

# **CaMV: Life cycle, symptoms and control measures**

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# *Cauliflower mosaic virus (CaMV)*

- CaMV belongs to the Caulimoviridae family of circular, ds-DNA viruses.
- It predominantly infects members of the Brassicaceae family, including radish, turnip, canola, mustard, cauliflower, broccoli, and cabbage. Some CaMV strains (D4 and W260) are also able to infect Solanaceae species, such as devil's trumpets (genus *Datura*) and tobacco plants (genus *Nicotiana*).
- CaMV is a widespread virus in temperate regions and can cause significant loss.
- CaMV incidence can easily exceed 70%, and subsequent yields may be reduced up to 20–50%.
- CaMV genetic variants have been described in different host species with different symptoms, virulence, and transmission rates, and recent studies have identified a high diversity of CaMV genomic sequences.
- The CaMV genome consists of approximately 8,000 base-pairs of circular, double-stranded DNA.
- The genome encodes seven genes (gene I to gene VII), also called P1 to P7 for encoded proteins 1-7.
- CaMV replicates by reverse transcription, and its genes are transcribed from two promoters, the 19S and 35S promoters.

# Infection cycle

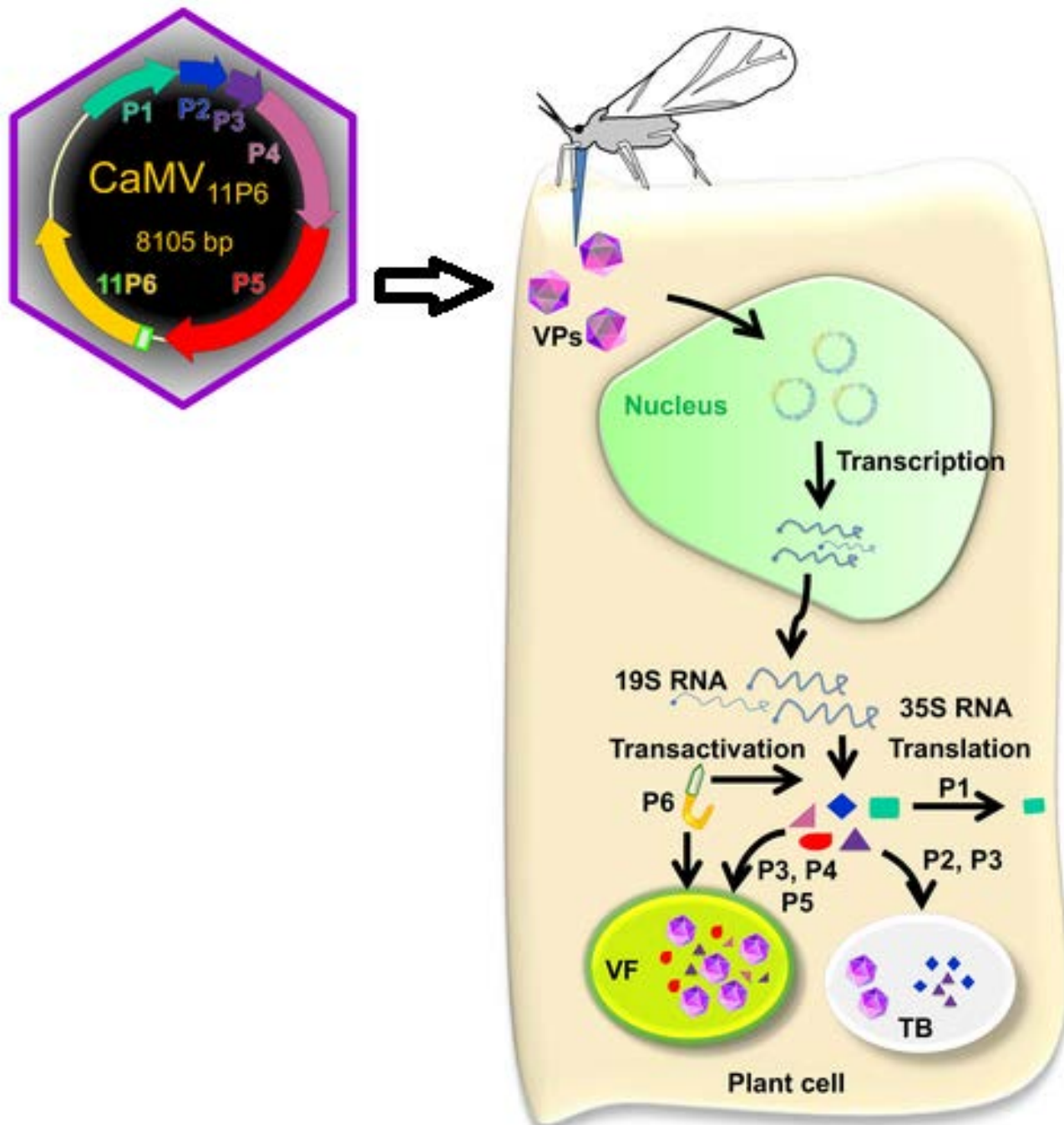
- CaMV is transmitted between host plants by more than 27 aphid species in a non-persistent and non-circulative manner, meaning that after an aphid acquires the virus from an infected plant, the virus does not circulate or replicate within the insect.
- The virus is retained for a short period (a few hours) in the aphid stylets (mouthparts), where CaMV receptor candidates have recently been identified (Protein P2 required for aphid transmission).
- The virus can then be released to initiate a new infection during aphid feeding on healthy plants. There are no known cases of CaMV transmission via seeds.
- The infection cycle starts with virus particles (VPs) being delivered into the cytoplasm of a plant cell after it has been punctured by the stylets of an aphid vector.
- VPs dock at the nuclear envelope and disassemble to allow the naked viral DNA to enter the nucleus, where viral DNA associates with host histones, forming a minichromosome .
- There, the viral genome is transcribed to produce two mRNAs, the 19S mRNA that encodes protein P6 and the 35S mRNA that encodes the other six proteins.

# ...Infection cycle

- P6 belongs to the early proteins that are translated in the cytoplasm.
- Within the cytoplasm, P6 accumulates in foci that will give rise to the virus factories [here is exemplified one (VF)] with P6 forming the matrix protein, where all viral synthesis occurs and most progeny VPs are stored.
- Viral synthesis in the VFs involves many coordinated events including the P6-mediated translation transactivation required for the translation of all viral proteins from the polycistronic 35S RNA.
- The translation products include P1 or MP, the movement protein that associates with the plasmodesmata and is required for cell-to-cell and systemic movement of the virus.
- P2 or ATF, the aphid transmission factor that binds the virus particles to the aphid vector mouthparts during plant-to-plant transmission
- P3 or VAP, the virus-associated protein,
- P4 or CP (capsid protein), and P5 or RT, the reverse transcriptase generating progeny DNA genomes from the 35S RNA.
- P7 function is unknown (appears not to be required for infection).

# ...Infection cycle

- P6 or TAV (transactivator-viroplasmin) is, besides a transactivator and VF matrix protein, an RNA silencing suppressor that interferes with specific anti-viral defense pathways.
- While the pregenomic 35S RNA is responsible for genome replication by reverse transcriptase, it also contains a non-coding 600 base pair leader sequence that serves as an important mRNA for the production of factors involved in viral counter-defense.
- A number of hosts of CaMV possess small RNA-based viral silencing mechanisms that serve to limit viral infection.
- The products of the aforementioned 600-bp sequence are viral small RNAs (vsRNA) of 21, 22, and 24 nucleotides in length that serve as decoys, binding and inactivating effectors of host silencing machinery.
- Besides VFs, a second type of viral inclusions, the transmission bodies (TBs), forms during infection.
- TBs contain P2, P3 and some VPs and are entirely dedicated to aphid transmission.



# Symptoms

- CaMV can affect plant development, especially in early infections, and the production of flowers can be blocked.
- Low seed yields have also been reported from plants with CaMV infection.
- The virus can induce a range of systemic symptoms, such as:
  - chlorosis (loss of green leaf color),
  - mosaic (patches of light and dark green on leaves),
  - vein clearing (abnormal clear or translucent color of veins), and/or
  - stunting
- CaMV survives in Brassicaceae crop and weed hosts, including wild radish, turnip weed, canola, mustard, cauliflower, broccoli and cabbage, and weed hosts are known reservoirs for the virus outside the growing season.
- It has recently been shown that water stress can influence CaMV virulence and transmission:
  - under well-watered conditions, viral load, virulence, and transmission rate increased,
  - whereas under water deficit, transmission rate, and virulence decreased.

# Management

- The best way to minimize CaMV infection is to inhibit aphid contact with seedlings, which are very susceptible to virus infection.
- Seedbeds can be isolated from aphids with a barrier of cereals or by growing the seedlings under insect-proof mesh.
- A barrier of cereals may act as a sink for the viruses and/or as a physical barrier, such that aphids will be more likely to land on the tall cereals first and lose their virus contents while probing.
- Pesticides are usually not an effective solution because aphids can transmit viruses before the pesticide has an effect.
- CaMV can also be transmitted mechanically by sap inoculation using contaminated hands and pruning tools.
- It has been shown that CaMV can stay for hours on surfaces such as doors, phones, and gloves, and can be exchanged by hand-shaking, so disinfecting tools, equipment, and anything that contacts plants will reduce infection.