**Intercellular Movement**

The cell-to-cell (or short-distance) movement is from the initially infected cell(s), which are usually epidermal or mesophyll cells, to the vascular bundle. In the majority of cases there are two major barriers to movement: movement from the first infected cell and movement out of parenchyma cells into vascular tissues.

the virus needs to move from the site of entry, often the cell walls or plasmodesmata, to the nucleus, where it can replicate, and to other parts of the cell to evade the plant's defense mechanisms and establish a successful infection. This movement is a complex process involving various mechanisms and interactions.

Here are some key points regarding the intracellular movement of plant viruses:

**1- Cell Entry**: Plant viruses often enter host cells through wounds, vectors (insects or nematodes), or mechanical damage. Once inside the cell, they must navigate through the cytoplasm to reach the nucleus and other cellular structures.

2. Plasmodesmata

Since the virus cannot cross the cell wall directly, it must use plasmodesmata, which are cytoplasmic connections between adjacent cells . However, plant virus particles, or even free, folded viral nucleic acids, are too large to pass through unmodified plasmodesmata. Thus, the plasmodesmatal size exclusion limit (SEL) has to be increased, and viral movement proteins (MPs) facilitate this.

3. Movement Proteins (MPs) Most plant viruses encode MPs, which have three functional characteristics:

• They are associated with and/or have the ability to increase the SEL of plasmodesmata.

• They have the ability to bind to either ssRNA or ssDNA.

• They have the ability to transport themselves and/or viral nucleic acid from cell to cell.

**4-Cytoplasmic Streaming**: Within plant cells, there is often a phenomenon called cytoplasmic streaming. This movement of cytoplasm helps disperse viruses throughout the cell and into neighboring cells.

**5.Nuclear Localization**: To replicate and produce more viral particles, plant viruses must reach the cell nucleus. Some plant viruses encode nuclear localization signals to facilitate their entry into the nucleus.

**Systemic Movement**

Plant viruses can move within plants primarily through two types of vascular tissues: xylem and phloem. The movement of viruses in the xylem and phloem plays a crucial role in systemic infection and the spread of viral diseases within plants.

Steps in Systemic Movement

the long-distance transport is through the plant vascular tissue, usually the phloem sieve-tubes following the flow of metabolites from the source leaves to the sink leaves or tissues. Then, further cell-to-cell movement establishes systemic infection of the young leaves.

1. **Phloem movement** : The phloem is responsible for the transport of organic compounds, such as sugars and amino acids, from the photosynthetic source tissues (usually leaves) to other parts of the plant. Viruses can actively move within the phloem and are often referred to as "symplastic" movement, as they enter and exit cells via plasmodesmata, which are small channels that connect plant cells.

Viruses in the phloem can be selective in terms of which tissues they infect. They often interfere with the plant's sieve tubes (the phloem cells responsible for transporting organic compounds) and use these to travel from source tissues (where they entered the plant) to sink tissues (where they can replicate and cause symptoms). This movement is central to the formation of symptoms characteristic of many viral diseases, such as leaf curling, mosaic patterns, and yellowing.

**2. Movement in the Xylem**

Xylem: The xylem is responsible for the transport of water and minerals from the roots to the rest of the plant. Viruses move within the xylem by utilizing the water stream. The movement through the xylem is passive and is often referred to as "apoplastic" movement. Viruses do not enter the xylem cells themselves but rather move in the water that flows within the xylem vessels

Few viruses move long distance through the xylem. For example, Southern bean mosaic virus (SBMV) and other sobemoviruses move as virus particles through dead tissue, which implicates xylem vessels.

**Form in Which Virus Is Transported**

Most viruses require coat protein for long distance transport, but some, like Barley stripe mosaic virus (BSMV), are capable of long-distance movement without a coat protein; BSMV forms a nucleoprotein complexed with TGB1 nonstructural protein. It is not clear if all the viruses that require coat protein for longdistance transport move in the sieve elements as virus particles.

**Rate of Systemic Movement**

The time at which infectious material moves out of the inoculated leaf into the rest of the plant varies widely, depending on such **factors as host**

**species and virus, age of host, method of inoculation, and temperature.** After transmission by aphids, Barley yellow dwarf virus may move out of the inoculated leaf within 12 hours. TMV moves out of tobacco leaves 32–48 hours after mechanical inoculation, and Cucumber mosaic virus can spread systemically 24–30 hours after inoculation.

**Host-Pathogen Interactions**: The intracellular movement of plant viruses involves complex interactions between the virus and the host plant. The plant's defense mechanisms try to restrict the movement of the virus, and viruses evolve various strategies to evade or counteract these defenses.

**Symptoms and Disease**: The movement of the virus within the plant is closely related to the symptoms and disease progression observed in the infected plant. The specific movement patterns of the virus can affect the severity and distribution of symptoms.