Principles of Plant Virus Disease Management

This lecture:

- Disease cycles and their role in developing management solutions
- Components of the virus/host/vector disease cycle
- Approaches that can be used to manage viruses
- Prevention as a virus management approach

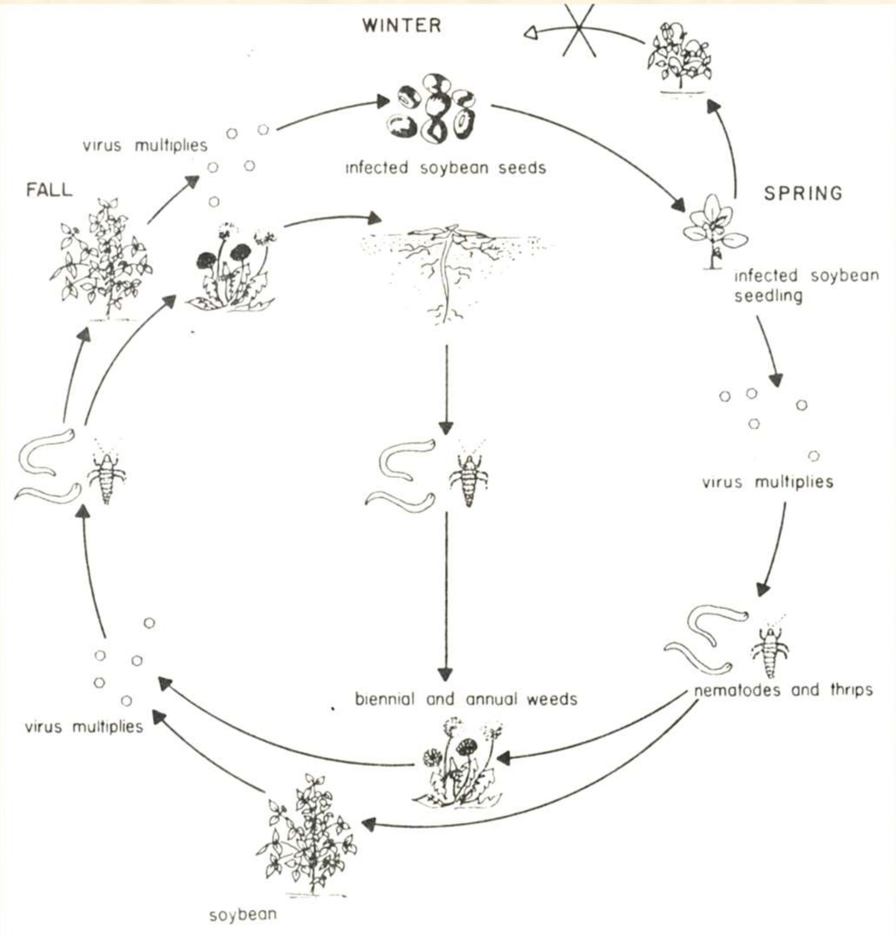
Plant viruses need the interior of a plant cell to replicate. Only a few viruses survive outside a host cell or a vector for any period of time.

So plant viruses need to find new hosts to survive, in other words, they need to have one or more means to disperse

Each virus has its own combination of mechanisms for survival and dispersal. These combined are known as its disease cycle.

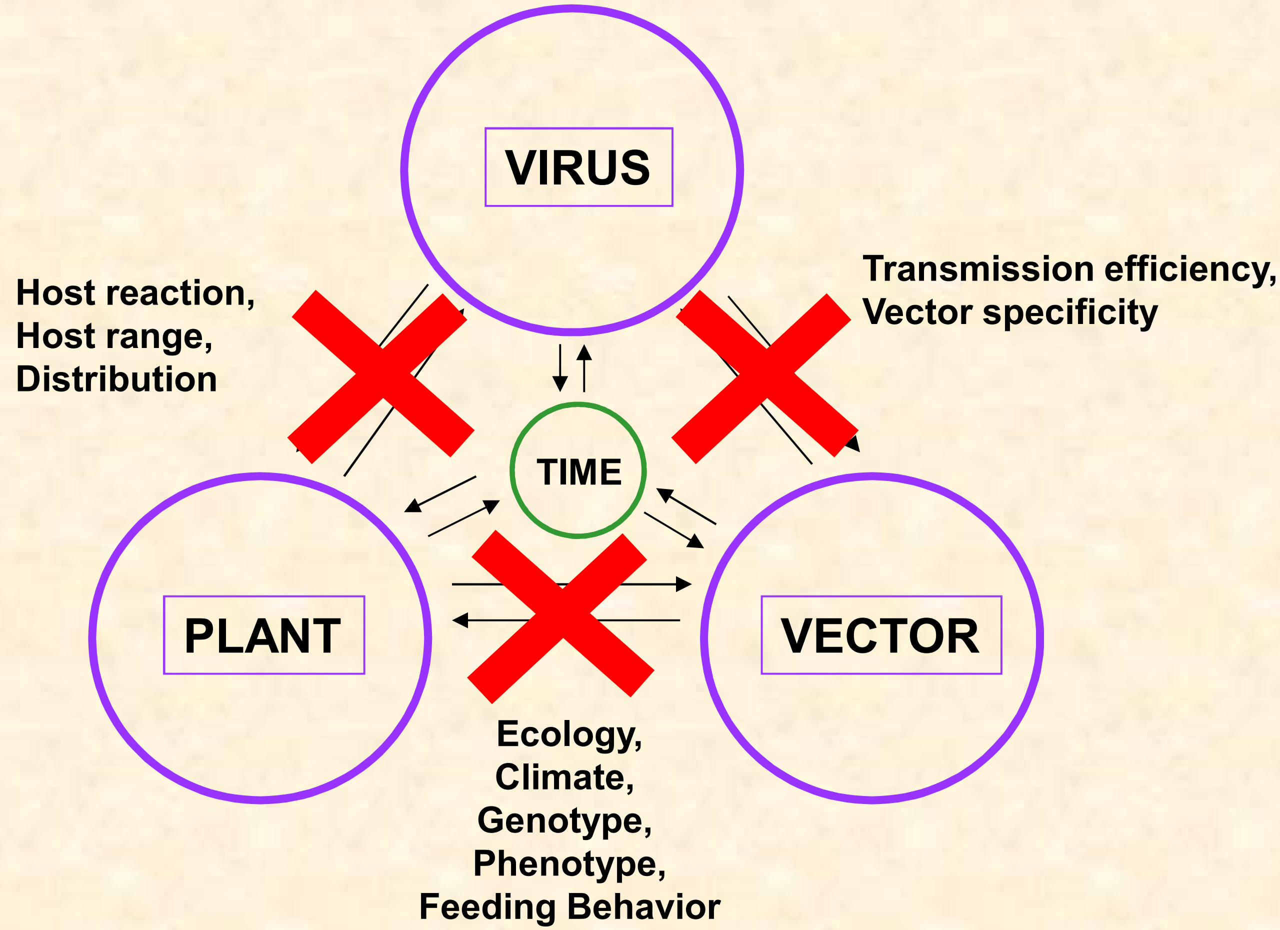
The key to effective management is knowing the details of the disease cycle, and then findings ways to interrupt or break the cycle.

Often these are not known, and may require research to elucidate.



Disease cycle of tobacco ringspot virus

Basic Virus Disease Cycle:



Some biological components of the Disease Cycle

Properties of the virus

- **Physical stability of the virus**
  - this can affect the means of dispersal, very stable viruses have more means of survival and dispersal than other less stabile viruses
- **Concentration of the virus in a host**
  - this can affect efficiency with which a virus is acquired by its vector
- **Rate of movement and distribution within the host**
  - How quickly is the virus available to be transmitted?
- **Severity of the disease**
  - Are infected hosts killed?
  - Is the shape of the plant altered so much that vectors will not land on it or will not feed on it?

Some biological components of the Disease Cycle

Properties of the virus

- **Mutability and strain selection**
  - In a given location, some viruses have more sequence diversity than others so might overcome resistant hosts faster

- **Host range of the virus**
  - Wide or narrow?
  - How many are in the area of the epidemic?
  - How large are the populations of the hosts?

Some biological components of the Disease Cycle

Properties of the virus

- **Means of dispersal – these vary among viruses**
  - very stable viruses can be moved in water or soil debris
  - many viruses can be moved by mechanical transmission under the right circumstances:
    - cutting tools (pruning or grafting)
    - leaves rubbing against each other
    - many viruses disperse through movement of infected plant parts: transplants, seeds, pollen, tubers, grafting, cuttings, etc…
  - Many viruses can be transmitted to the next generation (via ovule or pollen)

Biological Components of the Disease Cycle

Properties of the virus

- **Means of dispersal – these vary among viruses**
  - most viruses (85%) have a vector and most of those can move on their own or with wind or water assist (insects, mites, nematodes)
  - the mode of transmission (non-persistent, semi-persistent, etc… plays an important role in how quickly and for what distance viruses can disperse
  - the distance a virus is able to move varies and depends upon many factors,
    - ability of the vector to fly (migrate)
    - is often determined by humans and agricultural trade and practices

Biological Components of the Disease Cycle

Properties of the virus

- **Host range of the virus**
  - What are the hosts? Is the host range wide or narrow?
  - How many are in the area of the epidemic?
  - Size of host populations

- **Means of survival**
  - Many viruses survive in the same host or in propagative material (live hosts: perennial hosts, tubers, runners, seed)
  - Stable viruses (like TMV, TBSV) can over-season in plant refuse
  - Ornamental trees, shrubs, biennial, and perennial wild plants may be important over-seasoning sources

Some biological components of the Disease Cycle

Properties of the virus

- **Means of Survival Con't**
  - Viruses that replicate in their vector can survive in eggs and nymphs of their vector without any plant hosts
  - Some viruses can survive in their vector (in the absense of plant hosts) even though they don't replicate in the vector

Biological factors that influence the Disease Cycle

Cultural Practices

Planting date
Crop rotation
Soil cultivation
Field size
Population density and plant size
Effects of glass or plastic houses
Pollination practices
Transport of crop plants or parts
Monocropping

*Production practices vary among locations for the same crop. So the disease cycle may not be identical among different locations, and therefore effective disease management practices for a virus may be different for different locations

Physical factors that influence the Disease Cycle

Rainfall
Wind
Air temperature
Soil
Seasonal variation in weather

These physical factors affect hosts, vectors and host (production practices and their timing)

Movement of viruses into and within fields by aerial vectors

Primary spread – source of virus is outside the field (other crops, weeds, infected transplants) may be close or distant

Secondary spread – virus source is within the field (other plants, weeds within the fields)

Insect transmission and number of plants infected per vector

Non-persistent transmission: one insect-one potentially infected plant

Semi- and persistent transmission: one insect-potentially many infected plants

Disease Cycles and Management:

- Determine the correct identity of the virus causing the disease
- Determine the specifics of the disease cycle: vectors, hosts, etc….
  - Some of this information can be obtained from literature
  - Some must be identified by research
- Use that information to design a disease cycle if one does not exist
- Develop means to disrupt or break the cycle
  - Some of this information can be obtained from literature
  - Some must be identified by trial

General Approaches to Management:

There are no chemicals that can be sprayed to kill viruses or to completely protect plants from infection, like there are for pathogens like fungi and bacteria. Usually once a plant is infected, it stays infected (except for ???)

In fact, once a field has infected plants there are only limited practices that can be employed that will be effective.

The most effective management practices are done **before** the crop is planted. So grower education regarding the viral pathogen's disease cycle is an important part of management.

- Prevention: remove or avoid sources of the pathogen
- Manage Vectors: control or avoidance
- Protect the plant from infection

Note: Epidemics are often the result of human activities

- Introduction of viruses into new areas through infected seed, or vegetative material
- Introduction of virus vectors into new areas
- Introduction of a new cultivar which is susceptible to viruses present in the area
- Production using monoculture: genetically-uniform plants in large areas, replacing traditional polyculture
- Use of irrigation to prolong the cropping seasons with overlapping plantings
- Repeated use of the same fields for the same crop

Note: Epidemics are often the result of human activities

Commercial tomato field in Manatee Co. Florida – 100% of plants infected with TYLCV

Both virus and vector were introduced into Florida. They came from different locations at different times and on different plants, but both established and have caused millions of dollars in direct crop loss and in the expense of management.

General Approaches to Management:

- **Prevention: remove or avoid sources of the pathogen**
- Protect the plant from infection
- Manage Vectors

Management: Prevention

- Produce or purchase virus-free plants.
- Remove all weeds.
- Destroy all crop debris from fields and greenhouses.
- Immediately set aside plants with viral symptoms and obtain a diagnosis from your Plant Disease Clinic.
- Discard virus-infected plants.
- Disinfest tools used for vegetative propagation frequently by placing them in a clorox solution (10%), hydrogen peroxide, or quartenary ammonium salt solution for at least 10 min. Rinse thoroughly with tap water.
- Propagate plants using certified virus-free seed rather than vegetatively when possible.

Management: Prevention

- **Removal or avoidance of sources of the pathogen**
  - Start with virus-free plants. Use certified virus-free seed, use tomato/tobacco/pepper seed treated to remove tobamoviruses.
  - Select transplants that have not been produced near production fields.
  - Select transplants/plants that are certified virus-free

> Certified lettuce seed reduced losses due to *Lettuce mosaic virus* (*Potyviridae, Potyvirus*) (<0.003% infection was effective)
>
> Seed certification of barley for *Barley stripe mosaic virus* (*Virgaviridae, Hordeivirus*) has saved millions US $$

Management: Prevention

- **Removal or avoidance of sources of the pathogen**
  - Growers should collect a symptomatic plant and get a good diagnosis from their local Plant Disease Clinic (so they can know which management approaches will work the best)
  - Living virus-infected or susceptible hosts – remove weeds, volunteer plants, abandoned fields (especially those upwind)
  - Remove crop debris promptly at the end of the crop
  - Rogueing: remove infected crop plants from the field.
    - Recommend only after much consideration.
    - Rogueing may not always be effective; will add costs; not clear when and if to rogue
    - Only effective when you remove plants infected by primary spread early in the season, and when you expect that there will be significant secondary spread.
    - Discard virus-infected plants as they are rogued – don't leave in the field.

Management: Prevention

- **Modify cultivation procedures**
  - Make changes in planting/harvesting times that create breaks in the disease cycle (ex. Change planting date to avoid flights of vectors)
  - Separate plantings in time so that the virus cannot move from old plantings to new ones
  - Isolate plantings by distance – the greater the distance of a planting from a source of virus, the lower the chance of movement of the virus
  - Modify plant spacing (has helped in some virus/host combinations) (plant spacing affects the decision by an aphid to land on a plant)

Management: Prevention

- **Prevention of introduction or long distance movement by regulation**
  - Prevent movement of virus-infect plants by individuals
  - Prevent movement of virus-infect plants through experimental sources (new breeding lines, germplasm, etc.)
  - Commercial trade in plant propagules (seed, tubers, transplants, cuttings, plants, etc…)
  - Regulation of potential virus vectors upon entry
  - Foreign certification before entry
  - Quarantine after entry
  - Seed certification for the absence of specific viruses

General Approaches to Management:

- Prevention: remove or avoid sources of the pathogen
- **Protect the plant from infection**
- Manage Vectors

Protect the Plant from Infection

- **Protect the host from the effects of systemic disease**
  - **Genetic resistance**
  - **Induced resistance**

- **Genetic Resistance:**
  - Conventional Resistance
  - Transgenic Resistance

- **Induced Resistance:**
  - Systemic Acquired Resistance
  - Cross-protection

Protect the Plant from Infection

- **Conventional Resistance**

- One of the best approaches to protect crops from virus infection
- Resistant varieties, where available, are still considered the most cost-effective and reliable approach to virus management
- Considerable time and cost may be involved in developing varieties with the appropriate range of resistances
- If resistance proves durable, then the use of resistant crop varieties is clearly the preferred method to control agricultural losses to viruses.

Protect the Plant from Infection

Conventional Resistance

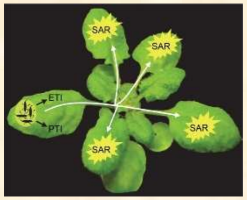
- Plant genotypes within a species are resistant to a given virus due to a constitutive OR active (induced) mechanism
- Genes that confer this type of resistance are known as R genes
- Over 200 R genes that confer resistance to viruses have been identified in crops and their wild relatives
- More than 80% of reported viral resistance is monogenically controlled (single R gene); the remainder shows oligogenic or polygenic control (multiple genes).
- About half of all monogenic resistance traits is recessive.

Protect the Plant from Infection

Transgenic Resistance

- Plant genotypes with good horticultural characteristics are transformed with a gene or part of viral gene which usually creates resistance through PTGS
- Not all viral genes will induce good resistance
- Only a few examples of deployed transgenic resistance are being used due in part to the high costs associated with registration and resistance by some vocal people
- New methods of creating resistance using gene editing (not considered transgenic) are in progress

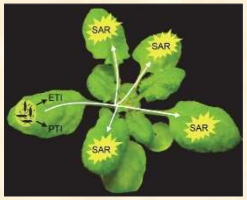
Protect the Plant from Infection



- **Induced Resistance – Systemic Acquired Resistance**

- In a normally susceptible species, resistance can be induced by elicitors other than viruses, e.g. infection with other pathogens, application of chemicals, physiological changes or changes in environmental conditions.
- This response depends on the presence of an early warning signal which is then followed by the activation of specific defense response genes.
- It has been shown that microorganisms and chemicals can turn on these defense responses.
- Most of these chemicals have been demonstrated to turn on defense responses to bacteria and fungi, but some have been shown to produce defense responses to viruses.

Protect the Plant from Infection



- **Induced Resistance – Systemic Acquired Resistance**

Plant activators (elicitors) of SAR:
Unlike pesticides, plant elicitors have no direct effect on pathogens. Plant activators induce plants to produce natural disease-fighting compounds.

- Acibenzolar (Actigard)
- Biological control organisms
- Salicylic acid
- Benzothadiazone (BTH)
- Brassinolide (BL) a brassinosteroid
- Pyraclostrobin (strobilurin fungicide)
- Probenazole (PBZ, the active ingredient in Oryzemate, a fungicide used in rice)
- Isonicotinic acid
- 2,6-dichloroisonicotinic acid (imidacloprid)
- *N*-cyanomethy-2-chloroisonicotinamide (NCI)

*Shown to elicit virus resistance

Protect the Plant from Infection

Plant activators (elicitors) of SAR:

- Plant activators (elicitors) reduce the severity of symptoms which translates to a reduction in the % of visible symptoms

- The effect of SAR elicitors is short lived.
- Must be reapplied approx. every 2 weeks.

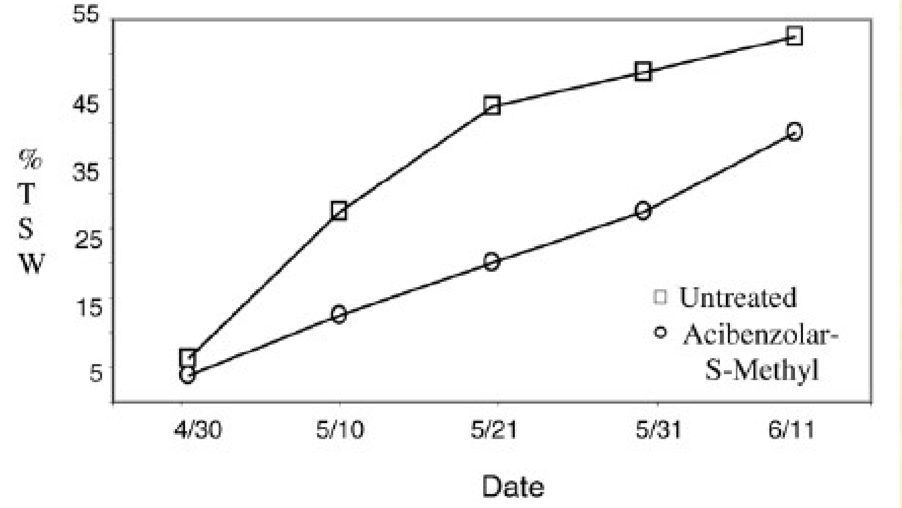


Fig. 2. Disease progress curves of tomato spotted wilt (TSW) as affected by acibenzolar-*S*-methyl in the experiment conducted in 2002.

Effect of Actigard on incidence of plants with symptoms of TSWV

Protect the Plant from Infection

- **Cross-protection**

Table 1 . Viruses for which mild strains have been used for cross protection in the fields (on an experimental [E] or a commercial [C] basis), means by which mild strains have been obtained, and crops which have been cross protected

Virus	Origin of mild strains	Crops (experimental [E] or commercial [C] field tests)
Badnavirus		
cocoa swollen shoot	field isolates (8)	cocoa [E]
Closterovirus		
citrus tristeza	field isolates (3,18)	citrus [C]
Nepovirus		
arabis mosaic	field isolates (9)	grapevine [E]
Potyvirus		
papaya ringspot	mutagenesis (31)	papaya [C], squash [E]
zucchini yellow mosaic	greenhouse variants (12)	squash [C], cucumber [C]
soybean mosaic	cold treatment (11)	soybean [E]
Tobamovirus		
tomato mosaic	mutagenesis (24) heat treatment (22) field isolates (4)	tomato [C]

Protect the Plant from Infection

- **Cross-protection**

Some risks associated with cross protection:

- Protecting (mild) strain may spread to other hosts in which it may have more severe effects
- Amplified disease symptoms caused by synergism with another pathogen
- Genetic recombination between the protecting strain and other virus(es) in mixed infection
- Potential mutation of the protecting virus into a more severe form that would cause a destructive disease (not yet reported)

Protect the Plant from Infection

- **Cross-protection**

Squash leaf curl virus (SLCV) (Begomovirus)

Zucchini yellow mosaic virus (ZYMV) (*Potyvirus*) mild isolate

SLCV plus ZYMV mild

Next Lecture:

General Approaches to Management:

- Prevention: remove or avoid sources of the pathogen
- Protect the plant from infection
- **Manage Vectors**