Overview

- Types of vector-borne plant pathogens
- Types of vectors
- Steps in transmission
- Ecology and disease cycle
- Factors affecting transmission efficiency
- Pathogen affecting transmission efficiency
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- Vector relationships
- Epidemic development (spatial and temporal dynamics)
- Effects of control strategies
- Summary

Types of vector-borne plant pathogens

- Many plant pathogens can be vector-borne (nonspecifically), but also have other means of transmission
  - Fungi (birds, rodents, insects, nematodes etc.)
  - Bacteria (insects, birds, rodents, nematodes etc.)
- Other pathogens are dependent on transmission by specific vectors
  - Viruses (insects, mites, nematodes, fungal-like organisms)
  - Bacteria (phloem- or xylem-bound bacteria like phytoplasma’s, Candidatus Liberibacter, Xylella transmitted by leaf-/planthoppers, psyllids and sharpshooters, respectively)
  - Some fungi like Raffaelea lauricola by ambrosia beetles (Xyleborus glabratus)

Types of vectors

- Insects
  - Piercing-sucking insects (aphids, whiteflies, mealybugs, psyllids, plant- and leafhoppers)
  - Rasping insects (thrips)
  - Chewing insects (beetles)
- Mites
  - Eriophyid mites
- Nematodes
  - Piercing-sucking (Xyphinema, Longidorus, Thichodorus etc.)

Steps in transmission

- Acquisition of pathogen by vector
- Movement inside vector (persistent viruses)
- Multiplication (in case of propagative transmission)
- Inoculation of pathogen into host plant
- Replication and movement in host plant

Disease cycle of vector-borne diseases
Transmission efficiency

Factors affecting transmission
- Intensity of virus infected source plants
- Virus content per source plant
- Vector intensity
- Vector aggregation
- Vector movement (short- vs. long-distance)
  - ‘crowd diseases’ that spread slowly like cocoa swollen shoot disease by mealybugs
  - ‘vagile diseases’ that spread quickly like African cassava mosaic by whiteflies
- Presence of alternate hosts (e.g. weeds)

Inoculum density (vectors as propagules)

- Landing and impaction traps
  - Water pan trap
  - Catch depends on trap size, color, height, and location
- Yellow sticky traps
  - Rectangular plates or cylinders of variable size
  - Better to catch Hemiptera than water pans
  - Longer time intervals, greater catch
- Vertical sweep net
  - Good for live insects
  - Not good for measuring insect density
  - Labor intensive

Types of transmissions

- Non-persistent
  - Vector acquires in seconds to minutes
  - Vector transmits the pathogen soon (minutes) after contact with plant (needs to re-acquire to transmit again)
  - Casual transmission from vector surface (bacteria by bees)
  - Non-specific transmission by vector stylet
  - E.g.: potyviruses and cucumoviruses by aphids, bacteria by bees
- Semi-persistent
  - Vector keeps pathogen for longer period
  - E.g.: criniviruses by whiteflies and caulimoviruses by aphids, Xylella fastidiosa by sharpshooter leafhoppers

Inoculum density (vectors as propagules)

- Light trap
  - Water pan underneath will trap insects
- Suction traps
  - Use for measuring vector density
  - Catch depends on both wind speed and vector behavior
  - Requires a motor for fan - expensive
  - Difficult to replicate due to expenses
- Direct collection from plants (e.g. flower thrips)
- Determining proportion of insects capable of transmitting
  - Very difficult to achieve
  - Detection in the vector does not equate to ability to transmit
  - Capture live insects and place each one on a host plant and determine the no. of infected plants that result, ELISA, qPCR

Types of transmissions

- Persistent and circulative
  - Vector keeps pathogen for long period, can transmit repeatedly
  - Pathogen moves from the gut into the hemolymph (whole body)
  - Transmission to host through mouth parts or salivary gland, several hours after ingestion
  - Examples: Begomovirus by whiteflies, Luteovirus by aphids
- Persistent and propagative
  - Vector keeps pathogen indefinitely, can transmit repeatedly through salivary gland, transmission through molds, transovarial transmission to offspring sometimes possible
  - Pathogen can multiply inside vector, i.e. insect cells
  - Examples: Tospovirus by thrips, Rhabdovirus by leafhoppers, C. Liberibacter by psyllids

Aphid growth and increase on virus-infected potatoes

Development rate: faster on virus-infected plants

- PLRV=potato leafroll virus
  - circulative persistent
- PVY=potato virus Y
  - nonpersistent
- PVX=potato virus X
  - not aphid-transmitted

Castle and Berger, 1993
Aphid growth and increase on virus-infected potatoes

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Epidemic development

- Vector-borne diseases polycyclic, except viruses transmitted by nematodes like Longidorus
- Spatial spread depends on vector aggregation and movement
- Vector movement affected by wind direction and speed
- Vector-borne diseases start often from field margins, especially if there are alternate hosts
- Disease gradients estimated from frequencies at different distances from the source plant

Epidemic development (spatial aspects)

- Disease gradient of wheat streak mosaic virus transmitted by wheat curl mite
  - Broad host range on various grasses
  - Disease starts at the edges of fields
  - Inverse relationship with yield
  - Data analyzed by state-space modeling in SAS

Incidence of African Cassava Mosaic virus infection and number of whiteflies per plant

- Most spread from outside sources ('vagile' vectors)
- Along the axis of the prevailing wind direction
- Spread from within plantings limited

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Epidemic development (spatial aspects)
Epidemic development (temporal aspects)

- Model for virus transmission by 4 mechanisms
  - non-persistent
  - semi-persistent
  - circulative
  - propagative

- Plant categories: H, L, S, R

- Vector categories: X, Y, Z

EPI

Madden et al., 2000

Epidemic development (temporal aspects)

- Model infection in perennial plants (cassava mosaic, persistent transmission)
  - Latent
  - Infectious
  - Post-infectious
  - Symptoms visible after start of infectious period
  - Plant roguing not effective

EPI

Chan and Jeger, 1994

Epidemic development (temporal aspects)

- Model for healthy, latent, infectious, post-infectious plant tissues
  - NP=nonpersistent
  - SP=semi-persistent
  - CP=persistent circulative
  - PP=persistent propagative

EPI

Madden et al., 2000

Epidemic development (temporal aspects)

- Disease incidence over time
  - NP=nonpersistent
  - SP=semi-persistent
  - CP=persistent circulative
  - PP=persistent propagative
  - (Number)=vector density
  - \(R_0 = 3.8\) in all cases

- Conclusion: NP transmission very effective, CP and SP very much affected by vector characteristics, PP less

EPI

Madden et al., 2000

Control of vector-borne diseases

- Control methods depend on pathogen, host, vector and other means of spread
- Spraying of vector mostly not effective, especially in case of non-persistent transmission
- Prevention of landing better, e.g. by reflective mulches or a barrier or deterring oil on plant surface
- Roguing of perennial hosts when incubation period is short relative to the latent period
- Host plant resistance to pathogen and vector best

EPI

Madden et al., 2000

Effects of a barrier around a tomato crop

- Tomato yellow leaf curl virus; transmitted by B. tabaci
- Expt 1. Barrier with insecticide strip
  - Reduced immigration
- Expt 2. Barrier without insecticide strip
  - Reduced immi- and emigration; vector buildup

EPI

Holt et al., 2008
Effects of a barrier around a tomato crop

- At low permeability
  - Immigration is a constraint
- At intermediate permeability
  - Movement in and out
  - But promotes rapid growth inside the fence
- At high permeability
  - Emigration is a constraint

Control of vector-borne virus diseases

- Effects of roguing:
  - Reduced r
- African cassava mosaic virus
  - Transmitted by whiteflies
  - Most spread from outside sources
  - Arrow: significant treatment effects

Model of plant virus disease dynamics

- Effects of roguing different categories
  - (a) roguing R
  - (b) roguing S
  - (c) roguing L+S
  - (d) roguing L
- H=healthy
- L=latent
- S=infectious
- R=post-inf.
- K=contact rate

Summary

- Types of vector-borne plant pathogens, vectors and transmission steps
- Factors affecting transmission efficiency
- Measuring inoculum density
- Types of transmission
- Vector growth and development on infected/healthy plants
- Epidemic development (spatial and temporal aspects)
- Vector movement and disease gradients
- Models for virus transmission
- Effects of control strategies as predicted from models