Review Article

Viruses infecting main ornamental plants: an overview [1]

MITROFANOVA, I.V.[2*]; ZAKUBANSKIY, A.V.[3]; MITROFANOVA, O.V.[2]

ABSTRACT

Ornamental plants are cultivated for decorative and utility purposes in urban landscapes throughout the world. They are much valued for their aesthetic properties and constitute an important part of the global horticulture industry. Plant viruses and viroids of various taxonomic groups have a significant negative impact on ornamentals provoking a wide range of symptoms, reducing both decorative value and quality of propagated material and causing large economic damage. A significant growth of the ornamental plants market in recent years promotes the spread of viral diseases. Therefore, systematization of data on virus and viroid phytopathogens diversity in these cultures is an urgent research task. Among the most popular ornamentals are chrysanthemum, rose, clematis, canna, and lavender. More than fifty viruses and viroids from 17 different families (including two viroid families) have been identified in these crops to date. In the presented review, we described the variety of these pathogens and their effect on the above-mentioned ornamentals.

Keywords: plant viruses and viroids, chrysanthemum, garden and essential oil rose, clematis, canna, lavender.

1. INTRODUCTION

Ornamental plants are very popular and economically important worldwide. The international market of ornamentals is constantly expanding. It includes production of cut and potted flowers, cut foliage plants, as well as propagation material. Viruses and viroids can significantly reduce both decorative value and quality of propagated material of ornamentals. Due to the wide range of ornamental plant species and cultivars and their wide geographical distribution, the diversity of viruses that infect them is also high. Vegetative propagation contributes to the uncontrolled spread of viral phytopathogens. Perennial ornamental crops can be natural reservoirs for plant viruses, promoting circulation of viruses and their transmission to other economically important crops. Investigation on the diversity of viruses and viroids associated with ornamentals is very important for their effective detection and prevention of the further spread of infections. In this review, the most important virus and viroid pathogens of chrysanthemum, garden and essential oil rose, clematis, canna and lavender have been characterized briefly.

2. CHRYSANTHEMUM

Chrysanthemum (genus *Chrysanthemum* L., family Asteraceae) is one of the most popular ornamentals worldwide. Currently, the genus includes dozens of species and myriad of cultivars. The global market of potted and garden cultivars is constantly expanding (CHO et al., 2013). Some chrysanthemum species are also used for medicinal purposes and as the source of insecticides (HITMI et al., 2000; CHANG et al., 2010; PARK et al., 2012). Viral and viroid infections cause up to 30% losses of infected plants (ZHAO et al., 2015). About twenty viruses have been identified on chrysanthemum to date. The most detrimental ones are the widespread RNA viruses such as *Tomato aspermy virus* (TAV) and *Cucumber mosaic virus* (CMV) from the genus *Cucumovirus* (family Bromoviridae), *Chrysanthemum virus B* (CVB) (genus *Carlavirus*, family Betaflexiviridae), *Tobacco mosaic virus* (TMV, genus *Tobamovirus*, family Virgaviridae) and *Potato virus Y* (PVY, genus *Potyvirus*, family Potyviridae) (VERMA et al., 2003; SONG et al., 2012; CHOI et al., 2015; ZHAO et al. 2015). Cucumoviruses cause yellow mosaic, stunting, deformation and decrease in the number of inflorescences in garden chrysanthemums (RAJ et al., 2007; KUMAR et al., 2009). Symptoms of CVB infection vary from leaf mottling or vein clearing to pronounced mosaic and inflorescences deformation, although asymptomatic infections are also observed. CVB is transmitted from plant to plant by various aphid species and characterized by high genetic diversity (OHKAWA et al., 2007; SINGH et al., 2007). Chrysanthemum plants infected with the PVY strain N-Wilga demonstrated spotting and yellowing symptoms (LIU et al., 2014). TMV causes mosaic, mottling and discoloration of petals (NASSAR et al., 2012). Other known chrysanthemum viruses belong to

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[2] Plant Developmental Biology, Biotechnology and Biosafety Department, Federal State Funded Institution of Science "Nikita Botanical Gardens – National Scientific Center of the RAS", Yalta, Russia. * Corresponding author: irimitrofanova@yandex.ru

[3] Lomonosov Moscow State University, Moscow, Russia.

families Potyviridae (*Turnip mosaic virus*, *Zucchini yellow mosaic virus*, *Chrysanthemum spot virus*, *Soybean mosaic virus* from the genus *Potyvirus*) (BERTACCINI et al., 1992; BELLARDI et al., 1993; FARZADFAR et al., 2005; MEHRA et al., 2009; NIU et al., 2015) and Bunyaviridae (*Chrysanthemum stem necrosis virus*, *Tomato spotted wilt virus* (TSWV), *Impatiens necrotic spot virus* from the genus *Tospovirus*) (MATSUURA et al., 2002; KONDO et al., 2011; DULLEMANS et al., 2015; WU et al., 2015). The poty- and bunyaviruses have a wide range of hosts and it is highly pathogenic for many economically important crops. The existence of efficient vectors can result in the formation of natural foci of these viruses and their continuous transmission from chrysanthemum plants to neighboring crops and vice versa. The other viruses detected on chrysanthemum were *Potato virus X* (genus *Potexvirus*, family Alphaflexiviridae) (CHOI et al., 2015), *Chrysanthemum vein chlorosis virus* (genus *Nucleorhabdovirus*, family Rhabdoviridae) (KITAJIMA and COSTA, 1979), *Oat blue dwarf virus* (genus *Marafivirus*, family Tymoviridae) (WESTDAL, 1968), *Chrysanthemum indicum yellow vein Delhi virus* (genus *Begomovirus*, family Geminiviridae) (MARWAL et al., 2013) and *Chrysanthemum virus R* (genus *Carlavirus*) (WANG et al., 2018).

Chrysanthemum stunt viroid (CSVd, genus *Pospiviroid*, family Pospiviroidae) and *Chrysanthemum chlorotic mottle viroid* (CChMVd, genus *Pelamoviroid*, family Avsunviroidae) are spread worldwide and considered the most devastating pathogens of chrysanthemum (DIENER and LAWSON, 1973; CHO et al., 2013). Apart from family-specific molecular differences (HASELOFF and SYMONS, 1981; NAVARRO and FLORES, 1997), they differ in symptomatology and epidemiological properties. CSVd-infected chrysanthemum plants are characterized by chlorotic spots, stunting, smaller size of flowers and leaves and lower rooting. It was reported that this viroid could be mechanical, graft and seed transmitted (CHO et al., 2013). CChMVd infection is either asymptomatic or leads to yellow-green mottling, chlorosis and stunting of infected plants. This viroid is sap- and graft-transmitted (CHO et al. 2013).

3. ROSE

Rose (genus *Rosa* L., family Rosaceae) is one the most important ornamental, industrial and essential oil crops. Viral infections can significantly weaken plants, reduce the quality of buds, yield and cuttings ability to rooting (GOLINO et al., 2007; MILLEZA et al., 2013). They reduce the yield and quality of rose oil and other products made from the petals of oil rose cultivars (YARDIMCI and ÇULAL, 2009). Ilarviruses (genus *Ilarvirus,* family Bromoviridae) and nepoviruses (genus *Nepovirus,* family Secoviridae) are probably detected in rose plants more often than others are. The most common is *Prunus necrotic ringspot virus* (MOURY et al., 2001). *Apple mosaic virus* (ApMV) was detected predominantly in Australia, New Zealand, the USA and Turkey (PEARSON et al., 2006; YARDIMCI and ÇULAL, 2009). These are the causal agents of rose mosaic that is one of the most common viral diseases of this crop. Infected plants can be asymptomatic or demonstrate the symptoms of light green or yellow mottling, ringspots, oak-leaf or net-like patterns and leaf deformation. Two other ilarviruses, *Tobacco streak virus* (TSV) and *Blackberry chlorotic ringspot virus,* were detected in rose plants in the USA (TZANETAKIS et al., 2006; GOLINO et al., 2007). Rose-associated nepoviruses, such as *Arabis mosaic virus*, *Strawberry latent ringspot virus*, *Tobacco ringspot virus*, and *Tomato ringspot virus*, have a wide geographical distribution (SALEM et al., 2008; MITROFANOVA et al., 2014). Two viruses from the genus *Tospovirus* (family Bunyaviridae), *Impatiens necrotic spot virus* and TSWV*,* were found on rose in Iran (SHAHRAEEN, 2002). *Rose leaf curl virus* (genus *Begomovirus*, family Geminiviridae), which is considered to be the causal agent of rose leaf curl disease, was identified in Pakistan in *Rosa chinensis* Jacq., (KHATRI et al., 2014). *Rose yellow vein virus* was discovered in the cultivated roses in the USA. Complete genome analysis revealed that this virus is a member of the family Caulimoviridae (MOLLOV et al., 2013a). One of the most devastating rosette diseases of *Rosa multiflora* Thunb. is apparently caused by *Rose rosette virus* from the genus *Emaravirus* (family Fimoviridae) (LANEY et al., 2011). *Rose spring dwarf-associated virus* from the genus *Luteovirus* (family Luteoviridae) was detected in the USA and Chile (SALEM et al., 2008; RIVERA and ENGEL, 2010). A number of other viruses were identified and characterized in various rose cultivars in recent years. These was *Rose cryptic virus-1* (synonyms: *Rose multiflora cryptic virus* and *Rose transient mosaic virus*) from the genus *Alphacryptovirus* (family Partitiviridae) (MARTIN and TZANETAKIS, 2008; SABANADZOVIC and GHANEM-SABANADZOVIC, 2008; LOCKHART et al., 2011); *Rose yellow mosaic virus*, that is the putative member of a new genus in the family *Potyviridae* (MOLLOV et al., 2013b); *Rosa rugosa leaf distortion virus* and *Rose yellow leaf virus*, both related to the family Tombusviridae (MOLLOV et al., 2013c; 2014a; 2015). In addition, a putative new alphapartitivirus was detected in *Rosa* spp. in Canada (PHELAN and JAMES, 2016). Rose viruses can be transmitted by mechanical inoculation, grafting, seeds, pollen and vectors that significantly complicating control of diseases (YARDIMCI and ÇULAL, 2009).

4. CLEMATIS

The genus *Clematis* (family Ranunculaceae) contains perennial climbing plants of temperate climate zones, popular as ornamental crops. About ten different viruses were reported to infect clematis plants. CMV was detected in New Zealand in *Clematis afoliata* Buchanan (DINGLEY, 1969) and *C. paniculata* J.F.Gmel. plants with leaf mottle symptoms (GUY, 2011). In the UK CMV was isolated from *Clematis x jackmanii* 'Superba' with chlorotic vein banding and 'Vyvyan Pennell' with diffuse chlorotic flecks around the veins (THOMAS, 1975). *Tobacco rattle virus* (TRV, genus *Tobravirus*, family Virgaviridae) was reported in the UK in *C. heracleifolia* DC. showing chlorotic lesions in

its foliage (BRUNT and THOMAS, 1975). Two ilarviruses, TSV and ApMV were also reported to infect clematis. TSV, associated with chlorotic spots or yellow netting of the leaves of wild *C. vitalba* L., was revealed on the territory of the former Yugoslavia (MILIČIĆ et al., 1983; RANA et al., 1987). ApMV was detected in asymptomatic *C. vitalba* plants in Turkey (ARLI SOKMEN et al., 2005; ARLI SOKMEN et al., 2008). TSWV was detected in *C. flammula* and *C. vitalba* plants in Greece being apparently transmitted by thrips from tobacco plantations infected with this virus (CHATZIVASSILIOU et al., 2001). Numerous isolates of tomato black ring nepovirus (TBRV, family Secoviridae) were identified in Lithuania in ornamental plants including clematis. Leaves of infected plants demonstrated chlorotic and necrotic ringspots, mottling and deformation (ŠNEIDERIS and STANIULIS, 2014). Clematis was also shown to be susceptible to tomato ringspot nepovirus (FULTON, 1975). *Tomato bushy stunt virus* (TBSV, genus *Tombusvirus*, family Tombusviridae) was detected in severely damaged clematis plants from the UK (KOENIG, 1985). Another member of the family Tombusviridae, *Clematis chlorotic mottle virus* (ClCMV), has been discovered by the methods of transmission electron microscopy and reverse transcription-polymerase chain reaction on clematis plants from the USA and the UK, exhibiting yellow mottling, veining, chlorotic ringspots, line pattern mosaics, flower distortion and discoloration (MOLLOV et al., 2014b). Genomic and phylogenetic analyses allowed to refer ClCMV to the genus *Pelarspovirus* (McLAUGHLIN et al., 2017). Recently, *Moroccan pepper virus* (genus *Tombusvirus*) was detected on the clematis cultivar 'Valge Daam' in Russia (ZAKUBANSKIY et al., 2018).

5. CANNA

Canna (genus *Canna* L., family Cannaceae) is a perennial ornamental plant originated from Central and South America. Most canna cultivars were obtained on the basis of interspecific hybrids of *Canna indica* L., *C. flaccida* Salisb., *C. iridiflora* Ruiz & Pav., and *C. glauca* L. (MAAS-VAN DE KAMER and MAAS, 2008). They are widely used in landscape design due to their large bright flowers and spectacular green, burgundy, purple, red or variegated leaves. Eight viruses were reported to infect canna. *Bean yellow mosaic virus* (CASTILLO et al., 1956; WYLIE et al., 2008) and *Canna yellow streak virus* (MONGER et al., 2007; MONGER et al., 2010; CHAUHAN et al., 2015; Alexandre et al., 2017) from the genus *Potyvirus* (family Potyviridae) as well as *Canna yellow mottle virus* (genus *Badnavirus*, family Caulimoviridae) (YAMASHITA et al., 1985) are the most frequent to occur. Another badnavirus, *Canna yellow mottle associated virus 1*, was also found on canna (WIJAYASEKARA et al., 2017). CMV (LOKHARDT, 1988) and TAV (HOLLINGS and STONE, 1971) are less common in this crop (RAJAKARUNA et al., 2014). Viruses infecting canna were found in the UK, Belgium, the Netherlands, France, Italy, Austria, Israel, Kenia, India, Japan, Thailand, Brazil, the USA and Russia. In addition, TSWV was detected on *C. indica* in Iran (MOINI and IZADPANAH, 2000) and sugarcane mosaic potyvirus was recently reported from canna in China (TANG et al., 2016). Symptoms of viral diseases appeared as vein necrosis, yellow mosaic, streak, mottling and discoloration of leaves are significantly impaired the decorative values of these plants. Canna is predominantly propagated by rhizome dividing, which, in combination with a wide international market of planting stock, promotes the rapid spread of viral diseases. The cost of individual canna specimen reaches 30 €, so the potential economic damage from viral infections can be very high (MONGER et al., 2007). Symptoms may significantly vary depending on the cultivar and may be masked in varieties with dark-colored leaves. Mixed infections with two or three viruses of different taxonomic groups are common in canna (RAJAKARUNA et al., 2014; CHAUHAN et al. 2015; KUMARI et al., 2016; ZAKUBANSKIY et al., 2017).

6. LAVENDER

Lavender (genus *Lavandula* L., family Lamiaceae) is one of the most important essential oil crops, cultivated mainly in the Mediterranean region, the Crimea, northern and eastern Africa, several regions of Asia, Australia and the USA. The lavender oil is widely used in aromatherapy, pharmacology, perfumery and cosmetology. In addition, lavender is a popular ornamental crop, cultured for decoration of gardens and landscapes all over the world (STANKOVIĆ et al., 2014). The most common disease of lavender and its hybrid form lavandin (*Lavandula hybrida* Rev.) is the yellow mosaic caused by *Alfalfa mosaic virus* (AMV, genus *Alfamovirus*, family Bromoviridae). The virus was detected in France, Italy and Croatia in *L. hybrida* (MARCHOUX and ROUGIER, 1974; GIUNCHEDI and de FERRER, 1977; VRANDEČIĆ et al., 2013), *L. stoechas* L. (PARRELLA et al., 2010), and *L. officinalis* Chaixex Vill. in Spain (MARTINEZ-PRIEGO et al., 2004). Infected plants are characterized by yellow spots on leaves and stems, yellow mottling, light yellow mosaic, leafroll, and stunting. Viral infection does not presumably affect the amount, size or color of flowers, but reduces the quality of lavender oil due to the change in the concentration of one of its main components (BRUNI et al. 2006). TMV was reported on lavender and lavandin in Russia (MITROFANOVA et al., 2017). In Poland, CMV was detected in *L. angustifolia* Mill. plants with symptoms of yellow mottling and leaf distortion (KOBYŁKO et al., 2008). Lavender is a perennial plant and thus, it can serve as a reservoir of AMV and CMV, which are known to have an extremely wide host range and are capable of infecting many economically important crops.

7. CONCLUSION

Many viruses from various taxonomic groups are described in rose, lavender, clematis, canna and chrysanthemum to date. They can affect growth and development of infected plants, their yield, decorative qualities and the secondary metabolites production utilized by people. Mixed infections by different viruses usually increase the detrimental effect of each of them. Viruses are transmitted from plant to plant by vegetative propagation; most of them have insect vectors, and some viruses are pollen- and seed-transmitted. Many viruses are characterized by extremely wide host range. Infecting plants from different families, they are able to spread rapidly to neighboring plantings of various crops by vectors that seriously complicates control over their distribution and can lead to the formation of stable natural foci of viral infection. Understanding the genetic diversity, geographical distribution and biological properties of ornamental crop viruses can contribute to the development of effective methods for their molecular and serological diagnostics in order to prevent their further spread.

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AUTHORS CONTRIBUTIONS

Analyzed data: **IVM** and **AVZ**. Checked and correct the manuscript: **OVM** and **IVM**. Wrote the paper: **AVZ** and **IVM**.

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