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

# Arthropod Pests, Plant Diseases and Abiotic Disorders and their Management on *Viburnum* Species in the Southeastern U.S.: A Review[1]

**William E. Klingeman[2], Sarah A. White[3], Anthony LeBude[4], Amy Fulcher[5], Nicole Ward Gauthier[6], and Frank Hale[7]**

## Abstract

The genus *Viburnum* encompasses a group of about 150 species of evergreen, semi-evergreen or deciduous trees and large shrubs. Viburnums 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 *Viburnum* species have become prominent landscape plants in the southeastern United States due to their beauty, utility, relative ease of maintenance and broad adaptability to the region's climate and soils. Efficient management of viburnum pests to maintain healthy viburnum plants in nurseries and landscape settings is crucial for sustaining the economic competitiveness and profitability of green industry professionals competing in the horticulture marketplace. Diversity of species within the genus, however, is vast, and can contribute to many host-pest complexes that differ among growing environments and cause severe economic or aesthetic losses. Additionally, some abiotic disorders may mimic biotic damage or may render viburnum more susceptible to pests and diseases. This review focuses on viburnum culture in production and landscape settings with an emphasis on major insect and mite pests, plant diseases and abiotic disorders affecting management of *Viburnum* species in nursery and landscape settings.

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

**Species used in this study:** mapleleaf viburnum (*V. acerifolium* L.), *V. awabuki* 'Chindo' K. Koch, *V. bracteatum* Rehd., Korean spice viburnum (*V. carlesii* Hemsl.), witherod viburnum (*V. cassinoides* L.), David viburnum (*V. davidii* Franch.), arrowwood viburnum (*V. dentatum* L. complex), wayfaringtree viburnum (*V. lantana* L.), hobblebush (*V. lantanoides* Michx.), nannyberry viburnum (*V. lentago* L.), Chinese snowball viburnum (*V. macrocephalum* Fort.) and (*V. macrocephalum* form *keteleeri* (Carr.) Rehd.), smooth witherod (*V. nudum* L.), small viburnum (*V. obovatum* L.), sweet viburnum (*V. odoratissimum* Ker.-Gawl.), European cranberrybush viburnum (*V. opulus* L.) and (*V. opulus* var. *americana*), Japanese snowball (*V. plicatum* Thunb.), doublefile viburnum (*V. plicatum* var. *tomentosum* (Miq.) Rehd.), blackhaw viburnum (*V. prunifolium* L.), Rafinesque viburnum (*V. rafinesquianum* Schultes), *V. recognitum* Fern. (formerly *V. lucidum*), leatherleaf viburnum (*V. rhytidophyllum* Hemsl.), tea viburnum (*V. setigerum* Hance.), Siebold viburnum (*V. sieboldii* Miq.), Sandankwa viburnum (*V. suspensum* Lindl.), Laurustinus (*V. tinus* L.), American cranberrybush viburnum (*V. trilobum* Marsh.), service viburnum (*V. utile* Hemsl.), Burkwood viburnum (*V.* ×*burkwoodii* Burkw. & Skipw.), Carlcephalum viburnum (*V.* ×*carlcephalum* Burkw. ex. R.B. Pike), Judd viburnum (*V.* ×*juddii* Rehd.) and Lantanaphyllum viburnum (*V.* ×*rhytidophylloides* J. Sur.).

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[2]University of Tennessee, Department of Plant Sciences, 2431 Joe Johnson Drive, Knoxville, TN 37996. wklingem@utk.edu.

[3]Corresponding author: Clemson University, School of Agricultural, Forest, and Environmental Sciences, 167 Poole Agricultural Center, Clemson, SC 29634. swhite4@clemson.edu.

[4]North Carolina State University, Department of Horticulture, Mountain Horticultural Crops Research and Extension Center, 455 Research Drive, Mills River, NC 28759. ALeBude@ncsu.edu.

[5]University of Tennessee, Department of Plant Sciences, 2431 Joe Johnson Drive, Knoxville, TN 37996. afulcher@utk.edu.

[6]University of Kentucky, Department of Plant Pathology, 1405 Veterans Drive, Lexington, KY 40546-0312. nicole.ward@uky.edu.

[7]University of Tennessee, Department of Entomology and Plant Pathology, 5201 Marchant Drive, Nashville, TN 37211-4571. fahale@utk.edu.

### Significance to the Horticulture Industry

The genus *Viburnum* contains species and cultivars that are staples of the nursery and landscape industries within the southeastern U.S. This review provides a comprehensive overview of abiotic (environmental) and biotic (insect and disease) factors that influence viburnum culture in the nursery (production) and landscape settings, specifically focusing on cultural practices and insect and disease pests that influence plant health, and ultimately plant salability. This review directly applies to green industry professionals who grow, sell, install or maintain viburnum in production and landscape settings in the southeastern U.S.

### Introduction

The genus *Viburnum* contains deciduous or sometimes evergreen, shrubs or small trees with tremendous ornamental merit for all seasons. There are approximately 150 species of viburnum native to North and Central America, Europe, North Africa, and Asia (Dirr 2007; Krüssmann 1984; Rehder 1927). Those viburnum species native to North America and common in commerce include *V. acerifolium*, *V. bracteatum*, *V. cassinoides*, *V. dentatum*, *V. lantanoides*, *V. lentago*, *V. nudum*, *V. obovatum*, *V. opulus* var. *americana*, *V. prunifolium*, *V. rafinesquianum*, and *V. rufidulum*. None of the U.S.-native *Viburnum* species are evergreen nor do they have a particularly pleasing fragrance. Native viburnums possess vibrant fall foliage, produce large volumes of bright colored berries, and have the capability of surviving in wetlands to dry uplands and in a variety of habitats ranging across these two extremes. Evergreen foliage can be found in viburnum species like *V. tinus* from Southern Europe, *V. rhytidophyllum* from central Asia, and *V. awabuki* 'Chindo,' *V. suspensum*, and *V. davidii* from the Far East. With the exception of *V. rhytidophyllum*, plants with evergreen foliage are not usually as cold hardy as their deciduous counterparts, and may not be as fragrant as other viburnums native to the same area. *Viburnum* species have been hybridized to create cultivars with desirable foliage, fall color, and fragrance, while other breeding strategies have produced stalwart evergreens for the landscape (Table 1).

*Economic value.* About 30 species or hybrids comprise most viburnum sales in the southeastern United States. (Plant and Supply Locator 2014; Table 2). Including these selections, some 4.67 million evergreen and deciduous viburnum plants are produced by about 1,592 U.S. operations, which, in turn reported wholesale revenues exceeding $40.9M in 2007 (USDA 2009). Roughly 25 percent of the total wholesale revenue ($10.7M) is generated from Region 4, containing the southeastern U.S., followed by Regions 2 ($6.7M) (Northeast) and 5 ($5.2M) (upper Midwest) (Table 3). Regionally, wholesale revenues are from sales of evergreen viburnum in the South, a balance of evergreen and deciduous viburnum in the mid-Atlantic region, and deciduous viburnum in the upper Midwest. Presumably, this is due to cold hardiness of the two types of viburnum and not to market preference. Demand for viburnum is so great that GIE Media polled 4,000 of its *Lawn & Landscape Magazine* readers in April 2011 regarding their plant material purchases. Viburnum was number two on the list behind boxwood (NMPro 2011).

*Adaptability and nutritional needs.* Viburnum species are tolerant of a range of solar exposures from full sun to part shade. For example, *V.* 'Pragense' tolerates full sun to up to 60% shade during production; plants produced in both conditions were of similar size and overall quality (Fini et al. 2010). Plants grown in shade had a higher number of leaves per plant (Fini et al. 2010).

Most of the nitrogen (N) absorbed by *V. odoratissimum* is taken up when shoots are actively growing, rather than when roots are actively growing. *Viburnum odoratissimum* shoot and root growth is cyclical, yet can be affected by N. Normally, peak root growth occurs 6 to 12 days after shoot growth begins (Schoene and Yeager 2006, 2007). Daily fertigation of *V. odoratissimum* with 100 $mg \cdot L^{-1}$ N resulted in three root growth flushes, while plants fertigated with 50 $mg \cdot L^{-1}$ N or less had four root growth flushes. During periods of high root elongation (root growth flush), newly-emerging, immature *V. odoratissimum* leaves are green in coloration; while during periods of low root elongation newly-emerging leaves are reddish in coloration (Schoene and Yeager 2006). The majority of N (70%) absorbed during periods of low root elongation is translocated into mature leaves with only 1.5% to immature leaves. During an active root growth flush, when new shoots are also actively growing, 14.8% of N is translocated into immature leaves and 35.2% into mature leaves (Schoene and Yeager 2007). When scheduling fertilizer applications for *V. odoratissimum*, timing an application for periods when immature leaves are green may help to increase uptake efficiency and transport into newly expanding tissues (Schoene and Yeager 2007).

Many species of *Viburnum* can adapt to a range of soil moisture levels (García-Navarro et al. 2004). As a consequence, viburnum plants should be irrigated according to daily water use (DWU), which represents the daily volume of water lost to transpiration from plants plus that lost via evaporation from the growing substrate. This approach has been examined as a means of enhancing crop growth while reducing water applications to commercial nursery systems. Plants of *V. dentatum* 'Ralph Senior' produced in 11.4 L (3 gal) trade containers were irrigated to achieve either 100% DWU (100 DWU), 100 DWU alternated every other irrigation cycle with 75% DWU (75 DWU), or a three-cycle schedule of 100 DWU, 75 DWU, and 75 DWU. Warsaw et al. (2009) reduced irrigation volumes by 33, 41, and 44% respectively, when treatments were compared with a control irrigation standard of 1.9 cm (0.75 in) water per application. At the end of two subsequent growing seasons, *V. dentatum* 'Ralph Senior' plants grown with water deficit treatments were larger than control plants, perhaps due to increased nutrient availability because fewer nutrients were leached from the container. After two seasons of growth, EC measurements indicated that salinity levels had not increased enough to affect plant quality (Warsaw et al. 2009). Similarly, the leaf area of *V. tinus* grown with deficit irrigation was larger than *V. tinus* irrigated daily to container capacity, and deficit irrigated plants used the water applied more efficiently, with no decrease in plant quality (García-Navarro et al. 2004).

By contrast, sweet viburnum (*V. odoratissimum*) are high water use plants, and plant quality will decline if plants are allowed to dry down excessively (>20% plant available moisture used) between irrigation events (Beeson 1995). As long as plants receive the appropriate volume of irrigation, whether in a single application or via cyclic irrigation, plant growth will not be affected (Beeson 1998). Million et al. (2007a) determined that 1 cm (0.4 in) per day of applied overhead irrigation was adequate for commercial production of *V. odoratissimum*. When 2 cm (0.8 in) per day was applied, 95% of the water was collected as runoff. Plants grown under a higher irrigation regime were smaller, regardless of controlled release fertilizer (CRF) application rate. The excessive irrigation rates led to nutrient leaching from containers, which reduced the amount of nutrients available for plant growth (Million et al. 2007b).

When evapotranspiration-based irrigation scheduling was used for container-grown *V. odoratissimum*, water application volumes were reduced by 39% and water lost to leaching by 42% (Million et al. 2010). Evapotranspiration-based irrigation scheduling also reduced N, P, and K leaching by 16, 25, and 22%, respectively, when compared with nutrient leaching from *V. odoratissimum* plants irrigated with 1 cm (0.4 in) per day. The maximum evapotranspiration rate of market-ready *V. odoratissimum* grown in trade 11.4 L (3 gal) containers was 1.14 L (0.3 gal) per day (Beeson 2010).

Typical foliar tissue analyses results are provided for micro- and macronutrient concentrations that may be determined by technical analyses of recently-mature foliage collected from container-grown viburnum plants (Table 4). In general, viburnums grow well when supplemented with a variety of nitrate ($NO_3$) fertilizer forms and rates, but viburnums are sensitive to ammoniacal forms of supplemented nitrogen.

**Table 1. Growth and horticultural characteristics of selected *Viburnum* species and cultivars currently in production in southeastern United States nurseries[z].**

| Species | Growth form | Flower, timing[y] | Foliage | Fruit |
|---|---|---|---|---|
| **Deciduous shrubs** | | | | |
| *Viburnum acerifolium* | Suckering thickets | Yellow-white flowers, May–June | Pastel pink to purple (F)[x] | Bright red, turn black, persists in winter |
| *V. ×bodnantense* | — | Pale-pink buds, white flowers, fragrant | Bronze fade to green (S) | Red, turn black |
| *V. bracteatum* | Rounded, coarse textured | White cymes, May | Yellow to bronze (F) | Blue-black |
| *V. ×bracteatum* | Compact | 8 cm (3 in) wide cymes | Maroon (F) | Early red, black |
| *V. ×burkwoodii* | Upright, multi-stemmed | — | — | — |
| *V. ×carlcephalum* | Upright, rounded | White 10–15 cm (4–6 in) snowball cymes | | Red, egg-shaped fruit (Sep–Oct) |
| *V. carlesii* | Rounded outline, dense foliage | Pink-red buds, 5–8 cm (2–3 in) white cymes, spice fragrance | Wine-red, muted purple (F) | Red, turn black |
| *V. cassinoides* | Upright, arching | White 5–13 cm (2–5 in) cymes | Bronze-purple (S), yellow, orange, red, purple (F) | Pink, rose, blue-black concurrently |
| *V. corymbiflorum* | Rounded | Small white | Yellow, orange, to red (F) | Abundant red |
| *V. dentatum* | Varies | White cymes | Yellow to red (F) | — |
| *V. dilatatum* | Upright, arching, compact, rounded | White cymes, May–Jun, malodorous | Red (F), unreliable in south | Red, ovoid fruit (Sep–Oct), persistent[w] |
| *V. farreri* | Rounded | Pink flowers, fragrant | Reddish purple (F), unreliable in south | Red-black, unreliable |
| *V. ×juddii* | Rounded, broad | Pink buds, white 5–8 cm (2–3 in) cymes, Mar–Apr, fragrant | — | — |
| *V. lantana* | Rounded, upright | White 8–13 cm (3–5 in) cymes, Apr–May, malodorous | — | Yellow, red, black (Aug–Sept) |
| *V. lantanoides* | Rounded, spreading | White 8–13 cm (3–5 in) cymes | Red-scarlet (F) | Red to purple to black. |
| *V. lentago* | Rounded, upright, suckers | White 8–10 cm (3–4 in) cymes | Yellow, red, purple (F) | Yellow, pink, rose, blue-black |
| *V. luzonicum* | Rounded, dense | White 2.5–5 cm (1–2 in) cymes, Apr, malodorous | Reddish purple (F) | Red, sparse[w] |
| *V. macrocephalum* | Rounded, dense | White 8–20 cm (3–8 in) lace-caps, Apr and fall | — | — |
| *V. macrocephalum* f. *keteleeri* | Rounded, dense | White 13–15 cm (5–6 in) lace-caps | — | Shiny red to black 1.3 cm (0.5 in) long |
| *V. mongolicum* | Oval, rounded | Creamy-white, flat-topped cymes, May | Wine-red (F) | Yellow to red (Aug), then black |
| *V. nudum* | — | White 5–10 cm (2–4 in) cymes, May | Yellow, red, purple (F) | Pink to blue (Sept), persist |
| *V. opulus* | Rounded, thicket | White 5–8 cm (2–3 in) lacecaps | Yellow, red, purple (F) | Red (Sept–Oct), persist |
| *V. plicatum* | Rounded, horizontal | White 5–8 cm (2–3 in) snowball cymes, sterile, Apr | Reddish purple (F) | — |
| *V. prunifolium* | Rounded, multi-stemmed | White 5–10 cm (2–4 in) cymes | Bronze-red (F) | Pink-rose to bluish black, Sept |
| *V. rafinesquianum* | Compact | White 4–8 cm (1.5–3 in) cymes, Apr–May, malodorous | Russet-red (F) | Black (July) |
| *V. ×rhytidophylloides* | Rounded | White 8–10 cm (3–4 in) cymes, Apr | — | Red to black (Aug–Sept)[w] |
| *V. rufidulum* | Rounded | Rusty brown buds, cream-white 13 cm (5 in) cymes, Apr, fragrant | Maroon to burgundy (F) | Blue 1.3 cm (0.5 in) |
| *V. sargentii* | Rounded | White 8–10 cm (3–4 in) lace caps. purple anthers, malodorous | Yellow to red (F) | Scarlet-red (Aug–Oct)[w] |
| *V. setigerum* | Upright, vase | White 2.5–5 cm (1–2 in) cymes, Apr | Red (F), persistent | Red 1.3 cm (0.5 in) |
| *V. sieboldii* | Tree, upright | White 5–8 cm (2–3 in) cymes, Apr–May, fragrant | Red (F), unreliable in south | Bright red, pink, rose-red (Aug–Oct) |
| *V. trilobum* | Rounded | — | Deep red (F) | Red, persist |
| *V. wrightii* | Upright, rounded | White 5–10 cm (2–4 in) cymes, Apr–May | Red (F) | Red (Aug), persist |
| ***Evergreen shrubs*** | | | | |
| *V. carlesii* × *V. ×carlcephalum* | Upright, mounded | Profuse white, fragrant | — | Red, turn black |
| *V. burkwoodii* | Compact | Pink buds, 5–8 cm (2–3 in) white, fragrant Mar–Apr | Maroon (F) | Small red, turn black |
| *V. davidii* | Compact, mounded | Pink buds open to white 5–8 cm (2–3 in) cymes, Apr–May | — | Blue ¼ in berries, persist[w] |
| *V. ×globosum* | Rounded, dense | Pink buds and flowers, fragrant | — | Red-black, unreliable |
| *V. odoratissimum* | — | Cream-white 8–15 cm (3–6 in), Apr–May, fragrant | — | Red to purple to black |
| *V. rhytidophyllum* | Rounded | White 10–20 cm (4–8 in) flat cymes, Apr | — | Red to black[w] |
| *V. ×rhytidophylloides* | Arching | White 15 cm (6 in) cymes, spring and fall (south) | — | — |

Continued …

**Table 1. Continued...**

| Species | Growth form | Flower, timing[y] | Foliage | Fruit |
|---|---|---|---|---|
| *V. suspensum* | Rounded | White, pink-tinged cymes, Feb, fragrant | — | Red, infrequent |
| *V. tinus* | Upright, oval | Pink buds, white 5–10 cm (2–4 in), Feb–Apr fragrant | — | Metallic blue[w] |
| ***Semi-evergreen shrubs*** | | | | |
| *V. carlesii* × *V.* ×*carlcephalum* | Compact, mounded | Pink buds, white 5 cm (2 in) cymes, fragrant | — | — |
| *V. obovatum* | Upright, rounded | White 4–6.4 cm (1.5–2.5 in) cymes | — | Red to shiny black, small |
| *V.* ×*pragense* | Pyramidal | Pink buds, creamy-white 8–15 cm (3–6 in), Apr | — | Red, infrequent |
| *V.* ×*rhytidophylloides* | Rounded | White 15 cm (6 in) cymes, abundant, May | — | Bright red (Sept–Oct) |

[z]Personal communication, Dirr 2013, Dirr 2007, Krüssmann 1984.

[y]Flower timing in USDA Plant Hardiness Zone 8.

[x]Foliage in spring (S) and fall (F).

[w]May require cross pollination.

**Table 2. Number of production nurseries[z] growing various *Viburnum* species reported[y] for twelve southern states.**

| Species | Number of nurseries |
|---|---|
| *Viburnum odoratissimum* and cultivars | 122 |
| *V. suspensum* | 116 |
| *V. obovatum* and cultivars | 71 |
| *V. dentatum* and cultivars | 23 |
| *V. plicatum* var. *tomentosum* and cultivars | 13 |
| *V.* ×*pragense* | 13 |
| *V. macrocephalum* | 10 |
| *V. tinus* and cultivars | 10 |
| *V. trilobum* and cultivars | 6 |
| *V. carlesii* and cultivars | 5 |
| *V. lentago* | 5 |
| *V. nudum* and cultivars | 5 |
| *V. prunifolium* | 5 |
| *V. rhytidophyllum* and cultivars | 5 |

[z]Only *Viburnum* species in production at more than 5 nurseries were included. Cultivars were grouped within each species when more multiple cultivars were available.

[y]Plant and Supply Locator 2014.

Fertilizer application rates of 200 to 400 mg·L$^{-1}$ $NH_4$-N, induced severe marginal necrosis and eventual death for most viburnum plants (Raker and Dirr 1979). In addition to ammoniacal nitrogen sources, viburnums are sensitive to excess (> 400 mg·L$^{-1}$) fertilization with urea-based fertilizer, which causes marginal necrosis, foliar wilting and premature leaf abscission. If N is supplied as calcium-nitrate-N [$Ca(NO_3)_2$], slight marginal necrosis can occur (Raker and Dirr 1979). *Viburnum odoratissimum* grew sufficiently in Florida when a range of nitrogen rates from 3.0 to 5.7 g N (~ 50% $NO_3$-N and 50% $NH_4$-N) per gallon container volume was applied using common 8–9 month controlled-release fertilizer (CRF) plus micronutrients (Cashion and Yeager 1991).

To determine if time of potting and fertilization application rate could influence viburnum cold hardness or plant growth, *V. awabuki* 'Chindo' were potted in July, September, October, March, and May, then the potting substrate was amended with either a 0.5×, 1× or 2× rate of CRFs (as polymer-coated urea, ammonium nitrate and ammonium phosphate), either all at once or with a split timing (Ivy et al. 2002). One year after potting, 'Chindo' viburnum potted in September or October grew larger than plants potted in March, regardless of fertilizer and rates of fertilization. 'Chindo' viburnum potted in September had significantly greater N and P content in plant tissues compared to viburnum potted in March or May, in part because nutrients stored within root tissues during the fall remobilize and translocate easily to promote shoot growth during the spring. No plants were injured by winter temperatures experienced during the study period regardless of potting date or rate of fertilization. In fact, plants potted in July, September, or October had the highest substrate EC values in March, compared with plants potted in either March or May, which had the highest EC values in August, regardless of fertilizer or rate of fertilization (Ivy et al. 2002). Nitrogen fertilization rate does not affect degree of freeze injury, but the form of N applied does. Ammoniacal forms of N predisposed doublefile viburnum (*V. plicatum* var. *tomentosum*) to freezing injury, as evidenced by soft, brown cambial tissue on stems and the inability of vegetative buds to resume active growth (Raker and Dirr 1979).

Table 3. **Wholesale revenue generated by region for deciduous or evergreen sales of viburnum in the United States[z].**

| Region[y] | States within region[x] | Deciduous | Evergreen | Total |
|---|---|---|---|---|
| | | Value ($1,000) | | |
| 1 | CT, MA | 708 | 19 | 727 |
| 2 | NJ, PA, NY | 3,876 | 2,837 | 6,713 |
| 3 | MD, VA | 173 | 1,460 | 1,633 |
| 4 | FL, TN, NC, SC, KY, GA, AL | 3,215 | 7,465 | 10,680 |
| 5 | OH, IL, WI, MI, IN, MN | 3,717 | 1,453 | 5,170 |
| 6 | TX, AR, LA[w] | 23 | 18 | 41 |
| 9 | CA | 2,496 | 1,293 | 3,789 |
| 10 | OR, WA, ID | 2,652 | 3,712 | 6,364 |
| Total | United States | 18,767 | 22,090 | 40,857 |

[z]USDA Census of Agriculture 2009.

[y]Standard federal regional boundaries.

[x]States are arranged within region by descending total sales of viburnum.

[w]Not all states reported revenue from this region.

This might not be true of *V. awabuki* 'Chindo' since Ivy et al. (2002) used ammoniacal forms of N to supply nutrients and reported no instances of freeze injury.

Plant spacing in nurseries also influences crop growth and resource use efficiency. To achieve optimal resource use and spacing efficiency, plant canopies should be touching, yet spaced to the minimum required for commercial quality (Beeson and Yeager 2003). For example, optimal irrigation efficiency, defined as the highest proportion of water collected within the crop canopy during overhead irrigation, was achieved in *V. odoratissimum* production blocks when plants were grown at the minimum spacing required to produce saleable material (Beeson and Yeager 2003). Timing of plant spacing also effects resource uptake and capture efficiency. When *V. odoratissimum* were spaced at planting to 16 cm (6.3 in) on center, instead of in mid-season once canopies were developed, a 37% growth reduction in plant mass was observed, likely the result of increased heat stress. In addition, 9% more fertilizer leached from containers spaced at planting compared with those spaced mid-season, especially when CRFs were incorporated within the media, rather than top-dressed to the substrate surface because higher internal substrate temperatures increased nutrient release rates (Million et al. 2007b).

Use of containers lined with the root growth regulator cupric hydroxide (Spin Out™, SePRO Corp, Carmel, IN) promoted secondary root branching in *V. plicatum* var. *tomentosum* 'Mariesii' and *V. ×rhytidophylloides* 'Alleghany' with no signs of copper toxicity (Krieg and Witte 1993). *Viburnum odoratissimum*, grown in containers treated with cupric hydroxide also developed improved root system architecture, but canopy quality was not improved compared with plants grown in non-treated containers (Beeson 1996).

## Abiotic Disorders

Several abiotic disorders can be induced by winter cold; these disorders can be confused with insect damage or plant diseases. Once cold damage occurs, viburnum plants will be predisposed to injury both by opportunistic insect pests and infection by plant diseases. Managers who can discriminate pest injury and plant appearance caused by abiotic disorders

Table 4. **Average-desired range of foliar concentrations reported[z] for macro- and micro-nutrients measured in recently mature leaves collected at mid-season from current season's growth of select[y] *Viburnum* species.**

| Macronutrient | (% dry weight) | Micronutrient | ($ug \cdot g^{-1}$) |
|---|---|---|---|
| Nitrogen (N) | 1.51–2.16 | Aluminum (Al) | 117–256 |
| Phosphorus (P) | 0.18–0.33 | Boron (B) | 42–80 |
| Potassium (K) | 1.17–1.89 | Copper[X] (Cu) | 4.8–11 |
| Calcium (Ca) | 1.31–2.02 | Iron[W] (Fe) | 59–166 |
| Magnesium(Mg) | 0.23–0.38 | Manganese[X] (Mn) | 104–329 |
| Sulfur (S) | 0.15–0.23 | Molybdenum (Mo) | 0.11–0.95 |
| | | Sodium (Na) | 48–122 |
| | | Zinc[X] (Zn) | 28–110 |

[z]Gori et al. 2000; Mills and Jones 1996; Robinson and Hamilton 1980a, 1980b.

[y]For full list of species and cultivars with specific sufficiency range see Chapter 5 in: *IPM for Shrubs in Southeastern US Nursery Production, Part 1.* 2014 (White and Klingeman 2014).

[x]Leaf tissue analysis of Cu, Mn, and Zn may not be reliable indicators of *Viburnum* species. nutritional status because foliage in commercial plant nurseries may be exposed to fungicides and nutrient solutions containing trace elements, and trace levels of surface contamination may persist, even after leaves are washed.

[w]Surface contamination of foliage from soil and presence of unavailable (physiologically inactive) and immobile iron in plant tissues limits the information value of iron measured by foliar analyses.

will be able to limit unnecessary pesticide applications that would result from misdiagnosis of the problem.

*Leaf desiccation.* The desiccation or drying of evergreen leaves, sometimes referred to as winter burn or leaf scorch, is a common problem during winter months, and may be more of a concern for container-grown plants than field- or landscape-grown plants. Desiccation of leaf margins will be most pronounced on the sunward or windward sides of the plant. Because evergreen foliage continues to lose moisture during winter, leaf discoloration and burning are most severe following clear, cold sunny winter days when the ground is frozen and plant roots cannot absorb water to replace that which is lost through transpiration (Relf and Appleton 2007).

*Bark cracking and sunscald.* Excess N fertilizer or unseasonably warm temperatures in early fall, mid-September in Tennessee, 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 (Hartman et al. 2000). Bark cracking and sunscald appear most commonly on wood from the south or southwest sides of exposed trunks and limbs because these exposures experience the greatest winter temperature fluctuations. Vertical frost cracks that appear in bark, particularly on thin-barked trees and shrubs, usually become evident in the spring but may have originated from freezing conditions experienced from the late fall throughout early spring. Where sunscald occurs, sunken or discolored bark may precede bark splitting. Split bark and trunk cracks will generally close and heal, often leaving callus tissue formation as evidence of past injury. However, affected shrubs may not be marketable at point-of-sale. Damaged plants can also become susceptible to subsequent insect and plant disease infestations.

*Leaf desiccation management.* In areas where desiccation of foliage on cold, clear days has been a problem, evergreen shrubs and trees should be planted in early fall, which will allow roots to become established and optimally hydrate the plant prior to the onset of freezing conditions and drying winds (Adkins et al. 2010). Managers should schedule irrigation of newly-planted shrubs to maintain adequate soil-moisture levels, which will support root growth. 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 (Adkins et al. 2010; Fulcher 2013). Summer applications of top-dressed or soluble fertilizers should be timed so that these products will not continue releasing nitrogen too late in the season. Most CRFs 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 paper mitigates temperature fluctuations. Wraps must be used carefully as they can lead to other problems, such as harboring insect pests. Anti-desiccants have not been found to consistently benefit plants during transplanting (Relf and Appleton 2007).

*Boron and salinity-related injury.* Symptoms of boron toxicity in *V. tinus* include development of yellow to orange spots on the leaf tips of new foliage and leaf margins along older leaves within the canopy. These symptoms are likely to develop only when boron concentrations exceed 6 mg·L$^{-1}$ in irrigation water. As symptoms advance with sustained exposure to boron, affected leaves curled inward and prematurely senesced (Bañon et al. 2012). *Viburnum davidii* is highly sensitive to rhizospheric salt stress (either as Na or Cl) and does not recover from salinity stress induced by irrigation (Devecchi and Remotti 2004). By contrast, *V. recognitum* (formerly *V. lucidum*) grown under increasing salt stress regimes of 1.4, 4.4, and 7.4 dS·m$^{-1}$ (770, 2,420, and 4,070 ppm) for 6 months displayed few foliar symptoms when rated visually, even at the highest exposure levels. *Viburnum recognitum* tolerated salt exposure by limiting salt uptake into shoot tissues (Cassaniti et al. 2009). Exposure of salt-sensitive *V. tinus* to 6 dS·m$^{-1}$ (3,300 ppm) salinity induced necrotic lesions on leaves, preceded by foliar wilting that started at the leaf tips and spread to the center of the leaf blade. Leaves curled inward and were eventually dropped. *Viburnum tinus* growth was reduced by 12% when exposed to boron (6 mg·L$^{-1}$) and by 60% when exposed to salinity [6 dS·m$^{-1}$ (3,300 ppm)] in comparison with control plants exposed to 2 dS·m$^{-1}$ (1,100 ppm) salinity and no boron (Bañon et al. 2012).

Fox et al. (2005) determined that reclaimed water containing >0.75 dS·m$^{-1}$ (413 ppm) salinity could be safely used for landscape irrigation of *V. tinus* 'Compactum', as quality ratings were similar to plants irrigated with potable water. Maximum exposure concentrations of 2 dS·m$^{-1}$ (1,100 ppm) salinity and 1 mg·L$^{-1}$ B are recommended to maintain commercial quality of *V. tinus* (Bañon et al. 2012). Cassaniti et al. (2009) used irrigation water applied via drip emitters at a rate 1.89 L·hour$^{-1}$ (0.5 gal·hr$^{-1}$) and applied until a 50% leaching fraction was reached to mitigate salt concentrations in field soils when growing *V. lucidum*. Limiting salt accumulation in the root zone by increasing leaching may be an important irrigation management strategy, particularly when poor quality water sources are used.

*Ozone-related injury.* Symptoms of ozone sensitivity in viburnum include seasonally-premature reddish coloration to upper leaf surfaces, often paired with inter-veinal stippling. As injury progresses, reddish stippling can cover the majority of the upper leaf surfaces (Novak et al. 2008). *Viburnum tinus* tolerated ozone exposures of 200 μg·L$^{-1}$ (ppb) for 5 hours without injury symptoms, while *V. lantana* plants were much more sensitive and demonstrated foliar sensitivity after exposure to ozone at 21.8 to 41.5 mg·L$^{-1}$ per hour (Lorenzini et al. 1999).

### Insect and Mite Management

Most viburnum species and cultivars are considered to be 'trouble-free' and generally support very few insect and plant diseases that cause significant or lasting aesthetic injury (Dirr 2007; Johnson and Lyon 1991). Despite the pest tolerance and durability of viburnums, diverse insect pests and plant diseases are capable of causing injury in the southeastern U.S.

*Viburnum leaf beetle.* The native range of viburnum leaf beetle [*Pyrrhalta viburni* (Paykull)] extends across most of Europe. This leaf beetle (Coleoptera: Chrysomelidae) has become an invasive pest of viburnum species in northeastern North America. First encountered in North America in 1947 in Ontario, Canada, breeding populations causing severe defoliation of ornamental viburnum were not discovered until 1978 in the Ottawa/Hull region of Canada. It was first detected in the United States in 1996 in Cayuga County, New York, where extensive larval feeding was occurring on the native *V. dentatum* complex. This pest has spread into many parts of Ontario, the Canadian Maritime Provinces, Maine, New York, Pennsylvania, Vermont, Massachusetts, and Ohio (Weston et al. 1999).

Adult viburnum leaf beetles are 6.4 mm (0.25 in) long with a brownish head, thorax and elytral wing covers. The dorsal (top) surface has a thick, golden-grey pubescence (Weston et al. 1999). Viburnum leaf beetle larvae are longer [6.1 to 9.4 mm (0.24 to 0.36 in)] than adult viburnum leaf beetles and are elongate and with a shiny, greenish-yellow body covered with black dots (Barr and Hoover 2011). Both larvae and adults feed on viburnum foliage. Eggs hatch by early to mid-May and the resulting larvae skeletonize the foliage, devouring all but the midribs and major veins. Adults emerge by early July and make irregular circular holes in the foliage. The adults feed on foliage until the first killing frost in the fall. Adult females chew holes in small branches in which to deposit their egg clusters. It takes 8 to 10 weeks for the insect to develop from egg hatch to adult emergence (Weston et al. 1999).

Defoliation, branch dieback and shrub death can occur under heavy infestations, especially when injury persists for two or more years. Viburnum leaf beetle has a strong preference for *V. dentatum*, *V. opulus*, *V. opulus* var. *americanum*, and *V. rafinesquianum* (Table 5). Species most resistant include *V. carlesii*, *V. ×burkwoodii*, *V. plicatum* var. *tomentosum*, *V. ×juddii*, *V. ×rhytidophylloides*, and *V. rhytidophyllum* (Weston et al. 1999). Other viburnum species are moderately resistant (Table 5).

*Viburnum leaf beetle management.* In addition to use of resistant and tolerant *Viburnum* species, fertilization rates can be reduced to limit herbivory by viburnum leaf beetles. For example, container-grown *V. dentatum* shrub fertilization rates should be less than 563 g $m^{-3}$ (0.75 oz per $ft^3$) N. When N fertilization levels were kept below this rate, kaolin (Surround WP, Tessenderlo Kerley Inc., Phoenix, AR), a clay-based wettable powder, effectively lowered foliar feeding injury and egg mass numbers in experimental trials (Schultz et al. 2007). Surround WP is an Organic Materials Review Institute certified organic pest management control product (OMRI 2014). *Viburnum* species are not specifically listed on the label. Viburnum leaf beetles can be controlled where they occur with insecticide sprays or soil drenches of systemic insecticides (Table 6). These applications should target the larvae when they become active in the spring and any adults after their emergence in early summer (Table 7).

*Japanese beetle.* Adult Japanese beetles (*Popillia japonica* Newman) attack flowers, fruits and foliage of more than 300 species of plants including viburnum. Since its introduction in 1916 via infested nursery stock, Japanese beetles have become one of the most damaging pests in the eastern U.S. (Held 2004). Adult beetles are 8 to 11 mm (0.3 to 0.4 in) long and metallic green and copper-brown in color. They are active day fliers that disperse readily across long distances. Japanese beetles require one full year to complete egg to egg development. Larvae, or white grubs, feed on roots of turfgrasses and other susceptible plants. Up to five dozen eggs per female are deposited into moist soil, hatch and develop through three instars. Third instar larva overwinter and pupation occurs in the spring. Adult beetles emerge in early summer, usually following a rainfall event (Table 7). They are highly mobile and gregarious, capable of rapidly defoliating susceptible plants. On viburnum, adult beetles skeletonize leaves.

*Japanese beetle management.* Traps used for monitoring include both a floral lure and sex attractants that are intended to help track first flight of adult Japanese beetles. Traps should be placed at least 61 m (200 feet) away from plants under protection. Because only a fraction of lured beetles are caught in traps, trapping is ineffective for managing beetles, but does serve as a monitoring tool (Chappell et al. 2012). Japanese beetle adults on susceptible plants can be controlled with foliar applications of short-residual insecticides that require repeated applications to maintain uninjured plants during adult flight periods. Systemic insecticides can provide longer residual control (Table 6). Follow the National Plant Board's U.S. Domestic Japanese Beetle Harmonization Plan when shipping nursery stock from areas that may be infested with Japanese beetles to beetle-free areas (NPB 2013).

**Table 5. Susceptibility[z] of *Viburnum* species to defoliation and death after infestation by viburnum leaf beetle (*Pyrrhalta viburni*)[y].**

| Viburnum species | Common name |
|---|---|
| **Highly susceptible** | |
| *V. dentatum* | Arrowwood |
| *V. opulus* | European cranberrybush |
| *V. rafinesquianum* | Downy-leaved arrowwood |
| *V. trilobum* | American cranberrybush |
| **Susceptible** | |
| *V. acerifolium* | Mapleleaf |
| *V. lantana* | Wayfaringtree |
| *V. sargentii* | Sargent |
| *V. rufidulum* | Southern blackhaw |
| **Moderately susceptible** | |
| *V. ×burkwoodii* | Burkwood |
| *V. ×carlcephalum* | Fragrant |
| *V. dilatatum* | Linden |
| *V. lentago* | Nannyberry |
| *V. macrocephalum* | Chinese snowball |
| *V. ×pragense* | Prague |
| *V. prunifolium* | Blackhaw |
| *V. ×rhytidophylloides* | Lantanaphyllum |
| **Particularly resistant** | |
| *V. carlesii* | Koreanspice |
| *V. davidii* | David |
| *V. ×juddii* | Judd |
| *V. plicatum* | Doublefile |
| *V. rhytidophyllum* | Leatherleaf |
| *V. setigerum* | Tea |
| *V. sieboldii* | Siebold |

[z]Highly susceptible: species first to be attacked and extensively defoliated by larvae or beetle, few remaining leaves after 2 or more years of feeding, death in 2–3 years. Susceptible: species eventually attacked and killed by larvae and beetle, after highly susceptible species eliminated. Moderately susceptible: species fed on only slightly, feeding sites noticeable, but species rarely destroyed by infestations. Particularly resistant: thick-leaved species, little to no feeding damage, survives infestation. More susceptible if grown in shade.

[y]McNeil et al. 2000; Weston 2004; Weston and Desurmont 2002; Weston et al. 2000.

Table 6. **Pest-directed insecticidal activity and Insecticide Resistance Action Committee (IRAC) codes for use in developing a pesticide rotation plan to manage key pests of viburnum[z,y].**

| Active ingredient: Brand name (Management system[x]) / IRAC category: Chemical class (Mode of action)[w] | | Viburnum leaf beetle, Japanese beetle, cranberry rootworm | Four-lined plant bug | Aphids | Armored scale (crawlers) | Wood-boring beetles | Clearwing moth borers | Spider mites |
|---|---|---|---|---|---|---|---|---|
| **1A: Carbamates (Acetylcholinesterase (AChE) inhibitors)** | | | | | | | | |
| carbaryl: | Carbaryl, Sevin SL (L, N, G) | Y[v] | Y | Y | Y | Y[u] | *N/A* | *N/A* |
| methiocarb: | Mesurol 75W (N, G) | *N/A* | *N/A* | Y | *N/A* | *N/A* | *N/A* | *N/A* |
| **1B: Organophosphates (Acetylcholinesterase (AChE) inhibitors)** | | | | | | | | |
| acephate: | Acephate, Orthene (N, G) | Y | Y | Y | Y | *N/A* | *N/A* | *N/A* |
| chlorpyrifos: | Chlorpyrifos, Dursban (N), | Y | Y | Y | Y | Y | Y | Y |
| | DuraGuard 20 ME (G) | Y | Y | Y | Y | Y | Y | Y |
| malathion: | Malathion (L) | Y | Y | Y | Y | *N/A* | *N/A* | Y |
| **3A: Pyrethrins and Pyrethroids (Sodium channel modulators)** | | | | | | | | |
| bifenthrin: | Onyx (L), | Y | Y | Y | Y | Y | Y | Y |
| | OnyxPro (L, N), | Y | Y | Y | Y | Y | Y | Y |
| | Talstar (L, N) | Y | Y | Y | Y | *N/A* | *N/A* | Y |
| cyfluthrin: | Decathlon (N, G), | Y | Y | Y | Y | *N/A* | *N/A* | *N/A* |
| | Tempo (L) | Y | Y | Y | Y | *N/A* | *N/A* | *N/A* |
| lambda-cyhalothrin: | Scimitar CS (L), | Y | Y | Y | Y | *N/A* | *N/A* | Y |
| | Scimitar GC (L, N, G) | Y | Y | Y | Y | *N/A* | *N/A* | Y |
| permethrin: | Astro (L), Perm-Up (N) | Y | Y | *N/A* | Y | Y | Y | Y |
| cyfluthrin + imidacloprid [4A]: Discus (N) | | Y | Y | Y | Y | Y | *N/A* | *N/A* |
| bifenthrin + imidacloprid [4A]: Allectus SC (L) | | Y | Y | Y | Y | Y | *N/A* | *N/A* |
| **4A: Neonicotinoids (Acetylcholine receptor (nAChR) agonists)** | | | | | | | | |
| acetamiprid: | TriStar 30SG, 8.5 SL (L, N, G) | Y | Y | Y | Y | *N/A* | *N/A* | *N/A* |
| clothianidin: | Arena (L) | *N/A* | *N/A* | Y | *N/A* | *N/A* | *N/A* | *N/A* |
| dinotefuran: | Safari (L, N, G) | Y | *N/A* | Y | Y | Y | *N/A* | *N/A* |
| imidacloprid: | Merit (L) | Y | Y | Y | *N/A* | Y | *N/A* | *N/A* |
| | Marathon (G, N) | Y | *N/A* | Y | *N/A* | Y | *N/A* | *N/A* |
| thiamethoxam: | Meridian (L), | Y | Y | Y | *N/A* | *N/A* | *N/A* | *N/A* |
| | Flagship (N, G) | Y | Y | Y | *N/A* | *N/A* | *N/A* | *N/A* |
| **5: Spinosyns (Nicotinic acetylcholine receptor channel agonists)** | | | | | | | | |
| spinosad: | Conserve SC (L, N, G) | Y[t] | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* |
| **6: Avermectins (Chloride channel activators)** | | | | | | | | |
| abamectin: | Avid 0.15 EC (L, N, G) | *N/A*[s] | *N/A* | Y | *N/A* | *N/A* | *N/A* | Y |
| **7A: Juvenile hormone analogues (Juvenile hormone mimics)** | | | | | | | | |
| kinoprene: | Enstar AQ (G) | *N/A* | *N/A* | Y | Y | *N/A* | *N/A* | *N/A* |
| **7C: (Juvenile hormone mimics)** | | | | | | | | |
| pyriproxifen: | Distance (L, N, G) | *N/A* | *N/A* | Y | Y | *N/A* | *N/A* | *N/A* |
| **8D: Miscellaneous non-specific (multi-site) inhibitors** | | | | | | | | |
| sodium tetraborate: | Borax, Prev-AM Ultra (N, G)[r] | *N/A* | *N/A* | Y | Y | *N/A* | *N/A* | Y |
| **9C: Compounds of non-specific mode of action (Selective feeding blockers)** | | | | | | | | |
| flonicamid: | Aria (L, N, G) | *N/A* | Y | Y | Y | *N/A* | *N/A* | *N/A* |
| **10A: Mite growth inhibitors** | | | | | | | | |
| clofentezine: | Ovation SC (N, G) | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | Y |
| hexythiazox: | Hexygon DF (L, N, G) | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | Y |
| **10B: Mite growth inhibitors** | | | | | | | | |
| etoxazol: | TetraSan 5 WDG (L, N, G) | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | Y |
| **12B: Organotin miticides (Inhibitors of mitochondrial ATP synthesis)** | | | | | | | | |
| fenbutatin-oxide: | ProMITE 50WP (L, N, G) | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | Y |
| **13: (Uncouplers of oxidative phosphorylation via disruption of H proton gradient)** | | | | | | | | |
| chlorfenapyr: | Pylon (G) | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | Y |
| **15: Benzoylureas (Inhibitors of chitin biosynthesis, type 0)** | | | | | | | | |
| novaluron: | Pedestal (N, G) | *N/A* | *N/A* | *N/A* | Y | *N/A* | Y | *N/A* |

Continued …

**Table 6. Continued…**

| Active ingredient: Brand name (Management system[x]) <br> IRAC category: Chemical class (Mode of action)[w] | | Viburnum leaf beetle, Japanese beetle, cranberry rootworm | Four-lined plant bug | Aphids | Armored scale (crawlers) | Wood-boring beetles | Clearwing moth borers | Spider mites |
|---|---|---|---|---|---|---|---|---|
| **16: Insect growth regulator (Inhibitors of chitin biosynthesis, type 1)** | | | | | | | | |
| buprofezin: | Talus 70DF (L, N, G) | *N/A* | Y | Y | Y | *N/A* | *N/A* | *N/A* |
| **20B: Insect growth regulator (Mitochondrial complex III electron transport inhibitors)** | | | | | | | | |
| acequinocyl: | Shuttle O Miticide (N, G) | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | Y |
| | Shuttle 15SC (L) | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | Y |
| **21A: MET I acaricides (Mitochondrial complex I electron transport inhibitors)** | | | | | | | | |
| fenazaquin: | Magus Miticide (L, N, G) | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | Y |
| fenpyroximate: | Akari 5SC (N, G) | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | Y |
| pyridaben: | Sanmite (N, G) | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | Y |
| **23: Tetronic and tetramic acid derivatives (Inhibitors of acetyl CoA carboxylase)** | | | | | | | | |
| spiromesifen: | Judo (N, G) | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | Y |
| | Forbid 4F (L) | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | Y |
| **28: Diamides (Ryanodine receptor modulators)** | | | | | | | | |
| chlorantraniliprole: | Acelepryn (L) | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | Y | *N/A* |
| ***nr:* (not required to have an IRAC code)** | | | | | | | | |
| *Beauveria bassiana*: | BotaniGard ES (N, L, G) | Y | Y | Y | *N/A* | *N/A* | *N/A* | Y |
| horticultural oil: | Ultra-Fine Spray Oil | *N/A* | Y | Y | Y | *N/A* | *N/A* | Y |
| insecticidal soap: | M-Pede (L, N, G) | *N/A* | Y | Y | Y | *N/A* | *N/A* | Y |
| neem oil: | Triple Action Neem Oil (L) | *N/A* | *N/A* | Y | Y | *N/A* | *N/A* | Y |
| | Trilogy (L, N) | *N/A* | *N/A* | Y | *N/A* | *N/A* | *N/A* | Y |
| ***unk:* (mode of action unknown)** | | | | | | | | |
| azadirachtin: | Azatin XL (L, N, G) | Y | *N/A* | Y | *N/A* | *N/A* | *N/A* | *N/A* |
| bifenazate: | Floramite SC (L, N, G) | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | *N/A* | Y |

[z]Check current products for labeled pesticides, sites for control and plant safety and efficacy on pest species. Products listed include several available only to certified professional applicators and may not be available for homeowner use. Check for more current guidelines in regularly up-dated resources [e.g., Hale 2013].

[y]Check labels carefully to determine if any ornamental phytotoxicity has been reported.

[x]Management System: (L) =labeled for use in residential landscapes, (N) = labeled for use in commercial nurseries, (G) = labeled for use in commercial greenhouses.

[w]Insecticide Resistance Action Committee database 2014 (IRAC 2013).

[v]Y = a product with this active ingredient is labeled for control of the pest indicated; *N/A* = Not available for use.

[u]Locust borer (a roundhead borer) is listed on label.

[t]Not labeled for Japanese beetle adults. Cranberry rootworm and viburnum leaf beetles (Chrysomelidae) are leaf feeding beetles that are listed on the label.

[s]*Lyriomyza* leafminers are listed on label.

[r]Thrips suppression demonstrated when sodium tetraborate plus orange oil and biodegradable surfactants [as TriCon™, BioWorks, Inc. (no longer commercially available)] was applied as foliar spray (Seal and Kumar 2010).

Predation by birds, small mammals and generalist insect predators also can reduce Japanese beetle populations. Two wasp species (*Tiphia vernalis* Rohwer and *T. popilliavora* Rohwer) parasitize larvae underground, and a tachinid fly (*Hyperecteina aldrichi* Mesnil) attacks adult beetles. The bacteria *Bacillus popilliae* Dutky exclusively attacks Japanese beetle larvae, but it is best suited for large scale, regional application rather than individual site applications. Microscopic entomopathogenic nematodes occur naturally in the soil, and, together with a symbiotic bacterium, can ultimately kill larvae by means of septicemia. Nematodes that have been shown to be most effective against Japanese beetle larvae are *Steinernema glaseri* Steiner and *Heterorhabditis bacteriophora* Poinar. The latter is commercially available.

*Cranberry rootworm*. Cranberry rootworm (*Rhadopterus picipes* Olivier) is a chrysomelid leaf feeding beetle widely distributed east of the Mississippi River. Adults and larvae of this nursery and landscape pest have an extremely broad host plant range. In addition to viburnum species, cranberry rootworm feed on camellia (*Camellia* sp.), cherry laurel (*Prunus laurocerasus* L.), golden raintree (*Koelreuteria paniculata* Laxm.), Japanese holly (*Ilex crenata* Thunb.), Chinese holly (*Ilex cornuta* Lindl. & Paxton), magnolia (*Magnolia* sp.), oaks (*Quercus* sp.), redtips (*Photinia* sp.), rhododendron (*Rhododendron* sp.), roses (*Rosa* sp.), silver maple (*Acer saccharinum* L.), sycamore (*Platanus* sp.), sumac (*Rhus* sp.), sassafras (*Sassafras albidum* (Nutt.) Nees.), and Virginia creeper (*Parthenocissus quinquefolia* (L.) Planch.). Adult beetles are about 0.51 cm (0.2 in) long, dark brown, and shiny. Adults bear one brood per year and emerge from late April to mid-May in Mississippi (Harman 1931; Johnson and Lyon 1991; Oliver and Chapin 1980). Adults are nocturnal feeders, create c-shaped curving holes in viburnum leaves, and hide in leaf litter and debris during the day. Adults feed for about 2 weeks after emergence, and then seek refuge in leaf litter where they deposit eggs. Larvae are active root feeders (Oliver and Chapin 1980).

*Cranberry rootworm management.* Pesticides may provide control when beetles are actively feeding (Tables 6 and 7). A fraction of applications can also be directed toward leaf litter and debris beneath the affected plant where nocturnal beetles will hide. Entomopathogenic nematodes including *Heterorhabditis bacteriophora* Poinar and *Steinernema scarabei* (Stock & Koppenhöfer) can control cranberry rootworm larvae (Polavarapu 1999; van Tol and Raupp 2005).

*Four-lined plant bug.* The four-lined plant bug [*Poecilocapsus lineatus* (Fabricius)] is a native and widespread generalist feeder with host plants including more than 250 species across 57 plant families. Host preferences are for several dicots including many herbaceous and woody ornamental plants. Azalea (*Rhododendron* sp.), deutzia (*Deutzia* sp.), dogwood (*Cornus* sp.), forsythia (*Forsythia* sp.), Amur maple (*Acer ginnala* Maxim.), rose, sumac, and weigela (*Weigela florida* Thunb.), in addition to viburnum, are occasionally attacked (Johnson and Lyon 1991). Feeding on shade trees is generally restricted to juvenile sucker and water sprouts (Wheeler and Miller 1981). Feeding injury is caused by lacerate-flush feeding, in which barbed stylet mouthpart tips are used to slice and tear plant cells beneath the leaf surface. Softer leaf, bud and flower parts are preferred, but seed, stem and root tissues may also be affected (Schuh and Slater 1995). The feeding pocket in a leaf is flooded with saliva and digestive enzymes that liquefy rigid parts of the ruptured cells before fluids are ingested. Injury may take several days to become widely apparent and can be misidentified as shot-holes caused by fungal pathogens. Feeding points darken then are transformed into small, nearly transparent 'windows' of just clear upper and lower leaf tissues. With time, clear windows coalesce into a necrotic patch that drops from the leaf to leave a shot hole.

Adult four-lined plant bugs are extremely mobile and are readily recognizable from the black and yellow stripes on the hemelytra. Newly-hatched four-lined plant bug nymphs are reddish-orange with black spots. Older instars have black wing pads with a yellow stripe on each pad. Nymphs hatch in mid- to late-spring from banana-shaped eggs deposited the previous fall. Eggs are deposited at right angles in 5.0 to 7.5 cm (2 to 3 in) long vertical slits along host plant stems (Johnson and Lyon 1991; Wheeler and Miller 1981). Clusters of six or more four-lined plant bug eggs can be laid in cinquefoil (*Potentilla* sp.), loosestrife (*Lythrum* sp.), and rose campion [*Lychnis coronaria* (L.) Murray] that may serve as refuge resources (Wheeler and Miller 1981). Nymphs stay near hatching sites and within about one month, complete metamorphosis to adults (Table 7). There is typically only one generation of *P. lineatus* per season.

*Four-lined plant bug management.* Deciduous plants can be scouted once they lose their leaves in fall. Infested plant portions can be manually pruned and discarded (Johnson and Lyon 1991). Trap crops, including mints, can be used in crop borders to protect sensitive crops and landscape beds (Filotas and Westerveld 2011). Scout for feeding injury and live four-lined plant bugs in late May or early June. Insecticides for managing four-lined plant bugs include both broad-spectrum, persistent pesticides that can eliminate beneficial arthropod predators in the garden and landscape, as well as alternatives less toxic to natural enemies (Table 6).

*Aphids.* In the eastern U.S. and Canada, two aphid species are common pests of viburnum. Mature snowball aphids (*Ceruraphis viburnicola* (Gillette), formerly *Neoceruraphis (=Aphis) viburnicola*) are about 2.5 mm (0.1 in) long and bluish, dusty white (MacGillivray 1960). Their multivoltine life-cycle includes secondary host plant(s), which are not yet known (Johnson and Lyon 1991). Snowball aphids overwinter on viburnum host plants. In fall, mature *C. viburnicola* lay eggs on twigs and buds of viburnum species (Table 7). Spring egg hatch coincides with viburnum bud break, allowing pale pink to purplish nymphs to feed on newly-expanding plant tissues (Johnson and Lyon 1991). Foliar feeding in several native viburnum species results in rapid and severe contortion of leaves and bent stems (Johnson and Lyon 1991; MacGillivray 1960). *Viburnum plicatum* var. *tomentosum* appears to be resistant to these malformations (Johnson and Lyon 1991). About two months after egg hatch, *C. viburnicola* emigrate from viburnum onto alternate host plants. In about

**Table 7. Seasonal activities of the major arthropod pests of *Viburnum* in the mid-southern U.S., and unless otherwise noted, represent occurrence in USDA Plant Hardiness Zone 7[z].**

| Arthropod pest | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Viburnum leaf beetle[y] | | | | | D | | | | | | | |
| Japanese beetle | | | | | | | | | | | | |
| Cranberry rootworm | | | | | | | | | | | | |
| Four-lined plant bug | | | | | | | | | | | | |
| Snowball and viburnum aphids | | | | | | | | | | | | |
| Oystershell scale | | | | | | | | | | | | |
| Clearwing borers (*Synanthedon fatifera* and *S. viburni*) | | | | | | | | | | | | |
| Dogwood twig borer (*Oberea myops*) | | | | | | | | | | | | |
| Thrips | | | | | | | | | | | | |
| Southern red mite (*Oligonychus ilicis*) | | | P | | | | | | | | | |

[z]Depicted activity may be early or later than shown depending on location. Activities represented in the table are scale insect crawler emergence, as well as adult or nymphal activity of the most common insect and mite pests. Peaks in arthropod feeding injury (damage) and pest abundance, when reported are denoted by 'D' and 'P', respectively.

[y]Viburnum leaf beetle activity is based on observations in New York where it has become widespread, thus reflects seasonality primarily within USDA Plant Hardiness Zones 4b and 5a.

September, winged migrant adults return to viburnum, give birth to live young without mating (parthogenesis), which, in turn, becomes a sexual generation that lays eggs for the overwintering generation (Johnson and Lyon 1991; MacGillivray 1960). Viburnum aphids (*Aphis viburniphila* Patch), which also feed on viburnum species, may be active through much of the year (Table 7). *Aphis viburniphila* feeding differs from C. *viburnicola* by not producing visible leaf or stem deformation (Johnson and Lyon 1991).

*Aphids management.* Although viburnum aphid infestations do not cause a long-term decline in plant health, *C. viburnicola* foliar distortion is persistent on shrubs, can be aesthetically unpleasant, and may limit access to cutting stock for propagation. In seasons providing warm, wet conditions, entomopathogenic fungi [e.g., *Beauveria bassiana* (Balsamo-Crivelli) Vuillemin] can restrict aphid population growth. In structurally diverse and ecologically complex landscape habitats, natural enemies may reduce need for active aphid management. Ants are commonly associated with aphids and feed on excreted honeydew. In turn, monitoring for ant activity in viburnum crops and landscape plantings can help with early detection of small aphid populations that can be spot treated. Ladybeetles, lacewings, syrphid flies and parasitic wasps all feed on aphid adults and nymphs, yet may be killed if broad spectrum contact insecticides are used.

When aphid infestations are large, topical insecticide applications provide effective control (Table 6). Monitor contact treatment efficacy on a weekly or biweekly basis and re-treat hot spots to prevent re-establishment. Systemic insecticides move into plant tissues slowly and provide long, residual control of aphid populations.

*Oystershell scale.* Oystershell scale [*Lepidosaphes ulmi* (L.)] is the principal scale insect pest associated with viburnum species in the eastern U.S. (Johnson and Lyon 1991). Oystershell scale is an armored scale broadly distributed across the U.S. that, in addition to viburnum, feeds on twigs and branches of more than 100 plant species. Severe infestations may cause branch die-back. Because female oystershell scales are about 2.5 mm (0.098 in) long and blend in with bark colors, detection is difficult. Oystershell scale crawlers emerge in April in Kentucky (Mussey and Potter 1987), May in Michigan and Ohio (Herms 2004), and May and July (two generations) in Virginia (Day 2009). Emergence coincides with first flowering of Vanhoutte spirea (*Spiraea* ×*vanhoutii*) (Herms 2004).

*Oystershell scale management.* Armored scale insects such as oystershell scale are difficult to control. Good sanitation practices are important for preventing scale insect outbreaks. Prune infested stems from lightly infested plants and remove cut tissues and dead plants from the production area. Debris including senesced leaves and pruned stems should be destroyed to ensure scale insect crawlers will not emerge to re-infest host plants. Dead scales do not fall from plants; thus, to determine if pesticide treatments are necessary or were effective in controlling scales, crush the waxy covering. When crushed, gut contents will be extruded from live armored scale insects.

Management actions for scale insect pests are best timed to coincide with visual confirmation of crawler emergence and activity (Table 7). Degree-day models indicate that oystershell scale eggs hatch following accumulations of about 760 degree-days using a 4.4C (40F) base temperature (Mussey and Potter 1987) or about 360 degree-days using a 10C (50F) base temperature (Herms 2004). Oystershell scale crawlers have been observed in Ohio and Kentucky at about the time that eastern redbud (*Cercis canadensis* L.), flowering dogwood (*Cornus florida* L.), Japanese flowering crabapple (*Malus floribunda* Siebold ex Van Houtte), Sargent's crabapple (*Malus sargentii* Rehder), lilac (*Syringa vulgaris* L.) and doublefile viburnum (*Viburnum plicatum* var. *tomentosum*) have begun to flower (Herms 2004; Mussey and Potter 1987).

Oystershell scales feed on woody tissues of viburnum and pesticides will be most effective when applied to crawlers shortly after peak crawler emergence (Table 6). Horticultural oils and insect growth regulators can help conserve natural enemy populations (Frank and Sadof 2011; Raupp et al. 2006; Rebek and Sadof 2003). Dormant-season horticultural oils can be applied to dormant viburnum in winter and early spring. Control with oil is likely achieved through both impaired respiration and disruption of cellular membranes in treated arthropods. Follow-up applications of dormant oil, after leaf drop and before bud swell in fall and early winter, will also help reduce armored scales population growth by limiting impact of subsequent generations. Refined, or summer, horticultural oil treatments can be applied to control eggs, crawlers and immature instars on actively growing trees and shrubs. Refined horticultural oils, for example, 2% SunSpray Ultra-Fine spray oil (Hollyfrontier Refining & Marketing, LLC, Philadelphia, PA), can be safely used on *Viburnum dentatum*, *V. opulus*, *V. opulus* var. *americanum*, and *V. opulus* var. *americanum* 'Alfredo' to control scales, which are sap-feeding insects (Miller 1997).

*Clearwing borers.* Two species of clearwing moth borers (Lepidoptera: Sesiidae) are infrequent pests in the eastern U.S. of both native and non-native viburnum plants. Moth species include the lesser viburnum clearwing (*Synanthedon fatifera* Hodges) and viburnum borer (*S. viburni* Englehardt), which are widely distributed across the eastern half of the U.S. and north into Canada (Chouinard et al. 2006; Solomon 1995). Larval hosts of lesser viburnum clearwings are reported to include both American (*V. opulus* var. *americanum*) and European (*V. opulus*) cranberry bush species (Eichlin and Duckworth 1988; Solomon 1995). Viburnum borer larvae are reported to infest native arrowwood viburnum (*V. dentatum* complex) and European native wayfaringtree viburnum (*V. lantana*) (Eichlin and Duckworth 1988; Solomon 1995).

Female clearwing moths deposit eggs directly onto bark of viburnum host tissues. Once eggs hatch, larvae enter wound tissues or penetrate directly into the bark. Larvae are cream-colored (*S. fatifera*) or pinkish (*S. viburni*) and have a hardened, or sclerotized, head capsule. Lesser viburnum borer prefers to feed within stems, while *S. viburni* develops within wound-related swollen branches or galled tissues (Solomon 1995). Developing larvae feed on callus tissues or on the cambium causing foliar chlorosis, shoot wilt, loss of plant vigor and even plant death (Englehardt 1946; Johnson and Lyon 1991; Solomon 1995). When larvae are young, newly-infested plants can retain foliar turgor for weeks (Solomon 1995). Larval feeding can yield noticeable swellings in stems. Bark may also split or flake off on smaller branches. Larval galleries beneath bark may be filled with frass, which is a mix of moist, loose sawdust and excrement. Frass may be ejected from the gallery, thus used as a scouting sign to detect larval presence. Both viburnum borers are capable of completing their life cycles within a single year, and *S. fatifera* can extend their development to include an entire second season when conditions are unfavorable (Snow et al. 1985).

*Clearwing borers management.* Clearwing moth pests of viburnum are unlikely to be present in large numbers in nurseries and managed landscapes where viburnum crops and ornamental plantings are actively growing and healthy. Pupae and eggs are seldom found while scouting nurseries and landscapes. When active wound sites are detected, presence of live larvae can be confirmed by direct extraction from bark or stems. The thin-skinned larvae are frequently destroyed during removal, making further identification impossible. Once actively feeding larvae are confirmed, other infested stems can often be pruned out and discarded. Adult male clearwing moths of both species can also be trapped and identified using pheromone lures paired with a bucket (e.g. Multi-pher or Universal style, Shaver et al. 1991) or sticky boards within delta or wing traps.

Engelhardt (1946) reported that several parasitic wasps are effective in managing natural populations of *S. viburni* larvae. For these reasons, active efforts to control clearwing borers are seldom warranted (Solomon 1995). Should monitoring of adult flight activity and active infestations (Table 7) suggest that pesticide use may be warranted, several control options are available (Table 6).

*Dogwood twig borer.* The dogwood twig borer (*Oberea tripunctata* Swederus) is a type of longhorned woodboring beetle (Coleoptera: Cerambycidae), so named because of the long antennae visible on adult beetles. Larvae of these adults are called roundheaded borers because they are cylindrical in shape and chew round exit holes through the wood and bark just prior to pupation and adult emergence. The dogwood twig borer adults are slender beetles about 0.31 cm (0.12 in) wide and 1.0 to 1.5 cm (0.4 to 0.6 in) long. Adult beetles have dark to almost black heads with the top of the reddish thorax having three black spots that form a triangle. The yellow-to-tan elytra have a thin black line along the middle edge and a wider black line along the outer edge or side (Baker 1994; Carter et al. 1980).

While dogwood is the preferred host, dogwood twig borers also attack azalea, blueberry (*Vaccinum* sp.), elm (*Ulmus* sp.), laurel, mulberry (*Morus* sp.), poplar (*Populus* sp.), rhododendron, sourwood, viburnum, and willow (*Salix* sp.). Dogwood twig borers can also infest fruit trees in the genera *Malus* and *Prunus* (Solomon 1995). In early to mid-June, adult female dogwood twig borer individuals make two encircling bands of punctures about 1.3 to 2.5 cm (0.5 to 1 in) apart near the branch tip (Table 7). Females then make a vertical slit between the rings and insert a single egg beneath the bark flap (Solomon 1995). After eggs hatch, larvae chew through the bark and enter the branch, then begin tunneling toward the branch tip. After a short distance, larvae turn around and bore down the center of the branch toward the main trunk (Solomon 1995). Along the way, larvae cut a line of small, closely spaced holes in the branch so that frass can be pushed out. In fall, branch portions that contain larval tunnels will die and larvae overwinter in the hollowed out branch between two plugs of frass (Solomon 1995). In spring, mature larvae girdle the branch from the inside out, which weakens the branches leading to visible breaks in spring. Larvae plug the openings of broken branches with frass then pupate within small chambers during April and May. There is one generation per year in the South (Solomon 1995).

*Dogwood twig borer management.* Tunneling by the larvae should cause tip die-back in the summer. Look for tip die-back and for sawdust-like frass being pushed out of the small holes in the branch by the larva. Prune several inches below where the larva is tunneling. Dispose of the branch containing the larva because the larva should continue to tunnel inside and expel the frass. Protective insecticide applications to the bark are seldom needed for this pest because damage levels rarely exceed economic-damage thresholds. If the amount of damage from this pest was objectionable over the prior year, one of the insecticides listed under wood boring beetles in Table 6 can be applied to the bark in the spring just prior to when egg laying is expected in your area.

*Thrips.* In the southern U.S. range for viburnum, two thrips species can also become occasional pests causing aesthetic injury to foliage. In Florida, *V. odoratissimum* and *V. suspensum* may be injured by redbanded thrips [*Selenothrips rubrocinctus* (Giard)] (Johnson and Lyon 1991). The common name of this thrips originates from the appearance of the cream-colored juveniles (only) that have a bright red band around the upper abdomen and a red spot at the abdominal tip. Adult *S. rubrocinctus* are dark brown to black colored and about 1.2 mm (0.05 in) long. In Florida, south Georgia, and along the Gulf Coast, multiple generations per year can be expected (Table 7; Johnson and Lyon 1991).

Chilli thrips (*Scirtothrips dorsalis* Hood) is a non-native pest from Asia and the Indian subcontinent (Kumar et al. 2013). This species has recently become established in Florida and Texas and perhaps other portions of the deep-southern U.S. It was first detected in Florida in 1991 (Kumar et al. 2013) and its first established population was detected in 2005 in a Florida planting of landscape roses (Ludwig and Bogran 2007) and has since been identified as far north as New York state (Kumar et al. 2013). Beyond viburnum, chilli thrips commonly infest roses, schefflera (*Schefflera* sp.), Indian hawthorn[(*Raphiolepis indica* (L.) Lindl. ex Ker Gawl.] and pittosporum (*Pittosporum* sp.) (Ludwig and Bogran 2007). Chilli thrips can complete reproduction on at least 36 common annual and perennial ornamental plant species, yet have a food resource host plant range that includes more than 112 species of plants in 40 different plant families (Kumar et al. 2013). Redbanded thrips also feed on avocado (*Persea americana* Miller), lychee nut (*Nephelium litchi* Cambess), tung (*Aleurites* sp.), acacia (*Acacia* sp.), persimmon (*Diospyros virginiana* L.), sweetgum (*Liquidambar styraciflua* L.), Brazil pepper tree (*Schinus molle* L.), pyracantha (*Pyracantha* sp.), as well as many other fruit, shade and ornamental trees, shrubs, and vines (Johnson and Lyon 1991).

Feeding injury by thrips is generally concentrated on young plant foliar tissues and flower portions. The rasping action of feeding thrips causes cellular damage to leaf, bud, and flower tissues, with plant portions becoming bronzy to silver in color. Across time, infested tissues become stunted, contorted and brittle with premature senescence of plant parts commonly observed (Johnson and Lyon 1991; Ludwig and Bogran 2007). Leaves of plants infested by chilli thrips curl upward in response to upper surface cellular sap removal (Kumar et al. 2013). Honeydew has been noted in association with redbanded thrips infestations (Johnson and Lyon 1991).

Degree day modeling for chilli thrips determined that a 9.7C (49.5F) base temperature and 33C (91F) upper temperature threshold best predicted development and revealed that just 281C (506F) degree days are required to complete an egg-to-egg developmental cycle, thus multiple annual generations will occur in the southern U.S. (Holtz 2006). Chilli thrips are capable of vectoring viral pathogens to plants and may be accidentally distributed in commerce. The thrips are unlikely to persist across seasons in regions of the U.S. where winter temperatures are about –4C (25F) for five consecutive days (Kumar et al. 2013).

*Thrips management.* Thrips species are thigmotactic, having a behavioral preference for inhabiting dense plant tissues and flower parts where they are not easily dislodged. This behavior, as well as frequency at which eggs are deposited within leaf tissues, makes detection extremely difficult during both scouting and nursery inspections prior to shipping. Sampling for thrips may be assisted by washing affected plant portions with 70% ethanol, then scouting the screened portion of the rinsate. Yellow sticky cards are also effective at collecting *S. dorsalis*, while other thrips species are preferentially attracted to blue colored cards (Kumar et al. 2013). Several classes of insecticides are available for thrips control (Table 6).

Natural enemies including minute pirate bugs (*Orius* spp.), the phytoseiid mites (*Neoseiulus cucumeris* McGregor and *Amblyseius swirskii* Athias-Henriot), and predatory mites (*Euseius* spp.) can also be effective predators of chilli thrips and other thrips species. Other pest thrips species have been managed, in part, by several predatory thrips species, lacewings (*Chrysoperla* spp.), ladybird beetles, and predatory mirid bugs (Kumar et al. 2013).

*Southern red mite.* Southern red mite (*Oligonichus ilicis* McGregor) is a widely distributed, cool-season mite that feeds on many broad-leaved ornamental host plants in the eastern U.S. In addition to viburnum (Carter et al. 1980), susceptible hosts include camellia, clethra (*Clethra alnifolia* L.), eleagnus (*Eleagnus* sp.), eucalyptus (*Eucalyptus* sp.), *Eugenia* sp., hibiscus (*Hibiscus* sp.), Japanese holly and other *Ilex* sp., photinia, pyracantha, laurel, rhododendron and azalea species (Carter et al. 1980; Johnson and Lyon 1991). Adult female southern red mites are about 0.5 mm (0.02 in) long, rounded and reddish brown body, have no clear division between body segments, and have four pairs of legs. In New Jersey, the first peak in mite activity was observed in April (Mague and Streu 1980). Populations build during spring and fall and mites become quiescent, resting during hotter summer temperatures (Table 7). Despite this cycle, southern red mites achieve multiple generations per year.

*Southern red mite management.* Successful mite management requires nursery growers and landscape managers to actively scout seasonal hot spots (e.g., dry areas, next to dusty roadways, and close to exhaust fans and doorways), and to monitor efficacy of control efforts once initial treatment is made. Remove weeds, debris, and dehisced plant material to maintain a clean environment. Increasing humidity and spraying foliage with water can limit mite development. Scout for mites by inspecting stippled, bronzed, or curled leaf undersides of suspect plants. Adult and nymphal southern red mites will appear red or pink. Commercially-available biological agents include *Phytoseiulus persimilis* Athias-Henriot and *Amblyseius andersoni* (Chant) predatory mites that can be deployed in individual sachets or shaken onto foliage from bottles containing an inert carrier. In general, plant-feeding mites move more slowly than predatory mites.

Many chemical miticides are available for mite control in nurseries, as well as horticultural oil, insecticidal soaps and neem oil (Table 6). Oils and soaps have more limited contact and residual efficacy than chemical miticides and need to be reapplied more frequently to prevent populations from rebounding. Although broad-spectrum insecticides, including pyrethroids, can control mite populations, broad-spectrum insecticides negatively impact beneficial-insect populations within nursery and landscape systems, and their use should be limited within IPM-based programs (Adkins et al. 2010; Frank and Sadof 2011). For efficient mite management, pesticide applications should be repeated at 7 to14 day intervals, as directed by monitoring efforts. Thorough canopy coverage is needed for successful management. Adding a surfactant or penetrant may increase penetration of spray solutions into hard to reach crevices or between bud scales. If used, test a portion of the crop for possible phytotoxicity. Because mite populations reproduce rapidly, it is critical to rotate among different pesticide modes of action to restrict development of miticide resistance.

**Viburnum Diseases and Management**

*Phytophthora root rot.* Root rot-causing species of *Phytophthora* include several species of water mold pathogens, or oomycetes. *Phytophthora* infections can become problematic in container production and are most difficult to manage in warm, wet soils and container substrates. Soil-borne pathogens initially infect small feeder roots, and then spread to main roots of viburnum and many other host plants. Plant crowns may be invaded if conditions remain conducive for spread (e.g. extended periods of leaf wetness). Above-ground symptoms of root rot, which include yellowing of leaves, sudden wilting, premature leaf drop, slowed shoot growth, branch dieback, and plant death, are the most visible indicators of infection and are usually the first problem reported (Benson and von Broembsen 2001).

Water molds, such as *Phytophthora* spp., require free water to survive and reproduce. Spores have long whip-like structures, or flagella, that assist them to swim. In turn, spores are easily and quickly spread by contaminated water in nurseries, particularly where irrigation water runs through rows and production areas. Wet soils and saturated substrates provide a medium for pathogens to move into root zones. Once established, these pathogens produce overwintering structures, or chlamydospores, that can survive in a variety of climate extremes (Agrios 1997). When environmental conditions reach optimal levels between 20 to 32C (68 to 90F), accompanied by saturated soils, the pathogen breaks out of dormancy and infects susceptible plants (Benson and von Broembsen 2001).

*Phytophthora root rot management.* Proper irrigation management and timely fungicide applications are important in management of *Phytophthora* root rot in container-grown viburnum. Avoid conditions that allow water to puddle around containers. Sheet flow of nursery irrigation runoff can be restricted from pooling around container bottoms by adding 5.2 to 7.6 cm (2 to 3 in) of gravel beneath containers. Thoroughly wash and disinfest recycled containers before use. Fungicides that are most effective against water molds are listed (Table 8).

*Phytophthora leaf blight.* Disease symptoms of *Phytophthora* leaf blight, also known as sudden oak death, are caused by *Phytophthora ramorum* Werres, De Cock & Man in't Veld. Visible disease symptoms in host plants, including viburnum, appear as shoot blight, or rapid shoot death with dropping foliage, resulting in leafless shoots, to leaf blight evidenced by rapid foliar discoloration. Young leaves and shoots are most susceptible to *P. ramorum* infection. Often, roots look healthy, even when they are infected. Spores, also called sporangia, may also move through wind-driven rain or water splash during rains or overhead irrigation. Humans and equipment can also move the pathogen under shoes, tires, or other equipment. Long distance movement occurs though movement of infected plant material (Dailey at al. 2004; ODA 2013). *Phytophthora* leaf and shoot blight ultimately leads to plant death (Sinclair and Lyon 2005).

*Phytophthora leaf blight management.* Fungicides suppress but do not cure *Phytophthora* leaf and shoot blights. Healthy plants should be protected with fungicides like cyazofamid (Segway) or dimethomorph (Stature), particularly when confirmed infections are reported nearby (van Tol and Raupp 2005). Fungicide applications have the ability to mask disease, thus once routine applications cease, symptoms may resume and again become noticeable (Dailey et al. 2004). Cuttings should be propagated only from plants that are known to be pathogen-free. Take steps to employ sanitary standards and precautions when moving susceptible nursery plants, and walking or driving through areas with susceptible species or suspected symptoms (Dailey et al. 2004).

*Downy mildew.* Downy mildew pathogen (*Plasmopara viburni* Peck) prefers cool, humid or wet conditions; thus, symptom development is often most common during spring and fall. Symptoms begin as light green to yellow spots on upper sides of leaves. As leaf wetness persists, spots or blotches become large, reddish brown, and irregular, sometimes with a yellow halo, delimited by leaf veins. White cottony fungal growth is often visible on undersides of leaves. Spots coalesce, causing rapid leaf necrosis. Leaves usually become bronze-colored, curl up and drop (Sinclair and Lyon 2005). Often leaf drop is the first noticeable symptom. *Plasmopara* spp., like *Phytophthora* pathogens described above, are also oomycete water molds that require free water to survive and reproduce. Their spores also have long whip-like flagella that assist in their swimming movement.

*Downy mildew management.* Sanitation is a critical step in downy mildew management. Rake and destroy fallen infected leaves to prevent spores from splashing onto healthy foliage during rain or overhead irrigation (Rane 2001). Preventative fungicides (Table 8) should be used if downy mildew is a recurring problem and at first signs of disease on viburnum.

*Fungal leaf spots.* There are several fungi that cause leaf spot diseases on viburnum, including *Cercospora* spp., *Septoria* spp., *Ascochyta* spp., *Phoma* spp., and *Phyllosticta* spp. (Sinclair and Lyon 2005). Plant damage is often minimal, but unsightly appearance may restrict retail sales. Prolonged periods of leaf wetness and high humidity tend to favor infection, sporulation, and symptom development of leaf spots. Leaf spot diseases are most serious when overhead irrigation is used or during extended periods of rain (Sinclair and Lyon 2005).

*Fungal leaf spots management.* Fungal leaf spot management relies on reducing leaf wetness by avoiding overhead irrigation within nurseries and possibly increasing plant spacing and branch spacing within individual plants to improve air circulation. Fungicide applications are often not needed to manage leaf spot diseases on viburnum because foliar damage levels typically remain below economic damage thresholds.

*Anthracnose diseases.* Anthracnose disease symptoms can be caused by several different fungal pathogens, including *Elsinoe*, *Discula*, *Glorosporium*, and *Sphaceloma* spp. Anthracnose is most prevalent when overhead irrigation is used or during extended, cool rainy conditions (Sinclair and Lyon 2005). Plant damage is often minimal, but unsightly appearance may negatively influence retail sales. Each of these pathogens can cause leaf blight or large black, sometimes sunken lesions that develop blotchy patches, as opposed to spots. Symptoms may appear either as angular, elongated, or round lesions that will eventually coalesce, leaving large portions of dead leaf tissue (Agrios 1997). Anthracnose lesions quickly turn brown or black, causing rapid blighting of leaves. Fungi overwinter on dead and fallen twigs and leaves (Agrios 1997).

*Anthracnose diseases management.* Fungicides are only recommended as preventive applications when leaf blighting becomes aesthetically intolerable or jeopardizes planned time-to-sale. Avoid overhead irrigation and splashing water to limit infection potential. If necessary, apply labeled pesticides when conditions are conducive for disease (Table 8).

*Powdery mildew.* Powdery mildew disease in viburnum is caused by the fungus *Microsphaera penicillata* (Wallr. Lev.) and is distinctive when the white, powdery fungal masses appear on upper leaf surfaces. New plant growth, including buds and shoots, is most susceptible. Infection is typically initiated in spring and symptoms do not appear until early summer. The powdery mildew pathogen prefers cool, dry shade; thus, the disease may be prevalent in nursery production settings with poor air circulation. When conditions are conducive for disease, fungal mycelia masses and spores are produced, primarily on upper leaf surfaces during summer and fall. Mycelia and spores are occasionally found on lower surfaces. These spores are readily wind-dispersed and do not require free water for infection (Benson 2001). Thus, new infections are perpetuated throughout the season. In late summer, the fungus produces scattered black fruiting structures, called cleistothecia, on undersides of leaves (Benson 2001). These structures are easily disseminated by wind and also serve as overwintering structures. If the fungus invades buds in late fall, new spring growth may be

**Table 8. Fungicides arranged by Fungicide Resistance Action Committee (FRAC) codes[z] to facilitate development of a fungicide rotation plan for managing key plant pathogens of viburnum[y].**

| FRAC code: Class description<br>(Action and management notes)<br>Active ingredient(s): Brand name(s)<br>*Causal organism* | | Leaf spots<br>*fungal* | Powdery mildew<br>*fungal* | Stem/Root rots by water molds[x]<br>*oomycetes* | Leaf blight<br>*fungal* | Downy mildew<br>*oomycetes* |
|---|---|---|---|---|---|---|
| **1: MBC Benzimidazoles** | | | | | | |
| (Upwardly systemic. Broad spectrum fungicide for various fungi. Fungicide resistance risk high. Tank mix with fungicides from a different fungicide group (FRAC) to prevent or delay resistance development. Do not mix with copper.) | | | | | | |
| thiophanate methyl: | Cleary's 3336, Allban | Y | Y | *N/A* | *N/A* | *N/A* |
| etridiazole + thiphanate methyl: | Banrot[w] | *N/A* | *N/A* | Y | *N/A* | *N/A* |
| thiphanate methyl + manxozeb: | Zyban[w] | Y | Y | *N/A* | *N/A* | Y |
| **2: Dicarboximides** | | | | | | |
| (Locally systemic, long protection period during wet conditions. Broad spectrum fungicide for greenhouse and nursery use. Medium to high risk for resistance. Toxic to honey bees; do not apply during bloom.) | | | | | | |
| iprodione: | Chipco 26019[v] | Y | *N/*A | *N/A* | *N/A* | *N/A* |
| **3: DMI or SI Triazoles** *Note: this group was formerly known as De-Methylation Inhibitors (DMI) and are now classified as Sterol Biosynthesis Inhibitors (SBI or SI)*. | | | | | | |
| (Upwardly systemic. Rain-fast in 2 hours. Some curative activity. There is wide variation in activity within this group. Effective on powdery mildew. Not effective on downy mildew. Medium risk for resistance.) | | | | | | |
| propiconazole: | Banner | Y | Y | *N/*A | *N/A* | *N/A* |
| triademifon: | Bayleton, Strike[v] | Y | Y | *N/*A | *N/A* | *N/A* |
| myclobutanil: | Eagle | Y | Y | *N/*A | *N/A* | *N/A* |
| triflorine: | Funginex | Y | Y | *N/*A | *N/A* | *N/A* |
| **4: Phenylamides** | | | | | | |
| (Systemic. Effective against diseases caused by oomycetes, or water molds, including damping-off, root and stem rots, and foliar diseases. Use as soil drench or foliar application.) | | | | | | |
| mefenozam: | Subdue[v] | *N/*A | *N/*A | Y | Y | Y |
| **7: Succinate Dehydrogenase Inhibitors (SDHI)** | | | | | | |
| (Locally systemic, long protection period during wet conditions. Broad spectrum fungicide for greenhouse and nursery use. Medium to high risk for resistance. Toxic to honey bees; do not apply during bloom.) | | | | | | |
| pyraclostrobin + boscalid: | Pageant[w] | Y | Y | Y | *N/A* | Y |
| **11: Quinone outside Inhibitors (QoI)** *Note: These fungicides are also known as strobilurins.* | | | | | | |
| (Locally systemic. Effective on mildews, foliar pathogens, and most fungi. Some control of oomycetes, or water molds.) Fungicide resistance risk high.) | | | | | | |
| azoxystrobin: | Heritage | Y | Y | Y | *N/A* | Y |
| pyraclostrobin + boscalid: | Pageant[w] | Y | Y | Y | *N/A* | Y |
| trifloxystrobin: | Compass[v] | Y | Y | Y | *N/A* | Y |
| **12: Phenylpyrroles** | | | | | | |
| (Non-systemic but good residual protection. Broad spectrum fungicide, not effective against oomycetes, or water molds.) | | | | | | |
| fludioxonil: | Medallion | Y | *N/*A | *N/A* | *N/A* | *N/A* |
| **14: Aromatic Hydrocarbons** | | | | | | |
| (Locally systemic. Effective against water molds, or oomycetes). | | | | | | |
| etridiazole: | etridiazole | *N/*A | *N/*A | Y | *N/A* | *N/A* |
| triflumizole: | Terraguard[v] | Y | Y | *N/A* | *N/A* | *N/A* |
| etridiazole + thiphanate methyl: | Banrot[w] | *N/A* | *N/A* | Y | *N/A* | *N/A* |
| **17: Hydroxyanilides** | | | | | | |
| (Locally systemic. For use in outdoor and greenhouse nursery crops.) | | | | | | |
| fenahexamid: | Decree[v] | Y | *N/*A | *N/A* | *N/A* | Y |
| **21: Quinone inside Inhibitors** | | | | | | |
| (Locally systemic. Effective against water molds, or oomycetes. Resistance risk unknown but presumed to be medium to high.) | | | | | | |
| cyazofamid: | Segway | *N/*A | *N/*A | Y | Y | Y |
| **28: Carbamates** | | | | | | |
| (Locally systemic. Control of oomycetes, or water molds. Not for use in landscapes.) | | | | | | |
| propamocarb: | Banol[v] | *N/*A | *N/*A | Y | *N/A* | *N/A* |
| **33: Phosphonates** | | | | | | |
| (Fully systemic; when applied to leaves, product can translocate to lower parts. Effective against water molds, or oomycetes, such as *Phytophthora, Pythium*, and downy mildew pathogens. Low risk for fungicide resistance development.) | | | | | | |
| phosphoric acid: | Alude, Vital | *N/*A | *N/*A | Y | *N/A* | *N/A* |
| fosetyl-Al: | Aliette | *N/*A | *N/*A | Y | *N/A* | *N/A* |

Continued …

**Table 8. Continued…**

| FRAC code: Class description (Action and management notes) Active ingredient(s): Brand name(s) *Causal organism* | | Leaf spots *fungal* | Powdery mildew *fungal* | Stem/Root rots by water molds[x] *oomycetes* | Leaf blight *fungal* | Downy mildew *oomycetes* |
|---|---|---|---|---|---|---|
| **40: Carboxylic Acid Amides** | | | | | | |
| (Locally systemic. Control of oomycetes, or water molds. Not for use in landscapes.) | | | | | | |
| mandipropamid: | Micora | *N*/A | *N*/A | Y | Y | Y |
| dimethomorph: | Stature | *N*/A | *N*/A | Y | Y | Y |
| **M: Multi-site inhibitors** | | | | | | |
| (No systemic activity. Effective as protectants on broad spectrum including most fungi and mildews. Fungicide resistance risk low.) | | | | | | |
| copper: | Kocide, Champion | Y | *N*/A | *N*/A | *N*/A | *N*/A |
| captan: | Captan | Y | *N*/A | *N*/A | *N*/A | *N*/A |
| chlorothalonil: | Daconil, Manicure | Y | Y | *N*/A | *N*/A | *N*/A |
| mancozeb: | Dithane | Y | *N*/A | *N*/A | *N*/A | *N*/A |
| ziram: | Ziram | Y | *N*/A | *N*/A | *N*/A | *N*/A |
| **NC: Not a Classified substance** | | | | | | |
| (Contact fungicide for greenhouse and nursery use. Low risk for resistance.) | | | | | | |
| sodium tetraborate: | Prev-AM Ultra | *N*/A | Y | *N*/A | *N*/A | Y |

[z]FRAC 2013.

[x]Check current products for labeled pesticides, sites for control, plant safety, and efficacy on fungal species. This table reports information on fungicide labels and does not necessarily reflect product efficacy. Refer to fungicide labels for rates and usage, specific host information, possible phytotoxicity, re-entry intervals and resistance management. Within columns, products indicated by 'Y' are labeled for use against the listed pathogen type.

[w]Including the causal agent of sudden oak death, *Phytophthora ramorum*.

[v]Chemical contains more than one active ingredient, thus product may be listed within more than one FRAC code designation (FRAC 2013).

[y]Not for use in residential landscapes; commercial use only.

*N*/A = not applicable or not currently labeled for use against the listed plant pathogen.

stunted or distorted (Rane 2001). Powdery mildew seldom kills plants, but crop growth can be impaired during extreme infections (Agrios 1997).

*Powdery mildew management.* If nursery stock has a history of powdery mildew infection, apply labeled fungicides during late spring and continue at 1 to 3 week intervals through summer (Table 8). Do not use sulfur, as most *Viburnum* species are sensitive to sulfur fungicides (Rane 2001). Discolored leaves will not return to a green coloration, even after the fungus is killed. Prune, rake and destroy infected plant tissue to reduce inoculum load. Improve air movement through pruning and plant spacing. Cultural controls such as plant-demand based irrigation control (Warsaw et al. 2009) and reduced nitrogen fertilization levels can reduce succulent growth, which encourages powdery mildew. Viburnum cultivars resistant or tolerant to powdery mildew infections include *V. ×burkwoodii* 'Mohawk' and *V. ×carlcephalum* 'Cayuga' (Rane 2001).

*Botryosphaeria canker.* Botryosphaeria, or Bot canker [*Botryosphaeria dothidea* (Moug. ex Fr.) Ces. & De Not.], is a common disease of viburnum in the southeastern U.S. Plants under drought stress, as well as those with mechanical injuries, unhealed pruning cuts, and affected by other environmental stressors are more likely to become infected. Healthy plants are more resistant to infections, in part because they are more capable of wound responses that help isolate fungal-infected cells, thus preventing further spread (Sinclair and Lyon 2005).

Bot fungi kill cambium and sapwood, causing cankers. Small cankers appear as dark areas of discolored bark, followed by coalescing lesions that can expand to girdle branches. Water movement within the plant vascular system is stopped, leading to rapid wilting and browning of foliage (Sinclair and Lyon 2005). Disease symptoms may also include branch dieback, or flagging during summer months, during which small branches may die and leaves suddenly turn brown.

Cankers are the sole source of fungal inoculum (Sinclair and Lyon 2005). During wet weather, fungi sporulate from diseased cankers on branches and twigs. Spores can be produced in young cankers throughout the year and can be dispersed by splashing rain or irrigation water. Older cankers produce dark fruiting structures, as well as a different type of spore that can overwinter in cankers and dead bark. In spring, these overwintering structures germinate to initiate a new disease cycle. Once spores germinate, fungal hyphae can survive as saprophytes on bark, obtaining nutrients from dead and dying matter. It is unknown how long the fungus can maintain this state before infecting plant tissue. Trees weakened by drought or other stresses, as well as those wounded by freeze or pruning cuts, are often infected and parasitized by *B. dothidea*. Lenticels, or growth cracks, can also serve as points of entry (Sinclair and Lyon 2005).

*Botryosphaeria canker management.* Maintain plant vigor and avoid environmental stress (e.g. drought) to maintain optimal crop health and limit potential for canker infection. No chemical treatments are available to control bot canker. For best control, eliminate sources of inoculum by removing diseased and infected stems and branches 15 to 20 cm (6 to 8 in) below visible cankers.

*Cytospora canker.* Cytospora cankers, including valsa canker, are typically associated with dieback of scattered branches throughout the canopy. Stressed and unhealthy shrubs are most susceptible to valsa canker. Fungi enter plants through injured bark, including unhealed pruning cuts, injury caused by freeze-damage, and branch crotches. Once infection occurs, fungi spread rapidly though healthy tissue (Sinclair and Lyon 2005). Symptoms often follow drought, causing leaf yellowing and wilting, and eventual leaf browning. Wilted leaves remain attached to limbs. Branches die back to their point of union with a larger limb. Cankers are often difficult to detect on viburnum when canopies are intact and because lesions are not always apparent by simply viewing outside bark. When suspect tissues are dissected, a dark green line will separate healthy from diseased wood (Sinclair and Lyon 2005). White fruiting bodies, or pycnidia, may be visible in newly formed cankers and recently killed bark. Likewise, black fruiting structures called perithecia may appear in newly-killed wood during spring and early summer (Sinclair and Lyon 2005). Spores will be exuded from these structures during rainfall and following irrigation. Infection can occur throughout the year, especially during periods of rainfall and high humidity.

*Cytospora canker management.* Fungicides are not effective for control of cytospora canker, and there is no cure for infected plants. Branches with cankers should be removed as soon as possible, cutting at least 15 to 20 cm (6 to 8 in) below the canker. Avoid pruning during wet weather during which spores are most easily disseminated.

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