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► **To cite this version:**

F. M. Zerbini, R. W. Briddon, A. Idris, D. P. Martin, E. Moriones, et al.. ICTV Virus Taxonomy Profile: Geminiviridae. *Journal of General Virology*, 2017, 98 (2), pp.131-133. <10.1099/jgv.0.000738>. <hal-01607476>

HAL Id: hal-01607476

<https://hal.science/hal-01607476v1>

Submitted on 9 Feb 2025

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ICTV Virus Taxonomy Profile: *Geminiviridae*

F. Murilo Zerbini,^{1,*} Rob W. Briddon,² Ali Idris,³ Darren P. Martin,⁴ Enrique Moriones,⁵ Jesús Navas-Castillo,⁵ Rafael Rivera-Bustamante,⁶ Philippe Roumagnac,⁷ Arvind Varsani⁸ and ICTV Report Consortium

Abstract

The geminiviruses are a family of small, non-enveloped viruses with single-stranded, circular DNA genomes of 2500–5200 bases. Geminiviruses are transmitted by various types of insect (whiteflies, leafhoppers, treehoppers and aphids). Members of the genus *Begomovirus* are transmitted by whiteflies, those in the genera *Becurtovirus*, *Curtovirus*, *Grablovirus*, *Mastrevirus* and *Turncurtovirus* are transmitted by specific leafhoppers, the single member of the genus *Topocuvirus* is transmitted by a treehopper and one member of the genus *Capulavirus* is transmitted by an aphid. Geminiviruses are plant pathogens causing economically important diseases in most tropical and subtropical regions of the world. This is a summary of the International Committee on Taxonomy of Viruses (ICTV) Report on the taxonomy of the *Geminiviridae* which is available at www.ictv.global/report/geminiviridae.

Table 1. Characteristics of the family *Geminiviridae*

Typical member:	bean golden yellow mosaic virus-[Dominican Republic:1987] (DNA-A: L01635; DNA-B: L01636), species <i>Bean golden yellow mosaic virus</i>, genus <i>Begomovirus</i>
Virion	Twinned (geminiate) incomplete icosahedra, T=1, 22×38 nm with a single coat protein
Genome	2.5–5.2 kb of single-stranded, circular DNA, mono- or bipartite
Replication	Complementary strand synthesized in the nucleus by host replication factors; double-stranded circular molecules serve as templates for both transcription and replication; replication employs a rolling-circle mechanism and also a recombination-dependent mechanism
Translation	From transcribed mRNAs
Host range	Plants (monocots and dicots)
Taxonomy	Nine genera collectively containing >360 species

VIRION

Geminiviruses have a unique particle morphology of twinned (geminiate) icosahedra. For maize streak virus (genus *Mastrevirus*), virions are 22×38 nm, consisting of two incomplete icosahedra (T=1) containing 110 coat protein subunits organized as 22 pentameric capsomers (Table 1 and Fig. 1) [1].

GENOME

Viruses in the genera *Becurtovirus*, *Capulavirus*, *Curto-*
virus, *Eragrovirus*, *Grablovirus*, *Mastrevirus*, *Topocuvirus*

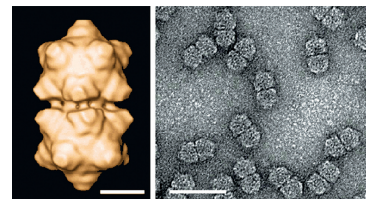


Fig. 1. (Left) Cryo-electron microscopic reconstruction of maize streak virus viewed along a two-fold axis of symmetry. Bar, 10 nm. (Right) Purified particles of maize streak virus stained with uranyl acetate showing typical twinned quasi-isometric subunits. Bar, 50 nm. (From [1]; courtesy of R. McKenna.)

Received 18 January 2017; Accepted 8 February 2017

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Keywords: *Geminiviridae*; ICTV Report; taxonomy.



Fig. 2. Genome organization of isolates in various geminivirus lineages. The ORFs (V1, V2, V3, C1, etc.) are colour-coded according to the function of their protein products (rep, replication-associated protein; ren, replication enhancer protein; trap, transcriptional activator protein; cp, capsid protein; mp, movement protein; nsp, nuclear shuttle protein). LIR, long intergenic region; SIR, short intergenic region; CR, common region. The hairpin which includes the origin of replication is indicated in the LIR (modified from [4]).

and *Turncurtovirus* have monopartite genomes, whereas those in the genus *Begomovirus* have mono- or bipartite genomes. The genome of mastreviruses (Fig. 2) consists of a circular single-stranded DNA of 2.6–2.8 kb that encodes a capsid protein (CP, ORF V1), a movement protein (MP, ORF V2) and a replication-associated protein (Rep, expressed from ORFs C1 and C2 by transcript splicing). The genomes of bipartite begomoviruses consist of DNA-A and DNA-B components, each of 2.5–2.6 kb. The two components share approximately 200 bases of sequence within the long intergenic region (LIR) that includes the replication origin. DNA-A encodes CP (AV1/V1), a putative MP (AV2/V2; New World bipartite viruses lack AV2), Rep (AC1/C1), a transcriptional activator (TrAP, AC2/C2), a replication enhancer (REn, AC3/C3) and C4 (AC4/C4). DNA-B encodes a

nuclear shuttling protein (NSP, BV1) and MP (BC1). The genomes of monopartite begomoviruses resemble the bipartite DNA-A component [2].

REPLICATION

Complementary-sense DNA synthesis to produce dsDNA depends solely on host factors. Virus ssDNA synthesis is initiated by cleavage of the virion-sense strand by Rep in a conserved 5'-TAATATTAC-3' sequence within the LIR. Geminiviruses do not encode a DNA polymerase, relying on host factors recruited during the early stages of replication. Coding regions in both strands diverge from the LIR, and transcription is bi-directional. Geminiviruses use multiple overlapping transcripts for gene expression [3].

TAXONOMY

Becurtovirus

This genus contains two species, *Beet curly top Iran virus* and *Spinach curly top Arizona virus* [4]. Members are transmitted by leafhoppers to dicot plants.

Begomovirus

This genus consists of >320 species. Begomoviruses infect dicots and are transmitted by whiteflies [5]. Most monopartite begomoviruses are associated with DNA satellites. Important pathogens include members of the species *African cassava mosaic virus*, *Bean golden mosaic virus*, *Cotton leaf curl Kokhran virus* and *Tomato yellow leaf curl virus*.

Capulavirus

This genus contains four species. Isolates of the species *Alfalfa leaf curl virus* are transmitted by an aphid [6].

Curtovirus

This genus contains three species including *Beet curly top virus*, members of which are important pathogens in North America and Iran [7]. Members infect dicots and are transmitted by leafhoppers.

Mastrevirus

Mastreviruses infect either monocots or dicots, and are transmitted by various leafhopper species [8]. Of the >30 species, members of the species *Maize streak virus* and *Wheat dwarf virus* are the best studied.

Eragrovirus

This genus has one species, *Eragrostis curvula streak virus* [9].

Grablovirus

This genus has one species, *Grapevine red blotch virus* [6].

Topocuvirus

Isolates of the single species in this genus, *Tomato pseudo-curly top virus*, are transmitted by a treehopper [10].

Turncurtovirus

Turnip curly top virus is the only species [11]. All isolates of this leafhopper-transmitted virus have been recovered from the dicot plants *Brassica rapa* or *Raphanus sativus* in Iran.

RESOURCES

Full ICTV Online (10th) Report: www.ictv.global/report/geminiviridae.

Funding information

Production of this summary, the online chapter, and associated resources was funded by a grant from the Wellcome Trust (WT108418AIA).

Acknowledgements

Members of the ICTV Report Consortium are Elliot J. Lefkowitz, Andrew J. Davison, Stuart G. Siddell, Peter Simmonds, Michael J. Adams, Donald B. Smith, Richard J. Orton and H el ene Sanfa on.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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