Transmission

Cuscuta provides an excellent way to transmit phytoplasmas.

Phylum Arthropoda, Class Insecta, Order Hemiptera

Phylum Arthropoda, Class Insecta

Order Thysanoptera

Order Coleoptera
Phylum Arthropoda, Class Arachnida, Order Acariformes

Phylum Nematoda, Class Secernentea, Order Tylenchida

Kingdom: Fungi
Phylum: Chytridiomycota
Class: Chytridiomycetes
Order: Incertae sedis
Family: Olpidiaceae
Genus: Olpidium

Kingdom: Rhizaria
Phylum: Cercozoa
Class: Plasmodiophorea
Order: Plasmodiophorida
Family: Plasmodiophoridae
Genus: Polymyxa

Plant virus vectors are mostly Unikonts, and sometimes Rhizaria

Vectors and plant viruses they transmit

- Includes 110 virus species of the genus Polymyxa; family Polymyxidae;
- Virus species of the genus Begomovirus; family Geminiviridae;
- These are all tenuiviruses that have multiple shapes;
- These viruses probably have insect vectors.
Four modes of virus transmission

<table>
<thead>
<tr>
<th>Biological characteristic</th>
<th>Non-persistent</th>
<th>Semipersistent</th>
<th>Persistent</th>
<th>Persistent</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAP and IAP</td>
<td>Seconds, minutes</td>
<td>Minutes, hours</td>
<td>Hours, days</td>
<td>Hours, days</td>
</tr>
<tr>
<td>Latent period</td>
<td>None</td>
<td>None</td>
<td>Hours, days</td>
<td>Days, weeks</td>
</tr>
<tr>
<td>Retention time in vector</td>
<td>Minutes, last after</td>
<td>Hours, last after</td>
<td>Days, weeks</td>
<td>Life span of insect</td>
</tr>
<tr>
<td>Presence in vector's hemolymph</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Multiplication in vector</td>
<td>No</td>
<td>No</td>
<td>No(^2)</td>
<td>Yes</td>
</tr>
<tr>
<td>Transovarial transmission</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Often</td>
</tr>
</tbody>
</table>

* AAP: Acquisition access period; IAP: inoculation access period; \(^1\): A recent publication revealed that the semi-persistent virus Cauliflower Mosaic virus (CaMV) is repressed in the style (171). \(^2\): The time period during which virus can be acquired from and inoculated into plant epidermal cells; \(^3\): AAP and IAP times depend on the location of the virus in the plant, i.e., acquisition of the virus from the plant tissue takes longer than acquisition from the epicormis or mesophyll cells; \(^4\): Except for TYLCV for which there is evidence that it replicates in its whitefly vector.

Viruses transmitted in a non-persistent mode

- **Polyviridae**
  - +RNA
- **Bromoviridae**
  - +RNA

Viruses transmitted in a semi-persistent mode

- **Closteroviridae**
  - +RNA
- **Caulimoviridae**
  - dsDNA(RT)

Viruses transmitted in a circulative persistent mode

<table>
<thead>
<tr>
<th>Virus family</th>
<th>Virus genus</th>
<th>Number</th>
<th>Aphids</th>
<th>Leafhoppers</th>
<th>Planthoppers</th>
<th>Thrips</th>
<th>Hemiptera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luteoviridae</td>
<td>Enamovirus</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Luteovirus</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Potexvirus</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Geminiviridae</td>
<td>Mastrevirus</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Curtovirus</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Begomovirus</td>
<td>-</td>
<td>115</td>
<td>-</td>
<td>-</td>
<td>115</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tospovirus</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Nanoviridae</td>
<td>Nanovirus</td>
<td>3</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Badovirus</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td></td>
<td>144</td>
<td>12</td>
<td>13</td>
<td>115</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

* It was found that each transmission event involves ~2 virions; a narrow bottleneck indeed.

Viruses transmitted in a circulative propagative mode

- **Enveloped viruses;**
  - The insect vectors of three nucleorhabdoviruses and two cytorhabdoviruses have not yet been identified.
  - One nucleorhabdovirus, Coffee ringspot virus, and the unclassified Ochrall fleck virus are transmitted by the vine Brevipalpus phoenicis; no vectors identified.

Insect anatomy review
Body parts and plant tissues involved in distinct transmission modes

Non-persistent transmission I

**Cucumber mosaic virus**
Transmission determinant: Coat protein

Non-persistence: transmitted viruses (propagating behavior)

Non-persistent transmission II

**Tobacco etch, Potyvirus**
Transmission determinants:
- Helper component protease, Coat protein

Motifs within the HC-Pro (a KITC and PTK that mediate stylet binding and CP binding, respectively) and CP (a DAG that mediates PTK binding)Domains in the HC-Pro that are associated with virus transport, protease activity, and suppression of RNA interference (RNAi, PTGS and VIGS, respectively) are indicated.

Semi-persistent transmission I

**Cauliflower mosaic virus, genus Caulimovirus**
Transmission determinants:
- Aphid-transmission factor, Virion-associated protein, Coat protein

Circular map of CaMV DNA (double circle). ORFs are indicated by black arrows in the outer circles (VII (function unknown), I (MP, cell-to-cell movement protein), II (ATF, aphid-transmission factor p2), III (VAR, virion-associated protein, transmission function, p3), IV (CP, capsid protein precursor, structural function) and V (POL, protease, reverse transcriptase, RNase H, enzymatic functions)).

Semi-persistent transmission II

**Beet yellows virus, genus Closterovirus**
Transmission determinants:
- Proteins associated with virion tail

BYV structure, assembly and transmission

BYV-GFP
BYV-GFP-p20

Hsp70h, p64, Cpm and CP are each required for the assembly of tailed, movement-competent virions. p20 forms the tail tip.
**Semi-persistent transmission II 1/2**

*Lettuce infectious yellows virus, genus Crinivirus*

![Diagram of viral components]

**Persistent circulative transmission I**

*Beet western yellows virus, genus Polerovirus*

Ingested virus moves up the food canal (FC), through the foregut (FG) and accumulates in the midgut (MG) or hindgut (HG). Virus is then acquired into the hemocoel (HC). Virus accumulate in the hemocoel and remain viable for weeks. Transmissible virus (black hexagons) is transported into the accessory salivary gland (AG), but not the principal salivary gland (PG). Transmissible virus is then injected into the plant through the salivary duct (SD).

**Persistent circulative transmission II**

*Tomato yellow leaf curl virus, genus Begomovirus*

A component encodes Rep (replication initiation protein), a transcriptional activator protein (TrAP), Ren (replication enhancer) and a C4 protein (RNAi suppression), and CP. B component encodes proteins involved in intra- and intercellular viral movement.

**Persistent propagative transmission**

*Tomato spotted wilt virus, genus Tospovirus*

Tospovirus transmission depends on thrips ontogeny and requires binding of virions to thrips cell receptors.

**Fungal transmission**

*Kingdom: Fungi*

*Phylum: Chytridiomycota*

*Class: Chytridiomycetes*

*Order: Incertae sedis*

*Family: Olpidiaceae*

*Genus: Olpidium*

ZS, zoospores transmit viruses RS, resting spores can also harbor viruses for years/decades making infestation virtually permanent. The protoplast of ZS is injected into root cell via the holes in ZS cell and a root cell.
**Table 1: Viruses transmitted by Ophiobolus vectors**

<table>
<thead>
<tr>
<th>Virus</th>
<th>Host Genus</th>
<th>Fungal vector</th>
<th>Acquisition mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cucumber necrotic virus</td>
<td>C. sativum</td>
<td>O. sp.</td>
<td>In vivo</td>
</tr>
<tr>
<td>Cucumber leaf spot virus</td>
<td>C. sativum</td>
<td>O. sp.</td>
<td>In vivo</td>
</tr>
<tr>
<td>Cucumber yellow spot virus</td>
<td>C. sativum</td>
<td>O. sp.</td>
<td>In vivo</td>
</tr>
<tr>
<td>Melon necrotic spot virus</td>
<td>M. melo</td>
<td>O. sp.</td>
<td>In vivo</td>
</tr>
<tr>
<td>Squash necrotic virus</td>
<td>Cucurbita</td>
<td>O. sp.</td>
<td>In vivo</td>
</tr>
<tr>
<td>Red clover necrotic mosaic virus</td>
<td>D. pratensis</td>
<td>O. sp.</td>
<td>In vivo</td>
</tr>
<tr>
<td>Clover necrotic mosaic virus</td>
<td>D. pratensis</td>
<td>O. sp.</td>
<td>In vivo</td>
</tr>
<tr>
<td>Lilies necrotic virus</td>
<td>L. tigrinum</td>
<td>O. sp.</td>
<td>In vivo</td>
</tr>
<tr>
<td>Tobacco mosaic virus</td>
<td>N. tabacum</td>
<td>O. sp.</td>
<td>In vivo</td>
</tr>
<tr>
<td>Tobacco mosaic virus Q</td>
<td>N. tabacum</td>
<td>O. sp.</td>
<td>In vivo</td>
</tr>
<tr>
<td>Tobacco mosaic virus O</td>
<td>N. tabacum</td>
<td>O. sp.</td>
<td>In vivo</td>
</tr>
</tbody>
</table>

**Specific adsorption of virus by zoospores**

Virus is acquired in the infected plants; it is present within RS and ZS.

Virus is acquired in soil/water outside infected plants; it is present on the surface of ZS; no virus in RS.

**Up to 10,000 virions per ZS can be bound**

**Kingdom: Rhizaria**

**Phylum: Cercozoa**

**Class: Plasmodiophorea**

**Order: Plasmodiophorida**

**Family: Plasmodiophoridae**

**Genus: Polymyxa**

**Polymyxa life cycle**

Virus found inside ZS released from SpR or RS. As ZS start new infection virus released in host.

**Bymovirus, +RNA**

The read-through domain of the CP of furoviruses and the CP of bymoviruses seem to be the primary determinants of Polymyxa transmission.
Virus transmission

Mechanically transmitted viruses: Stability is the way

Vectors: High specificity, other organisms may be involved (bacteria etc.)

The major determinants are commonly found in the CP

Receptors: A major unknown in plant viruses movement and replication in their vectors (pp)