



ICTV Virus Taxonomy Profile: *Yadokariviridae* 2023

Yukiyo Sato^{1†}, Subha Das², Leonardo Velasco³, Massimo Turina⁴, Hideki Osaki⁵, Ioly Kotta-Loizou⁶, Robert H. A. Coutts⁶, Hideki Kondo¹, Sead Sabanadzovic⁷, Nobuhiro Suzuki^{1,*} and ICTV Report Consortium

Abstract

The family *Yadokariviridae*, with the genera *Alphayadokarivirus* and *Betayadokarivirus*, includes capsidless non-segmented positive-sense (+) RNA viruses that hijack capsids from phylogenetically distant double-stranded RNA viruses. *Yadokarivirids* likely replicate inside the hijacked heterocapsids using their own RNA-directed RNA polymerase, mimicking dsRNA viruses despite their phylogenetic placement in a (+) RNA virus lineage. *Yadokarivirids* can have negative or positive impacts on their host fungi, through interactions with the capsid donor dsRNA viruses. This is a summary of the International Committee on Taxonomy of Viruses (ICTV) report on the family *Yadokariviridae*, which is available at [ictv.global/report/yadokariviridae](https://www.ictv.global/report/yadokariviridae).

Table 1. Characteristics of members of the family *Yadokariviridae*

Example:	yado-kari virus 1 (LC006253), species <i>Alphayadokarivirus ichibani</i> , genus <i>Alphayadokarivirus</i>
Virion	<i>Trans</i> -encapsidated into non-enveloped spherical virions, 33–50 nm in diameter, encoded by phylogenetically distant dsRNA viruses
Genome	Non-segmented linear positive-sense (+) RNA of 3.6–6.3 kb
Replication	Assumed to replicate inside the heterocapsids encoded by an unrelated dsRNA virus
Translation	From a genomic RNA serving as a polyprotein-encoding monocistronic or bicistronic mRNA with or without a poly(A) tail
Host range	Fungi and possibly oomycetes
Taxonomy	Realm <i>Riboviria</i> , kingdom <i>Orthornavirae</i> , phylum <i>Pisuviricota</i> , order <i>Yadokarivirales</i> ; multiple genera including >9 species.

VIRION

Yadokarivirids (members of the family *Yadokariviridae*) encode no putative capsid protein (CP). Instead, *yadokarivirids* are *trans*-encapsidated by the CPs of phylogenetically distant dsRNA viruses (Table 1, Fig. 1) [1–4]. These spherical, non-enveloped heterocapsids encase the dsRNA replicative form and RNA-directed RNA polymerase (RdRP) of *yadokarivirids*. Capsid donor (partner) dsRNA viruses span at least five distinct families/genera within the order *Ghabrivirales*. Heterocapsids range from 33 to 50 nm, apparently identical to the virion size of their respective donor viruses.

Each member of a given *yadokarivirid* species only partners with a specific dsRNA virus [4].

GENOME

Yadokarivirids have a non-segmented linear positive-sense (+) RNA genome with or without a poly(A) tract, most having a monocistronic genome that encodes a polyprotein containing a 2A-like self-cleaving peptide. The cleavage of the polyprotein produces mature RdRP and a relatively small protein, both

Received 20 December 2022; Accepted 24 December 2022; Published 27 January 2023

Author affiliations: ¹Institute of Plant Science and Resources, Okayama University, Kurashiki 710-0046, Japan; ²Veterinary and Biomedical Sciences, South Dakota State University, Brookings, SD 57007, USA; ³Instituto Andaluz de Investigación y Formación Agraria, Centro de Málaga, Almería, 290140 Málaga, Spain; ⁴Institute for Sustainable Plant Protection-CNR, Torino 10135, Italy; ⁵Institute for Plant Protection, National Agriculture and Food Research Organization, Tsukuba 305-8666, Japan; ⁶Department of Life Sciences, Faculty of Natural Sciences, Imperial College London, London SW7 2AZ, UK; ⁷Department of Biochemistry, Molecular Biology, Entomology and Plant Pathology, Mississippi State University, Mississippi, MS 39762, USA.

*Correspondence: Nobuhiro Suzuki, nsuzuki@rib.okayama-u.ac.jp

Keywords: ICTV Report; taxonomy; *Yadokariviridae*.

Abbreviations: (+), positive-sense; CP, capsid protein; dsRNA, double-stranded RNA; RdRP, RNA-directed RNA polymerase.

†Present address: Institute for Plant Sciences, University of Cologne, Cologne 50674, Germany.

001826 © 2023 The Authors



This is an open-access article distributed under the terms of the Creative Commons Attribution License.

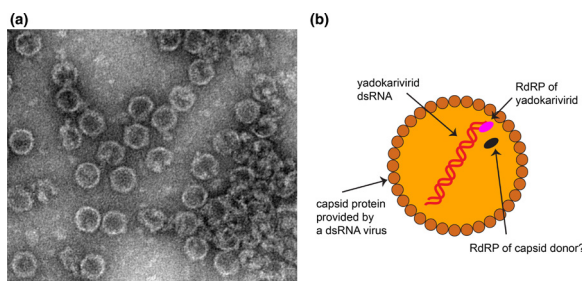


Fig. 1. Virions of a yadokarivirus *trans*-encapsidated by a dsRNA virus. (a) Transmission electron micrograph of negatively-stained virions of yado-kari virus 1 and its capsid donor (yado-nushi virus 1), prepared as previously described [1]. (b) Schematic cross-section of a yadokarivirus virion. RdRP, RNA-directed RNA polymerase. Whether the RdRP of a capsid donor is co-packaged along with yadokarivirus RNA and RdRP remains unknown.

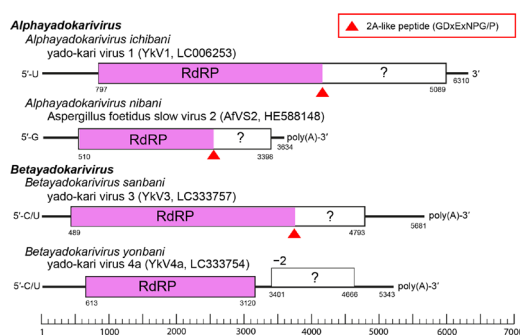


Fig. 2. Genome organization of four representative yadokariviruses.

essential for replication (Fig. 2) [1, 5]. Several betayadokariviruses appear to have a bicistronic genome and do not encode a 2A-like peptide (Fig. 2) [6]. Some betayadokariviruses also show heterogeneity at the 5'-terminal nucleotide of the genome (Fig. 2) [6].

REPLICATION

Although yadokariviruses show phylogenetic affinity to (+) RNA viruses, they are hypothesized to replicate in the capsids hijacked

from dsRNA viruses, as if they were dsRNA viruses [7]. This hypothesis is based on three lines of evidence: *trans*-encapsidation of yadokarivirus replicative form dsRNA; the absolute necessity of the capsid donor dsRNA viruses for yadokarivirus replication and infection [1]; and encapsidation of yadokarivirus-encoded RdRP that is essential for replication [5]. The RdRP requirement for replication clearly distinguishes yadokariviruses from subviral RNAs such as RNA satellites or satellite viruses and deltaviruses (family *Kolmioviridae*) that do not encode their own RdRPs [8].

PATHOGENICITY

Co-infection by the alphayadokarivirus yado-kari virus 1 and its unclassified capsid donor yado-nushi virus 1 causes a growth defect in the host phytopathogenic fungus *Rosellinia necatrix* but enhances the accumulation of the donor virus [1, 9]. In contrast, a betayadokarivirus, yado-kari virus 4a decreases the accumulation of its capsid donor dsRNA virus and rescues its host fungus *R. necatrix* from the growth defect caused by the partner dsRNA virus [4]. Another betayadokarivirus, yado-kari virus 3 has no effect on either its capsid donor or host fungus *R. necatrix* [4].

TAXONOMY

Current taxonomy: ictv.global/taxonomy. Phylogenetic analysis of RdRP amino acid sequences indicates that yadokariviruses are distantly related to members of (+) RNA virus families such as *Caliciviridae* (phylum *Pisuviricota*) [7], and so are placed in the order *Yadokarivirales*.

RESOURCES

Full ICTV Report on the family *Yadokariviridae*: ictv.global/report/yadokariviridae.

Funding information

Production of this Profile, the ICTV Report and associated resources was supported by the Microbiology Society.

Acknowledgements

Members of the ICTV Report Consortium are Stuart G. Siddell, Elliot J. Lefkowitz, Peter Simmonds, F. Murilo Zerbini, Donald B. Smith and Sead Sabanadzovic.

Conflicts of interest

The authors declare that there are no conflicts of interest.

References

- Zhang R, Hisano S, Tani A, Kondo H, Kanematsu S, et al. A capsidless ssRNA virus hosted by an unrelated dsRNA virus. *Nat Microbiol* 2016;1:15001.
- Kozlakidis Z, Herrero N, Ozkan S, Bhatti MF, Coutts RHA. A novel dsRNA element isolated from the *Aspergillus foetidus* mycovirus complex. *Arch Virol* 2013;158:2625–2628.
- Jia J, Mu F, Fu Y, Cheng J, Lin Y, et al. A capsidless virus is *trans*-encapsidated by a bisegmented botybirnavirus. *J Virol* 2022;96:e0029622.
- Sato Y, Hisano S, López-Herrera CJ, Kondo H, Suzuki N. Three-layered complex interactions among capsidless (+)ssRNA yadokariviruses, dsRNA viruses, and a fungus. *mBio* 2022;13:e0168522.
- Das S, Alam MM, Zhang R, Hisano S, Suzuki N. Proof of concept of the yadokari nature: a capsidless replicase-encoding but replication-dependent positive-sense single-stranded RNA virus hosted by an unrelated double-stranded RNA virus. *J Virol* 2021;95:e0046721.
- Arjona-Lopez JM, Telengech P, Jamal A, Hisano S, Kondo H, et al. Novel, diverse RNA viruses from Mediterranean isolates of the phytopathogenic fungus, *Rosellinia necatrix*: insights into evolutionary biology of fungal viruses. *Environ Microbiol* 2018;20:1464–1483.
- Hisano S, Zhang R, Faruk MI, Kondo H, Suzuki N. A neo-virus lifestyle exhibited by A (+)ssRNA virus hosted in an unrelated dsRNA virus: taxonomic and evolutionary considerations. *Virus Res* 2018;244:75–83.
- Das S, Suzuki N. Yado-kari virus 1 and Yado-nushi virus 1. In: Bamford DH and Zuckerman M (eds). *Encyclopedia of Virology*, 4th edn. Oxford: Academic Press; 2021. pp. 658–663.
- Yaegashi H, Nakamura H, Sawahata T, Sasaki A, Iwanami Y, et al. Appearance of mycovirus-like double-stranded RNAs in the white root rot fungus, *Rosellinia necatrix*, in an apple orchard. *FEMS Microbiol Ecol* 2013;83:49–62.