Lecture Supplements

Plant Bacteriology

Bacterial Disease Symptoms-Part 1

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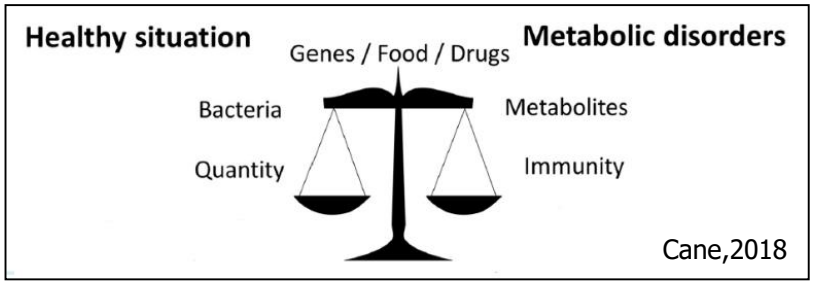


List of plant diseases caused by bacteria
More than 160 species of plant bacteria

- Bacterial diseases of plants are more than just unsightly; they are often destructive to plants.
- The University of Minnesota explains that there are more than 160 species of plant bacteria, each with its own growth rate. While some bacteria will quickly overwhelm your plant, others will slowly ravish your plant.
- Bacterial diseases are non aggressive and cannot penetrate the foliage or stems of plants.
- However, bacterial diseases do take advantage of your plant's natural state, entering the plant through its natural and man-made wounds and opening, such as with pruning cuts, cracks and stomata.

Smith,2017

Host Plants Names

- Alder
- Alfalfa (*Medicago sativa*)
- Almond
- Aloe
- Anthurium
- Apple
- Apricot
- Fern (*Asplenium nidus*)
- Aster
- Banana
- Barley
- Basil
- Batata
- Beans
- Berries
- Bird's nest fern
- Bird-of-paradise
- Brinjal (Egg plant)
- Bouganvillea
- Cabbage/lettuce
- Cactus
- Carnation/Pelargonium
- Carrot
- Cassava
- Cauliflower
- Celery
- Cherry
- Chestnut
- Chrysanthemum
- Citrus
- Clove
- Clover
- Coconut
- Coffee
- Coneflower
- Cotton
- Cucurbits
- Coriander
- Corn (maize)
- Crucifers
- Dieffenbachia
- Dragon fruit
- Elm
- Eucalyptus
- Euonymus (Evergreen spindle)
- Fig
- Garlic
- Geranium
- Ginger
- Grape

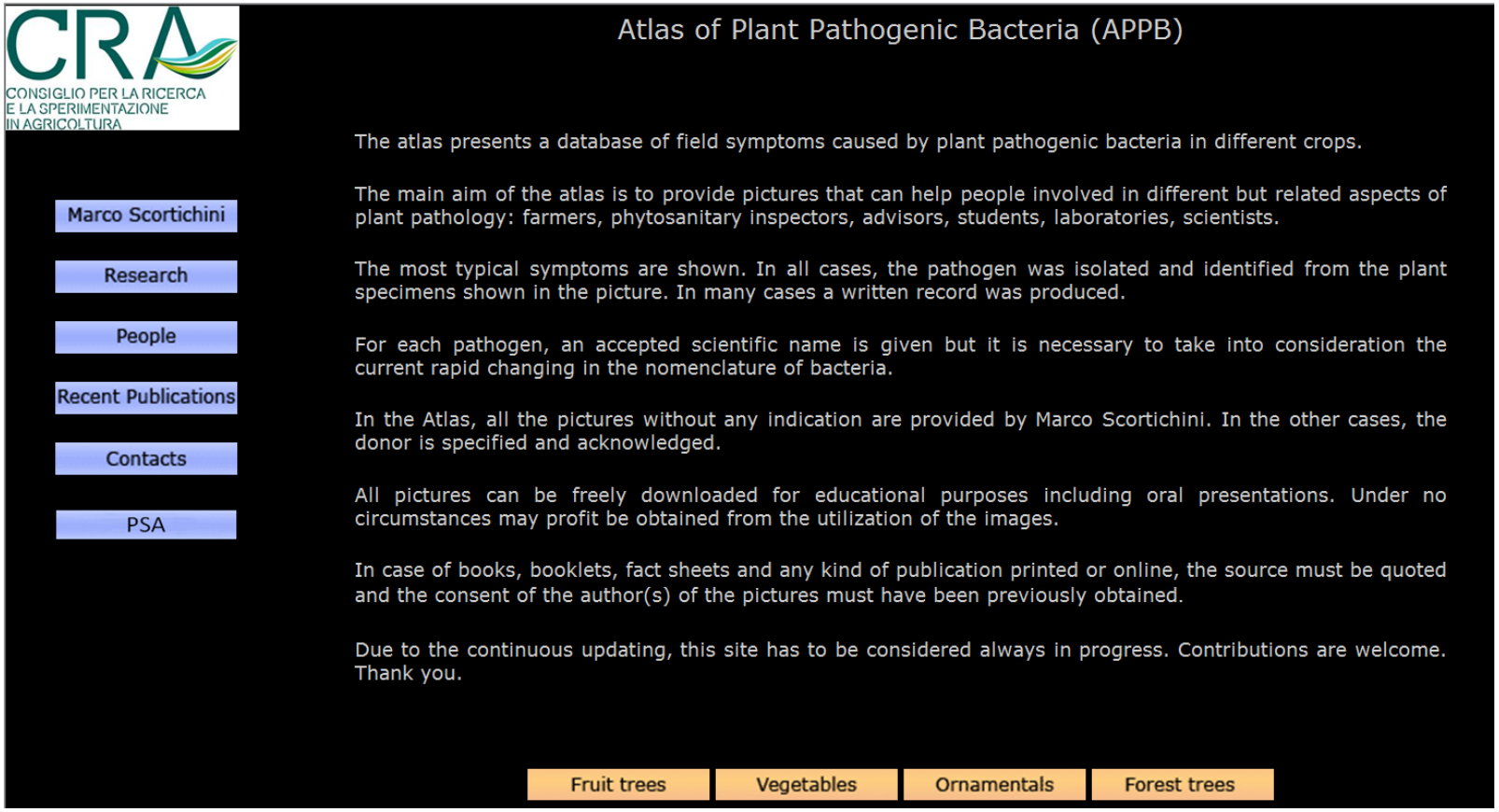
Host Plants Names (Contd.)

- Grapefruit
- Guava
- Hazel
- Hawthorn
- Heliconia
- Horseradish
- Hyacinthus
- Hybiscus
- Impatiens
- Iris
- Ivy
- Kiwfruit

PowerPoints/PDF files

- Allen, S.J., G.A. Constable, P.E. Reid and W.N. Stiller.2010. Breeding for cotton disease resistance in Australia. 1.34 Mb.
- Jones, J.B. 2006. Lecture 1 phytobacteriology. 19 pages.
- Sundin, G.W. 2008. Fire Blight Talk. Northwest Orchard and Vineyard Show. Michigan University, USA. 11.9 Kb.
- UMass Extension Vegetable Program. 2024. Vegetable Notes Vol. 36:14

Atlas of Plant Pathogenic Bacteria
APPB



www.atlasplantpathogenicbacteria.it

What is a Plant Pathologist?
Plant Bacteriologists

- A plant pathologist is someone who's interested in:

1. Understanding the organisms and agents that cause plant diseases, and
2. How diseases affect plant health.

- There is a massive range of plant pathology careers.
- Most plant pathologists work in university departments, commercial companies or do government funded research.

What is a Plant Pathogen?

Pathogens and Vectors

- A **pathogen** is an organism that bears ("gen") suffering ("pathos") upon another organism.
- A **vector**, in pathology, is an organism that carries pathogens from one organism to another (example: insects).

What is a Plant Pathogen?
Symptoms of plant diseases

- Symptoms are expressions of pathological activity in plants.
- They are visible manifestations of changes in color, form, and structure: leaves may become spotted, turn yellow, and die; fruits may rot on the plants or in storage; cankers may form on stems; and plants may blight and wilt.
- Diagnosticians learn how to associate certain symptoms with specific diseases, and they use this knowledge in the identification and control of pathogens responsible for the diseases.

https://www.thefreedictionary.com/

What is a Plant Pathogen?
Symptoms of plant diseases

- All symptoms may be conveniently classified into three major types because of the manner in which pathogens affect plants.
- Most pathogens produce dead and dying tissues, and the symptoms expressed are categorized as necrosis.
- Early stages of necrosis are evident in such conditions as hydrolysis, wilting, and yellowing. As cells and tissues die, the appearance of the plant or plant part is changed, and is recognizable in such common conditions as blight, canker, rot, and spot.

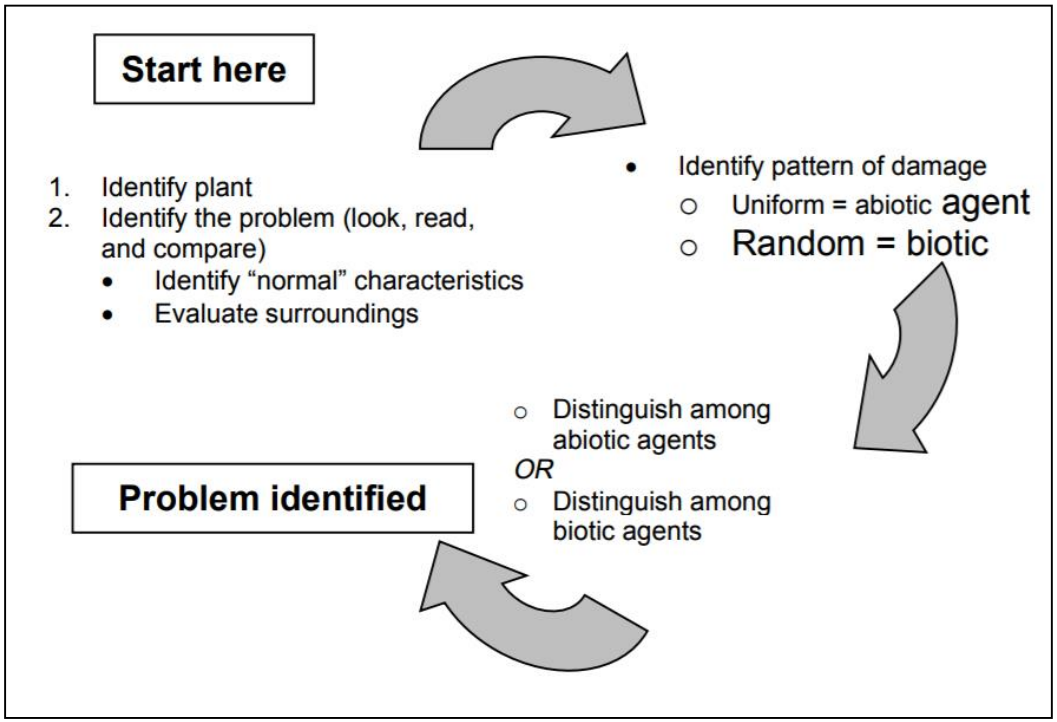
https://www.thefreedictionary.com/

What is a Plant Pathogen?
Symptoms of plant diseases

- Many pathogens do not cause necrosis, but interfere with cell growth or development. Plants thus affected may eventually become necrotic, but the activity of the pathogen is primarily inhibitory or stimulatory.
- If there is a decrease in cell number or size, the expressions of pathological activity are classified as hypoplases (e.g. mosaic, rosetting, and stunting); if cell number or size is increased, the symptoms are grouped as hyperplases (crown gall, scab, and witches'-broom).
- Third groups are a variety of noninfectious agents.

https://www.thefreedictionary.com/

A flow chart displaying the systematic approach to determining causal agents of plant damage



Mechanical factors include string trimmer damage to tree trunks, improper pruning cuts, injury during transportation of plant material and guy wire damage. Physical factors include temperature extremes, light differentials, and extreme changes in oxygen and moisture levels. Chemical factors include pesticide damage, fertilizer damage, nutritional disorders, and pollutants.

Small,2017

Comparison of fungal and bacterial leaf spots

Symptom Description	Bacterial	Fungal
Water-soaked appearance	yes	no
Texture	slimy, sticky*	dry, papery
Smell	yes	none
Pattern	irregular, angular	circular, target-like
Disintegration	yes	no
Color change	none	red, yellow and purple halos
Structures of pathogen	none	mycelia, spores, fruiting structures

*ends to oozing, dripping in infected plant tissues

Small,2009

Bacterial vs. fungal plant diseases

- While fungi cause about 85% of plant diseases, bacteria cause some that are the most difficult to control.
- This is especially true in Florida, because bacterial diseases are most intense in warm, humid, rainy environments.

courtesy of University of Flourida,2011

Symptomatology of bacterial diseases

- Symptomatology of bacterial diseases is extremely varied, but usually characteristic for a particular pathogen.
- Symptoms can range from:

1. Mosaics, resembling viral infections, to large
2. Plant abnormalities, such as galls or distorted plant parts (phyllody and virescence).

- Symptoms may vary with photoperiod, plant variety, temperature and humidity, and infective dose.
- In some cases, symptoms may disappear or become inconsequential with further growth of the plant.
- For example, Holcus spot of corn caused by *Pseudomonas syringae* pv. *syringae* is arrested at the onset of hot dry weather.

Vidaver and Lambrecht,2004

Bacterial disease symptoms

Symptoms caused by plant pathogenic bacteria

1. Bacterial leaf spot disease:

- Symptoms include water-soaking, slimy texture, fishy or rotten odor, confined initially between leaf veins resulting in discrete spots that have straight sides and appear angular.
- This vein frequently acts as a barrier and inhibits the bacteria from spreading further.
- A chlorotic halo frequently surrounds a lesion.
- Lesions may enlarge through coalescence to develop blight lesions.
- In:

1. Dry weather: dead areas dry up and remain intact.
2. Wet weather: spots continue to enlarge and center fall off (Shot holes).

Bacterial disease symptoms

Symptoms caused by plant pathogenic bacteria

- Some lesions exude fluid containing bacteria.
- Water-soaking frequently occurs in bacterial leaf spot diseases.
- Holding the leaf to light usually reveals the water-soaking.

2. Vascular wilt:

- In some cases the bacteria poison or plug the water conducting tissue and cause yellowing, wilting, browning and dieback of leaves stems and roots.

Bacterial disease symptoms

Symptoms caused by plant pathogenic bacteria

3. Stunting or other growth inhibition:

- The reduction in photosynthesis, because of less chlorophyll leads to shorter internodes, smaller leaves and blossoms and reduced yield.

4. Distortions of leaves and flowers:

- Witches' brooms or rosettes result from no uniform growth within a tissue or uncontrolled growth.

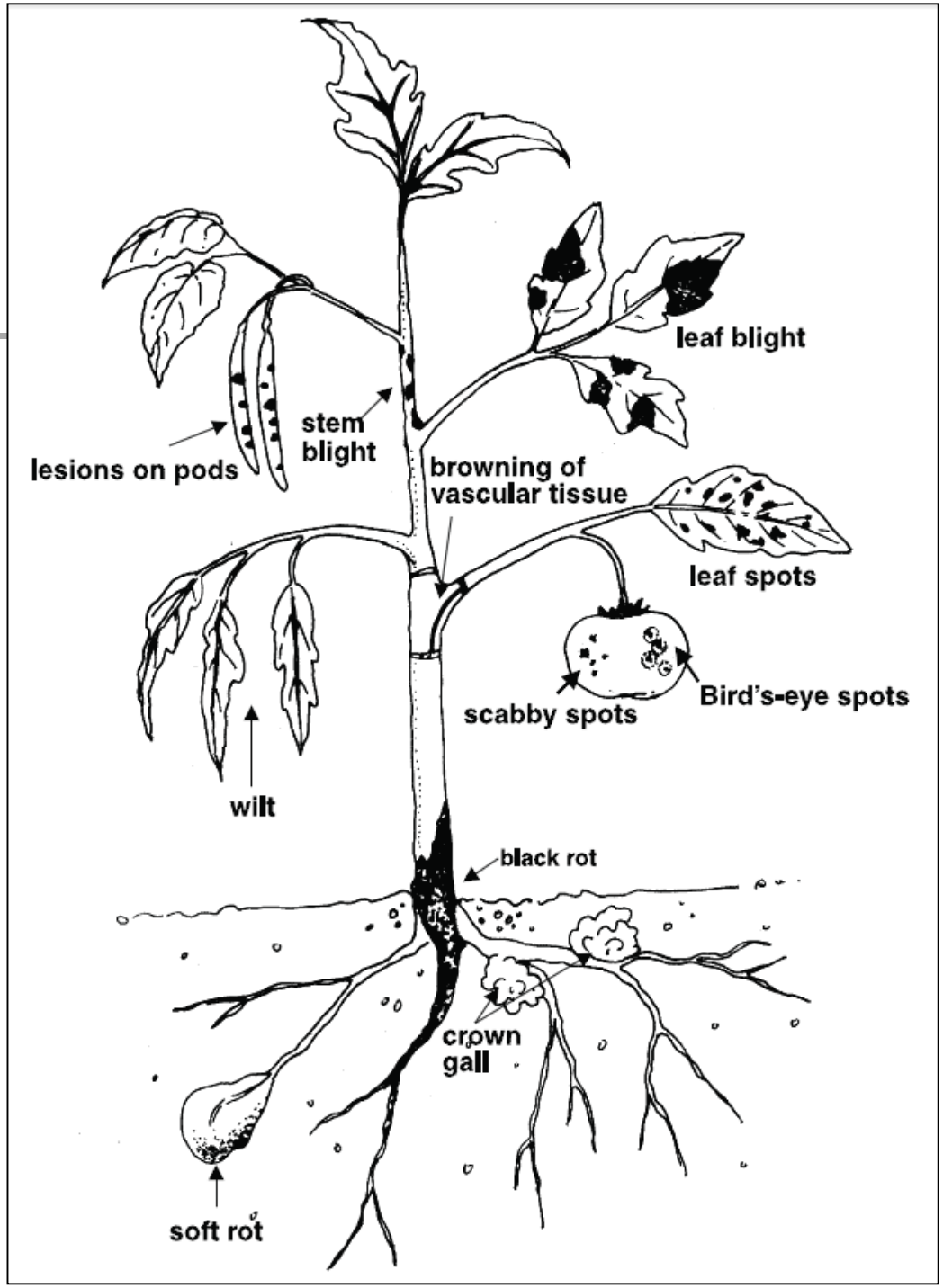
5. Necrotic areas or lesions:

- Necrosis that does occur is usually confined to discrete areas of the plant; necrosis rarely occurs to such an extent that the entire plant is killed.

Symptoms caused by bacteria on plants.

scab/spot: ***Xanthomonas vesicatoria***

Goszczynaska *et al.*,2000



Schematic representation of the basic functions in a plant (left) and of the kinds of interference with these functions (right) caused by some common types of plant diseases.

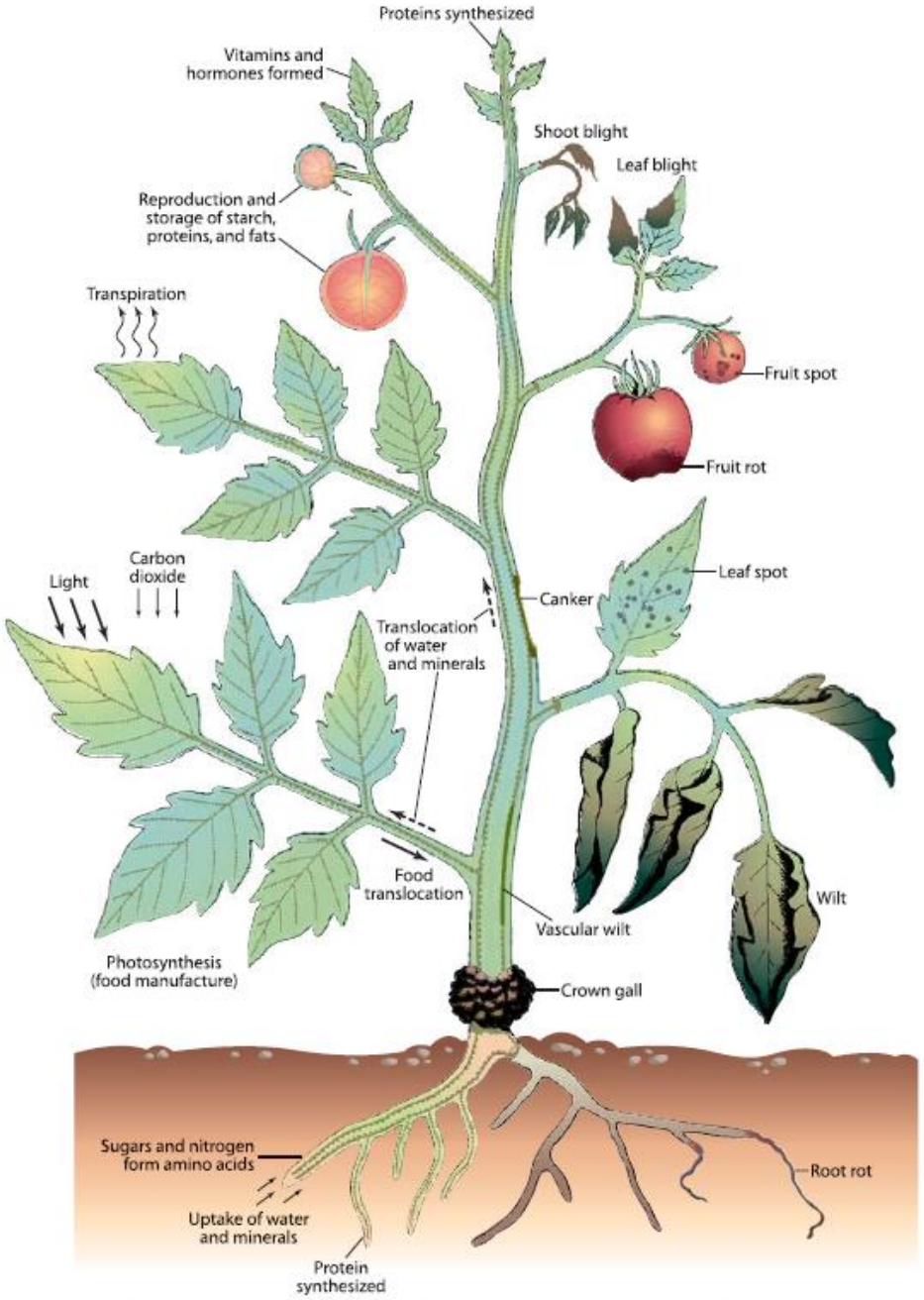
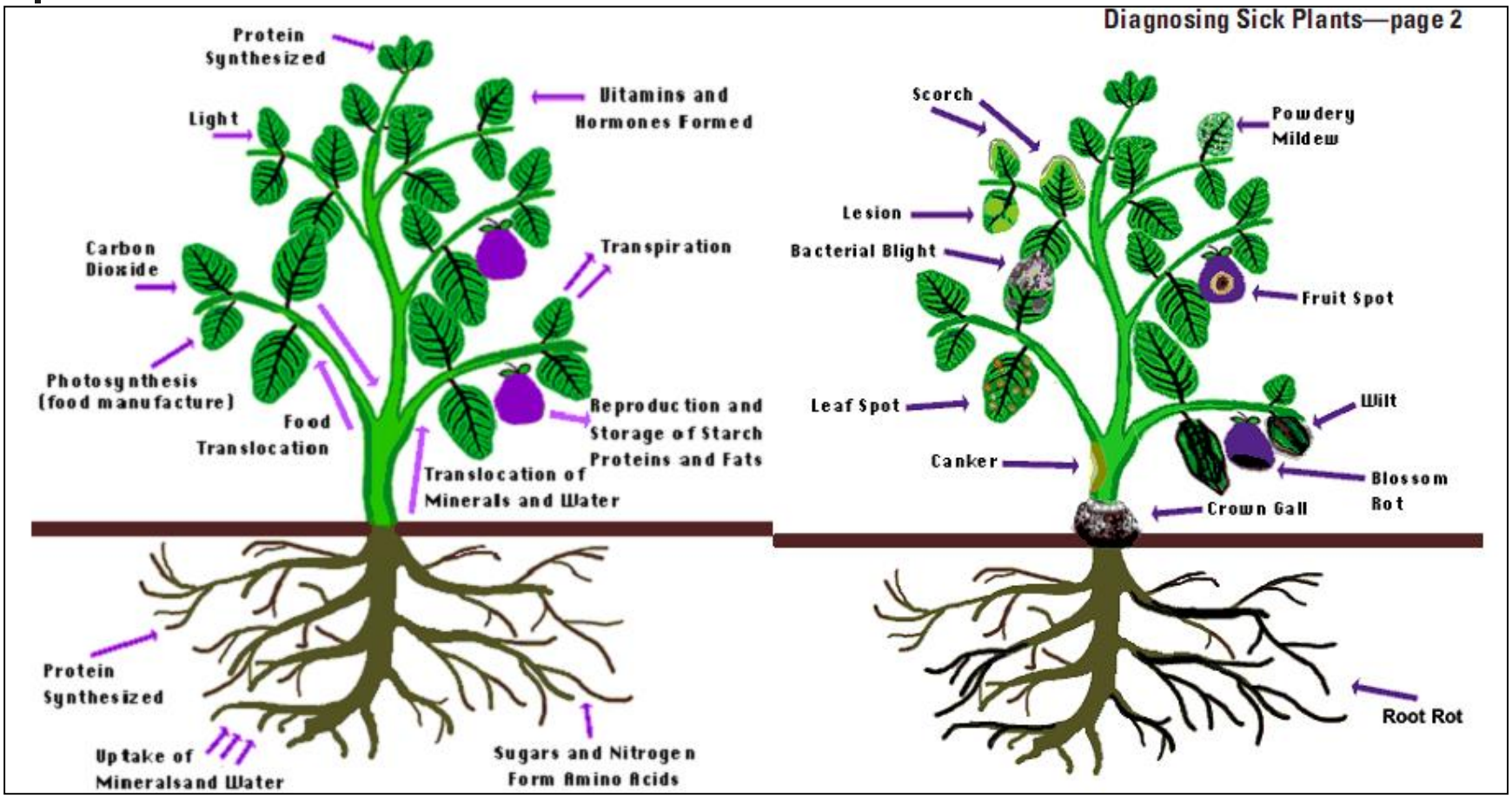


FIGURE 1-1 Schematic representation of the basic functions in a plant (left) and of the kinds of interference with these functions (right) caused by some common types of plant diseases.

Agrios,2005

Healthy plant versus sick plant

Note the differences between the two



Smith, The Ohio State University,2008

Typical Bacterial Disease Symptoms

1. water-soaking
2. angularity
3. oozing

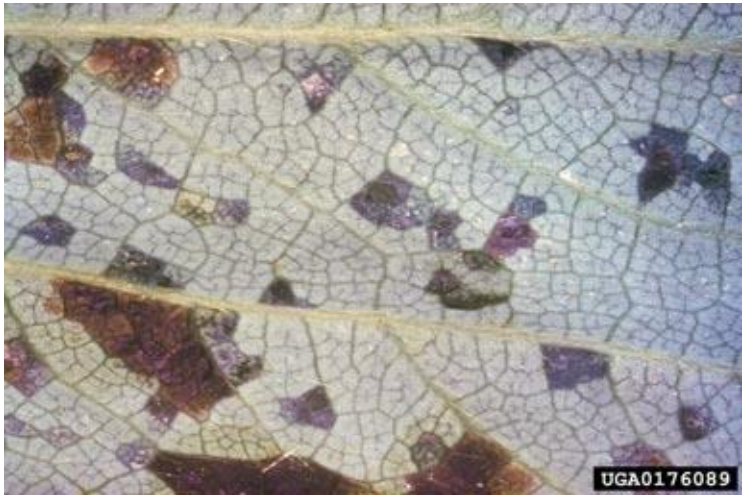
Typical bacterial symptoms

Water-soaked and angular leaf spots

- Bacterial leaf spots are often angular because they are initially limited by the leaf veins.
- Color of the bacterial spots is usually uniform.
- Bacteria are one-celled organisms that kill as they go.
- Tissue may first appear oily or water-soaked when fresh, but on drying becomes translucent and papery tan.

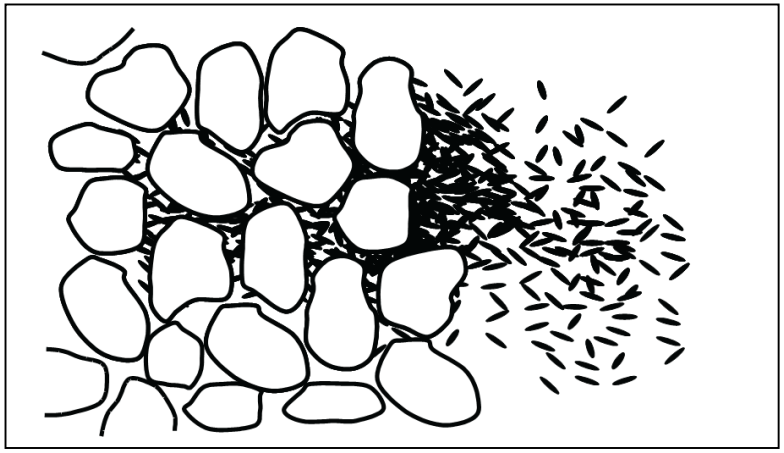
Typical bacterial symptoms

Water soaking and distinct lesions of bacterial leaf diseases

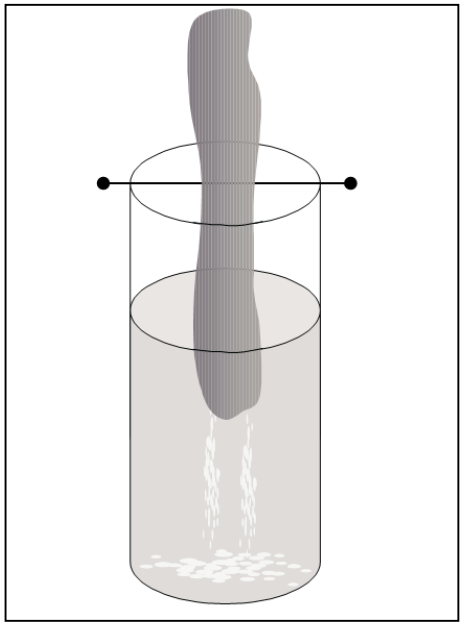


Angular leaf spot

Bacterial oozing or exudation



Schematic drawing illustrating bacterial streaming from diseased tissues.

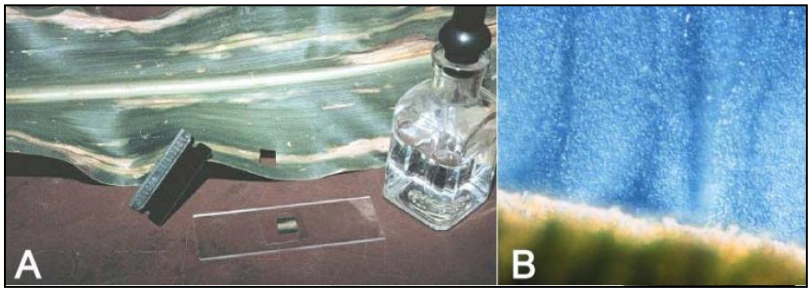


Milky exudate from tomato stem infected by *Ralstonia solanacearum*.

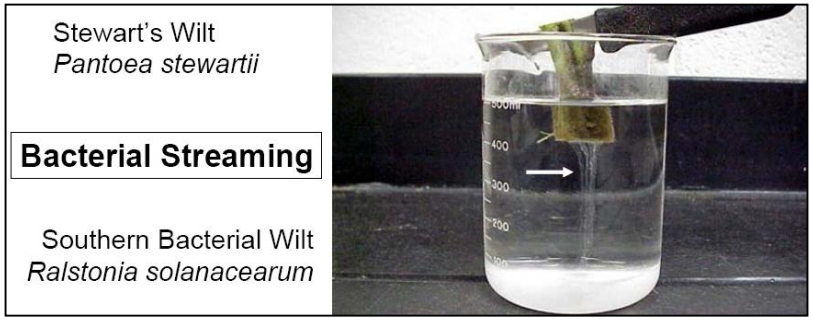
Goszczynaska *et al.*,2000

Bacterial oozing

Streaming



Stewart's wilt of corn caused by *Pantoea stewartii*.



Southern bacterial wilt of geranium caused by *Ralstonia solanacearum*.

Fire blight symptom developments
Blight and oozing
E. amylovora

- Minimum of 50 cells to cause as shoot blight strike.
- 100-1000X or more cells come out as ooze.

Amplification of Fire Blight Bacteria in Orchards

- Where do we see extensive growth -- And spread of the pathogen -- and infection?
- Blossoms
  - Rattail bloom
- Secondary spread from the initial shoot blight strikes
  - Minimum of 50 cells to cause a shoot blight strike
  - 100-1,000 X or more cells come out as ooze

Targets for management: initial inoculum, blossoms, prevention of the first shoot blight strikes

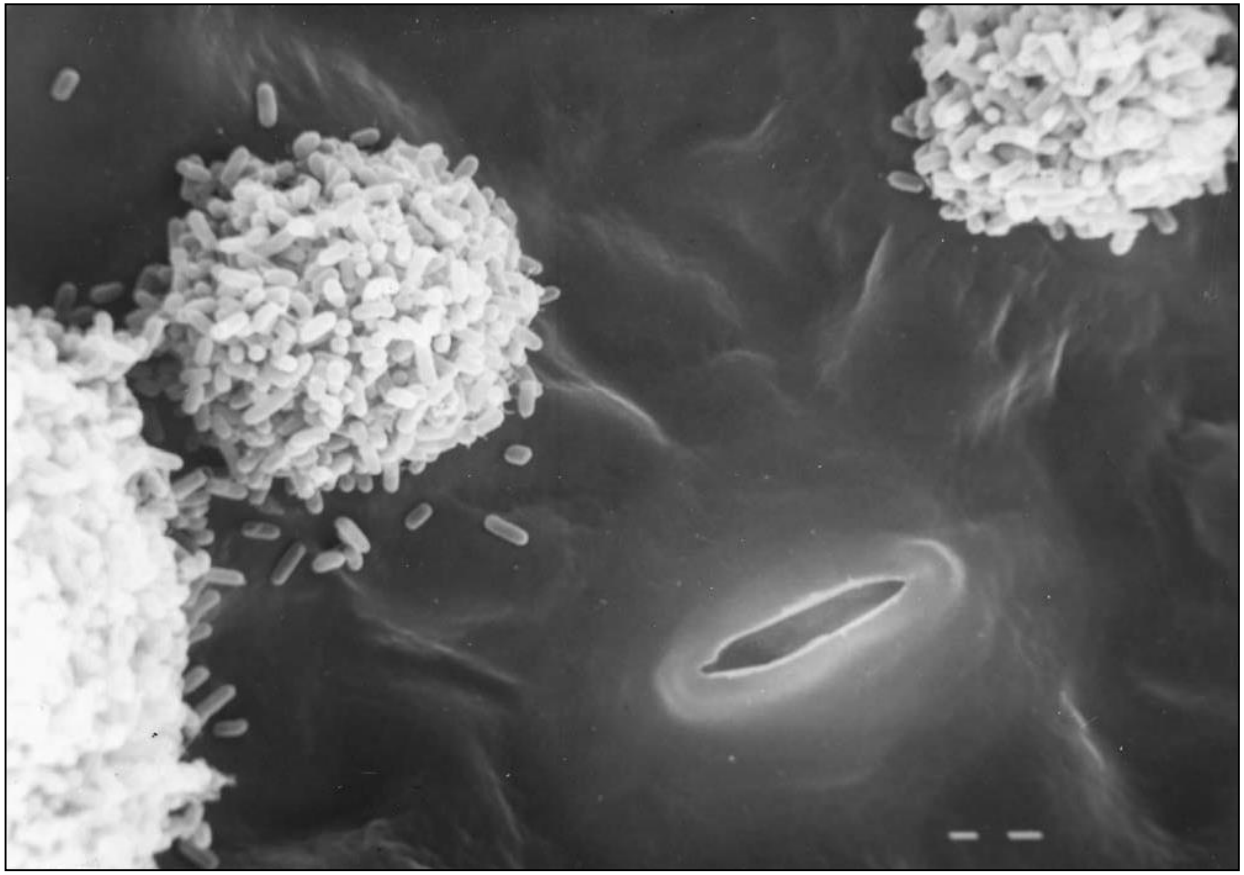
Sundin,2008

Typical bacterial symptoms

Bacterial strands of *Erwinia amylovora* on a twig of *Crataegus* (hawthorn)

Janse,2006

Exuding from stomata of infected cherry leaves *Pseudomonas syringae* pv. *morsprunorum*



Photograph courtesy of Roos and Hattingh (1983).

Agrios,2005

Bacterial disease diagnosis

Symptoms

- Symptoms of disease are the plant's reaction to the causal agent.
- **Plant symptoms include:**

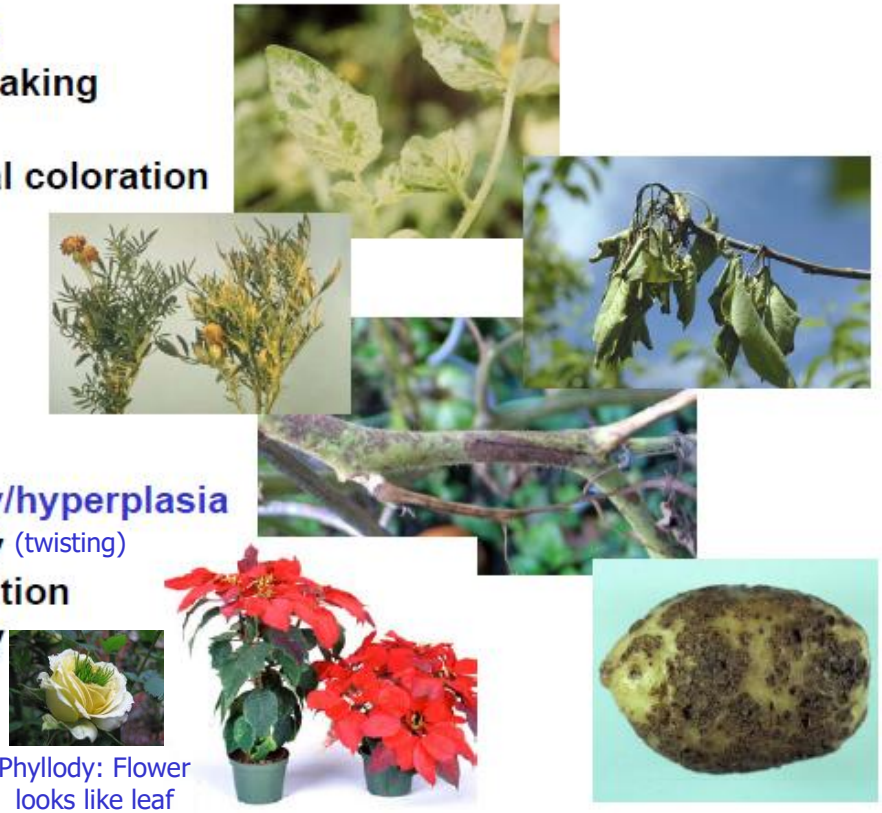
1. Chlorosis – Loss of green color
2. Mosaic – Varying patterns of light and dark plant tissue
3. Necrosis – Dead plant tissue
4. Blight – Sudden death
5. Wilting – Limp, droopy appearance
6. Canker – Sunken, discolored areas on any plant part
7. Stunting – Lack of growth
8. Galls – Localized swellings of plant tissue
9. Distortion – Malformed plant tissue
10. Blister – An enclosed raised spot.

Bacterial disease diagnosis

Types of common bacterial diseases/symptoms

Symptoms of Bacterial Infection

- **Pre-necrotic**
  - Water-soaking
  - Wilting
  - Abnormal coloration
- **Necrotic**
  - Blight
  - Canker
  - Rot
  - Spot
  - Streak
- **Hypertrophy/hyperplasia**
  - Epinasty (twisting)
  - Proliferation
  - Phyllody
  - Scab
  - Gall



Phyllody: Flower looks like leaf

Cuppels lecture
Biology 4218a

Bacterial disease diagnosis

Types of common bacterial diseases/symptoms

- Epinasty: downward bending of a petiole, so that the angle between its base and the stem becomes obtuse (of an angle more than 90° and less than 180°).
- Wilting/epinasty of potato plants at leaf margin caused by *Clavibacter sepedonicus*.

Xanthomonas vesicatoria may exhibit severe epinasty (twisting) on pepper.

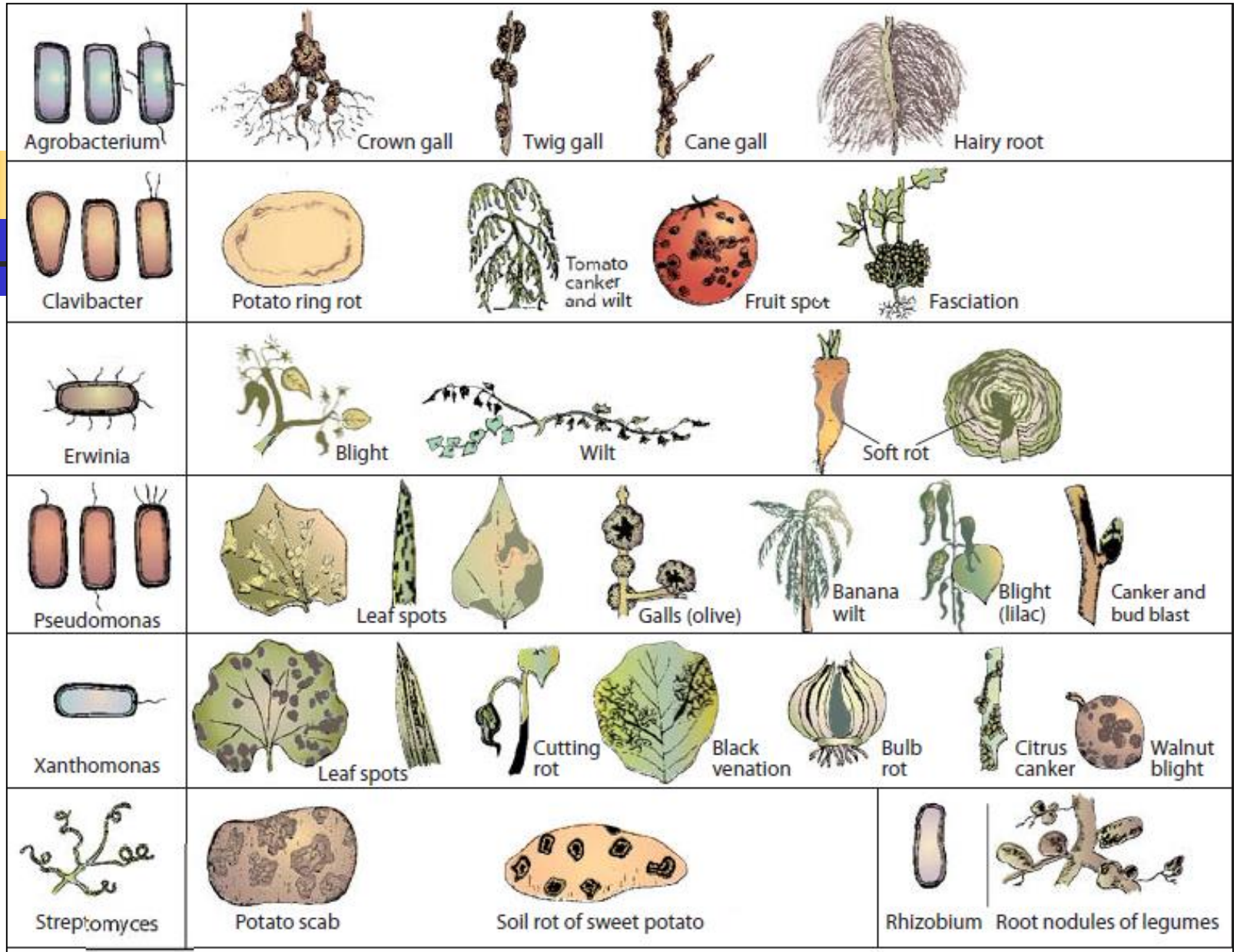


FIGURE 12-4 The most important genera of plant pathogenic bacteria and the kinds of symptoms they cause.

Agrios,2005

Bacterial disease diagnosis

Types of fastidious bacterial diseases/symptoms

- Distortion of leaf and flower tissue
- Growth abnormalities
- Short internodes
- Yellows/stunt

Mollicutes Diseases

Phytoplasma and *Spiroplasma*

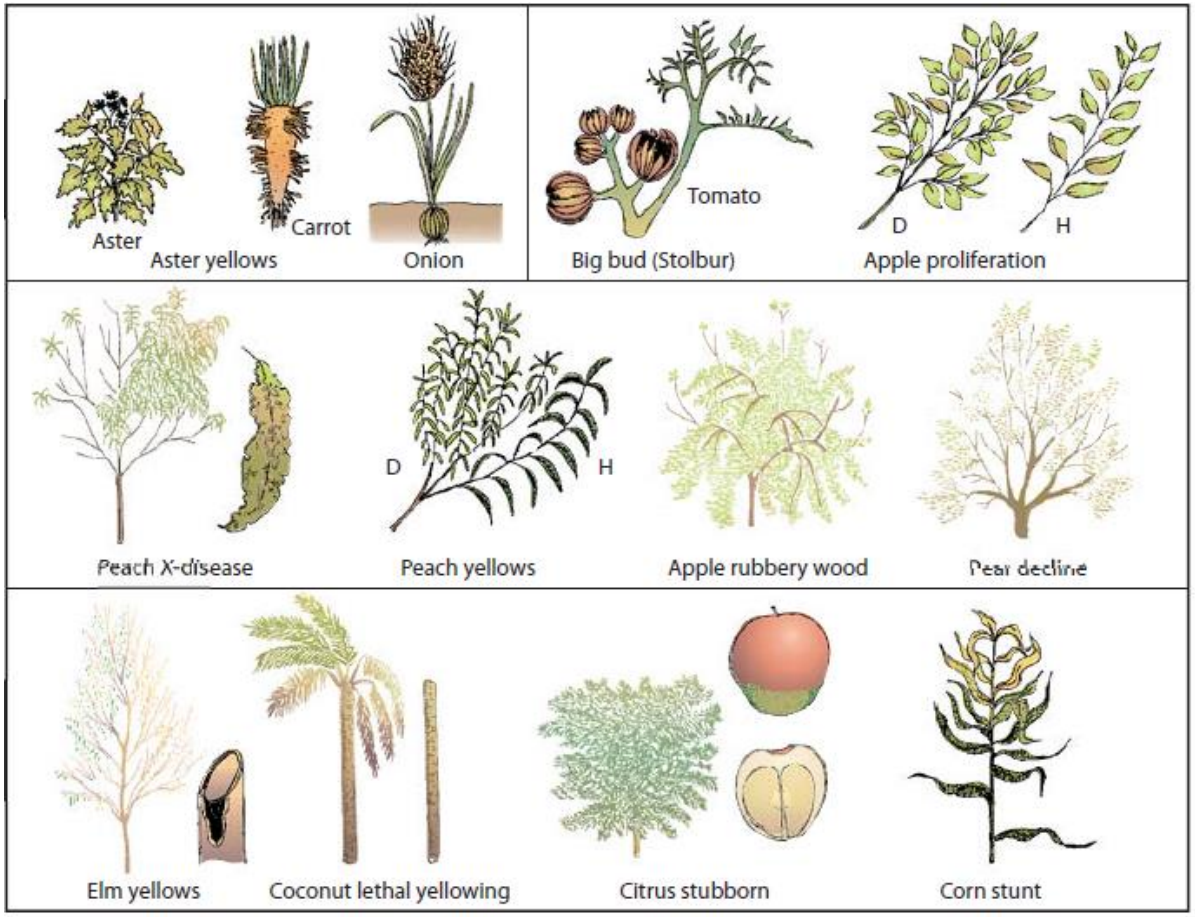


FIGURE 12-53 Symptoms caused by mollicutes. D, diseased plant; H, healthy plant.

Agrios,2005

Bacterial disease diagnosis

Symptoms or Signs

- **Symptoms** are changes in the appearance or growth of the plant in response to a damaging factor.
- In other word, the external and internal reactions or alterations of a plant as a result of a disease such as wilting.
- **Signs** are visual evidence of the damaging factor.
- In other word, the pathogen or its parts or products seen on a host plant e.g. bacterial ooze or fungal spores.
- Ooze, a diagnostic sign of a bacterial infection.

Bacterial disease diagnosis

Symptoms or Signs

Xanthomonas oryzae pv.*oryzae*

	
▪ Droplets of bacterial exudate on young lesions observed during early morning with high dew formation.	▪ Infected leaves wilt and roll up, turning grayish-green to yellow, until the whole seedling dies. ▪ Plants which have survived the disease are stunted and yellowish.

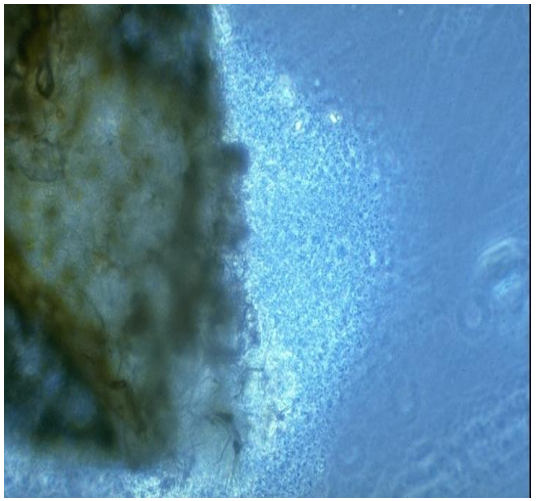
Bacterial disease diagnosis

Disease sign - Bacterial ooze from fruit, stems, and trunks

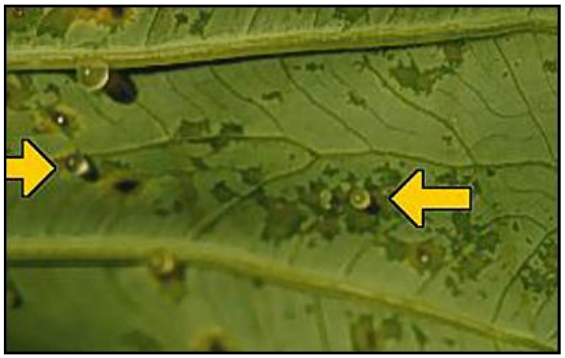
Erwinia amylovora

The fire blight of apple and pear

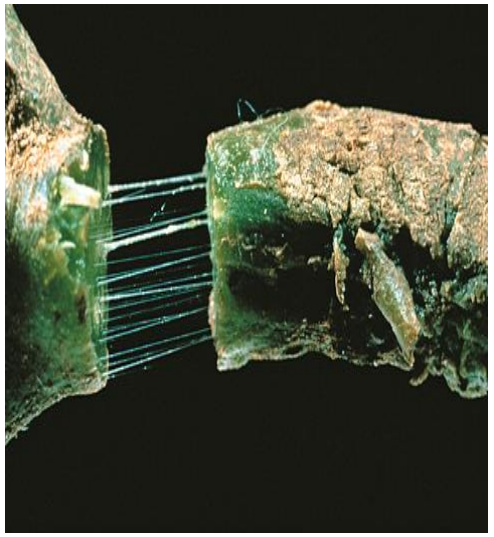
Signs of bacterial infection



Streaming



Oozing



Threads

These droplets are a sign of the pathogen, being composed mostly of bacterial cells.

Necrosis & stunting

Water soaking of tissue

Necrosis, but also some …

Extreme stunting

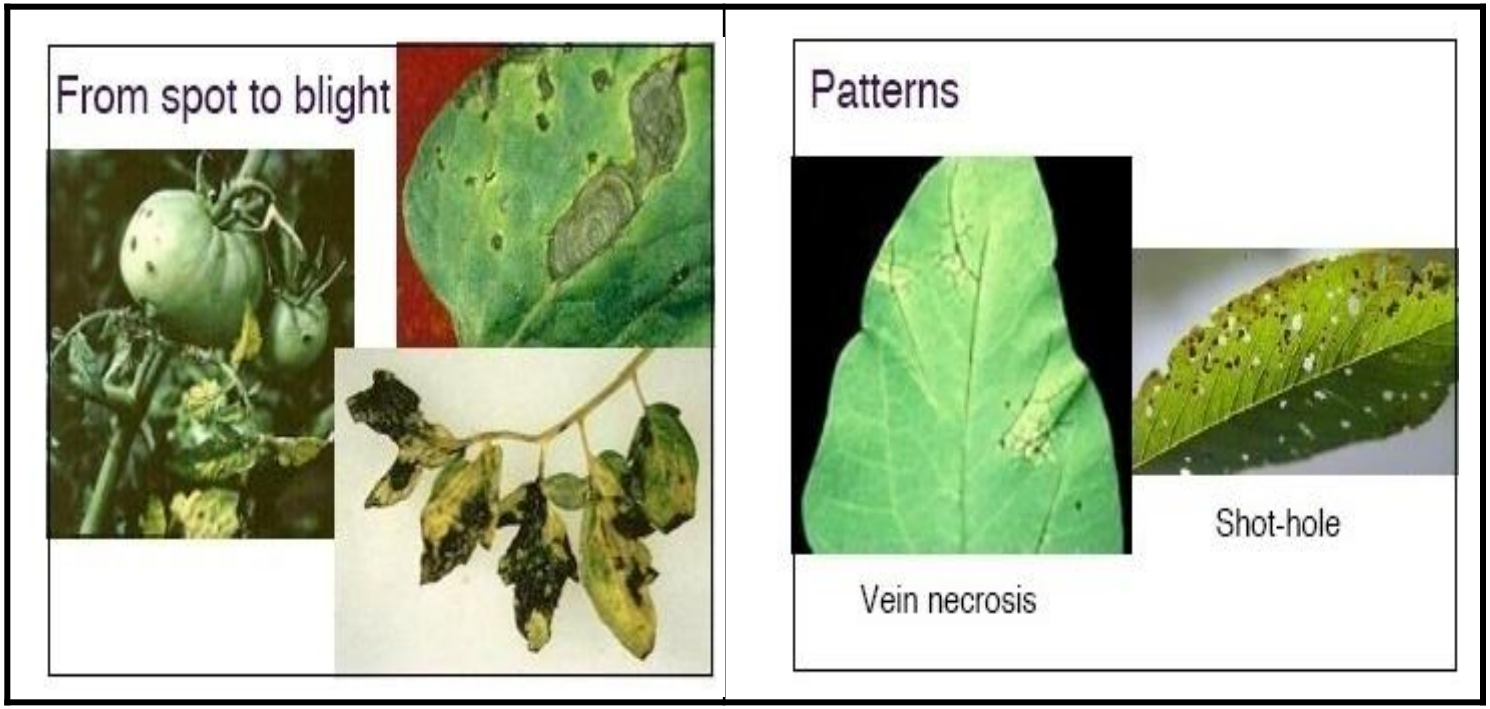
Chorosis, Necrosis & Blight

Chlorosis is the yellowing of normally green tissues due to the destruction of the chlorophyll or the partial failure of the chlorophyll to develop.

Necrosis is dead tissue or plant parts.

Blight is a rapid death of leaf, stem or branch tissues.

Spot, Necrosis & Blight



Blight

Types of Symptoms

Blights

Initially, the bacteria reside on surface of foliage as epiphytes; enter plant via a natural opening (nectarthodes, hydathodes) or wounds

Fire blight of pear and apple

Black rot of cabbage

Guttation drops on hydathodes

Blight

Halo blight

P. savastanoi* pv. *phaseolicola

Bacterial blight of geranium

Xanthomonas hordorum* pv. *pelargonii

Canker

A necrotic (dead), often sunken area on a stem, trunk, or branch of a plant

- Cankers in hardy nursery stock species are characterized by the death of cambium (inner bark) tissue of woody stems, branches or twigs, causing them to sink in.
- They can completely girdle the stem, disrupting the vascular system so that shoots beyond the canker wilt and die through a lack of water.
- Large numbers of smaller cankers can also disrupt the vascular system enough to cause gradual wilting and the death of shoots.

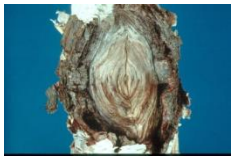
Adlam,2008

Canker

The most common canker pathogens

- The most common canker pathogens are:

1. The fungus *Nectria galligena*, which causes cankers on subjects such as apple, pear, willow, mountain ash, beech and poplar.

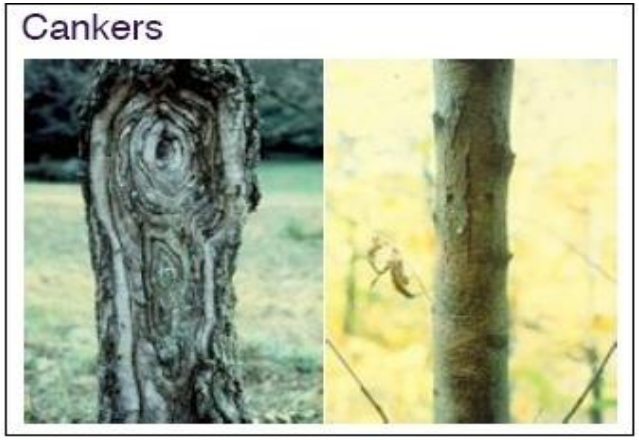


2. The bacterium *Pseudomonas syringae*, which exists as a large number of subspecies or races, which can cause cankers in a wide range of species of trees and shrubs.

Adlam,2008

Canker

A necrotic (dead), often sunken area on a stem, trunk, or branch of a plant



Canker on mulberry
(*P. syringae* pv. *mori*)

Cankers

Canker symptoms

	
Twig canker. Note the black discoloration of diseased bark.	Trunk canker. Discolored inner bark associated with branch and trunk cankers.

Blister

An enclosed raised spot

	
Bacteria blisters on young stem of Eucalyptus caused by *Erwinia psidii*.	Blister spots (small water-soaked raised spots near the calyx end of fruit caused by *Psuedomonas syringae* pv. *papulans*.

Dieback

The browning and death of a plant shoot starting at the tip; either due to disease or climate conditions

Dieback is the progressive death of branches or shoots beginning at the tips and moving toward the main stem, or trunk.

Vascular discoloration: Plants infected with a disease of the vascular tissues (the part of the plant that carries water from the roots to the leaves) will often have brownish streaks in the vascular tissues.

Streak vs. stripe

Sreak is an irregular line left from smearing or motion while stripe is a long, straight region of a single colour

- **Streak:**
- A disease characterized by elongate lesions or areas of discolouration, usually of limited length, on leaves with parallel venation or on stems.
- • An elongated lesion with irregular sides.
- **Stripe:**
- A disease characterized by elongate areas of discolouration, of indefinite length, on stems or on leaves with parallel venation.

Streak vs. stripe

Sreak is an irregular line left from smearing or motion while stripe is a long, straight region of a single colour

	
Bacterial leaf streak of corn caused by *Xanthomonas vasicola* pv. *v asculorum* (synonym *X. campestris* pv. *zeae*).	Sorghum bacterial stripe causad by *Burkholderia andropogonis*.

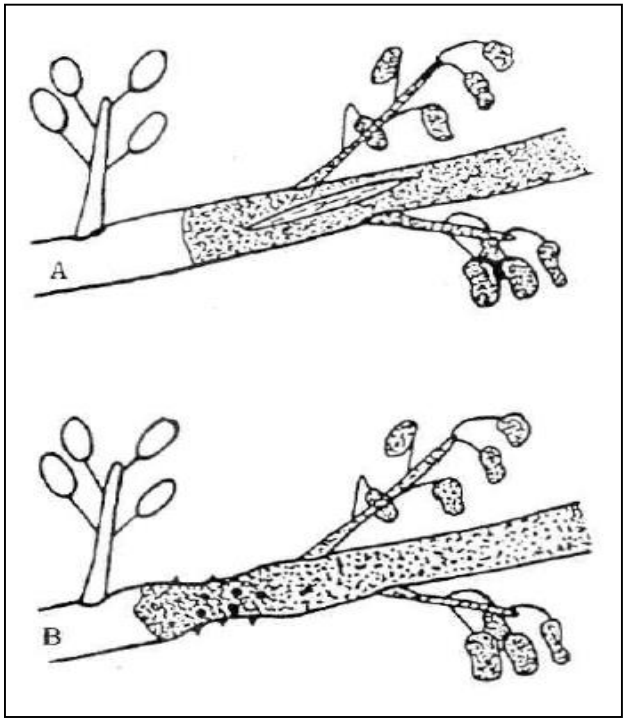
Dieback

A. **Shoot dieback caused by nonliving factors(abiotic):**

- Sudden dying back of a shoot usually indicates nonliving cause such as climatic or chemical damage, not a living factor.
- Damage caused by nonliving factors usually results in a sharp line between affected and healthy bark.
- If dieback is more gradual and there is also cracking of the bark and wood, suspect winter injury.

B. **Shoot dieback (blight) caused by living factors(biotics):**

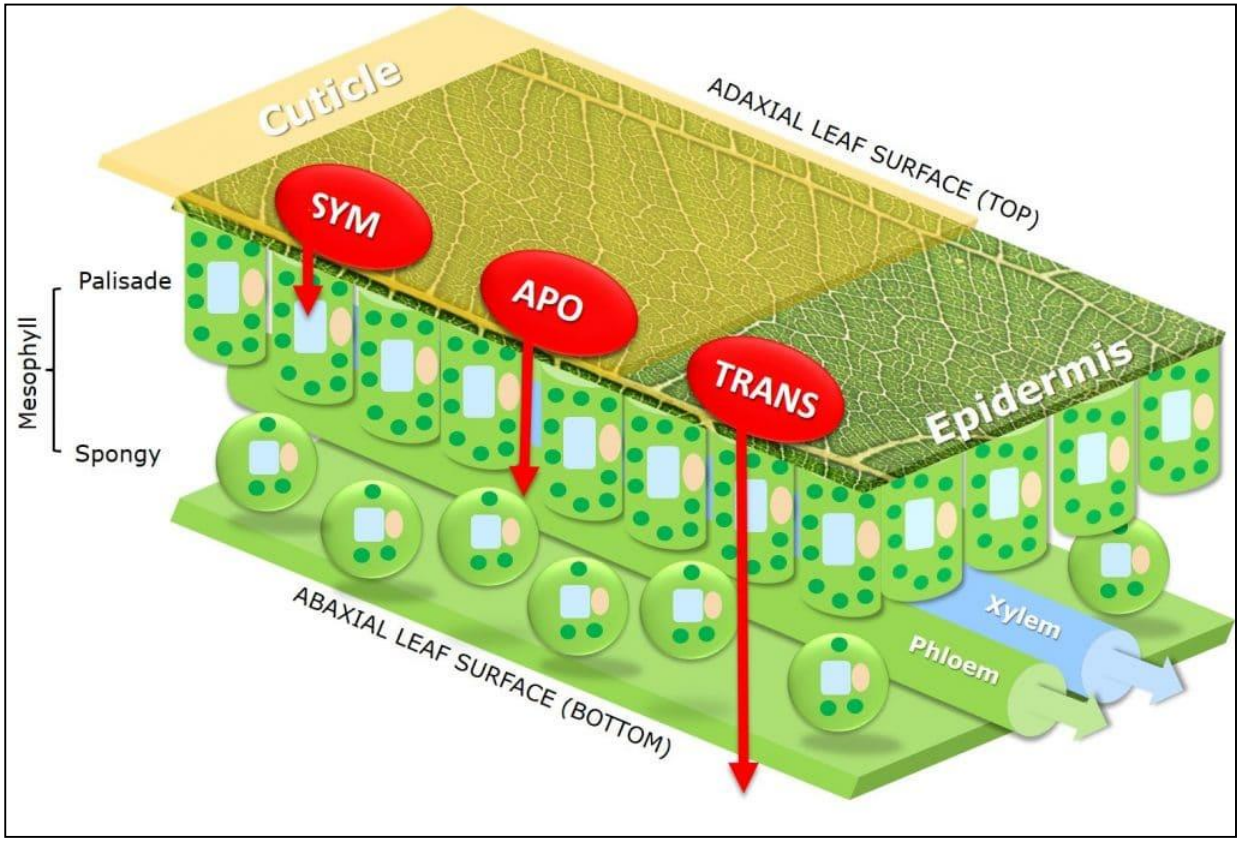
- Gradual decline of shoots and retention of dead leaves may indicate a living factor.
- The margin between affected and healthy tissue is often irregular and sunken.
- There may be small, pinlike projections or bumps over surface of dead bark: These are spore-producing structures of pathogenic fungi.



Vascular symptoms

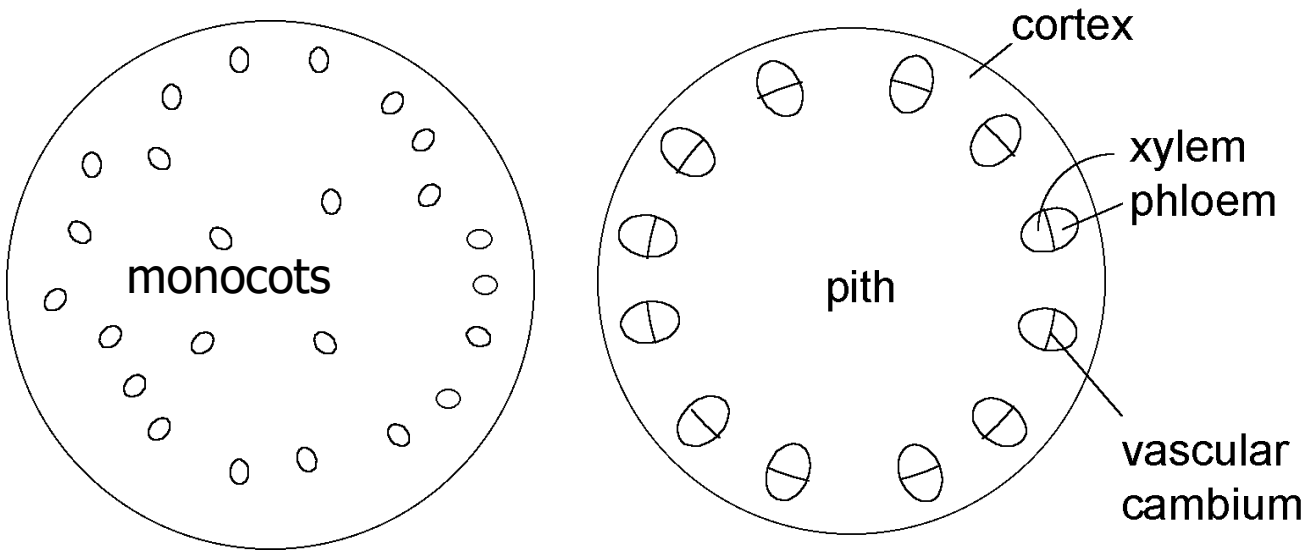
The vascular tissue

Apoplastic (extracellular), symplastic (intracellular) or translaminar (from adaxial to abaxial leaf surface) active ingredient pathways

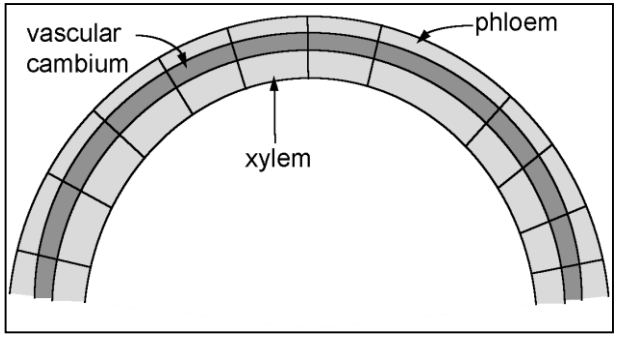


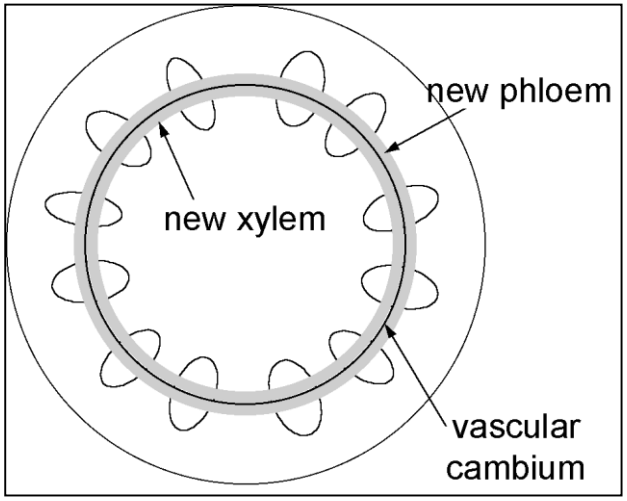
The vascular tissue

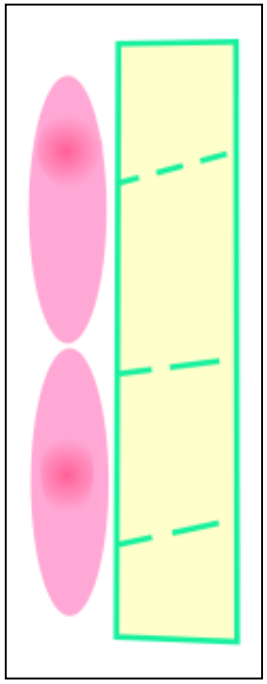
- The vascular tissue is found in bundles that are arranged in a ring (dicots) or scattered (monocots).
- In dicots, the xylem is toward inside; the phloem is toward the outside.



Secondary growth



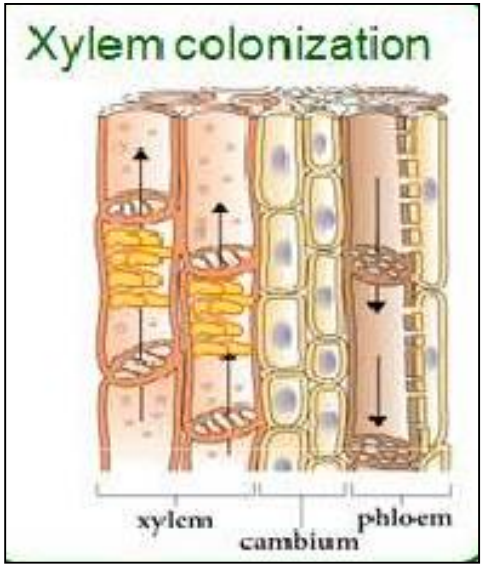


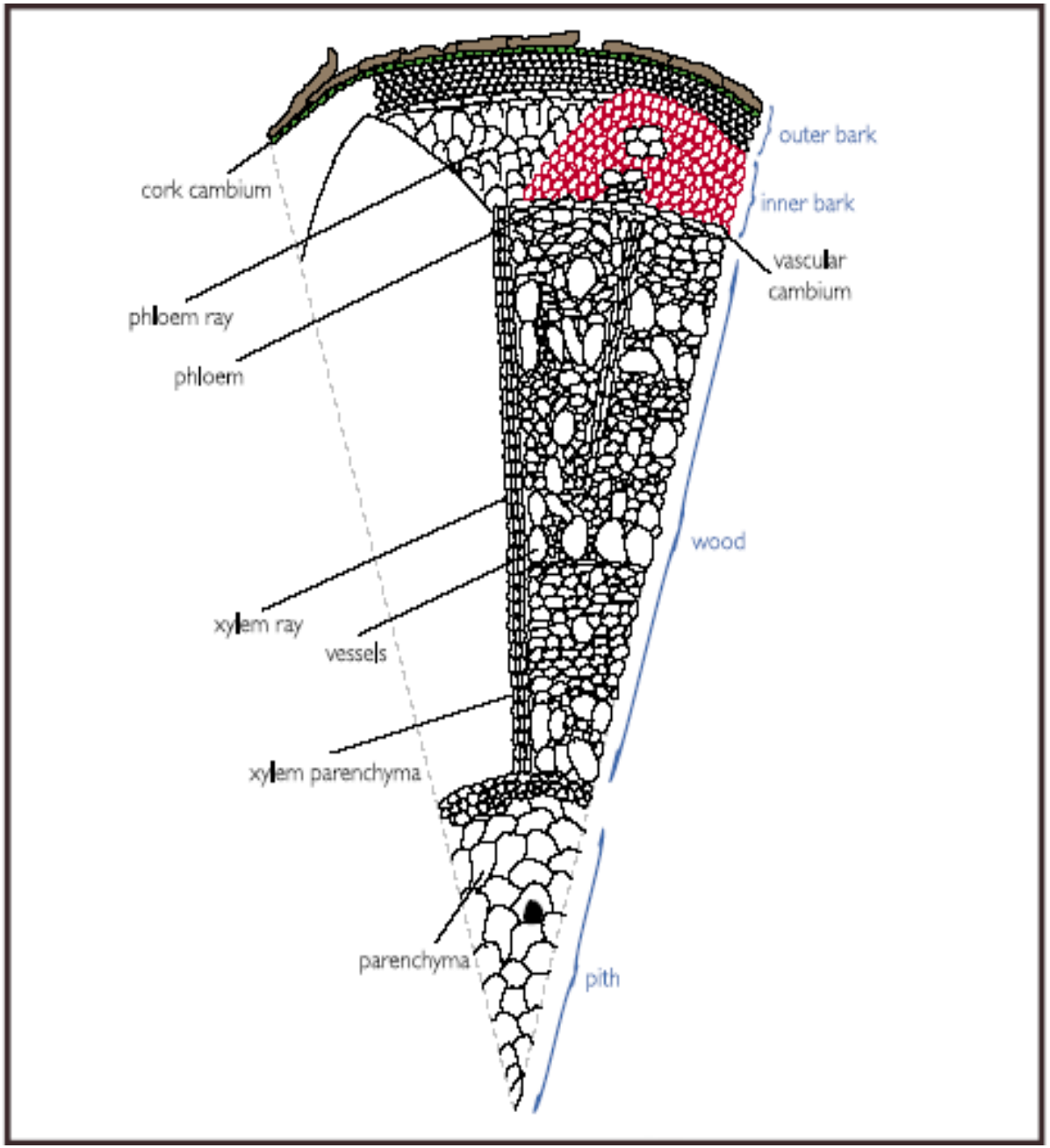


Sieve tube element
Solid green: sieve tube; dashed green: sieve tube plates; light pink: companion cell; dark pink: nucleus; yellow: nutrients. Each sieve tube element is normally associated with one or more nucleated companion cell, to which they are connected by plasmodesmata (channels between the cells).

Chapter 46 - Plant Structure;Wikipedia

Vascular system

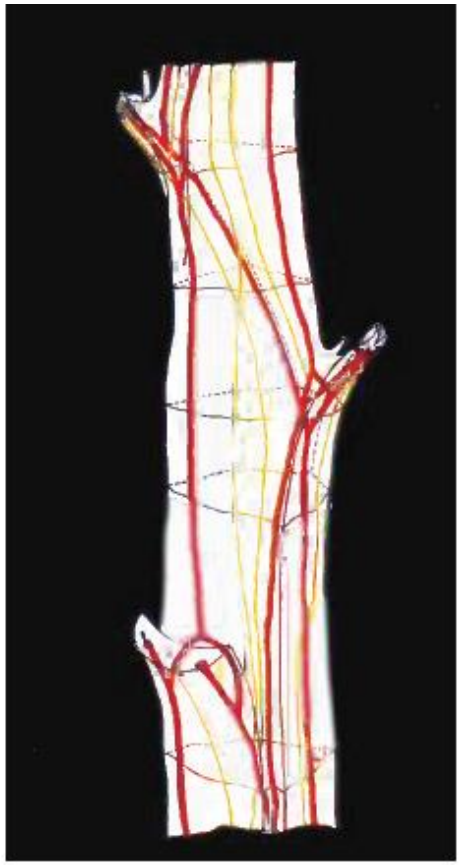




Vascular bundles

Vascular pathogenic bacteria movement

- Diagrammatic longitudinal section of a potato stem, showing the course of vascular bundles in main stem and petiole bases.
- Vascular pathogenic bacteria can easily move through these bundles to all plant parts, including seeds and roots.
- Large vascular bundles: red.
- Small vascular bundles: yellow.



Janse,2006

Bacterial Wetwood

Tree bleeding

1. Slime flux or bacterial slime

- This familiar symptom is associated with bacterial wetwood or slime flux disease.
- This disease is a major cause of rot in the trunks and branches of hardwood trees.
- Slime flux is caused by a bacterial infection in the inner sapwood and outer heartwood areas of the tree and is normally associated with:

1. Wounding, or
2. environmental stress,
3. or both.

Slime Flux or Ooze: A bacterial discharge that oozes out of the plant tissues, may be gooey or a dried mass.

Nix,2019

Bacterial Wetwood

Tree bleeding

Slime flux or bacterial slime

Bacterial Wetwood

Tree bleeding

Slime flux or bacterial slime

- The attacking bacteria in a slime flux infection alters wood cell walls, causing moisture content of the wood to increase to the point of injury.
- Slime flux is identified by:

1. dark liquid streaks running vertically below an injury and
2. a foul-smelling and slimy seepage running down the bark.

- Chemically, the weeping liquid is actually fermented sap, which is alcohol-based and toxic to new wood.

Nix,2019

Bacterial Wetwood

Tree bleeding

Slime flux or bacterial slime

- Bacterial wetwood is a is a common disease that affects the central core or bark of many shade and forest trees.
- A water-soaked condition of wood, occurs in the trunk, branches, and roots of many shade and ornamental trees such as elms, especially older elms, willow, populars, oak, plane (*Platanus orientalis*), common hornbeam, etc.
- The disease also affects species of apple, ash, birch, cherry, fir, honeylocust, linden, maple, oak, sycamore, plum, and poplars.
- The disease is often not obvious in trees less than 10 years old.

Jacobi,2014;Small,2017

Bacterial Wetwood

Slim flux or bacterial slime

		
Wetwood slime	**Dried slime**	**Retarded callus formation**

Jacobi,2005

Bacterial wetwood on elm

Slim flux or bacterial slime

		
Bacterial wetwood on elm (*Ulmus*)	**Discoloration on trunk of elm (*Ulmus*) caused by bacterial wetwood**	**Ooze of bacterial wetwood on Scotch or wych elm (*Ulmus glabra*)**

Missouri Botanical Garden

Bacterial Wetwood

Slime flux or bacterial slime

- A wound may be a single puncture as with the nail holding this number tag.
- The flow started within minutes of the nail being driven through the bark.

Patch,2004;..

Bacterial Wetwood

Tree bleeding

2. Alcohol flux

- Alcohol flux is a similar disease but is characterized by a milky frothy ooze and sweet alcohol smelling infection of the bark.
- This disease is most commonly seen on poplars and globe willow in Colorado.

Jacobi,2014

Bacterial Wetwood

Alcohol flux

		
White ash with milky alcohol flux **(J. Walla)**	**Milky froth of alcohol flux** **(J. Walla)**	**Globe willow with alcohol flux** **(W.R. Jacobi)**

Jacobi,2014

Bacterial Wetwood

Causal agents

- In some trees, especially elms and poplars, bacteria are consistently associated with wetwood and apparently cause it.
- In elms, the following bacteria are commonly isolated from diseased wood:

1. *Enterobacter cloacae*
2. *Enterobacter nimipressuralis* (formerly *Erwinia nimipressuralis*),
3. *Pantoea agglomerans* (synonym *Erwinia herbicola*),
4. *Bacillus megaterium*
5. *Pseudomonas fluorescens*
6. *Klebsiella oxytoca.*

- In plane trees(*Platanus orientalis*), the bacterium not identified(Wikipedia,2017).

Bacterial wetwood vs. normal sapwood

- Bacterial wetwood in broadleaved trees is differentiated from normal sapwood or heartwood by its visibly:
- Darkened color,
- Sour or rancid odor due to an accumulation of fatty acids,
- Higher moisture content,
- Increased alkalinity (by one pH unit or more)
- High gas pressure,
- Higher mineral content,
- Less oxygen and more carbon dioxide.
- It often contains methane gas.
- Liquid from elm wetwood may have up to 11 times more calcium, magnesium, and potassium cations than healthy sapwood.

Pataky,1999

Bacterial Wetwood
Causal agents and Managment

- Causes:
- Bacteria complex
- Enters through wounds
- Management:
- The cause of the damage, which can be living or non-living, should be determined before remedial or preventive action is decided upon.
- Problem is mostly cosmetic(superficial)
- Consider tree removal
- 10% bleach solution to reduce mess.

Patch,2004; Horticulture/PlantProblems/2010

Bacterial Wetwood
Causal agents and Managment

- In reality, there are no active measures to effectively treat the bole(the stem or trunk of a tree) rot caused by slime flux disease.
- The best current advice is to maintain the tree's overall health so that the tree can isolate the spot and grow good wood around the diseased portion.
- Affected trees will usually overcome the problem themselves and seal off the damage.

Nix,2019

Bacterial Wetwood
Causal agents and Managment

- The basic control for slime flux disease is prevention.
- Avoid wounding the tree and make sure to plant trees in locations where there are no stresses from urban soil compaction, such as walking and vehicle traffic.
- Trim away broken, torn(remove) branches promptly.
- **Avoid Insecticide Use**. Spraying for insects in an effort to cure slime flux is a waste of money and may actually perpetuate slime flux disease.

Nix,2019

Bacterial rots

- Rot is the disintegration, discoloration, and decomposition of plant tissue.
- A dry or hard rot if the decay is firm and dry.
- A wet rot if soft, watery and foul smelling.

Bacterial rots

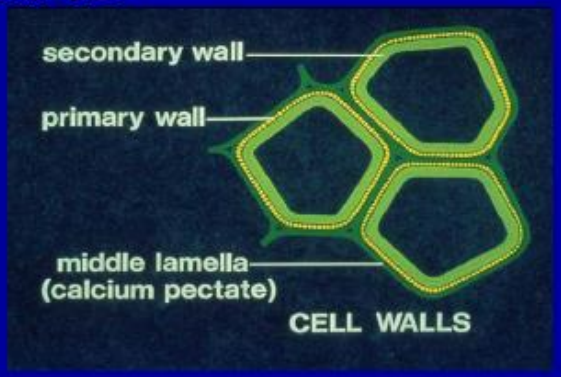
Types of Symptoms

Soft Rots

Bacteria reside in lenticels

Under anaerobic conditions, they hydrolyze the pectin in the middle lamella, which leads to necrosis and collapse of tissue.

Cause disease in stems, fruits, and storage organs (tubers).



Soft rot of potato

Pectin-based
Selective media
for isolation

Soft rot

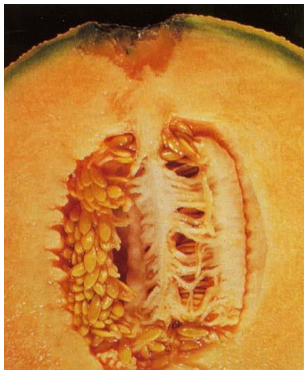
Pectobacterium (ex. *Erwinia*) *carotovorum*

Cabbage

Lettuce

Cabbage vs lettuce

Cabbage consists of a short stem and a head that forms a bulb-type shape. It is usually green in color and the outer leaves are harder to eat while the inner ones are softer. On the other hand, lettuce also has a short stem and leaves that wrap around each other. It tends to be greener than cabbage, owing to a high amount of chlorophyll. Compared to cabbage, lettuce is soft in texture and has high water content.



Cantaloupe

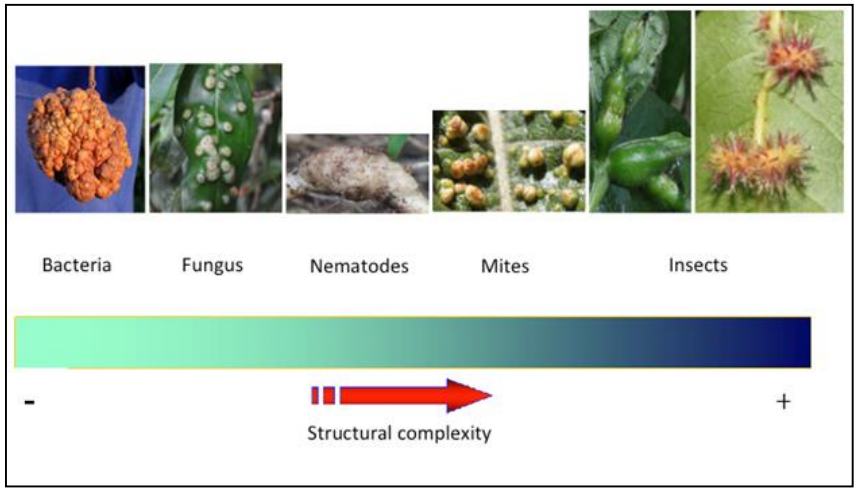
Galls have a variety of cases

Causal agents

- Galls can be the result of attack by certain:

1. Insects,
2. Bacteria,
3. Fungi, or
4. Nematodes.

- Whereas crown gall tumor is caused by pathogenic species of *Agrobacterium*.



Galls and tumors

Underdevelopment

Overdevelopment

Underdevelopment, distortion

Virus, or some herbicides

Overdevelopment, gall, tumor

here: nematodes

Bacterial galls or tumors

Neoplastic (abnormal proliferation) growths

- Bacterial galls:

1. *Pseudomonas savastanoi* pv. *savastanoi*
2. *Rhodococcus fascians*
3. *Pantoea agglomerans* pv. *betae*

- Bacterial crown-gall tumors:

1. *Agrobacterium tumefaciens*. Virulent strains carry large Ti (tumour-inducing) plasmids with a size of 150-250 kb.

- **These plasmids contain:**
- tumour genes, virulence genes, genes for production of growth hormones, production and utilization of amino acid derivatives (opines).

Crown gall tumor

Agrobacterium tumefaciens

- The host range of this bacterium is extremely wide, including more than 600 species of (mainly) dicotyledon plants.
- The galls are initially small and usually white or tan, more or less round, and spongy in texture.
- As the galls enlarge, the outer tissue gradually darkens to brown and becomes convoluted and rough, and the inner tissue becomes hard.
- On perennial hosts(plant that lives for more than two years), the galls often grow to about 2.5 centimeters (1 inch) in diameter.

Bacterial galls and tumors

- Bacterial galls are tissue swellings generated by:

1. Hypoplasia(inadequate or below-normal number of cells), or
2. Hypertrophy (increase in the size of cell),
3. hyperplasia(increase in the number of cell).

- physiological proliferative increase in number of cells) caused by the hormone-balance disturbing influence of the bacterium.

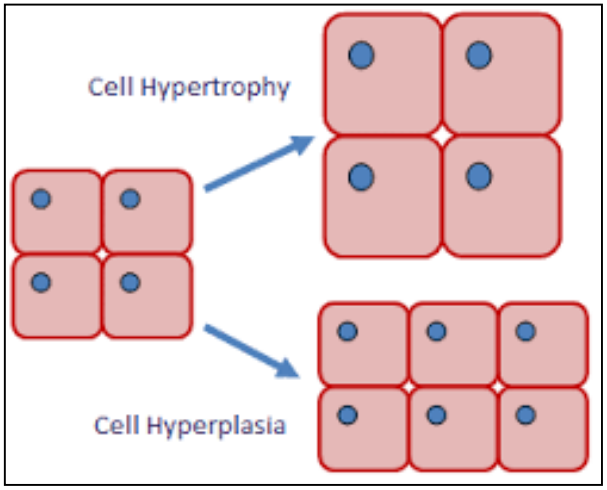
Janse,2006; Mansfield *et al.*,2012

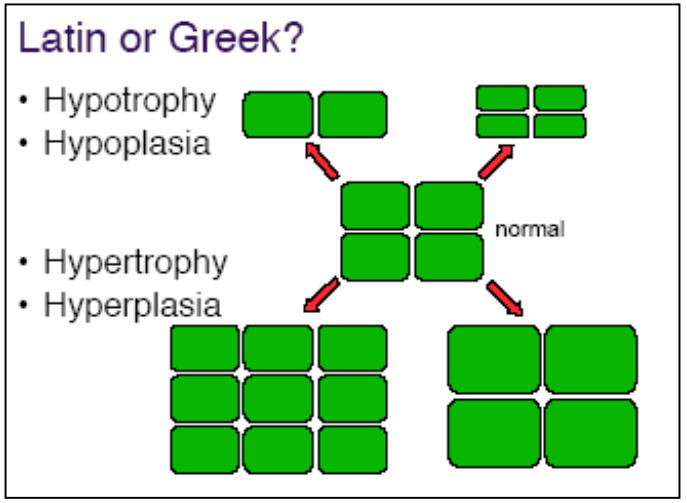
Bacterial galls and tumors

The uncontrolled growth of plant tissue

Hypertrophy and hyperplasia vs. hypotrophy and hypoplasia

- **The prefix "hyper" means abnormally increased, and "hypo" means abnormally decreased.**





Hypertrophy (increase in the size of cell),
hyperplasia(increase in the number of cell).
hypotrophy (decrease in the size of cell),
hypoplasia(decrease in the number of cell).

Leafy galls
Rhodococcus fascians

The Royal Horticultural Society

Leafy gall of *Verbascum* at the base of the plant

Leafy galls of *Viola* at leaf axils

Leafy gall at the base of *Erysimum* inoculated with *Rhodococcus fascians*

Putnam and Miller

Tumors/Crown gall

Hypertrophy

		
Crown gall on chrysanthemum ***Agrobacterium tumefaciens***	**Crown gall on *Ficus benjamina*** ***Agrobacterium larrymoorei***	**Crown gall on *Gypsophila*** ***Pantoea agglomerans***

Leafy galls
Rhodococcus fascians

- The nature of fasciation induced upon *R. fascians* infection is dependent on:

1. The host plant (genus, species and cultivar),
2. Age of plant (young growing tissue is particularly sensitive but becomes less sensitive as it matures),
3. Bacterial strain (avirulent to virulent strains have been characterized), and on
4. Plant growth conditions and infection path.

- Symptoms range from witches'-broom and over-fasciation to leafy gall fasciation to leafy gall.

Leafy galls
Rhodococcus fascians

- Fasciations are formed when several hypertrophied shoots coalesce.
- They carry malformed, small leaves that show thickened petioles and veins (Roussaux, 1965).
- Fasciation further develops into leafy galls when the growth of the fleshy shoots is completely inhibited and their structure is disorganized.
- The root system is generally not affected.
- *R. fascians* has been isolated from root galls on raspberry.
- *R. fascians* provokes severe malformation of the bulbs.

R. fascians vs. *Agrobacteria* infections

1. Both *Rhodococcus fascians* and *A. tumefaciens* are known to infect herbaceous and woody plants.
2. Both bacteria have a wide host range:

- Over 60 species for *R. fascians*, and
- Hundreds for *A. tumefaciens*.

3. *R. fascians* infects monocots as well as dicots,

- *A. tumefaciens*, infects only dicots.
- There is no evidence that *R. fascians* can systemically infect plants.

Oregon Association of Nurseries,2011

R. fascians vs. *Agrobacteria* infections

4. *Rhodococcus fascians* isolates produced only leafy galls or shoot proliferation.

- In no case did *Agrobacterium* inoculation result in leafy gall production.

5. Infection with *A. tumefaciens* causes swelling of tissue into tumors or galls on stems or roots, but these galls do not differentiate into buds or stems.

- In contrast, leafy galls caused by *R. fascians* are well differentiated into easily recognized plant parts.

Oregon Association of Nurseries,2011

R. fascians vs. *Agrobacteria* infections

Iberis flower	Hibiscus flower
	
	
Shoot proliferation of *Iberis* (candytuft) caused by *R. fascians*.	Crown gall at the base of a hibiscus (mallow family) caused by *A. tumefaciens*.

Oregon Association of Nurseries,2011

Bacterial stem fasciation

Rhodococcus fascians

- Fasciation (flattened growth) of a pumpkin stem, which may be due to:

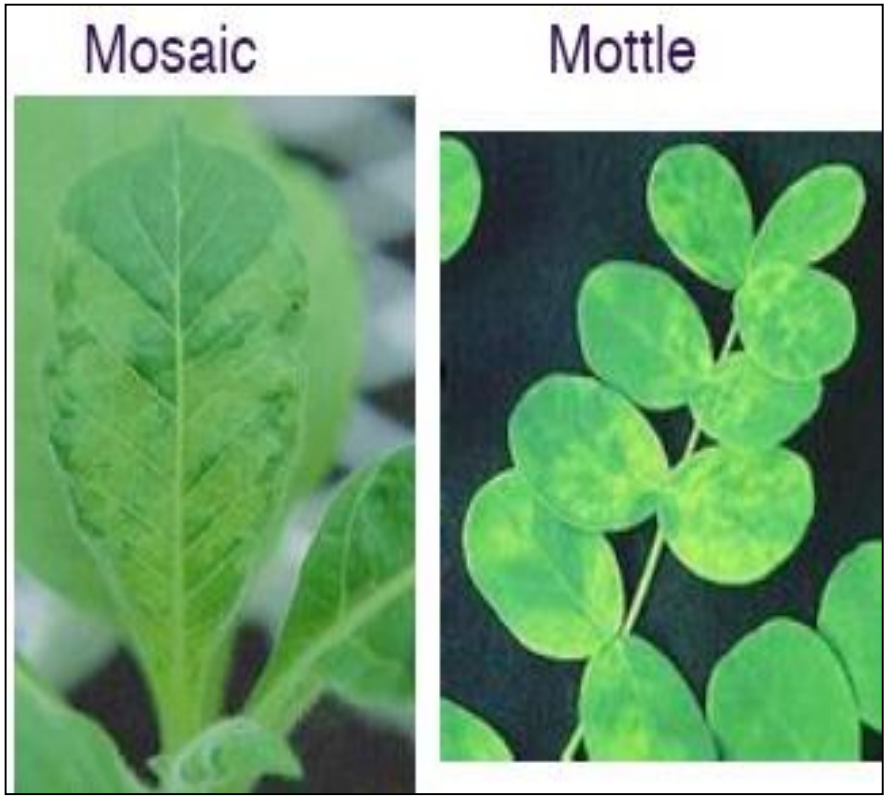
1. disease,
2. a genetic condition, or
3. injury.

Oregon Association of Nurseries,2011

Scab

- Scab: The filamentous bacterium *Streptomyces scabiei* causes excrescences, called scab, on:
- potato (sugar) beet, radish and carrot.

Leaf symptoms
Mosaic and mottle



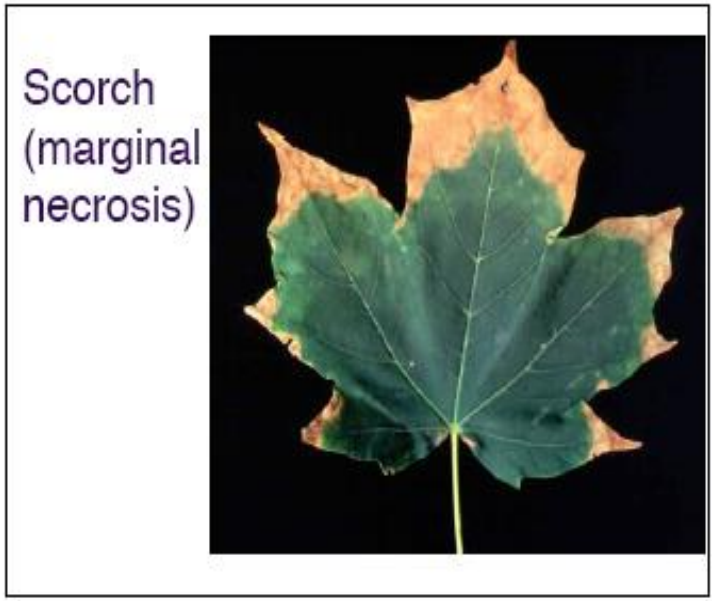
Mosaic on wheat caused by *Clavibacter tessellarius*.

Damping-off

- Damping-off diseases caused by soilborne fungi and transplant diseases usually associated with fungi or bacteria which survive with seed or plant residue.
- Bacterial leaf spot and damping off of lucerne or alfalfa (*Medicago sativa*) caused by *X. alfalfae* subsp. *alfalfae*.

Leaf scorch
Xylella fastidiosa

Pierce's Disease of grape
Xylella fastidiosa



Scorch is the burning or drying and browning of leaf margins.

Scorch usually results from unfavorable environmental conditions for the plant.

Virescence

Floral parts are replaced by vegetative structures

Virescence is closely associated with phyllody (the abnormal development of flower parts into leaves)

Virescence: loss of normal flower color, green flowers.

plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf;..

Phyllody

Conversion of floral organs into leaves

Virescence is closely associated with phyllody (the abnormal development of flower parts into leaves).

Phyllody: production of leaf like structures in place of flowers.

Wikipedia,2018

Discoloration
Reddening

RED STRIPE
(Xanthomonas Rubrilineans)

- **Symptoms**
- Appears in may
- Leaves show red streaks

Rosette or resetting

Phytoplasma, or a virus causes rose rosette disease

- symptoms vary on different rose types and cultivars.
- Symptoms associated with rose rosette disease include:
- Witches' broom;
- Malformed flowers and leaves;
- Excessive leaf growth and thorniness;
- Extreme red discoloration of plant tissue; Lateral shoot elongation (abnormal lengthening of side branches/twigs);
- Enlarged/thickened stems.

Rosette or resetting

Phytoplasma, or a virus causes rose rosette disease

	
Phytoplasma Associated with Rose Witches'-Broom. Distorted flowers and increased, atypical reddish color on the bulb.	Malformed shoots, smaller leaves and increased red discoloration.

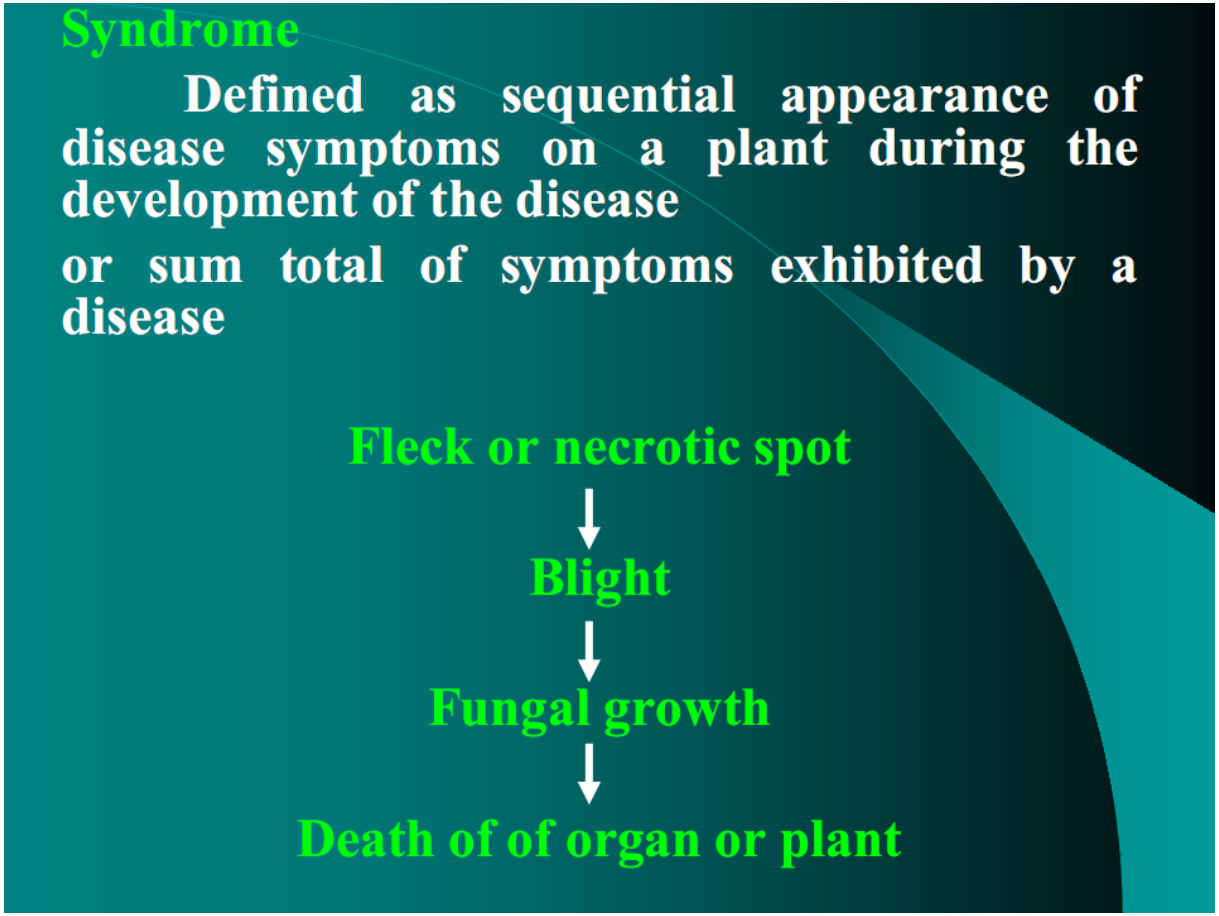
Ong and Co-workers

Syndromes
Group of signs and symptoms

- Syndrome means basically "running together".
- A disease syndrome is the group of signs and symptoms which collectively characterize a disease.
- A syndrome is a group of symptoms that doesn't have a definitive diagnosis.
- Familiarity with a disease's signs or symptoms is not enough to diagnose a disease.
- It is necessary to know the syndrome and case history.
- Laboratory work is necessary for diagnosis.

University of California,2009;..

Syndromes
Group of signs and symptoms



The Syndrome

Angular leaf spot, bacterial blight and rot of cotton bolls

X. axonopodis pv. *malvacearum*

- Infected leaf has angular, dark-green watersoaked spots with red to brown margin that will eventually turn dark-brown or black due to death of the infected tissues.
- Severe infestation leads to premature falling of leaves (defoliation).
- As the disease progresses, the leaf petiole and stem may become infected resulting in premature defoliation.
- An infected stem is girdle with black lesions (black arm syndrome) causing it to die and break.
- An infected boll has round watersoaked spots causing it to rot.

The Syndrome
"Basses Richesses" of Sugar (SBR)beet
SBR BLO or *Ca.* Arsenophonus phytopathogenicus

- The disease of sugar beet known as the syndrome "basses richesses" (SBR).
- It mainly is associated with an uncultivable phloem-restricted bacterium-like organism (BLO) called SBR BLO or SBR bacterium, tentatively identified as `*Candidatus* Arsenophonus phytopathogenicus.
- SBR symptoms appear in late summer.
- SBR causes a loss of taproot sugar content.
- A brownish discoloration of vascular tissues, seen after cutting the tap root, is the most characteristic symptom of plants affected by SBR.

SBR bacterium is closely related but distinct from the phloem restricted plant pathogen, "*Candidatus Phlomobacter fragariae*".

Sémétey *et al.*,2007;Bressan *et al.*,2009

The Syndrome
"Basses Richesses" of Sugar (SBR)beet
SBR BLO or *Ca.* Arsenophonus phytopathogenicus

- It is a novel species, for the bacterium associated with sugar beet and strawberry diseases and transmitted by the planthopper *P. leporinus*.
- Affected plants present new shoots with small, narrow leaves and narrow and chlorotic laminae.
- Old leaves are yellow and necrotic.
- A honey brown discoloration of tap root vascular tissues was observed in all plants.
- Although it is acknowledged that many aspects of the biology and epidemiology of this disease remain highly uncertain.

Gatineau *et al.*,2001;EPPO,2012; Bressan *et al.*,2012

The Syndrome
Varnish spot of lettuce to lettuce rot
P. cichorii

- Specific syndromes have been described on some hosts.
- 'Varnish spot of lettuce' affects the blades and petioles of the inner leaves of head lettuce varieties, and is characterized by shiny, dark-brown, necrotic lesions.
- Lesions range in size from a few millimeters to very large and are not delimited by veins (Grogan *et al.*, 1977).
- Vein blackening of the outer leaves is possible on lettuce grown in severely infested soils.
- Disease on lettuce is frequently reported as lettuce rot.

Bacterial disease symptoms on specific host plants

Bacterial disease (symptom) diagnosis

Alder- ***Alnus glutinosa***

Canker disease

Pseudomonas syringae pv. *syringae*

Alder canker disease

Scortichini,2006

Alfalfa- ***Medicago sativa***

The main bacterial diseases of alfalfa

Bacterial leaf spot and damping off	***Xanthomonas alfalfae* subsp. *alfalfae***
Bacterial sprout rot	***Dickeya chrysanthemi***
Bacterial sprout wilt	***Erwinia persicinia***
Bacterial wilt	***Clavibacter insidiosus* = *Corynebacterium insidiosum***
Crown gall	***Agrobacterium tumefaciens***
Bacterial stem blight	***Pseudomonas savastanoi* pv. *phaseolicola***
Crown and root rot complex	***Pseudomonas viridiflava***
Brown rot of alfalfa or lucerne plants	***Pseudomonas marginalis* pv. *alfalfae***
Bacterial stem blight	***Pseudomonas syringae* pv. *syringae***
Dwarf	***Xylella fastidiosa***
Stunted and yellow alfalfa	**'*Candidatus* Phytoplasma asteris'**

Association of *P. viridiflava* with alfalfa root and crown rot was also reported(Lukezic *et al.*,1983 and Heydari *et al.*,2012).

Bacterial wilt

C. michiganensis subsp. *insidiosus*

Infected plants are yellow-green in colour, exhibit stunted growth. Root infection appears in the form of yellow–brown discoloration of the vascular vessels. Seed production is limited in plants infected with *C. michiganensis* subsp. *insidiosus*.

US IPM Online; EFSA PLH Panel,2014; CAB International, 2007

Bacterial wilt

C. michiganensis subsp. *insidiosus*

- Symptoms become apparent as the stand gets older (3 or more years).
- Infected plants are stunted and have a yellow-green colour.
- In severe cases, the plant has spindly stems with small, distorted leaves.
- Infected plants that are stressed by water, heat or both will wilt or die and are scattered throughout the stand.
- Infection stresses the plant and increases its susceptibility to winterkill.

Staff,2009

Bacterial wilt

C. michiganensis subsp. *insidiosus*

Symptoms on plant: A plant infected by bacterial wilt showing stem proliferation, stunting and discoloration.

A healthy (left) and infected plant comparison: Healthy (left) and infected (right) plants. The infected plant shows slight discoloration of the taproot.

Bacterial wilt

C. michiganensis subsp. *insidiosus*

Cross sections of a healthy root (bottom) and diseased roots (top) of Lucerne infected by *Cmi*.

Healthy plants (right) and diseased plants (left) of Lucerne.

CAB International, 2007;Alipour,2013

Bacterial leaf spot
X. alfalfae subsp. *alfalfae*

- Bacterial leaf spot with stem lesions is caused by the bacterium *Xanthomonas campestris* subsp. *alfalfae* (*X. alfalfae*).
- Bacterial leaf spot begins as small, irregular, yellowish, watersoaked spots on the leaves. These spots enlarge, turn brown to black, and may develop a light yellow to tan, papery center.
- The lesions usually shine due to dried, bacterial exudate.
- Severe defoliation is common.
- The stem lesions are watersoaked and "greasy" at first, later turning light to dark brown or black. Lesions may coalesce and extend for several inches.
- Seedlings are often killed, especially in late summer or early fall seedings.
- The disease is favored by extended periods of hot, rainy, windy weather. Optimum growth of the bacterium occurs at 82 to 90 F (27 to 32° C).
- The casual bacterium overwinters in crop debris and seed. It is spread by wind and rain, insects, all types of equipment, and by infected forage.
- An invasion of alfalfa tissue occurs through a variety of wounds, especially those made by blowing sand or soil particles.

courtesy of University of Minnesota,2002

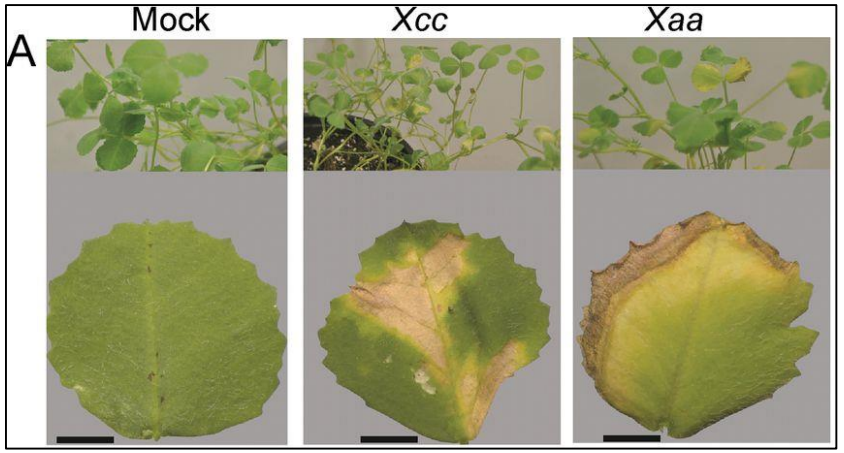
Alfalfa

Bacterial leaf spot

Effect of xanthomonad contamination on *Medicago truncatula*

X. alfalfae subsp. *alfalfae*

- Representative phenotypes after infiltrating leaves with:
  1. Water (control),
  2. *Xanthomonas campestris* pv. *campestris* (*Xcc*), and
  3. *Xanthomonas alfalfae* subsp. *alfalfae* (*Xaa*).
- Observations were made 10 d after inoculation.
- HR following *Xcc* inoculation was already visible 48h after inoculation.



Terrasson *et al.*,2015

Alfalfa bacterial stem blight

Pseudomonas syringae pv. *syringae*

- Typical symptoms of bacterial blight of alfalfa on leaf and petiole.
- Symptoms were initially yellowed area on leaves, within which water-soaked, irregular spots developed.
- These spots eventually coalesced to produce large necrotic areas.
- Symptoms on petiole and stem include water-soaked lesions, which later turned brown.

A new disease of alfalfa was observed for the first time in some areas of the Kurdistan province in Iran.

Harighi,2007

Dwarf disease

Xylella fastidiosa

The small, stunted blue green plant at the right is infected with alfalfa dwarf.

US IPM Online

Stunted and Yellow Alfalfa

'*Candidatus* Phytoplasma asteris'

	
Stunted yellow alfalfa plant. (photo by Tim Fritz)	**Leaf crinkling on problem alfalfa plant.** (photo by Jeff Graybill)

Hall,2011

The main bacterial diseases of almond

Crown gall	***Agrobacterium tumefaciens***
Bacterial canker	***Pseudomonas amygdali***
Bacterial spot	***Xanthomonas arboricola* pv. *pruni***
Almond leaf scorch	***Xylella fastidiosa***
Phony Peach Disease	***Xylella fastidiosa***
Almond witches broom	**'*Candidatus* Phytoplasma phoenicium'**

Crown gall of almond

Agrobacterium tumefaciens

Bacterial canker

Pseudomonas amygdali

- Natural and artificial infection only successful on almond.
- Perennial cankers on branches and twigs, usually at leaf scars, that show a lot of hyperplastic activity (swelling).
- Girdling caused death of branches.
- Leaf scars are likely places of infection, just after leaf fall and in wet conditions.

Janse,2006

Bacterial spot

Xanthomonas arboricola pv. *pruni*

- The symptoms of bacterial spot include multiple lesions on the hulls with large balls of amber colored "gum" or "sap".
- Over time, these spots can grow into slightly depressed lesions on the hull.
- Eventually the infected nuts may shrivel and fall from the tree.
- Occasionally angular leaf spots can be seen.
- The symptoms should not be misdiagnosed as leaf footed bug feeding injury or anthracnose.

Duncan *et al.*,2013

Almond leaf scorch

Xylella fastidiosa

Infected trees bloom and leaf out later than healthy trees, are stunted, less productive, and have reduced terminal growth. Trees with almond leaf scorch usually survive for many years.

Niederholzer and Connell,2013; UC Pest Management Guidelines

Almond leaf scorch

Xylella fastidiosa

- Winters variety on Lovell rootstock showing ALS symptoms throughout the entire canopy.
- The adjacent Winters tree shows some foliar symptoms, but much less than the end tree.
- The rate of symptom spread from first visible to covering the entire tree can be slow (years) or fast (months).

Niederholzer,2013;

Almond leaf scorch
Xylella fastidiosa

A. Typical leaf scorch symptoms on an almond tree, caused by *X. fastidiosa*.

B. Almond tree with symptoms of "golden death".

C. Almond leaf scorch symptoms on an almond seedling 5 months after inoculation.

Amanifar *et al.*,2014

Almond leaf scorch

Xylella fastidiosa

Scortichini,2006;..

Phony Peach Disease

Xylella fastidiosa

- PPD symptoms are typically not visible until 18 months or more after infection.
- Infected trees take on a more compact, bushy appearance due to a shortening of internodes and a reduction in terminal growth.
- Foliage is often dark green and is shed later than usual in the fall.
- Bloom and fruit ripening periods will occur several days earlier than normal and a reduction in the size, quantity, and quality of fruit will occur.

Giesbrecht and Ong,2012

Almond witches broom

'*Candidatus* Phytoplasma phoenicium'

- Almond witches broom disease symptoms.

A. yellows and extensive witches broom

B. witches Broom

Ghayeb Zamharir,2011

Almond witches broom

Stolbur infection on almond

Gáborjányi,2010

Stem rot

D. chrysanthemi

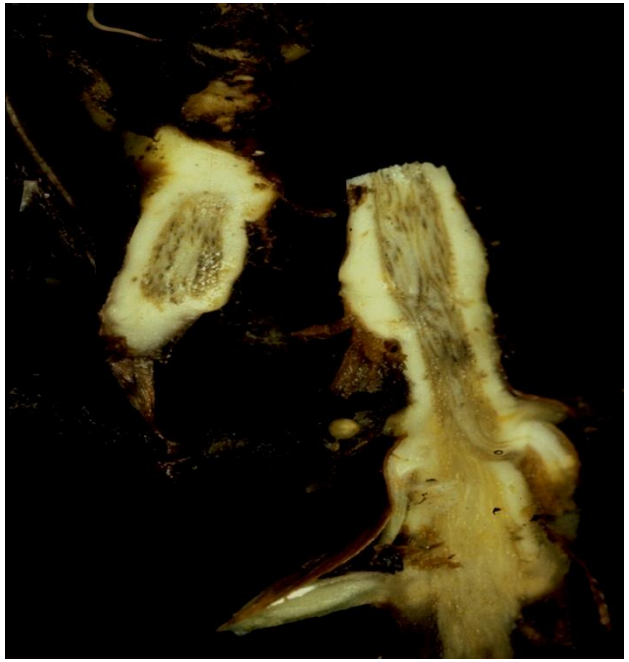
Stem rot of *Aloë vera*, caused by *Erwinia chrysanthemi*, resulting in complete loss of the plant.

plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf

Bacterial blight of anthurium

Xanthomonas axonopodis pv. *dieffenbachiae*

- Bacteria invade the vascular system.
- Black streaks are symptoms of infection.



Bacterial blight of anthurium

Xanthomonas axonopodis pv*. dieffenbachiae*

Bacterial blight of anthurium

Xanthomonas axonopodis pv. *dieffenbachiae*

Typical section of the field with bacterial blight.

A. Alvarez;..

Bacterial blight of anthurium

Xanthomonas axonopodis pv. *dieffenbachiae*

	
Blacking of the spathe in the 'flower blight' stage. Photo by T. Vowell.	Water-soaked lesions surrounding stomates on underside of leaf. Photo by A. Alvarez.

Alvarez *et al.*,2006

The main bacterial diseases of apple

Fire Blight	***E. amylovora***
Blister spot	***Psuedomonas syringae* pv. *papulans***
Crown Gall	***A. tumefaciens***
Apple proliferation	**'*Candidatus* Phytoplasma mali'**

Fire Blight

E. amylovora

Bacterial ooze from infected apple, Van der Zwet, USDA

Van der Zwet; British Columbia

Fire Blight

E. amylovora

Burnt appearance of apple caused by severe fire blight. (Courtesy T. Smith)

Apple shoot with fire blight showing shepard's crook symptom.

Johnson,2000;..

Fire Blight

E. amylovora

Scortichini,2006

Blister spot

Psuedomonas syringae pv. *papulans*

- A local swelling of the skin that contains watery fluid and is caused by burning or irritation.
- A similar swelling on a plant.
- Blister spot, caused by the bacterium *Psuedomonas syringae* pv. *papulans*, is probably present in most apple orchards.

Staff,2011

Apple

Blister spot

Psuedomonas syringae pv. *papulans*

Midvein necrosis of leaves on tender shoots infected with the blister spot bacteria.

Crusty brown lesions on the midvein and petiole of the lower surface of blister spot infected leaf.

Staff,2011

Apple

Blister spot

Psuedomonas syringae pv. *papulans*

Blister spots (small water-soaked raised spots are often initially detected near the calyx end of fruit growing on the outside of the tree canopy facing the sun.

Blister spot lesions eventually become purplish black with a tan centre expanding no more than 4-5 mm in diameter on the fruit surface.

Staff,2011

Crown Gall

A. tumefaciens

- Plants with crown gall have swollen knots, called galls, near the crown and sometimes on the roots and twigs as well.
- The galls are tan in color and may be spongy in texture at first, but they eventually harden and turn dark brown or black.
- As the disease progresses, the galls can totally encircle the trunks and branches, cutting off the flow of sap that nourishes the plant.

Ellis,2008; Carroll,2016

Apple proliferation

'*Candidatus* Phytoplasma mali'

Witches' broom symptoms on apple trees infected with '*Candidatus* Phytoplasma mali'.

Apple proliferation on reduced fruit size (C).

CFIA,2013;Agrios,2005

Apple proliferation

'*Candidatus* Phytoplasma mali'

Apple proliferation disease symptoms in northern Italy.

Bertaccini and Duduk,2009

Bacterial canker

Pseudomonas syringae

There may also be leaf spot and blast of young flowers and shoots.

US IPM Online

Bacterial Canker

Pseudomonas syringae






Scortichini,2006

Crown gall

Agrobacterium tumefaciens

Crown gall on the crown and roots of a young tree.
Photo by Joseph M. Ogawa.

Bacterial leaf stripe

Burkholderia

Pegg and Manners,2014

Bird's nest fern- *Asplenium nidus*

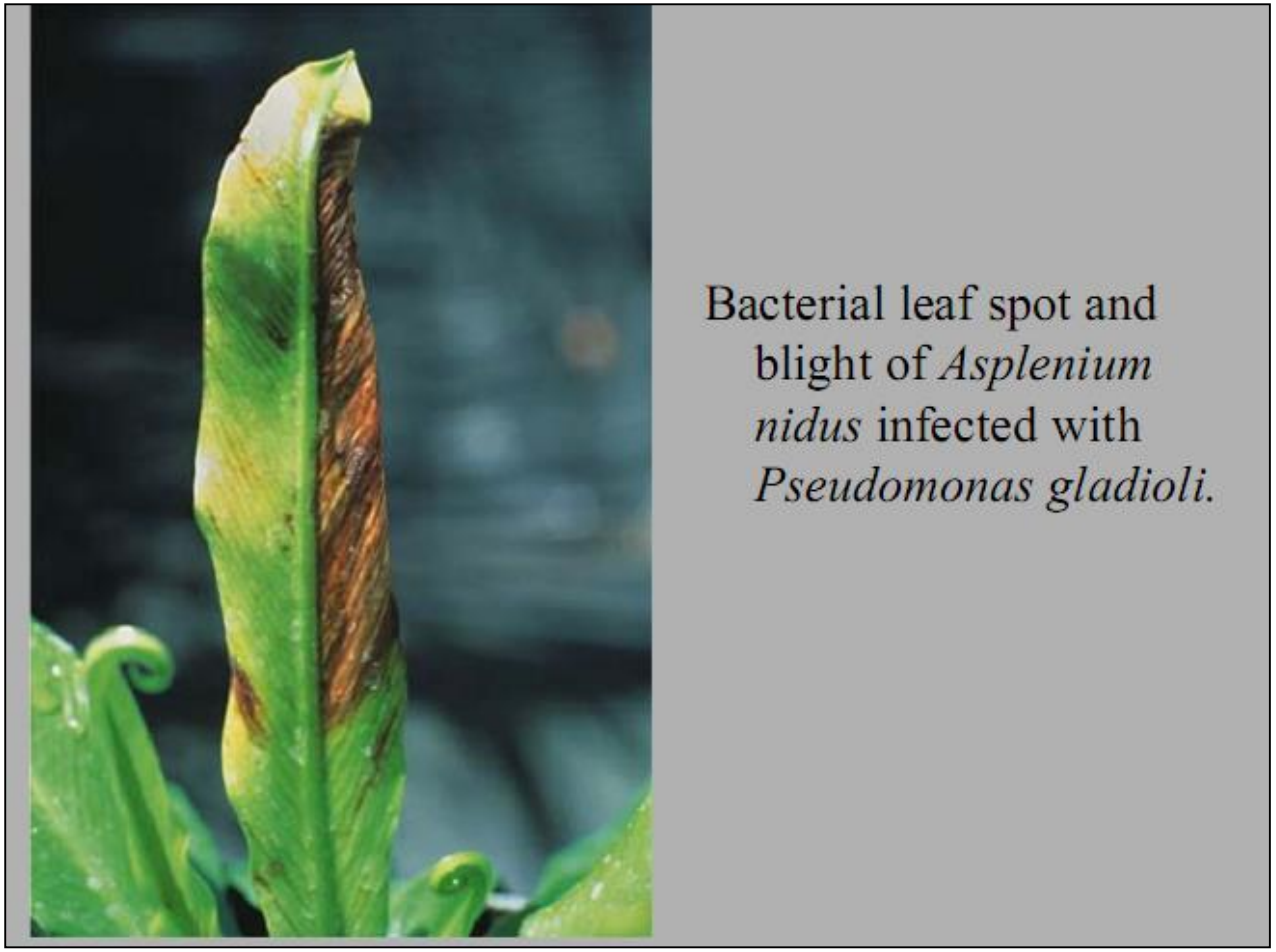
Leaf Spot/blight

Burkholderia gladioli pv. *gladioli*

A.R. Chase

Leaf spot

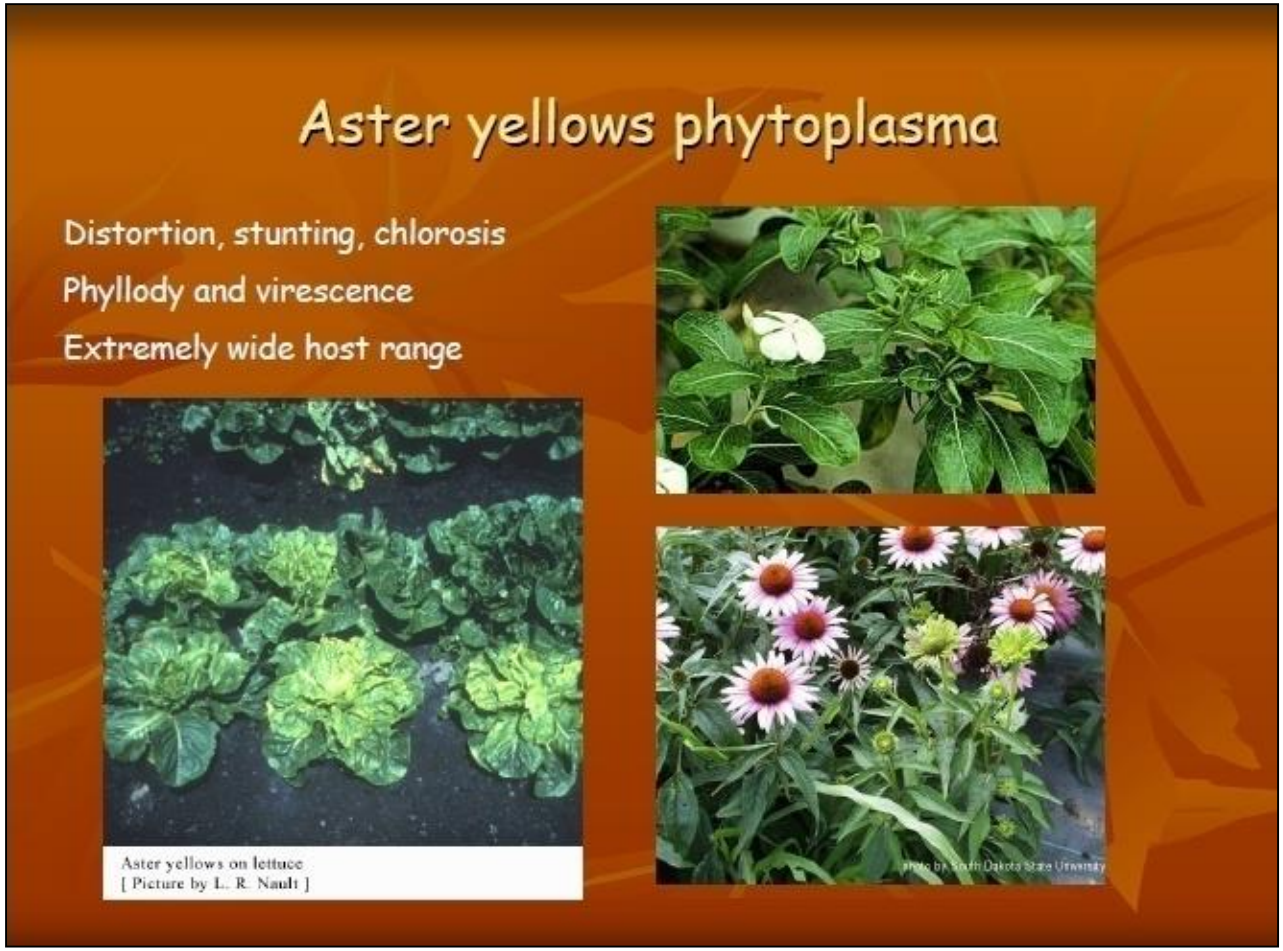
Burkholderia gladioli



Bacterial leaf spot and blight of *Asplenium nidus* infected with *Pseudomonas gladioli*.

plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf

Aster yellows phytoplasma



A. Wayadande

Aster yellows phytoplasma

- Example of control by application of insecticides to control vector.
- Timing of insecticide is critical.

The main bacterial diseases of banana

Bacterial wilt or Moko disease of banana	***Ralstonia solanacearum* (race 2, biovar 1)**
Bugtok (=Bacterial hard pulp)	***Ralstonia solanacearum* (race 2, biovar 1)**
Blood bacterial wilt (BDB)	***R. syzygi* subspecies *celebensis***
***Xanthomonas* wilt, or banana bacterial wilt (BXW) or enset wilt** (infects all types of banana cultivars)	***Xanthomonas vasicola* pv. *musacearum***

Banana sheath rot	***Pantoea agglomerans***
Javanese vascular wilt	***Pseudomonas* spp.**
Rhizome rot	***Dickeya chrysanthemi*** ***Pectobacterium carotovorum* subsp. *carotovorum*** ***Pectobacterium atrosepticum***
Bacterial pulp decay	***D. chrysanthemi*; *Pseudomonas* sp.**
Finger-tip rot(gumming)	***Burkholderia cenocepacia*; *Pseudomonas* sp.**

Wikipedia,2012;..

Moko disease of banana

R. solanacearum (race 2,biovar 1)

Marina P. Natural

Moko disease of banana

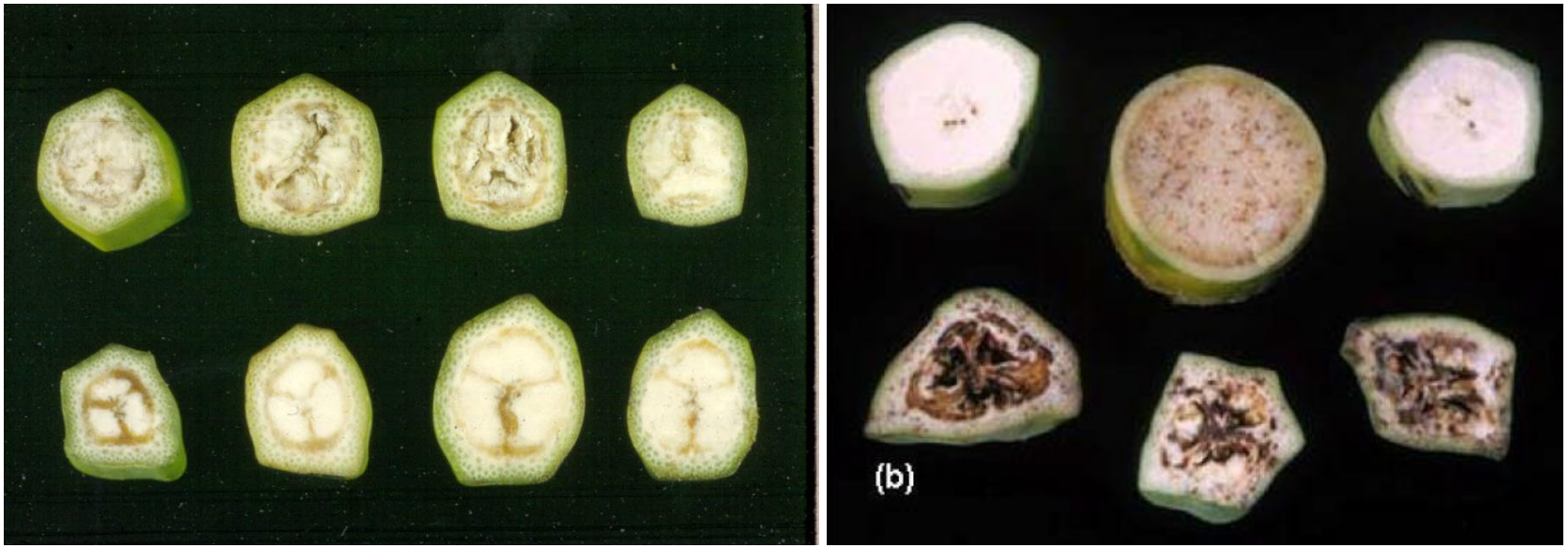
R. solanacearum (race 2,biovar 1)

Internal rot of fruit caused by Moko.

Moko disease of banana

Banana fruits with Moko Disease

R. solanacearum (race 2,biovar 1)



Bacterial Wilt of Banana Diagnostics Manual,2006;..

Bugtok (bacterial hard pulp)

R. solanacearum (race 2, biovar 1)

- Commonly observed in "Saba" or "Cardaba" cultivars.
- Bacterial ooze can be seen when the peduncle is cut.
- Unlike Moko however the infected plants do not wilt.
- Plants appear healthy in the field but fruits are discolored and lumpy.
- Suckers are also generally not affected.

Marina P. Natural; Plant Heath Australia,2006

Blood disease bacterium

Ralstonia syzygii subsp. *celebesensis*

Liberato,2007; Plant Heath Australia,2006

Blood disease bacterium

Moko disease vs. of blood disease

- BDB is also pathogenic to a single host, banana, and is transmitted by pollinating insects.
- The symptoms of blood disease are similar to those induced by *R. solanacearum* strains that cause the Moko disease of banana.
- However, unlike Moko disease causing strains, BDB is not pathogenic to *Heliconia* spp.(banana family with parrot flower) in the wild, nor to solanaceous hosts following artificial inoculation.

Moko disease and bugtok diseases are caused by Phylotype II (race 2 biovar 1) strains, whereas, the banana blood disease bacterium caused by Phylotype IV strains.

Remenant *et al.*,2011;..

Banana *Xanthomonas* wilt (BXW)

Banana bacterial wilt

Xanthomonas vasicola pv. *musacearum*

- Banana plantation damaged due to *Xanthomonas* wilt(BXW).

Tripathi *et al.*,2009;..

Banana bacterial wilt

Xanthomonas vasicola pv. *musacearum*

Wilting banana plant showing yellowing of leaves.

Drying and withering of infected male bud of banana.

Reeder *et al.*,2007

Banana bacterial wilt

Xanthomonas vasicola pv. *musacearum*

Internal rotting of banana fruit caused by *Xanthomonas vasicola* pv. *musacearum*.

Cross-section of banana pseudostem showing vascular discolouration and oozing of *X. vasicola* pv. *musacearum*.

Reeder *et al.*,2007;..

Soft rot disease of banana

Pectobacterium carotovorum

Rotten rhizome-typical symptom

Rhizome rot-above ground symptoms

Tip-over disease of banana

Erwinia head rot or Tip over disease

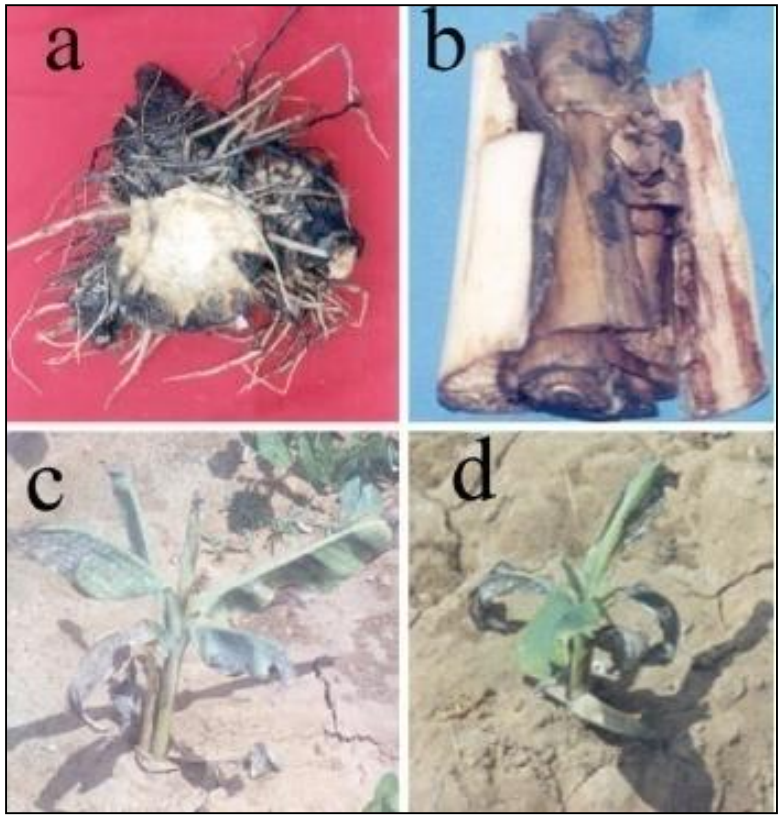
- Symptoms of tip-over disease of banana.

a. Soft rot of the rhizome.

b. Internal decay of the pseudo-stem.

c. Severely infected banana plant.

d. Diseased banana leaves.



Snehalatharani and Khan,2010

Tip-over disease of banana

ex. soft rot *Erwinia* spp.

- Rotting of collar region is the commonest symptom this disease.
- The leaves of affected plant show epinasty (A downward bending of leaves or other plant parts) and dry out suddenly.

Bacterial blight

Xanthomonas translucens pv. *translucens*

Barley and Oats: They're different species of grain.
Barley is used in beer and in soup. Oats make oatmeal.

Forestry Images;..

Leaf streak/black chaff

Xanthomonas translucens pv. *translucens*

Infected heads have blackened glumes.

Forestry Images;..

Leaf spot

Pseudomonas viridiflava

Scortichini 2006

Stem and root rot

Dickeya chrysanthemi

Courtesy C.A. Clark

Common foliar bacterial diseases of beans

Halo blight	***Pseudomonas savastanoi* pv. *phaseolicola***
Bacterial brown spot	***Pseudomonas syringae* pv. *syringae***
Common bacterial blight	***Xanthomonas axonopodis* pv. *phaseoli***
Bacterial wilt	***Curtobacterium flaccumfaciens* ssp. *flaccumfaciens***
Pink seed	***Erwinia rhapontici***
Witches'- broom	**Phytoplasma**

Wikipedia,2008

Halo blight

Pseudomonas savastanoi pv. *phaseolicola*

Photograph provided by H. F. Schwartz
AgImage - Colorado State University

Bacterial brown spot

Pseudomonas syringae pv. *syringae*

Young brown spot lesions.

Brown spot lesions on pods.

Schwartz,2011

Common blight lesions

Xanthomonas axonopodis pv. *phaseoli*

X. a. pv. *phaseoli* symptoms expressed on a bean seedling following the pathogenicity assay protocol.

Common bacterial blight natural disease symptoms (Schwartz,2011).

Common blight lesions

Xanthomonas axonopodis pv. *phaseoli*

Striking water-soaking symptoms of common bacterial blight on bean pods.

Zhang *et al.*,2012

Bacterial wilt of dry beans

The Multicolored Bacterium

Curtobacterium flaccumfaciens pv. *flaccumfaciens*

	
Leaf wilting symptoms on dry beans due to bacterial wilt.	Marginal necrosis and yellowing symptoms associated with common bacterial blight.

Harveson *et al.*,2011

Bacterial wilt of dry beans

The multicolored bacterium

Curtobacterium flaccumfaciens pv. *flaccumfaciens*

- Orange (upper right), violet (upper left), and yellow (lower left) variants of *Curtobacterium flaccumfaciens* pv. *flaccumfaciens* infected bean seed shown adjacent to the non infected seed (bottom right).

(Courtesy A. W. Saettler and M.L. Schuster)

Bacterial wilt of dry beans

The multicolored bacterium

Curtobacterium flaccumfaciens pv. *flaccumfaciens*

Dry bean field in Nebraska severely affected by wilt.

Note the large gaps without plants, indicating early infection of seedlings that did not survive.

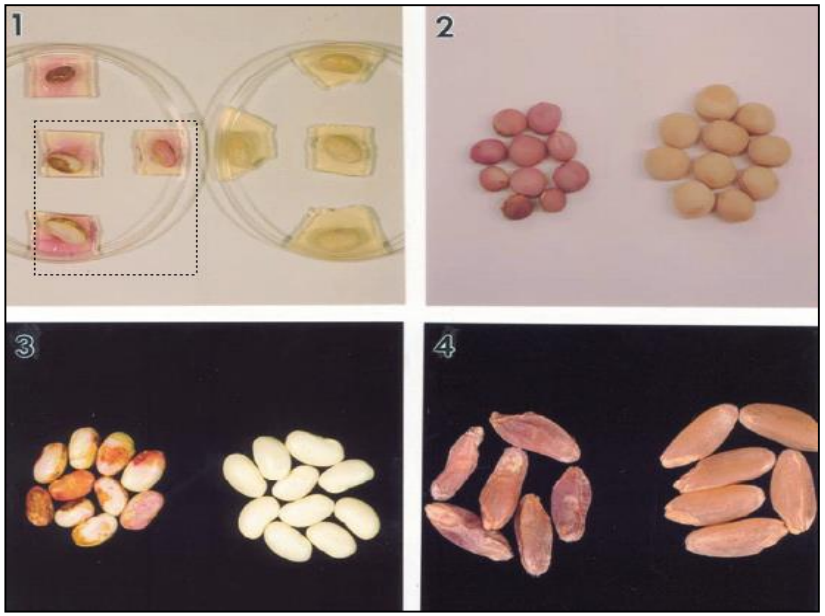
Yield of one infected dry bean plant showing staining of surviving, mature seeds.
Note that not all seeds become infected.

Robert M. Harveson

Pink seed

Erwinia rhapontici

- Pink seed of pea, bean and wheat caused by *Erwinia rhapontici*.
- Each figure show diseased seeds (left) and healthy seeds (right).



Huang *et al.*,2003

Witches'- broom

Phytoplasma

Witches'-broom of bean, caused by phytoplasma.

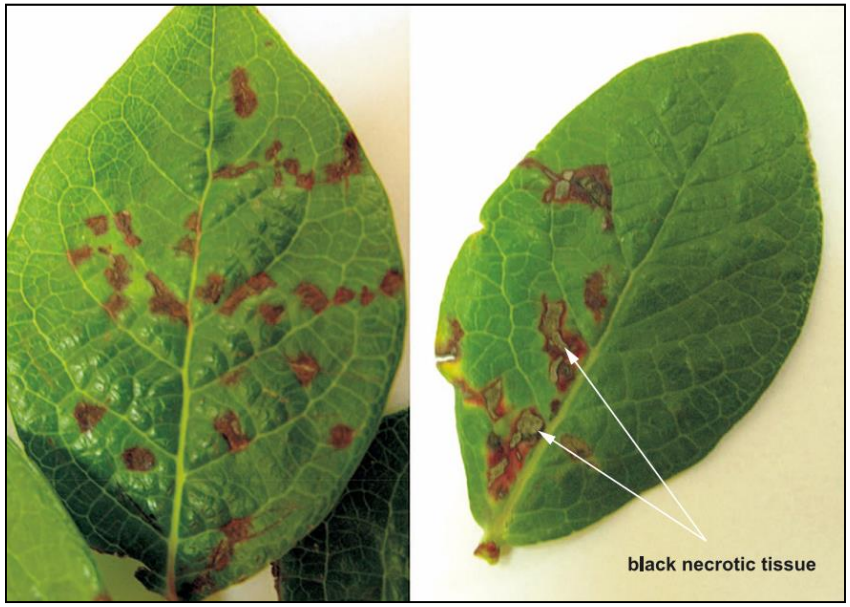
plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf

Blueberry Crown gall

Agrobacterium tumefaciens

Leaf spot disease
Pseudomonas spp.

- On the left are symptoms caused by isolates belonging to the LOPAT group Ib-group of *P. syringae* subsp. *savastanoi* and *Pseudomonas delphini*.
- On the right are symptoms caused by the isolate of the LOPAT group Ia-*P. syringae*.



Kałużna *et al.*,2013

Leaf spot disease

Burkholderia andropogonis

D. Noble

Leaf Spot

Pseudomonas syringae pv. *berberidis*

- **Symptoms on barberry (*Berberis*):**
- Lesions first appear water soaked, becoming very dark brown or black.
- Chlorotic halos usually are present.
- Leaves may fall prematurely, and lesions may occur on petioles and succulent twigs.
- Most produce a powerful plant toxin, syringomycin, that destroys plant tissues as bacteria multiply in a wound.
- Bacteria also produce a protein that acts as an ice nucleus, increasing frost wounds that bacteria easily colonize and expand.

Leaf Spot

Pseudomonas syringae pv. *mori*

Scortichini,2006

Leaf spot

Burkholderia andropogonis

Scortichini,2006

Ralstonia wilt disease

R. solanacearum

Ralstonia wilt disease

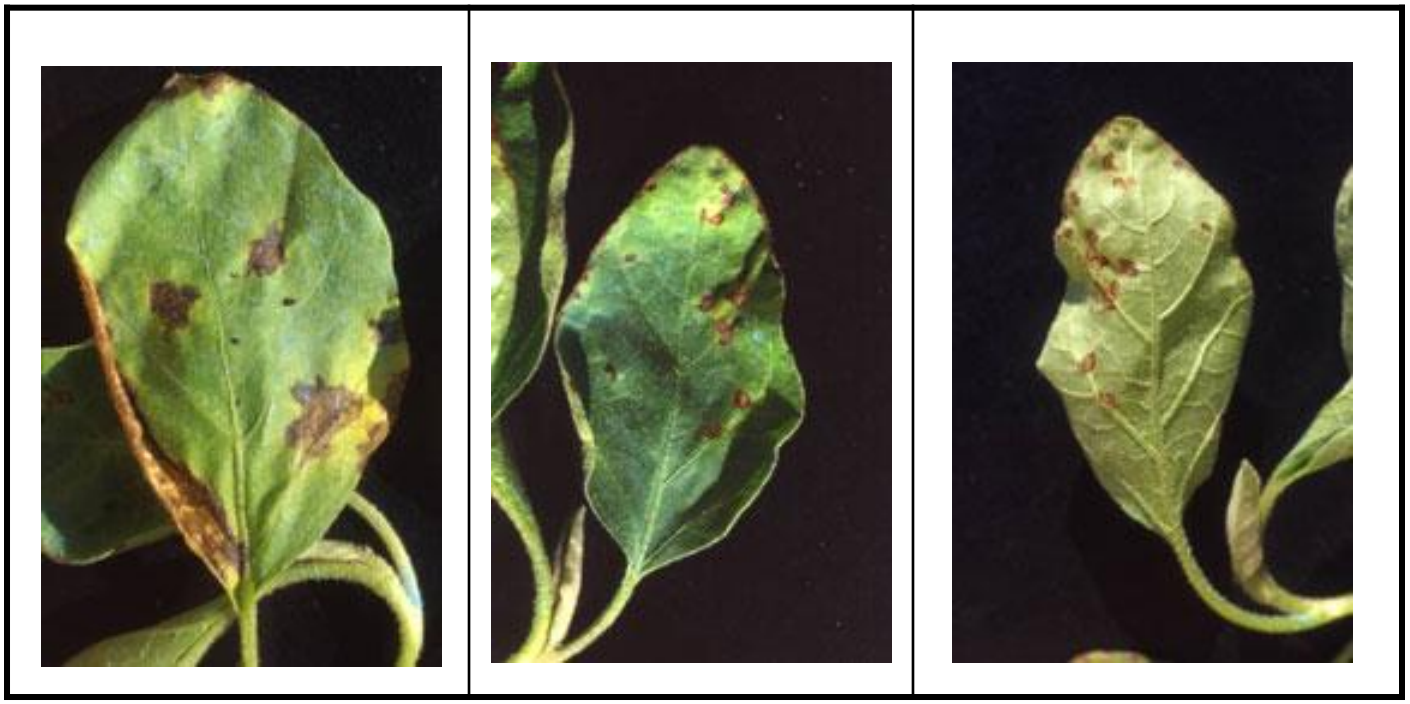
R. solanacearum

Ralstonia wilt disease of eggplant

Vascular discoloration

Leaf spot

Pseudomonas syringae pv. *syringae*



Scortichini,2006

Leaf blight

Pseudomonas viridiflava

Scortichini,2006

Soft rot

Pectobacterium carotovorum subsp. *carotovorum*

Scortichini,2006

Black rot

X. campestris pv. *campestris*

Black rot of cabbage caused by *Xanthomonas campestris* pv. *campestris*

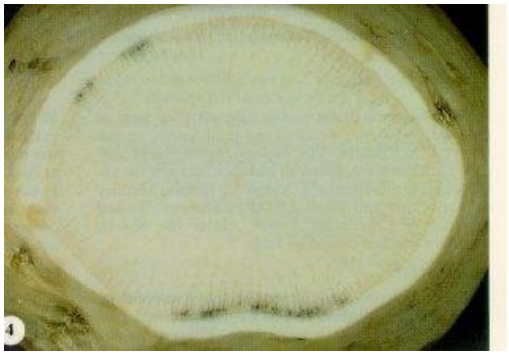
V-shaped lesions

Black rot

X. campestris pv. *campestris*

Entire cabbage leaf showing several black rot lesions.

Veins of plant systemically infected with black rot turn dark brown to black.



Blackened vascular system of black rot infected rutabaga.

Soft rot

Pectobacterium

- Brown, mushy, soft-rotted tissue on this cabbage head is caused by bacterial soft rot organisms.

Gáborjányi,2010;..

Soft rot

Pectobacterium

Bacterial soft rot affecting cabbage plant.

Cabbage

Aster yellows

Aster yellows phytoplasma on cabbage

'*Ca.* Phytoplasma asteris'

Gáborjányi,2010

Bacterial necrosis of giant cactus

Pectobacterium cacticida

Figure 13. Bacterial necrosis of saguaro causes exudation of dark brown liquid

USDA Forest Service,2008; AZ 1399 revised 2011

Bacterial necrosis of saguaro

Pectobacterium cacticida

- Bacteria occur in the diseased plant tissue of living cacti, and in the exudate associated with the infected areas.
- Infection begins when the pathogen is introduced into the cactus through wounds or natural openings.
- Symptoms appear at one or more positions on the trunk or branches of saguaros.

Note the black ooze coming from the infection site above the two arms.

Oozing cactus plants

Due to several reasons including bacterial disease

- There are several reasons for sap leaking from a cactus.

1. It could be an indication of a fungal disease, pest problem, tissue injury or even the result of freezing or excess sun exposure.
2. The cactus sap may appear to be brown or black, which indicates a bacterial problem.

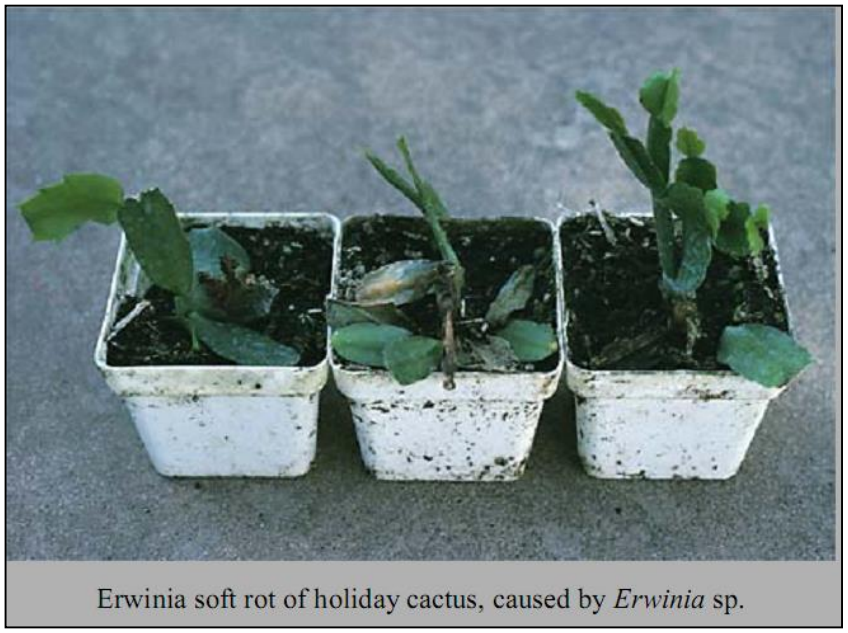
Bonnie L. Grant

Soft rot of holiday cactus

Erwinia sp.

Christmas cactus (*S. bridgesii*)

- As houseplants, holiday cacti are grown for their beautiful, exotic flowers.
- Holiday cacti include Christmas cactus, Thanksgiving cactus, and Easter cactus.
- These are popular houseplants and often given as gifts during the holiday season. They can also be very long-lived.



Erwinia soft rot of holiday cactus, caused by *Erwinia* sp.

Stem rot /wilt

Burkholderia caryophylli

Scortichini,2006

Leaf spot

Burkholderia andropogonis

Scortichini,2006

Bacterial rot and wilt

Dickeya dianthicola

Scortichini,2006

Bacterial soft rot

Dickeya chrysanthemi

Bacterial diseases of carrot

Bacterial leaf blight	***Xanthomonas campestris***
Bacterial soft rot	***Dickeya chrysanthemi*** ***Pectobacterium carotovorum* subsp. *carotovorum*** ***Pectobacterium atrosepticum***
Carrot bacteriosis	***X. hortorum* pv. *carotae***
Crown gall	***Agrobacterium tumefaceins***
Hairy root	***Agrobacterium rhizogenes***
Milky disease	***Bacillus popilliae* var. *rhopaea***
Scab	***Streptomyces scabiei***

Wikipedia,2008;..

Soft rot

Pectobacterium carotovorum subsp. *carotovorum*

Witches' broom and adventitious root symptoms

Phytoplasma

- Witches' broom and adventitious root symptoms of aster yellows in the carrot leaves and roots.

Bacterial Leaf Blight

X. hortorum pv. *carotae*

Jodi,2011

Bacterial Leaf Blight

Xanthomonas hortorum pv.*carotae*

Scortichin,2006

Carrot gall

Rhizobacter dauci

Scortichin,2006

Cassava bacterial blight

Xanthomonas axonopodis pv. *manihotis*

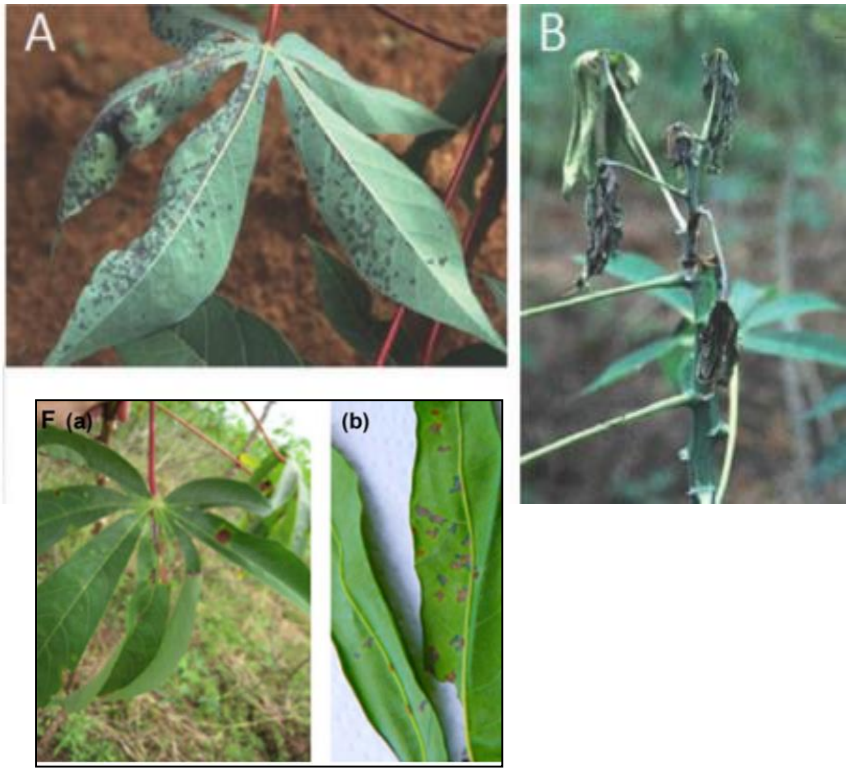
Agrios,2005

Angular leaf spots and leaf wilting
X. axonopodis pv. *manihotis*

- Bacterial blight symptoms caused by *Xanthomonas axonopodis* pv. *manihotis*:

A. Angular leaf spots (Courtesy of V. Verdier, IRD Montpellier, France);

B. Leaf wilting (courtesy of B. Boher, IRD Montpellier, France).



Mansfield *et al.*,2012: Sundin *et al.*,2016

Bacterial leaf spot

Pseudomonas syringae pv. *apii*

- Initial symptoms of bacterial leafspot are small, water-soaked spots that are visible from both sides of the leaf.
- These water-soaked lesions rapidly turn brown and with aging may dry out and become papery and tan.
- On greenhouse transplants, bacterial blight lesions may develop extensively on the foliage.

Koike *et al.*,1994; UC IPM,2005

Bacterial canker

Pss and *Pseudomonas syringae* pv. *morsprunorum* race1

- In Belgium *Pss*, *Psm* race 1 and 2, and other sour cherry and plum *P. syringae* strains were frequently found in cherry and plum orchards (Bultreys and Gheysen, 2003; Gilbert *et al.*,2009).
- *Psm* race 1 was especially damaging to dwarf trees.

Alain Bultreys

Crown gall

Agrobacterium tumefaceins

- This flowering cherry has been dug up and the dirt removed from the roots to show the galled areas on many of the roots.

Photo part of OSU Extension Plant Pathology Slide

Blight & canker of chestnut

Pseudomonas syringae pv. *castanae*

K. Takanashi

Bacterial spot
Pseudomonas cichorii

- *P. cichorii* causes disease on a wide range of vegetable, flowering ornamentals, and foliage plants.
- Host specificity is not known to exist.
- Chrysanthemums and other hosts are known to carry epiphytic (on top of leaf surfaces) populations of *P. cichorii*; long range distribution of the pathogen results from these populations.
- Symptoms (leaf spots to rots) may vary depending on the host and the infected part of the plant.

Bacterial diseases of citrus

Citrus bacterial blast	***Pseudomonas syringae* pv. *syringae***
Citrus black pith(fruit)	***P. syringae* pv. *syringae***
Citrus canker disease(CDD)	***Xanthomonas axonopodis* pv. *citri***
Citrus Variegated Chlorosis (CVC)	***Xylella fastidiosa* subsp. *pauca***
Citrus huanglongbing (greening) disease (citrus greening)	***Candidatus* Liberibacter asiaticus, africanus and americanus**
Citrus stubborn disease(CSD)	***Spiroplasma citri***
Lime witches' broom	**'*Ca.* Phytoplasma *aurantifolia*'**

Citrus bacterial blast

Pseudomonas syringae pv. *syringae*

- Infection starts as black lesions in the leaf petiole and progresses into leaf axils.
- Leaf blades curl, dry, and drop prematurely, often leaving petioles remaining stuck on the twig.
- When twig lesion girdles the stem, twig and branch dieback can result.

Jack Kelly Clark

Citrus bacterial blast

Pseudomonas syringae pv. *syringae*

- Bacterial blast infections of citrus occur during cool or wet weather during the winter or spring and usually start as black lesions in the leaf petiole and progress into the leaf axil.
- Once the petiole is girdled, leaves wither, curl, and eventually drop.
- Entire twigs may die back.
- Diseased areas are covered with a reddish brown scab.
- Infections result in small black spots on the fruit.

Black lesions in leaf petiole and axil

Withering leaves

UC IPM Online,2009

Citrus blast and black pit

Pseudomonas syringae pv. *syringae*

Citrus blast on lemon twigs cv. Eurêka.

Black pit on lemon fruit cv. Eurêka.

Abdellatif *et al.*,2015

Three citrus bacterial diseases

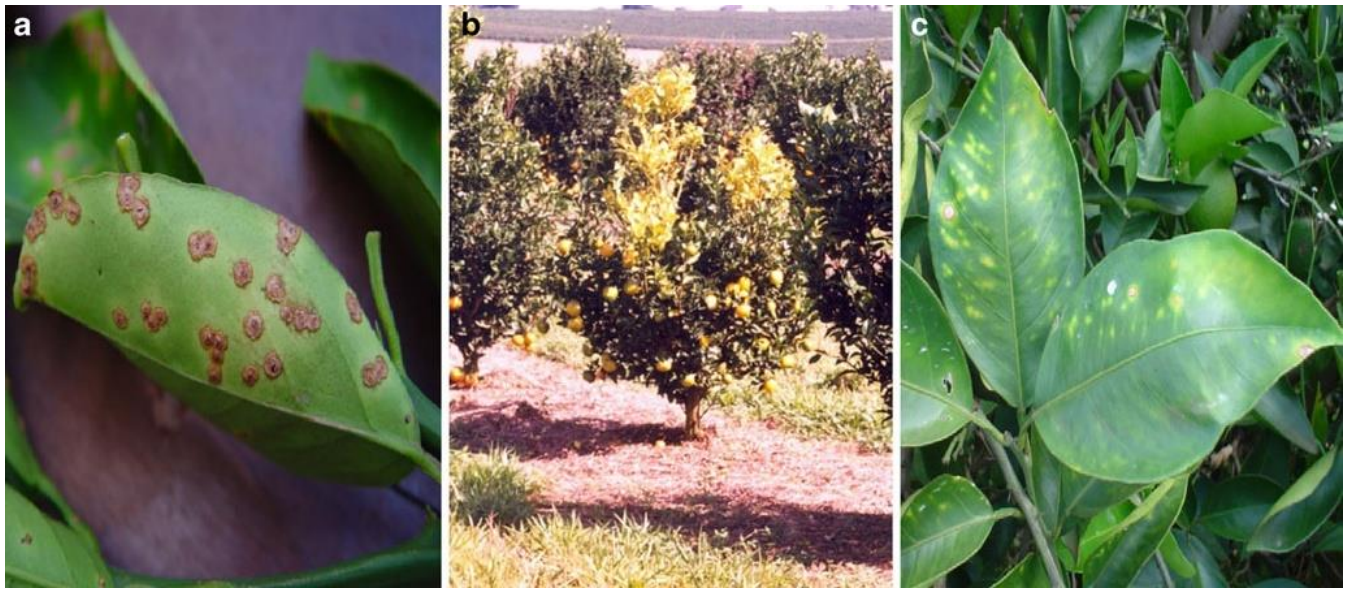
X. citri, *X. fastidiosa* and *Ca.* Liberibacter asiaticus

- Bacterial symptoms on citrus plants:

a) Lesions caused by citrus canker on citrus leaves,

b) 'yellow shoot' symptoms of huanglongbing on citrus tree, and

c) Citrus variegated chlorosis.



Vojnov *et al.*,2010

Citrus canker disease(CDD)

Xanthomonas axonopodis pv. *citri*

	
Early leaf lesion	Mature leaf cankers

Citrus canker

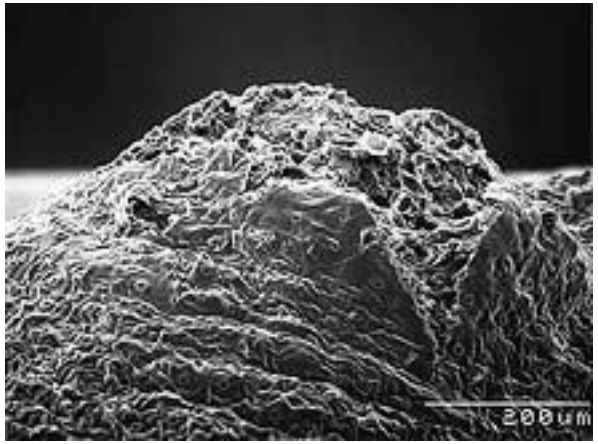
Xanthomonas axonopodis pv. *citri*

Citrus canker

Xanthomonas axonopodis pv. *citri*

Close up of citrus canker lesion

Xanthomonas axonopodis pv. *citri*

	
SEM of erumpent citrus canker lesion. (Courtesy J. Cubero)	Close up of citrus canker lesion demonstrating crater-like appearance and water soaking on margins.

Gottwald *et al.*,2002

Citrus canker

Xanthomonas axonopodis pv. *citri*

Hamlin sweet orange tree showing fruit drop due to citrus canker infection, Brazil.

Sweet orange tree showing fruit drop due to citrus canker infection, Brazil.

Gottwald *et al.*,2002

Bacterial spot

Xanthomonas axonopodis pv. *citri*

Citrus canker lesions on immature fruit stems and foliage of grapefruit.

Gottwald *et al.*,2002

Citrus canker

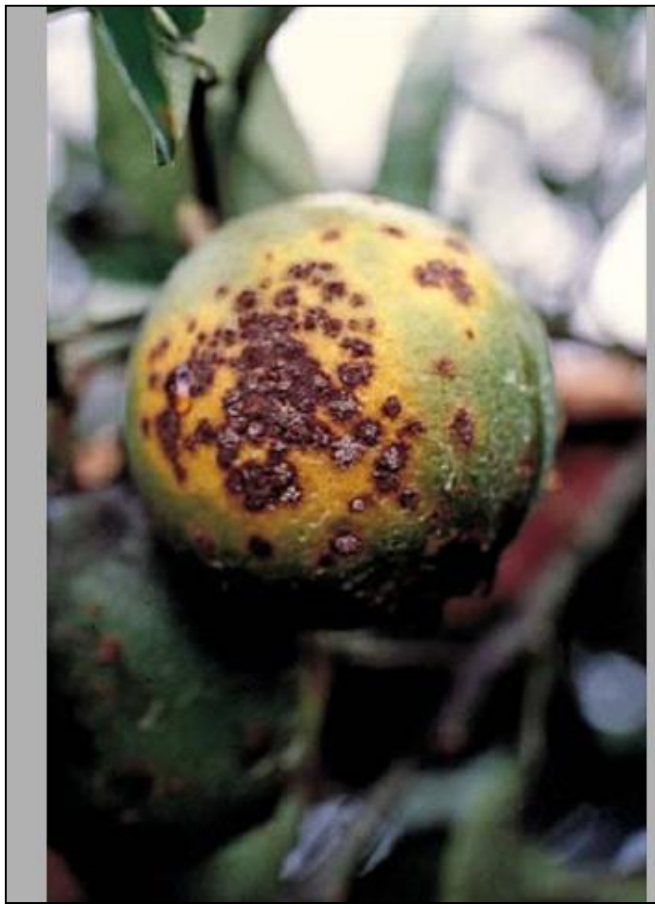
Xanthomonas axonopodis pv. *citrumelo*

Lesions caused by citrus canker on sweet orange leaves, caused by *Xanthomonas campestris* pv. *citrumelo*.

plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf

Citrus canker

Xanthomonas axonopodis pv. *citrumelo*

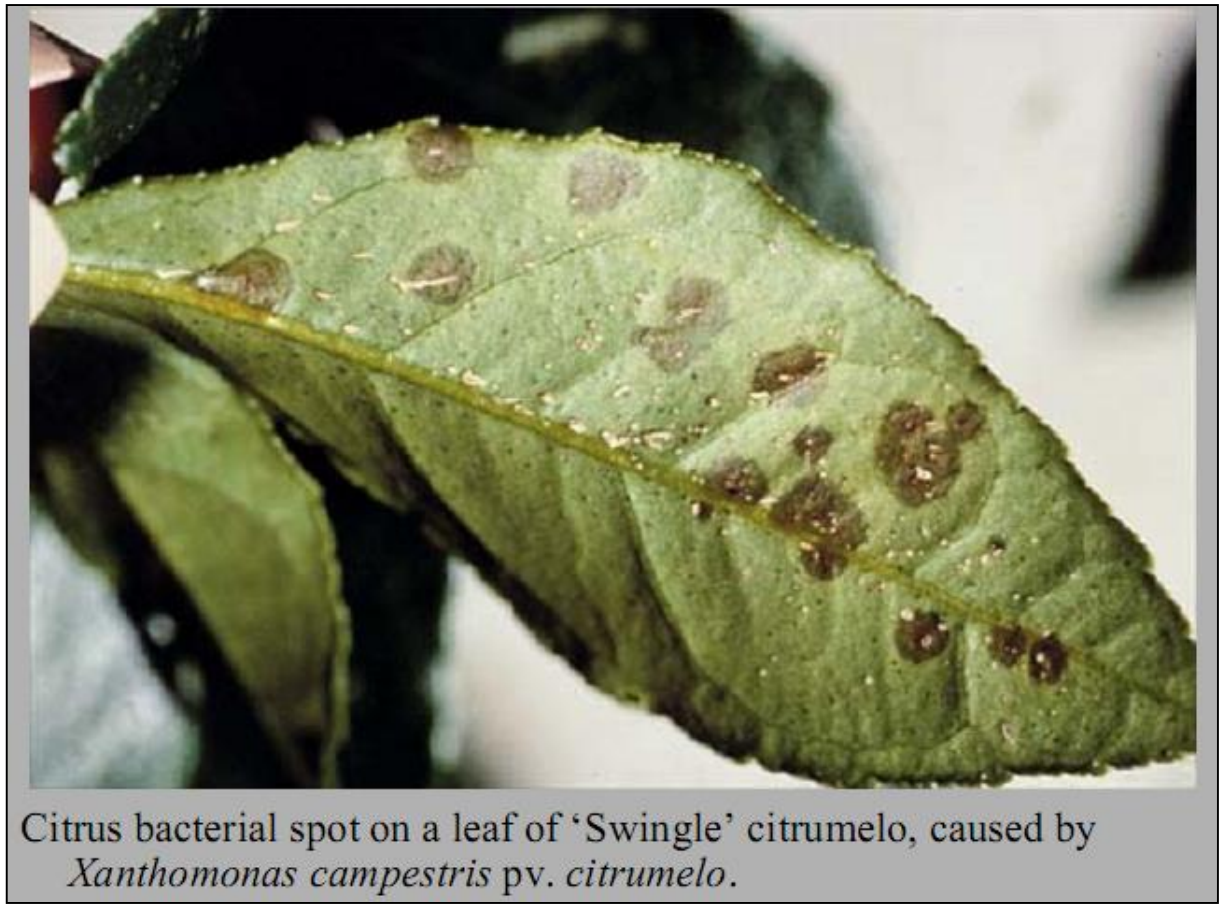


Lesions caused by citrus canker on sweet orange fruit, caused by *Xanthomonas campestris* pv *citrumelo*.

plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf

Citrus canker

Xanthomonas axonopodis pv. *citrumelo*

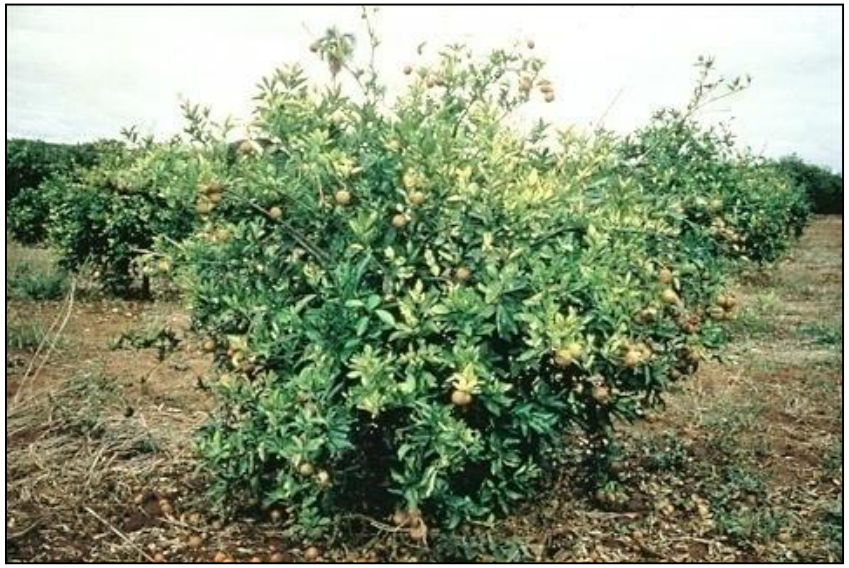


Citrus bacterial spot on a leaf of 'Swingle' citrumelo, caused by *Xanthomonas campestris* pv. *citrumelo*.

plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf

Citrus Variegated Chlorosis (CVC)
Xylella fastidiosa subsp. *pauca*

- Symptoms of citrus variegated chlorosis caused by distinct strains of *Xylella fastidiosa*.



Fruits are smaller and mature earlier than fruits from healthy trees. Small raised lesions appear on the underside of leaves.

Citrus variegated chlorosis(CVC)
Xylella fastidosa

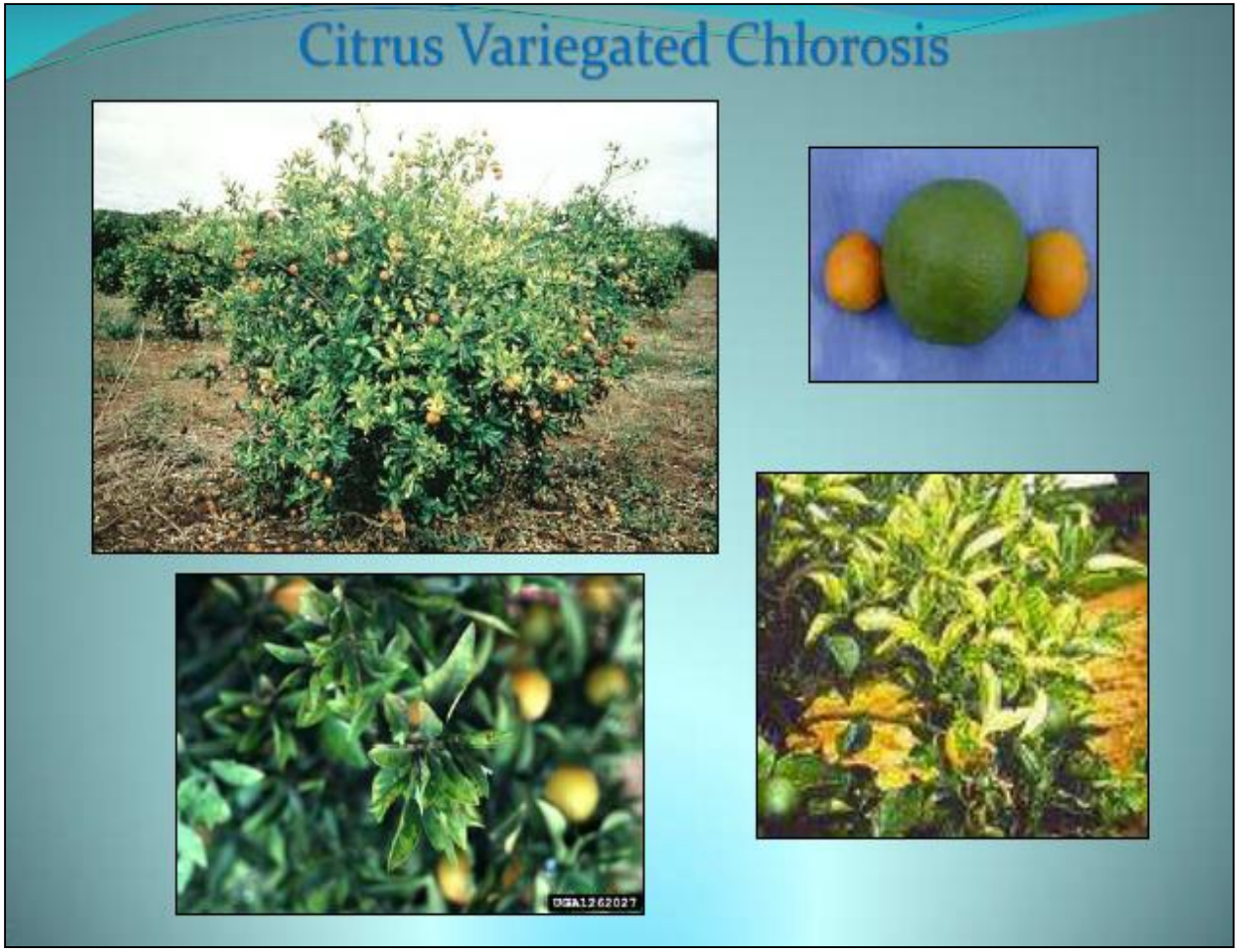
- The growth rate of affected trees is greatly reduced, and twigs and branches may wilt.
- Trees in nurseries can show symptoms of variegated chlorosis as do trees aged over 10 years.
- Young trees (1-3 years) become systemically colonized by *X. fastidiosa* faster than older trees.
- Trees more than 8-10 years old are usually not totally affected, but rather have symptoms on the extremities of branches.

Small raised lesions appear on the underside of the citrus leaves.

EPPO,2018

Citrus Variegated Chlorosis

Xylella fastidiosa



M. J. Davis

Citrus Variegated Chlorosis (CVC)

Xylella fastidiosa subsp. *pauca*

Citrus Variegated Chlorosis (CVC)
Xylella fastidiosa subsp. *pauca*

Janse,2009

HLB or Citrus Greening Disease

Candidatus Liberibacter asiaticus, africanus and americanus

- HLB attacks a tree's phloem- the vascular tissue that it uses to transport nutrients—so infected trees don't grow at the rate of healthy ones, and their canopies become sparse.
- The most noticeable symptom of HLB is greening and stunting of the fruit, especially after ripening.

Citrus Pest Management (PMA 5205), 2013; Zhang,2019

HLB or Citrus Greening Disease

Candidatus Liberibacter asiaticus, africanus and americanus

- Infected trees develop yellow shoots and mottled leaves.
- Trees eventually die; but before that, fruit is distorted and bitter, can't be used for juice.
- Fruit and leaf drop increase as the disease progresses.

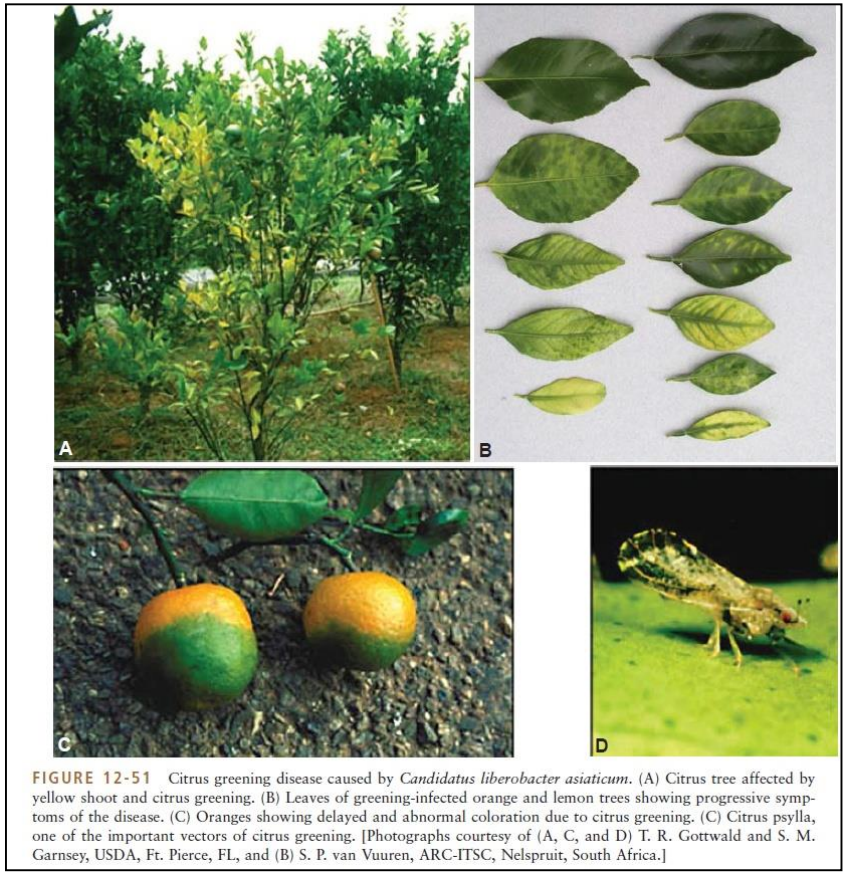


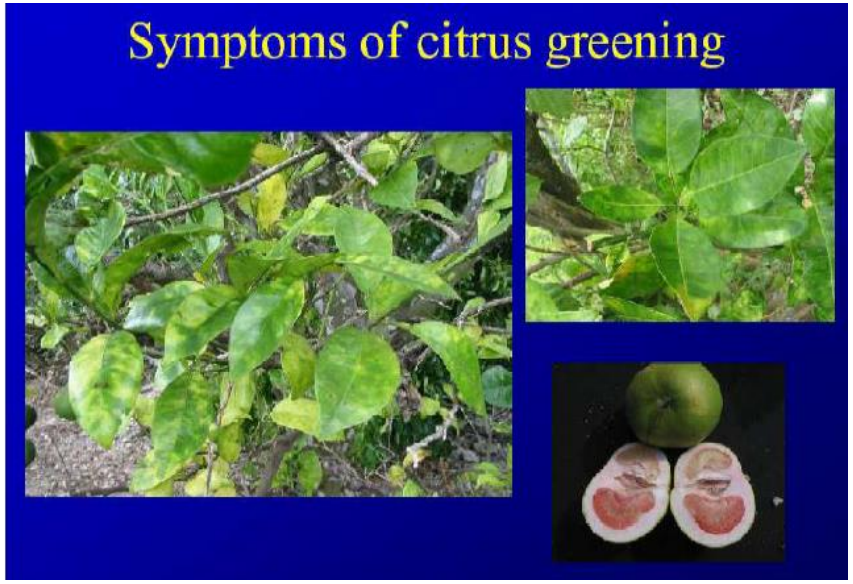
FIGURE 12-51 Citrus greening disease caused by *Candidatus liberobacter asiaticum*. (A) Citrus tree affected by yellow shoot and citrus greening. (B) Leaves of greening-infected orange and lemon trees showing progressive symptoms of the disease. (C) Oranges showing delayed and abnormal coloration due to citrus greening. (C) Citrus psylla, one of the important vectors of citrus greening. [Photographs courtesy of (A, C, and D) T. R. Gottwald and S. M. Garnsey, USDA, Ft. Pierce, FL, and (B) S. P. van Vuuren, ARC-ITSC, Nelspruit, South Africa.]

Agrios,2005; Nesbitt,2014

HLB or Citrus Greening Disease

Candidatus Liberibacter asiaticus, africanus and americanus

- Three species of *Candidatus* Liberibacter cause huanglongbing:
- *Ca. L. asiaticus*,
- *Ca. L. africanus*, and
- *Ca. L. americanus*.
- The Asian form is the most widespread.

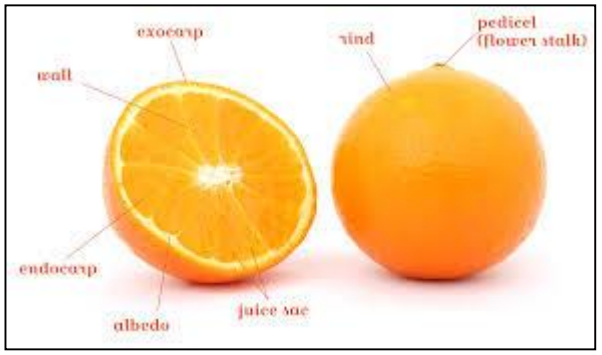


Note: Association of phytoplasma with *Ca.* Liberibacter asiaticus'(CLas) in sweet lime was reported for the first from Iran (Saberi *et al.*, 2017).The HLB-associated phytoplasma was a member of peanut witches' broom (16SrII) phytoplasma group. Recently same type of association (phytoplasma with Huanglongbing (HLB) disease) was reported in pomelo (*Citrus grandis*) from India. Here, the pathogen belongs to 16SrXIV Group of phytoplasma, '*Candidatus* Phytoplasma cynodontis'(Ghosh *et al.*,2019).

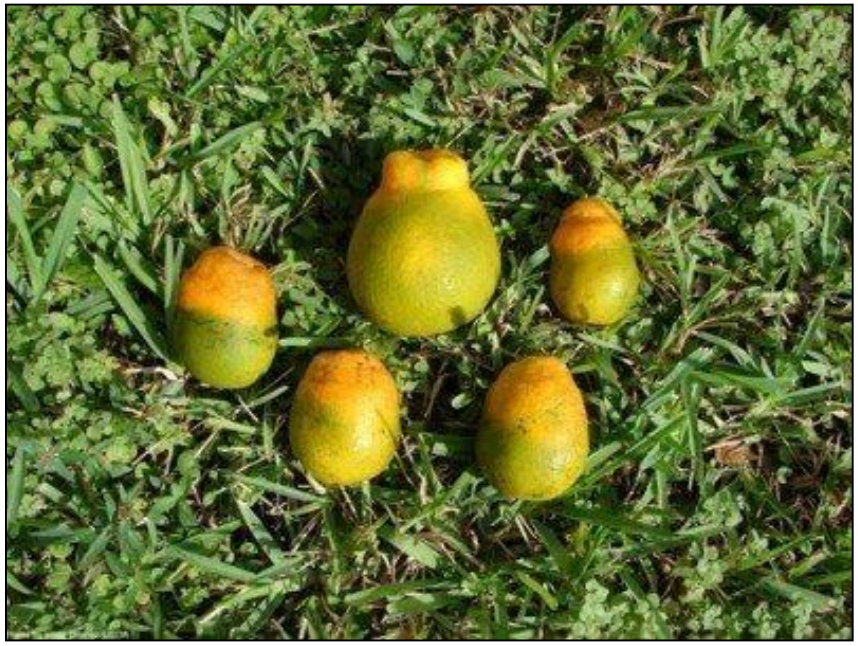
M. J. Davis; Zhang,2019

Citrus Greening

Fruit symptoms



- Fruits on HLB infected trees show color inversion with the presence of brownish, aborted seeds in the fruit.
- Normal fruits break color and turn orange first at the stylar end, the peduncle end being still green.
- HLB affected fruits become orange first at the peduncle end, the stylar end being still green.



National Plant Protection Centre; Gardening Know How

HLB or Citrus Greening Disease

Candidatus Liberibacter asiaticus, africanus and americanus

- Huanglongbing-infected orange trees bear fruits that are small and lopsided (right) compared with healthy fruit (left).

Zhang,2019

HLB or Citrus Greening Disease

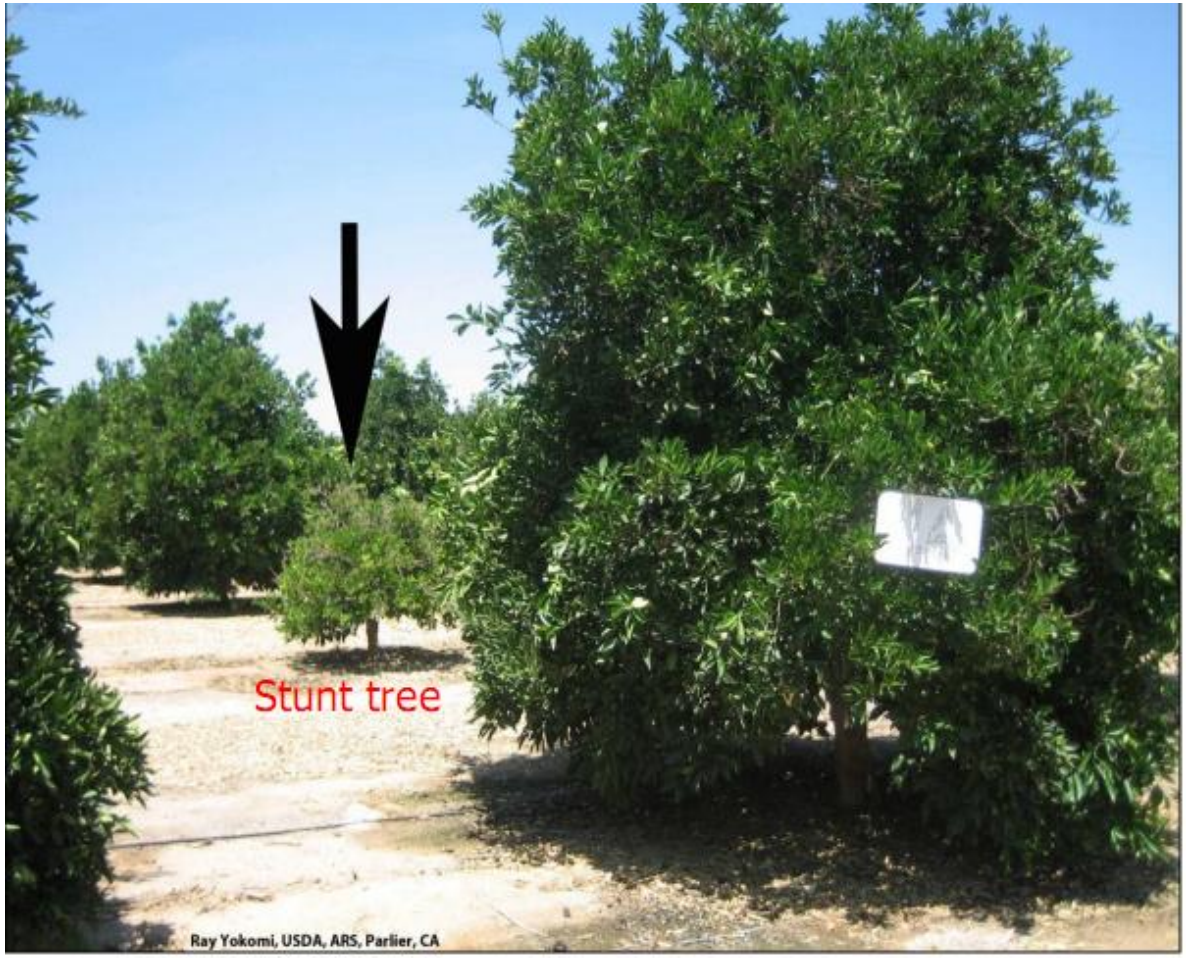
An irregular arrangement of patches of color (mottle)

Candidatus Liberibacter asiaticus, africanus and americanus

Leaf mottle: spots or blotches of different shades or colors.

Citrus stubborn disease(CSD)

Spiroplasma citri

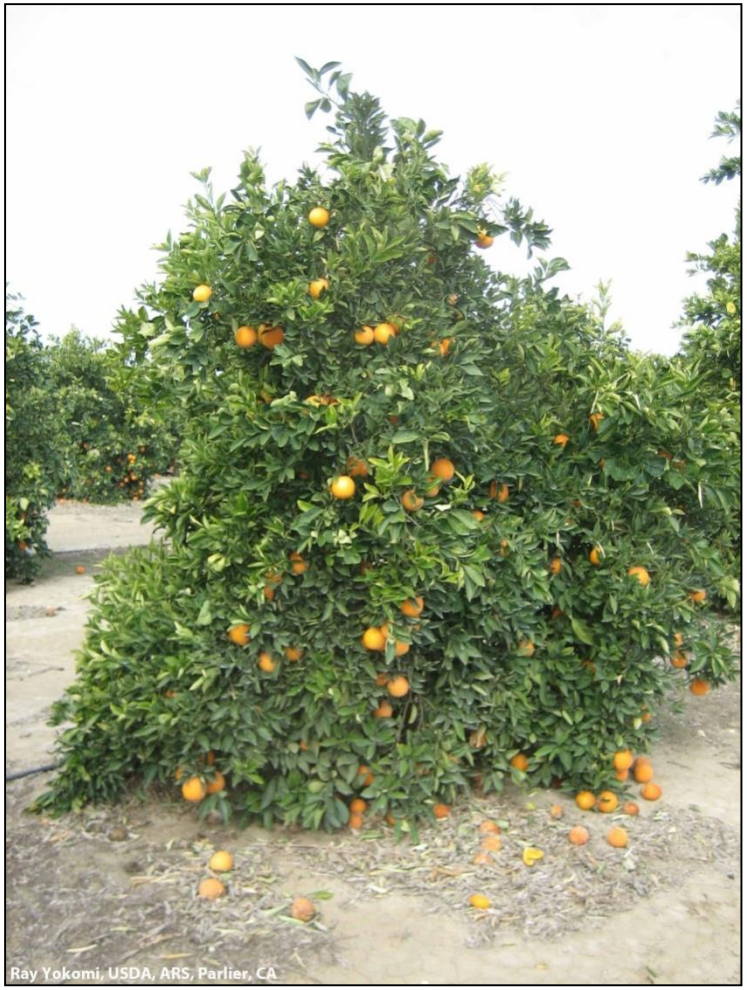


Fact sheets

Citrus stubborn disease(CSD)

Fruit drop

Spiroplasma citri



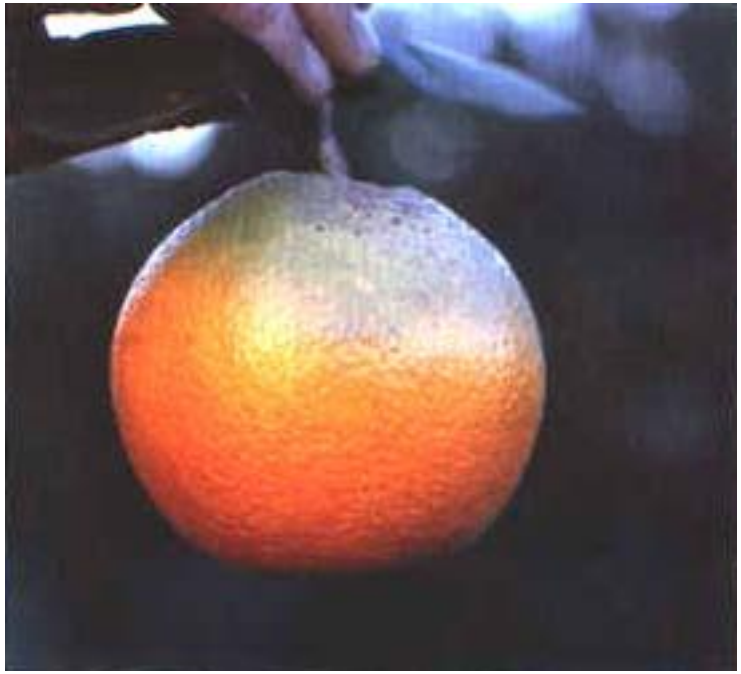
Fact sheets

Stubborn disease

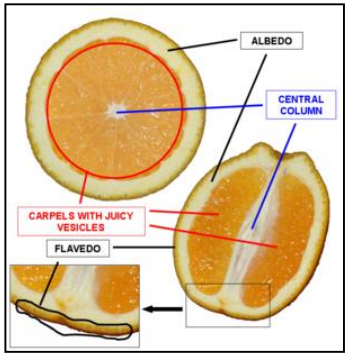
Spiroplasma citri

Outside

- Lopsided shape
- Oblong shape
- Reduced size in fruits,
- Inversion of colour formation on fruit (yellowing of fruit from top down on orange colour varieties of citrus)
- Fruit drop.



The Citrus Greening FAO TCP Project,2012;..



Stubborn disease

Spiroplasma citri

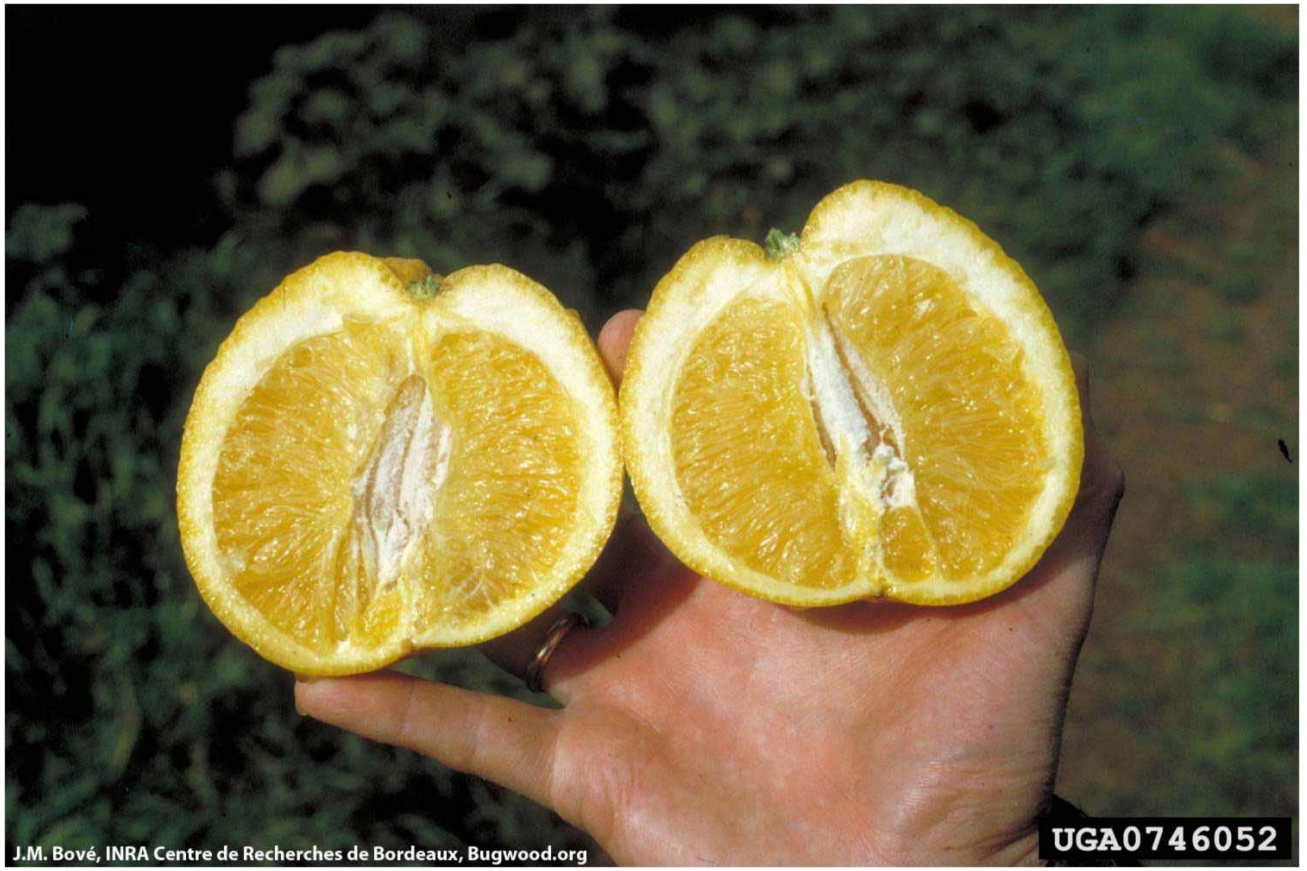
Inside

- Fruits with aborted seeds.
- Curvature of the columella or central core.
- Yellow stain beneath the calyx button
- Bitter tasting.

The Citrus Greening FAO TCP Project,2012;..

Citrus stubborn disease(CSD)

Spiroplasma citri



Misshapen and malformed, uneven fruit size
With poor taste aborted seeds.

Citrus stubborn disease(CSD)

Spiroplasma citri

- Top row: unaffected seeds;
- Bottom row: seeds affected by CSD.

Fact sheets

Lime witches' broom

'*Ca.* Phytoplasma *aurantifolia*'

Bertaccini and Duduk,2009

Association of *Pantoea agglomerans* with the citrus bacterial canker disease in Iran

Pantoea* has gained the ability to induce canker on citrus. This event can occur by transmission of parts of PAI from *Xanthomonas* to *Pantoea

- Symptoms on leaf surface of grapefruit (*C. paradisi*) developed 5-14 days after inoculation by *Pantoea* (left) and *Xcc* (right) isolates.

- Canker like symptoms (b) on adaxial (a) and abaxial (c) leaf of *C. paradisi.* Symptoms developed 60 days after inoculation by *Pantoea* isolate.

Note: *Erwinia herbicola* as the causal agent of citrus fruits blister was already reported in west Mazandaran, Iran (Nazeriyan *et al.*,2000).

Sherafati *et al.*2014

Sumatra disease of clove

Ralstonia syzygii subsp. *syzygii*

a) Field infection of Sumatra Disease of Clove caused by *Ralstonia syzygii* subsp. *syzygii* in Magelang, Central Java, Indonesia.

b) Infected twig.

c) Horizontal section of infected twig.

d) Bacterial ooze oozing from the infected twig section.

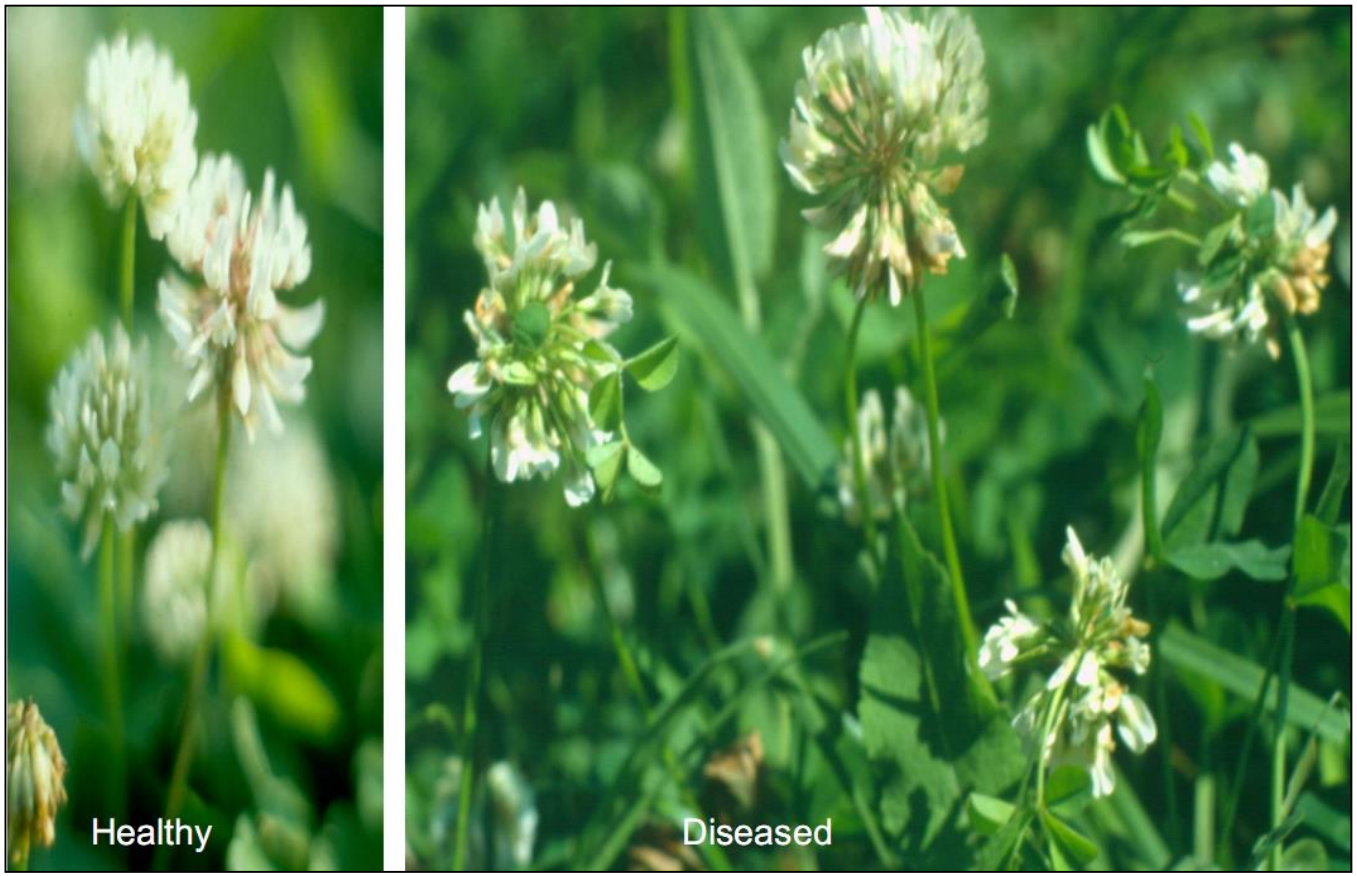
- Reprinted with permission from Bambang Trianom.

Safni *et al.*,2018

Leaf blight

Burkholderia andropogonis

Clover green petal phytoplasma



Gáborjányi,2010

Virescence
Phytoplasma

- Phytoplasma causes distortion and virescence (greening) infection of ray and disk florets (left).
- Normal flower appears on the right.
- Purple coneflower from Italy infected with 16SrIX-C phytoplasmas.

Agdex 630-2,1999; Bertaccini *et al.*,2009

Coconut lethal yellowing

Phytoplasma

Coconut inflorescence necrosis an early symptom of lethal yellowing.

Leaf yellowing on *Cocos nucifera* (coconut palm).

https://caps.ceris.purdue.edu/dmm/1910, 2013

Lethal yellows of coconut palm

Phytoplasma

FIGURE 12-59 Lethal yellowing of coconut palms. Symptoms begin at the lower leaves, which turn yellow (A) and later fall off while younger leaves turn yellow (B). Eventually all the leaves are killed, fall, and are followed by death of the tree bud (B and C), leaving the dead trees standing like utility poles (D). [Photographs courtesy of Plant Pathology Department, University of Florida.]

Agrios,2005

Bacterial blight of coffee(BBC)

Pseudomonas syringae pv. *garcae*

A, Typical symptoms of BBC disease on coffee,
B, BBC disease symptoms on new flash of suckers.

Hinkosa *et al.*,2017

Virescence
Phytoplasma

- Close-up of an infected flower of *E. purpurea* with symptoms of virescence (greening) and proliferation of disk florets.

Bacterial leaf spot

Pseudomonas syringae pv.*coriandricola*

	
Typical brown necrotic leaf lesions caused by *Pseudomonas syringae* pv. *coriandricola*. Stem lesions are also visible to the left and right.	'Oedema', physiological disorders on coriander leaves, may be confused with bacterial leaf spot, a seed-borne disease.

HDC,2009; Roberts,2024

Bacterial diseases of corn

Bacterial leaf blight and stalk rot	***Pseudomonas avenae* subsp. *avenae***
Bacterial leaf spot	***Xanthomonas campestris* pv. *holcicola***
Bacterial stalk rot	***Enterobacter dissolvens***
Bacterial stalk and top rot	***Dickeya chrysanthemi* pv. *zeae*** ***P. carotovorum* subsp. *carotovorum***
Bacterial stripe	***Pseudomonas andropogonis***
Chocolate spot	***Pseudomonas syringae* pv. *coronafaciens***
Goss's bacterial wilt and blight (leaf freckles and wilt)	***Clavibacter nebraskensis***
Holcus spot	***Pseudomonas syringae* pv. *syringae***
Seed rot-seedling blight	***Bacillus subtilis***
Stewart's disease (bacterial wilt)	***Erwinia stewartii***
Corn stunt(pale stunt)	***Spiroplasma kunkelii***
Maize bushy stunt (MBS) or red stunt or maize redness	**Stolbur phytoplasmas**

Shurtleff *et al.*,1993;..

Stewart's wilt of corn

Pantoea stewartii

- Maize also known as corn.
- Necrotic lesions on mature leaves; second phase of Stewart's wilt disease.

Stewart's wilt of corn

Pantoea stewartii

	
Cavities form at the base of the stalk on severely diseased plants.	Leaf stripe, leaf blight, wilting, and death of corn seedlings; first phase of Stewart's wilt disease.

Leaf spot

Pantoea ananatis

- Field grown maize plants showing leaf spot disease.

Pérez-y-Terrón *et al.*,2009

Stalk rot on corn

Xanthomonas campestris pv. *zeae*

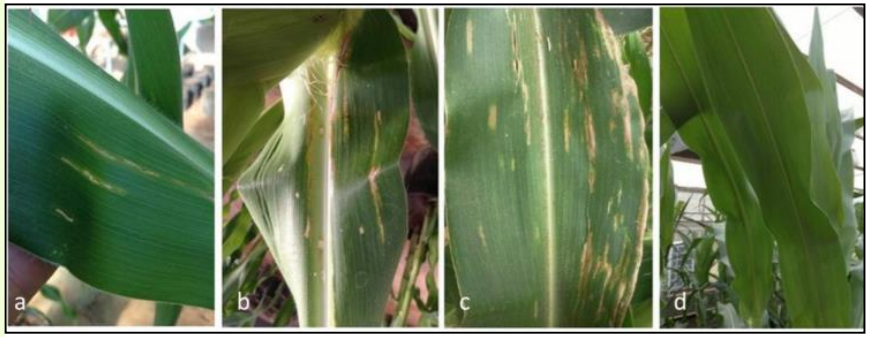
- Photographs showing symptom development as a result of spray inoculation with *Xanthomonas campestris* pv. *zeae* during pathogenicity testing. Where

a. was taken after the initial onset of symptoms (2 weeks post-inoculation),

b. 4 weeks after inoculation,

c. 7 weeks post-inoculation and

d. control plant inoculated with saline 7 weeks after inoculation.



Nienaber,2015

Stalk rot on corn

Dickeya chrysantemi

Bacterial stalk rot on corn, caused by *Erwinia chrysanthemi.*

plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf

Bacterial stalk rot

Enterobacter dissolvens

USDA Forest Service,2008

Comparison of important features of the two primary bacterial wilts of corn in Nebraska:

1. Stewart's wilt (*Pantoea stewartii*)
2. Goss' wilt (*Clavibacter nebraskense*)

	Stewart's wilt	Goss' wilt
Inoculation corn	flea beetle	hail storm
Long irregular lesions	yes	yes
Leaf freckle symptom	no	yes
Crown cavity symptom	yes	no
Vascular discoloration	yellow	orange

Goss' bacterial wilt and blight (leaf freckles and wilt)

Clavibacter nebraskensis

- General stunting and wilting.
- On leaves, gray-green streaks along veins, with water-soaked spots that resemble freckles.
- Bacterial exudate may appear on diseased tissue.
- In stalk, rotting with discoloration of vascular bundles.
- Plants may be infected at any growth stage.

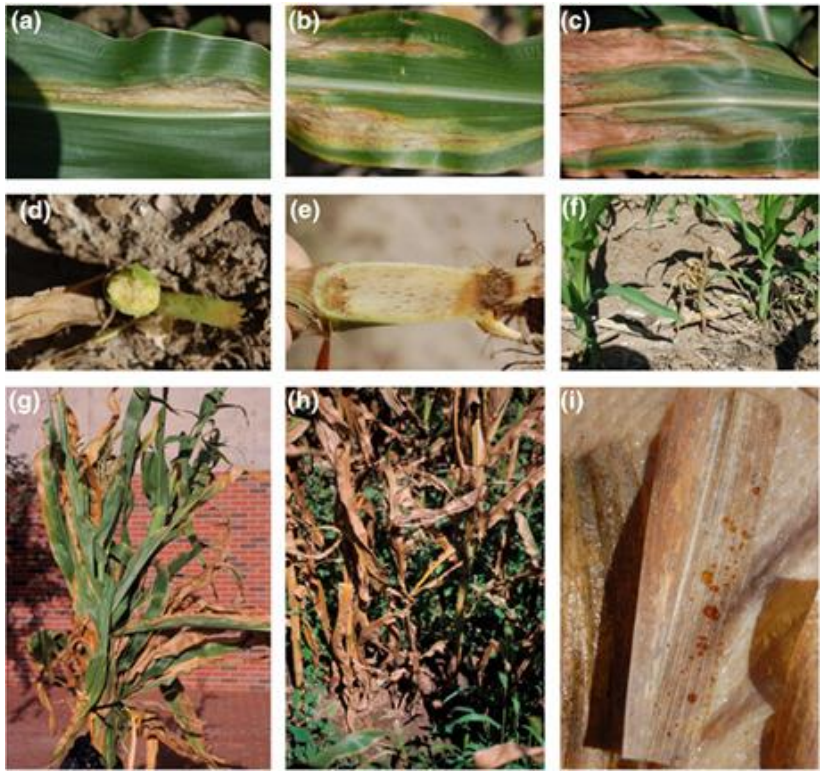
Howard F. Schwartz; Crop Genebank Knowledge Base

Corn or maize

Goss' bacterial wilt and blight (leaf freckles and wilt)

Clavibacter nebraskensis

- Field symptoms of Goss's wilt caused by *Clavibacter nebraskensis* on aerial parts of maize plants.
- Aerial symptoms include large, tan-to-grey elongated oval leaf lesions (a) that run parallel to the leaf veins (b), which could result in severe blighting or plant death (c).
- Bacterial colonization of stems during systemic infection can be identified as orange discolouration that may darken to brown or black (d) and be slimy as the infection progresses (e).
- Early infection of seedlings may result in wilt and plant death (f).
- While the leaf blight phase may occur at any stage of growth (g), the wilt phase of the disease is less common and usually occurs on severely blighted plants (h).
- The pathogen produces an extracellular polysaccharide exudate that can ooze out of infected leaf tissue and frequently is found on the surface of infected leaves (i).



Osdaghi *et al.*,2023

Chocolate spot of corn

Pseudomonas syringae pv. *coronafaciens*

Chocolate spot on corn, caused by *Pseudomonas syringae* pv. *coronafaciens*.

plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf

Corn stunt

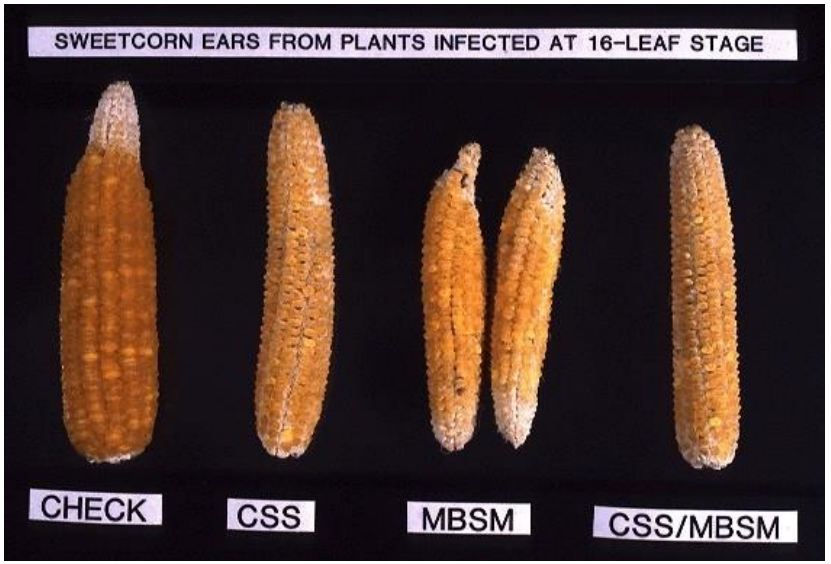
Spiroplasma kunkelii

Corn stunt

Spiroplasma kunkelii

- Symptoms on sweet corn ears.
- left to right:

1. control;
2. infected with *S. kunkelii* (CSS);
3. with maize bushy stunt mycoplasma (MBSM); and
4. with both diseases (transmitted by leafhopper *Dalbulus maidis*).



CABI,2014

Corn stunt

Spiroplasma kunkelii

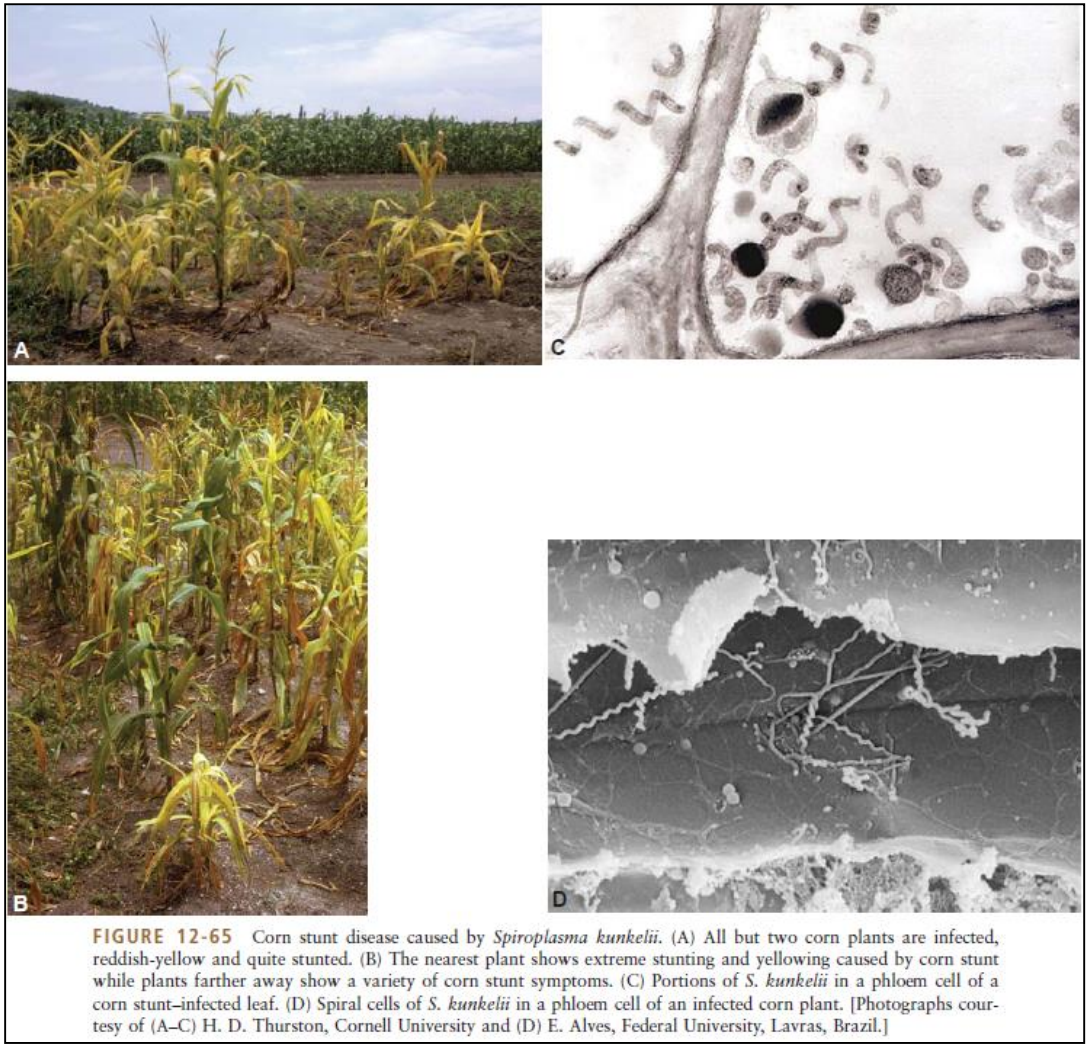


FIGURE 12-65 Corn stunt disease caused by *Spiroplasma kunkelii*. (A) All but two corn plants are infected, reddish-yellow and quite stunted. (B) The nearest plant shows extreme stunting and yellowing caused by corn stunt while plants farther away show a variety of corn stunt symptoms. (C) Portions of *S. kunkelii* in a phloem cell of a corn stunt–infected leaf. (D) Spiral cells of *S. kunkelii* in a phloem cell of an infected corn plant. [Photographs courtesy of (A–C) H. D. Thurston, Cornell University and (D) E. Alves, Federal University, Lavras, Brazil.]

Agrios,2005

Corn red stunt

Maize bushy stunt (MBS)

Infected with stolbur phytoplasmas

Bertaccini and Duduk,2009

Bacterial diseases of cotton

Bacterial blight	***Xanthomonas citri* pv. *malvacearum***
Crown gall	***Agrobacterium tumefaceins***
Lint degradation	***Pantoea agglomerans* (ex. *Erwinia herbicola*)**

Wikipedia,2011;..

Bacterial blight (angular leaf spot)
Xanthomonas citri pv. *malvacearum*

Allen *et al.*,2010

Bacterial blight lesions on leaf and the blackleg symptom on the leaf petiole

Xanthomonas citri pv. *malvacearum*

Bacterial blight lesions on leaf and the blackleg symptom on the leaf petiole.

Koenning,2004

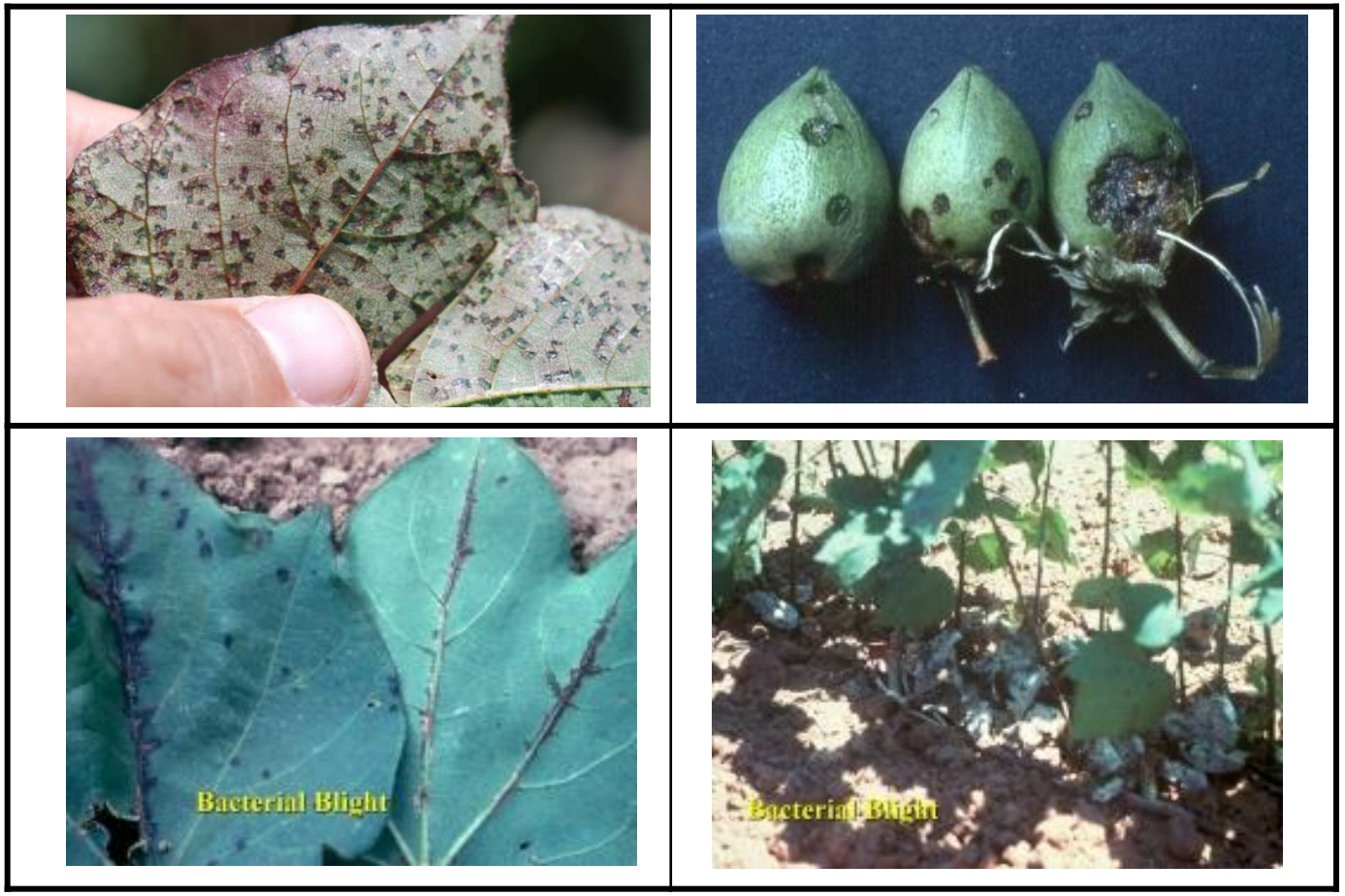
Bacterial blight (angular leaf spot)
Xanthomonas citri pv. *malvacearum*

Bacterial blight (angular leaf spot) caused by
Xanthomonas campestris pv. *malvacearum*
(=*Xanthomonas axonpodis* pv. *malvacearum*)

Koenning,2004

Bacterial blight (angular leaf spot)

Xanthomonas citri pv. *malvacearum*



Scortichini,2006; Jason Woodward;…

Bacterial leaf spot

P. syringae pv. *maculicola*

Bacterial Diseases Cucurbits

Bacterial wilt of cucurbits	*Erwinia tracheiphila*
Angular Leaf Spot	*Pseudomonas syringae* pv. *lachrymans*
Bacterial wilt of cucurbits	*Erwinia tracheiphila*
Bacterial soft rot	*Pectobacterium* spp.
Yellow vine disease of cucurbits	*Serratia marcescens*
Aster yellows	Phytoplasma

Angular Leaf Spot

Pseudomonas syringae pv. *lachrymans*

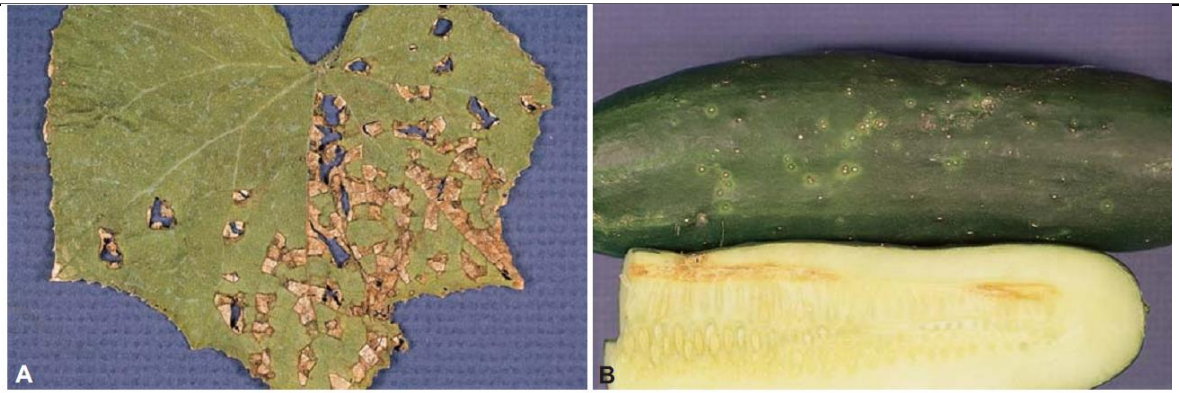
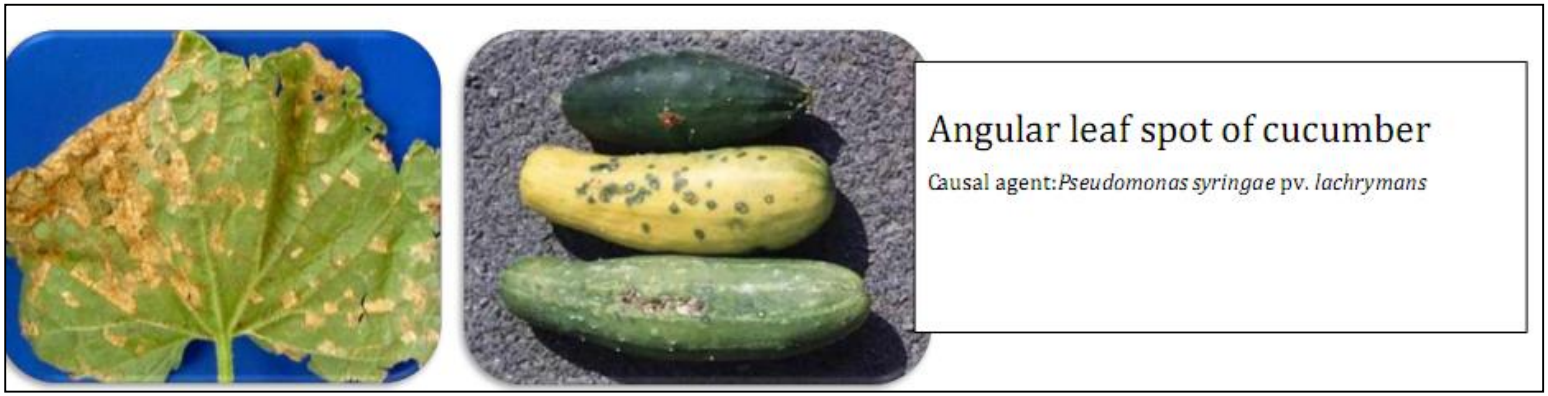


FIGURE 12-12 Angular leaf spots on cucumber leaf (A) and small circular spots with halo on cucumber fruit (B) caused by the bacterium *Pseudomonas lacrymans*. [Photographs courtesy of Plant Pathology Department, University of Florida.]

Agrios,2005

Bacterial Leaf Spot

Pseudomonas syringae pv. *lachrymans*



Technical Bulletin No. 28,2004; Shankar co-workers

Bacterial Leaf Spot

Pseudomonas syringae pv. *lachrymans*

	
Water-soaked lesions on the abaxial surface of a cucumber leaf.	Cucumber leaves: left- old, dry and necrotic leaf spots of angular leaf spot; right- young leaf spots surrounded by a yellow halo.

Cucumber disease field guide

Bacterial wilt of cucurbits

Erwinia tracheiphila

Early symptom of bacterial wilt in cucumber.

Vine death of cucumber caused by bacterial wilt.

Miller *et al.*,

Bacterial wilt of cucurbits

Erwinia tracheiphila

Symptoms of yellowing, wilting and dieback of the foliage of squash (provided by the Plant Disease Diagnostic Clinic, Cornell University).

Bacterial wilt of cucurbits

Erwinia tracheiphila

Bacterial wilt "silk thread"

This disease is severe on cucumber and melon, but is less damaging to squash and watermelon.

Masses of bacteria streaming from xylem

Yellow vine disease of cucurbits (Watermelon, squash, pumpkin) *Serratia marcescens*

- Cucurbit yellow vine disease showing yellowing and collapse of vines.
- (Image by Elizabeth Little)

Yellow vine disease of cucurbits (Watermelon, squash, pumpkin) *Serratia marcescens*

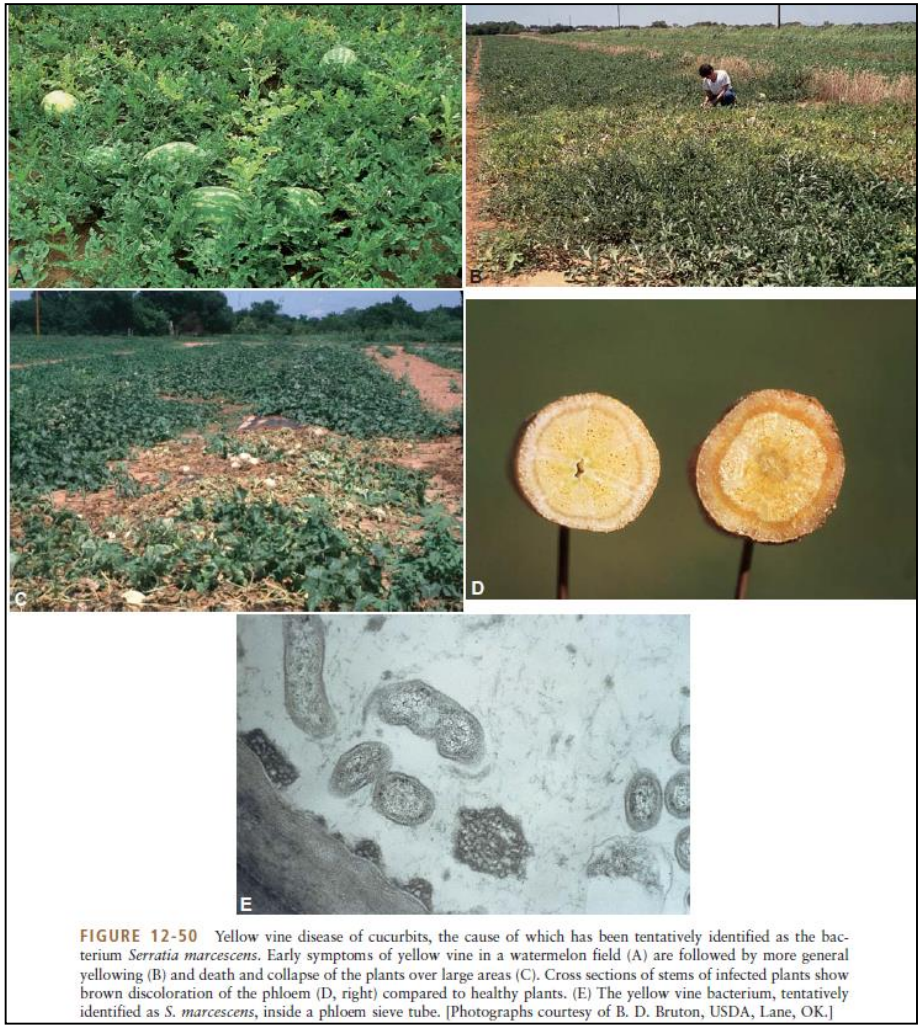


FIGURE 12-50 Yellow vine disease of cucurbits, the cause of which has been tentatively identified as the bacterium *Serratia marcescens*. Early symptoms of yellow vine in a watermelon field (A) are followed by more general yellowing (B) and death and collapse of the plants over large areas (C). Cross sections of stems of infected plants show brown discoloration of the phloem (D, right) compared to healthy plants. (E) The yellow vine bacterium, tentatively identified as *S. marcescens*, inside a phloem sieve tube. [Photographs courtesy of B. D. Bruton, USDA, Lane, OK.]

Agrios,2005

Soft rot

Dickeya dieffenbachiae

Scortichini,2006

Marginal necrosis

Pseudomonas marginalis pv. *marginalis*

Scortichini,2006

Bacterial leaf spot

Xanthomonas axonopodis pv. *dieffenbachiae*

- Xanthomonas leaf spot of Dieffenbachia is caused by the same pathogen as the disease on Anthuriums.
- This disease was found regularly on many other species of ornamental plants belonging to the family of Araceae, but only occasionally on dieffenbachia (EPPO... 2004, Janse 2005).

Chase,1991; Mikiciński *et al.*,2010

Soft rots

Bacillus pumilus*, *Chryseobacterium vrystaatense*, *Flavobacterium defluvii* or *F. johnsoniae

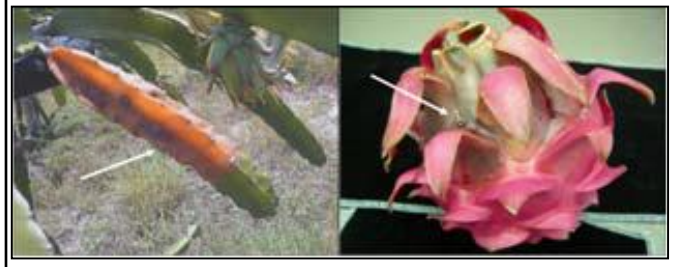
- The leaves of *Dieffenbachia maculata* cv. 'Camilla' with disease symptoms such as beige water soaked as well as necrotic lesions located at the base of shoots and on the leaves near the main vein.

Mikiciński *et al.*,2010

Bacterial soft rot

Enterobacter cloacae

Red Pitaya, Dragon Fruit

	
The symptoms of soft rot disease on infected stem and fruit.	The symptoms appeared on the inoculated stem and fruit during *in vitro* pathogenicity test.

Masyahit *et al.*,2009

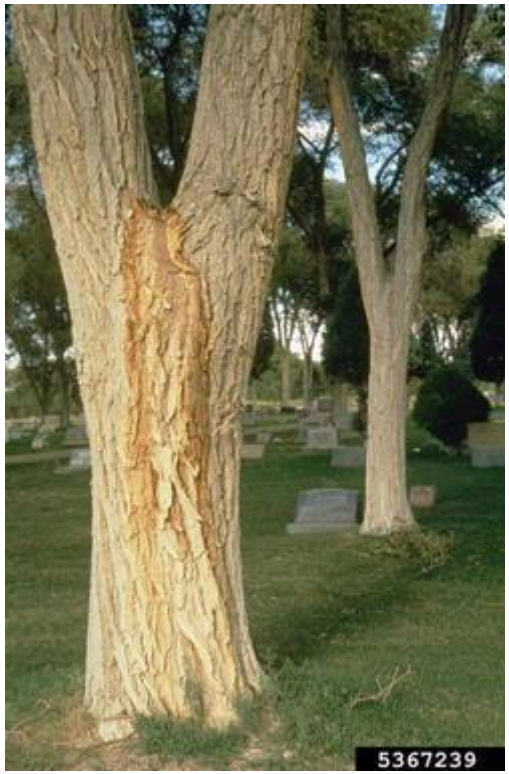
Wetwood or slime flux of elm

Certain kinds of fermenting bacteria and yeasts

- This disease is most often found on elm, maple, birch, oak, poplar, sycamore, and willow.
- Certain kinds of fermenting bacteria and yeasts cause this condition.

Bacterial wetwood on elm

Enterobacter nimipressuralis



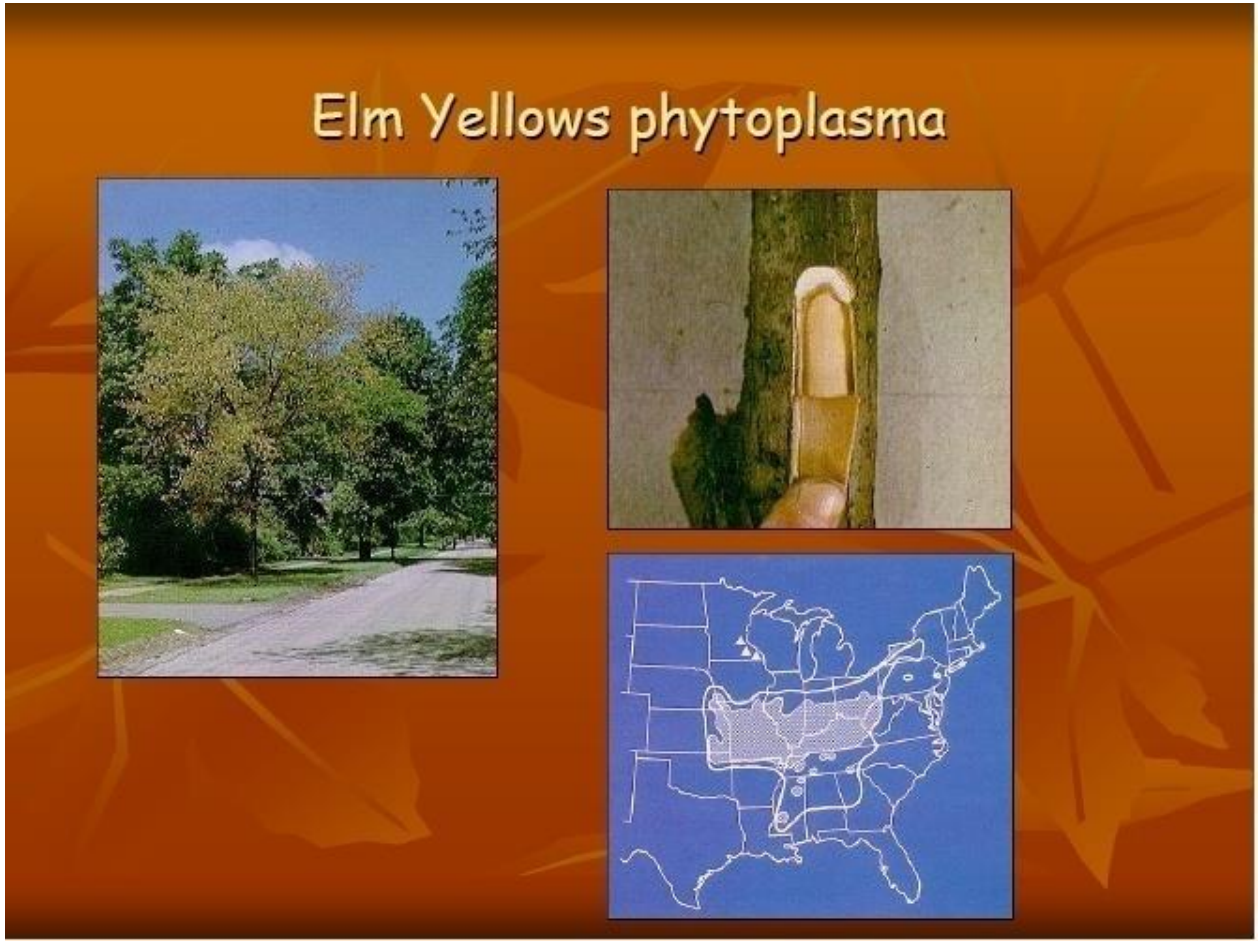
USD Forest Service,2008

Leaf scorch of elm

Xylella fastidiosa

Leaf scorch of elm

Xylella fastidiosa

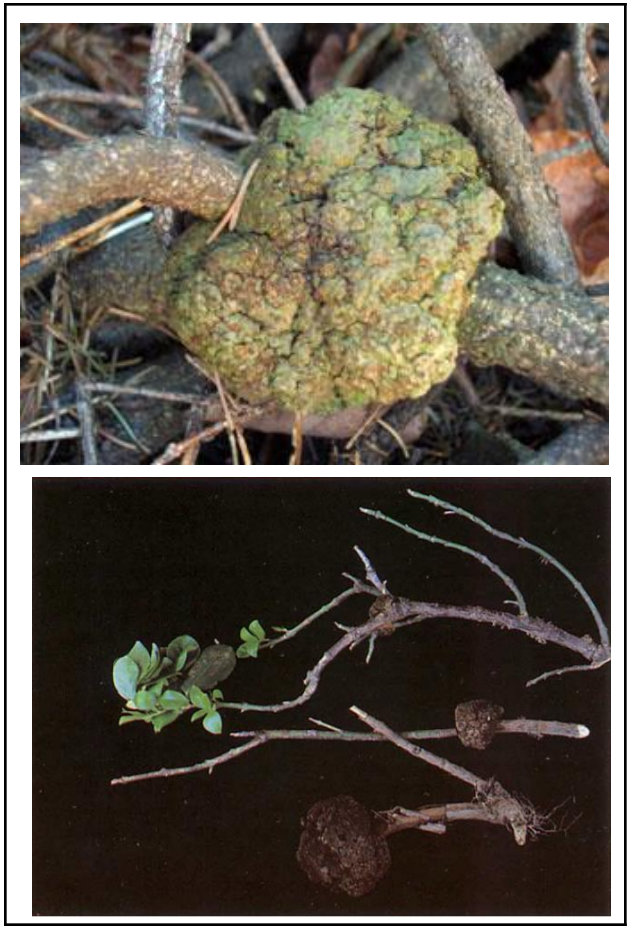


A. Wayadande

Crown gall

Agrobacterium tumefaciens

- Evergreen spindle or Japanese spindle trees (*Euonymus japonicus*- Family Celastraceae) are evergreen shrubs grown for hedges in parks.
- This disease is characterized by the growth of galls (tumor-like swellings) on roots and/or stems, generally at the soil line.



Feather,2009;Queen's Printer for Ontario,1991;..

Japanese spindle witches' broom
Phytoplasma

- Recently, diseased trees in Tehran (Iran) were observed with symptoms of little leaves and a bushy appearance suspected to be caused by a phytoplasma.
- Since the trees showed witches' broom in one or more of their branches we named it "Japanese spindle witches' broom" (JSWB).

Rashidi *et al.*,2009

Bacterial leaf and dieback diseases of Eucalyptus

Bacterial leaf blight of eucalyptus	***Xanthomonas, Pseudomonas, Erwinia, Rhizobiaceae***
Shoot and stem die-back	***Erwinia psidii***
Bacterial blight of eucalyptus	***Pantoea ananatis*** ***Xanthomonas axonopodis* pv. *eucalyptorum*** ***Xanthomonas dyei* pv. *eucalypti*** ***Pseudomonas syringae*** ***P. putida*** ***P. cichorii*** ***Enterobacter cowanii*** ***Erwinia* sp.** ***Pantoea vagans*** ***Pantoea eucalypti*** ***Pantoea deleyi*** ***Pantoea anthophila***

Gonçalves *et al.*,2008; Brady *et al.*,2009:FABI

Bacterial leaf blight of eucalyptus

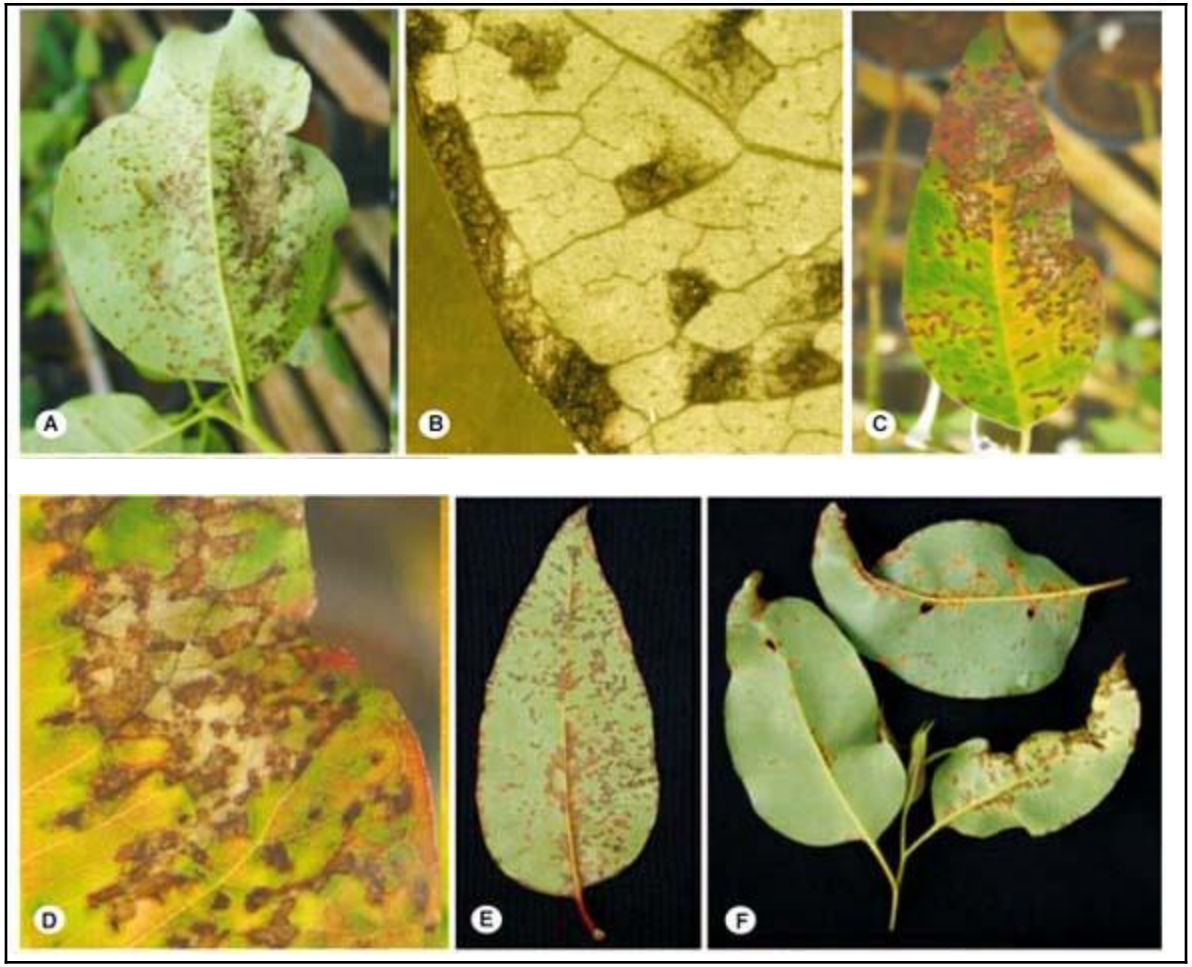
Xanthomonas, Pseudomonas, Erwinia, Rhizobiaceae

- Disease symptoms may vary depending on leaf age, development stage of the lesion and species of *Eucalyptus*:
- Water soaked, angular, interveinal, and anphighenous lesions (Figure 1 A-B), sometimes with chlorotic or reddish edges, distributed over the limb or just on one half of the leaf blade, but especially along the main vein and on the edges of the leaf (Figure 1 C-E).
- Deformities in the leaf limb and abortion of the lesioned area are usually observed, resulting in cut or perforated limbs (Figure 1 F).
- Unequivocal diagnosis is accomplished by bacterial cell exudation from leaf sections placed in a water drop under light microscope (200 x) (Figure 1 G).
- Defoliation commonly occurs on highly susceptible genotypes due to the early senescence of infected leaves (Figure 1 H-I).
- The pathogen may also infect the terminal twigs of the plant, causing die-back (Alfenas *et al.*,2004).

Gonçalves *et al.*,2008

Bacterial leaf blight of eucalyptus

Xanthomonas, Pseudomonas, Erwinia, Rhizobiaceae



Gonçalves *et al.*,2008

Bacterial leaf blight of eucalyptus

Xanthomonas, *Pseudomonas*, *Erwinia*, and *Rhizobiaceae*

Symptoms of bacterial leaf blight in *Eucalyptus* spp.: A. Lesions at initial stage.; B. Detail of water soak; C. Interveinal angular lesions; D. Detail of angular necrotic lesions with chlorotic or reddened edges; E. Lesions concentrated along the main nerve and at the limb margins; F. Perforation, deformity and cutting of leaf limb; G. Microscopic exudation of bacterial pus; H. Defoliation; I. Detail of diseased branch.

Gonçalves *et al.*,2008

Bacterial shoot and stem die-back disease of eucalyptus

Erwinia psidii

- Field symptoms of the disease on Eucalyptus caused by *E. psidii*.

a. Shoot tip dieback of a young *E. grandis* clone.

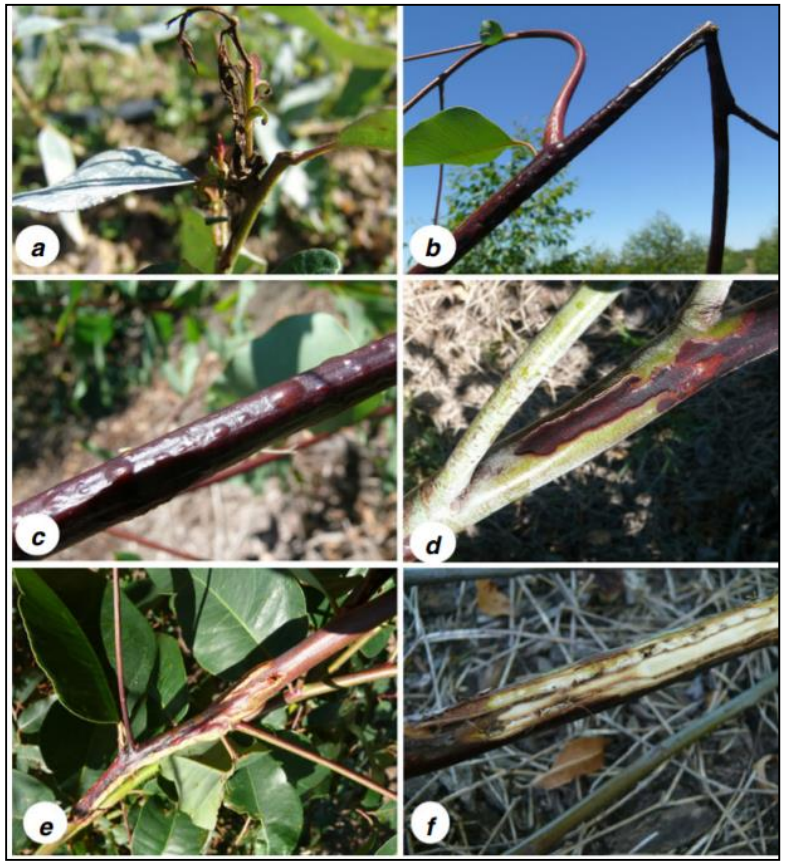
b. Weakened stem due to infection which led to breakage.

c. Blisters on a *E. grandis* stem.

d. Stem canker on young, actively growing *E. grandis* tissue.

e. Advanced stem canker.

f. After removal of the bark, discoloured tissue is evident which is the result of both *E. psidii* and endophytic *Botryosphaeria* spp. secondary fungal infections.



Coutinho *et al.*,2011

Bacterial shoot and stem die-back disease of eucalyptus

Erwinia psidii

- Shoot blight associated with *Erwinia psidii* on Eucalyptus dunnii in Uruguay.

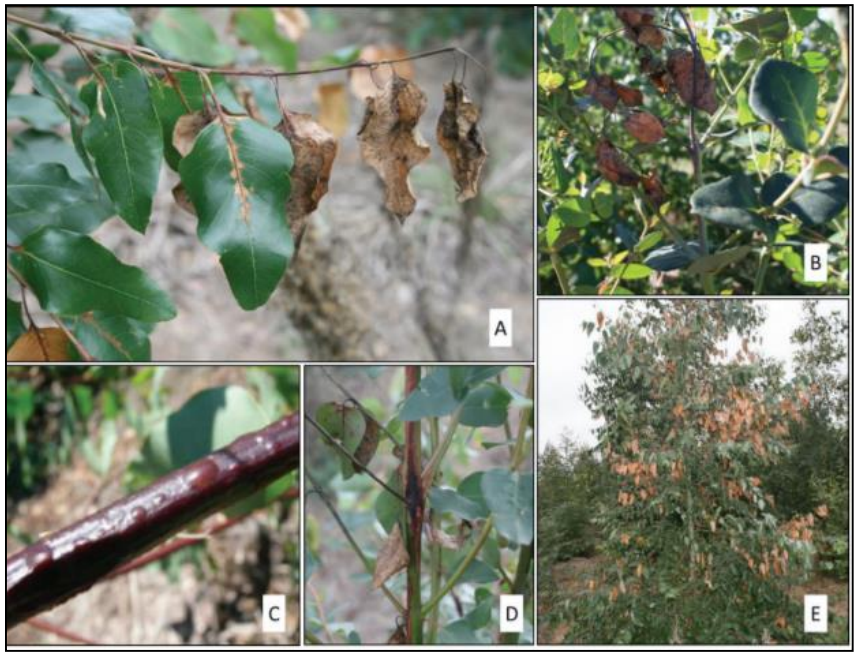
A. Shoot blight with leaf spots located on the midrib,

B. Young shoot dieback from top to bottom,

C. Bacteria blisters on young stem,

D. Canker driven from stem blight, and

E. Tree showing multiple infected leaders after a severe blight attack.



Palladino *et al.*,2016

Bacterial blight of Eucalyptus

Pantoea ananatis

Typical symptoms of bacterial blight of Eucalyptus

P. ananatis is responsible for bacterial blight and die-back of *Eucalyptus*.

Bacterial leaf blight of Eucalyptus

Xanthomonas axonopodis

- Bacterial leaf spot associated with *X. axonopodis* on *Eucalyptus grandis* Hill ex Maiden in Uruguay.

A. Leaf spots mainly irregularly distributed around the upper surface of the leaf and concentrated on the edges of the leaf,

B. On the lower leaf surface watery spots are observed; they are not observed in the upper side of the blade,

C. Leaf blotch on the main ridge that can deform the sheet,

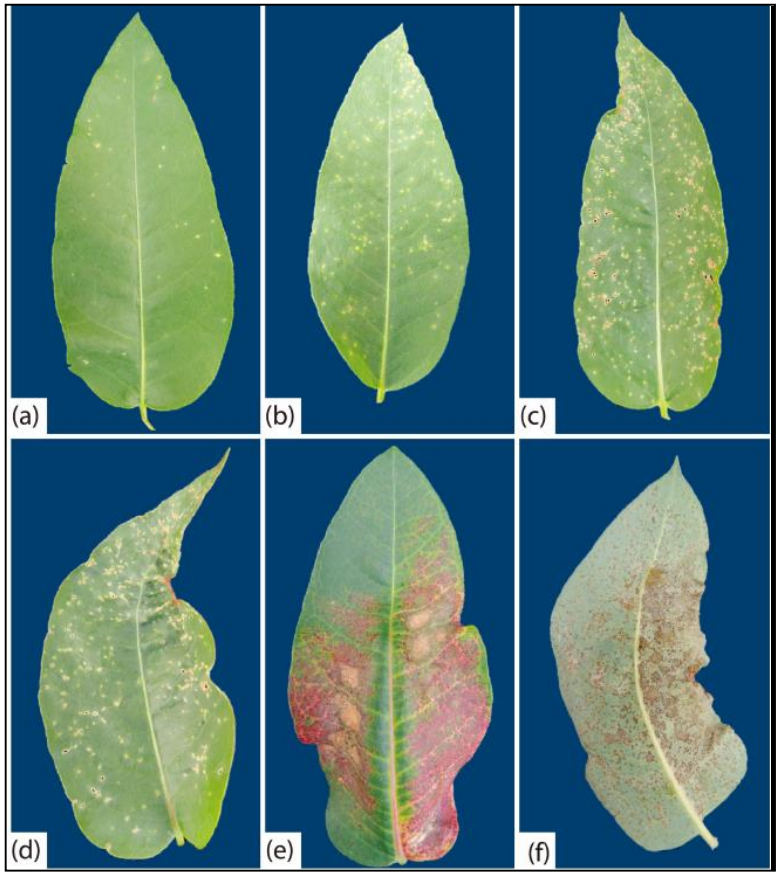
D. Bacterial spots on the petiole and young stems.

Palladino *et al.*,2016

Bacterial leaf blight of Eucalyptus

Xanthomonas axonopodis pv. *eucalyptorum*

- Symptoms caused by *Xanthomonas axonopodis* in clone CLR368 of *Eucalyptus urophylla* × *E. globulus*.
- (a) Small chlorotic lesions caused by LPF 588;
- (b) coalescing lesions caused by LPF601;
- (c) perforation in the centers of lesions caused by LPF 573;
- (d) tanned injuries caused by LPF 591;
- (e) and (f) necrotic and rough lesions on the adaxial and abaxial sides of the leaf caused by LPF 594.
- Pictures were taken at 23 days after inoculation.



Ferraz *et al.*,2018

Bacterial diseases of fig trees or figs
Edible and ornamental foliage figs

- *Ficus* spp., collectively known as fig trees or figs.

1. The common edible Fig (*F. carica*) is a temperate species native to southwest Asia and the Mediterranean region. It has been widely cultivated from ancient times for its fruit.
2. *Ficus* species used as foliage plants include *F. altissima*, *F. benjamina* (weeping fig), *F. binnedijkii*, *F. elastica* (Indian rubber plant), *F. lyrata* (fiddle-leaved fig), *F. microcarpa*, *F. pumila*, *F. retusa*, and *F. rubiginosa*, among others.

- Bacterial diseases are generally fatal to ficus trees.
- *Xanthomonas* leaf spot begins as tiny water soaked spots on the foliage. The spots enlarge rapidly and may develop bright yellow margins.

Wikipedia,2014; www.gardenguides.com

Bacterial diseases of fig trees or figs
Edible and ornamental foliage figs

Crown gall	*Agrobacterium tumefaciens*
Crown gall of foliage weeping fig(*F. benjamina*)	*Agrobacterium larrymoorei*
Leaf spot on foliage fiddle-leaved fig (*F. lyrata*)	*Pseudomonas cichorii*
Leaf spot on a Japanese ornamental fig (*Ficus erecta*)	*Pseudomonas ficuserectae* (synonyms of *Pseudomonas amygdali*)
Bacterial blight on foliage Indian rubber plant (*Ficus elastica*)	*Xanthomonas* sp.
Leaf spot, also called bacterial blight on foliage weeping fig(*F. benjamina*) and tiger bark fig (*Ficus retusa*)	*Xanthomonas campestris* pv. *fici*

Note: *P. amygdali* would take priority (Bull *et al.*,2010

Wikipedia, 2016; Campoverde and Palmateer,2010; Moorman,2014

Bacterial diseases of fig fruits

Fruit souring

- Souring was the first disease of the fruit of the fig.
- Various yeasts, fungi, and bacteria apparently responsible for the disease.
- Organisms are carried into the fruit by the dried fruit beetle, *Carpophilus hemipterus*.
- It is a preharvest problem resulting from yeasts and bacteria carried into the figs by insects, especially vinegar flies, resulting in odors of alcohol or acetic acid.

Crisosto and Kader,2004;..

Bacterial diseases of fig fruits

Fruit souring

- Figs can't see, but they do have eyes.
- The eye of a fig is an opening at the apex of the fruit (the ostiole) where the skin comes together.
- Closed Closed eyes prevent bacteria, fungi and insects from getting inside the fig and causing souring.
- Many types of rot were observed, from the soft, watery, fermented type to the typical dry-rot type.

Just Fruits and Exotics; Caldis,1930

Fig

Crown gall of foliage weeping fig(*F. benjamina*)

A. tumefaciens

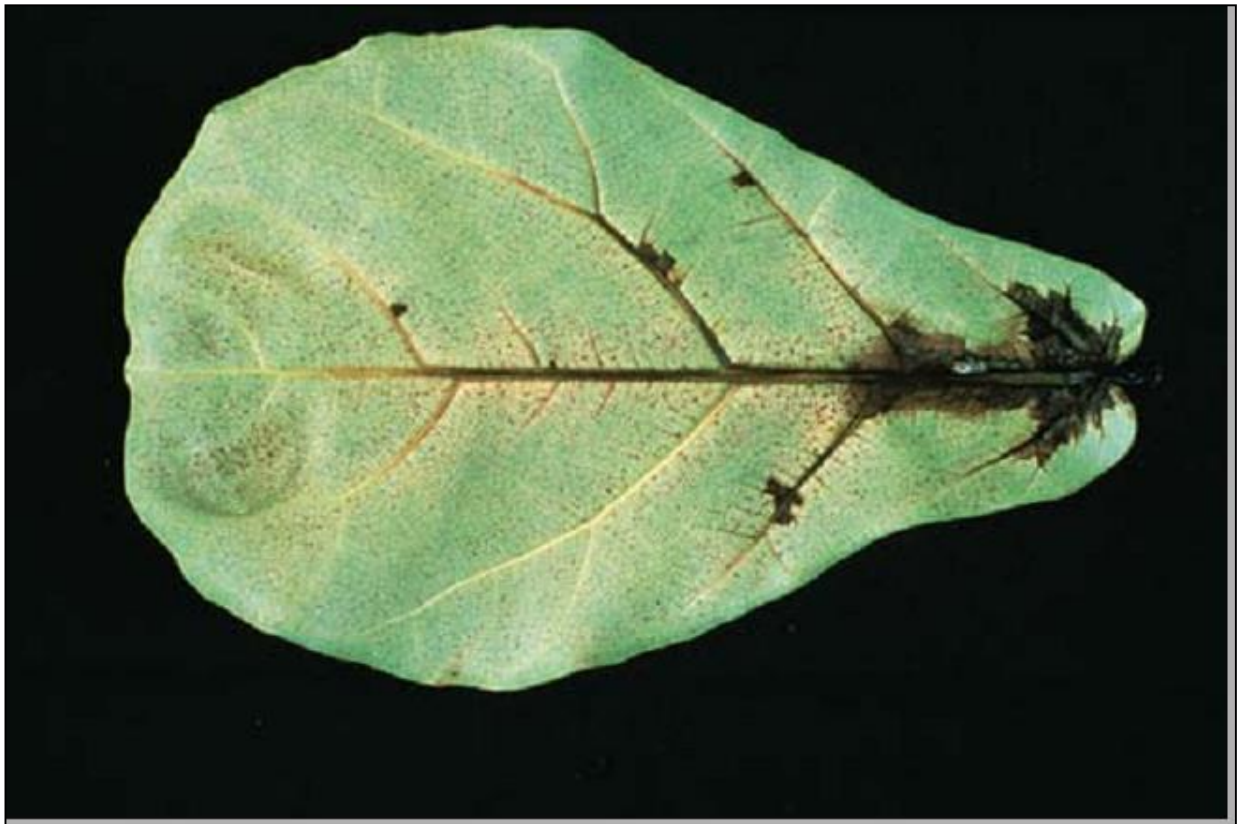
Crown gall of *Ficus benjamina*, caused by *Agrobacterium tumefaciens*.

plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf; D. J. Norman

Fig

Leaf spot on foliage fiddle-leaved fig (*F. lyrata*)

Pseudomonas cichorii



Leaf disease of *Ficus lyrata* infected with *Pseudomonas cichorii*.

plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf

Fig

Leaf spot on foliage *Ficus elastica* and *F. lyrata* figs

Pseudomonas cichorii

	
Pseudomonas leaf spot on *Ficus elastica*. Credits: D. J. Norman.	Pseudomonas leaf spot on *Ficus lyrata*. Credits: D. J. Norman

Norman and Ali,2013

Fig

Xanthomonas leaf spot on foliage *Ficus benjamina* and *Ficus retusa*

Xanthomonas campestris

Xanthomonas leaf spot on *Ficus benjamina* and *Ficus retusa*.
Credits: D. J. Norman

Norman and Ali,2013

Fig

Bacterial blight on foliage Indian rubber plant (*F. elastica*)

Xanthomonas sp.

High incidence and severity of *Xanthomonas* blight on *F. Elastica*.

Classic symptoms on older leaves showing on both sides of *Ficus* leaf.

Campoverde and Palmateer,2010

Fig

Bacterial blight on foliage Indian rubber plant (*F. elastica*)

Xanthomonas sp.

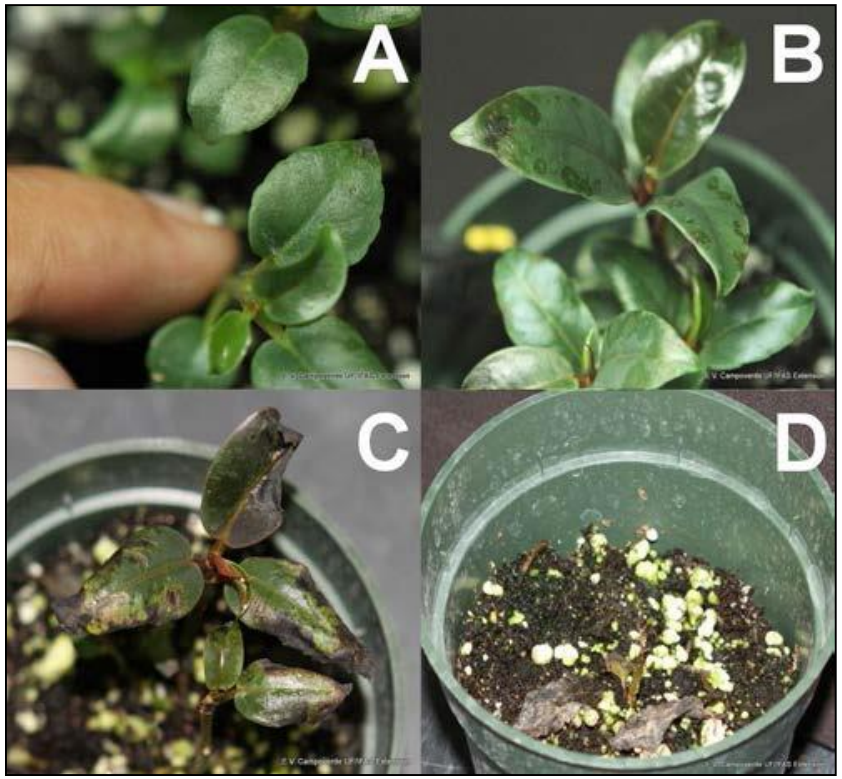
- *Ficus elastica* plant inoculated with *Xanthomonas* showing disease progress.

A. Local lesions after 7 days.

B. Water-soaked lesions after 10 days.

C. Necrosis symptoms.

D. Death, 21 days after inoculation.



Campoverde and Palmateer,2010

Bacterial Soft Rot

Erwinia carotovorum ssp. *carotovorum, D. chrysanthemi, B. gladioli,* and *Enterobacter cloacae*

Sour skin

Burkholderia cepacia

Onion scales affected by sour skin turn soft and tan.

Photo by Ronald E. Voss

Southern wilt of geranium

Ralstonia solanacearum Race3 Biovar2

	
Cutting rot	**Chlorosis & Necrosis**
	
Bacterial ooze	**Fe/Mn toxicity**

Images by Margery Daughtrey, Cornell University

Southern wilt of geranium

Ralstonia solanacearum Race3 Biovar2

Wilting and cupping generally occurs on the older leaves first and is apparent on younger growth as disease develops.

Roots brown and rotten stems.

Bacterial blight or wilt of geranium
X. hortorum pv. *pelargonii*

V-shaped yellowing that ends on the vein

Ooze from cut water conducting tissue

Typical wilting

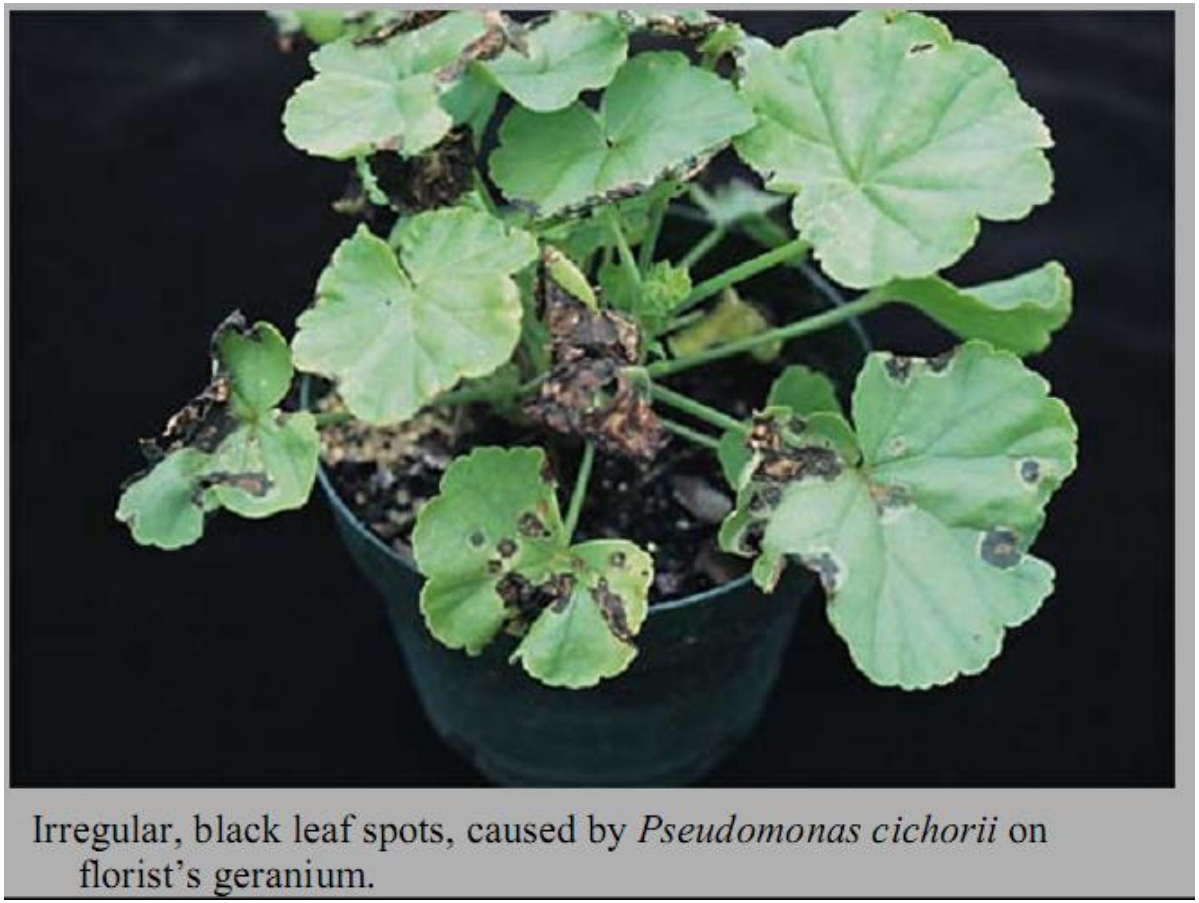
Blight

Xanthomonas hortorum pv. *pelargonii*

Scortichini,2006

Leaf spot of Geranium

Pseudomonas cichorii

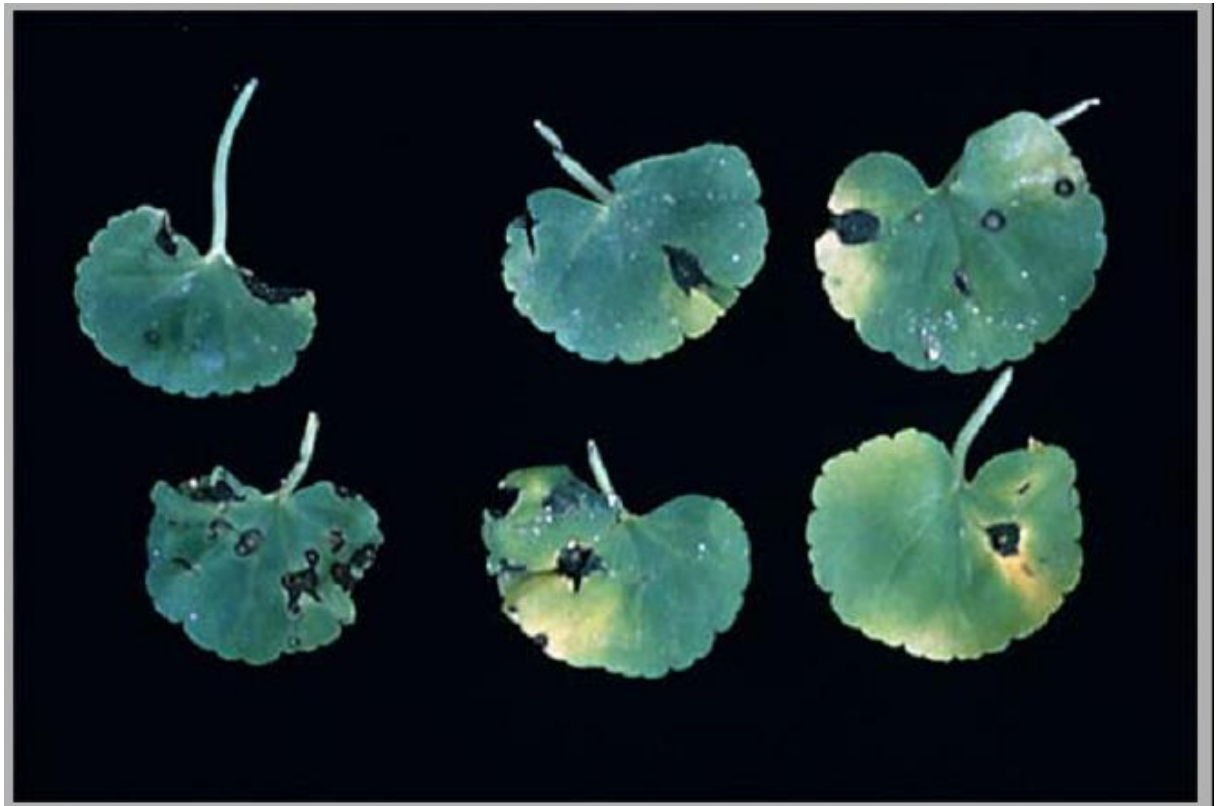


Irregular, black leaf spots, caused by *Pseudomonas cichorii* on florist's geranium.

plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf

Leaf spot of geranium

Pseudomonas syringae

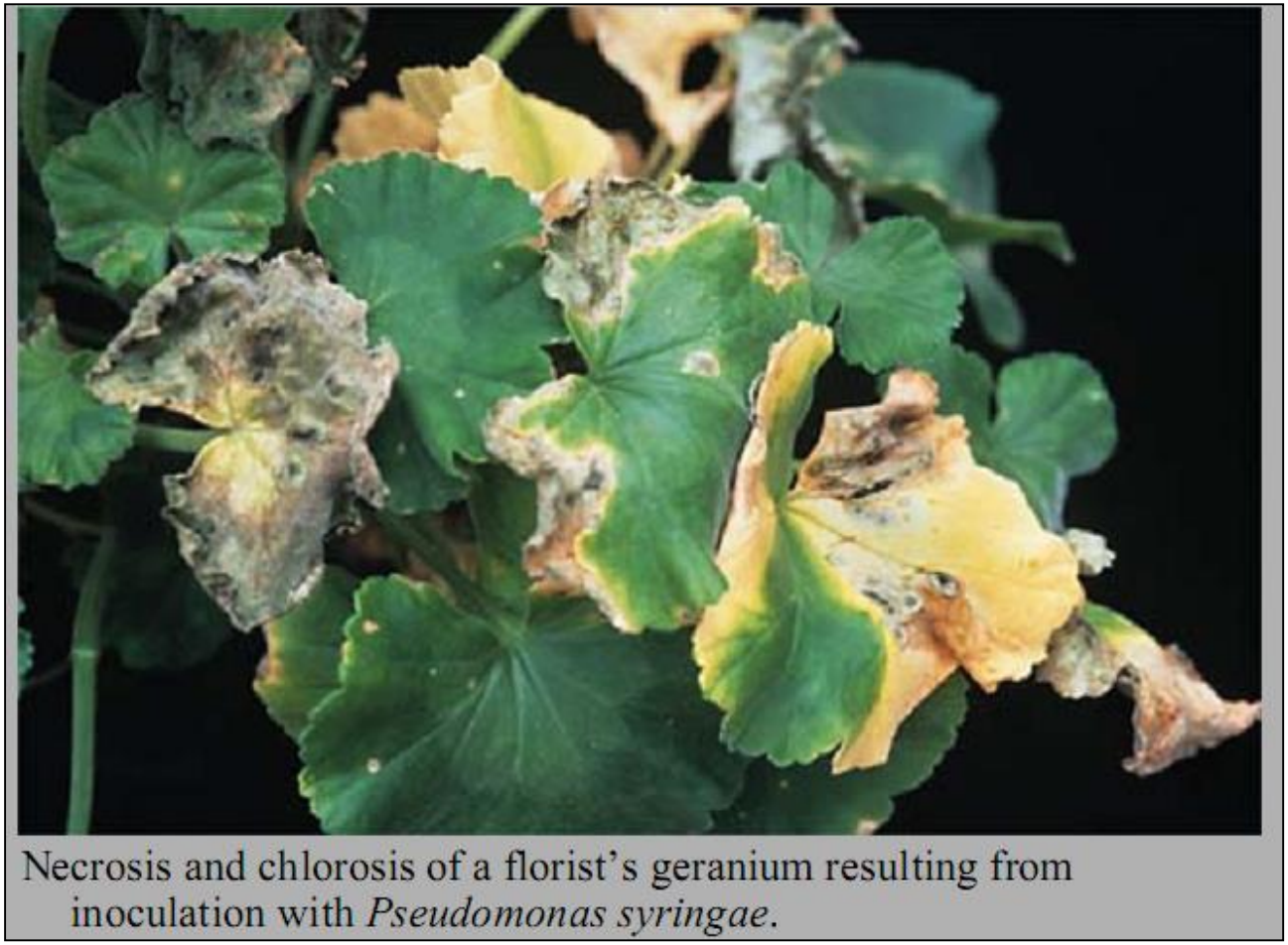


Hybrid seedling geranium leaves with bacterial leaf spots caused by *Pseudomonas syringae*.

plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf

Leaf spot of geranium

Pseudomonas syringae



Necrosis and chlorosis of a florist's geranium resulting from inoculation with *Pseudomonas syringae*.

plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf

Abnormal branching and stem development near the base of infected plants *Rhodococcus fascians*

- Stunted basal shoots typical of bacterial fasciation of florists' geranium, caused by *Rhodococcus fascians*.
- (Courtesy M. Daughtrey)

Ginger wilt

R. solanacearum

- Strands of milky white, plant-pathogenic bacteria streaming from an infected ginger rhizome suspended in a beaker of water, a sign of bacterial wilt disease.

Ginger bacterial wilt website

Ginger wilt

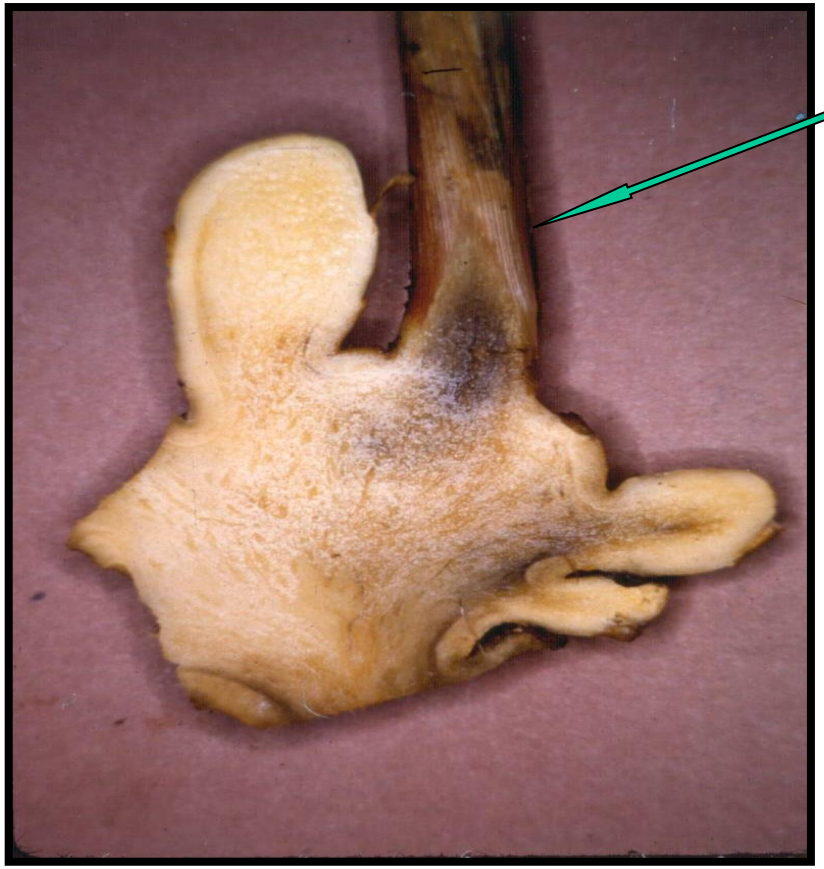
R. solanacearum

Decayed rhizomes

Wilted foliage

Ginger wilt

R. solanacearum



Discoloration of vascular tissues

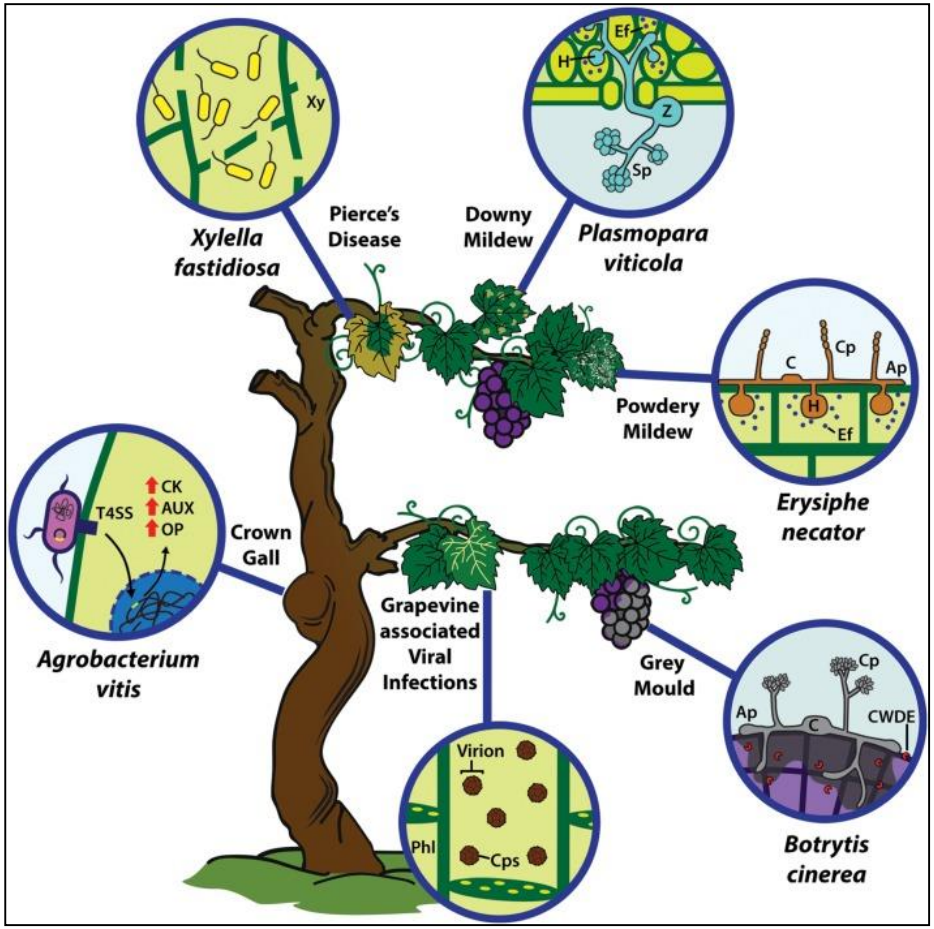
Secondary rots by enteric bacteria.

Ginger bacterial wilt website

Grape Bacterial Diseases

Crown gall	***Agrobacterium vitis***
Bacterial canker of grapevine	***X. campestris* pv. *viticola***
Bacterial inflorescence rot	***Pseudomonas syringae* pv. *syringae***
Bacterial blight of grapevine	***Xylophilus ampelinus***
Pierce's disease	***Xylella fastidiosa***
1. Flavescence dorée 2. Bois noir (black wood) 3. Grapevine yellows	**Phytoplasma**

Grapevine pathogenic microorganisms
Bacteria, fungi, oomycetes and viruses
Agrobacterium and *Xylella*

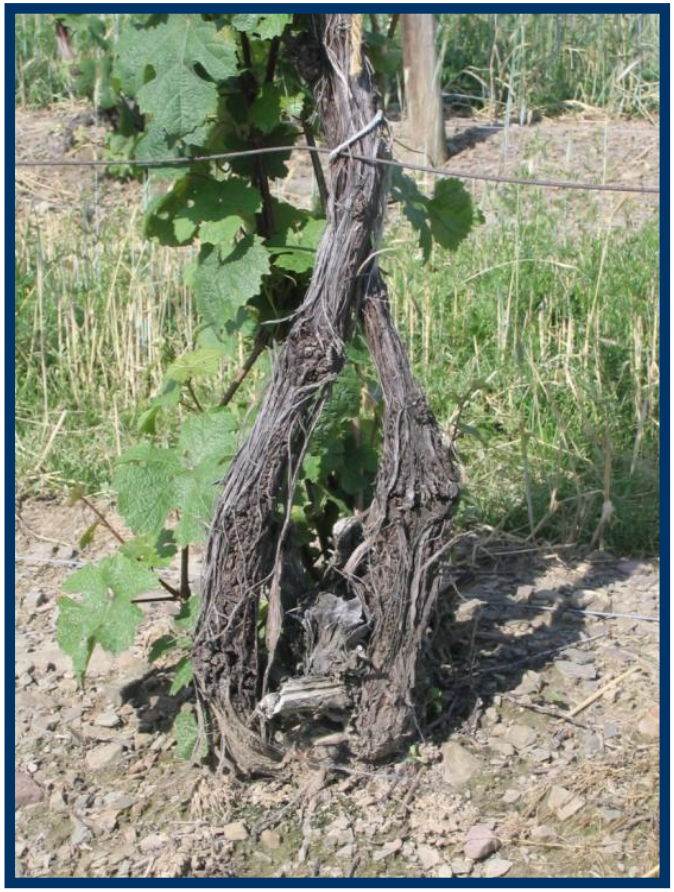


Armijo *et al.*,2016

Crown gall

Tumors or galls on the lower stem

Agrobacterium vitis



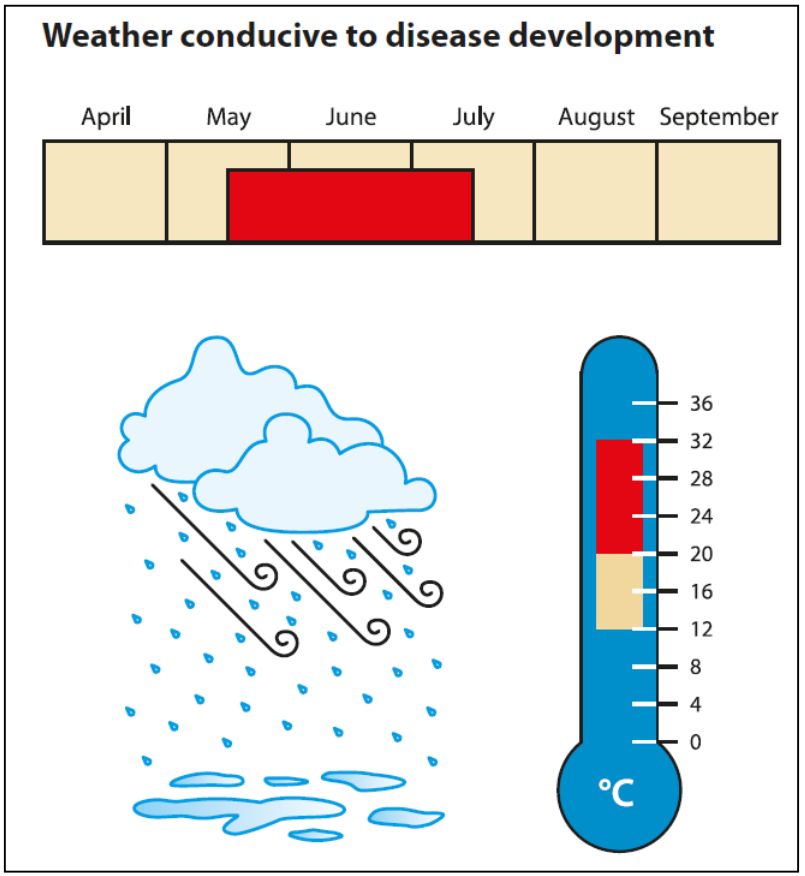
De La Fuente,2009; Hartman,2007

Crown gall

Tumors or galls on the lower stem

Agrobacterium tumefaciens

- Crown galls can take several years to appear.
- They develop normally at temperatures of 20 to 32°C and more slowly at temperatures of 15°C and below.
- *A. vitis* is also capable of surviving for up to 5 years in root debris after infected vines have been removed.

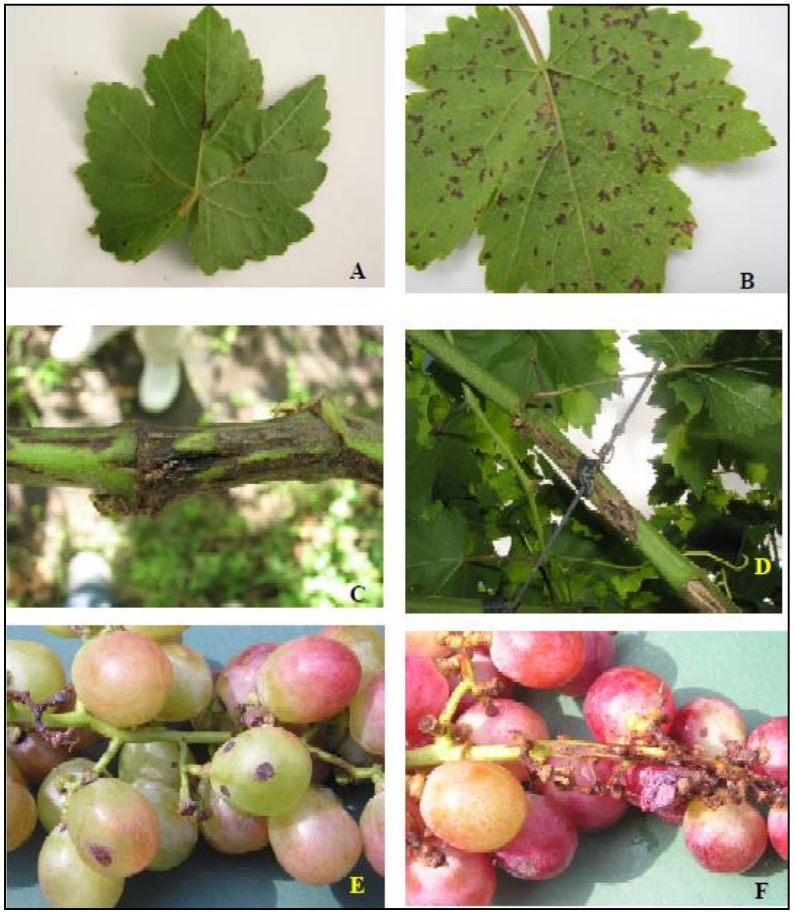


Carisse *et al.*,2006

Bacterial canker of grapevine

Xanthomonas campestris pv. *viticola*

- The disease is characterized by necrotic leaf spots, which sometimes coalesce, producing extensive necrosis.
- Symptoms also develop on leaf veins, petioles, pedicels and rachis of grape clusters. Cankers and vascular discoloration are usually observed on stems.



Trindade,2007

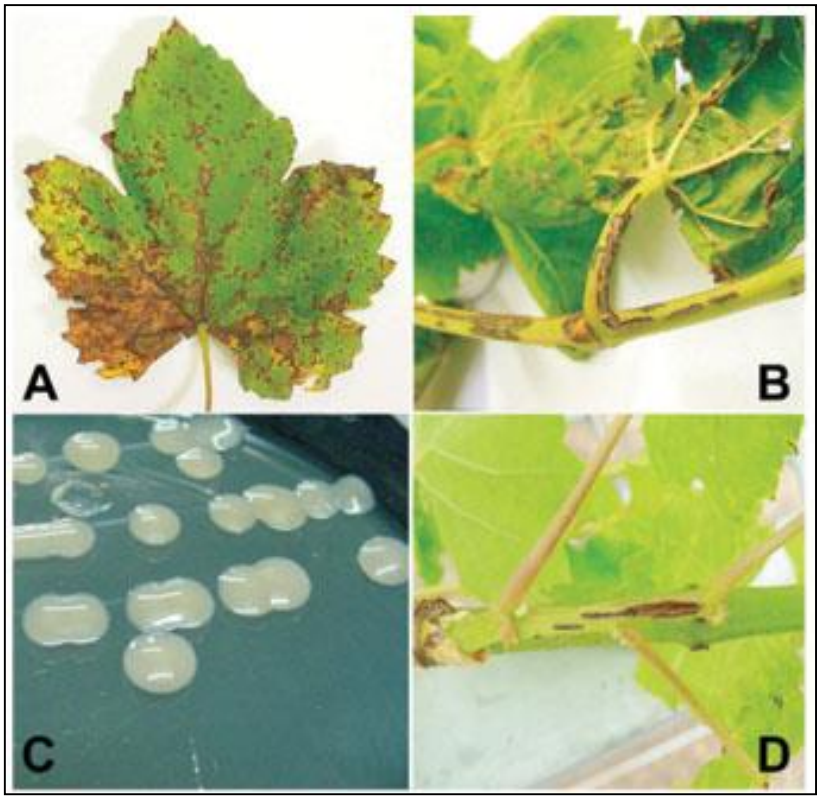
Bacterial canker of grapevine
Xanthomonas campestris pv. *viticola*

A. Leaf necrosis caused by *Xanthomonas campestris* pv. *viticola*;

B. typical bacterial canker in a stem and petiole of *Vitis vinifera*;

C. colonies of Xcv in Kado & Heskett 523 culture medium.

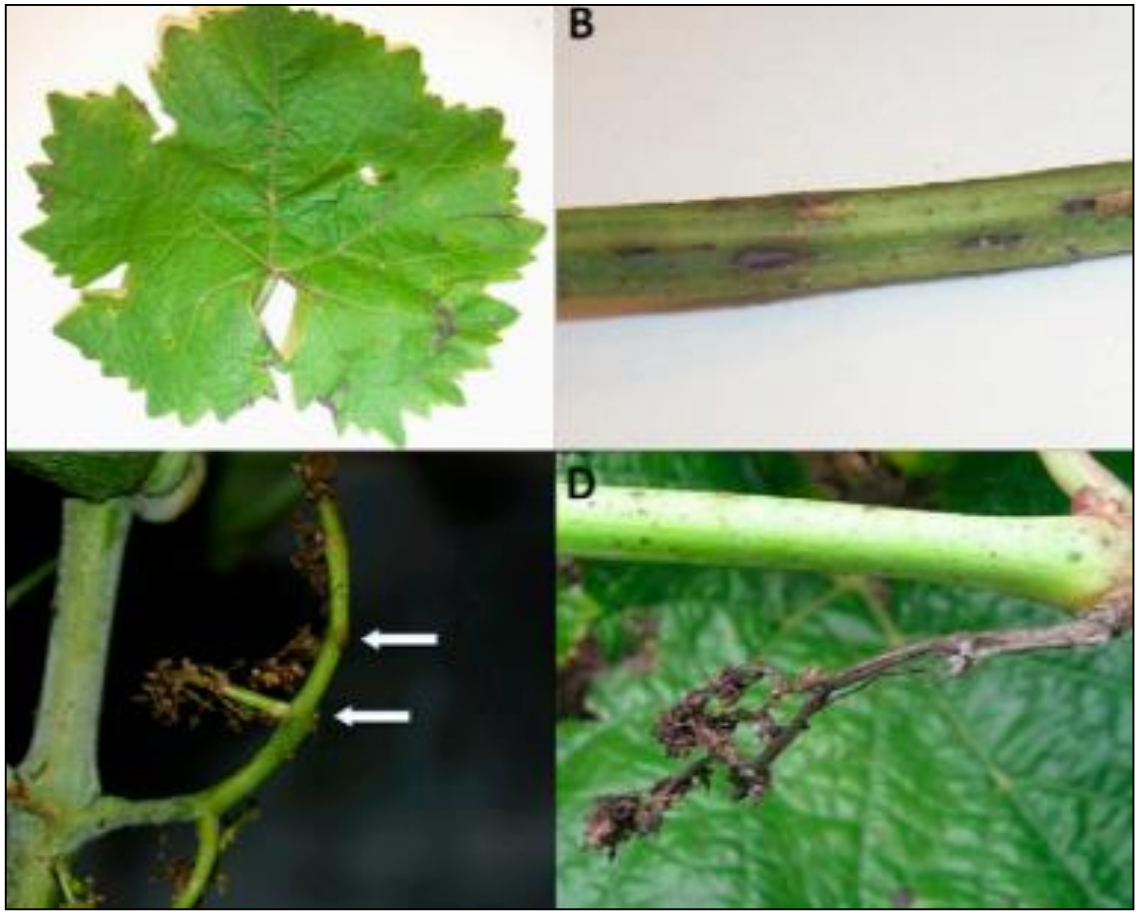
D. canker in grapevine var. Italia stem incited by the bacteria after inoculation.



Halfeld-Vieira & Nechet,2006

Bacterial inflorescence rot

Pseudomonas syringae pv. *syringae*



Hall *et al.*,2016

Bacterial inflorescence rot

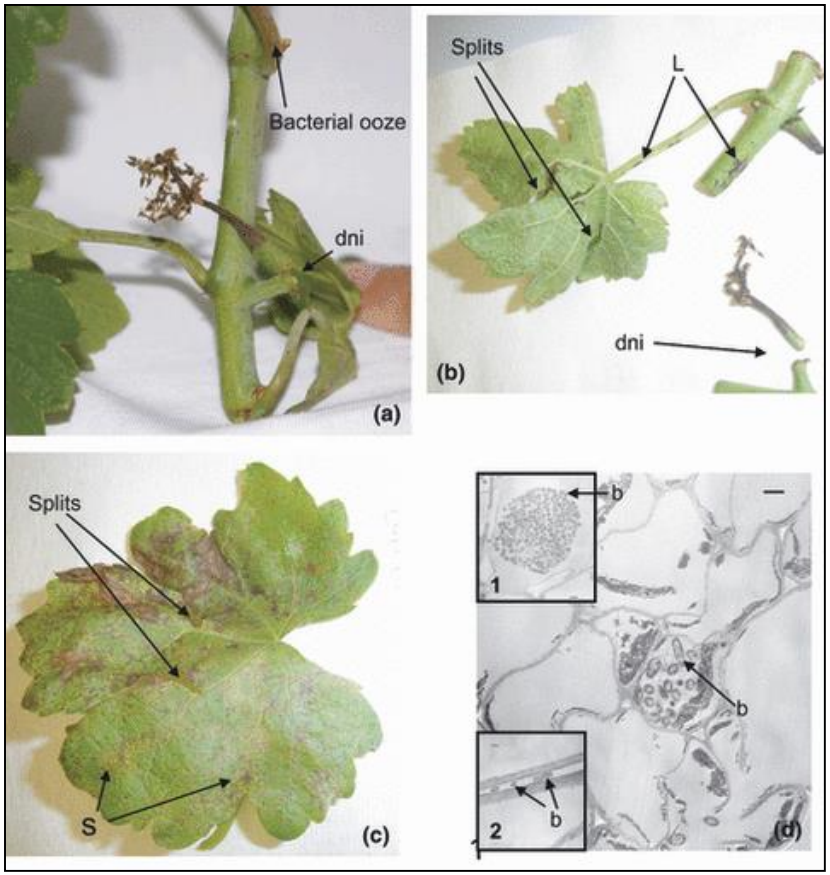
Pseudomonas syringae pv. *syringae*

a) Detached necrotic inflorescence (dni) and bacterial ooze on the leaf petiole.

b) Leaf with splits through necrotic lesions in blade, dark longitudinal lesions (L) on petiole.

c) Leaf with dark spots (s) with yellow chlorotic halos; and angular necrotic lesions delineated by veins resulting in leaf splits.

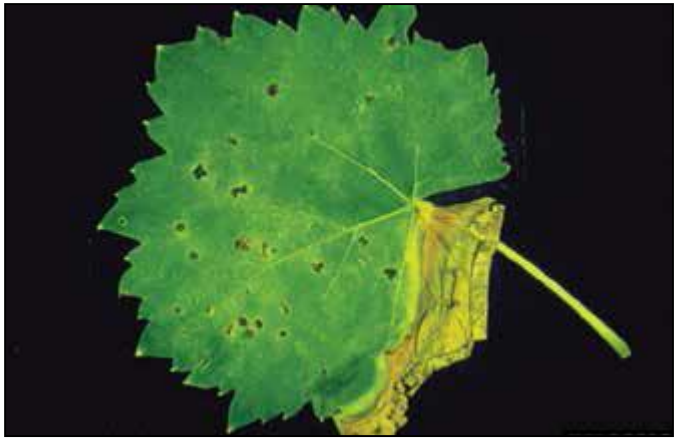
d) TEM of bacteria in naturally infected vines in vineyard; inset 1: bacteria inside cortical cell of inflorescence pedicel, inset 2: extracellular bacteria between two cortical cell walls, b= bacterium.



Whitelaw-Weckert *et al.*,2011

Bacterial blight of grapevine

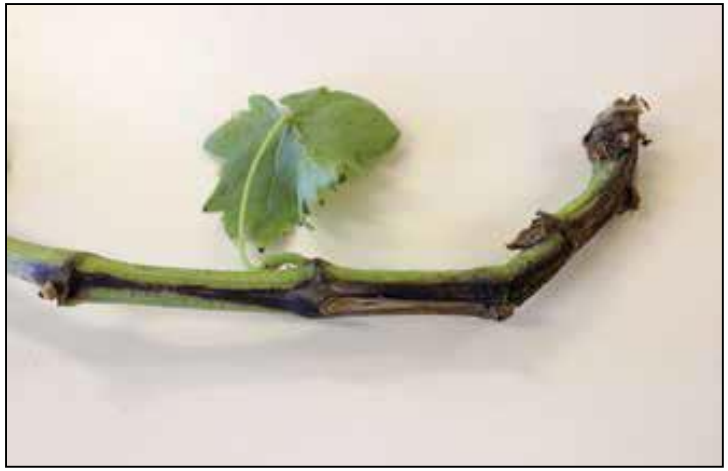
Xylophilus ampelinus



Plant Health Australia

Bacterial blight of grapevine

Xylophilus ampelinus

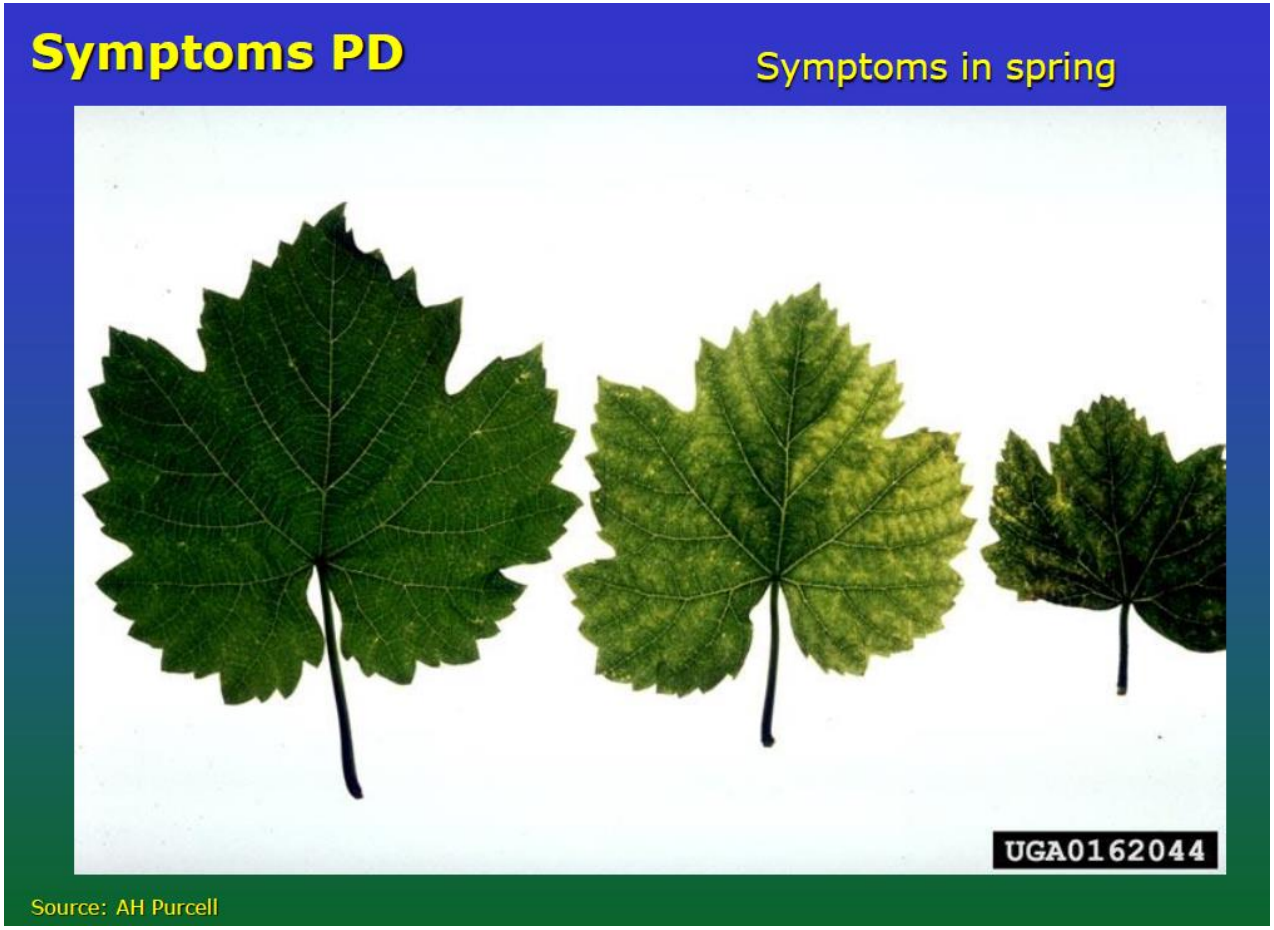


Shoots will eventually die back as the cankers spread throughout the stem.

Parts of the grape bunch may become necrotic and die back.

Pierce's disease(PD)

Xylella fastidiosa



Janse,2009

Pierce's disease(PD)

Xylella fastidiosa

- Leaf scorching is the first symptom of Pierce's disease to appear midsummer.
- Leaf margins may become slightly yellow (chlorotic) and then die.
- The first several leaves on a shoot with early-spring symptoms may be small and distorted with interveinal chlorosis.

Varela *et al.*,2001

Pierce's disease(PD)

Xylella fastidiosa

- Late summer and fall foliar symptoms for a white variety show that leaf margins become slightly yellow and then die, leaving concentric zones of progressive marginal discoloration.

Varela *et al.*,2001

Pierce's disease(PD)

Xylella fastidiosa

- Late-summer and fall foliar symptoms for a red variety show that leaf margins become slightly red and then die, leaving concentric zones of progressive marginal discoloration.

Varela *et al.*,2001

Pierce's disease

Xylella fastidiosa

Autumn foliar symptoms of Pierce's disease in a red fruit variety.

Pierce's disease

Xylella fastidiosa

- A common symptom of this disease is irregular, patchy bark maturity.
- Note that half of the shoots are green and half are islands of green.

Pierce's disease

Xylella fastidiosa

- Irregular, patchy bark maturity is prominent on many varieties affected with Pierce's disease.
- The petioles of leaves remain attached to the cane after the leaf blades fall.

Pierce's disease(PD)

Xylella fastidiosa

- The chronically infected vine, right, has a smaller canopy than the adjacent healthy vine, left.

Varela *et al.*,2001

Phytoplasma diseases

All grapevine yellows diseases have similar symptoms, including growth reduction, leaf discolouration, downward rolling of leaves, and reduced quality and quantity of fruit. Symptoms are not uniform, and may appear on some or all shoots of infected vines

- **There are several diseases of grapevine caused by phytoplasmas:**

1. **Flavescence dorée**
2. **Bois noir (black wood)**
3. **Grapevine yellows**

		
Flavescence dorée	**Bois noir infected leaves**	**Bois noir- black pustules on shoot.**

British Columbia,2010

Phytoplasma diseases

Grapevine flavescence dorée symptoms in Serbia

Bertaccini and Duduk,2009

Bacterial blight & wilt

Erwinia pisidii





Scortichini,2006

Bacterial blight & wilt

E. pisidii





Scortichini,2006

Gall formation

Pantoea agglomerans pv. *gypsophilae*

- Gall formation on *Gypsophila paniculata* by:
- ex.*Erwinia herbicola* pv. *gypsophilae* (left labelled *Ehg*) and by
- ex.*Erwinia herbicola* pv. *betae* (right labelled *Ehb.*
- Illustrations kindly provided by Isaac Barash and Shulamit Manulis).

Strange,2003

Twig and branch dieback

P. syringae pv. *coryli*

Male flowers of Common Hazel in early spring

Scortichini,2006

Bacterial blight

X. arboricola pv. *corylina*

Symptoms of bacterial blight on hazel: A) Bud destruction and dieback; B) Yellowing on young leaves; C) Leaf spot symptoms on hazel leaf; D) Canker with cracks on bud; E) Close up of angular leaf spots; F) necrosis with halo on young hazel nut.

Images coutesy of L Gardan, INRA

Stead,2008

Bacterial blight

X. arboricola pv. *corylina*

Scortichini,2008

Bacterial canker and decline

P. avellanae







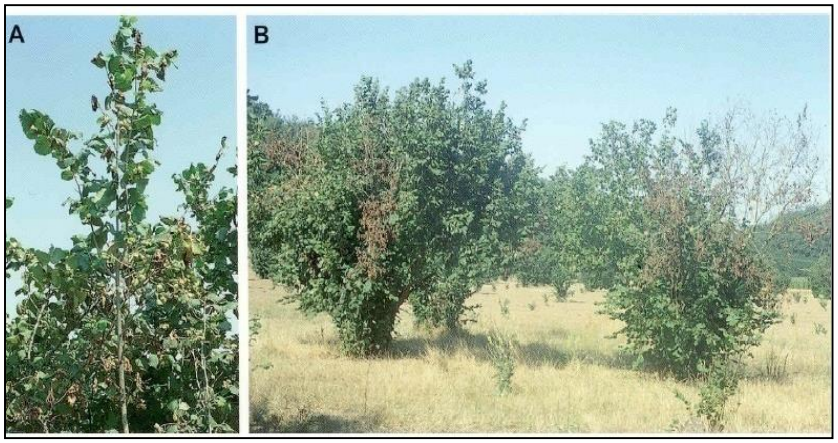

Scortichini,2006

Bacterial canker and decline

P. avellanae

A. During summer, diseased European hazelnut trees exhibit rapid wilting and branch dieback.

B. After the wilting, the desiccated leaves remain firmly attached to the branch throughout the growing season.



Scortichini,2002

Bacterial canker and decline

P. avellanae

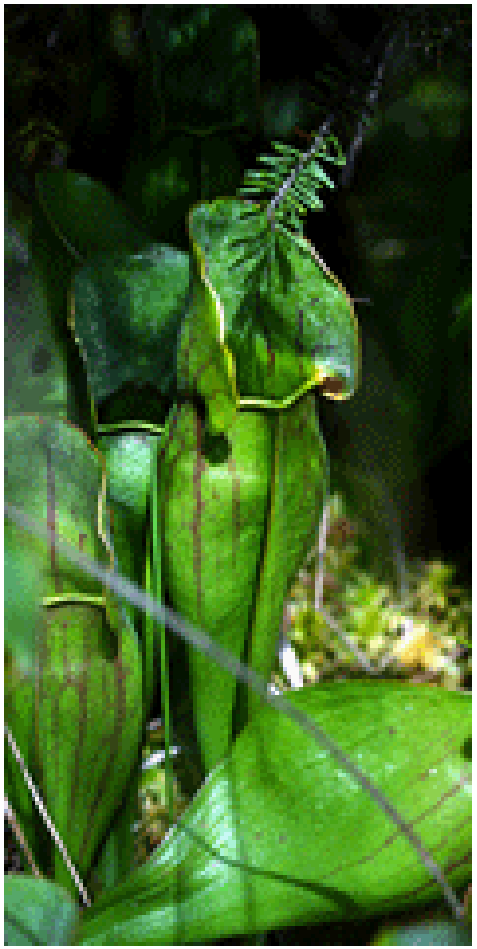
The new shoots become systemically infected with *Pseudomonas avellanae*.

Longitudinal cracks on the trunk of a European hazelnut tree caused by spring frosts. The wounds subsequently are colonized by *P. avellanae*.

Scortichini,2002

Bacterial gall disease of sharinbai *Pseudomonas syringae* pv. *raphiolepidis*

- Bacterial gall disease of Indian hawthorn (*Rhaphiolepis* spp.) caused by *Pseudomonas syringae* pv. *raphiolepidis* [sic rhaphiolepidis].



Heliconia wilt

R. solanacearum

Banana family with parrot flower.

Virescence
Phytoplasma

Virescence caused by Phytoplasma infection in horseradish.

Yellow disease

Xanthomonas hyacinthi

Janse,2006

Leaf spot

Xanthomonas sp.

Scortichini,2006

Virescence

Phytoplasma

A partially virescent flower head in a hydrangea infected with a phytoplasma.

plp3002.ifas.ufl.edu/pdfs/slides/bacterial_diseases.pdf

Bacterial spot

Pseudomonas viridiflava

Scortichini,2006

Bacterial leaf blight

Xanthomonas campestris pv. *tardicrescens*

- Faint water soaked spots on leaves enlarge along the leaf when weather is wet but cease activity when it is dry.

Leaf spot symptoms.

leaf spots

Pseudomonas and *Xanthomonas*

- Many species of bacteria can cause bacterial leaf spot of landscape plants.
- The most common bacterial pathogens that cause leaf spots include *Pseudomonas* and *Xanthomonas*.

Sharon L. von Broembsen

leaf spots

Xanthomonas hortorum pv. *hederae*

- Leaf spot of English ivy caused by *Xanthomonas hortorum* pv. *hederae*.

Wikipedia,2009

Bacterial spot

X. arboricola pv. *pruni*

Kiwifruit Bacterial Diseases

Crown gall	***Agrobacterium tumefaciens***
Bacterial canker disease	***Pseudomonas syringae*** **pv.** ***syringae***
Bacterial canker disease	***Pseudomonas syringae*** **pv.*actinidiae* (Psa)**
Blossom blight	***Pseudomonas viridiflava***
Blossom blight	***Pseudomonas syringae*** **pv.** ***syringae*** **and** ***Pseudomonas fluorescens***

Bacterial Crown gall

Agrobacterium tumefaciens

Crown gall at base of vine.
Photo by William J. Moller

Bacterial Canker

Pseudomonas syringae pv. *syringae*

Scortichini,2006

Bacterial Canker

Pseudomonas syringae pv. *syringae*

Scortichini,2006

Bacterial Canker

Pseudomonas syringae pv. *actinidiae* (Psa)

Scortichini,2006

Bacterial Canker

Pseudomonas syringae pv. *actinidiae*

- Brown, angular leaf spots sometimes surrounded by a yellowish halo are the symptoms seen at the affected site.
- Leaf spots, possible cankers, dieback or oozing are some of the advanced disease symptoms.

Figure 1 and 2. Brown, angular leaf spot

Zespri.com,2010

Bacterial Canker

Pseudomonas syringae pv.*actinidiae*

Zespri.com,2010

Bacterial Canker

Bacterial canker symptoms of kiwi plants cv. Hort 16 A under natural infection

Pseudomonas syringae* pv.*actinidiae

Balestra *et al.*,2009

Bacterial Canker

Trunk exudation in *Actinidia chinensis* cv. Hort 16 A (left) and of *Actinidia deliciosa* cv. Hayward (right)

Pseudomonas syringae pv. *actinidiae*

Cankers with white to reddish (oxidation) exudate on twigs and trunks, and reddening of lenticels, fruit collapse, wilting and eventually plant mortality. The most conspicuous symptom is the red-rusty exudation which covers bark tissues on trunks and twigs.

Courtesy of Balestra *et al.*,2009;EPPO,2014

Kiwifruit

Bacterial Canker

Cankers and red exudates(left),Cross section of heavily infected Jin Tao leader kiwi(Right)

Pseudomonas syringae* pv. *actinidiae

Courtesy Balestra *et al.*,2009

Bacterial blossom blight

Pseudomonas sp.

Blossom infection

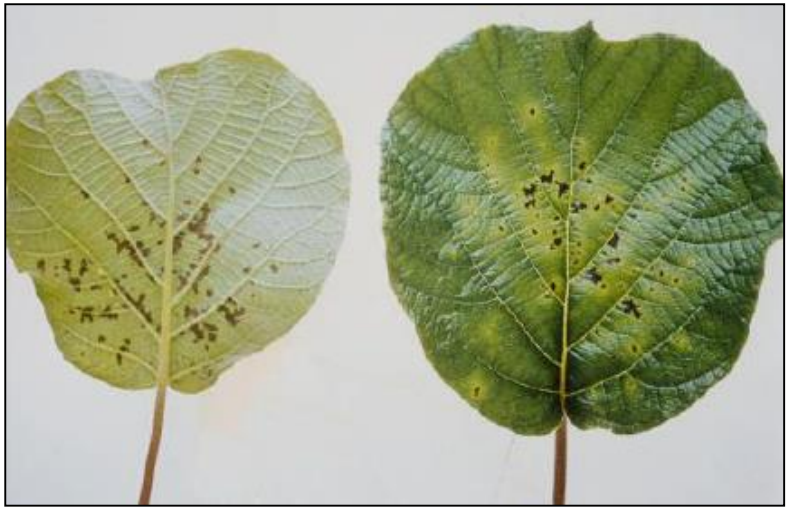
Bud infection

Everett and Henshall,2012

Bacterial blossom blight

Pseudomonas sp.

- Bacterial blight symptoms on leaves dark angular spots surrounded by yellow halos.



Everett and Henshall,2012

Blossom Blight of Kiwifruit

Partnerships (synergists)

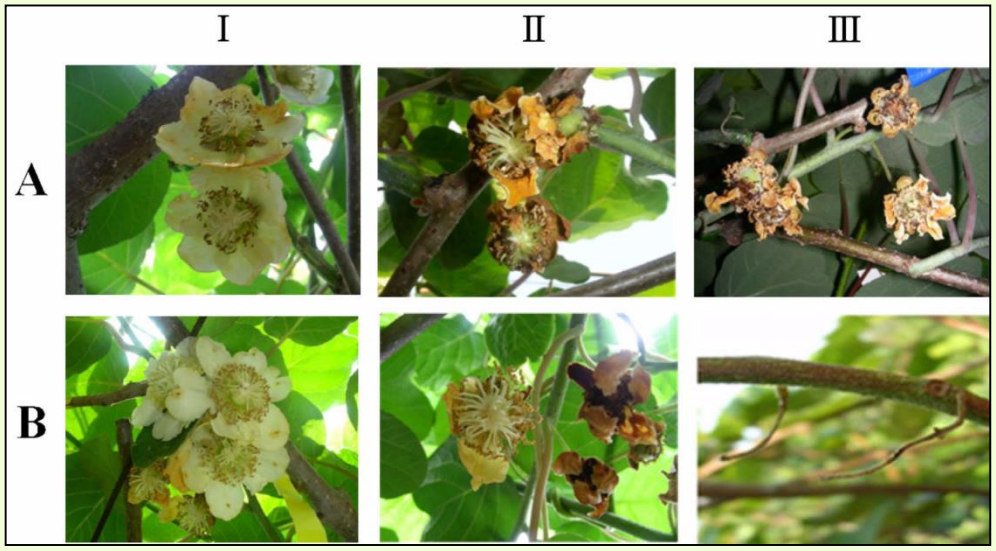
Pseudomonas syringae pv. *syringae* and *P. fluorescens*

- Symptoms on flowers caused by:

A. *P. s.* pv. *syringae* TDS2, and

B. *P. fluorescens* KDK8.

- *Pss* primarily affected the stamen, while *P. fluorescens* caused rotting of all internal tissues of buds or flowers.



Lee *et al.*,2009

Terminology

- LEAF SPOTS: Discolored, distinct spots on leaves.
- LEAF BLOTCHES: Blotchy dead or discolored areas on leaves.
- BLIGHTS: Rapid death of plant parts or entire plant.
- GALLS: Tumorous tissue on plant.
- CANKERS: Sunken dead areas on surface of stem.
- ROOT ROTS: Softened, blackened or brown tissue in the roots.
- LESIONS: Small local area of malformed tissue.
- NECROTIC LESIONS: Dying and dead tissue; blackened, holes.
- CHLOROSIS: Yellowing of tissue.
- WILTING/FLAGGING: Foliage on all or part of plant wilted, dying.
- VASCULAR STREAKING: Discolored streaks in xylem and phloem.

Allen,2009

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