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GLOBAL STATUS OF PHYTOPLASMA ASSOCIATED DISEASES ON DIFFERENT ORNAMENTAL CROPS. A REVIEW OF RECENT RESEARCH

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ABSTRACT

This paper reviews the global status of phytoplasma disease associated with different ornamental crops. This paper investigated phytoplasmas, an equally important group of pathogens that severely harm the growth and marketing properties of ornamental plants, lowering their commercial worth. In this paper, number of ornamental plants was found to be infected with '*Ca.* Phytoplasma' species and treatment techniques were adapted using tetracycline insecticides for elimination and emission of phytoplasmas.

***Keywords*:** Phytoplasma, Ornamental Crops, Treatment techniques

INTRODUCTION

Ornamental Plants are having different level of importance either economically or its value to the human. Phytoplasmas are pleomorphic bacteria that lack a cell wall Phytoplasma infection has been associated with a variety of ornamental plant species found throughout India, including "aster yellows (16SrI), peanut witches' broom (16SrII), clover proliferation (16SrVI), pigeon pea witches' broom (16SrIX), rice yellow dwarf (16SrXI), and bermuda grass white leaf (16SrXI) (16SrXIV)". Virus and phytoplasma-related diseases in ornamental crops have been detected on a global scale, resulting in significant economic losses (Rao and Kumar, 2017; Bertaccini and Duduk, 2009; Rao *et al.*, 2011, 2017c; Bertaccini and Duduk, 2009; Rao *et al.,* 2011, 2017c; Marcone, 2014; Liu *et al.,* 2017; Marcone, 2014; Liu *et al.,* 2017; Rao and Kumar, 2017).

Disease in Ornamental Plants

Phytoplasmas cause infections in a variety of commercial cut flowers and ornamental plants, resulting in significant economic losses around the world. In India, phytoplasma identification on ornamental plants has long been relied on symptomatology; however, the absence of peculiar symptoms in infected plants might make precisely identifying all phytoplasma-associated diseases challenging.

Symptomatology

Many plant species have been identified as phytoplasma hosts, however the causal organism has yet to be identified. Phytoplasmas are small (0.3-1.2 m) single-celled polymorphic mollicutes that live inside the sieve tissues of plant phloem cells (Fig. 1) and are distinguished by a small genome ranging from 680 to 1600 kb (among the smallest known for any self-replicating organism), a low G+C content in their DNA (23.0-29.5 mol percent), and a parasitic lifestyle. Phytoplasma genomes are smaller in size than those of their forefathers (walled Bacillus/Clostridium bacteria) (Bertaccini *et al.,* 2014).

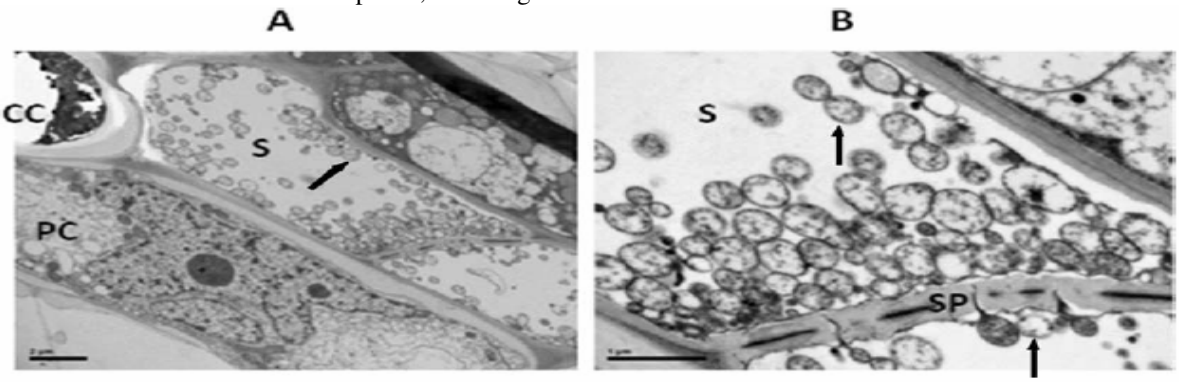

Fig. 1: "Ultrathin sections of phloem tissue of phytoplasma,A: Ultrathin section of variegated leaf phenotype shows phytoplasmas (arrows) phloem sieve element with a large number of phytoplasma cells in one sievetube. B: higher magnification of the same ultrathin section. Sieve cell(S), companion cell (CC), parenchyma cell (PC), sieve plate(sp), plastid (P), callose(CA).(A):bar= 2µm.(B):bar=1µm."

Phytoplasmas are constantly cycling between plants and insects, and in nature, both organisms are required for disease survival and spread (Bertaccini *et al.,* 2014). Diseases affecting ornamental plants are categorized based on their symptoms, which are depicted in Fig. 2.

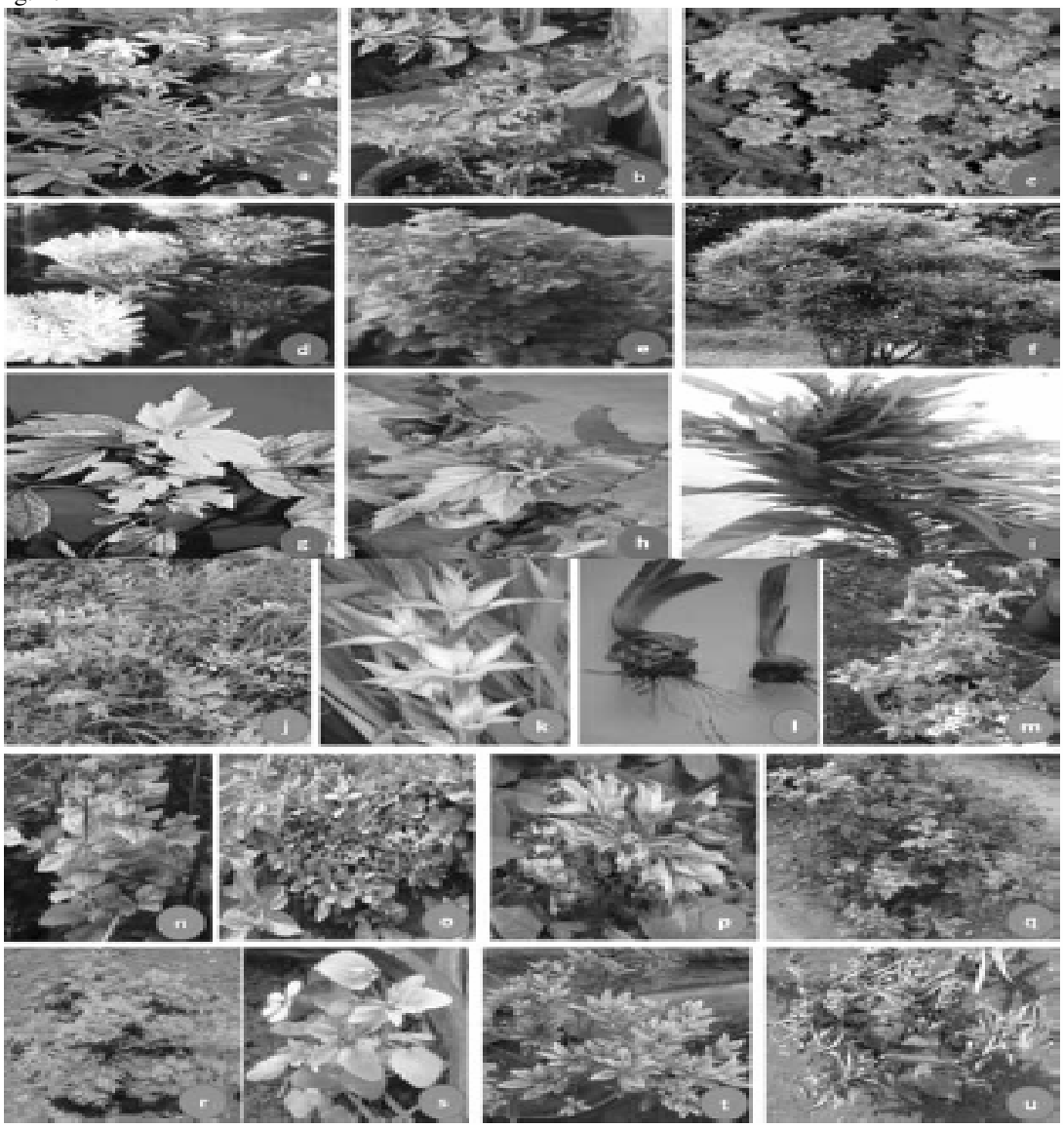

Fig. 2: Symptoms in ornamentals. (a-c) Little leaf in Adenium, Allamanda and Catharanthusroseus; (d-e) virescence and phyllody in Chrysanthemum; (f) witches' broom in Codiaeumvariegatum;(g-h) leaf yellows and phyllody in Hibiscus rosa-sinensis; (i) flat stem and witches' broom in Celosia argentea ;(j) yellowing and little leaf and stunting disease in Jasminumsambac; (k) discoloration of flowers in Gladiolus; (l) reduced sized corm and poor root systemin Gladiolus; (m) yellowing, little leafand discoloration of flowers in Phlox drummondi; (n and o) leaf yellowing and witches' broomin Petunia; (p) bud proliferation in rose;(q) little leaf and yellowing in rose; (r) stunting and leaf yellowing in Tagetes spp.; (s) leaf yellowing and reduced flowing in Viola tricolor; (t) leaf chlorosis and witches'broom in Xanthostemonchrysanthus; and (u) crinkling of leaves and abnormal flowers in Zinnia.

Virescence/phyllody (Fig. 2d and e), proliferation of axillary buds resulting in witches' broom behavior are some of the symptoms caused by phytoplasmas in ornamental plants in India. (Fig. 2 f and o) generalized stunting (Fig. 2r), yellows and little leaf (Fig. 2a and c), leaf chlorosis (Fig. 2 s and t), flat stem (Fig. 2i), discoloration of flowers (Fig. 2k and m), reduced sized corm and poor root system (Fig. 2l) and abnormal flower bud proliferation (Fig. 2p) (Chaturvedi *et al.,* 2010b; Shukla, 2015; Madhupriya, 2016; Rao *et al.,* 2017).

Description of Diseases Identified in Ornamental Plants

Adenium obesum*:* Desert rose (*Adenium obesum*) of the Apocynaceae family is a tropical ornamental plant renowned for its attractive fleshy stem, leaves, and vividly colored blooms. *Allamanda cathartica* L.: *Allamanda cathartica,* sometimes known as golden trumpet or yellow allamanda, is a flowering plant of the Apocynaceae family. Khasa *et al.* (2016) observed *A. cathartica* leaf yellowing as a sign of the disease and linked it to the 'clover proliferation' (16SrVI) group of phytoplasma.

Brachycome spp.: *Brachycome* is a genus of flowering plants in the Asteraceae family. The flower heads are solitary or in little corymbs. The head is ornamented with a row of commercially valuable ray florets in a range of colors. Madhupriya *et al.* (2013b) discovered leaf yellowing (LY) and witches' broom (WB) symptoms on Brachycome in New Delhi, which is a *'Ca*. P. asteris' (16SrI) species.

Calendula officinalis: *Calendulas* are in the family Asteraceae. It is one of the most adaptable flowers to cultivate in a garden, as it can grow in a wide range of soil conditions. Phyllody and virescence were also reported in *Calendula officinalis* in Uttar Pradesh, India (Rani *et al.* 2014).

Callistephus chinensis* [L.] *Nees.: China aster is a popular floriculture crop in Karnataka (India) because of its lovely cut flowers. From 2014 to 2016, field investigations in Karnataka showed virescence and phyllody symptoms on China aster plants caused by *'Ca. P. aurantifolia'* (16SrII-D) (Mahadev Kumar *et al.,* 2017).

Carpobrotus edulis* (L.) *N.E. Br: *Carpobrotus edulis,* also known as ice plant, pig face, or hottentot fig, is a succulent ornamental species native to South Africa that is creeping, easy to grow, and mat-forming. Shukla*et al.* (2014) observed significant yellowing, few leaves, and reduced bloom size in *C. edulis* at Gorakhpur gardens in Eastern Uttar Pradesh in 2012-2013. The phytoplasmas linked with C. edulis were identified as an isolate of pigeon pea witches' broom phytoplasma (16SrIX-C subgroup) (Shukla*et al.* 2014).

***Celosia argentea L.* :** *Celosia argentea,* often known as plumed cockscomb or silver cock's comb, is a tropical herbaceous ornamental plant commercially farmed in India as a potted or cut flower (Varadharaj and Muniyappan, 2017). Celosia is grown as an ornamental plant. In New Delhi and Karnal, India, Madhupriya*et al.* (2017) observed flattened stem and witches' broom symptoms on *Celosia argentea* associated with *'Ca. P. asteris'* subgroup 16SrI-B and *'Ca. P. australasia'* subgroup 16Sr II-D.

Jasminum sambac* (L.) *Aiton: *Jasminum* is a genus of olive-related shrubs and vines (Oleaceae). It featured over 200 species native to Europe, Asia, and Africa's tropical and warm temperate zones..Madhupriya *et al*. (2015b) discovered a link between jasmine symptoms such tiny leaves, yellow leaves, and witches' broom and the phytoplasma Indian rice yellow dwarf (16Sr XI). In Devanahalli, Bangalore, Gopala (2017) discovered a relationship between a *'Ca. P. asteris*' 16Sr I-B subgroup and jasmine yellowing, small leaf, and stunting disease..

Justicia gendarussa Burm. f.: *Justicia gendarussa Burm. f. (family Acanthaceae)* is an evergreen shade-loving hedge plant that thrives in moist conditions. Witches' broom and tiny leaf symptoms were found on *Justicia gendarussa* plants in Shahjahanpur, Uttar Pradesh, India, in 2013-14, with a disease incidence of 2%. *Mirabilis jalapa* L.: *Mirabilis jalapa,* also known as the Peruvian marvel or four o'clock flower, is the most commonly grown ornamental species of Mirabilis plant and comes in a variety of colors. The flower is a native of tropical South America. *Portulaca grandiflora Hook.: Portulaca grandiflora* is a flowering plant in the Portulacaceae family that is native to Argentina, southern Brazil, and Uruguay but is often grown in gardens. Ajaya Kumar *et al.* (2007) described *P. grandiflora* leaf disease from India. *Rosa x hybrid:* Roses are a genus of over 100 species of perennial flowering shrubs in the Rosaceae family. The vast majority of the species live in Asia, Europe, North America, and northwest Africa. In India, Chaturvedi *et al.* (2009b) discovered a phytoplasma from the aster yellows (16SrI) group that was linked to phyllody symptoms. "Madhupriya *et al.* (2017) confirmed the association of two phytoplasma groups, aster yellows (16Sr I) and peanut witches' broom (16SrII), with 13 rose genotypes by observing regular occurrences of phytoplasma-associated symptoms such as little leaf, yellowing, internode shortening, phyllody virescence, and flower bud proliferation" (Fig.2 p-q) at IARI, New Delhi.

Stages of Symptoms

Plants go through stages of symptom development. The disease symptoms begin with the characteristic bud multiplication, downward curling, and decreased leaf size, followed by overall plant growth reduction and yellowing (Fig. 3). Some plants also produced rosettes and a profusion of axillary shoots that resembled a witch's broom (Fig. 3c). Plants infected in the advanced phases of disease development would either not flower or set seeds.

Fig. 3: Different stages of disease (a) Healthy twig, (b) Initiation of symptoms, and (c) Severe symptoms.

In 1971, Essex County was the site of the Peach X-disease discovery, which impacted over 50% of peach orchards. 16SrIII group phytoplasmas have been connected to many cherry and peach diseases in North America (Scott & Zimmerman, 2001). *Ca. P. pruni* strain, found in Trillium, threatens the species *T. grandiflorum* and other Trillium species in Ontario as well as plant species grown nearby. This is the first time a phytoplasma has been detected in Trillium species in Canada or elsewhere in the world, to our knowledge (Arocha-Rosete *et al.,* 2016).

(a) (b)

Fig. : Symptoms of virescence observed in *T. Erectum* (a) and *T. grandiflorum* (b) plants collected in the Sparta area, London, Canada.

Furthermore, numerous investigations found two or more different phytoplasma groups in a single plant. This is proven by a stunt disease in broccoli that may be caused by phytoplasma groups 16SrI, 16SrIII, or 16SrXII (Eckstein *et al.,* 2013). Additionally, phytoplasma contamination of vegetable crops may be associated with non-specific symptoms such as leaf yellowing, reddening, curling, vein clearing, stunting, and fruit deformity (Pereira *et al.,* 2016).

Treatment – an overview

Sap transfer of the infectious virus was not possible in glasshouse settings. Using a transmission electron microscope, we collected and processed plant tissue samples for ultrastructural analysis (TEM). We found typical pleomorphic entities ranging in shape from round to oval and in size from 340 to 1100 nm. (Fig. 4). The bodies featured cytoplasms that were opaque and low in electron density, with ribosome-like granules and DNA-strand-like structures but no nuclear membranes. Phloem tissue necrosis was very frequently detected.

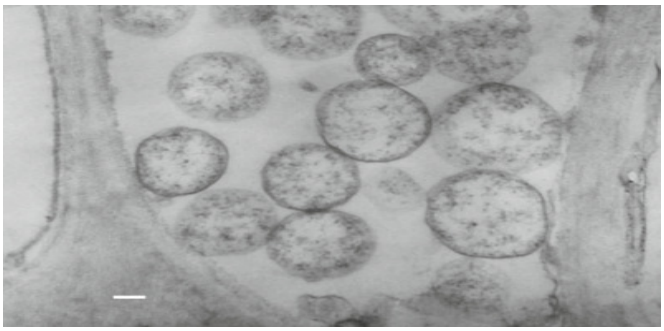

Fig. 4: "Phytoplasma colonising a phloem sieve tube of *P. grandiflora*. Bar = 300 nm"

Epidemiology and host metabolism

Little is known about the epidemiology of phytoplasma diseases on ornamentals in India. *Empoascamotti.* a leafhopper was identified as a host of 16Sr I group phytoplasma on *Brachycome spp., Petunia sp.* and rose fields infected with similar phytoplasma strain at ICAR-IARI,New Delhi suggested its possible role as vector (Madhupriya, 2016). Aido (2017) identified *Cannabis sativa, Parthenium hysterophorus* and *Chenopodium album* as positive alternate host of *'Ca. P. aurantifolia'* (16Sr II-D) subgroup and' *Candidatus* Phytoplasma trifolii' (16SrVI-D) subgroup of phytoplasma in and around chrysanthemum fields at ICAR-IARI, New Delhi infected with similar strain of phytoplasmas. These results further suggested the role of these weed species as natural reservoir and transmission of the phytoplasma strain from weed to ornamental plant species through potential leafhoppers. Madhupriya *et al.* (2017) also detected phytoplasmas in seeds from symptomatic *Celosia* plants associated with 16Sr I-B subgroup of phytoplasma. Aido (2017) also reported the successful transmission of chrysanthemum phytoplasma (16Sr II-D subgroup) from infected chrysanthemum plants to healthy *Catharanthus roseus* plant through dodder (*Cuscuta reflexa* R.).

Phytoplasma symptoms were relieved in *Portulaca grandiflora* plants infected with *Candidatus phytoplasma* sp (Ajaya Kumar *et al.,* 2007). Weekly foliar sprays of tetracycline hydrochloride or penicillin at concentrations of 250, 500, and 1000 g/mL. "Singh *et al.* (2007) used in vitro treatment with kinetin (2.0 mg/L), 6-benzyl aminopurine (0.75 mg/L), and indole-3-butyric acid (0.1mg/L) to try to produce phytoplasma-free plants from yellow leaf sick *Catharanthus roseus*." A dosage of 75 mg/L of oxytetracycline was shown to be best for removing phytoplasma from affected tissues. Madhupriya (2016) reported the effect of oxytetracycline at various concentrations (0, 20, 40, 60 and 80 ppm) showed noticeable effect on the growth and development of *C. roseus* plants *in vitro* 80 ppm of the tetracycline treatment in the elimination of phytoplasma from infected *C. roseus* plants.

CONCLUSION

This article provides an update on the status of scientific work done on phytoplasma diseases of ornamentals around the world, as well as an overview of a number of ornamental phytoplasma diseases in the current context. Number of ornamental plants are found to be infected with phytoplasma diseases on ornamental species and attributed to six '*Ca.* Phytoplasma' species. Major management techniques were adapted for phytoplasma disease management are using tetracycline treatment, insecticides for vector control and micro-propagation for emission and elimination of phytoplasmas.

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