Pseudomonas syringae: Life cycle, symptoms and control measures

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Pseudomonas syringae

- *Pseudomonas syringae* is one of the best-studied plant pathogens and serves as a model for understanding bacterial pathogenicity, molecular mechanisms of plant-microbe interactions as well as microbial ecology and epidemiology.
- So far more than 50 pathovars have been identified in the species, with each pathovar infecting a characteristic group of host plant species.
- Collectively, the ~50 pathovars of *P. syringae* infect almost all economically important crop species, making *P. syringae* one of most common pathogens on plants.
- *Pseudomonas syringae* is a phytopathogenic bacterium that causes diseases of monocots, herbaceous dicots, and woody dicots, worldwide.
- On woody plants, reports of disease due to *P. syringae* have markedly increased in the last years and the diseases have been recognized as a major threat to the primary products of agroforestry practices.

Plant Symptoms Caused by *P. syringae*

- **Flower blast:** flowers and/or flower buds turn brown to black.
- **Dead dormant buds**, common on cherries and apricots.
- **Necrotic leaf spots** (entire clusters of younger, expanding leaves may be killed on filbert trees).
- **Discolored and or blackened leaf veins** and petioles resulting from systemic invasion and infection.
- **Spots and blisters** on fruit.
- **Shoot-tip dieback**, appears as dead, blackened twig tissue extending down some distance from the tip (very common on maples and other seedlings).
- **Stem cankers**: depressed areas in the bark, which darken with age.
  - A gummy substance often exudes from cankers on fruiting and flowering stone fruits (this symptom is referred to as "gummosis").
  - If cankers continue to enlarge, they may girdle the stem and subsequently kill a branch or the entire plant.
  - If the outer tissues of the canker area are cut away, the tissue underneath shows a reddish-brown discoloration.
  - This discoloration may also occur as vertical streaks in the vascular tissue.

Growth phase

- *P. syringae* bacteria have two interconnected phases of growth in or on plants:
  - the epiphytic phase, when the bacteria live on the surface of plant tissues (usually the above-ground parts, such as leaves, stems and fruits, collectively known as the phyllosphere), and
  - the endophytic phase, when bacteria enter the plant tissue and colonize the intercellular space called the apoplast.
- While many *P. syringae* strains, such as those of *P. syringae* pv. *syringae,* are strong epiphytes and had been widely used in microbial ecological studies, disease occurs only after *P. syringae* bacteria enter the plant and multiply in the apoplast (i.e., the endophytic phase).
- The initial epiphytic populations of some *P. syringae* strains on the plant surface can be good predictors of their later endophytic populations inside the plant tissue and disease outbreaks under favorable environmental conditions.

- Tolerance to ultraviolet light and dry environment is generally considered important for a strong epiphytic life style.
- Another notable feature of *P. syringae* bacteria that may be important for the epiphytic phase is ice nucleation and the associated ability to cause frost injury in plants, which may lead to water and nutrient release from plants and could create openings on the plant surface to facilitate bacterial entry.
- Ironically, many strains of *P. syringae* catalyze ice crystal formation on and in plant tissues (Lindow, 1983).
- These generally are referred to as ice nucleation-active (INA) bacteria.
- Their presence on the plant serves to raise the freezing temperature above that at which sensitive plant tissues would normally freeze.
- Ice nucleation activity of *P. syringae* is conferred by a single gene that encodes an outer membrane protein.
- Individual ice-nucleation proteins do not serve as ice nuclei, but they form large, homogeneous aggregates that collectively orient water molecules into a configuration mimicking the crystalline structure of ice, thereby catalyzing ice formation.
- Oriented water molecules freeze at temperatures slightly below zero (-2C to -10°C) instead of supercooling.

Disease cycle

- *Pseudomonas syringae* is one of the most common plant pathogens that infect the phyllosphere (i.e., the aboveground plant organs).
- *P. syringae* can live on the plant surface as an epiphyte.
- To cause disease it enters the plant, through wounds or natural openings such as stomata, and multiplies within the intercellular space called the apoplast.
- *P. syringae* has also been subdivided into ~50 pathovars based on host of isolation, host range and other properties.
- *P. syringae* attacks plants using a variety of virulence factors, including “effector proteins” that are translocated into the plant cell via the type III secretion system (T3SS), small-molecule toxins, exopolysaccharides, cell wall-degrading enzymes and plant hormones (or hormone mimics).
- Whereas all pathogenic strains of *P. syringae* possess the T3SS and effectors, they may or may not produce other virulence factors.

...Disease cycle

- Plants have evolved a defense mechanism (stomatal closure) to reduce bacterial entry through stomata by detection of pathogen-associated molecular patterns (PAMPs).
- To defeat stomatal defense, *P. syringae* use toxins and T3SS effector proteins to overcome PAMP-induced stomatal closure.
- Stomatal closure is sensitive to high atmospheric humidity, which could promote bacterial entry into the plant.
- After entry into the plant, *P. syringae* encounters the apoplast, a potentially carbohydrate-rich but heavily defended living space for microbes.
- Immune suppression and establishment of aqueous apoplast are two principal pathogenic processes required for *P. syringae* multiplication inside the apoplast.
- *P. syringae* infection is profoundly influenced by external environmental conditions, such as air humidity, temperature and microbiota that live on healthy plants.

Predisposing factors

- **Wounding:** of any kind seems to play a major role in initiating disease development. Wounds may be mechanical or environmental such as frost injury.
- **Plant Dormancy:** may also predispose susceptible trees to damage from *Pseudomonas syringae*.
- **Soil Factors:** such as soil pH and mineral nutrition may also predispose trees to *Pseudomonas syringae* infection.

Spread of *P. syringae*

- *Pseudomonas syringae* can be moved by wind, rain, insects, infested budwood, and transportation of infested nursery stock.
- Mechanical equipment and pruning tools may be a frequently overlooked means of dispersal or of generating aerosols containing the bacteria.

Management

- **Soil Conditions:** Liming planting-site soil reportedly promoted peach tree growth and vigor.
- Altering soil pH affected the susceptibility of peach to *Pseudomonas syringae.*
- Other soil amendments of iron, calcium, and magnesium reportedly affect tree susceptibility to bacterial canker and short-life.
- **Pruning:** Pruning in fall and early winter also predisposed trees to more severe damage from *Pseudomonas syringae* infections and the short-life syndrome.
- In those cases where trees may be threatened by *Cytospora* sp. and *Pseudomonas syringae*, pruning in early spring when trees are more resistant to *Cytospora* may be of benefit.
- Summer pruning during dry weather has also been very effective.

- **Cauterization:** Burning *Pseudomonas syringae* cankers on limbs of stone fruit trees in New Zealand with a hand-held propane burner cauterized the tissues and limited the canker's further spread so the branch or trunk did not become girdled and killed.
- Cauterization was fast and easy to use in the orchard, and a single treatment controlled most cankers. The method was tested successfully on apricots, sweet cherries, and peaches.
- This method is part of a total control strategy that also includes a spray program of autumn and winter Bordeaux sprays followed by spring sprays of streptomycin.
- **Biological Control with Bacterial Antagonists:** Biological control has been directed almost entirely at frost control using bacterial antagonists to prevent buildup of ice-nucleation- active (INA) populations of *Pseudomonas syringae.*
- **Chemical control:** Fixed copper compounds (such as bordeaux and copper hydroxide), streptomycin (an antibiotic), and coordination productions (such as Bravo CM) are registered and have been used to control *Pseudomonas syringae* with various degrees of success.