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Mini Review

Apple Mosaic Disease: Potential Threat to Apple Productivity

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Abstract

Apple (*Malus × domestica* Borkh.) is commercially most important remunerative crop, grown in temperate regions throughout the world. Viruses and virus like organisms associated with apple has reduced the yield to a considerable extent. Among viral problems, apple mosaic disease caused by *Apple mosaic virus* (ApMV) decreased fruit yield to a greater extent. The ApMV can be detected by various methods ranging from traditional (biological assays) to advanced next generation sequencing methods. The virus is graft transmissible; hence for production of quality virus free planting material, robust and fast virus indexing is very important for ascertaining the scion material as virus free. Here, we review the importance of mosaic disease, its causal agent, transmission, detection and management.

Keywords: *Apple Mosaic Disease; Apple Productivity*

Introduction

Temperate fruits belong to the family *Rosaceae*, which includes pome (apple, pear and quince) and stone fruits (cherry, apricot, peach and plum). Cultivation of temperate fruits is the main source of economy of the temperate regions throughout the world as well as in India. Among these fruits, apple (*Malus × domestica* Borkh.) is an important commercial and remunerative crop [1]. Various factors are responsible for its less productivity, among them diseases caused by a number of pathogens are the most important factors, which has reduced yield levels, both quantitatively and qualitatively [2]. Among the diseases, viral problems need more attention, because virus infection is systemic in nature which passes to the successive generations through the propagating material and cannot be controlled by chemical means, thus causes a severe decline in health of trees. Apple trees are infected by more than 12 viruses and virus like diseases, leads to significant economic losses [3]. Among various viruses infecting apple crop, most of the viruses are latent in nature, which does not produce any symptom [4].

Apple mosaic disease

Apple mosaic disease is an economically important disease, which is prevalent throughout the world, where apple is being cultivated and poses a severe threat to the apple industry. The disease was first reported from Europe during 1930 [5]. The net photosynthetic rate of infected leaves can reduce from 2.93% - 45.83% [6] and decrease fruit yield by as much as 30% - 50% [7]. Trees with symptomatic leaves throughout the tree lack vigor and growth [8].

Causal agent

The apple mosaic disease is reported to be caused by *Apple mosaic virus* (ApMV) in plants with mosaic symptoms [5] which belongs to the family *Bromoviridae*, subgroup 3 in the genus Ilarvirus *Ilarvirus* [9,10]. The genome is tripartite having single stranded positive-sense RNA (RNA1, RNA2 and RNA3) and an encapsidated subgenomic RNA4. The RNA1 and RNA2 each encode single replication-associated proteins; RNA3 encodes a movement protein (MP) and coat protein (CP), whereas RNA4 is a subgenomic RNA that functions as mRNA for CP [9]. The ApMV is a labile virus, so its concentration can be negatively affected by high temperatures [11]. Recent studies have shown that ApMV is not the only viral pathogen causing apple mosaic disease, but the disease is also associated with *Prunus necrotic ring spot virus* (PNRSV), *Cucumber mosaic virus* (CMV) and *Apple necrotic mosaic virus* (ApNMV) [12].

Symptomatology

The symptoms differ in expression on different host plants with different virus strains. Leaves of apple trees infected with mosaic disease develop bright pale-yellow, bright cream colored irregular chlorotic spots, which expand during spring (Figure 1). Chlorosis can develop along leaf veins, creating a reticulated appearance or, in other cases, can manifest as large, amorphous chlorotic areas between leaf veins [10]. Lesions may change to necrotic spots in the affected leaves after exposure to summer sun heat (Dursunoglu and Ertunc, 2008) and leaves may drop prematurely. The distribution of symptomatic leaves may be erratic throughout individual trees or limited to a single limb. The number and severity of symptomatic leaves directly correlate with temperature, with more severe symptoms in years with moderate spring temperatures [6].

Figure 1: *Symptoms of mosaic along with necrosis on apple leaves.*

Detection and diagnosis

Symptomatology alone is not reliable for definite virus identification, as symptoms can be mistaken for nutritional deficiencies, toxicities or damage caused by other pests. Therefore, further diagnostic methods are needed for ApMV detection, including biological assays using indicator plants, serological methods (ELISA) and molecular detection (RT-PCR). More recently, the deep sequencing assay has provided a powerful alternative for the detection and identification of total viral pathogen load associated with the particular infected plant (Virome) without a prior knowledge (Li., *et al.* 2012). Deep sequencing analysis has confirmed that symptoms of mosaic are not associated with *Apple mosaic virus* (ApMV) and led to the discovery of a novel Ilarvirus, named *Apple necrotic mosaic virus* (ApNMV) [13].

Transmission

The ApMV is generally graft-transmissible as it persists in vegetative propagation material (scion) from infected trees, which constitutes the main source of inoculum for the virus. The virus can be experimentally sap-transmitted by mechanical inoculation, although not easy, to several herbaceous plants, such as *Cucumis sativus*, *Vigna sinensis*, *V. unguiculata*, *Petunia hybrida*, *Chenopodium quinoa*, *C. amaranticolor*, *Cucurbita maxima*, *C. pepo*, *Nicotiana benthamiana*, *N. megalosiphon* and *Phaseolus vulgaris* cv. Pinto and [14]. The efficiency of mechanical transmission differs in individual hosts (Both at species and cultivars levels) and/or depending on inoculation technique [15]. Transmission of ApMV has also been demonstrated by pruning with virus contaminated scalpel blades [16]. Although ApMV has a wide host range, no natural vectors of ApMV are known. Confirmation of transmission by seed and pollen is problematic, as these studies are demanding in terms of time and space requirements. However, Cameron and Thompson (1986) demonstrated seed transmission of ApMV in hazelnut trees and suggested that the occasional occurrence of mosaic symptoms on apple seedlings may also be due to this route of transmission. However, the possibility of pollen transmission remained undetermined [17].

Management

As the virus is transmitted mostly by grafting, hence preventive measures to avoid planting of infected material are of the greatest importance. To control apple mosaic disease testing of planting material is an important, although not exclusive, method for controlling viral diseases [18]. The various techniques for production of virus free planting material include thermotherapy, tissue culture, etc. Thermotherapy is an efficient technique to eliminate viruses from infected plants and the combination with shoot-tip grafting can increase the efficiency of virus elimination. Thermotherapy performed on the infected apple trees did not show any symptoms in the following year, although symptoms can be present on trees that were the sources of the buds [12,19] described that complete ApMV inhibition was observed with hot water treatment of wood scions at 47°C for 30 minutes and 50°C for 15 minutes. Pandey., *et al*. [20] also reported that exposure to 50°C for 8 to 12 minutes was completely effective in deactivating ApMV. Following dry heat treatments, a decrease in the survival percentage was observed concomitant with the increase in temperature and duration of exposure.

Tissue culture has partly replaced heat treatment to eliminate viruses. Meristem tip cultures have been frequently used to obtain virus free plants, because the virus titer has been observed to be low or absent in meristematic regions in a large number of plant species [11,19] compared *in vitro* micro grafting to thermotherapy to evaluate which method was more effective for ApMV elimination from stone fruits and found that ApMV was more easily eliminated by micrografting. During experiments with meristematic cultures, it was demonstrated that a correlation existed between the elimination of virus and explants size. The recovery was successful only with small axillary buds (0.5 mm) where it reached 87%, but with large buds (2 to 3 mm) only 25% of plants was virus-free. Complete elimination of ApMV was achieved using apical meristems [22-25].

Conclusion

Mosaic disease of apple is an important viral disease-causing severe yield loss in apple growing regions of the in India as well as the world. The presence of the virus can cause severe damage and the wide host range of ApMV constitutes an inconspicuous virus reservoir for virus spread through plant populations. The mosaic disease is detected by various means as early indexing is important for the production of virus free quality planting material.

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