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An Overview Analysis Of Viruses Infecting Main Ornamental Plants

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Abstract

Around the world, there are many ornamental plants found in urban landscapes for both decorative and practical purposes. In the global horticulture industry, they are valued for their aesthetic properties and they are important because they play a prominent role in the field. Viruses, both infectious and non-infectious, cause severe diseases to ornamentals, both ornamental and non-ornamental species of different taxonomical types, and cause both a reduction in decorative value and a reduction in the quality of propagated material, and cause considerable economic loss. In recent years, the ornamental plant market has seen significant growth which has facilitated the spread of diseases. In light of this, it is urgent that data on viruses and viroid phytopathogen diversity in these cultures are organized and systematized to facilitate future research. Chrysanthemums, roses, clematis, cannas, and lavender are among the most popular ornamental plants. Until now, there have been over fifty viruses and viroids discovered in these crops (and from four different families including two viroid families). We examined the variety of pathogens that are associated with the above-mentioned ornamental plants and then described their effect on the ornamentals involved.

Keywords: Chrysanthemum, clematis, canna, rosemary, chrysanthemum virus, chrysanthemum viroids

Introduction

It is a well-known fact that bacteria, fungi, and viruses are commonly found in humans, animals, and plants. Some of these microorganisms, however, are beneficial. The organisms responsible for the production of drugs such as penicillin are bacteria found in the digestive tracts of people and animals, yeast from which bread, beer, wine, and cheese are produced, and fungus responsible for producing pharmaceuticals, such as penicillin. It has been recognized that the presence of various microorganisms in plants can benefit the plants as well as indirectly benefit humans, and as an example of this not only in plants but also in humans [1].

There are certain microbes that are an advantage to plants. Despite the fact that many plant diseases are caused by fungi, there are several fungi that have the capability of establishing a symbiotic relationship with their hosts, which is mutually beneficial both to the individual and the organism. As a consequence of mycorrhizae, a variety of soil inhabitants [2], such as Trichoderma spp., may be involved in nutrient absorption. Mycorrhizae are known to protect plants from disease-causing fungi. The growth of many plant species is facilitated by endosymbiotic fungi that are found associated with the plants. A bacterium called Rhizobium leguminosarum, a microorganism which is beneficial to plants due to its nitrogen-fixing abilities, is another important microorganism. The Free-branching habit of poinsettias has been attributed to phytoplasmas, according to a report published recently. The free-branching habit of poinsettias helps growers of this plant make a profit every year. In addition, there have been discoveries of beneficial viruses for plants.

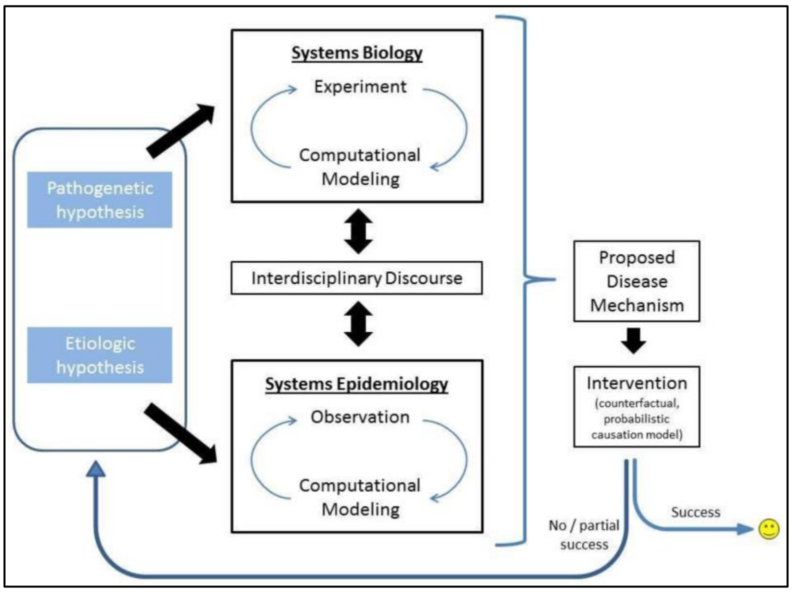

Figure 1: In epidemiology the conceptual view [21]

Plants that are grown as ornamental plants have a lot of popularity as well as economic importance around the world. As a result, the ornamental market is continually growing internationally. The products that are made in this process are cut and potted flowers, cut foliage plants, as well as propagation materials. It is a fact that viruses and viroids are responsible for greatly reducing both the decorative value of ornamental plants and their quality. Infecting ornamental plants can take many forms [2]. Many different viruses are found among them. Additionally, ornamental plants are distributed widely geographically in this region.

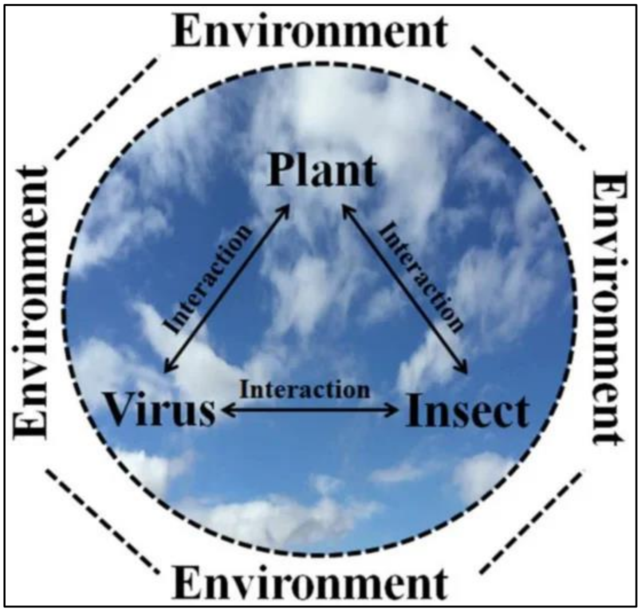

Figure 2: Vector-borne disease triangle concept [21]

Chrysanthemum

As one of the most popular ornamental plants in world history, Chrysanthemums are one of the most well-known genera and families of plants. A number of species are currently known to exist in this genus, as well as a variety of cultivars. Potted and garden cultivars are becoming increasingly popular in many parts of the world [3]. The chrysanthemum plant is also used as a source of insecticides and for medicinal purposes in some parts of the world. Viruses and viroids can cause the loss of up to 30% of plants when they are infected. In current times, there have been approximately twenty viruses discovered in chrysanthemums. A variety of RNA viruses have been detected in plants. These include tobacco mosaic virus (TMV, genus Tobamo virus, family Virgaviridae) and potato virus Y (PVY, genus Potyvirus, family Potyviridae). Chrysanthemums are susceptible to cucumber viruses that can lead to yellow mosaics, stunting, deformities, and a decrease in the number of inflorescences. Although asymptomatic CVB infections can also occur, mottled leaves, vein clearing, and distorted inflorescence can be a part of the symptoms of CVB infections [3][4].

There are several species of aphids that carry CVB from one plant to another and this aphid species is characterized by a high degree of genetic diversity. The symptoms of spotting and yellowing have been observed in chrysanthemum plants infected with the PVY strain N-Wilga. These symptoms are related to TMV, which creates mottled, mosaic-like patterns on the petals. The Potyviridae (Turnip mosaic virus, Tomato spotted wilt virus, Impatiens necrotic spot virus) and Bunyaviridae (Chrysanthemum stem necrosis virus, Tomato spotted wilt virus, Soybean mosaic virus) families also cause Chrysanthemum viruses as well [4-7].

Among the many economically important crops that can be infected with the poty and bunyavirus, many are highly pathogenic. In the presence of effective vectors, virus foci can form on chrysanthemum plants and spread from the plants to the neighboring crops and vice versa [5]. Therefore, the viruses of this family are Potexvirus (genus Potexvirus, family Alphaflexiviridae), Chrysanthemum vein chlorosis virus (genus Nucleorhabdovirus, family Rhabdoviridae), Merafivirus (genus Merafi, family Tymoviridae), Yellow Vein Delhi Virus (genus Begomovirus, family Geminiviridae) and Chrysanthemum virus R (genus Carlavirus) were found [5].

Viruses of plants consist of small structural units of RNA or DNA, which are commonly covered by thick coats of proteins. Viruses are mainly transmitted through vectors, vegetative propagation, or seed, although in some cases they may also be transmitted by mechanical contact, or through mechanical contact with environment. The primary reason for studying plant viruses is that they cause disease and economic losses to crops; it is for this reason that they have been studied [3][6].

Over the past few years, many viruses have been reported to affect plants without causing any disease. It is possible to contract these diseases through infections with dsRNA viruses belonging to the families Partitiviridae and Endornaviridae. While these viruses have the ability to replicate in plants, they have no visible effect on their phenotypes [4].

However, this has been particularly common in dry environments, especially ones where viruses can virulently harm plants [5][7]. Some viruses are capable of causing positive changes in their hosts, and in some cases ornamental horticulturists have used infected plants to enhance their aesthetic properties or even use them as part of a nursery breeding program. Most of the time, this will mean an increase in the commercial value of the property [6].

Plants Desired by Plant Enthusiasts and Ornamental Plant Industries

Horticulturists and a large number of ornamental plant enthusiasts are highly attracted to plants that have an unusual foliage or flower arrangement. Flowers with a flower breaking appearance have petals that are not uniformly colored, but have a variegated appearance because pigments are distributed in an irregular pattern creating an uneven coloration. In addition to vein discoloration, leaves can also show varying degrees of whiteness and yellowness. The most common cause of foliar or flower variegations and vein discolourations is mutations occurring at critical developmental stages of plastids or transposable genetic elements which result in abnormal pigment production [2][7]. The symptoms caused by plant viruses can be very close to those associated with genetic variegation problems and vein discoloration. It is not an easy task to distinguish between mutations that are caused by the genetic code and those that are caused by viruses, and it is often assumed that genetic mutations are the cause of forms of variability [6].

Taking this into consideration, it is obvious that a virus infection can actually be seen as beneficial from a commercial point of view. It was during the seventeenth century Dutch growers who became the first to exploit the aesthetic properties of the plant viruses, by producing and marketing highly valued variegated tulips (Tulipa spp. ; Liliaceae) which were highly prized and highly sought after. The flower variegation, as we know now, is caused by the potyvirus Tulip breaking virus and other potyviruses [8-11]. A lot of plant viruses have been reported as being associated with unique phenotypes of ornamental plants in the past few years and some of these plants are being marketed as new cultivars. We discuss in this article some viruses that increase the natural beauty and commercial value of ornamental plants, as well as some of the possible disadvantages in using them and the potential repercussions that may result [10].

Virus Infected Ornamental Plants

It is thought that the striking yellowing of the plant results from both the begomoviral genome and satellite DNA of Ageratum conyzoides (Asteraceae), which grows in much of Asia. To our knowledge, ornamental ageratum has not been reported to be infected with the virus, and deliberately introducing it would be unwise [3]. AnFBV is a carmovirus that was first discovered in Angelonia spp. There has also been separate reports of Angelonia flower mottle virus (Scrophulariaceae) in the US [1], as well as from Germany [5]. There is sometimes foliar mottle present, but most frequently, there are spots of increased coloration in the flowers, which may appear blistered (raised or sunken in relation to the surrounding tissue. Phlox, nemesia, and verbena are also known hosts. The virus is used by breeders and growers to eradicate angelonia flower break, which some may find attractive. However, the occurrence of the yellow stripes characteristic of the cultivars listed above has not yet been conclusively proven to be the result of the Ca YMV virus. It seems that although previous reports have noted that other badnaviruses have the ability to integrate with their hosts' genomes, there is evidence that Ca YMV may also be able to do the same within the canna genome. This was confirmed by deep sequencing, that showed partial badnavirus sequences within the canna genome [15][16]. Two other potyviruses, as well, have been observed in canna, namely BYMV [13] and Canna yellow streak virus (CaYSV).

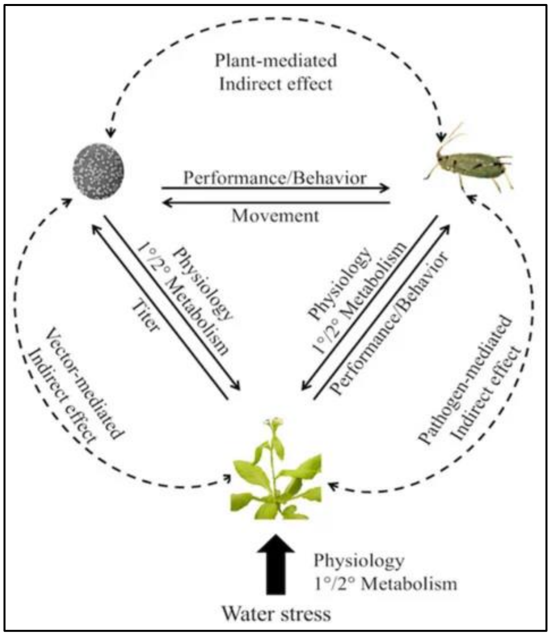

Figure 3: Direct/indirect effects between viruses and vectors arising due to the stressed plants interactions [21]

Several species of Croton (Coidageum variegatum; Euphorbiaceae) have been found to show calcium YSV-associated speckling and streaking (56) Croton, a common ornamental plant valued for the variety of leaf morphology and the bright colors of the many cultivars which have been discovered. In addition to the appearance of the leaves, they can also contain yellow spots or be completely yellow. Yellow veins have been observed in a few varieties [12] as well as yellow to red spots on certain cultivars. It is true that the colors on the leaves are similar to symptoms caused by virus infections, however, the general consensus is that the patterns are genetic in origin. Virus-like symptoms have been observed in several plants in the context of eight, thirty, and seventy, and isolates have been made of a begomovirus, a Croton yellow vein mosaic virus (CYVMV), and potentially a rhabdovirus. Molecular hybridization techniques employed by the THP-lab showed the presence of CYVMV in several croton cultivars [20]. In addition to the croton virus, several other plant species [20] also carry the virus, which is spread by grafting and whiteflies (B. tabaci). There are clear associations between excessive yellowing and poor growth in croton that are associated with CYVMV infection, but it has not been well established that these make a clear distinction between those caused by the virus and those that come from genetics. Croton rhabdovirus inoculated plants were found to show dwarfing, vein yellowing, and leaf malformation as a result of the infection [15][18] (Table 1).

Table 1: Summary of the vector preferences (A denotes the non-viruliferous vectors for the plants that are infected and B denotes the viruliferous vectors for the plants that are healthy)

Virus	Host	Vector	A	B	Additional Comments
Soybean vein necrosis virus	Soybean	*Neohydatothrips variabilis*	?	Y	Viruliferous vectors produced more offspring but excessive accumulation led to lower viability
Tomato spotted wilt virus	Pepper	*Frankliniella occidentalis*	Y	Y	Exposure to TSWV as larvae gave shorter developmental times
Tomato spotted wilt virus	Arabidpsis thaliana	*Frankliniella occidentalis/Thrips tabaci*	?	?	Plants infected with a non-transmissible thrips strain were preferred over uninfected plants. Transmissibility by thrips of TSWV was unrelated to vector preference
Watermelon silver mottle virus (P)	Watermelon	*Thrips palmi*	Y	N	T palmi also preferred feeding on thrips -damaged plants to healthy plants. Mixed effect on thrips performance parameters
Tomato spotted wilt virus (P)	Peanut	*Frankliniella fusca*	?	?	Preference refers to "speed of feeding" of non-viruliferous compared with viruliferous F fusca
Tomato chlorosis virus (SP)/Tomato severe rugose virus (P)	Tomato	*Bemisia tabaci*	?	?	ToSRV whiteflies preferred volatiles from non-infected plants; non-viruliferous whiteflies avoided volatiles from ToCV infected plants
Tomato yellow leaf curl virus (P)	Tomato	*Bemisia tabaci*	Y	Y	Preferences were only prominent on a susceptible rather than resistant genotype. Developmental time was only reduced on TYLCV-infected plants
Tomato yellow leaf curl virus (P)	Tomato	*Bemisia tabaci*	Y/N	N	Virus-free Q-type preferred TYLCV infected plants; virus-free B-type preferred healthy plants. TYLCV whiteflies (both Q and B) show no preference for TYLCV-infected or virus-free plants
Barley yellow dwarf virus	Wheat	*Rhopalosiphum padi*	Y	N	Non-viruliferous preference was not affected by plants co-infected with *Gibberella zeae*, which also supported greater population growth
Cardamon bushy dwarf virus	Cardamon	*Micromyzus kalimpongensis*	?	Y	Aphids grown on CBDV plants had shortened nymphal periods and increased longevity and fecundity
Pea enation mosaic virus (P)/Bean leaf roll virus (P)	Pea	*Acyrthrosiphum pisum*	Y	?	The two viruses differed in their distribution within the plant, but aphids did not discriminate between plants infected by the two viruses. There was earlier nymph production on both infected plants but divergent age specific effects depending on the virus
Cucumber mosaic virus (NP)	Squash/Pepper	*Aphis gossypii*	Y	?	Isolates from squash induced in squash the type of preference behaviour previously found. An isolate from pepper on pepper was more neutral. Cross-host inoculations showed (mal)adaptive effects.
Sweet potato potyviruses	Sweet potato and Ipomea weeds	*Myzus persicae*	Y/N	?	In sweet potato there was preference for virus-infected plants. In the Ipomea weeds, there was preference for noninfected plants

Virus-infected ornamental plants have a potential for posing problems in the marketplace

Some ornamental plants are considered to have an improved aesthetic value as a result of the injection of certain viruses, however, most of the virus-infected plants are not able to endure the infection successfully. The major purpose of ornamental plants is to cause desirable effects in crop plants. The virus that produces the desired effects in ornamental plants could also be used to cause disease in crops that are economically important, including plants that are ornamental. If a virus is transferred from its original host to another host, it can cause a varying set of symptoms. Some viruses cause severe symptoms in a separate host, even if they do not cause symptoms in their original host -- such as Lily symptomless virus [15], this virus usually is not symptomatic in Lilium species, but the virus may cause chlorotic striations and chlorotic curling in Hymenocallis littoralis lilies as well as some cultivars of Lilium [16].

As a consequence of these shifts in distribution, the evidence that some viruses are becoming genetically recombinant with each other, and the widespread distribution of a number of their vectors worldwide, there is a potential for disease outbreaks around the world. In so far as ornamental plants are concerned, begomoviruses are the most frequent source of yellow foliar symptoms at the present. Many of these virus strains are begomoviruses that cause yellow foliar symptoms to appear on ornamental plants. Beeboviruses are an ever-changing group of viruses that are transmitted by whiteflies [19]. A great number of reports are in the media reporting that viruses belonging to this genus have been causing significant crop losses throughout the world. The list of them includes outbreaks of serious diseases in vegetable crops like pepper, cucurbits, and tomatoes.

A major factor limiting the production of tomatoes in tropical and subtropical areas of the world [17] is the prevalence of diseases by begomoviruses, specifically the Tomato yellow leaf curl virus. TYLCV-Israel was probably introduced into the United States in infected plants, which implies the possibility of having plants that have been infected by viruses [18]. A recent outbreak of infected tomato transplants occurred throughout Florida, and retailers distributed infected transplants through retail garden centers. Infected plants purchased by homeowners were also cited as sources of the virus for nearby commercial nurseries and production fields. A number of neighboring states were quickly affected by the virus, mostly because of transplants that had been infected. The spread of this virus is evident to be at least partially a result of the movement of infected plants. In addition, TYLCV has been reported to be present on lisianthus [19], which could also serve as a vector for the introduction of this virus into a tomato-growing region. According to most of the scientific literature, recombination plays a major role in the evolution of begomoviruses as well as their genetic diversity. There has been evidence that mixed infections in nature have resulted in new species of begomoviruses [7]. Many of the recombination-derived begomoviruses described recently, including those described in the last few years, are the products of Molecular recombination with many of their sequences [12].

Conclusion

In spite of the fact that the interactions between some of these viruses and the ornamental plants they are associated with do not appear to harm the host plants, the deliberate utilization of plants viruses in order to enhance the appearance of ornamental plants could provide a potential problem. It appears that the virus does not spread naturally. Though the virus is supposed to belong to the same genus as viruses transmitted by O. brassicae, or camellia virus, CYMoV-free cultivars have not been infected by the virus for more than 20 years in Louisiana along with virus-infected camellias (R. Valverde, unpublished observations). NSPV changes the leaf color, shape, and vigor of Nicotiana NSPV changes the leaf color, shape, and vigor of Nicotiana Nicotiana domestica is affected by NSPV, which can have a positive effect on leaves' color, shape, and vigor. Nandina is the only known host of the virus, and no vector is known. In this regard, NSPV is similar to CY Mo V in that it may be a good aesthetic virus. As a matter of fact, these viruses are not only capable of causing disease, but they are also capable of interacting with other plant viruses in addition to indigenous plant species, or to combine with related viruses to form new and more destructive strains of virus. As clonally propagated ornamental plants have many viruses that are prevalent and some of them are symptomless, by giving them additional viral infections they can cause synergistic effects that lead to severe disease. Plants that have a virus infection cannot only be susceptible to viral diseases, but they can also be susceptible to other pathogens. As a result, these viruses are very common in botanic gardens throughout the world due to their ability to produce unique foliar and flower color patterns in plants. As a result, many of these viruses have been distributed throughout the world widely. As a consequence of the information that has been presented here, special care should be taken to prevent further spreading and introduction of these viruses to new geographical locations without crops or vectors that are already susceptible I would like to raise the caution that once virus is established in an ornamental crop that is grown from vegetative reproduction, it will be extremely difficult, time-consuming, and possibly expensive to eradicate the virus and begin to cultivate healthy clones of that plant again. Tulips are a prime example of a crop where obtaining safe virus-free tissue culture samples, and then subsequently expanding to commercial production levels, may require years of tissue culture.

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