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Abstract

China aster, *Callistephus chinensis* (L.) Nees., family Asteraceae, is a popular ornamental flower worldwide. Diverse cultivars have been bred for garden, potted, and cut flowers. Numerous diseases have been reported in the cultivation of China aster. Frequently occurring and highly damaging diseases are caused by *Botrytis cinerea*, *Fusarium oxysporum* f. sp. *callistephi*, and an ever-increasing number of viruses, including tospoviruses. Recent studies on management strategies for China aster diseases include chemical, cultural, and physical control, sanitation, host resistance, and their integration.

Keywords

*Botrytis cinerea* • *Fusarium oxysporum* f. sp. *callistephi* • Tospovirus spp.

1 Introduction

China aster, *Callistephus chinensis* (L.) Nees., family Asteraceae, is a popular flower worldwide. China aster seeds were first introduced from China into France in 1731, and cultivation of the flower spread across Europe (Tsurushima 1983). Diverse cultivars for garden flowers were bred in France, Germany, and the UK. China aster was introduced into Japan from China in the 1700s, and many cut flower cultivars such as the Matsumoto series have been bred. In the 1800s, China aster was introduced into the USA, and a vast array of different cultivars was developed for cut flower production. Fusarium wilt has caused the greatest damage to the China aster cultivation, and a number of control measures have been developed for this challenging disease. Outbreaks of other China aster diseases that limit its production have also been reported such as those caused by viruses and phytoplasma. This chapter covers diseases that occur in China aster and describes their epidemiology and management. Also refer to the chapters in the introductory section “Components of Integrated Disease Management” for general strategies applicable to florists’ crops.

2 Fungal and Fungus-Like Diseases

2.1 Botrytis Blight, Gray Mold (*Botrytis cinerea* Pers.)

2.1.1 Geographic Occurrence and Impact

Botrytis blight or gray mold occurs in many floral plants and other commercial crops worldwide and causes extensive damage both during production and after harvest (Horita 1995; Williamson et al. 2007).
2.1.2 Symptoms
Initially brown lesions are observed in the margins of young leaves. The lesions rapidly enlarge to blight entire leaves. Blighted tissues expand to the petioles and stems. Lesions may girdle stems, which exhibit an internal brown discoloration, and stems die above the infection site. When stems are infected at the soil line, the whole plant ultimately wilts and dies. The pathogen also causes petal blight under cool, moist conditions. Growth of *B. cinerea* on leaves, stems, and flowers is indicated by the presence of a profuse gray mold which consists of masses of fungal hyphae and spores (Fig. 1).

2.1.3 Biology and Epidemiology
*Botrytis cinerea* is an airborne pathogen which infects over 200 hosts including all floral crops. The fungus can survive as a pathogen or saprophyte in infected plant debris. *Botrytis cinerea* also produces small, black stress-resistant sclerotia. Sclerotia and mycelia in infected tissues enable long-term survival during unfavorable periods. When disease-conducive conditions return, quiescent mycelia become active, and sclerotia germinate and produce mycelia and conidiophores. The conidia of *Botrytis* are dispersed by wind and rainfall and cause new infections. *Botrytis cinerea* is favored by cool, moist conditions. A severe outbreak of gray mold in China aster was observed during the rainy season in cultivated fields in Japan (Nishikado and Inoue 1956). Seed infection by *Botrytis* sp. of China aster was reported in Poland (Rymar 1984).

2.1.4 Management
- **Cultural practices and sanitation** – Remove dead and dying leaves and flowers from plants and the soil surface. In greenhouse cultivation, avoid overhead irrigation, or if this is not possible, water early in the day to reduce the duration of leaf wetness. Increasing plant spacing will increase ventilation and also reduce leaf wetness. Bertus (1967) reported control of *B. cinerea* and *Alternaria tenuis* on China aster seed by treatment with aerated steam at 53 °C/127 °F for 30 min.
• *Fungicides* – Rymar (1984) found that carbendazim, benomyl, and thiophanate methyl were effective in treating aster seed contaminated with Botrytis sp.. However, widespread resistance to thiophanate methyl and iprodione has occurred in *B. cinerea* in floral crops (Daughtrey et al. 2000). Thiophanate methyl resistance frequency in China aster isolates of *B. cinerea* in Japan was reported to be 31% (Irie et al. 1989). The fungicide azoxystrobin and natural product D-limonene inhibited the development of *B. cinerea* in China aster in Poland (Nawrocki 2013). It is important to rotate fungicides with different modes of action in order to prevent the development of resistance. Information on fungicide mode of action and resistance management strategies can be found at the Fungicides Resistance Action Committee (FRAC) website: http://www.frac.info/.

2.2 *Fusarium Root Rot, Wilt* (*Fusarium oxysporum* Schlechtend.: *Fr. f. sp. callistephi* (Beach) W.C. Snyder & H.N. Hans; *Fusarium sp.*)

2.2.1 Geographic Occurrence and Impact
Fusarium wilt of China aster has occurred in Australia, the Czech Republic, Germany, Japan, New Zealand, Poland, and the USA (Cunningham 1931; Hanning and Orlicz-Luthardt 2002; Kodama and Horita 1995; Nečas and Kobza 2008; Rataj-Guranowska et al. 2007; Simmonds 1956; Snyder and Hansen 1940). Disease incidences of Fusarium wilt up to 71.2% were reported in the USA (Connecticut and Florida) (Elmer and McGovern 2013).

2.2.2 Symptoms/Signs
Initial symptoms are observed in the seedling stage as damping-off. The stems of tiny seedlings rot at the soil line, the cotyledons wither, and the plants fall over. At the transplant stage, infected plants are stunted, have brown lower leaves, wilt during the heat of the day, and die. Brown lesions occur in the stem bases, and black streaks extend to the upper stems at harvest. Vascular discoloration is visible when infected stems are cut lengthwise. White mycelia and masses of salmon-colored spores are produced on stem bases of dead and declining plants (Fig. 2).

2.2.3 Biology and Epidemiology
*Fusarium oxysporum* f. sp. *callistephi* produces three types of asexual spores, microconidia and macroconidia, which enable aerial dissemination, and thick-walled, stress-resistant chlamydospores which enable the survival of the pathogen for many years even in the absence of aster plants. All of the *F. oxysporum* f. sp. *callistephi* isolates are highly virulent to China aster; however, some isolates also exhibit a lower virulence to *Dianthus caryophyllus*, *Narcissus* sp., and *Tulipa gesneriana* (Rataj-Guranowska et al. 2007). *Fusarium oxysporum* f. sp. *dianthus* showed a low level of virulence in China aster but may aggravate Fusarium wilt caused by *F. oxysporum* f. sp. *callistephi* (Orlicz-Luthardt et al. 2000). Four races of *F. oxysporum* f. sp. *callistephi* were identified under experimental conditions based
on differential pathogenicity to China aster cultivars (Armstrong and Armstrong 1971). Sources of the pathogen are plant debris in the soil and seed infection (Neergaard 1977). Elmer and McGovern (2013) attributed serious outbreaks of Fusarium wilt in the USA to a high incidence (12%) of the pathogen on seed. The pathogen is also moved on infested tools, equipment, and shoes. Warm temperatures (~27 °C/80 °F) favor the disease, as well as acidic soils and soils that have been disinfested by steam or fumigation and subsequently re-infested by *F. oxysporum* f. sp. *callistephi*, e.g., through infected transplants (Baker 1953), presumably because of the elimination of microorganisms which are antagonistic to the pathogen.

### 2.2.4 Management

- **Sanitation and cultural practices** – Sodium hypochlorite was effective in eliminating the fungus from seeds (Elmer and McGovern 2013). Rymar (1984) found that carbendazim, benomyl, and thiophanate methyl were effective in treating aster seed contaminated with *Fusarium* sp.. The reuse of propagative containers such as transplant trays should be avoided without thorough chemical or steam disinfection. The use of pathogen-free transplants is essential. Avoid fertilizing with ammoniacal sources of nitrogen. Lime the soil to 6.5–7.0.

- **Soil disinfestation** – Elmer and McGovern (2013) demonstrated that soil disinfestation with methyl bromide + chloropicrin, 1,3-dichloropropene + chloropicrin, or metam sodium maintained Fusarium wilt at a low level in the USA (Florida). The incidence of Fusarium wilt was reduced by 73.4% by soil solarization conducted for 3–4 weeks in Taiwan using clear 0.025 mm-thick polyethylene mulch (Huang and Sun 1991).

- **Resistance** – Nečas and Kobza (2008) in the Czech Republic classified China aster cultivars according to their reactions to artificial inoculation with
F. oxysporum f. sp. callistephi as resistant, moderately resistant, and sensitive. The “Matsumoto”, “Einf. Madeleine”, and “Americká kráska” series were found to be resistant in these trials. The “Bouquet Powderpuff Mix”, “Benary’s Princess Formula Mix”, “Finest Mixed”, and “Matsumoto Formula Mix” series were rated as resistant in a greenhouse trial, and the “Bouquet Powderpuff Mix”, “Astoria Mix”, “Aster Sandy Mix”, and “Aster Composition” (Stokes Seeds) series were moderately resistant to the fungus in field trials in Connecticut (Elmer and McGovern 2013). Interestingly, the densities of Trichoderma viride, T. polysporum, and Penicillium jensenii, fungal antagonists of F. oxysporum f. sp. callistephi, were found to be higher in the root system of a resistant aster cultivar than in a susceptible one in a field experiment in Poland (Manka and Kacprzak 1998).

- Fungicides and biocontrols – The biocontrol Pythium oligandrum and the fungicide azoxystrobin were effective in reducing infection of China aster plants by F. oxysporum in Poland (Nawrocki 2013).

2.3 Itersonilia petal blight (Itersonilia perplexans derx)

2.3.1 Geographic Occurrence and Impact
To date, Itersonilia petal blight of China aster has only been reported in the USA (Florida, Hawaii) (McGovern and Seijo 1999; J. C. Trolinger personal communication). In Florida, 10–50% postharvest losses occurred (McGovern and Seijo 1999).

2.3.2 Symptoms
Initially the fungus causes pinpoint, bleached lesions on petals. The lesions enlarge and result in bleached streaks on ray flowers. Eventually the entire blossom turns brown (Fig. 3).

2.3.3 Biology and Epidemiology
Growth, spore production, and infection by I. perplexans are favored by plentiful rainfall, high RH (>70%), and cool temperatures (10–15 °C/50–59 °F) (Brown et al.
1964; Horita et al. 2005; Horst 1997). Often symptoms of the disease are not apparent until after postharvest processing. Two groups of *I. perplexans* have been reported which are specific to Asteraceae or Apiaceae. In host range tests, China aster isolates were pathogenic to Asteraceae, including such florists’ crops as chrysanthemum, gerbera and sunflower, but not to Apiaceae (McGovern et al. 2006). *Itersonilia perplexans* was isolated from *Emilia fosbergii*, Asteraceae, a weed species growing adjacent to a China aster production facility that has had a long history of *Itersonilia* petal blight outbreaks (Fig. 3). Since *Emilia* isolates produced severe petal blight on China aster, this weed represents a remarkable reservoir of this cool-season fungus that enables it to survive in a subtropical climate.

### 2.3.4 Management

- **Cultural practices** – The use of effective sanitation methods, such as removal of non-harvested flowers and weed hosts, especially Asteraceae, is critical in controlling *Itersonilia* petal blight.
- **Fungicides** – McGovern et al. (2006) found that myclobutanil, propiconazole, and potassium bicarbonate were generally more effective than azoxystrobin in lowering the severity levels of petal blight on detached flowers in controlled environment experiments.

### 2.4 Rhizoctonia Stem and Root Rot, Blight [*Rhizoctonia solani* Kühn, (Teleomorph: *Thanatephorus cucumeris* (A.B. Frank) Donk)]

#### 2.4.1 Geographic Occurrence and Impact

This disease has occurred in China aster in Finland (Linasalmi 1952), Japan (Ito et al. 2006), and the USA (Ullstrup 1936).

#### 2.4.2 Symptoms/Signs

Initially, infected plants have light brown lesions on stems at the soil line. The lesions enlarge to girdle the stems and spread to the root system. As stem girdling and root rot progresses, infected plants become stunted, wilt, and die. Occasionally, blight symptoms appear on the lower leaves in contact with the soil. Eventually dark brown hyphae are readily visible on the surface of stems at the soil line. Small, black survival structures, sclerotia, may form in mycelia of the fungus.

#### 2.4.3 Biology and Epidemiology

*Rhizoctonia solani* is a major pathogen with worldwide distribution which infects most cultivated crops and weeds. China aster isolates of *R. solani* belong to hyphal anastomosis group AG-2-2 (Ito et al. 2006). They are very active at high temperatures (35 °C/95 °F) (Ullstrup 1936). The fungus survives as hyphae and sclerotia in plant debris or soil, and seed infection has also been detected in China aster (Crosier 1968).
2.4.4 Management

- **Cultural practices** – Rapidly remove infected plants. Excessive irrigation and, where possible, high temperatures should be avoided.
- **Soil disinfestation** – Soil disinfestation strategies include fumigation, steam, or soil solarization and preventative fungicide application.
- **Fungicides and biocontrols** – Prior to planting or transplanting, incorporate PCNB or *Trichoderma* spp. into the top 2.5 cm of soil; spray the bases of seedlings with thiophanate methyl, iprodione, or *Trichoderma* spp. (Koike et al. 2016). A talc-based formulation of *Pseudomonas fluorescens* combined with thiophanate methyl applied to soil was found to be effective in increasing germination of China aster seed and in decreasing root rot incidence in India (Babu et al. 2013).

2.5 Additional Fungal and Fungus-Like Diseases

The following fungal diseases of China aster have also been reported:

- **Alternaria leaf spot, flower blight** [*Alternaria alternata* (Fr.) Keissl. *Alternaria* sp.] (the USA, Baker and Davis 1950a)
- **Anthracnose** [*Colletotrichum gloeosporioides* (Penz.) Penz. and Sacc., (teleomorph: *Glomerella cingulata* (Stoneman) Spauld. & H. Schrenk; *Colletotrichum* sp.] [the USA (Florida), Alfieri et al. 1994]
- **Ascochyta leaf spot** [*Ascochyta asteis* (Bres.) Gloyer; *Ascochyta* sp.] (Germany, Gloyer 1924)
- **Camarosporium leaf spot** (*Camarosporium eriogonii* Ellis & Everh.) [the USA (Florida), Alfieri et al. 1994]
- **Downy mildew** [*Basidiophora entospora* Rose & Cornu] [the USA (Florida), Alfieri et al. 1994]
- **Phialophora wilt** [*Phialophora asteris* (Dowson) Burge & Isaac] (UK, Burge and Isaac 1974)
- **Phomopsis stem canker** [*Phomopsis callistephi* Tehon & E. Y. Daniels] (the USA, Tehon and Daniels 1925)
- **Phymatotrichopsis root rot** [*Phymatotrichopsis omnivora* (Duggar) Hennebert (syn. *Phymatotrichum omnivorum*)] (the USA, Farr et al. 1989)
- **Pythophthora root and foot rot** [*Pythophthora cryptogea* Pethybr. & Laff., *Pythium* sp.] (Ireland etc. Erwin and Ribeiro 1996)
- **Powdery mildew** [*Oidium asteris-punicei* Peck (teleomorph: *Golovinomyces cichoracearum* (DC.) V.P. Heluta) as “cichoracearum“) (syn: *Erysiphe cichoracearum*); *Erysiphe polygoni*] (Japan, Sato et al. 1992)
- **Pythium root and stem rot, wilt** [*Pythium splendens* H. Braun, *P. ultimum*, *Pythium* sp.] (Japan, Tasugi and Siino 1940)
- **Rust** [*Colesporium asterum* (Dietel) Syd. & P. Syd.] [the USA (California), (Raabe and Pyeatt 1990)]
- **Sclerotinia rot** [*Sclerotinia sclerotiorum* (Lib.) de Bary] (Japan, Narita 1998)
– **Sclerotium blight** [Sclerotium rolfsii Sacc. (teleomorph: Athelia rolfsii (Curzi Tu & Kimbrough)] [the USA (Florida), Alfieri et al. 1994]

– **Septoria leaf spot** [Septoria atropurpurea Peck, S. callistephi Gloyer (1921) (teleomorph: Mycosphaerella sp.)] (Poland, Madej 1970)

– **Stemphylium leaf spot** [Stemphylium botryosum Wallr., (teleomorph: Pleospora tarda E. Simmons); S. lycopersici (Enjoji) W. Yamamoto (syn. S. floridanum Hannon & G.F. Weber)] (the USA, Baker and Davis 1950b)

– **Verticillium wilt** (Verticillium albo-atrum Reinke & Berthier) (the USA, Baker et al. 1940)

### 3 Bacterial and Phytoplasma Diseases

#### 3.1 Aster Yellows (‘Candidatus Phytoplasma asteris’)

**3.1.1 Geographic Occurrence and Impact**

Aster yellows in China aster has been reported in Canada, Germany, Japan, Myanmar, and the USA (Illinois) (Babadoost 1988; Lee et al. 2004; Murayama et al. 1963; Win et al. 2011).

**3.1.2 Symptoms/Signs**

The China aster phytoplasma produces a range of symptoms which include yellowing of leaves, stunting of whole plants, and yellow-green discoloration of flowers (Fig. 4). Flower virescence (greening of flowers) has also been observed in Myanmar (Win et al. 2011).

![Fig. 4 Aster yellows symptoms: infected plant (left), healthy plant (right) (Photo courtesy of Whitney Cranshaw)](image-url)
3.1.3 Biology and Epidemiology

‘Candidatus Phytoplasma asteris,’ which comprises the aster yellows group, is associated with diseases of over 100 plant species. The China aster phytoplasma strains belong to the 16SrI group based on analysis of the 16S rDNA sequences (Lee et al. 2004). A different group of phytoplasma, 16SrII, was reported in China aster in Myanmar (Win et al. 2011). Aster leafhoppers [Macrosteles fascifrons (Hemiptera: Cicadellidae)] acquire the phytoplasma and spread it to new plants (Babadoost 1988). Infection of aster yellows in temperate areas occurs by migration of leafhoppers that overwinter on infected host plants in warmer areas. However, high temperatures (approximately 31 °C/88 °F) inactivate the phytoplasma in leafhoppers and plants.

3.1.4 Management

- **Cultural practices** – Rapidly remove infected plants. Eradicate susceptible hosts (including weeds) around China aster production sites. Use reflective mulches in field-grown asters to disorient the vectors. In greenhouse cultivation, use physical barriers such as fine mesh nets or screens to exclude the leafhoppers.

3.2 Bacterial Wilt [Dickeya sp. (Formerly Erwinia chrysanthemi)]

3.2.1 Geographic Occurrence and Impact

This disease has occurred in Japan (Komatsu et al. 2002).

3.2.2 Symptoms

Early symptoms include water-soaked, black lesions in the stem at the soil line. The rot gradually expands, petioles exhibit a black rot, and the foliage yellows. The plants eventually wilt and die. Infected stems reveal a typical black discoloration of the vascular tissue when dissected (Fig. 5).

3.2.3 Biology and Epidemiology

Komatsu et al. (2002) identified the causal pathogen as *Erwinia chrysanthemi*. Samson et al. (2005) proposed that *Pectobacterium chrysanthemi* (=*Erwinia chrysanthemi*) and *Brenneria paradisiaca* be reclassified as a novel genus, *Dickeya*, which includes six species. However, *Dickeya* from China aster has not yet been speciated. The bacterium is very active at warm temperatures and spreads to new plants by splashing water from infected plants and via infested tools.

3.2.4 Management

- **Cultural and sanitation practices** – Rapidly remove infected plants. Disinfest tools.
- **Resistance** – Greenhouse trials conducted in Japan indicated that the China aster cvs. Stella and Top Rose were partially resistant to the disease (Komatsu et al. 2002).
3.3 Additional Bacterial Disease

The following bacterial disease of China aster has also been reported:

- **Bacterial black spot** \(Pseudomonas \textit{viridiflava}\) (Burkholder 1930) Dowson 1939] (Japan, Moriwaki et al. 2013)

4 Viral Diseases

4.1 Bromoviridae \textit{Cucumber Mosaic Virus} (CMV, Genus: \textit{Cucumovirus})

4.1.1 Geographic Occurrence and Impact
This disease has occurred in Korea (Oh et al. 2008) and in the USA (Ferreira 1992).

4.1.2 Symptoms/Signs
Symptoms on China aster are a severe leaf mosaic.
4.1.3 Biology and Epidemiology
In experiments using dsRNA, RT-PCR, and restriction enzyme analysis, CMV isolated from China aster belongs to subgroup IA. CMV is spread by a number of aphids (Hemiptera: Aphididae), including the green peach aphid, *Myzus persicae*, in a noncirculative (nonpersistent) manner. The virus infects numerous vegetables, ornamentals, and weeds.

4.1.4 Management
Virus management is based on reduction of vector populations through chemical or biological measures. In greenhouse cultivation, use physical barriers, such as fine mesh nets or screens, to exclude the aphids, or reflective mulches to disorient them in field-produced asters. Weeds growing near China aster production sites should be removed in order to eliminate reservoirs of the virus and its vectors.

4.2 Bunyaviridae

4.2.1 Geographic Occurrence and Impact
Thus far five viruses in genus *Tospovirus*, Bunyaviridae, have been detected in China aster: Chrysanthemum stem necrosis virus (CSNV), Groundnut ringspot virus (GRSV), Tomato chlorotic spot virus (TCSV), and Tomato spotted wilt virus (TSWV) (Alexandre et al. 1999; Bakardjieva et al. 1998; Chatzivassiliou et al. 2000; Ishikawa et al. 2002; Kim et al. 2006; Kitajima 2015; Latham and Jones 1997; Marchoux et al. 1991; Momonoi et al. 2011; Ramasso et al. 1994; Sether and DeAngelis 1992). Alexandre et al. (1999) found that one China aster plant in Brazil was coinfected with CSNV + GRSV. The geographic occurrence of these viruses in China aster is indicated in Table 1. CSNV symptoms were observed on about 6,000 China aster plants in a commercial facility in Japan (Toyama Prefecture) (Momonoi 2011). The incidence of TSWV was 10% in seedlings in a greenhouse in Japan (Ishikawa et al. 2002). In open-field surveys in Greece, the incidence of TSWV was 37.7% (Chatzivassiliou et al. 2000).

4.2.2 Symptoms/Signs
The range of symptoms caused by tospoviruses in China aster is presented in Table 1.

4.2.3 Biology and Epidemiology
The tospoviruses are vectored in a circulative and propagative manner (they enter and replicate within the insect’s hemolymph) by a number of thrips species (Thysanoptera: Thripidae) (Table 1). Only first- and early second-instar larvae can acquire tospoviruses, and only immature thrips that acquire these viruses or adults derived from such immatures are vectors. Adult thrips remain viruliferous for life; but tospoviruses are not transovarial. Tospoviruses may be disseminated over long distances in vegetatively propagated plant material; but seed infection has not been reported. Therefore, thrips population dynamics and the proximity of infected
<table>
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<th>Transmission¹</th>
<th>Other natural hosts</th>
<th>Symptoms in China aster</th>
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<tr>
<td><em>Chrysanthemum stem necrosis virus</em> (CSNV)</td>
<td>Brazil, Japan</td>
<td><em>Frankliniella occidentalis, F. schultzei</em></td>
<td>Lisianthus (<em>Eustoma grandiflorum</em>), chrysanthemum (<em>Chrysanthemum morifolium</em>), tomato (<em>Solanum lycopersicum</em>)</td>
<td>Mosaic, necrotic spot, and lines on leaves (Fig. 6)</td>
<td>Alexandre et al. (1999) and Momonoi et al. (2011)</td>
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<tr>
<td><em>Groundnut ringspot virus</em> (GRSV)</td>
<td>Brazil</td>
<td><em>F. gemina, F. intonsa, F. occidentalis, F. schultzei</em></td>
<td>Lisianthus, chrysanthemum, tomato</td>
<td>Mosaic, necrotic spots, and lines on leaves</td>
<td>Alexandre et al. (1999)</td>
</tr>
<tr>
<td><em>Tomato chlorotic spot virus</em> (TCSV)</td>
<td>Brazil</td>
<td><em>F. intonsa, F. occidentalis, F. schultzei</em></td>
<td>15 species in six plant families</td>
<td>Not determined</td>
<td>Kitajima (2015) and Polston et al. (2013)</td>
</tr>
<tr>
<td><em>Tomato spotted wilt virus</em> (TSWV)</td>
<td>Australia, Bulgaria, France, Italy, Greece, Japan, Korea, the USA</td>
<td><em>F. bispinosa, F. cephalica, F. fusca, F. gemina, F. intonsa, F. occidentalis, F. schultzei, T. palmi, T. setosus, T. tabaci</em></td>
<td>&gt;900 species in &gt;90 monocotyledonous and dicotyledonous plant families</td>
<td>Necrotic spots and ring spots and yellowing in leaves (sd) (Fig. 7)</td>
<td>Bakardjieva et al. (1998); Marchoux et al. (1991); Chatzivassiliou et al. (2000); Ishikawa et al. (2002); Kim et al. (2006); Latham and Jones (1997); Ramasso et al (1994) and Sether and DeAngelis (1992)</td>
</tr>
</tbody>
</table>

¹Transmission data from Riley et al. (2011)
reservoir plants are the determining factors in *Tospovirus* outbreaks. Momonoi et al. (2011) detected CSNV in chrysanthemum, tomato, China aster, and lisianthus in the same transplant facility and hypothesized that viruliferous *Frankliniella occidentalis* and *F. schultzei* were dispersed from chrysanthemum to China aster and other plants.
4.2.4 Management

- **Cultural practices** – Use virus-free transplants, fine mesh screening for greenhouse culture to exclude thrips, and reflective mulches in the field to disorient the vectors. Workers who handle plants should avoid wearing yellow- and blue-colored clothing which attracts thrips.

- **Sanitation** – Removal of weeds and other hosts of tospoviruses and their vectors from greenhouses and the surrounding area is essential. Momonoi (2011) reported that removal of host plants and weeds in and around a transplant facility alone was not effective for controlling CSNV. However, CSNV and thrips could be eradicated by these methods when practiced during the winter season. Similarly, Kakizaki (2005) reported that *F. occidentalis* was eradicated by the removal of a greenhouse plastic film during the winter (approximately 4 months) in Hokkaido, the northern part of Japan, presumably by cold temperatures.

- **Scouting** – Thrips populations should be routinely monitored in the greenhouse and field through the use of yellow or blue sticky cards and/or tapping foliage over white paper.

- **Insecticides** – Resistance management of the limited number of insecticides effective against the two major Tospovirus vectors, *F. occidentalis* and *Thrips tabaci*, is a major challenge (Martin et al. 2003; Reitz and Funderburk 2012; Robb et al. 1995). Therefore, insecticides cannot be viewed as a stand-alone treatment for either thrips or virus, even if resistance management regimes such as rotation and limited usage are rigorously maintained.

- **Biological control** – Biological control should be used preventively and not when thrips populations are high. Commonly used biocontrols for thrips management in greenhouses include predatory mites such as *Neoseiulus cucumeris* (formerly known as *Amblyseius cucumeris*) (Mesostigmata: Phytoseiidae); predatory bugs, *Orius* spp. (Hemiptera: Anthocoridae); and entomopathogenic nematodes such as *Steinernema feltiae* (Rhabditida: Steinernematidae) and *Thripinema nicklewoodi* (Tylenchida: Allantonematidae).

4.3 **Virgaviridae Tobacco Rattle Virus (TRV, Genus: Tobravirus)**

4.3.1 **Geographic Occurrence and Impact**
This disease has occurred in Japan, where losses in China aster of up to 63% occurred (Komuro et al. 1970), and in the USA (Florida) (Anderson 1954).

4.3.2 **Symptoms/Signs**
Symptoms of TRV vary based on the cultivar of China aster. The common symptom is concentric yellow ring spots on the foliage. Infected plants are slightly stunted. Occasionally, chlorotic chevron or vein-banding patterns on foliage or malformation of flowers occur.

4.3.3 **Biology and Epidemiology**
TRV is transmitted by nematodes in the *Paratrichodorus* and *Trichodorus* species, known as stubby root nematodes (Brown et al. 1989). TRV on China aster is reported
to be only transmitted by *Paratrichodorus minor* (syn. *Trichodorus minor*) (Komuro et al. 1970). However, TRV is not transmitted through the seeds of China aster (Komuro et al. 1970).

### 4.3.4 Management

- **Cultural practices** – Rapidly remove infected plants. Rotate crops with nonhost plants. Spinach is useful as a nematode trap plant for TRV (Komuro et al. 1970).
- **Soil disinfestation** – Reduce nematode populations by soil disinfestation using fumigation, steam, or soil solarization.

### 4.4 Additional Viral Diseases

The following viral diseases of China aster have also been reported:

- **Potyviridae**, *Bidens mottle virus* (BiMoV, genus: *Potyvirus*) (the USA, Logan et al. 1983)
- **Rhabdoviridae**, *Callistephus chinensis chlorosis virus* (CCCV, genus: *Nucleorhabdovirus*) (Brazil, Kitajima and Costa 1979)

### 5 Nematode Diseases

The following nematode diseases of China aster have been reported:

- **Foliar nematode** (*Aphelenchoides ritzemabosi*) (Germany, Burckhardt 1972)
- **Reniform nematode** (*Rotylenohulus reniformis*) (the USA, Linford and Yap 1940)
- **Root knot nematode** (*Meloidogyne incognita*) (India, Nagesh et al. 1999)

### References


Diseases of China Aster

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