FORUM: *Review, symposia, program and/or viewpoint papers.*

Management of Pests, Plant Diseases and Abiotic Disorders of *Magnolia* Species in the Southeastern United States: A Review[1]

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Abstract

The genus, *Magnolia*, encompasses a group of about 240 species of evergreen or deciduous trees and large shrubs. Magnolias are native to temperate, subtropical and tropical areas of southeastern Asia, eastern North America, Central America, the Caribbean and parts of South America. Native and nonnative *Magnolia* species have become prominent landscape plants in the southeastern U.S. due to their beauty, utility, relative ease of maintenance and broad adaptability to the region's climate and soils. Species introductions, breeding and selection programs over the last 50 years have produced superior selections with improved flowering, new flower colors and ornamental foliage and buds often featuring brown, copper or gold indumentum. Magnolia health and pest management is sometimes overlooked in both landscape and production settings because magnolia is considered to have relatively few pest and disease problems. Some abiotic disorders may mimic biotic damage or may render magnolia more susceptible to pests and diseases. When they occur, abiotic disorders, pests or diseases on magnolia can cause significant economic or aesthetic losses. This review focuses on magnolia culture in production and landscape settings with an emphasis on major pests, plant diseases and abiotic disorders affecting management of *Magnolia* species.

Index words: IPM, ornamental, disease, nursery, landscape.

Species used in this study: tuliptree (*Liriodendron tulipifera* L.); cucumber-tree (*Magnolia acuminata* (L.) L.); magnolia (*Magnolia delavayi* Franch.); lilytree (*Magnolia denudata* Desr.); banana-shrub (*Magnolia figo* (Lour.) DC.); magnolia (*Magnolia foveolata* (Merr. ex Dandy) Figlar); southern magnolia (*Magnolia grandiflora* L.); magnolia (*Magnolia insignis* Wall.); magnolia (*M. insignis* × *M. grandiflora* (hybrid)); magnolia (*Magnolia laevifolia* (Y.W.Law & Y.F.Wu) Noot.); purple magnolia (*Magnolia liliiflora* Desr.); magnolia (*Magnolia lotungensis* Chun & C.H.Tsoong); big-leaf magnolia (*Magnolia macrophylla* Michx.); Ashe's magnolia (*M. macrophylla* var. *ashei* (Weath.) D.L. Johnson); magnolia (*Magnolia maudiae* (Dunn) Figlar); saucer magnolia (*Magnolia ×soulangeana* Soul.-Bod.); star magnolia (*Magnolia stellata* (Sieb. & Zucc.) Maxim.); magnolia (*Magnolia tamaulipana* Vazquez); umbrella magnolia (*Magnolia tripetala* (L.) L.); sweet bay (*Magnolia virginiana* L.).

Significance to the Nursery Industry

The genus *Magnolia* includes species that are of major horticultural importance to the nursery and landscape industries of the southeastern United States. Magnolia health and pest management is sometimes overlooked in both landscape and production settings because magnolia is considered to have relatively few pest and disease problems. This review of biotic (insects and diseases) and abiotic (environmental) factors provides a comprehensive overview of magnolia culture in production and landscape environments, focusing on environmental factors and pests that can significantly injure or detract from plant value and aesthetics. This review will directly apply to Green Industry professionals who grow, sell, install and maintain magnolia in production and landscape settings in the southeastern U.S.

Introduction

The genus *Magnolia* encompasses a group of about 240 species of evergreen or deciduous trees and large shrubs (3). Magnolias are native to temperate, subtropical and tropical areas of southeastern Asia, eastern North America, Central America, the Caribbean and parts of South America extending south to southeastern Brazil (4). These plants characteristically have showy flowers that are white, pink, red, purple, green or yellow. Each flower is followed by a showy red or pink follicetum, a woody aggregate of carpels often called a 'cone.' When ripe, the carpels dehisce to display red, orange or pink seeds, each of which hangs from the fruit by a thread-like strand (14).

Magnolia is one of two genera currently recognized in the Magnoliaceae family, the other being *Liriodendron* spp. L. Molecular systematics and re-examination of morphological characters resulted in all Magnoliaceae genera other than *Liriodendron* (i.e., *Michelia* and *Manglietia*) being combined into *Magnolia* (27). The Magnoliaceae family is ancient with fossil remains dating between 36 and 58 million years (14). Thus, surviving magnolia species represent some of the

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more primitive angiosperms. Magnolia flowers do not have true petals and sepals but are composed of petal-like tepals. Flowers do not produce true nectar, but attract pollinating beetles in the *Nitidulidae* family with fragrant, sugary secretions. Magnolia flowers are primarily pollinated by beetles, in part because magnolias evolved long before bees and other flying pollinators.

Plant care and culture. Magnolias grow best in moist, well-drained, slightly acid soils but neutral to slightly alkaline soils are also suitable for growth (4). Magnolias are adaptable to clay, loam or sand soils, but most grow poorly in wet or poorly drained soils. Plants grown in warm or dry climates benefit from planting locations shaded from afternoon sun, although magnolias can tolerate full sun and heavier soils. Well-established plants are moderately tolerant of dry periods.

Landscape and other uses. Magnolias have been harvested for timber and medicinal uses but are usually cultivated for their beautiful flowers, fruits, foliage and plant forms (14). Asians have long cultivated spring-blooming *Magnolia denudata* Desr., *Magnolia liliiflora* Desr., *Magnolia stellata* (Sieb. & Zucc.) Maxim. and others for their flowers (33). These Asian species were first introduced to Europe and America in 1780, stimulating intensive breeding programs to develop more floriferous and hardy forms with a wider range of flower colors. The hybrids and selections produced by these breeding programs, still ongoing, resulted in many superior ornamentals that are some of the most widely grown flowering trees in the U.S. (14).

Other magnolias are grown for their value as specimen, street or shade trees. For example, the native American tree, *Magnolia grandiflora* L., was introduced to Europe by 1731 and quickly became popular because of its glossy evergreen foliage, large beautiful flowers and elegant form (33). *Magnolia grandiflora* also was found to be widely adaptable to different climates, soils, and exposures. Thus, it was the first magnolia to be planted widely as a street or shade tree and is now grown nearly worldwide wherever suitable climate and soils exist.

Magnolia spp. have become prominent landscape plants in the southeastern U.S. due to their beauty, utility, relative ease of maintenance and broad adaptability to the region's climate and soils. Species introductions, breeding and selection programs over the last 50 years have produced superior selections with improved flowering, new flower colors and ornamental foliage and buds often featuring brown, copper or gold indumentum.

A 2011 review of a commercial plant locator resource identified a number of *Magnolia* spp. that are widely produced by commercial nurseries in the southeastern states of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas and Virginia (2). *Magnolia grandiflora* is the most widely grown (168 nurseries) because its cultivars are heavily favored for landscape use. Other species produced by many growers are *Magnolia virginiana* L. (65 nurseries) and *M. stellata* cultivars and hybrids (47 nurseries). Only 16 nurseries produce *Magnolia ×soulangeana* Soul.-Bod. and cultivars derived from complex hybrids of this and other deciduous species (i.e., *Magnolia* 'Jon Jon'); just six nurseries produce *Magnolia figo* (Lour.) DC (=*Michelia figo*). New yellow-flowered hybrids derived from *Magnolia acuminata* (L.) L. are attracting great interest but are grown by only five nurseries. Less widely known natives such as *Magnolia macrophylla* Michx. and *Magnolia tripetala* (L.) L. are rarely produced, each listed by a single nursery, and *M. macrophylla* var. *ashei* (Weath.) D.L. Johnson is grown by two nurseries. Of the more recently introduced Asian species such as *Magnolia laevifolia* (Y.W. Law & Y.F. Wu) Noot. (=*Magnolia dianica=Michelia yunnanensis*), *Magnolia insignis* (Wall.) Blume S (=*Manglietia insignis*) and *Magnolia maudiae* (Dunn) Figlar (=*Michelia maudiae*), only the latter is currently produced and by just one nursery.

Pests and Plant Diseases

Most magnolias are considered to be 'trouble-free' with few pests and plant diseases (21). Held (43) found *M. grandiflora*, *M. ×soulangeana* and *M. virginiana* were resistant to Japanese beetle (*Popillia japonica*), as are *Magnolia* spp. in general (53). Similarly, *M. ×soulangeana* exhibited host plant resistance to *Lymantria dispar* (Linnaeus) (gypsy moth; Lepidoptera: Lymantriidae) by losing less than 4% of its foliage in a study of gypsy moth feeding and defoliation of 21 shade and flowering trees (70). In feeding preference choice test studies with eight woody taxa, *M. grandiflora* was not consumed by adult *Phyllophaga ephilida* (Say) (June bug; Coleoptera: Scarabaeidae) (20). Phytochemicals in *Magnolia* spp. show a wide range of biological activity. Phenolics and neolignans are among the magnolia compounds with antimicrobial, nematicidal and insecticidal properties (51, 58, 64). Other magnolia compounds act as attractants of natural enemies (6).

Nonetheless, a wide array of pests and diseases are reported on *Magnolia* spp. in the southeastern United States. Table 1 lists pest-specific insecticidal activity and Insecticide Resistance Action Committee (49) codes for use in developing a pesticide rotation plan to manage key pests of magnolia. Table 2 lists labeled fungicidal active ingredients and Fungicide Resistance Action Committee (28) codes to help managers integrate plant disease control within a pesticide rotation plan for magnolia. Table 3 shows life stage and seasonal activity of primary pests of magnolia based on normal monthly occurrence in USDA Plant Hardiness Zone 8.

Arthropods

Wood boring insects, soft scales, foliar feeders and leafminers are the primary arthropod pests of magnolia.

Wood boring pests. Magnolia root borer, *Euzophera magnolialis* Capps (Lepidoptera: Pyralidae), is a wood boring pest with larvae that feed on 6 mm (0.2 in) and larger magnolia roots and tunnel approximately 15 cm (6 in) upward into the trunk above the crown (56). The resulting girdling injury can injure and even kill nursery seedlings (56, 67, 72). Root feeding may be in a spiral pattern, causing affected roots to have a candy cane-patterned injury (56). Initial plant decline is induced by larval feeding that limits root function including nutrient and water uptake. Adult moths live approximately 10 days (56) and adults and larvae are often difficult to detect. They are more of an economic threat to magnolias under nursery production, rather than in an urban landscape setting (56). Eggs may be deposited on the tree bark (a single female laid about 400 eggs under laboratory

Table 1. Pest-directed insecticidal activity and Insecticide Resistance Action Committee (49) codes for use in developing a pesticide rotation plan to manage key pests of magnolia. Check current products for labeled pesticides, sites for control and plant[z] and pest species.

Active ingredient	IRAC Code	Foliar feeders & leaf miners	Soft scales	Armored scales	Wood borers	Thrips
Abamectin	6	*N/A*[y]	*N/A*	*N/A*	*N/A*	Y[x]
Acephate	1B	Y	Y	Y	*N/A*	Y
Acetamiprid	4A	Y	Y	Y	*N/A*	Y
Azadirachtin	*unk.*[w]	Y	Y	Y	*N/A*	Y
Bacillus thuringiensis	11	Y	*N/A*	*N/A*	*N/A*	*N/A*
Beauveria bassiana: BotaniGard	*nr*[v]	Y	Y	Y	*N/A*	Y
Bifenthrin	3A	Y	Y	Y	Y	Y
Buprofezin	16	*N/A*	Y	Y	*N/A*	*N/A*
Carbaryl	1A	Y	Y	Y	*N/A*	Y
Chlorpyrifos	1B	Y	Y	Y	Y	Y
Clothianidin: *Arena*	4A	Y	*N/A*	*N/A*	*N/A*	*N/A*
Cyfluthrin: *Decalthlon*	3+4A	Y	Y	Y	*N/A*	Y
Cyfluthrin + Imidacloprid	3A	*N/A*	Y	Y	*N/A*	Y
Diazinon[u]	1B	Y	Y	Y	*N/A*	Y
Dimethoate	1B	Y	Y	Y	*N/A*	Y
Dinotefuran	4A	*N/A*	Y	Y	*N/A*	Y
Esfenvalerate	3A	Y	Y	Y	*N/A*	Y
Flonicamid	9C	*N/A*	F	F	*N/A*	Y
Horticultural oil	*nr*	Y	Y	Y	*N/A*	Y
Imidacloprid	4A	*N/A*	Y	Y	*N/A*	Y
Insecticidal soap	*nr*	Y	Y	Y	*N/A*	Y
Kinoprene	7A	*N/A*	Y	Y	*N/A*	Y
Lambda-Cyhalothrin	3A	Y	Y	Y	*N/A*	Y
Malathion	1B	*N/A*	Y	Y	*N/A*	Y
Methiocarb	1A	*N/A*	Y	Y	*N/A*	Y
Neem oil extract	18B	*N/A*	Y	Y	*N/A*	Y
Novaluron	15	Y	*N/A*	*N/A*	*N/A*	Y
Permethrin	3A	Y	*N/A*	*N/A*	Y	Y
Pyriproxifen	7C	*N/A*	Y	Y	*N/A*	*N/A*
Spinosad	5	Y	Y	Y	*N/A*	Y
Tau-Fluvalinate	3A	Y	Y	Y	*N/A*	Y
Thiamethoxam	4A	*N/A*	Y	Y	*N/A*	Y

[z]Check labels carefully to ascertain if any ornamental phytotoxity has been reported and test on a small portion of ornamental plants before spraying the entire nursery crop or range.

[y]*N/A* = Not available for use.

[x]Y = a product with this active ingredient is labeled for use on the pest indicated.

[w]*unk.*= unknown mode of action.

[v]*nr* = not required to have an IRAC code.

[u]Diazinon is no longer available in the market.

conditions) from the crown up to 1.5 m (~ 4.9 ft) (56) and larvae tunnel down to feed on tree roots. As larvae mature, they migrate up toward the crown and begin tunneling beneath bark to pupate. In Florida and the deep southern U.S., *E. magnolialis* has at least two generations per year, where adult moth flight activity occurs from February through April and again from June through August (56, 72).

Management. High fertilization and irrigation rates in nurseries may mask plant injury by allowing adventitious roots to overcome damage symptoms and plant stress (72). If first order lateral, or structural, roots are compromised, root systems may only persist shallowly once trees are planted in the landscape, yielding poor structural support to the mature tree. Information about pesticide efficacy against this insect is limited. The extent to which biological control may be effective is unknown. Root and crown drenches with a systemic insecticide labeled for borers may provide some control.

Wood boring pests. Exotic ambrosia beetles, primarily *Xylosandrus crassiusculus* Motschulsky (granulate (formerly Asian) ambrosia beetle) and *Xylosandrus germanus* Blandford (black stem borer), (Coleoptera: Curculionidae), attack over 100 tree species and are among the most damaging pests of nursery-grown trees and some shrubs (1, 5, 17, 45, 66). These insects are noted as occasional pests of magnolia (54). Female beetles are 2–3 mm (0.08–0.12 in) in length, with males much smaller. Both genders range in color from reddish-brown to black depending on species (5). They become active in early spring, and monitoring is typically needed before leaf flush of deciduous shade trees (66). Ambrosia beetles bore into host tree trunks and excavate galleries in the heartwood where adult females deposit eggs and larvae develop (45, 88). Female ambrosia beetles inoculate trees with symbiotic ambrosia fungus on which the larvae feed (5, 7). After approximately 60 days, mature female beetles mate with their brothers and emerge from the galleries to find new hosts. Although *X. crassiusculus* and *X. germanus* are capable of producing three generations per year in the southern U.S., for reasons that are not understood, plant injury is primarily inflicted by the first generation.

Xylosandrus crassiusculus and *X. germanus* typically attack small caliper [< 9 cm (3.5 in) diameter] tree trunks and branches (22). *Xylosandrus germanus* ranges from central

Table 2. Labeled fungicidal active ingredients and Fungicide Resistance Action Committee (28) codes to help pest managers integrate plant disease control within a pesticide rotation plan for magnolias[z]. Efficacy and phytotoxicity data available are largely unavailable for magnolia species and cultivars.

Active ingredient	FRAC code	Plant pathogen(s) managed[y]
Azoxystrobin	11	Anthracnose; powdery mildew
Bacillus subtilis strain QST 713	44	Anthracnose; powdery mildew
Calcium Polysulfides	*n.l.*[x]	Powdery mildew
Chloropicrin	8B	Phytophthora
Chlorothalonil + Thiophanate Methyl: Spectro 90 WDG	M5[w] + 1	Anthracnose; powdery mildew
Clove oil + Rosemary oil + Thyme oil: *Sporatec*	*n.l.*	Anthracnose; powdery mildew
Copper	M1	Bacterial spot; bacterial blight; anthracnose; powdery mildew
Corn oil + Cotton seed oil + Garlic oil: *Mildew Cure*	*n.l.*	Powdery mildew
Hydrogen dioxide		Phytophthora
Mancozeb	M3	Anthracnose
Metconazole	3	Anthracnose; powdery mildew
Myclobutanil	3	Anthracnose; powdery mildew
Neem oil: *Trilogy*	*n.l.*	Anthracnose; powdery mildew
Polyoxin D zinc salt	19	Anthracnose; powdery mildew
Potassium bicarbonate	*n.l.*	Anthracnose; powdery mildew
Potassium phosphite	*n.l.*	Anthracnose; powdery mildew
Potassium phosphate	*n.l.*	Powdery mildew
Potassium phosphate + sulfur: *Sanction*	*n.l.* + M2	Powdery mildew
Potassium silicate	*n.l.*	Powdery mildew
Propiconazole	3	Anthracnose; powdery mildew
Reynoutria sachalinensis extract: *Regalia*	P[v]	Anthracnose; powdery mildew
Sulfur	M2	Powdery mildew
Tebuconazole	3	Anthracnose; powdery mildew
Thiophanate methyl	1	Anthracnose; powdery mildew
Triadimefon	3	Powdery mildew
Trifloxystrobin	11	Anthracnose; powdery mildew

[z]Check labels carefully to ascertain if any ornamental phytotoxity has been reported and test on a small portion of ornamental plants before spraying the entire nursery crop or range.

[y]Plant disease management information for magnolia derived from the ornamentals category within the CDMS Database (15, 25).

[x]*n.l.* = FRAC code not listed; not required to have a FRAC code, or mode of action unknown.

[w]'M' category modes of action have multi-site activity.

[v]'P' category modes of action acts to induce the host plant's defense mechanisms.

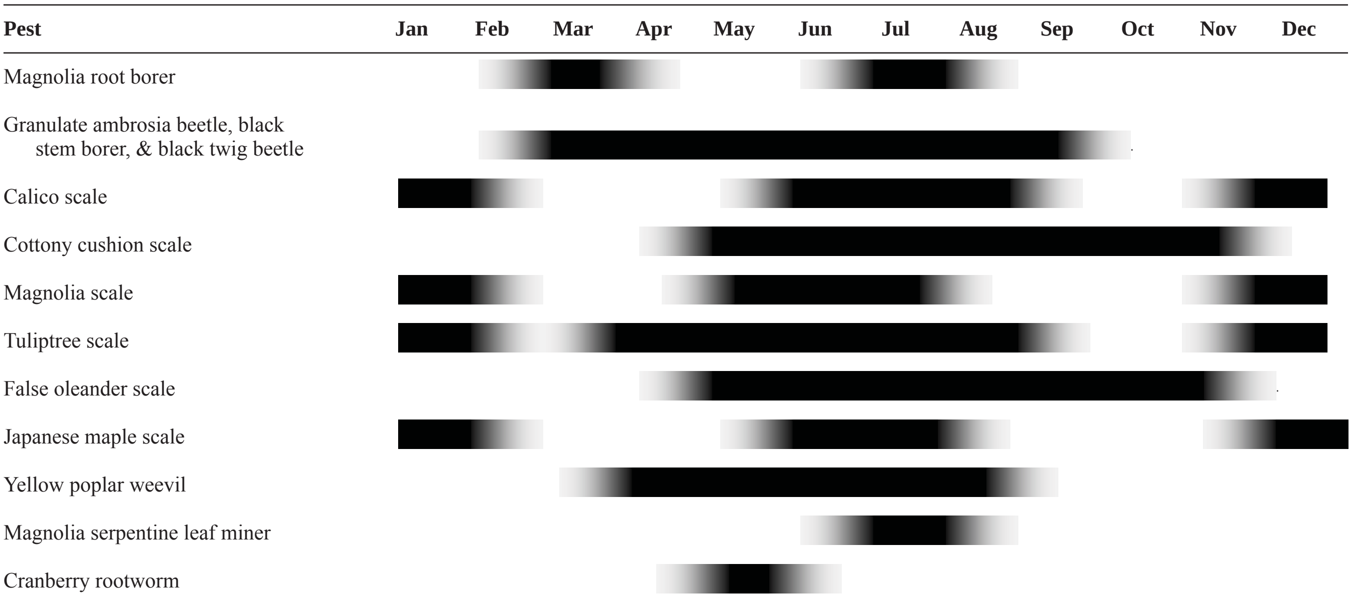
Georgia, and possibly north Florida, north to Connecticut (22). Attacks by these wood boring beetles occur most heavily within 1 m (39 in) of the base of the trunk and are rare on smaller diameter branches above the first scaffold branches (66). Damage is characterized by 'frass tooth picks,' mixtures of sawdust and excrement, that are pushed out of holes as beetles excavate their galleries. The diagnostic value of these is short lived as they are easily dislodged by wind, rain, and irrigation, thus exposing a 1 mm (0.04 in) round hole. Infested plants die or become unmarketable from boring damage or infection by a secondary pathogen (11).

Xylosandrus compactus Eichhoff (black twig beetle; Coleoptera: Curculionidae) is an occasional pest of magnolias and more than 200 other plant species (22). Injury may be inflicted on otherwise healthy plants, particularly in twigs less than 2 cm (0.8 in) diameter, and can limit plant growth and affect aesthetic losses (22). Cankers may be observed on larger twigs and branches that extend 10 to 210 mm (0.4–8.3 in) away from the 0.8 mm (0.03 in) entry holes that indicate the point of occurrence (22). Populations of these beetles may be encountered in the southeastern U.S. along the coastal plain from Florida to North Carolina and west to Texas (22, 90). Adult male and female *X. compactus* are generally smaller than *X. crassiusculus* and *X. germanus* and are dark brown to black (22). Within excavated twig galleries, females establish brood galleries either individually [typically in twigs smaller than 7 mm (0.3 in) diameter] or in groups of up to 20 females [in twigs and branches ranging between 8 and 22 mm (0.3–0.9 in)]. Development from egg stage to adulthood takes about 28 days at 25C (77F) (22). Adults overwinter within damaged twigs (90) and emerge during the first warm days in spring with highest population levels found between June and September (22).

Management. Effective ambrosia beetle management begins with monitoring adult flight with ethanol-baited traps which can be constructed by growers (73). Optimal trap height of *X. germanus* and *X. crassiusculus* is > 0.5 m (20 in) and < 1.7 m (67 in), respectively, to capture first adult flight (74). To limit *X. compactus* populations, prune and destroy infested twigs and branches from affected host plants (22). When adult beetles are captured, growers can protect their trees by spraying susceptible tree trunks with pyrethroids, such as permethrin or bifenthrin, every 2 to 4 weeks, preventing beetles from boring into the tree. It is recommended that growers avoid spraying tree canopies because this wastes insecticide, negatively affects natural enemies and can result in secondary outbreaks of other arthropod pests (e.g., 29). Once beetles are inside trees there is no effective control and infested trees should be removed and destroyed (5).

Soft scale pests. Cottony cushion scale, *Icerya purchasi* Maskell (Homoptera: Margarodidae), is found in the western U.S., as well as along the Gulf Coast and eastern U.S. states

Table 3. **Life stage and seasonal activity of primary pests of landscape and nursery field-grown magnolias based on normal monthly occurrence in USDA Plant Hardiness Zone 8. It is important to note that the activity of each pest may vary outside of Zone 8 and may differ depending upon exposure to cooler and warmer microclimates, including polyhouse nursery structures, within Zone 8. Faded portions of bars indicate periods of frequent seasonal variability necessitating active monitoring to detect first and final pest activity.**



as far north as North Carolina (50). Winter temperatures of –12C (about 10F) may limit spread of cottony cushion scales in landscapes and nurseries. Individuals may persist season-long if protected in propagation structures and greenhouses (8). Immature cottony cushion scales reduce vigor of host plants, including *Magnolia* spp., by piercing plant tissues and sucking out sap (8, 50). Heavily infested plant foliage becomes chlorotic and often darkened by excreted honeydew and resultant sooty mold. Leaves and fruit on heavily infested plants may drop prematurely following abiotic (environmental) or other stressors.

Cottony cushion scale is often obscured by exuded wax that helps to protect the insect from predation and direct pesticide contact. Hidden beneath the wax, adult females are approximately 4.5 mm (0.2 in) long and rusty red with black legs and antennae. Male cottony cushion scales are approximately 3 mm (0.12 in) long and slender. Adult male scales are uncommon and, when present, are reddish-purple insects that have metallic blue wings (8). Cottony cushion scales have approximately two generations per year in northern areas with three and more generations possible in southern U.S. areas.

Female cottony cushion scales can be diagnosed by the presence of 9.5 mm (⅜ in) long ridged egg sacs, or ovisacs, formed from waxes extruded from the underside of the female body. The ovisac contains hundreds of reddish oval eggs that may hatch to crawlers within 3 weeks (in summer) to 8 weeks (in winter) of being laid. All three nymphal instars are mobile as crawlers, seeking leaves and twigs to feed on, and upon hatching, can travel up to 0.9 m (3 ft) in 10 minutes (8). Adult female scales may live 2 to 3 months and may not need to feed after beginning to lay eggs. They are capable of producing ovisacs and laying eggs after moving from the host plant.

Calico scale, *Eulecanium cerasorum* (Cockerell) (Homoptera: Coccidae), adults and nymphs are insect pests that are readily visible on branches and leaves, giving trees a bumpy appearance under heavy infestation (50). Adults are rounded and globular, about 6–8 mm (0.24–0.31 in) long, and at maturity, are checkered in a white and dark brown 'calico' pattern. Nymphs are small, cream colored ovals. Scale feeding on phloem sap results in excreted honeydew that accumulates beneath infested trees. Calico scale feeding activity, as well as the sooty mold that grows on honeydew, can result in reduced tree vigor, premature leaf abscission and branch dieback. These symptoms and causal biotic stressors predispose infested trees to increased abiotic (environmental) stress (48, 55).

Calico scales have one generation per year. Juveniles overwinter as second instar nymphs on bark. Females can generate up to 4,600 eggs each, which remain protected beneath the female body until crawlers emerge. Egg laying begins about late April in Kentucky and eggs hatch synchronously about mid May, following ~818 C degree day accumulation (at base 4.4C, or about 40F) (47). Crawlers disperse during the following 2 to 3 weeks to feed on abaxial leaf surfaces. After initial feeding through late September to mid October (in Kentucky), nymphs migrate back to bark on the central leader to overwinter (47).

Magnolia scale, *Neolecanium cornuparvum* (Thro) (Homoptera: Coccidae), is an insect pest native to the United States that, at about 8–10 mm (0.3–0.4 in) [and up to 13 mm (0.5 in)] long, is one of the largest scale insects encountered in U.S. landscapes and nurseries (44, 87). *Magnolia stellata*, *M. acuminata*, *M. liliiflora* and *M. ×soulangeana* are preferred host plants of this pest (44, 50, 86). Magnolia scales produce copious amounts of honeydew. Feeding removes photosynthate and induces cell necrosis due to phytotoxic saliva. Heavy scale infestations can cause branch death, loss of tree vigor, eventual tree decline and death (83, 86).

Magnolia scales pass through a single generation per year, overwintering as 1st instar nymphs that are elliptical and slate gray in color, often gathering in masses along the undersides of 1- to 2-year twigs (50). In New York, 1st instars molt approximately late April or early May, and the 2nd instars molt during early June (50). By July in Ohio and Kentucky (10, 81) or August in New York and Pennsylvania (50, 59), the large, cream-to-yellow females have live-borne the next generation of scale nymphs. Newly hatched nymphs are mobile for a short time, and then settle to feed on the semi-hardwood new growth of host plant twigs.

Tuliptree scale, *Toumeyella liriodendra* (Gmelin) (Homoptera: Coccidae), is a significant insect pest of yellow poplar (*Liriodendron tulipifera* L.) in silviculture and landscapes, as well as to *Magnolia* spp. in landscapes and nurseries (46). Scales feed on all stages of seedling, sapling and poletimber yellow poplar trees, reducing tree vigor and health, and causing distortion and death of infested trees (13). Tuliptree scales are large: about 7 mm (0.3 in) in diameter, and light gray-green to pinkish orange ovals mottled with black (46). *Toumeyella liriodendra* overwinters as second instar nymphs, resume feeding in spring and mate in June. Females give live birth to approximately 3,000 crawlers beginning in August (46). Females produce copious amounts of honeydew from June through August (13). Nymphs are dark reddish and about 0.5 mm (0.02 in) long and may be dispersed by crawling, as well as via wind and transfer on plumage of songbirds (46). There is only one generation per year (13, 46).

Management. Twigs and branches can be inspected for soft scale nymphs and adults in spring, before leaf emergence, as well as when honeydew and sooty mold are observed. When foliage is present, inspect the main leaf veins and use double-sided tape wrapped around a twig to monitor emergence of tiny crawlers whereupon horticultural oils may be used for control (48, 55). For small populations, larger-bodied scale insects like wax scale, magnolia scale, and calico scales can be removed by hand before crawlers hatch. Severely infested branches can be pruned and destroyed. Heavy infestations may require chemical foliar sprays, soil drenches and granular systemic insecticide treatments to manage plantings. Sprays should be directed toward stems, branches and leaf undersides.

Dormant-season horticultural oils can be applied to magnolias while they are dormant in winter and early spring (59). Summer oil treatments can be made to control eggs, crawlers and immature instars on actively growing trees and shrubs. Control with oil is likely achieved both through impaired respiration and disruption of cellular membranes in treated arthropods. Crawler stages can be treated with acephate, azadirachtin, buprofezin, carbaryl, chlorpyrifos, cyfluthrin, cyfluthrin plus imidacloprid, deltamethrin, dinotefuran, horticultural oil, imidacloprid, insecticidal soap, lambda-cyhalothrin, neem oil extract and thiamethoxam insecticides (81, 59). Repeated insecticide applications based on label guidelines may be necessary regardless of the pesticide chosen. Use of spreader-stickers, including summer horticultural oil that can be used at 5 $mL \cdot liter^{-1}$ (2 $qt \cdot 100\ gal^{-1}$), is recommended to improve scale control by helping pesticides penetrate the waxy ovisac and scale covering. Horticultural oils themselves are moderately toxic to scales, and may also help disperse sooty mold (8).

Broad spectrum insecticides, including acephate, carbaryl, cyfluthrin, deltamethrin, imidacloprid and lambda-cyhalothrin may result in non-target kill of beneficial arthropods. When natural enemies including ladybird beetles, predatory mites and parasitic wasps are present, and if parasitized scales are apparent, azadiractin, horticultural 'summer' oil, insecticidal soap and neem oil extract may be good choices to preserve biological controls in the production system.

Predators and other biological control organisms, including green lacewing (Chrysopidae: Neuroptera) adults and larvae may be enhanced by using sticky bands to limit ant access to scales in landscape plants. This strategy successfully limited population growth of magnolia scale (87). For this reason, avoid broad spectrum and contact insecticides when natural enemies are present. Some scale insects, including calico scales, may be suppressed by supplementing populations of biological control organisms including many different predators and parasitoid species. Curative efficacy by biological controls for calico scales in landscapes and nurseries, however, has not been sufficiently tested (48, 55). By contrast, cottony cushion scale has relatively few known predators and parasites. Commercially available vedalia beetles [*Rodolia cardinalis* (Mulsant), Coleoptera: Coccinellidae] effectively control cottony cushion scales when temperatures are warm, but are susceptible to insecticides and may become non-target casualties following foliar pesticide applications (8). A parasitic fly from Australia, *Cryptochaetum iceryae* (Williston) (Diptera: Cryptochaetidae), has been introduced to control cottony cushion scale. Whether the fly has successfully become established or is effective at controlling *I. purchasi* in mid southern states has not been determined (8). Tuliptree scales have several reported predators including a predaceous moth larvae, *Laetilia coccidivora* (Comstock) (Pyralidae: Phycitinae), a ladybird beetle [*Hyperaspis proba proba* (Say)] (Coccinellidae: Scymninae) and syrphid fly (*Baccha costata* Say) (Diptera: Syrphidae) (13).

Armored scale pests. False oleander scale (sometimes referred to as magnolia white scale), *Pseudaulacaspis cockerelli* (Cooley) (Homoptera: Diaspididae), is an armored scale insect pest of Chinese origin that is commonly encountered on foliage of many ornamental *Magnolia* spp. (19, 38, 50). Foliage of affected plants can be scouted by looking on both upper and lower leaf surfaces for the pear-shaped, slightly convex, yellow-brown scale exuviae, or coverings. The shiny, white female 'armor' may extend 2 to 3 mm (0.08–0.12 in) in diameter and is composed of secreted waxes and cast skins. Males are smaller, at about 1 mm (0.04 in) in diameter (19, 38). Feeding injury may be apparent as chlorotic spots on the upper leaf surface with scales attached to the adaxial leaf surface. Heavy infestations of false oleander scale may lead to premature leaf drop and loss of host plant vigor (38). False oleander scales are present year-round where encountered, and controlled greenhouse studies indicate that a single generation can complete development within approximately five weeks (80).

Japanese maple scale, *Lopholeucaspis japonica* Cockerell (Hemiptera: Diaspididae), is a small, oyster shell-shaped, armored scale purportedly introduced into the United States from Asia. Japanese maple scale is currently found throughout the eastern half of the U.S., including portions of CT, DE, GA, KY, MD, NC, NJ, PA, RI, TN, VA and Washington, DC (35). Japanese maple scale has a wide host range that includes *Magnolia* spp. (32). Japanese maple scale infestation can cause branch dieback and even plant death, although plant death is uncommon. While not subject to quarantines, *L. japonica* infestation has caused nursery crop shipments to be rejected. Because Japanese maple scale is small and easily overlooked, infestations are often heavy and spread over a significant portion of a nursery before the pest is detected.

Japanese maple scales overwinter as immature nymphs on trunks and branches, maturing in spring (60). Two generations per year are typical in the mid southern U.S. First generation crawlers emerge in mid May, and the second generation in early August (32, 35). Lavender crawlers are very small and typically require 16× or greater magnification to detect. Management efforts are complicated by the extended crawler hatch for Japanese maple scale that results in overlapping first and second generations (32, 35) and rapid waxy development, beginning approximately 3 days after hatch (32). In Kentucky, crawler hatch coincides with flowering of *Syringa reticulata* (Blume) H. Hara 'Ivory Silk' (tree lilac) and *Hydrangea quercifolia* W. Bartram (oakleaf hydrangea) (32). In Maryland, first generation crawler activity began at 795C degree day accumulation (at base 4.4C, or about 40F) (GDD) and peaked at 1144 GDD while the second generation started at 2200 GDD and peaked at 3037 GDD (35).

Japanese maple scale adults and crawlers can be challenging to detect and are most readily observed on bark of dormant deciduous host plants. They can also be found on developing magnolia fruit and leaves. Managers may need to pull aside branches of densely branched trees and shrubs when scouting. The waxy coating on the body of male and female adult *L. japonica* scales is white and female body, eggs and crawlers are lavender.

Management. Like other armored scale insects, mature false oleander and Japanese maple scales are difficult to control. Armored scale insects do not produce honeydew, therefore sooty mold will not be present as a scouting cue. Dense plant canopies can be difficult to successfully treat for scale insects because the canopy interferes with adequate spray penetration and application uniformity. Pruning practices may need to be adjusted to open canopies and enable greater spray penetration. Water sensitive paper should be used to ensure that pesticide applications are reaching infested portions of the plant. Pesticides, including horticultural oils that conserve natural enemy populations, are best timed to crawler emergence. Egg hatch and crawler activity can be monitored with double-sided sticky tape. Because dead scales do not fall from plants once treated, efficacy of pesticide applications must be assessed. Crushing the waxy coating will cause guts to extrude from live scale. An in-field assessment can be difficult with these scales due to their small size. It may be necessary to determine mortality by clipping an infested twig or branch and flipping the scale upside down under a hand lens or microscope to expose the body. Dead scales are shriveled and papery. Live scales are firm and plump. Acephate, bifenthrin, diazinon, fenoxycarb (against immature scales only), horticultural oils, and malathion have been effective at managing scale insects on ornamental plants, including control of false oleander scale populations (57).

Foliar feeders and leafminers. Yellow poplar weevil, (*Odontopus calceatus* Say) (Coleoptera: Curculionidae), is also known as the sassafras weevil, magnolia leafminer and tuliptree leafminer. It is widespread throughout the eastern U.S. Larvae feed on leaves and buds of tuliptree (*L. tulipfera*) and both *M. virginiana* and *M. grandiflora* (12, 50). Heavy infestations can lead to apical meristem death resulting in multiple stem leaders that emerge below a damaged bud or branch and, in severe infestations, defoliation of the canopy. Weakened and malformed trees may become liabilities in the landscape or production environment. Populations have occasionally reached damaging levels in *L. tulipifera* orchards and mature trees within the Appalachian Mountain region (12, 42).

Adult yellow poplar weevils are about 2.5 mm (0.1 in) long, rounded and dark brown or black. Beetles overwinter in leaf litter beneath host plants and emerge with warm daytime temperatures to begin feeding in late March and early April, chewing notches and holes in expanding leaves and buds. In late April and early May, eggs are laid on leaf undersides along the mid-vein (12). Weevil larvae feed as leafminers, inflicting initial feeding injury in late April through May. Early larval feeding causes blotch mines that may contain up to nineteen white, legless larvae (12). Most larval feeding occurs in May, after which larvae pupate within the mine. Leaves with mines may look scorched. Adults continue to feed, causing significant injury into summer (12) and until August in Mississippi (42). *Odontopus calceatus* has one generation per year in the Ohio River Valley (12).

Magnolia serpentine leaf miner, *Phyllocnistis magnoliella* (Thro) (Lepidoptera: Gracillariidae), is widespread throughout the eastern U.S. and larvae feed within leaves of both sweet bay (*M. virginiana)* and southern magnolia (*M. grandiflora*) (24). After hatching, larvae feed beneath the leaf epicuticle cutting three or four tight spirals before extending the feeding gallery across the leaf in a winding, serpentine pattern that ends near the edge of the leaf. Pupation occurs within the mine and puparia are often located near leaf margins. Pupae may be the overwintering state of this caterpillar pest (23). Affected leaf tissues become necrotic, scorched-looking and curled. Larvae are active and mines are apparent on *M. virginiana* by early July in Maryland and North Carolina (34, 69). Adult moths are dark colored and nondescript and are active in late July in Florida (23, 62), where at least two overlapping generations per year have been reported (62).

Cranberry rootworm, *Rhadopterus picipes* (Olivier) (Coleoptera: Chrysomelidae), occurs east of the Mississippi River and has an extremely broad host plant range including *M. virginiana* and other *Magnolia* spp. Adult beetles are about 5 mm (0.2 in) long, dark brown and shiny. Adults are univoltine and emerge from late April to mid May in Mississippi (39, 50, 65). Adults are nocturnal feeders, hiding in leaf litter and debris during the day. Adults feed for approximately two weeks after emergence, and thereafter seek refuge in leaf litter where eggs are deposited (65).

Management. Late spring frosts may kill larvae and adult yellow poplar weevils that have emerged from overwintering sites. Known natural enemies of this pest include two pteromalid wasps [*Heterolaccus hunter* (Crawford) and *Habrocytus peircei* Crawford], two eulophid wasps [*Horismenus fraternus* (Fitch) and *Zagrammosoma multilineatum* (Ashmead)], and an ichneumonid wasp, *Scambus hispae* (Harris) (12). Parasitic wasps *Zagrammosoma multilineatum* (Ashmead) and *Sympiesis* sp. have been reared from parasitized *Phyllocnistis magnoliella* Chamb. pupae collected in Gainesville, FL (23). Entomopathogenic nematodes including *Heterorhabditis bacteriophora* Poinar and *Steinernema* *scarabei* (Stock & Koppenhöfer) have shown some potential for cranberry rootworm control (71, 84).

Insecticides labeled for beetles and caterpillars that feed on leaves may provide some control of yellow poplar weevils. Foliar applications of acephate or imidacloprid may be effective against magnolia serpentine leaf miner (34, 79). Limited work has been done to assess pesticide efficacy against magnolia serpentine leaf miner in magnolia. Pesticides including carbaryl, imidacloprid, permethrin and spinosad may provide control when cranberry rootworm beetles are feeding. Applications should also be directed toward leaf litter and debris beneath the affected plant where nocturnal beetles hide. Broad spectrum pesticides may reduce natural enemy populations in the nursery and landscape.

Minor and Nuisance Pests: Nematodes and Thrips

Magnolia spp. are hosts of sting nematodes (*Belonolaimus* sp. Steiner) that cause roots to darken and rot (37). Unknown nematodes have been found on some *Magnolia* spp. (76). Other studies found various *Magnolia* spp. were tolerant or resistant to many root knot nematodes (*Meliodogyne* sp.). Santamour and Reidel (77) inoculated seedlings of 23 tree taxa with four common root knot nematode species [*Meliodogyne arenaria* (Neal) Chitwood races 1 and 2, *Meliodogyne hapla* Chitwood, *Meliodogyne incognita* Kofoid and White and *Meliodogyne javanica* (Treub) Chitwood] and found *M. grandiflora* was resistant to all four nematode species. In greenhouse tests with 35 taxa, Bernard and Witte (9) found *M. ×soulangeana* 'Alexandrina' did not act as a host of *Meliodogyne hapla*, the primary root knot nematode of woody ornamentals in Tennessee.

Caliothrips striatus Hood (Thysanoptera: Thripidae) is a North American native thrips ranging throughout the eastern United States (89). A recent study by Tyler-Julian et al. (82) found *C. striatus* hosts included the native *L. tulipifera*, *M. grandiflora* and *M. virginiana* and the non-native *Magnolia delavayi* Franch., *Magnolia foveolata* (Merr. ex Dandy) Figlar, *M. insignis* × *M. grandiflora* (hybrid), *M. laevifolia*, *Magnolia lotungensis* Chun & C.H. Tsoong, *M. maudiae* and *Magnolia tamaulipana* Vazquez. Drought is believed to have forced this thrips to move from natural areas into formal gardens and production areas (26). Damage caused by *C. striatus* on *Magnolia* spp. appears as yellow-brown flecks covering the leaf surface. Adults are sometimes visible on leaves and appear black with two white bars. The absence of larvae on *L. tulipifera* and observations of numerous adults and larvae on *M. grandiflora* leaves indicate *C. striatus* utilizes *M. grandiflora* for feeding and reproduction.

Plant Disease Pathogens

Verticillium wilt, Phytophthora root rot and several foliar pathogens are the primary causes of disease on magnolia. No canker or virus diseases are reported.

Verticillium wilt. Verticillium wilt is caused by *Verticillium albo-atrum* Reinke & Berth and *Verticillium dahliae* Kleb., which are vascular pathogens of many ornamental shrubs and trees including magnolia (68). Verticillium wilt causes leaf and branch dieback often at one side of the tree. Vascular discoloration can be noticed on infected plants. Symptom progression can be slow, but the plants can completely wilt and die in 1 to 2 years. Sometimes large areas of cambial tissue die from infections by the fungus and opportunistic fungi such as *Nectria* spp. (Fr.) Fr. develop in elongated cankers (16). The characteristic symptom for Verticillium wilt is the discoloration of xylem and cambial tissues, visible as streaks within vertical cuts into affected wood (68). However, other diseases and stress factors can also cause these symptoms, and hence a definitive confirmation is required by a diagnostic lab.

Development of Verticillium wilt is favored by factors that stress roots, including wounding and prolonged drought. The fungus penetrates through root-wounds or directly into host tissues (68). Wilt symptoms are caused by fungal plugging of the vascular system. This blocks the xylem vessels, restricting water and nutrient movement, leading to plant wilting. The fungus survives in soil as long-lived microsclerotia that spread by wind, soil movement and on equipment. *Verticillium* spp. can survive in soil for many years making crop rotation impractical as a management option. In addition, many weedy plants are also susceptible hosts; therefore the cycle of contaminated soil is hard to break.

Management. Avoid stressful conditions for the plants including overwatering, drought and root-wounding that will facilitate *Verticillium* spp. infection. Avoid planting in areas with previous outbreaks of Verticillium wilt. Fungicides are not effective in management of Verticillium wilt (Table 2).

Phytophthora root rot. Phytophthora root rot caused by *Phytophthora cinnamomi* Rands is a major pathogen in container-grown southern and saucer magnolias (36). Typical symptoms of the disease include foliar yellowing, slowed shoot growth, premature leaf shed, limb dieback, sudden wilting of leaves and plant death. Infected plants typically have discolored feeder roots.

The causal agent, *P. cinnamomi*, is an oomycete that survives through resting structures known as chlamydospores and hyphae in infected roots, crop debris and soil (36). The pathogen is easily spread through contaminated water and by splashing, and the disease spreads rapidly in nurseries where irrigation water is recycled without proper treatment. Severe root infection is common in production areas with saturated substrates.

Management. Water management and timely and preventative fungicide applications are very important in managing Phytophthora root rot in container-grown magnolias. Pooling of water around container plants should be avoided. Irrigation should be optimized based on weather conditions to avoid conditions conducive for infection. Recycled containers should be washed thoroughly and disinfected before reuse.

Foliar diseases. Bacterial leaf spot, *Xanthomonas* sp., is a relatively new disease in commercial production systems as indicated in numerous pathogen identifications conducted on infected samples at the Plant Diagnostic Clinic, University of Florida, NFREC, in recent years (18). Based on the time of the year and conditions prevalent during disease occurrence, high rain and strong wind conditions, as well as heavy overhead irrigation, seem to favor the spread of the disease. The bacterial pathogen can enter through wounds, stomata and hydathodes. Symptoms of bacterial infections vary but usually start as small necrotic lesions with a yellow halo region. Under ideal environmental conditions, the pathogen can cause severe blighting of the foliage.

Bacterial blight is caused by *Pseudomonas syringae* pv. *syringae* Van Hall and *Pseudomonas cichorii* (Swing.) Stapp. These *Pseudomonas* spp. (61) cause leaf spots (63) similar to bacterial leaf spot on magnolia (36). The disease causes small necrotic spots with a yellow halo. It is difficult to separate the symptoms of bacterial blight from bacterial spot. However, bacterial blight is predominant during cooler and wet weather conditions. Splashing water and overhead irrigation help spread the disease from infected to healthy leaves. The disease is noticed in both container and field-grown magnolias. *Pseudomonas syringae* pv. *syringae* and *P. cichorii* are aggressive pathogens on southern magnolia.

Anthracnose, *Colletotrichum gloeosporioides* Penz, causes large circular spots towards the margins of magnolia leaves and can lead to premature leaf drop. The disease is most commonly reported on southern magnolia. Disease symptoms include a burned appearance or angular spots that are surrounded by a yellow halo (36). Black, blister-like fruiting bodies (acervuli) develop on the upper surface of the spot. At later stages, a distinctive pink spore mass will ooze from the fruiting bodies. Splashing water spreads the spores to new leaves. Warm, humid and wet conditions favor disease development. The fungal organism can overwinter in dead leaves and branches. The disease can lead to premature leaf drop.

Algal leaf spot, *Cephaleuros virescens* Kunze, is commonly seen on southern magnolia and is caused by a parasitic alga (85). The key symptom of algal leaf spot is the formation of raised blotches on the leaves. Occasionally symptoms can be seen on twigs. Spots develop with a velvety appearance on the plant surface. Plant tissues beneath the spots die and severe infection can cause premature leaf drop. The disease mostly affects weaker plants in the nursery or landscape. The algal spores have the ability to swim in water on the plant surface, thus continuous rain during warm and windy conditions serves as a major factor in spread of the spores. The algae may survive on infected leaves and twigs leading to repeated infection year after year under ideal conditions.

Pestalotiopsis leaf spot of magnolia (52), *Pestalotiopsis* spp. Steyaert, usually occurs during cooler weather conditions and causes unique circular spots with necrotic centers and black borders. Wind and water movement aids in spread of the fungal spores of the pathogen from infected leaves and plant debris.

Phyllosticta leaf spot, *Phyllosticta magnoliae* Sacc., is an infrequent disease that may affect southern magnolia in the landscape. The disease develops as small black spots on the upper leaf surface (36). As spots develop, their centers turn off-white and borders become purple to black. Black fruiting bodies (pycnidia) can be seen in the center of these spots. The pathogen is spread to new leaves by splashing water. Warm, humid and wet conditions favor disease progression.

Powdery mildew on magnolia is caused by at least two species, *Microsphaera alni* DC. ex Wint. [*M. penicillata* (Wallr.) Lév.] and *Phyllactinia corylea* Pers. ex Karst. [*P. guttata* (Wallr.) Lév.]. The disease is particularly common among saucer and star magnolia cultivars. Disease symptoms include white powdery patches on the top section of the leaves (36). The patches can cover the entire leaf during severe infection and both leaf curling and plant stunting can occur. The white fungal growth can also be seen on tender shoots. Powdery mildew can become a management challenge in production when days are warm to hot and nights are cooler and dew forms on leaves. Overcrowding of plants and lack of aeration also contribute to disease occurrence.

Powdery mildew fungi overwinter as hyphae (fungal strands) in dormant buds or as spores in fruiting bodies (cleistothecia) on fallen disease leaves. During the spring to early summer, spores are spread by wind.

Management. Most foliar diseases pose problems only when overhead irrigation is used, as is common in container nursery systems. Overhead irrigation should be managed to avoid high leaf wetness during overcast conditions, at night and other times when the pathogen may be present (Table 2). Removing infected leaves early in disease progression can prevent spread of anthracnose, phyllosticta leaf spot and algal leaf spots. Selective pruning to thin the canopy can make conditions less favorable for pestalotiopsis leaf spot, powdery mildew and algal leaf spots. If environmental conditions for infection persist, copper-based fungicides can be used to manage bacterial leaf spot and bacterial blight (Table 2). Other fungicides are used to manage anthracnose, phyllosticta leaf spot and powdery mildew (Table 2).

Abiotic Disorders

A number of abiotic disorders caused by winter cold damage can be confused with pest injury and plant diseases. Alternatively, these abiotic disorders may predispose magnolia to injury from opportunistic arthropod pests and infection by plant diseases. Also, recognition of abiotic disorders can prevent unnecessary pesticide applications resulting from misdiagnosis of pests and diseases by nursery and landscape managers.

Winter burn. Winter burn or scorch is a common problem of evergreen magnolias grown in the upper south (USDA hardiness zones 6b through 8a). Winter burn is characterized by desiccated leaf margins, often most extreme on the sunward or windward sides of the plant (75). Evergreen magnolias continue losing moisture through their leaves during winter. These evergreens are especially vulnerable to winter burn on warm sunny days when the ground is frozen and plants cannot absorb water to replace that which is lost through transpiration. Container plants are more likely to suffer from scorch than in-ground plants.

Management. In areas of the upper south where winter burn is a problem, evergreen magnolias should be planted in the fall earlier than their deciduous counterparts (1). This allows roots to become established and optimally hydrate the plant prior to the onset of freezing conditions and drying winds. Anti-desiccants have not been found to consistently benefit plants during transplanting (75). Managers should plan for regular irrigation in the fall to increase the availability of water to the newly planted liners.

Cold injury. Flower buds of *M. stellata* and *M. ×soulangeana* open in the late winter/early spring, often after just a brief warm spell between periods of cold temperatures. Freezing temperatures often kill mature flower buds and cause open flowers to turn brown due to the freeze injury.

This is an aesthetic problem; the overall health of the plant is not affected and subsequent management is unnecessary.

Bark cracking. Magnolias are thin-barked and thus considered susceptible to bark cracking. In particular, yellow magnolias can be prone to bark cracking at the base of the trunk. Excess nitrogen fertilizer or unseasonably warm temperatures can cause plants to remain actively growing too late in the season and as a result the basal portion of the trunk does not sufficiently harden before cold weather (41). Cracked bark usually becomes evident in the spring but may occur due to freezing conditions in the late fall to early spring. Some basal bark cracks have been observed in conjunction with large pruning cuts near the location of the crack (31).

Bark cracking on magnolia also occurs due to frost cracking and sunscald, which have many similarities (30). Frost cracking and sunscald both cause vertical cracks through the bark to the wood. Both often happen on the south or southwest side of a tree since this is where the greatest winter temperature fluctuations occur. Often, the temperature of bark receiving direct sun exposure is 20C (68F) greater than ambient temperatures during the winter (78); snow exacerbates the temperature increase.

Frost cracking occurs when water in the wood expands and contracts as a result of dramatic temperature fluctuations such as those occurring on warm, sunny winter days with periods of dense clouds or nightfall (30). Frost cracks often close and heal, but these trees generally are not marketable and may incur additional pest and disease problems.

Sunscald occurs when the same dramatic temperature changes damage or kill the cambium and bark. Often sunscald will not be detectable until spring when growth resumes (40). At this point the damage becomes evident as sunken or discolored bark. The bark may then split. If the tree is healthy enough to resume growth, a callus roll will develop around the wound as the season progresses. Frost cracking and sunscald are linked to root injury, above ground wounds and pruning cuts. Inadequate hydration is also linked to sunscald, but not frost cracks (40, 41).

Management. Avoid bark cracking in production by reducing irrigation and nitrogen availability towards the end of the growing season, e.g. September 15 in middle Tennessee, to prevent succulent growth late in the season. Applications of summer top-dressed or soluble fertilizers should be timed so that these products will not continue releasing nitrogen too late in the season. Most controlled release fertilizers release less nitrogen during colder temperatures. Sunscald can be prevented by wrapping the trunks of young trees in November with a commercial tree wrap in which the insulating paper mitigates temperature fluctuations. Wraps must be used carefully as they can lead to other problems, such as harboring insect pests.

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