PLP 6404 Epidemiology of Plant Diseases
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Lecture 7: Influence of Pathogen on Disease Development – vector-borne pathogens

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Overview

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

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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*)

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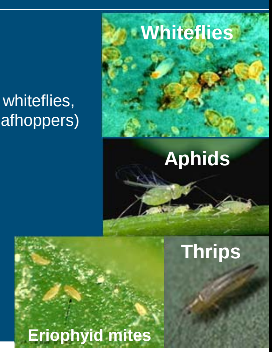
Types of vectors

- 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.)



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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

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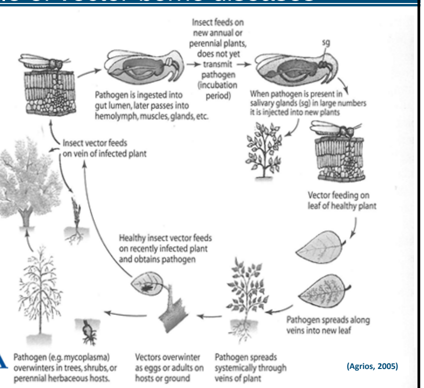
Disease cycle of vector-borne diseases



(Agrios, 2005)

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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 (Thresh, 1991)
  - 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
  - Can be positioned vertically
  - 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

Inoculum density (vectors as propagules)

- Light trap
  - Water pan underneath will trap insects
- Suction traps
  - Useful 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

- 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
  - In the vector gut, but not the hemolymph, e.g. foregut-borne viruses in aphids
  - E.g.: criniviruses by whiteflies and caulimoviruses by aphids, *Xylella fastidiosa* by sharpshooter leafhoppers

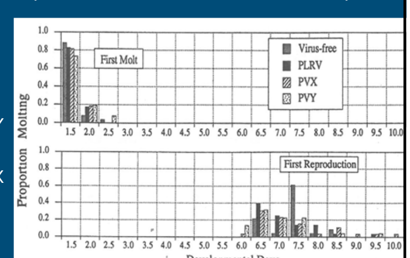
Types of transmissions

- 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 molts, transovarial transmission to offspring sometimes possible
  - Pathogen can multiply inside vector, i.e. insect cells
  - Examples: *Tospovirus* by thrips, *Rhabdovvirus* by leafhoppers, *C.* Liberibacter by psyllids

Aphid growth and increase on virus-infected potatoes

Development rate: faster on virus-infected plants

- PLRV=potato leafrol 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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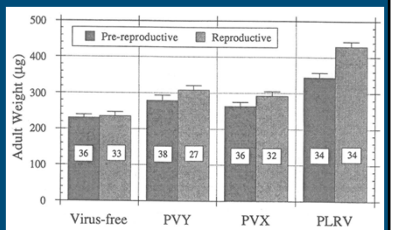
PLRV infected adults are heavier



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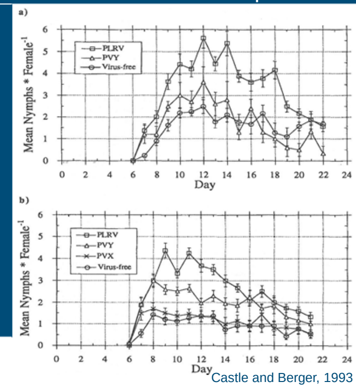

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Castle and Berger, 1993

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

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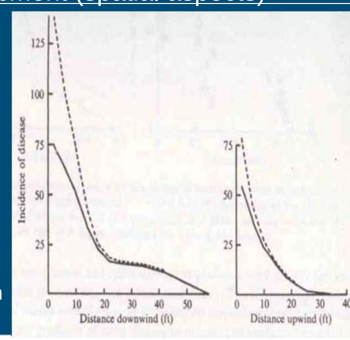
Epidemic development (spatial aspects)

- Disease gradients by black currant reversion virus transm. by aphids
  - Observed
  - After multiple infection transformation ln[1/(1-x)]
- Aphids carried further downwind than upwind from an in-field source



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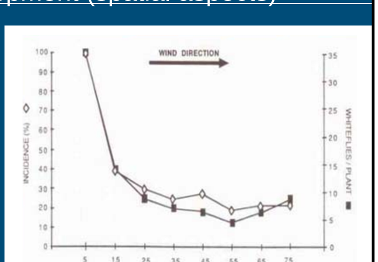
Thresh, 1976

Epidemic development (spatial aspects)

- 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



Distance from edge of field (m)

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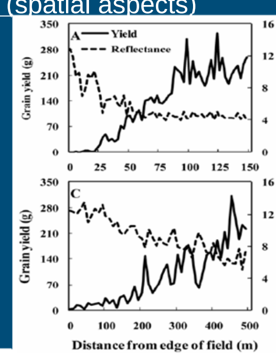
Fauquet and Fargette, 1990

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



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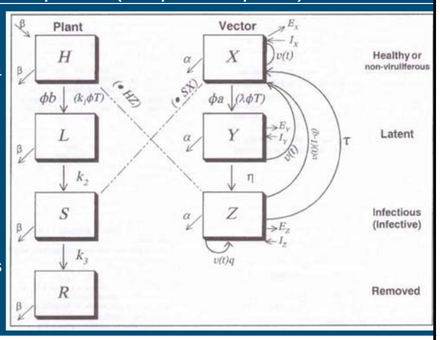
Workneh et al., 2009

Epidemic development (temporal aspects)

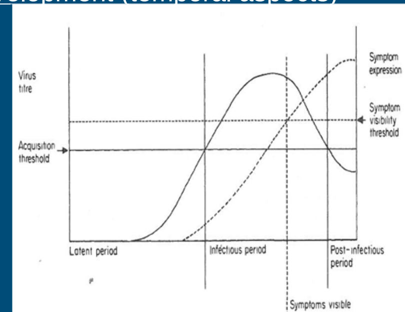
- Model for virus transmission by 4 mechanisms
  - non-persistent,
  - semi-persistent,
  - circulative
  - propagative
- Plant categories
  - H,L,S,R
- Vector categories
  - X,Y,Z



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

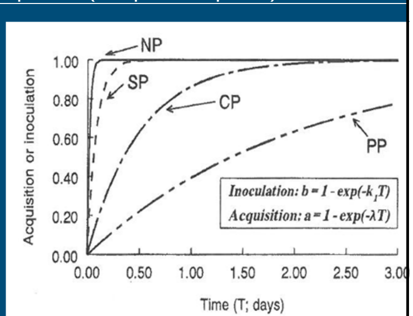


Virus titer and symptom expression over time

Chan and Jeger, 1994

Epidemic development (temporal aspects)

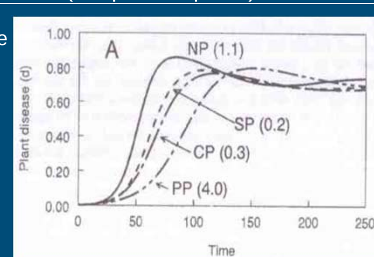
- Model for healthy, latent, infectious, post-infectious plant tissues
  - NP=nonpersistent
  - SP=semipersistent
  - CP=persistent circulative
  - PP=persistent propagative



Madden et al., 2000

Epidemic development (temporal aspects)

- Disease incidence over time
  - NP=nonpersistent
  - SP=semipersistent
  - CP=persistent circulative
  - PP=persistent propagative
  - (Number)=vector density
  - R0 =3.8 in all cases
- Conclusion: NP transmission very effective, CP and SP very much affected by vector characteristics, PP less



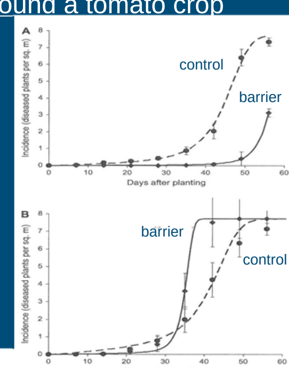
Madden et al., 2000

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

Effects of a barrier around a tomato crop

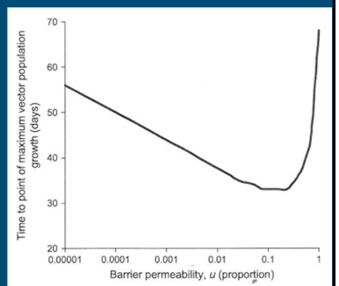
- Tomato yellow leaf curl virus, transmitted by B. tabaci
- Expt 1. Barrier with insecticide strip
  - Reduced immigration
- Expt. 2. Barrier without insecticide strip
  - Reduced immi- and emigration; vector buildup



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



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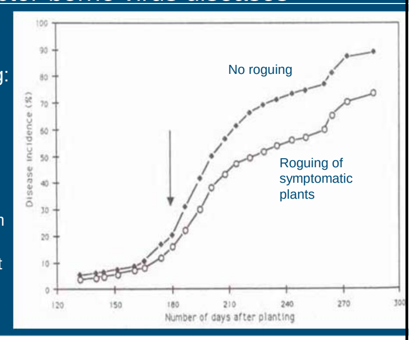
Holt et al., 2008)

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



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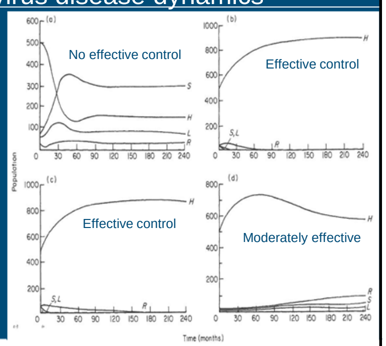
Fargette et al., 1990

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



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K=high

Chan and Jeger, 1994

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

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