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Insects: Vector Responsible for Transmitting Diseases in Plants

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SUMMARY

Insect-vectored pathogens pose one of the main global threats to plant and animal health, including human health. Nearly 80 percent of plant viruses depend on insect transmission vectors (other agents may be nematodes and fungi), and the interactions between plant viruses and vectors are quite complex. Aphids, whiteflies, leafhoppers, thrips, beetles or weevils, mealy bugs, and mites are insect vectors which transmit most plant viruses. Insects can spread plant viruses in multiple forms, such as non-persistent, semi-persistent, and persistent. This article briefly summarises the role of insects in causing viral, fungal, and bacterial plant diseases.

INTRODUCTION

In seven orders of the class Insecta, insect vectors of plant viruses are found. In the two orders of insects, Thysanoptera and Hemiptera, the majority of vectors are found. Orthoptera, Dermaptera, Coleoptera, Lepidoptera and Diptera are several species of insects that also serve as disease vectors. Plant virus vectors are very diverse taxonomically, and can be found among arthropods, nematodes, fungi, and plasmodiophorids. Aphids, whiteflies, leafhoppers, thrips, beetles or weevils, meal bugs, and mites are the insect vectors that spread most plant viruses. The most common vectors of plant viruses tend to be sucking insects that feed on plants and vascular tissues (xylem and phloem). The largest number of insect vectors of plant viruses is included in the Hemiptera order. With more than 200 known vector species, the most common are aphids (Ng and Perry, 2004). Over than half of the almost 550 viruses transmitted by vectors reported so far are spread by aphids (55 percent). Around 11%, 9%, 7% and 2% of viruses are transmitted by leafhoppers, beetles, whiteflies and thrips, respectively (Astier et al . 2001). In different ways, plant viruses can be spread by insects. These ones have been Non-persistent, semi-persistent, and persistent are graded. Potyviruses and colimoviruses encode the HC portion for the transmission of viruses by aphids, e.g. the aphid vector transmits the Potato Acuba Mosaic virus by PVY intervention, which serves as a helper virus. Transmission specificity is involved in coat protein (CP), or its variants, and non-structural proteins, including a helper component (HC) or a transmission factor. CP, protein P2, which is an aphid transmission factor, and protein P3, which bridges protein P2 and virions, are all essential for virus transmission in the Cauliflower mosaic virus.

There are several successive steps required for Vector–virus transmission to be followed:

- Virion acquisition from an infected source via vector
- Stable retention of acquired virions by binding of virions to ligands at particular sites.
- Release upon salivation or regurgitation of virions from the retention sites.
- Delivery of virions inside a viable plant cell to an infection site.
- For transmission to be efficient, each step of this sequence is required.

Mode of Transmission: Insects can spread viruses in different ways.

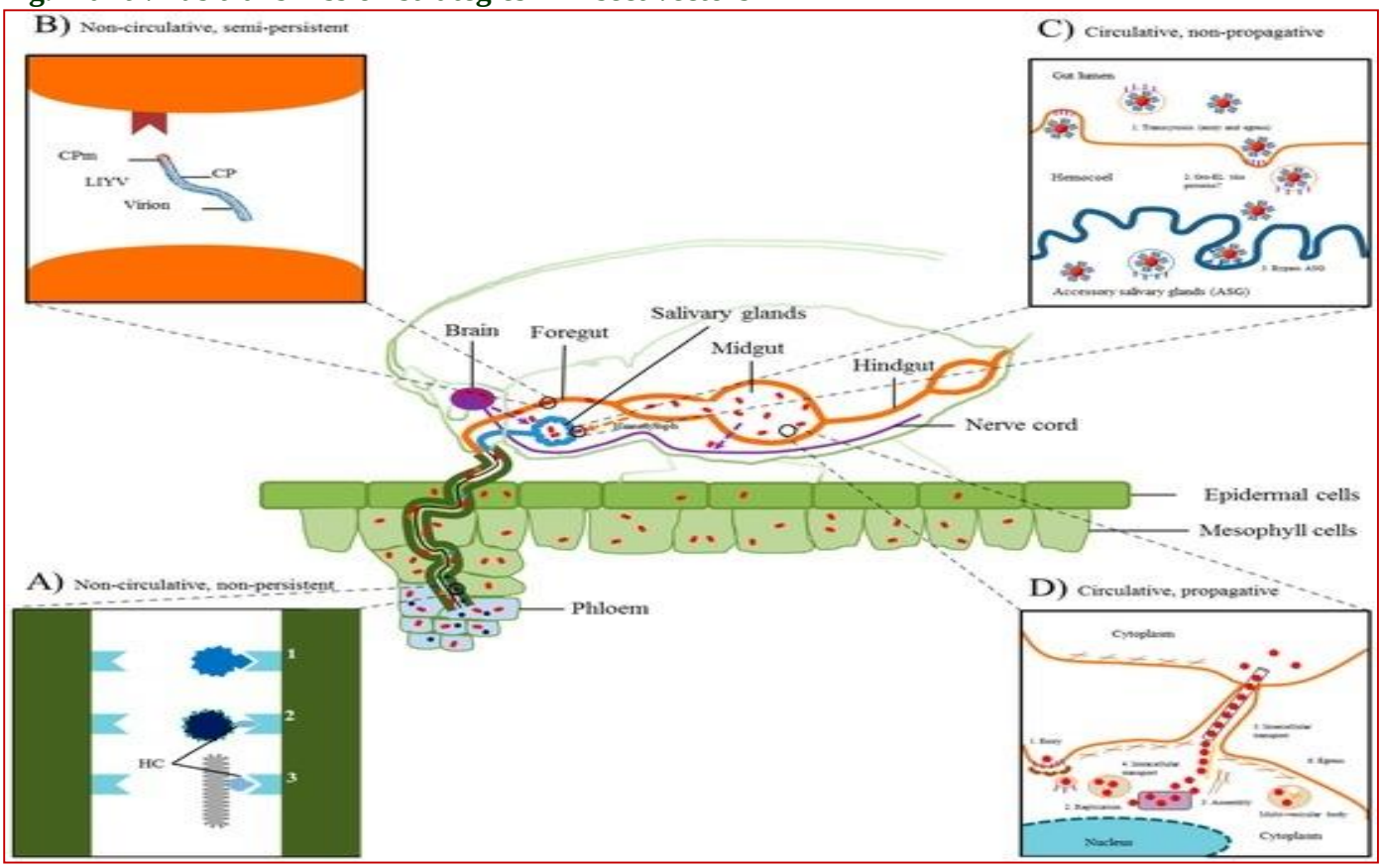
- **Non-Persistent Transmission:** Viruses multiply rapidly in epidermal cells and/or parenchyma in this form of transmission. In a couple of seconds, an insect will inoculate a healthy plant. For an insect to acquire the virus, feeding takes less than one minute. Retention only lasts for a few minutes to a few hours. If the aphid persists for a few minutes on a single plant, it loses the ability to transmit. Example-The most aphid-vectored viruses borne by stylet. Papaya ringspot virus, for instance:
- **Strategy of Helper (Indirect):** The helper components play a very important role in virus transmission in most non-persistent viruses. Potyviruses and caulimoviruses encode the HC portion to transmit aphids to viruses. The HC is a non-structural protein that binds to both the virion and the cuticular lining of the mouth sections of the aphid (Bridge hypothesis), thereby maintaining the virion inside the aphid stylet food channel. E.g. the aphid vector transmits the Potato Acuba Mosaic virus by PVY intervention, which serves as a helper virus.

- **Strategy of Capsid (Direct Strategy):** Purified viral particles are readily acquired and transmitted in some aphid transmitted viruses of the genera Cucumovirus, Alfamovirus, and Carlavirus conveyed by a vector. This suggested that the protein coat (capsid protein) of these viruses had to be capable of being directly bound to the vector receptor and thus transmitted to it. – for example Cucumber Mosaic Virus.
- **Semi-Persistent Transmission:** It takes a long time for these aphids to receive viruses. With feeding cycles of 12-24 hours, the risk of transmission increases. Once received, it is for a longer span, held. In the anterior gut, the virus tends to concentrate-likely binding at particular protein sites. Deeply found in plant tissue-phloem virus. Aphids, whiteflies, and leafhoppers of different genera and families are known as semi-persistently transmitted vectors. E.g. Beet pseudo yellows virus.
- **Persistent transmission**: For an insect to acquire the virus, it takes several hours of feeding. Before transmission will happen, the virus has to circulate through the insect's body to the salivary glands. There is a latent phase during which transmission cannot happen (while the particles of the virus pass through the body of the insect). The insect will then spread the virus for several weeks or the rest of its life until the latent cycle is finished, without having to receive more viruses from an infected plant. Tomato Spotted Wilt Virus, for example.

Two forms of persistent transmission exist

Non-propagative	Propagative
Virus circulates through the vectors body, but does not multiply.e.g Potato leaf roll	Virus needs to multiply in the cells of the insect vector before transmission can occur. The transmission latent period is normally longer with these viruses. e.g. Tomato spotted wilt

Fig. Plant virus transmission strategies in insect vectors



Transmission of Plant Viral Diseases by Insects

Cauliflower mosaic virus:	Cabbage aphid (*Brevicoryne brassicae*) transmission of CaMV occurs in a semi-persistent way. For the Cauliflower mosaic virus (CaMV), the transmission of viruses includes CP, protein P2, which is an aphid transmission factor, and protein P3, which bridges protein P2 and virions. Second, Aphids assess the prospective food supply by short, intracellular punctures in epidermis and mesophyll cells lasting just seconds. The aphids insert their proboscis into the phloem as mouthpieces after these exploratory punctures and feed from its sap for time periods that may exceed several hours when they assess the plant as necessary.
Tomato spotted wilt virus:	Various species of thrips, including the western flower thrips, *Frankliniella occidentalis*, the onion thrips, *Scirtothrips dorsalis*, chilli thrips, Thrips tabaci, and the onion thrips, are transmitted by tospoviruses. For the rest of their lives, nymphs that develop the virus by feeding on infected plants will maintain the ability to transmit it. The feeding time for inoculation must be 30 minutes or longer. The virus circulates in the vector and replicates the viruliferous thrips during their lifespan.
Potato leaf roll virus (PLRV):	It is a phloem-limited Luteovirus which is transmitted by aphids in a persistent manner. PLRV takes longer to be acquired (10-30 minutes) and transmitted (24 to 48 hours) by aphids, since the virus needs to move into the gut, through the body and back out through the salivary system of the aphid. The virus persists throughout the aphid's life and can be carried over long distances.
Rice dwarf virus:	Rice dwarf virus is the best-known virus disease in the world although the distribution of the disease seems to be limited to Japan and Korea. It was the first plant virus disease found to be transmitted by an insect; it provided the first evidence for the multiplication of a plant virus in an insect. Transmitted by three species of leaf hoppers: *Recilia dorsalis*, *Nephotetix cincticeps*, in most areas *N. cincticeps* plays the major role in transmission of the disease. Transovarial transmission of a plant virus by its insect vector was first described by Fukushi in 1933, who showed that rice dwarf virus, was transmitted for several generations through the egg of the leafhopper vector *Nephotettix apicalis*. Transovarial transmission has been often associated with replication of the virus in its vector.
Bean common mosaic virus (BCMV):	Bean common mosaic virus is a potyvirus, transmitted by many aphid species in the non-persistent manner. More than 20 aphid spp. can transmit the virus in a non-persistent manner, especially *Acyrthosiphon pisum*, *Macrosiphum euphorbiae*, *Myzus persicae* and *Aphis fabae*.
Papaya ring spot virus (PRSV):	Papaya ring spot was first coined by Jensen in 1949. It belongs to Genus Potyvirus and family Potyviridae. Aphids are the predominant means by which PRSV is transmitted in a non-persistent manner. Non-persistent viruses are transmitted quickly and easily between plants. Many species of aphid can transmit PRSV, particularly the Peach Aphid and Melon Aphid. Virus is grouped: papaya infecting type (PRSV-P) - affects both papaya and cucurbits and cucurbit infecting type (PRSV-W) which affects cucurbits but not papaya. This disease severely affected the papaya industry in Puna district in 1950s.
Rice tungro disease:	It is one of the most destructive diseases of rice in South and South east Asia, where epidemics of the disease have occurred since the mid-1960s. Tungro means degenerated growth. Tungro is caused by two viruses, an RNA virus, the rice tungro spherical virus (RTSV), and a DNA virus, the rice tungro bacilliform virus (RTBV). RTBV depends on the helper produced by RTSV for its transmission. It is the RTBV which is mainly responsible for the severe tungro symptoms. Tungro virus disease is transmitted by leathoppers, particularly the green leafhopper (GLH), *Nephotettix viriscens* in semi-persistent manner. The insect acquires the virus by feeding on the plant for a short time, and can transmit the virus immediately after feeding.

Citrus tristeza virus (CTV):	It is a viral species of the Closterovirus genus that causes the most economically damaging disease to its namesake plant genus, citrus. The disease has led to the death of millions of Citrus trees all over the world and has rendered other millions useless for production. Farmers in Brazil and other South American countries gave it the name "tristeza", meaning sadness in Portuguese and Spanish, referring to the devastation produced by the disease in the 1930s. The brown citrus aphid (*Toxoptera citricida*) is by far the most efficient vector of CTV, followed by the melon aphid (*Aphis gossypii*). CTV is transmitted semi-persistently by vectors that penetrate the phloem to extract sap, mostly the aphid species that colonize the crop.

Fungal Diseases Transmitted by Insects

Dutch elm disease:	It is caused by *Ophiostoma ulmi* (formerly, *Ceratocystis ulmi*), the vascular wilt fungus. Two species of elm bark beetles are vectored by this fungus: the smaller European elm bark beetle, and the native elm bark beetle. The native elm bark beetle (*Hylurgopinus rufipes*) is the main vector of Dutch elm disease (DED). This small beetle has a length of just 2 to 3.5 mm, around the size of a pin head. During its feeding, breeding, and over-wintering activities, the sticky spores of the DED fungus attach themselves to the beetle. Spreading the spores from infected elms to healthy elms as the beetle flies through it. *Ophiostoma novo ulmi* spores are kept in xylem vessels and replicate by budding. As larvae in their tunnels, the beetles overwinter, pupate in the outer bark and begin to emerge in May. They can be found from May to September on a continuous basis. Only in dead or dying elm tissue will elm bark beetles lay eggs. Spores are spread by bark beetles burrowing under the bark and laying their eggs in wood galleries. O. is dispersed by Elm Bark Beetles. Locally and over distances of many miles, *novo-ulmi*, whereas the fungus can be spread in elm logs and firewood over longer distances.

Bacterial Diseases Transmitted by Insects

Citrus greening disease:	During the 1890's, citrus greening disease was thought to originate as a "yellow shoot disease" in China. In Asia and Africa, the disease is extensively spread. The transmission is via the Asian citrus psyllid, Diaphorina citri, or the African citrus psyllid, Trioza erytreae, also known as the 2-spotted citrus psyllid, in Africa. In 1929, the disease was first identified and first documented in 1943 in China. CGD transmission occurs in a constant manner , i.e. bacteria in the psyllids multiply. In the haemolymph of the vectors, the greening bacterium is found. For African psyllids, the acquisition latent cycle is 24 hours, transmits greening 7 days later and can infect with less than 1 hour of exposure time. Yellow green of wavelength 550 nm highly attracts Pyslla, making diseased trees attractive targets. The pathogen can be derived from the fourth and fifth instars of *Diaphorina citri*, and the disease is transmitted by adults from these nymphs.
Stewart's Wilt:	It is a severe bacterial maize disease caused by the *Pantoea Stewartii* bacterium. The primary vector for *Pantoea stewartii*, *Chaetocnema pulicaria*, overwinters as adults and will begin feeding on corn seedlings early in the spring season. In the gut of the adult corn flea beetles, the bacterium overwinters. Warmer winter temperatures will allow for greater survival of beetles and higher populations will come in spring. Through feeding, emerging beetles in the spring move the bacteria into corn leaf tissue. The leaf is wounded by the corn flea beetles and the wounds are infected with insect frass (excrement), which also includes bacteria. They multiply and fill the xylem and intercellular spaces of the leaf until the bacteria are within the plant.
Sudden wilt of cucurbits:	It is a serious cucurbitus disease. This mostly affects the bottle gourd and is caused by *Xanthomonas* bacteria. The bacteria are spread by beetles from cucumbers. Beetles feed on all plant components, including flowers, fruits, roots , and leaves. In spring, the disease is inoculated by beetles inside new plants. It will infect only deep feeding wounds which expose the water-conducing tissue. Cucumber beetle larvae feed on the roots of cucumber plants and

	bore into both the roots and stems. The primary infection is caused by the feeding of beetles on young leaves or cotyledons. At the wound site, the bacteria multiply and join the xylem vessels, then pass down the petiole and stem. The key mechanism of wilting is vascular plugging by masses of bacteria and the development of gums and resins.
Fire blight of apple and pear:	In eastern North America, *Erwinia amylovora* is a native pathogen of wild rosaceous hosts. It was the first known bacterium to be a plant pathogen. The apple and pear fire blight is caused by *Erwinia amylovora*. *Erwinia amylovora* cells excrete large quantities of extracellular polysaccharide, which produces a pathogen-protecting matrix on the surfaces of plants. In a small percentage of the annual cancers that were developed on branches diseased in the previous season, *Erwinia amylovora* overwinters. Overwintering of these "The" hold over cankers "sites are named. The pathogen becomes involved in the peripheries of holdover cankers as temperatures warm in spring. Onto the bark surface, free bacterial cells are released, often as clear ooze. The bacteria are transmitted from the canker to blossoms by insects drawn to the ooze (e.g. flies) or rain.

CONCLUSION

Insects play a significant role in transmitting viral diseases to plants. The significant insect vectors of plant viral diseases that spread viruses in non-persistent, semi-persistent and persistent ways are aphids, whiteflies, leafhoppers, thrips, beetles or weevils, mealy bugs, and mites

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