increased surface area, which is necessary to compensate for reduced air flow.

Examples for appropriate greenhouse hygiene

Water characteristics influence pathogen survival, spreading and infective potential

- temperature
- nutrients
- infectious potential of fresh or recycled water → water disinfection!

Influence of water temperature on pathogen distribution and infection

- *Olpidium* spp. prefers < 20 °C
- *Phytophthora cryptogea* easier attacks tomato plants at < 20 °C
- *Pythium dissotocum* prefers < 20°C
- *Pythium aphanidermatum* is easier spread at > 24 °C
- *Fusarium* sp. favors temperatures of > 20 °C

(Stouvenakers, 2018)

Influence on nutrients and pH- value on pathogen survival and spread

- 10 – 30 mmol/l $Ca(NO_3)_2$ reduces sporulation of *Phytophthora parasitica* and infection of *vinca* roots
- high K/N ratio of 4:1 prevents *Erwinia carotovora* spp. *carotovora* on tomato
- addition of 1.7 to 3.4 mmol/l Si significantly reduces *Pythium ultimum* on cucumbers
- Increasing the Cu-ions in the nutrient solution lowers the risk of *Phytophthora cryptogea* on gerberas

pH- value

- at pH 7.5 reduced infection of *Fusarium oxysporum* f.sp. *dianthi* compared to 5.5
- at pH 6 reduced infection with *Pythium* sp. on cucumbers compared to pH 5

(reviewed in Stouvenakers et al., 2018)

Water treatment to lower pathogen potential

- water sources (rain water, tap water, recycled water, pond water)
- different degrees of contamination
- broad range of water disinfection methods available
- often in combination:
  - ❖chemical treatment
  - ❖irradiation, mainly UV-C
  - ❖heat
  - ❖filtration (pore size < 10 µm) or slow sand filtration
  - ❖biological control agents

Chemical treatment for water disinfection

- Copper
- Zn
- Ozone
- Hydrogen peroxide
- Chlorine

Chlorine in water disinfection- A case study

- Germany (2014), in NRW
- 7 growers in NRW (ornamental plants)
- Investigation of efficacy of installed water- disinfection system
- 2 different chlorine- based water disinfection methods:
  - chlorine dioxide ClO_2
  - ECA (electrochemically activated water; HOCl)

Synthesis of chlorine dioxide (ClO_2)

Sodium chloride ($NaCl$; 7.5%) +

Hydrochloric acid (HCl; 9%)

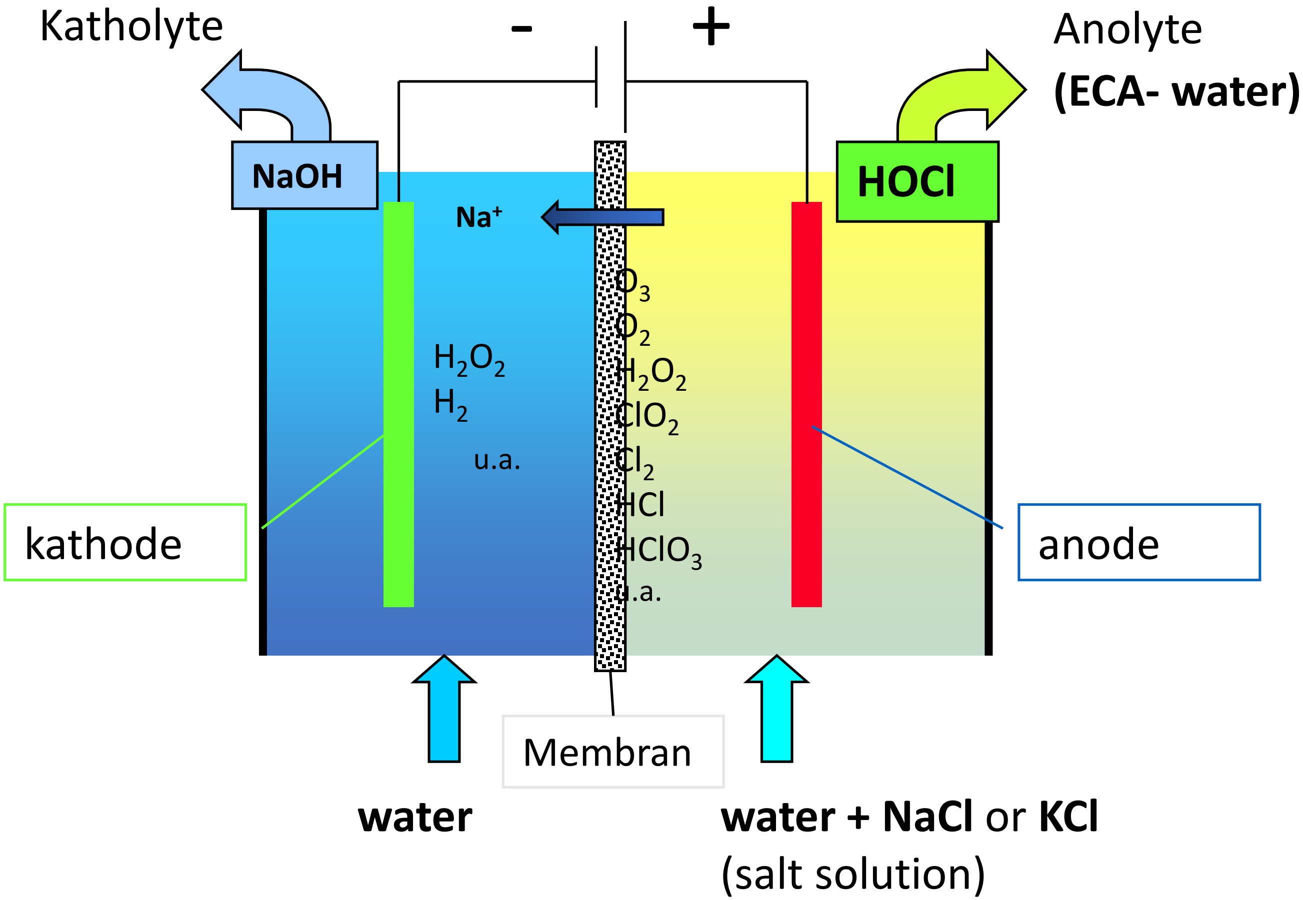
= chlorine dioxide + Sodium chloride + water

- produced on- site
- strong oxidising agent
- works within minutes
- stable for a few months

Working concentrations of chlorine dioxide (ClO_2)

- bacteria: < 0.5 ppm
- vegetative fungal spores < 1 ppm
- generative spores (e.g. oospores): not sufficient!
- nematodes > 3 ppm, longer incubation times

ECA- water synthesis: electrolysis of chlorine-containing water or concentrated salt solution



Katholyte

$-$ $+$

Anolyte
(ECA- water)

NaOH

HOCl

Na^+

H_2O_2
H_2
u.a.

O_3
O_2
H_2O_2
ClO_2
Cl_2
HCl
$HClO_3$
u.a.

kathode

anode

Membran

water

water + NaCl or **KCl**
(salt solution)

ECA water is synthesized on site and can be stored for a longer period.

Photo: www.brinkman.nl/ecaunit/Ecaunit.jpg

Electrochemically activated water (ECA- Water)

- 2-4 ppm active chlorine efficient against most bacteria and fungi
- phytotoxicity can occur above 5 ppm (woody plants above 50 ppm)

Case study
chlorine as water disinfectant in greenhouse water

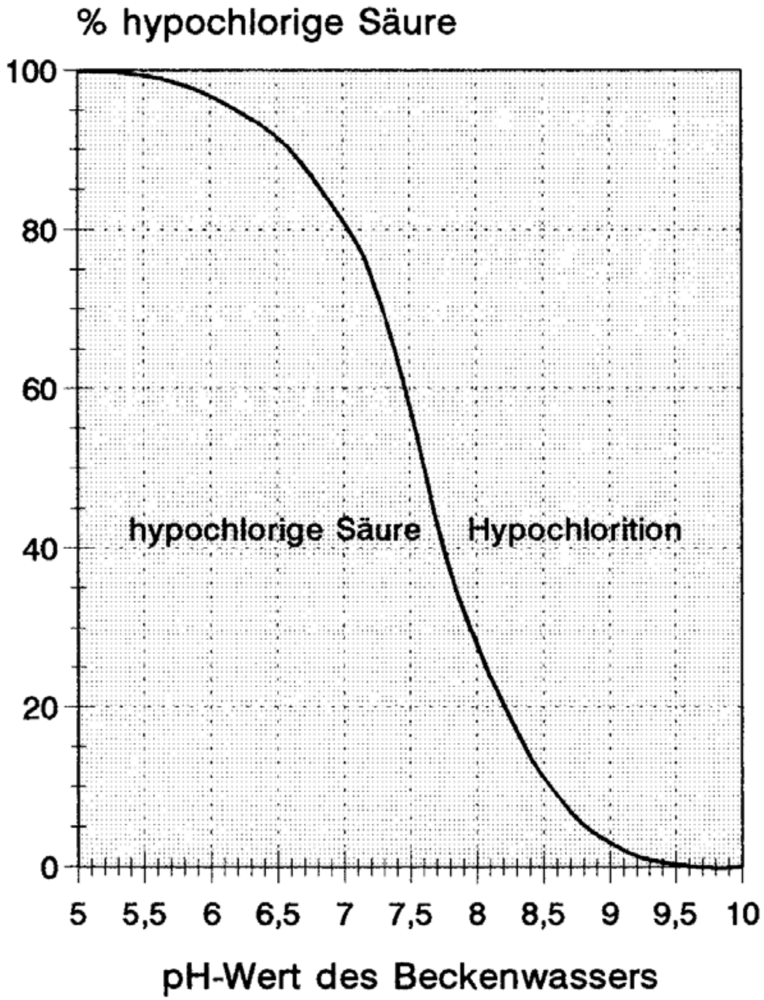
our observations

- 6 greenhouses: sufficient concentration in storage tank (up to 260ppm)
- 1 greenhouse: very low concentration of active ingredient in the storage tank
- Concentration of active chlorine in the treated water/ at the plant site: in 6 out of 7 sites no active ingredient detectable anymore, 1 grower very low concentration in the used water (< 0.5 ppm)

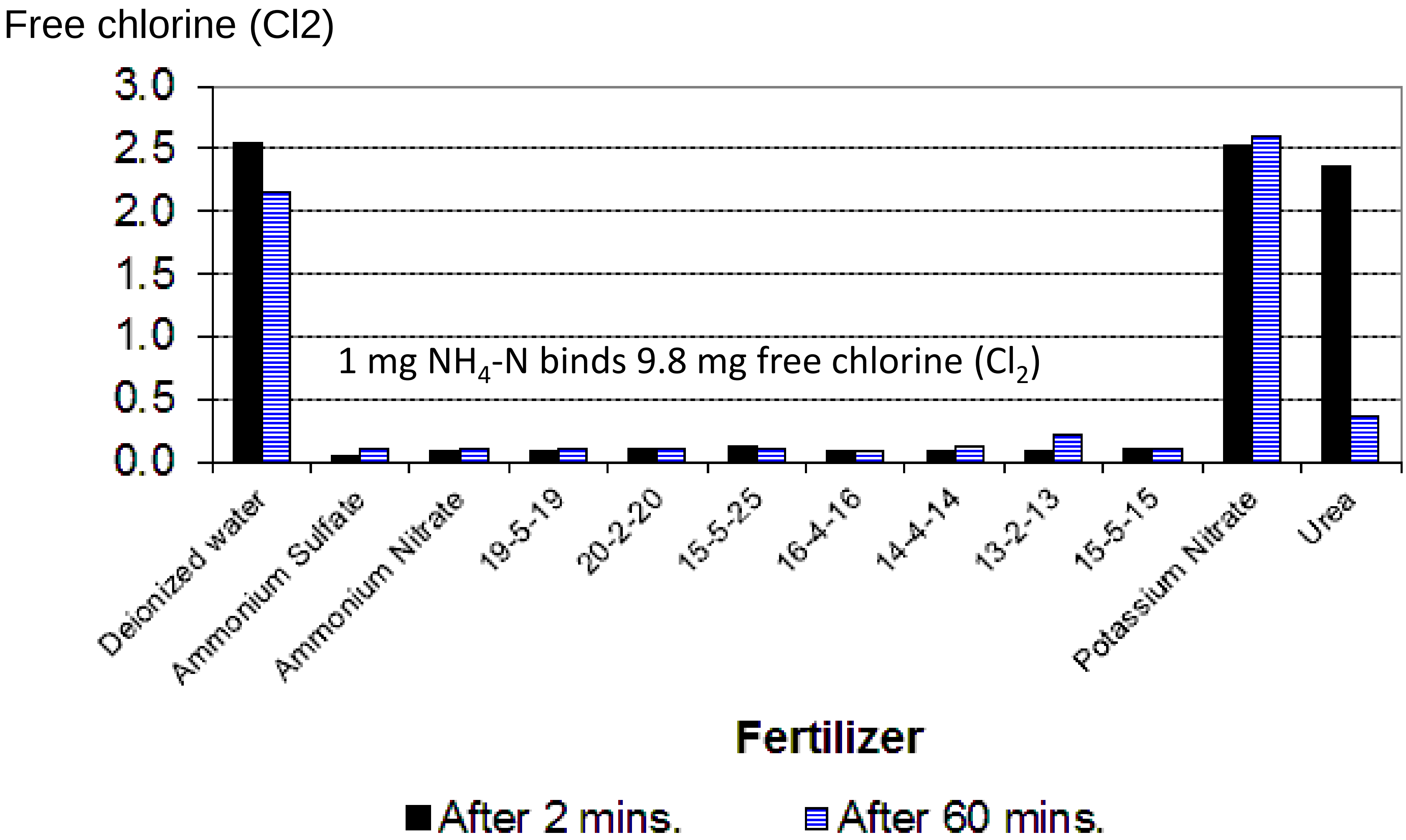
→ horticultural water is very challenging regarding disinfection!

Efficiency of water disinfection methods depends on water characteristics

- **pH- value** influences efficacy of chemical disinfection, for example HOCl- abundance (ECA- water)
- **organic compounds** (plant debris, soil) bind chlorine and other chemical disinfection agents and limit UV-C
- **fertilizer** can influence efficacy of chemical methods and UV-C



HClO reacts with ammonium- containing fertilizers



1 mg NH_4-N binds 9.8 mg free chlorine (Cl_2)

Quelle: Brooks,M.A. 1999

Conclusions on case study- also valid for many other disinfection systems

- loss of active compound through pH- Value, fertilizer, organic load
- regular control needed (both for the equipment and the active ingredient concentration)
- filtration before other treatments might be useful
- What happens to the beneficial microorganisms?

Role of the microflora in a hydroponic system

a) naturally occurring microorganisms in the hydroponic system

b) defined addition of beneficial microorganisms to nutrient solution

a)

- soon after starting soilless culture, microflora rapidly (within 20h) colonises substrate, nutrient solution and plant rhizosphere
- natural microflora can suppress diseases (Berger et al., 1996; Chen et al., 1998)
- active action: competing with pathogens for space and nutrients
- passive action: eliciting plant defence response (induced resistance) and promoting growth

Role of the microflora in a hydroponic system

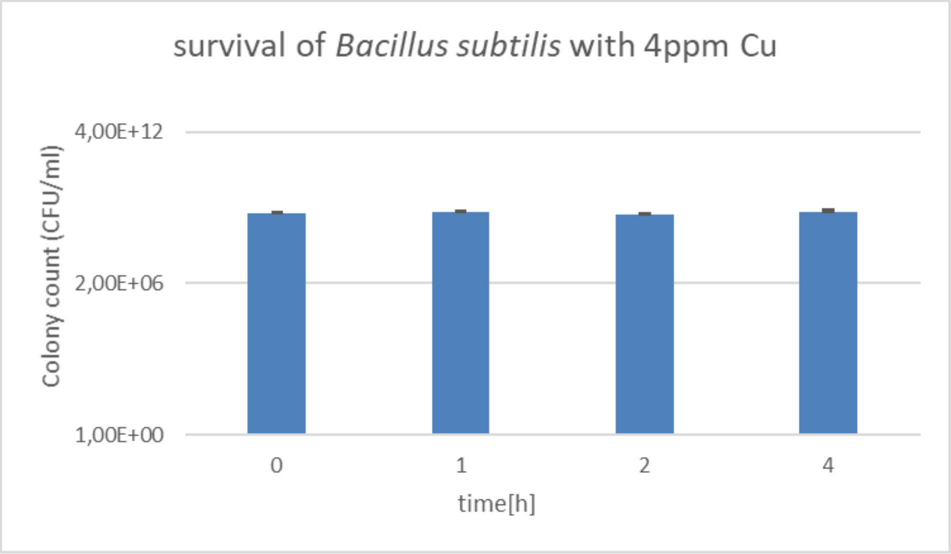
a) naturally occurring microorganisms in the hydroponic system

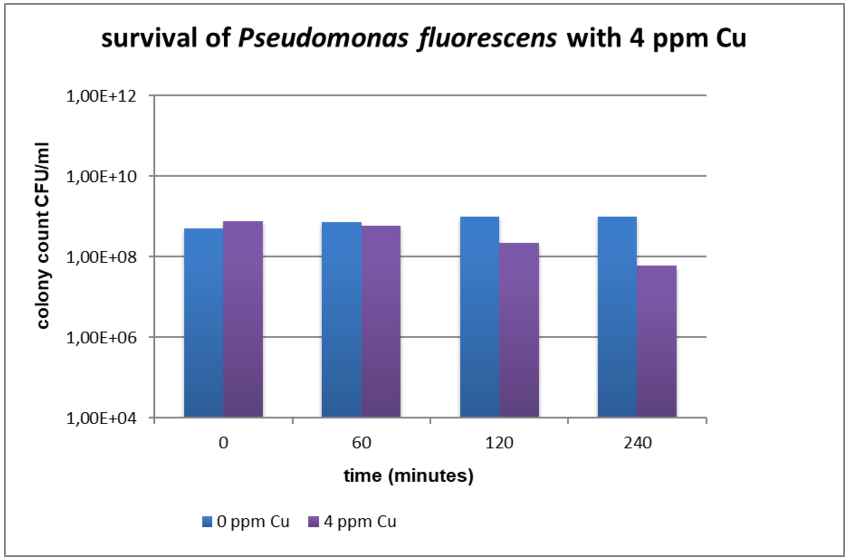
b) defined addition of beneficial microorganisms to nutrient solution

b)

- bacterial and fungal antagonistic organisms
- active action: antibiosis and competition with pathogens for space and nutrients
- passive action: eliciting plant defence response (induced resistance) and promoting plant growth
- e.g. *Bacillus subtilis*, *Pseudomonas fluorescens*, *Trichoderma* sp.

Many beneficial microorganisms are destroyed by water disinfection, but…..

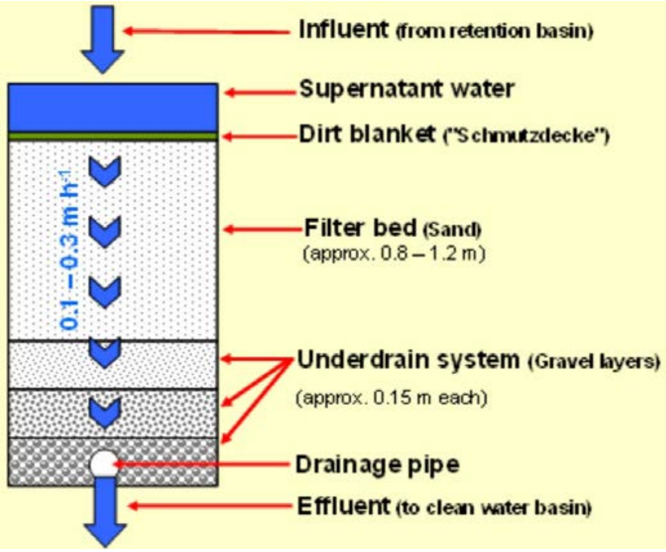




Survival depends on disinfection system, duration and beneficial species!

Falkner et al., Hochschule Geisenheim 2017

Slow sand filtration for water disinfection keeps microflora alive to a large extent!



Influent (from retention basin)

Supernatant water

Dirt blanket ("Schmutzdecke")

Filter bed (Sand)
(approx. 0.8 – 1.2 m)

Underdrain system (Gravel layers)
(approx. 0.15 m each)

Drainage pipe

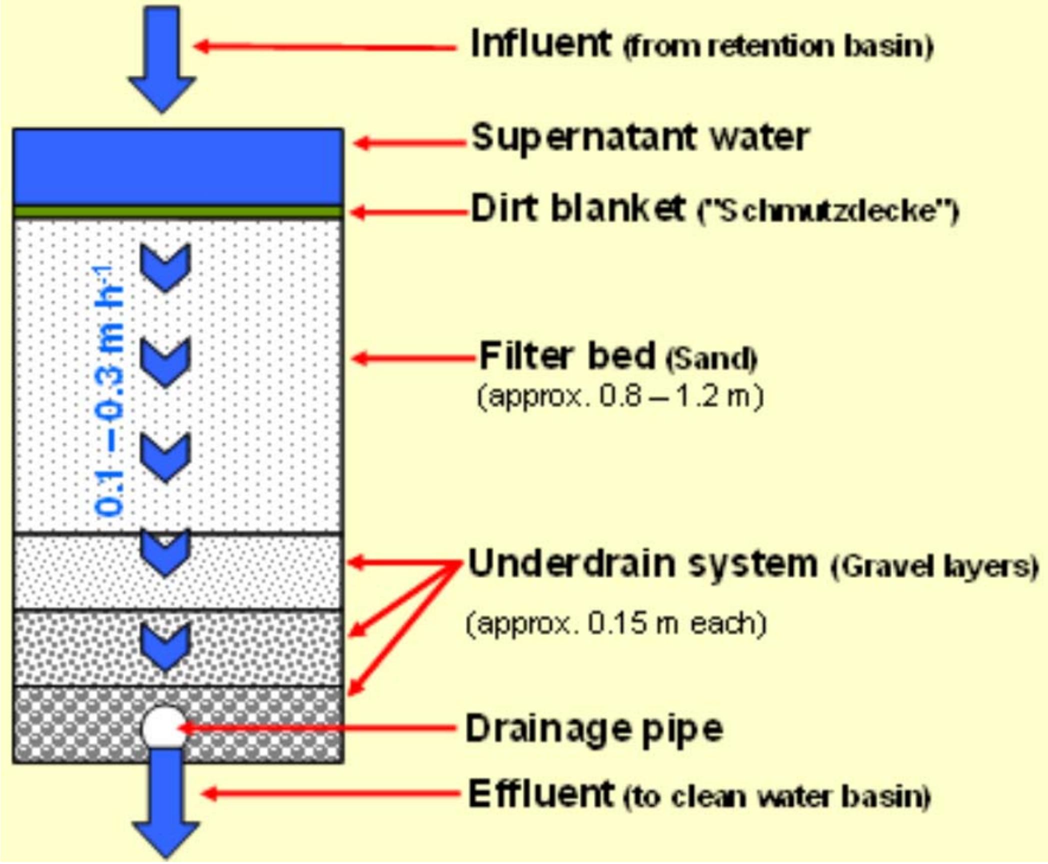
Effluent (to clean water basin)

Ufer et al. (2008); Plant Health Progress

Slow sand filtration for water disinfection works with mechanical and microbial action

efficacy influenced by

- ***flow rates*** through the filter unit (max. 100 l/m2/h),
- ***nature and pore size of substrates*** in filter tubes, and
- ***bacterial microcolonies*** on substrates



Ufer et al. (2008); Plant Health Progress

Slow sand filtration for water disinfection

- effective against soil- borne pathogens, such as *Pythium* spp., *Phytophtora* spp., *Xanthomonas campestris* and *Fusarium* spp.
- suppression of plant debris, algae, small particles
- leaves many beneficials intact
- limitations are viruses
- low cost
- low energy input and ease of construction and operation

Ufer et al. (2008); Plant Health Progress

Advantages and disadvantages of water disinfection methods

Method	**Advantage**	**Disadvantage**
heat (pasteurisation)	highly effective	high capital costs high maintenance costs
membrane filtration	highly effective, not affected by pH, easy to use, no by- products	frequent plugging, leaks, high capital costs
slow sand filtration	low costs, easy maintenance	high space requirement, efficacy differs between pathogens
chemical methods	high bactericidal action, usually low costs	risk of phytotoxicity, by- products, might be affected by pH or organic matter
UV-C	low space requirements, low costs, no by- products, not affected by pH, easy to use	Efficacy affected by organic matter, micronutrients and bulb age
microbial inoculation	environmentally friendly	inconsistent action

Modified from Alsanius and Wohanka, 2004

Water disinfection methods summary

- each system has individual advantages and disadvantages
- most suitable method (or combination) has to be decided individually based on crop species, hydroponic system, water source etc.
- every system needs regular control
- every method requires special education on how to handle it

Hochschule Geisenheim University

DAAD Deutscher Akademischer Austauschdienst
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UNIVERSITY OF THESSALY

SUMMER SCHOOL

Greenhouse Hydroponics

Automation & Management

September 23 – 29, 2019
Hochschule Geisenheim University
Classroom HS 3 in the Müller-Thurgau-Haus
Von-Lade-Str. 1, Geisenheim

Hochschule Geisenheim University

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Automation yes, but individual adjustment for every system!

Regular control!

Appropriate hygiene!