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INSECT VECTOR MEDIATED PLANT VIRUS TRANSMISSION

[1]M. SHANMUGA PREMA[1] AND V.S.L. SARANYA[2]

[1]Ph.D. Scholar, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore - 3

[2]Ph.D. Scholar, Department of Entomology, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan – 313 001

[1]Corresponding author's email ID: prema.ms1990@gmail.com

Introduction:

Transmission is the fundamental property of viruses. Plant viruses being obligate parasites must be spread from one susceptible host to another and need to be introduced in living cell for their survival and continuity. Plant virus transmission takes place by two means *i.e.*, Horizontal transmission and Vertical transmission. Horizontal transmission is by vectors, human pruning shears and tools, other direct or external contaminations. Vertical transmission occurs when a plant gets it from its parent plant. Either through asexual propagation (cuttings) or sexual reproduction *via* infected seeds.

Most plant viruses depend on insect vectors for their survival, transmission and spread. Insect vectors are the regular and specific agents which carry and transmit viruses. Over 75% of plant viruses are transmitted by insects. (Ammar *et al.*, 2009)

Insects as vectors:

Insect vectors of plant viruses are found in 7 out of the 32 orders of the class Insecta. Majority of insect vectors occurs in two major orders of insects with piercing and sucking type of mouthparts *viz.*, Thysanoptera and Hemiptera. Five orders of chewing insects also act as vectors *viz.*, Orthoptera, Dermaptera, Coleoptera, Lepidoptera and Diptera. The feeding organs of the Hemipterans are the principal reason for their successful role as vectors. Among the Hemipterans, aphids and whiteflies play a major role in transmission of plant viruses. Other than insects about 6% of nematodes are likely known to transmit plant viruses (Ng, and Falk 2006).

Virus vector relationships

Plant viruses have high level of specificity for the group of insects that may transmit them (a virus that is transmitted by one type of vector will not be transmitted by another). In 1939, Watson and Roberts proposed the modes of virus transmission by insects. He proposed two modes of transmission and they are mainly based on the duration of virus retention in the vectors body: **Non-persistent** for short retention and **Persistent** for extended retention (throughout their lifespan). However, several other viruses showed an intermediate retention in their vectors. Sylvester (1958) introduced the term Semi-persistent, based on the site at which the virus is carried in the insect body.

Table 1. Biological characteristics of different modes of virus transmission in insects

Feature	External (Non-circulative)		Internal (Circulative*)
	Non-persistent	Semi-persistent	Persistent
Duration of retention	Brief (few hours)	Intermediate (few days)	Long (days to months)
Duration of acquisition and transmission	Brief (seconds)	Intermediate (hours)	Long (hours to days)
Latent period	Not required	Not required	Required
Tissue where virus is acquired and inoculated	Epidermis and parenchyma	Epidermis, parenchyma and phloem	Mostly parenchyma and phloem
Pre-acquisition fasting	Increase transmission	No effects	No effect
Passage through moult	Negative	Negative	Positive
Insect species specificity	Low	Intermediate	High
Sequential inoculation	Poor	Intermediate	Good

*Internal circulative virus cross gut and salivary gland barriers

Different Modes of Transmission:

Depending on the mode of transmission, plant viruses are classified into three categories.

1. **Non-persistent (e.g.,** Cucumber mosaic virus)
2. **Semi-persistent (e.g.,** Cauliflower mosaic virus) } **Non-circulative viruses**
3. **Persistent**
    a. **Circulative propagative** (e.g., Potato leaf roll virus)
    b. **Circulative non-propagative viruses**

1. Non-persistent viruses:

Non-persistent viruses are termed as stylet-borne viruses. They are acquired and inoculated during brief probing times and do not require a latent period in the vector. These are usually transmitted by many aphid species e.g., Most aphid-transmitted viruses [**Cucumber mosaic virus** (CMV)].

2. Semi-persistent viruses

Semi-persistent viruses need longer periods (hours) for acquisition and transmission than non-persistent viruses. They have a narrower range of vector species. However, they too need no latent period and are lost when the vector moults e.g., Beetle and some whitefly transmitted viruses **(Cauliflower mosaic virus, Beets yellows virus)**

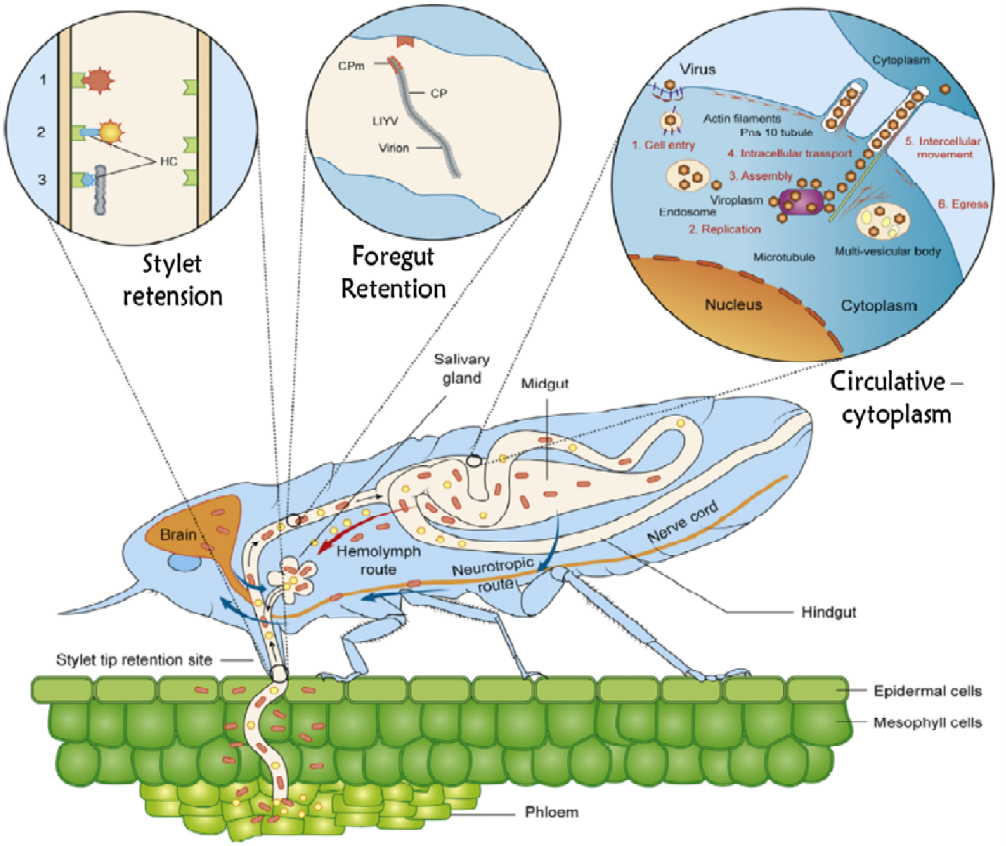

Fig 1. Virus localization sites in insect vectors. Non circulative viruses (Non-persistent and Semi-persistent) are retained in the insect stylet (A) or foregut (B). Circulative viruses move through haemolymph, reach salivary glands and get transmitted (Raccah and Fereres, 2009)

3. Persistent viruses/ Circulative viruses

Persistent viruses are termed as circulative viruses. In persistent viruses, the longer the acquisition and inoculation times, the higher is the rate of transmission. They mostly have a narrow range of vectors, pass through moults and need a latent period. Non-persistent and semi-persistent viruses have transient relationships with their vectors and are associated only with the mouthparts or foregut. In contrast, persistent viruses circulate in the vector body and have developed intimate interactions with internal organs and components of vectors.

a. Persistent circulative non-propogative transmission:

Virus particles move through the insect gut, enter into the haemolymph of the vector and eventually reach the salivary glands and mouthparts but do not multiply in the vector. The virus passes only to the circulative system from gut and back to salivary gland. Starving prior to acquisition doesn't influence their ability to acquire. They cannot be sap or mechanically transmittable. All Gemini viruses and many leafhopper transmitted viruses e.g., some aphids, most leafhoppers and whitefly-transmitted viruses come under this group (e.g., *Beet curly top virus, Maize streak virus and Wheat dwarf virus).*

b. Persistent circulative – Propagative transmission

Plant viruses which are circulated and also multiply inside the host are named as propagative plant viruses. These viruses multiply both in plants as well as in insect vectors. Following the acquisition by vector, the virus particles number increase e.g., Potato leaf roll

virus (transmitted by *Myzus persicae*), Wound tumor virus (transmitted by leaf hoppers and transovarially trasmitted to offsprings), *Tomato spotted wilt virus* (transmitted by thrips). Multiplication may occur in cytoplasm of cells of muscles, brain, fat bodies, mycetomes, trachae, epidermis and alimentary canal e.g., Thrips, some leafhoppers and aphid-transmitted viruses.

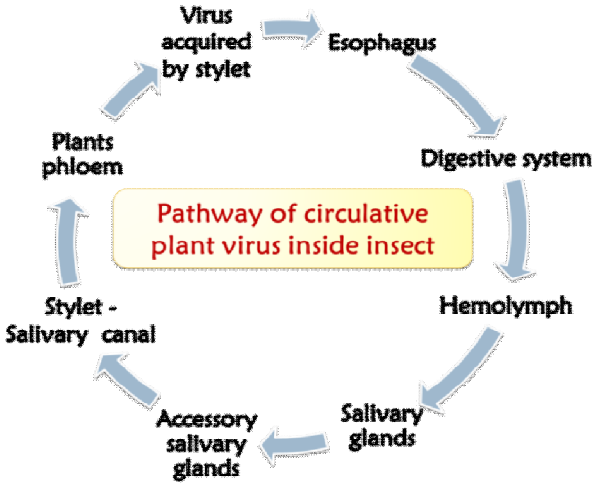

Fig 2. Pathway of circulative plant virus inside insect body

Table 2: Groups of viruses and insect species that serve as vectors

Virus groups	Mode	Persistence	Presence in vector	Insects involved
Alfamo virus	N	Few hours	External	Aphids
Badna virus	S	Days	External	Mealy bugs and leafhoppers
Bego virus	C	Weeks	Internal	Whiteflies
Carla virus	N	Few hours	External	Aphids
Caulimo virus	N	Many hours	External	Aphids
Clostero virus	S	Many hours	External	Aphids/mealy bugs
Como virus	S	Days	Internal	Beetles
Cucumo virus	S	Few hours	External	Aphids
Curto virus	C	Weeks	Internal	Leafhoppers
Enamo virus	C	Weeks	Internal	Aphids
Faba virus	N	Few hours	External	Aphids
Luteo virus	C	Weeks	Internal	Aphids
Polero virus	C	Weeks	Internal	Aphids
Machlomo virus	SP	Many days	External	Leafhoppers
Mastre virus	C	Weeks	Internal	Leafhoppers
Potyvirus	N	Few hours	External	Aphids
Sequi virus	SP	Few hours	External	Aphids
Sobemo virus	SP	Days	Not determined	Beetles
Tymo virus	SP	Days	Not determined	Beetles
Waika virus	SP	Few days	External	Leafhoppers

C, Circulative; N, Non-persistent; SP, Semi-persistent; Internal - virus cross gut and salivary gland barriers; External - virus does not cross the gut barrier; it remains attached to the foregut epithelium.

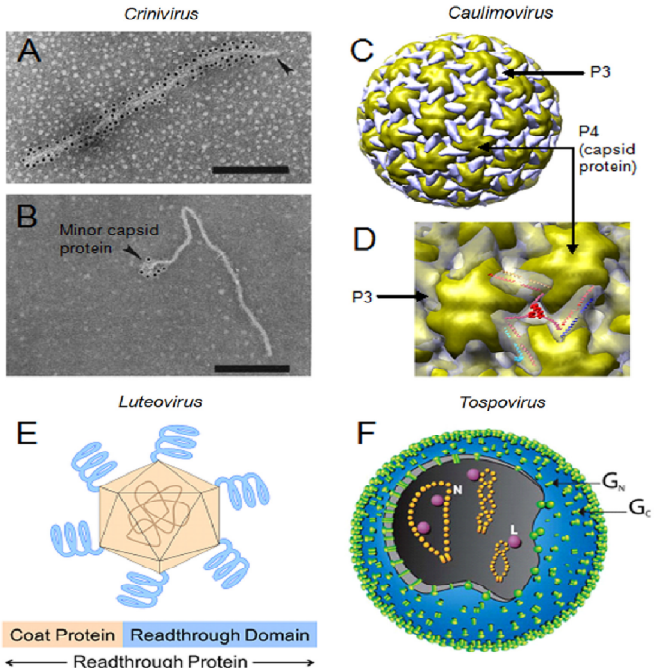

Fig 3. Virion structures and viral attachment proteins (Whitfield *et al.*, 2005)

Table 3. Viruses and their associated vectors and transmission strategies in different insects.

Taxonomic family	Virus genus	Representative virus	Types of vector	*Virus-encoded "transm-ission proteins"	Location of virion retention / initial entry
Non Circulative in the body of insect vectors					
Potyviridae	Poty virus	Tobacco etch virus (TEV)	Aphid	CP,HC-Pro	Stylet
Bromoviridae	Cucumo virus	Cucumber mosaic virus(CMV)	Aphid	CP	Stylet
Caulimovivridae	Caulimo virus	Cauliflower mosaic virus(CaMV)	Aphid	CP,P^2,P^3	Stylet, acrostyle
Closteroviridae	Crini virus	Lettuce infectious yellow virus (LIYV)	Whitefly	CPm	Forgut
Circulativein the body of insect vectors					
Luteoviridae	Luteo virus	Barley yellow dwarf virus (BYDV)	Aphid	CP-RTP	Midgut, Hindgut
Geminiviridae	Begomo virus	Tomato yellow leaf curl virus (TYLCV)	Whitefly	CP	Midgut, Filter Chamber
Circulative and replicative within the body of insect vectors					
Bunyaviridae	Tospo virus	Tomato spotted wilt virus(TSWV)	Thrips	G_N	Midgut
Reoviridae	Phytoreo virus	Rice dwarf virus(RDV)	Leaf hopper	P^2*	Midgut, filter chamber
Rhabdoviridae	Nucleo-rhabdovirus	Maize mosaic virus (MMV)	Plant hopper	G	Midgut

***Virus-encoded "transmission proteins":** CP - capsid protein or major capsid protein; HC-Pro - helper component proteinase, P^2- non-virion helper component protein, P^3 - protein anchored in the CaMV virion, CPm - minor capsid protein, CP-RT - capsid protein read through domain, G_N- glycoprotein N, P^2*- outer capsid protein encoded by RDV segment 2, G –glycoprotein (Blanc *et al* 1998)

Conclusion:

The interaction between viruses and vectors varies in duration and specificity. Some common features of vector transmission are as follows

1) Plant viruses encode structural proteins on the surface of the virion, which are essential for their transmission, and in some cases additional non-structural helper proteins bridge the virion to the vector binding sites.

2) Viruses bind to specific sites in the vectors and are retained there until they are transmitted to their plant hosts and

3) Viral determinants of vector transmission are promising candidates for translational research aimed at disrupting transmission or decreasing vector populations.

The virus and vector interaction is mainly decided by the structure of the proteins that are present on the surface of virus particles. So it is very important to understand the structure of the virus particles and the receptor sites in insects based on which management can be taken up.

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