Plant Archives
Journal home page: www.plantarchives.org
DOI Url: https://doi.org/10.51470/PLANTARCHIVES.2021.v21.no1.048

ASSOCIATION OF PHYTOPLASMA AND BEGOMOVIRUS WITH SOME ORNAMENTAL PLANTS: A REVIEW

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(Date of Receiving-12-10-2020; Date of Acceptance-08-01-2021)

ABSTRACT

In recent years, the development of the floriculture sector has received rising attention, particularly for the benefit of small-scale agricultural enterprises producing domestic seedlings of perennial ornamental plants and for export to neighbouring countries. Plant diseases, including those associated with phytoplasma infections and plant viruses, are affected by this industry, as are other sectors of the agricultural economy.In a number of commercial cut flowers and ornamental plants, phytoplasma and plant virus infection causes diseases, causing major economic losses globally.Therefore, phytoplasma and plant virus diseases are the key constraints in the production of lucrative ornamental plants and lower their quantum and quality, gaining international importance due to unspecific symptoms, different losses and complex epidemiology around the world. These disease epidemics forced the removal of several varieties of floricultural plants such as *gladiolus,* lily, *chrysanthemum* and rose from cultivation. In various ornamental plants in botanical gardens and various floriculture farms, symptoms of general yellowing as well as plant stunting, shoot proliferation, phyllody, virescence, lower cost of flowers and reddening of leaves were observed. The prevalent mode of distribution of plant viruses is vector transmission, vegetative propagation or seed, although in some cases, viruses are transmitted by mechanical contact. Begomoviruses in economically important ornamental plants, especially in the tropical and subtropical regions, are among the most dangerous epidemic-causing pathogens, but phytoplasmas of ornamental plants have been widely distributed geographically. Information on phytoplasma and begomovirus infecting ornamental plants has been addressed in this study.

Keywords: Phytoplasma, Begomoviruses, Ornamental Plants, Transmission and Symptomatology

Introduction

The floricultural sector is rapidly advancing in India, with 2.49 lakh ha of land and 1,659 million tonnes of loose flowers and 484 million tonnes of cut flowers. In 2018-19, India exported a total of Rs. 460.75 crores to dry flowers, cut flowers, foliage and branches, trees, seeds or planting material, and other flower products (22,947.23 million tons). The Indian flower-dominated demand also grew from roughly Rs 12 crores in the 1990s to Rs.1000 crores in 2015.Though traditional open-field flowers grow at the heart of Indian floriculture, the production of cut flowers under polyhouses, the production of potted plants, plug plants, landscaping plants, grasses, etc., is growing day by day. Significant manifestations of viruses, viroids and fastidious prokaryotes are experienced in all floriculture segments, are major concern because they are readily vectorized by insects and is toughto control once developed. Although awareness of virus infection among farmers has increased in the last decade, understanding of vascular insect-inhabiting vectored fastidious prokaryotes such as phytoplasma is minimal (Chaturvedi *et al.,* 2010). Because of the mistaken conviction that plants are new varieties, the plants are spread several times because of insufficient knowledge among farmers and stakeholders. Failure to understand the contaminated mother plants and indiscriminate distribution strengthens the rapid transmission of phytoplasmal and geminiviral diseases.

Phytoplasmas are non-helical mollicutes related to various plant diseases (Bertaccini, 2007 and Harrison *et al.,* 2008). Crop malformation, growth inhibits, yellowing and/or decrease, referred to collectively as a yellow disease, define these conditions. Until walllesspleomorphicbody was recognised by a community in Japan (Doi *et al.,* 1967), Phytoplasmas viruses range in size from 200 to 800 nm and can only live and multiply in plant phloems or hemolymphs of insects. Begomovirus (*Bemisiatabaci* genus, Geminiviridae family) is a class of transmitted plant viruses into a large array of cultivated and uncultivated plants with white flies *Bemisiatabacai* (Aleyrodidae). It has a single beach of circular DNA in twin icosahedral virus particles (Rojas *et al.,* 2005). There have been significant economic losses of geminivirus infection in ornamental plants in India and other countries. Begomovirus is a complex plant family that infects a variety of plants, such as ornamental products, weeds and crops, causing significant losses in global agriculture and horticulture (Mansoor *et al.,* 2003) (Lima *et al.,* 2013). The white flies transmit over 80 percent of known gemini viruses and belong to the Begomovirus family. DNA-A and DNA-B are known to infect dichotyledenic plants via the bipartite genome of these viruses. Ornamental plants are prolific and extremely climate-friendly worldwide. Therefore both phytoplasmas and gemini viruses cause significant losses for growers by infecting ornamental plants, which are a major source of income for small farmers in particular. Mixed infections

Table-1: Diseases of Phytoplasma found on Ornamental Plants.

Plants	Comments
Allamanda cathartica, (golden trumpet and yellow allamanda) Family: Apocynaceae	Khasa *et al.,* (2016) observed signs of leaf yellowing in A. cathartica and the established association of the phytoplasma group 'clover proliferation' (16SrVI) with New Delhi disease.
Catharanthus roseus (Madagascar periwinkle) Family: Apocynaceae	Previously, 16SrRNA gene sequence comparison and an RFLP analysis for PCR amplified rDNA from various restriction enzymes in different geographic areas of India examined and confirmed 16SrI-B phytoplasma strains on periwinkle (Ayman *et al.,* 2010 and Khanna *et al.,* 2015).
Codiaeum variegatum Family: Euphorbiaceae	For decades, it has been known for its beautiful colours and leathery leaves in tropical gardens. Symptoms of leaf yellow and witches' brooms were found on C. Grown in Lucknow (Uttar Pradesh, India) and Sitamadhii, Variegatum plants (Bihar, India). The 'Ca. Association P. asteris 'I-B and -D subgroups of *C. Variegatum* was reported from India (Tiwari *et al.,* 2014).
Hibiscus rosa-sinensis L (China rose) Family: Malvaceae	"It is widely cultivated in the tropics and subtropics as an ornamental plant. Chaturvedi *et al.,* (2010) and Khasa *et al.,* (2016) reported little Hibiscus rosa-sinensis leaf, phyllody, and yellowing disease caused by the phytoplasma subgroup 16SrI and 16SrVI-D from India, respectively."
Mirabilis jalapa L. (marvel of Peru or four o'clock flower)	The Mirabilis plant is the most widely cultivated ornamental species and is available in a variety of colours. A native of tropical South America, the four-o'clock flower has been naturalised in many parts of the world as an ornamental garden plant. M. was reported by Kumar *et al.,* (2012). Jalapa as hosts of a phytoplasma group 16SrII (peanut witches' broom) showing symptoms of leaf crowding in the apical zone, internodes' shortening, small flowers and leaves accompanied by stunting of Indian plants.
Rosa x hybrid Family: Rosaceae	"The rose is a general ornamental plant in the world and is the most important commercially grown shade. It is easy for species from various parts of the world to hybridise and many garden rose cultivars have been born. Chaturvedi *et al.,* (2009) have reported in India phytoplasma in the community of aster yellows associated with phyllody symptoms (16SrI). Madhupriya *et al.,* (2017) reported frequent occurrence in IARI, New Delhi and verified association of two phytoplasma classes of suspected symptoms of smaller leaf phytoplasma, yeldening, internode shortening, phyllodevirescence and blooming buds. Aster yellow (16Sr I) and peanut witches brooms (16SrII) with 13 rose genotypes."
Tagetes erecta L (Merigold) Family: Asteraceae	Symptoms of small leaves and witch's broom disease have been observed in T. In the years 2007 and 2008, erecta plants were grown in the Lucknow garden and in cultivated fields around Gorakhpur. The 'Ca. association was reported by Singh *et al.,* (2011). The marigold community of P. asteris (16SrI) displays signs of small leaf and witch's broom.

also often display both phytoplasmas and geminiviruses (Rihne *et al.,* 2020).

With 2.49 lakh ha of floriculture land and the production of 1659 million tonnes of loose flowers and 484 million tonnes of cut flowers, the floriculture sector is making rapid progress in India. India exported dry flowers, cut flowers, foliage and branches, plants, seeds or planting material and other flower items in 2014-15 (APEDA) to a tune of Rs. 460.75 crores (22,947.23 million tons). The Indian market dominated by loose flowers has also risen from approximately Rs 12 crores in the 1990s to Rs.1000 crores in 2015. Though traditional open-field flowers grow at the heart of Indian floriculture, the production of cut flowers under polyhouses, the production of potted plants, plug plants, landscaping plants, grasses, etc., is growing day by day. All floriculture segments experience significant manifestations of viruses, viroids and fastidious prokaryotes, which are of major concern as they are readily vectored by insects and once developed, very difficult

Table-2: Ornamental plants affected by Begomoviruses:

Plants	Comments
Catharanthus roseus (Madagascar periwinkle)	Khasa *et al.,* (2016) observed signs of leaf yellowing in A. cathartica and the established association of the phytoplasma group 'clover proliferation' (16SrVI) with New Delhi disease.
Family: Apocynaceae	"Peripheral plants are showing typical symptoms of irregular yellow mosaic symptoms with significant curling and distortment were collected at the University of Punjab, Lahore, Pakistan. A 2.8 kb band was obtained by isolating, rolling circle amplification (RCA) genomic DNA, restricted with different enzymes and the XhoI enzyme. There are collected and sequenced two clones (KN4 and KN6) (Ilyas *et al.,* 2013). BLAST review showed that the KN4 clone sequence has an undisclosed identity of less than 89 percent, Chilli leaf curl India (ChiLCIV-[IN:08] FM87958) and a 95 and 99 percent identity of newly registered papaya leaf crumple (PaLCrV) HM140369 clone KN6 sequence. KN4 is an isolate of the recently described Begomo virus species known as the yellow mosaic virus of Catharanthus (CYMV) (Ilyas *et al.,* 2013). No DNA-B and beta satellites were identified. Series analysis shows, the KN4 and KN6 recombinants are Pedilanthus leaf curl virus (PedLCV) and Croton yellow vein mosaic virus (CrYVMV) (Martin *et al.,* 2010). Therefore, recombination plays a significant role in the emergence of new virulent strains."
Vinca alba	For decades, it has been known for its beautiful colours and leathery leaves in tropical gardens. Symptoms of leaf yellow and witches' brooms were found on C. Grown in Lucknow (Uttar Pradesh, India) and Sitamadhii, Variegatum plants (Bihar, India). The 'Ca. Association P. asteris 'I-B and -D subgroups of *C. Variegatum* was reported from India (Tiwari *et al.,* 2014).
Family: Apocynaceae	Positive PCR results confirmed the begomovirus infection. Dot blot hybridization was performed for additional confirmation of Begomovirus infectivity. Infected samples hybridised with the probe in this technique; this was negative in the case of plants devoid of symptoms of begomovirus. The intense indication from Dot blot confirms that the virus is similar to the papaya leaf curl virus in *Vinca alba* (Marwal *et al.,* 2014a).
Melia azedarach (chinaberry tree, Cape lilac)	The Mirabilis plant is the most widely cultivated ornamental species and is available in a variety of colours. A native of tropical South America, the four-o'clock flower has been naturalised in many parts of the world as an ornamental garden plant. M. was reported by Kumar *et al.,* (2012). Jalapa as hosts of a phytoplasma group 16SrII (peanut witches' broom) showing symptoms of leaf crowding in the apical zone, internodes' shortening, small flowers and leaves accompanied by stunting of Indian plants.
Family: Meliaceae	In M, leaf curling and crinkled leaves, diseases typical of begomovirus, were observed during the survey of begomovirus infections. Trees of Azedarach (Marwal *et al.,* 2014b).
Rosa chinensis	Symptoms of small leaves and witch's broom disease have been observed in T. In the years 2007 and 2008, erecta plants were grown in the Lucknow garden and in cultivated fields around Gorakhpur. The 'Ca. association was reported by Singh *et al.,* (2011). The marigold community of P. asteris (16SrI) displays signs of small leaf and witch's broom.
Family: Rosaceae	In 2006, *Rosa chinensis* showed symptoms in Pakistan of leaf curling, slow growth, and upward or downward curling. Interaction between DNA-A and beta-satellite molecules was developed (Khatri *et al.,* 2014). Sequence analysis has shown that the DNA-A fragment is shared between less than 89percent of the nucleotide and other begomoviruses and showed 96percent identity with the Digeraarvensis yellow beta satellite in the Rose Leaf curl and beta virus (DiAYVB).
Tagetes erecta L (Marigold) Family: Asteraceae	In 2012, diseased plants were shown to be stunted with apical leaf curls and crooked leaves in Sikar province, India. The first study was conducted in 2013 in combination with beta satellite and alpha satellite molecules on the full nuclear sequence of Ageratum enation virus isolate (KC589699) (Marwal *et al.,* 2014). These molécules were known as DNA-β (Ageratum leaf curl betasatellite) and DNA-alpha (Marigold leaf curl alphasatellite). No DNA-B molecule was found. Furthermore, virus clone constructs in model plant N were prepared and tested to prove Koch's premises and to assess infectivity. Benthamian for disease growth. As the Virus is likely to bear the vector (DNA-A, DNA-β, and DNA-alpha), it poses an important threat to other economic and ornamental crops.

to control. While in the last decade, awareness of virus infection has increased among farmers, knowledge of vascular insect-inhabiting vectored fastidious prokaryotes such as phytoplasma is minimal (Chaturvedi *et al.,* 2010). Due to insufficient knowledge among growers and stakeholders, the affected plants are further propagated several times with the erroneous belief that the plants are novel variants. The lack of awareness and indiscriminate propagation of infected mother plants augment faster spread of phytoplasma and geminiviruses diseases.

Phytoplasmas are non-helical mollicutes associated with various plant species diseases (Bertaccini, 2007 and Harrison *et al.,* 2008). These disorders are characterised by flower malformation, growth aberrations, yellowing and/or decrease, collectively referred to as yellows disease. Until a group in Japan (Doi *et al.,* 1967) recognised wallless pleomorphic bo, they were thought to be caused by viruses Phytoplasmas range in size from 200 to 800 nm and can only survive and multiply in plant phloems or insect hemolymphs. Whereas Begomoviruses (Genus Begomovirus, Family Geminiviridae) are a group of plant viruses transmitted to a wide range of cultivated and uncultivated plant species by whitefly Bemisiatabaci (Aleyrodidae). They have a circular single-stranded DNA genome encapsulated in particles of twinned icosahedral viruses (Rojas *et al.,* 2005). Major economic losses have been observed in ornamental plants in India and other countries due to geminivirus infection. Begomovirus is an outsized complex family of plant viruses (Mansoor *et al.,* 2003) that infects a large range of plants such as ornamentals, weeds and crops and causes a major loss to worldwide agriculture and horticulture (Lima *et al.,* 2013). Of the known geminiviruses, more than 80% are transmitted by whiteflies and belong to the Begomovirus family. The bipartite genome of these viruses is designated as DNA-A and DNA-B and infects dichotyledenous plants. Ornamental plants are widely spread worldwide and are highly adaptable to the climate. Therefore both phytoplasmas and geminiviruses cause significant losses for growers by infecting ornamental plants, which are a major source of income for small farmers in particular. Mixed infections also often display both phytoplasmas and geminiviruses (Rihne *et al.,* 2020). Thus the interaction of phytoplasma and begomovirus with ornamental plants for their proper management is very important to consider. Plants Desired by the Ornamental Plant Industry and Plant Enthusiasts Plants Desired by the Ornamental Plant Industry and Plant Enthusiasts Plants Desired by the Ornamental Plant Industry and Plant Enthusiasts

Phytoplasma diseases on Ornamentals Plants

Phytoplasma is associated with ornamental diseases and has a wide geographic distribution. There are various reports available from various parts of India, too. Virescence (Green leaf development like flowers instead), proliferation of axillary buds resulting in broom behaviour of witches, generalised stunting, yellows and small leaves, leaf chlorosis, flat stem, decolouration of flowers, decreased corm and weak root system and irregular proliferation of flower buds are the various symptoms caused by phytoplasmas in ornamental plants (Chaturvedi *et al.,* 2010; Madhupriya, 2016 and Rao *et al.,* 2017). In commercial floriculture and ornamental plants, phytoplasma diseases result in significant economic losses (Chaturvedi *et al.,* 2010; Shukla, 2015 and Madhupriya, 2016) and are the main development and quality constraints in the cultivation of ornamental plants. Different molecular tools are currently being developed to detect phytoplasmas such as PCR assays, real-time PCR, cloning and sequencing to help characterise phytoplasma from more than 26 Indian ornamental plant species (Chaturvedi *et al.,* 2010; Shukla, 2015 and Tiwari *et al.,* 2014). The definition of diseases of phytoplasma found on ornamental plants is given in table-1

Begomoviruses on Ornamentals Plants

Viruses, many of which are begomoviruses that give your hosts bright yellow foliar symptoms, are also preferred to improve ornamental plant aesthetics. Begomoviruses are a group of viruses that are spread by whiteflies that grow rapidly (Bedford *et al.,* 1994).The expansion of the spatial spread of *B. tabaci*. Together with the advent and propagation of new biotypes, *tabaci*, the vector of the begomovirus, increases the risk that these viruses will spread to new areas and thus infect new ornamental plant species.There are many alerts that in many of the world's major ornamental plant crops, viruses belonging to this group are causing losses.In general, recombination plays a major role in the development and genetic variation of begomoviruses. It has been shown that mixed infections lead to new species of begomovirus in nature (Bedford *et al.,* 1994 and Moriones *et al.,* 2011). In several cases, molecular studies of sequences of some newly identified begomo viruses have shown that they are the result of recombination (Navas-Castillo *et al.,* 2011). Dicotyledonous plants are ideal for the growth and reproduction of begomoviruses, which are typically distributed primarily in tropical and sub-tropical regions by white flies (*Bemisia tabaci*).

CONCLUSION

The floricultural sector has received a growing focus in recent years, particularly to the benefit of small-scale farmers who produce domestic seedlings of perennial ornamental plants and export them to neighbouring countries. Plant diseases including phytoplasmas and begomovirus infections affect this area, as do other agriculture sectors. Phytoplasma affects many commercial flowers and ornamental plants, which cause considerable financial losses. The key constraints in production and decrease in the quantity and quality of viable ornamental plants are therefore phytoplasma disorders, with increasing international significance due to unspecific symptoms, many losses and complex epidemiology all

over the world. Likewise, begomo viruses are considered the largest virus in the world destroying between 50% and 90% of ornamental crops and the need for more and more molecular instruments to minimise current losses. Knowledge of the spectrum of phytoplasmas and begomo viruses has been increased in recent studies and by the availability of molecular methods for pathogen detection. The detection of new phytoplasmas as well as begomovirus hosts has increased the diversity of the disease potential reservoir and can be far higher than previously reported.

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