
Viruses, Viroids, Phytoplasmas

Viruses

The word virus means poison or venom. When it is used in connection with a plant disease, it means a filterable virus, an infective principle or etiological agent so small it passes through filters that will retain bacteria. Virus diseases in man range from infantile paralysis to the common cold and in plants from “breaking” of tulip flowers to the deadly raspberry ringspot disease on the Malling Jewel variety of raspberry.

Viruses are obligate parasites in that they are capable of increasing only in living cells. They are not organisms in the usual sense because they do not multiply by growth and fission, and they are too complex to be chemical molecules. F. C. Bawden, in the 1964 edition of his *Plant Viruses and Virus Diseases*, defines viruses as “submicroscopic infective entities that multiply only intracellularly and are potentially pathogenic.”

Virus diseases are old; our knowledge of them is relatively recent. Tulip mosaic, shown as breaking of flower color, was described in a book published in 1576. In 1892 it was shown that the cause of tobacco mosaic could pass through a bacteria-proof filter, and in 1935 a crystalline protein was prepared from tobacco mosaic virus juice. At present we believe that virus particles contain only two major components, nucleic acid embedded in a protein structure, and that they are built of uniform-sized subunits arranged in a fixed and regular manner. Many plant viruses contain ribonucleic acid (RNA). Some plant viruses and many animal

viruses contain deoxyribonucleic acid (DNA) instead of RNA. X-ray diffraction and electron microscopy have shown something of the morphology of virus particles. Some are rods, some filiform, and some are isometric, but polyhedral rather than spherical. They apparently act not as organisms but as disturbances in the host metabolism of nucleic acid.

There are over 850 described plant virus species. Many of the described viruses are definitive members of genera, whose names have been approved by the ICTV (International Committee on Taxonomy of Viruses) to be viruses and could be agents of other kinds. For example, aster yellows and elm phloem necrosis were thought for some time to be caused by viruses, but have now been determined to be caused by phytoplasmas. Moreover, in [Part 4](#) some phytoplasma may still be positioned under bacterial or viral caused disease since their true identity is not yet known or that the confirmation of identity has been made but missed for inclusion in the 7th edition. In addition, potato spindle tuber and chrysanthemum stunt disease were long thought to be caused by viruses, but have now been determined to be caused by viroids. Viroids consist solely of small RNAs with no protein coat. There are now about 30 plant diseases that have been identified as having viroid causal agents including potato spindle tuber, chrysanthemum stunt, citrus exocortis, chrysanthemum chlorotic mottle, and cadangcadang of palm. More diseases caused by viroids will probably be identified in future years. There are now about 68 identified phytoplasmas

and finally, some plant diseases formerly thought to be caused by viruses have now been determined to be caused by spiroplasma, such as citrus stubborn disease. Thus the field of virology has changed somewhat in recent years. In order to simplify the discussion of these viruses and virus-like agents and the diseases they cause, these agents are grouped under virus diseases, since the symptoms which they cause in plants are similar.

Some viruses attack a large number of different plants and are of great economic importance; others are confined to a single host. Virus symptoms fall into several categories, but commonly there is loss of color due to the suppression of chlorophyll development. Foliage may be mottled green and yellow, mosaic, or have yellow rings (ring spot); or there may be a rather uniform yellowing (yellows). Stunting is common. The reduction in manufactured food from the chlorophyll loss leads to smaller size, shorter internodes, smaller leaves and blossoms, and reduced yield. There may be various distortions of leaves and flowers, witches' brooms, or rosettes. There may be necrotic symptoms with death as the end result, and sometimes symptoms are "masked," not showing up under certain conditions, such as hot weather, or latent, not appearing until another virus is also present.

Viruses are transmitted from plant to plant by: insects, mites, fungi, and nematodes; rubbing, abrasion, or other mechanical means (sometimes handling tobacco and merely touching a healthy plant spreads mosaic); grafting or propagation by cuttings and bulbs; occasionally seeds; sometimes soil and water; and dodder, parasitic vines whose tendrils link one plant to another. About half of the insect vectors are aphids; a third are leafhoppers. Mealybugs and whiteflies transmit some viruses, and six, including tomato spotted wilt, are transmitted by thrips. In some cases the virus multiples within the insect as well as in the plant. Some viruses have many different vectors, 50 being recorded for onion yellow dwarf, and some have but a single known vector.

Control of virus diseases starts with obtaining healthy seed, cuttings, or plants. "Certified" means that plants have been inspected during

the growing season and found free of certain diseases. Virus-free foundation stock can be built up from heat treatment –rowing plants at high temperatures for weeks or even months – and/or meristem tip cultured plants. Virus-free stock is tested by "indexing", bioassays and/or serological assays, before using stock for propagating. Controlling insect vectors (by spraying plants or treating soil with systemic insecticides), eliminating weed hosts, roguing diseased plants before insects can transmit the virus, and using resistant varieties are all ways of combating virus diseases.

This handbook does not deal predominantly with the characteristics of the causal viral agent, but with the disease caused by the virus, viroids and phytoplasmas.

Viruses are classified now in the traditional taxonomic system (family – genus – species). Formal use of a virus species name should be printed in italics with the first word capitalized; an acronym, when used, should also be capitalized. In this book however, we used bold font for the generic name of viruses. Generally, the species name consists of the vernacular plus the generic names. For example, *Tomato spotted wilt tospovirus* is the species name, tomato spotted wilt virus is the vernacular name and *Tospovirus* the generic name. The scheme of virus and viroid classification (shown below) according to Murphy et al. (1995) and Brunt et al. (1996) include the following data: genus of virus, family (if designated), kind of nucleic acid in genome, shape of virions, presence of envelope and the type species:

Alfamovirus

Bromoviridae; (+)ssRNA; isometric particles; not enveloped; alfalfa mosaic virus.

Alphacryptovirus

Partitiviridae; dsRNA; isometric particles; not enveloped; white clover cryptic virus 1.

Badnavirus

dsDNA; bacilliform particles; not enveloped; commelina yellow mottle virus.

Betacryptovirus

Partitiviridae; dsRNA; isometric particles; not enveloped; white clover cryptic virus 2.

Bigeminivirus

Geminiviridae; ssDNA; isometric particles; not enveloped; bean golden mosaic virus.

Bromovirus

Bromoviridae; (+)ssRNA; isometric particles; not enveloped; brome mosaic virus.

Bymovirus

Potyviridae; (+)ssRNA; filamentous particles; not enveloped; barley yellow mosaic virus.

Capillovirus

(+)ssRNA; filamentous particles; not enveloped; apple stem grooving virus.

Carlavirus

(+)ssRNA; filamentous particles; not enveloped; carnation latent virus.

Carmovirus

Tombusviridae; (+)ssRNA; isometric particles; not enveloped; carnation mottle virus.

Caulimovirus

dsDNA; filamentous particles; not enveloped; cauliflower mosaic virus.

Closterovirus

(+)ssRNA; filamentous particles; not enveloped; beet yellows virus.

Comovirus

Comoviridae; (+)ssRNA; isometric particles; not enveloped; cowpea mosaic virus.

Cucumovirus

Bromoviridae; (+)ssRNA; isometric particles; not enveloped; cucumber mosaic virus.

Cytorhabdovirus

Rhabdoviridae; *Mononegavirales*; (–)ssRNA; bacilliform particles; enveloped; lettuce necrotic yellows virus.

Dianthovirus

(+)ssRNA; isometric particles; not enveloped; carnation ringspot virus.

Enamovirus

(+)ssRNA; isometric particles; not enveloped; pea enation mosaic virus.

Fabavirus

Comoviridae; (+)ssRNA; isometric particles; not enveloped; broad bean wilt virus 1.

Fijivirus

Reoviridae; dsRNA; isometric particles; not enveloped; Fiji disease virus.

Furovirus

(+)ssRNA; rod-shaped particles; not enveloped; soil borne wheat mosaic virus.

Hordeivirus

(+)ssRNA; rod-shaped particles; not enveloped; barley stripe mosaic virus.

Hybrigeminivirus

Geminiviridae; ssDNA; isometric particles; not enveloped; beet curly top virus.

Idaeovirus

(+)ssRNA; isometric particles; not enveloped; raspberry bushy dwarf virus.

Illarvirus

Bromoviridae; (+)ssRNA; isometric particles; not enveloped; tobacco streak virus.

Ipomovirus

Potyviridae; (+)ssRNA; filamentous particles; not enveloped; sweet potato mild mottle virus.

Luteovirus

(+)ssRNA; isometric particles; not enveloped; barley yellow dwarf virus.

Machlomovirus

(+)ssRNA; isometric particles; not enveloped; maize chlorotic mottle virus.

Macluravirus

(+)ssRNA; filamentous particles; not enveloped; maclura mosaic virus.

Marafivirus

(+)ssRNA; isometric particles; not enveloped; maize rayado fino virus.

Monogeminivirus

Geminiviridae; ssDNA; isometric particles; not enveloped; maize streak virus.

Nanavirus

ssDNA; small isometric particles; not enveloped; subterranean clover stunt virus.

Necrovirus

(+)ssRNA; isometric particles; not enveloped; tobacco necrosis virus.

Nepovirus

Comoviridae; (+)ssRNA; isometric particles; not enveloped; tobacco ringspot virus.

Nucleorhabdovirus

Rhabdoviridae; *Mononegavirales*; (–)ssRNA; bacilliform particles; enveloped; potato yellow dwarf virus.

Oryzavirus

Reoviridae; dsRNA; isometric particles; not enveloped; rice ragged stunt virus.

Ourmiavirus

(+)ssRNA; bacilliform particles; not enveloped; ourmia melon virus.

Phytoreovirus

Reoviridae; dsRNA; isometric particles; not enveloped; wound tumor virus.

Potexvirus

(+)ssRNA; filamentous particles; not enveloped; potato virus X.

Potyvirus

Potyviridae; (+)ssRNA; filamentous particles; not enveloped; potato virus Y.

Rymovirus

Potyviridae; (+)ssRNA; filamentous particles; not enveloped; ryegrass mosaic virus.

Satellivirus

ssRNA or DNA; the satellite viruses depended on helper viruses, but produce their own virions – small isometric; not enveloped; tobacco necrosis virus.

Sequivirus

Sequiviridae; (+)ssRNA; isometric particles; not enveloped; parsnip yellow fleck virus.

Sobemovirus

(+)ssRNA; isometric particles; not enveloped; southern bean mosaic virus.

Tenuivirus

(+/-)ssRNA; thin filamentous particles; not enveloped; rice stripe virus.

Tobamovirus

(+)ssRNA; rod-shaped particles; not enveloped; tobacco mosaic virus.

Tobravirus

(+)ssRNA; rod-shaped particles; not enveloped; tobacco rattle virus.

Tombusvirus

Tombusviridae; (+)ssRNA; isometric particles; not enveloped; tomato bushy stunt virus.

Tospovirus

Bunyaviridae; (-)ssRNA; large isometric particles; enveloped; tomato spotted wilt virus.

Trichovirus

(+)ssRNA; filamentous particles; not enveloped; apple chlorotic leaf spot virus.

Tymovirus

(+)ssRNA; isometric particles; not enveloped; turnip yellow mosaic virus.

Umbravirus

(+)ssRNA; isometric particles; enveloped; carrot mottle virus.

Varicosavirus

dsRNA; rod-shaped particles; not enveloped; lettuce big-vein virus.

Waikavirus

Sequiviridae; (+)ssRNA; isometric particles; not enveloped; rice tungro spherical virus.

Viroids

Unencapsidated, small circular ssRNAs. Viroid replication parasitizes plant host transcription. Known described viroids are: apple dimple fruit viroid, apple scar skin viroid, Australian grapevine viroid, avocado sunblotch viroid, chrysanthemum chlorotic mottle viroid, chrysanthemum stunt viroid, citrus bent leaf viroid, citrus exocortis viroid, citrus III viroid, citrus IV viroid, *Coleus blumei* 1 viroid, *Coleus blumei* 2 viroid, *Coleus blumei* 3 viroid, *Columnea* latent viroid, coconut cadang-cadang viroid, coconut tinangaja viroid, grapevine yellow speckle 1 viroid, grapevine yellow speckle 2 viroid, hop latent viroid, hop stunt viroid, Iresine viroid 1, Mexicana papita viroid, peach latent mosaic viroid, pear blister canker viroid, potato spindle tuber viroid, tomato apical stunt viroid, tomato planta macho viroid.

Phytoplasma

Classification, presented below, based on restriction fragment length polymorphism or putative restriction site analysis of 16s rRNA gene sequences according to Davis and Sinclair (1998).

Aster yellows group: tomato big bud, Michigan aster yellows, clover phyllody, Paulownia witches'-broom, blueberry stunt, apricot chlorotic leafroll, strawberry multiplier.

Peanut witches'-broom group: peanut witch'-s-broom, witches'-broom of lime – "*Candidatus* *Phytoplasma aurantifolia*", faba bean phyllody, sweet potato little leaf.

X – disease group: X – disease, clover yellow edge, pecan bunch, goldenrod yellows, Spirea stunt, milkweed yellows, walnut witches'-broom, poinsettia branch-inducing, Virginia grapevine yellows.

Coconut lethal yellows group: coconut lethal yellowing, Tanzanian coconut lethal decline.

Elm yellows group: elm yellows, cherry lethal yellows, flavescence doree. Clover proliferation group: clover proliferation, "Multicipita" phytoplasma. Ash yellows group: ash yellows.

Loofah witches'-broom group: loofah witches'-broom.

Pigeon pea witches'-broom group: pigeon pea witches'-broom.

Apple proliferation group: apple proliferation, apricot chlorotic leafroll, pear decline, *Spartium* witches'-broom, black alder witches'-broom.

Rice yellow dwarf group: rice yellow dwarf, sugarcane white leaf, leafhop-per-borne.

Stolbur group: stolbur phytoplasma, Australian grapevine yellows – "*Candidatus* *Phytoplasma australiense*".

Mexican periwinkle virescence group: Mexican periwinkle virescence. Bermudagrass white leaf group: Bermudagrass white leaf.