Apricot latent virus – Review

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Abstract

Grimová L., Ryšánek P., 2012. ***Apricot latent virus* – Review**. Hort. Sci. (Prague), *39*: 144–148.

Apricot latent virus (ApLV) is a definitive species of the *Foveavirus* genus, the Betaflexiviridae family. Although the virus is not highly prevalent, it was identified in several European and Mediterranean countries thus far. Biological experiments demonstrated that, in addition to the only known natural host, *Prunus armeniaca*, ApLV can be experimentally graft-transmitted to several *Prunus* species. Therefore, the eradication of the viral pathogen largely depends on the use of virus-free propagating materials and rootstocks, which should be seriously considered when designing and implementing stone fruit certification schemes. Although ApLV is not present on the list of viruses and other pathogens that require testing in the EPPO certification schemes for the production of healthy stone fruit trees for planting, Peach asteroid spot disease (PAS) causing agent whose occurrence was often justly correlated with ApLV, is included on the list. This review summarises the current available knowledge of ApLV on the biological, morphological, physicochemical and molecular levels and includes the contemporary management approaches.

Keywords: ApLV; *Foveavirus*; Betaflexiviridae; stone fruit

Apricot latent virus (ApLV) is a definitive species in the *Foveavirus* genus (Betaflexiviridae family, *Tymovirales* order) (Martelli, Jelkmann 1998; Adams et al. 2004; Martelli et al. 2007), together with a type member *Apple stem-pitting virus* (ASPV) (Jelkmann 1994), *Grapevine rupestris stem pitting-associated virus* (GRSPaV) (Zhang et al. 1998) and *Peach chlorotic mottle virus* (PCMoV) (James et al. 2007).

ApLV was first described in Moldavia in 1993 on apricot cv. Silistra N4, the cultivar that was introduced from Bulgaria. That cultivar, known for its resistance to many pathogens, was tested for virus infection by chip grafting on peach seedlings in a greenhouse test during the summer of 1989. Chlorotic lesions and then green spots appeared on the leaves in the spring of 1990. Later, the repeated transmission of the pathogen always produced identical symptoms, and it was established that the pathogen incubation period is 6 months (Zemtchik, Verderevskaya 1993). By utilising these biological indexing methods, it was revealed that the pathogen is significantly different from all of the other stone fruit viruses whose incubation period does not exceed 1–1.5 months (Marenaud 1966).

Geographical distribution

Although it is not highly prevalent, ApLV was identified in a number of countries to date, including Moldavia (Zemtchik, Verderevskaya 1993), France and Italy (Gentit et al. 2001a), Turkey (Gümüs et al. 2004), Iran (Sanchez-Navarro et al. 2005), Palestine (Abou Ghanem-Sabanadzovic et al. 2005), Egypt (El Maghraby et al. 2006), Lebanon (Jarrar et al. 2007), Spain (García-Ibarra et al. 2010), and the Czech Republic (Grimová 2011).

Biological properties

As with all currently known members of the genus *Foveavirus* (Adams et al. 2004), ApLV is transmitted by grafting and persists in the propagative materials of the host; no viral vector is known. The pathogen is characterised by the narrow host range, and it naturally infects only apricot trees (*P. armeniaca*), with no apparent symptoms, except of Tirynthos (Jarrar et al. 2006; Grimová et al. 2010) and Haward (Jarrar et al. 2006) cultivars; in these cultivars, it induces symptoms of chlorotic blotching (Fig. 1) and/or a malformation of the new leaves and shoots. Graft inoculation experiments demonstrated that, in addition to apricot, the ApLV host range includes several other *Prunus* species. As the most susceptible species, *P. persica* was found to develop yellow asteroid or sooty ring spots on the leaves (Fig. 1), which later became encircled by reddish rings that turn dark; no symptoms were observed on the bark, wood or fruits (Zemtchik, Verderevskaya 1993; Nemchinov, Hadidi 1998; Zemtchik et al. 1998; Grasseau et al. 1999; Nemchinov et al. 2000; Gentit et al. 2001 a, b; Abou Ghanem-Sabanadzovic et al. 2005, Grimová et al. 2010). Among other susceptible species are *P. cerasifera*, with occasional chlorotic-green spots (Nemchinov, Hadidi 1998), symptomless *P. serrulata* Shirofungen (Abou Ghanem-Sabanadzovic et al. 2005), *P. avium*, with either no apparent symptoms (Gentit et al. 2001b; Grimová et al. 2010) or with red to purple rings and mottling of the leaves (Abou Ghanem-Sabanadzovic et al. 2005) and asymptomatic *P. salicina* and *P. domestica* (Grimová et al. 2010).

ApLV has an extremely restricted herbaceous host range, including only *Nicotiana occidentalis* Wheeler (accession 37B) and *N. occidentalis* ssp. *obligua*, in which it induces mild vein yellowing, scattered necrotic areas on the leaf blade and the complete reduced plant vigour (Zemtchik et al. 1998; Abou Ghanem-Sabanadzovic et al. 2005). However, for inexplicable reasons, the sap transmission of the virus to herbaceous indicator species is not always successful (Grimová 2011).

Morphological, physicochemical and molecular properties

Filamentous particles of ApLV in the cytoplasm of parenchyma cells were revealed by a negative staining technique using symptomatic *P. persica* and *N. occidentalis* leaves (Zemtchik, Verderevskaya 1993). The cytopathological observations of symptomatic tobacco leaves showed that the particles were scattered in the cytoplasm or occasionally aggregated in bundles; the cytopathological changes were minor, and no inclusion bodies were observed in thin-sectioned cells (Abou Ghanem-Sabanadzovic et al. 2005). These results agree with the pattern that is generally reported for the genus, *Foveavirus* (Martelli, Jelkmann 1998).

The ApLV genome consists of a monopartite positive-sense ssRNA with a 3'poly(A) tail (Adams et al. 2004). It was reported that the dsRNA extracts from the symptomatic leaves of *N. occidentalis* and *P. persica* GF 305 had multiple electrophoretic bands, with the largest molecule corresponding to

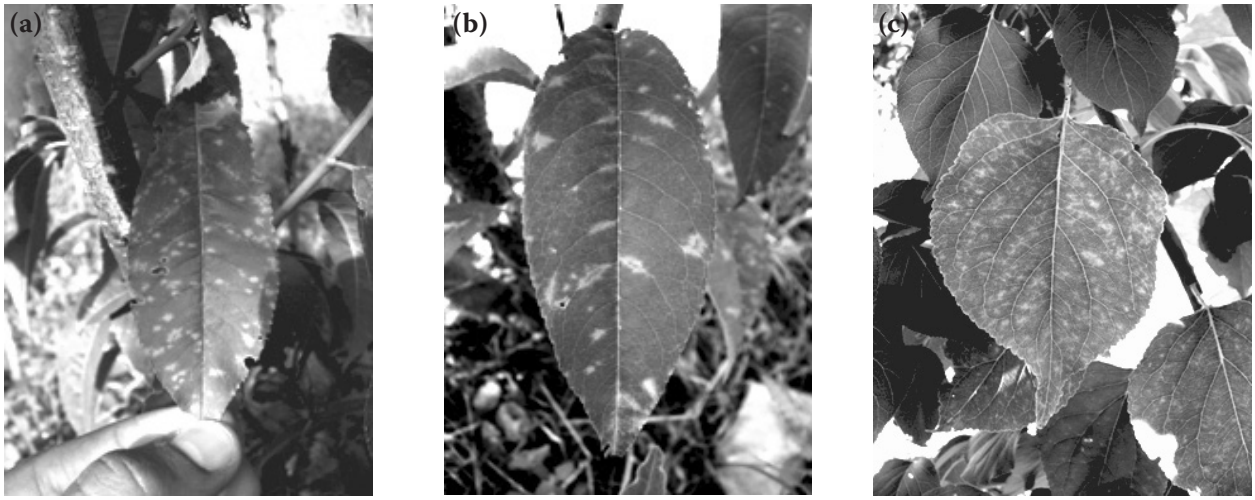

Fig. 1. Symptoms caused by ApLV on chip budding-infected leaves of some hosts: (a), (b) peach cv. Anderson, (c) apricot cv. Tirynthos

an estimated size of approximately 9 kbp (Gentit et al. 2001a, b; Abou Ghanem-Sabanadzovic et al. 2005; Grimová 2011), which is in accordance with the size range reported for the other members of this viral genus (Adams et al. 2004). To date, two French and two Italian fully sequenced ApLV isolates were molecularly described, with accession numbers HQ339956-HQ339959 (Youssef et al. 2011). All of these isolates have similar sizes (between 9,295 and 9,311 nucleotides) and show a typical *Foveavirus* genomic organisation, with five open reading frames (ORFs) from the 5' to 3' ends and corresponding to the replication-associated protein (ORF1), the movement-associated triple gene block (TGB, ORFs 2-4) and a capsid protein (CP, ORF5). The predicted molecular weights for the proteins encoded by various viral ORFs are as follows: ORF1 (Pol) 247.2 to 247.8 kDa; ORF2 (TGBp1) 25.2–25.3 kDa; ORF3 (TGBp2) 12.7–2.8 kDa; ORF4 (TGBp3) 7.4–7.6 kDa and ORF5 (CP) 43.0–44.8 kDa. The analyses of the complete genomic sequences indicate that, similar to the situation with many Betaflexiviridae, ApLV shows an overall high level of variability (Youssef et al. 2011).

ApLV is closely related to ASPV in many molecular aspects (Nemchinov, Hadidi 1998; Nemchinov et al. 2000; Grimová 2011; Youssef et al. 2011). In fact, some of the pair-wise comparisons in the polymerase gene show identity levels that falls within the species cut-off value. Despite the ambiguous taxonomic information, it seems reasonable to conclude that ApLV and ASPV represent distinct but closely related sister species, with ASPV being specialised to infect members of the Maloideae subfamily and ApLV infecting members of the Prunoideae (Youssef et al. 2011).

Virus detection

Biological indexing. ApLV can be detected by grafting, budding or chip-budding infected plant material onto peach GF 305 seedlings. The symptoms appear within a few months under greenhouse conditions or within one year in the open field (Nemchinov, Hadidi 1998; Nemchinov et al. 2000; Gentit et al. 2001a; Abou Ghanem-Sabanadzovic et al. 2005; Grimová et al. 2010). The virus can also be experimentally transmitted to herbaceous hosts, including *N. occidentalis* Wheeler (accession 37B) and *N. occidentalis* ssp. *obligua*, with apparent symptoms developing 10–15 days after inoculation (Zemtchik et al. 1998; Gentit et al. 2001a; Abou Ghanem-Sabanadzovic et al. 2005).

Serological and nucleic acid based assays. ApLV accumulates in very low amounts in *Prunus* and its herbaceous hosts and thus does not allow the preparation of purified particles that are suitable for antibody production and the development of serological methods (Zemtchik et al. 1998; Jarrar 2006). Cross-reactions were obtained when extracts of ApLV-infected *N. occidentalis* were tested with antiserum to ASPV using DAS-ELISA, immunosorbent electron microscopy, and western blot assays (Nemchinov, Hadidi 1998; Zemtchik et al. 1998) and with the polyclonal antiserum to *Plum pox virus* (PPV) within western blot analyses (Nemchinov, Hadidi 1998). Consequently, the presence of uniformly distributed common epitopes on the virions of ApLV, ASPV and PPV was suggested (James et al. 1996; Nemchinov, Hadidi 1998).

Many different nucleic acid-based techniques for the accurate diagnosis of ApLV were developed, including double-stranded RNA analysis (Nemchinov, Hadidi 1998; Gentit et al. 2001a, b; Abou Ghanem-Sabanadzovic et al. 2005; Grimová 2011), molecular hybridisation with different ApLV-specific digoxigenin riboprobes (Nemchinov et al. 2000; Gentit et al. 2001a; Abou Ghanem-Sabanadzovic et al. 2005, Grimová 2011) and different RT-PCR analyses (Nemchinov, Hadidi 1998; Nemchinov et al. 2000; García-Ibarra et al. 2010; Grimová 2011).

Management approaches and concluding remarks

Experiments have shown that ApLV can infect a wide range of *Prunus* species, but only some cultivars show symptoms. Thus, infected but symptomless stone fruit cultivars could constitute a major virus reservoir for the spread of ApLV throughout fruit-growing regions (Grimová et al. 2010). ApLV is a graft-transmitted virus, and therefore, the eradication of the pathogen largely depends on the use of virus-free propagating materials and rootstocks (Martelli, Jelkmann 1998). Such precautions should be seriously considered when designing and implementing stone fruit certification schemes to reduce or eliminate the potential contamination of the stocks with this virus (Grimová et al. 2010).

A certification system was recently established in several countries to deal with the viral diseases of fruit trees. Specifically, the certification scheme of the European and Mediterranean Plant Protection Organization (EPPO) for the production of healthy stone fruit trees for planting has compiled a list of the viruses and other pathogens of the varieties and rootstocks that occur in the EPPO region and that require testing, including Peach asteroid spot agent (PAS). A PAS disease of unknown aetiology was first reported in California (Cochran, Smith 1938) and was reported in other states of the western USA (Williams et al. 1976). Evidence correlating the presence of ApLV and the PAS agent was observed many times: all of the ApLV isolates induced yellow asteroid or sooty ring spots on the leaves during the experimental transmission of the pathogen to peach trees, symptoms that were identical to those caused by PAS disease (Zemtchik et al. 1998; Gentit et al. 2001b; Abou Ghanem-Sabanadzovic et al. 2005). If this hypothesis is confirmed, ApLV would be included in the EPPO list, and its presence in plant material would be strictly controlled during nursery production. However, until purified virus preparations from infected tobacco and/or an infectious transcript of ApLV are produced and used to infect peach trees, the aetiology of PAS will remain speculative (Myrta et al. 2008).

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Received for publication December 5, 2011
Accepted after corrections January 11, 2012

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