

Abstract

In the early period of plant virus research work, inadequate identification has led to lot of confusion due to lack of an internationally accepted classification of plant viruses. The discriminatory criteria are established by ICTV study groups, who have followed the rules laid out in the International Code of Virus Classification and Nomenclature (ICVCN). As new types of viruses continue to be discovered, new names must be created for taxa; several rules in the ICVCN govern the construction of these names.

Till now, nearly 231 virus and viroid diseases are reported to be seed transmitted in different crop plants. As per the latest ICTV classification by King et al. (Virus Taxonomy: 9th report of the international committee on taxonomy of viruses. Elsevier, San Diego, 2011), the seed-transmitted viruses were concerned to 231 virus families/plant virus groups. Among these plant virus groups, seed-transmitted viruses are distributed in 24 virus groups including Alfamovirus, Bromovirus, Capillovirus, Carlavirus, Carmovirus, Caulimovirus, Comovirus, Cryptovirus, Cucumovirus, Enamovirus, Fabavirus, Furovirus, Hordeivirus, Ilarvirus, Necrovirus, Nepovirus, Potexvirus, Potyvirus, Sobemovirus, Tobamovirus, Tobravirus, Tombusvirus, Tospovirus and Tymovirus groups. Greater number of seed-transmitted viruses are found in Poty (35), Nepo (28), Crypto (28), Ilar (14), Tobamo (7), Potex (7), Como (6), Carla (5), Carmo (5), Cucumo (5), Sobemo (5), Furo (4), Bromo (3) and Tymo (3) virus groups. On the other hand, in some groups such as Alfamo, Capillo, Caulimo, Enamo, Faba, Hordei, Necro, Tobra and Tombus groups, the seed-transmitted viruses recorded were very few. No seed transmission was noticed in Clostero, Diantho, Gemini, Luteo, Marafi, Parsnip yellow fleck, Reo, Rhabdo, Tenui and Waika groups.

2.1 Identification

In order to detect and identify a seed-transmitted virus, it is imperative to understand the characteristics of seed-transmitted viruses for comparison with the available information on previously described viruses. Diagnosis of a virus disease is never unequivocal unless the virus is isolated, studied outside its host and demonstrated by Koch's postulates. By following the 'ten commandments of the plant viruses' proposed by Bos (Bos 1976a), a reasonable diagnosis of the viral disease could be made. The diagnosis begins with particulars of the diseased plant and then deals with the virus itself, indicating a gradual shift from clinical observations to etiological diagnosis.

The pragmatic approach depends on the fact that each virus has a definite host range that is often confined to a wide or limited number of host plants. The natural hosts of the virus are first identified and a comparison is then made with previously isolated species or their close relatives, and their properties are also compared with those of the unknown virus. Based on the morphology of the virus involved, they can easily be differentiated by their shape and size. Serology and nucleic acid hybridisation tests are being widely used for the identification of different plant viruses and their strains. At present the virus identification is being done in scientific laboratories through specialised techniques. Different steps involve are seed morphology, indicator hosts, transmission, electron microscopy, serology, molecular methods, etc., which can help in detection and identification of seed-transmitted viruses. The total list of conventional viruses, cryptic viruses and viroids which are seed transmitted and reported from different parts of the world is presented in Table 1.2.

2.2 Classification of Viruses

In the early period of plant virus research work, inadequate identification has lead to lot of confusion due to lack of an internationally accepted classification of plant viruses. Looking into this

problem, Bos (1964) suggested the use of standardised vernacular names while listing out the viruses from legume crops. Subsequent schemes of nomenclature (Gibbs and Harrison (1976); Matthews (1979, 1982); Fauquet et al. (2005); King et al. (2011) and grouping Harrison et al. (1971); Francki (1981)) of viruses and the recent CMI/AAB descriptions have contributed greatly to the knowledge of plant viruses. During 1996, Brunt and his associates' compiled publication is one of the most important sources of descriptions of viruses of tropical plants. Information on the identification of virus diseases in the form of Virus Information Data Exchange (VIDE) is published by Boswell and Gibbs 1986 and Gibbs 1989. A system called 'DELTA' which is specifically designed to handle all forms of taxonomic information has been used to store the information in computers (Brunt et al. 1996).

The taxonomic approach assesses the group to which a virus belongs by determining some of its group-specific characteristics such as the shape and size of its particles. Then, more specific tests including host range are used to check whether the unknown virus is an already described member of the likely group or not. This approach requires some understanding in virus classification. Modern taxonomic classification is also taken into the consideration of molecular characterisation of viruses which has become reliable and authentic (Van Regenmortel et al. 2000; Fauquet et al. 2005; King et al. 2011). The ICTV 9th report of 2009 which was published by King et al. (2011) has 6 orders, 87 families, 19 subfamilies, 349 genera and 2,284 species.

Based on a set of characteristics, more than 975 plant viruses have been described and classified by International Committee on Taxonomy of Viruses (ICTV) into 34 well-defined groups and a few less well-defined groups or subgroups (Hamilton et al. 1981; Brown 1989; Martelli 1992; Brunt et al. 1996; Fauquet et al. 2005; Van Regenmortel et al. 2005; King et al. 2011).

In the Table 1.2, available information on seed-transmitted virus diseases of fruits, vegetable and ornamental crops, including in collateral hosts, was listed along with percentage of seed transmission. In Table 2.1 taxonomic position of seed-transmitted plant viruses is

Table 2.1 Taxonomic position of seed-transmitted viruses

| S. no | Species (virus/viroid) | Order | Family | Genus |
|-------|--|-------|-----------------------|-------------------------|
| 1 | <i>Alfalfa mosaic (Syn.) Berseem mosaic</i> | – | <i>Bromoviridae</i> | <i>Alfamovirus</i> |
| 2 | <i>Potato Yellowing</i> | – | <i>Bromoviridae</i> | <i>Alfamovirus</i> |
| 3 | <i>Alfalfa cryptic</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 4 | <i>Alfalfa temperate</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 5 | <i>Avocado viruses 1,2,3</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 6 | <i>Beet 1 alpha crypto (Syn.) Beet temperate</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 7 | <i>Beet 2 alpha crypto</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 8 | <i>Beet 3 alpha crypto</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 9 | <i>Carrot temperate 1</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 10 | <i>Carrot temperate 3</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 11 | <i>Carrot temperate 4</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 12 | <i>Fescue cryptic</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 13 | <i>Garland chrysanthemum temperate</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 14 | <i>Hop trefoil cryptic 1</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 15 | <i>Hop trefoil cryptic 3</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 16 | <i>Mibuna temperate</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 17 | <i>Radish yellow edge</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 18 | <i>Red clover cryptic</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 19 | <i>Red pepper cryptic-1</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 20 | <i>Red pepper cryptic-2</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 21 | <i>Rhubarb temperate</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 22 | <i>Rye grass cryptic</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 23 | <i>Santosai temperate</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 24 | <i>Spinach temperate crypto</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 25 | <i>Vicia cryptic</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 26 | <i>White clover cryptic 1</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 27 | <i>White clover cryptic 3</i> | – | <i>Partitiviridae</i> | <i>Alphacryptovirus</i> |
| 28 | <i>Pelargonium zonate spot</i> | – | <i>Bromoviridae</i> | <i>Anulavirus</i> |
| 29 | <i>Apple dapple viroid (Syn.) Apple scar skin viroid</i> | – | <i>Pospiviroidae</i> | <i>Apscaviroid</i> |
| 30 | <i>Grapevine yellow speckle</i> | – | <i>Pospiviroidae</i> | <i>Apscaviroid</i> |
| 31 | <i>Cucumber leaf spot carmovirus</i> | – | <i>Tombusviridae</i> | <i>Aureusvirus</i> |
| 32 | <i>Avocado sunblotch</i> | – | <i>Avsunviroidae</i> | <i>Avsunviroid</i> |
| 33 | <i>Banana streak</i> | – | <i>Caulimoviridae</i> | <i>Badnavirus</i> |
| 34 | <i>Cacao swollen shoot</i> | – | <i>Caulimoviridae</i> | <i>Badnavirus</i> |
| 35 | <i>Citrus mosaic</i> | – | <i>Caulimoviridae</i> | <i>Badnavirus</i> |
| 36 | <i>Citrus yellow mosaic</i> | – | <i>Caulimoviridae</i> | <i>Badnavirus</i> |
| 37 | <i>Kalanchoe top-spotting</i> | – | <i>Caulimoviridae</i> | <i>Badnavirus</i> |
| 38 | <i>Piper yellow mottle</i> | – | <i>Caulimoviridae</i> | <i>Badnavirus</i> |
| 39 | <i>Abutilon mosaic</i> | – | <i>Geminiviridae</i> | <i>Begomovirus</i> |
| 40 | <i>Carrot temperate 2</i> | – | <i>Partitiviridae</i> | <i>Betacryptovirus</i> |
| 41 | <i>Hop trefoil cryptic 2</i> | – | <i>Partitiviridae</i> | <i>Betacryptovirus</i> |
| 42 | <i>White clover cryptic 2</i> | – | <i>Partitiviridae</i> | <i>Betacryptovirus</i> |
| 43 | <i>Broad bean mottle</i> | – | <i>Bromoviridae</i> | <i>Bromovirus</i> |
| 44 | <i>Brome mosaic</i> | – | <i>Bromoviridae</i> | <i>Bromovirus</i> |
| 45 | <i>Cowpea chlorotic spot virus</i> | – | <i>Bromoviridae</i> | <i>Bromovirus</i> |
| 46 | <i>Oat mosaic</i> | – | <i>Potyviridae</i> | <i>Bymovirus</i> |
| 47 | <i>Citrus tatter leaf</i> | – | <i>Flexiviridae</i> | <i>Capillovirus</i> |

(continued)

Table 2.1 (continued)

| S. no | Species (virus/viroid) | Order | Family | Genus |
|-------|--|-----------------------|-------------------------|---------------------|
| 48 | <i>Carlavirus</i> | <i>Tymovirales</i> | <i>Betaflexiviridae</i> | <i>Carlavirus</i> |
| 49 | <i>Clover (red) vein mosaic</i> | <i>Tymovirales</i> | <i>Betaflexiviridae</i> | <i>Carlavirus</i> |
| 50 | <i>Cowpea mild mottle</i> | <i>Tymovirales</i> | <i>Betaflexiviridae</i> | <i>Carlavirus</i> |
| 51 | <i>Pea streak</i> | <i>Tymovirales</i> | <i>Betaflexiviridae</i> | <i>Carlavirus</i> |
| 52 | <i>Red clover vein mosaic</i> | <i>Tymovirales</i> | <i>Betaflexiviridae</i> | <i>Carlavirus</i> |
| 53 | <i>Blackgram mottle</i> | – | <i>Tombusviridae</i> | <i>Carmovirus</i> |
| 54 | <i>Cowpea mottle</i> | – | <i>Tombusviridae</i> | <i>Carmovirus</i> |
| 55 | <i>Melon necrotic spot</i> | – | <i>Tombusviridae</i> | <i>Carmovirus</i> |
| 56 | <i>Muskmelon necrotic spot</i> | – | <i>Tombusviridae</i> | <i>Carmovirus</i> |
| 57 | <i>Pea stem necrosis</i> | – | <i>Tombusviridae</i> | <i>Carmovirus</i> |
| 58 | <i>Cauliflower mosaic</i> | – | <i>Caulimoviridae</i> | <i>Caulimovirus</i> |
| 59 | <i>Dahlia mosaic</i> | – | <i>Caulimoviridae</i> | <i>Caulimovirus</i> |
| 60 | <i>Citrus leaf blotch</i> | <i>Tymovirales</i> | <i>Betaflexiviridae</i> | <i>Cittrivirus</i> |
| 61 | <i>Coconut cadang-cadang viroid</i> | – | <i>Pospiviroidae</i> | <i>Cocadviroid</i> |
| 62 | <i>Coleus blumei viroid 1</i> | – | <i>Pospiviroidae</i> | <i>Coleviroid</i> |
| 63 | <i>Coleus blumei viroid 2</i> | – | <i>Pospiviroidae</i> | <i>Coleviroid</i> |
| 64 | <i>Coleus blumei viroid 3</i> | – | <i>Pospiviroidae</i> | <i>Coleviroid</i> |
| 65 | <i>Bean pod mottle</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Comovirus</i> |
| 66 | <i>Broad bean true mosaic</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Comovirus</i> |
| 67 | <i>Broad bean stain</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Comovirus</i> |
| 68 | <i>Cowpea mosaic</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Comovirus</i> |
| 69 | <i>Cowpea severe mosaic</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Comovirus</i> |
| 70 | <i>Echtes Ackerbohnen mosaic</i> (Syn. <i>Broad bean true mosaic</i>) | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Comovirus</i> |
| 71 | <i>Muskmelon mosaic</i> (Syn.) <i>Squash mosaic</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Comovirus</i> |
| 72 | <i>Pea mild mosaic</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Comovirus</i> |
| 73 | <i>Red clover mottle comovirus</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Comovirus</i> |
| 74 | <i>Strawberry pallidosis</i> | – | <i>Closteroviridae</i> | <i>Crinivirus</i> |
| 75 | <i>Banana viruses</i> | – | <i>Bromoviridae</i> | <i>Cucumovirus</i> |
| 76 | <i>Cucumber mosaic</i> (Syn.) <i>Cowpea banding mosaic</i> (Syn.) <i>Cowpea ring spot</i> (Syn.) <i>Soybean stunt</i> | – | <i>Bromoviridae</i> | <i>Cucumovirus</i> |
| 77 | <i>Peanut stunt</i> | – | <i>Bromoviridae</i> | <i>Cucumovirus</i> |
| 78 | <i>Tomato aspermy</i> | – | <i>Bromoviridae</i> | <i>Cucumovirus</i> |
| 79 | <i>Winged bean ring spot</i> | – | <i>Bromoviridae</i> | <i>Cucumovirus</i> |
| 80 | <i>Beet curly top</i> | – | <i>Geminiviridae</i> | <i>Curtovirus</i> |
| 81 | <i>Pea enation mosaic</i> | – | <i>Luteoviridae</i> | <i>Enamovirus</i> |
| 82 | <i>Broad bean wilt</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Fabavirus</i> |
| 83 | <i>Nicotiana velutina mosaic</i> | – | <i>Virgaviridae</i> | <i>Furovirus</i> |
| 84 | <i>Peanut clump (Indian)</i> | – | <i>Virgaviridae</i> | <i>Furovirus</i> |
| 85 | <i>Wheat mosaic</i> | – | <i>Virgaviridae</i> | <i>Furovirus</i> |
| 86 | <i>Wheat soil-borne mosaic</i> | – | <i>Virgaviridae</i> | <i>Furovirus</i> |
| 87 | <i>Barley stripe mosaic</i> (Syn. <i>Barley false stripe</i>) | – | <i>Virgaviridae</i> | <i>Hordeivirus</i> |
| 88 | <i>Lychnis ring spot</i> | – | <i>Virgaviridae</i> | <i>Hordeivirus</i> |

(continued)

Table 2.1 (continued)

| S. no | Species (virus/viroid) | Order | Family | Genus |
|-------|--|-----------------------|----------------------|----------------------|
| 89 | <i>Hop stunt viroid</i> (Syn.) <i>Cucumber pale fruit viroid</i> (Syn.) <i>Grapevine viroid</i> | – | <i>Pospiviroidae</i> | <i>Hostuviroid</i> |
| 90 | <i>Raspberry bushy dwarf</i> (Syn.) <i>Loganberry degeneration</i> | – | – | <i>Idaeovirus</i> |
| 91 | <i>Apple mosaic</i> | – | <i>Bromoviridae</i> | <i>Ilarvirus</i> |
| 92 | <i>Asparagus latent</i> (Syn.) <i>Asparagus virus II</i> | – | <i>Bromoviridae</i> | <i>Ilarvirus</i> |
| 93 | <i>Black raspberry latent</i> | – | <i>Bromoviridae</i> | <i>Ilarvirus</i> |
| 94 | <i>Elm mottle</i> | – | <i>Bromoviridae</i> | <i>Ilarvirus</i> |
| 95 | <i>Fragaria Chiloensis Ilarvirus</i> | – | <i>Bromoviridae</i> | <i>Ilarvirus</i> |
| 96 | <i>Humulus Japonicas</i> | – | <i>Bromoviridae</i> | <i>Ilarvirus</i> |
| 97 | <i>Hydrangea mosaic</i> | – | <i>Bromoviridae</i> | <i>Ilarvirus</i> |
| 98 | <i>Lilac ring mottle</i> | – | <i>Bromoviridae</i> | <i>Ilarvirus</i> |
| 99 | <i>Prune dwarf</i> (Syn.) <i>Cherry ring mottle</i> (Syn.) <i>Cherry yellows</i> | – | <i>Bromoviridae</i> | <i>Ilarvirus</i> |
| 100 | <i>Prunus necrotic ring spot</i> (Syn.) <i>Peach necrotic leaf spot</i> (Syn.) <i>Peach ring spot</i> | – | <i>Bromoviridae</i> | <i>Ilarvirus</i> |
| 101 | <i>Raspberry latent</i> (Black <i>raspberry latent</i>) | – | <i>Bromoviridae</i> | <i>Ilarvirus</i> |
| 102 | <i>Spinach latent virus</i> | – | <i>Bromoviridae</i> | <i>Ilarvirus</i> |
| 103 | <i>Sunflower ring spot</i> | – | <i>Bromoviridae</i> | <i>Ilarvirus</i> |
| 104 | <i>Tobacco streak</i> (Syn.) <i>Asparagus stunt</i> (Syn.) <i>Bean red node</i> (Syn.) <i>Datura quercina</i> | – | <i>Bromoviridae</i> | <i>Ilarvirus</i> |
| 105 | <i>Maize chlorotic mottle machlomovirus</i> | – | <i>Tombusviridae</i> | <i>Machlomovirus</i> |
| 106 | <i>Olive latent virus-I</i> | – | <i>Tombusviridae</i> | <i>Necrovirus</i> |
| 107 | <i>Tobacco necrosis</i> | – | <i>Tombusviridae</i> | <i>Necrovirus</i> |
| 108 | <i>Arabis mosaic</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 109 | <i>Arracacha virus A</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 110 | <i>Arracacha virus B</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 111 | <i>Artichoke Italian Latent</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 112 | <i>Artichoke yellow ring spot</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 113 | <i>Australian Lucerne latent</i> | – | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 114 | <i>Cacao necrosis</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 115 | <i>Cherry leaf roll</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 116 | <i>Cherry rasp leaf</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 117 | <i>Chicory yellow mottle</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 118 | <i>Crimson clover latent</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 119 | <i>Cycas necrotic stunt</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 120 | <i>Eucharis mottle</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 121 | <i>Grapevine Bulgarian latent</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 122 | <i>Grapevine fanleaf</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 123 | <i>Hibiscus latent ring spot</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 124 | <i>Lucerne (Australian) symptomless</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |

(continued)

Table 2.1 (continued)

| S. no | Species (virus/viroid) | Order | Family | Genus |
|-------|---|------------------------|--------------------------|--------------------------|
| 125 | <i>Lucerne Australian latent</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 126 | <i>Mulberry ring spot</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 127 | <i>Peach rosette mosaic</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 128 | <i>Potato virus U</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 129 | <i>Raspberry ring spot</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 130 | <i>Rubus Chinese seed-borne</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 131 | <i>Satsuma dwarf</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 132 | <i>Sweet potato ring spot</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 133 | <i>Tobacco ring spot</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 134 | <i>Tomato black ring</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 135 | <i>Tomato ring spot (Syn.)</i> <i>Grapevine yellow vein</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | <i>Nepovirus</i> |
| 136 | <i>Clover (red) mosaic</i> | <i>Mononegavirales</i> | <i>Rhabdoviridae</i> | <i>Nucleorhabdovirus</i> |
| 137 | <i>Coffee ring spot</i> | <i>Mononegavirales</i> | <i>Rhabdoviridae</i> | <i>Nucleorhabdovirus</i> |
| 138 | <i>Maize mosaic</i> | <i>Mononegavirales</i> | <i>Rhabdoviridae</i> | <i>Nucleorhabdovirus</i> |
| 139 | <i>Wheat striate mosaic</i> | <i>Mononegavirales</i> | <i>Rhabdoviridae</i> | <i>Nucleorhabdovirus</i> |
| 140 | <i>Citrus psorosis</i> | — | <i>Ophioviridae</i> | <i>Ophiovirus</i> |
| 141 | <i>Peach latent</i> | — | <i>Avsunviroidae</i> | <i>Pelamoviroid</i> |
| 142 | <i>Beet mild yellowing</i> | — | <i>Luteoviridae</i> | <i>Polerovirus</i> |
| 143 | <i>Carrot red leaf</i> | — | <i>Luteoviridae</i> | <i>Polerovirus</i> |
| 144 | <i>Chrysanthemum stunt viroid</i> | — | <i>Pospiviroidae</i> | <i>Pospiviroid</i> |
| 145 | <i>Citrus exocortis viroid</i> | — | <i>Pospiviroidae</i> | <i>Pospiviroid</i> |
| 146 | <i>Pepper chat fruit viroid</i> | — | <i>Pospiviroidae</i> | <i>Pospiviroid</i> |
| 147 | <i>Potato spindle tuber</i> | — | <i>Pospiviroidae</i> | <i>Pospiviroid</i> |
| 148 | <i>Tomato apical stunt viroid</i> | — | <i>Pospiviroidae</i> | <i>Pospiviroid</i> |
| 149 | <i>Tomato chlorotic dwarf viroid</i> | — | <i>Pospiviroidae</i> | <i>Pospiviroid</i> |
| 150 | <i>Tomato planta macho viroid</i> | — | <i>Pospiviroidae</i> | <i>Pospiviroid</i> |
| 151 | <i>Clover (white) mosaic</i> | <i>Tymovirales</i> | <i>Alphaflexiviridae</i> | <i>Potexvirus</i> |
| 152 | <i>Clover yellow mosaic</i> | <i>Tymovirales</i> | <i>Alphaflexiviridae</i> | <i>Potexvirus</i> |
| 153 | <i>Foxtail mosaic potexvirus</i> | <i>Tymovirales</i> | <i>Alphaflexiviridae</i> | <i>Potexvirus</i> |
| 154 | <i>Hosta virus x</i> | <i>Tymovirales</i> | <i>Alphaflexiviridae</i> | <i>Potexvirus</i> |
| 155 | <i>Pepino mosaic</i> | <i>Tymovirales</i> | <i>Alphaflexiviridae</i> | <i>Potexvirus</i> |
| 156 | <i>Potato virus X</i> | <i>Tymovirales</i> | <i>Alphaflexiviridae</i> | <i>Potexvirus</i> |
| 157 | <i>White clover mosaic</i> | <i>Tymovirales</i> | <i>Alphaflexiviridae</i> | <i>Potexvirus</i> |
| 158 | <i>Mung bean mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 159 | <i>Artichoke latent</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 160 | <i>Asparagus virus I</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 161 | <i>Bean common mosaic (Syn.)</i> <i>Bean western mosaic (Syn.)</i> <i>Azuki bean mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 162 | <i>Bean common mosaic necrosis</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 163 | <i>Bean yellow mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 164 | <i>Blackeye cowpea mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 165 | <i>Bramble yellow mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 166 | <i>Broad bean mild mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 167 | <i>Cassia yellow spot (poty)</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 168 | <i>Celery latent</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 169 | <i>Cowpea aphid-borne mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |

(continued)

Table 2.1 (continued)

| S. no | Species (virus/viroid) | Order | Family | Genus |
|-------|--|--------------------|-------------------------|---------------------|
| 170 | <i>Cowpea green vein-banding</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 171 | <i>Cowpea moroccan aphid-borne mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 172 | <i>Desmodium mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 173 | <i>Guar symptomless</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 174 | <i>Hippeastrum mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 175 | <i>Leek yellow stripe</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 176 | <i>Lettuce mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 177 | <i>Maize dwarf mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 178 | <i>Onion yellow dwarf</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 179 | <i>Papaya ring spot</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 180 | <i>Pea mosaic</i> (Syn. <i>Bean yellow mosaic</i>) | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 181 | <i>Pea seed-borne mosaic</i> (syn. <i>pea fizzle top</i> and <i>Pea leaf rolling virus</i>) | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 182 | <i>Peanut mottle</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 183 | <i>Peanut stripe</i> (Syn. <i>Peanut mild mottle</i>) | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 184 | <i>Plum pox virus</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 185 | <i>Potato virus Y</i> (Syn.) <i>Brinjal mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 186 | <i>Soybean mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 187 | <i>Sugarcane mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 188 | <i>Sunflower mosaic potyvirus</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 189 | <i>Telfairia mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 190 | <i>Turnip mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 191 | <i>Watermelon mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 192 | <i>Zucchini yellow mosaic</i> | — | <i>Potyviridae</i> | <i>Potyvirus</i> |
| 193 | <i>Bean southern mosaic</i> (Syn. <i>Southern bean mosaic</i>) | — | — | <i>Sobemovirus</i> |
| 194 | <i>Lucerne transient streak</i> | — | — | <i>Sobemovirus</i> |
| 195 | <i>Panicum mosaic</i> | — | — | <i>Sobemovirus</i> |
| 196 | <i>Sowbane mosaic</i> | — | — | <i>Sobemovirus</i> |
| 197 | <i>Subterranean clover mottle</i> | — | — | <i>Sobemovirus</i> |
| 198 | <i>Cucumber green mottle mosaic</i> | — | <i>Virgaviridae</i> | <i>Tobamovirus</i> |
| 199 | <i>Paprika mild mottle tobamovirus</i> | — | <i>Virgaviridae</i> | <i>Tobamovirus</i> |
| 200 | <i>Pepper mild mottle</i> | — | <i>Virgaviridae</i> | <i>Tobamovirus</i> |
| 201 | <i>Pepper mild mottle tobamovirus</i> | — | <i>Virgaviridae</i> | <i>Tobamovirus</i> |
| 202 | <i>Sunn-hemp mosaic</i> (Syn.) <i>Sunn-hemp rosette</i> | — | <i>Virgaviridae</i> | <i>Tobamovirus</i> |
| 203 | <i>Tobacco mosaic</i> | — | <i>Virgaviridae</i> | <i>Tobamovirus</i> |
| 204 | <i>Tomato mosaic</i> | — | <i>Virgaviridae</i> | <i>Tobamovirus</i> |
| 205 | <i>Pea early browning</i> | — | <i>Virgaviridae</i> | <i>Tobravirus</i> |
| 206 | <i>Tobacco rattle</i> | — | <i>Virgaviridae</i> | <i>Tobravirus</i> |
| 207 | <i>Tomato bushy stunt</i> | — | <i>Tombusviridae</i> | <i>Tombusvirus</i> |
| 208 | <i>Tomato spotted wilt</i> | — | <i>Bunyaviridae</i> | <i>Tospovirus</i> |
| 209 | <i>Apple chlorotic leaf spot</i> | <i>Tymovirales</i> | <i>Betaflexiviridae</i> | <i>Trichovirus</i> |
| 210 | <i>Wheat streak mosaic</i> | — | <i>Potyviridae</i> | <i>Tritimovirus</i> |
| 211 | <i>Dulcamara mottle</i> | <i>Tymovirales</i> | <i>Tymoviridae</i> | <i>Tymovirus</i> |
| 212 | <i>Eggplant mosaic</i> (Syn. <i>Andean potato latent</i>) | <i>Tymovirales</i> | <i>Tymoviridae</i> | <i>Tymovirus</i> |

(continued)

Table 2.1 (continued)

| S. no | Species (virus/viroid) | Order | Family | Genus |
|-------|---|-----------------------|-------------------------|-------------------|
| 213 | <i>Melon rugose mosaic</i> | <i>Tymovirales</i> | <i>Tymoviridae</i> | <i>Tymovirus</i> |
| 214 | <i>Potato Andean latent</i> | <i>Tymovirales</i> | <i>Tymoviridae</i> | <i>Tymovirus</i> |
| 215 | <i>Turnip yellow mosaic</i> | <i>Tymovirales</i> | <i>Tymoviridae</i> | <i>Tymovirus</i> |
| 216 | <i>Sunflower rugose mosaic</i> | – | <i>Luteoviridae</i> | <i>Umbravirus</i> |
| 217 | <i>Cherry necrotic rusty mottle</i> | <i>Tymovirales</i> | <i>Betaflexiviridae</i> | Unassigned |
| 218 | <i>Potato virus T</i> | <i>Tymovirales</i> | <i>Betaflexiviridae</i> | Unassigned |
| 219 | <i>Strawberry latent ring spot</i> | <i>Picornavirales</i> | <i>Secoviridae</i> | Unassigned |
| 220 | <i>High plains virus</i> | – | – | Unassigned |
| 221 | <i>Urdbean leaf crinkle (Syn.)</i> <i>Black gram leaf crinkle (Syn.)</i> <i>bean urd leaf crinkle virus</i> | – | – | Unassigned |
| 222 | <i>Barley mottle mosaic</i> | – | – | Unassigned |
| 223 | <i>Brinjal ring mosaic</i> | – | – | Unassigned |
| 224 | <i>Brinjal severe mosaic</i> | – | – | Unassigned |
| 225 | <i>Carrot motley leaf</i> | – | – | Unassigned |
| 226 | <i>Cherry ring spot</i> | – | – | Unassigned |
| 227 | <i>Cineraria mosaic</i> | – | – | Unassigned |
| 228 | <i>Mung bean isometric yellow mosaic</i> | – | – | Unassigned |
| 229 | <i>Parsley latent</i> | – | – | Unassigned |
| 230 | <i>Peanut marginal chlorosis</i> | – | – | Unassigned |
| 231 | <i>Soybean mild mosaic</i> | – | – | Unassigned |

presented by taking the information from Fauquet et al. (2005) and King et al. (2011) classification tables. The seed-transmitted viruses are confined to 34 virus groups, which are in Table 2.2. To have more clarity, the information on a particle morphology and genome and vector is also provided.

Among these plant virus groups, 231 well-characterised seed-transmitted viruses are distributed in 24 virus groups including Alfamovirus, Bromovirus, Capillovirus, Carlavirus, Carmovirus, Caulimovirus, Comovirus, Cryptovirus, Cucumovirus, Enamovirus, Fabavirus, Furovirus, Hordeivirus, Ilarvirus, Necrovirus, Nepovirus, Potexvirus, Potyvirus, Sobemovirus, Tobamovirus, Tobravirus, Tombusvirus, Tospovirus and Tymovirus groups. Greater number of seed-transmitted viruses are found in Potyvirus (35), Nepovirus(28), Cryptovirus (28), Ilarvirus (14), Tobamovirus (7), Potexvirus (7), Comovirus (6), Carlavirus (5), Carmovirus (5), Cucumovirus (5), Sobemovirus (5), Furovirus (4), Bromovirus (3) and Tymovirus

(3) groups (Tables 2.1 and 2.2). On the other hand, in some groups such as Alfamovirus, Capillovirus, Caulimovirus, Enamovirus, Fabavirus, Hordeivirus, Necrovirus, Tobravirus, Tombusvirus and Tospovirus groups, the seed-transmitted viruses recorded were very few. No seed transmission was noticed in Closterovirus, Dianthovirus, Geminivirus, Luteovirus, Parsnip yellow fleck virus, Reovirus, Rhabdovirus, Tenuivirus and Waikavirus groups.

2.3 Variability in Certain Seed-Transmitted Viruses

From the above discussed aspects on plant virus taxonomy, it is clear that the viruses resembling each other in genome properties and virion morphology are grouped into genera and given genus names. The phylogenetic analysis of some of the viruses indicates that recently described viruses are established based on molecular studies as strains of the earlier described viruses. More

Table 2.2 Seed-transmitted viruses in different taxonomic groups of plant viruses and their characteristic features

| Sl. no. | Genus/group | Type member | Particle morphology | Particle size (nm) | Genome | Vector | No. of Seed-transmitted viruses |
|---------|----------------------|-------------------------------------|---------------------|-----------------------------|--------|-----------------|---------------------------------|
| 1 | <i>Alfamo virus</i> | <i>Alfalfa mosaic</i> | Bacilliform | 28–58 × 18 | ssRNA | Aphid | 2 |
| 2 | <i>Bromovirus</i> | <i>Brome mosaic</i> | Isometric | 26 | ssRNA | Beetle | 3 |
| 3 | <i>Capillovirus</i> | <i>Apple stem grooving virus</i> | Flexuous | 640 × 12 | ssRNA | – | 1 |
| 4 | <i>Carlavirus</i> | <i>Carnation latent virus</i> | Flexuous | 620–700 × 11 | ssRNA | Aphid, whitefly | 5 |
| 5 | <i>Carmovirus</i> | <i>Carnation mottle virus</i> | Isometric | 28–30 | ssRNA | Beetle | 5 |
| 6 | <i>Caulimovirus</i> | <i>Cauliflower mosaic virus</i> | Isometric | 50 | dsDNA | Aphid | 2 |
| 7 | <i>Closterovirus</i> | <i>Beet yellows virus</i> | Flexuous rods | 600–2,000 × 10 | ssRNA | Aphid | 0 |
| 8 | <i>Comovirus</i> | <i>Cowpea mosaic virus</i> | Isometric | 28 | ssRNA | Beetle | 6 |
| 9 | <i>Cryptovirus</i> | | | | | | |
| | Subgroup A | <i>White clover cryptic virus-1</i> | Isometric | 30 | ssRNA | – | 25 |
| | Subgroup B | <i>White clover cryptic virus-2</i> | Isometric | 38 | dsRNA | – | 3 |
| 10 | <i>Cucumovirus</i> | <i>Cucumber mosaic virus</i> | Isometric | 28 | dsRNA | Aphid | 5 |
| 11 | <i>Dianthovirus</i> | <i>Carnation ring spot virus</i> | Isometric | 31–34 | ssRNA | – | 0 |
| 12 | <i>Enamovirus</i> | <i>Pea enation mosaic virus</i> | Isometric | 28 | ssRNA | Aphid | 1 |
| 13 | <i>Fabavirus</i> | <i>Broad bean wilt virus</i> | Isometric | 30 | ssRNA | Beetle | 1 |
| 14 | <i>Furovirus</i> | <i>Soil-borne wheat mosaic</i> | Rigid rods | 280–330 × 20 92–160 × 20 | ssRNA | Fungus | 4 |
| 15 | <i>Geminivirus</i> | | | | | | 0 |
| | Group A mastro | <i>Maize streak virus</i> | Geminate | 18 × 30 | ssRNA | Leaf-hopper | – |
| | Group B begomo | <i>African cassava mosaic</i> | Geminate | 18 × 30 | ssRNA | Whitefly | – |
| 16 | <i>Hordeivirus</i> | <i>Barley stripe mosaic virus</i> | Rigid rods | 100–150 × 20 | ssRNA | – | 2 |
| 17 | <i>Ilarvirus</i> | <i>Tobacco streak virus</i> | Isometric | 26–35 | ssRNA | Thrips | 14 |
| 18 | <i>Luteovirus</i> | <i>Barley yellow dwarf virus</i> | Isometric | 25 | ssRNA | Aphid | 0 |
| 19 | <i>Marafivirus</i> | <i>Maize rayado fino virus</i> | Isometric | 31 | ssRNA | Leaf-hopper | 0 |
| 20 | <i>Necrovirus</i> | <i>Tobacco necrosis virus</i> | Isometric | 28 | ssRNA | Fungus | 2 |

(continued)

Table 2.2 (continued)

| Sl. no. | Genus/group | Type member | Particle morphology | Particle size (nm) | Genome | Vector | No. of Seed-transmitted viruses |
|---------|--|--|-------------------------|--------------------------------|----------------|-----------------------------|---------------------------------|
| 21 | <i>Nepovirus</i> | <i>Tobacco ring spot virus</i> | Isometric | 28 | ssRNA | Nematode | 28 |
| 22 | <i>Parsnip yellow fleck virus</i> | <i>Parsnip yellow fleck virus</i> | Isometric | 30 | ssRNA | Aphid | 0 |
| 23 | <i>Potexvirus</i> | <i>Potato virus X</i> | Flexuous rods | 470–580 × 13 | ssRNA | – | 7 |
| 24 | <i>Potyvirus</i> | <i>Potato virus Y</i> | Flexuous rods | 680–900 × 11 | ssRNA | Aphid, whitefly, mite | 35 |
| 25 | <i>Reovirus</i> (a) <i>Phytoreo</i> (b) <i>Fijivirus</i> | <i>Wound tumour virus</i> <i>Fiji disease virus</i> | Isometric Isometric | 70 71 | dsRNA dsRNA | Leaf-hopper Plant-hopper | 0 0 |
| 26 | <i>Rhabdovirus</i> | <i>Lettuce necrotic yellows virus</i> | Bacilliform | 160–380 × 50–95 14–114 × 22 | ssRNA | Aphid, Leafhopper | 0 |
| 27 | <i>Sobemovirus</i> | <i>Southern bean mosaic virus</i> | Isometric | 28–30 | ssRNA | Beetle | 5 |
| 28 | <i>Tenuivirus</i> | <i>Rice stripe virus</i> | Flexuous | >400 × 8 | ssRNA | Plant-hopper | 0 |
| 29 | <i>Tobamovirus</i> | <i>Tobacco mosaic virus</i> | Rigid rods | 300 × 18 | ssRNA | – | 7 |
| 30 | <i>Tobravirus</i> | <i>Tobacco rattle virus</i> | Short & long rigid rods | 160–215 × 22 14–114 × 22 | ssRNA | Nematode | 2 |
| 31 | <i>Tombusvirus</i> | <i>Tomato bushy stunt virus</i> | Isometric | 30 | ssRNA | – | 1 |
| 32 | <i>Tospovirus</i> | <i>Tomato spotted wilt virus</i> | Isometric | 85 | ssRNA | Thrips | 1 |
| 33 | <i>Tymovirus</i> | <i>Turnip yellow mosaic virus</i> | Isometric | 29 | ssRNA | Beetle | 3 |
| 34 | <i>Waikavirus</i> | <i>Maize chlorotic dwarf</i> | Isometric | 25 | ssRNA | Leaf-hopper | 0 |

examples one can find are in potyvirus group. Viruses like *Blackeye cowpea mosaic* and *Peanut stripe virus* are nothing but strains of the *Bean common mosaic virus* with little variation. Variability in viruses is noticed in almost all described virus groups. The molecular structure of viruses has the capacity of transferring its characters to its duplicates produced in the host cells.

- (a) *Hybridisation*: This is one of the means by which new virus strains are formed. If two strains of virus are inoculated into the same host plant, one or more new virus strains may be recovered with properties (virulence, symptomatology, etc.) different from those of either of the original strains introduced into the host. These new strains are probably hybrids (RNA or DNA recombinants). Albersio et al. (1975) reported variability in *Squash mosaic virus* (SqMV) by hybridisation between two strains of virus. They had crossed strain 1 H and II A of SqMV in pumpkin (*Cucurbita pepo*) and cantaloupe (*Cucumis melo*) plants and observed the interaction between them.
- (b) *Mutations*: The evolution of new strains of viruses may also be due to mutation. These may be a heritable change in the genetic material (RNA or DNA). The production of mutants differing in virulence has also been reported in several viruses, especially TMV, although they seem to vary mostly in the type of symptoms and severity of disease they produce rather than in their ability to infect different host plant varieties.

The previous reports when the advanced identification techniques were not available have reported very negligible (<1%) percentage of seed transmission in certain virus–host combinations, which the later research workers have disproved. Without any discrimination based on the available literature all the seed-transmitted viruses, Cryptoviruses and viroid diseases were reported in the Tables 1.2, 2.1 and 2.2.

In the earlier days, when the computer knowledge was not available, the students, research workers and others used to depend on Review of Plant Pathology, review articles

and other abstract journals for locating subject literature for use in their research work. Since 1990, lot of databases and websites are available which are quite useful for day-to-day plant virus research work, where even the poor library facilities existed and such problems were solved by certain international organisations. For example, the ‘Crop Protection Compendium’ (CPC), which was available on CD-ROM, was published by CAB International, which is being updated annually on <http://www.cabicompendium.org/cpc>. Another valuable information source for viruses is of AAB descriptions on plant viruses and can be accessed on <http://www.dpvweb.net>. Even the descriptions and lists from VIDE Database of the International Committee on Taxonomy of Viruses are available on <http://www.ncbi.nlm.nih.gov/ICTVdb/index.htm>. ‘The Plant Pathology Internet Guide Book’ (<http://www.pk.uni-bonn.de/ppigb/ppigb.htm>) is another source of information for many virology topics. Because of the availability of databases of plant viruses on internet, it has become much easier for the virus research workers to know the latest progress that is happening in any corners of the world (<http://www.virology.net>).

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