Blueberry Culture and Pest, Disease, and Abiotic Disorder Management during Nursery Production in the Southeastern U.S.: A Review[1]

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

Abstract

The genus *Vaccinium* represents an increasingly important group of plants for the U.S. green industry. In 2012, blueberries (*Vaccinium* sp.) ranked the second most important berry crop in the U.S. with a total crop value over $780 million. The popularity of blueberries creates opportunities as well as challenges for nursery crop producers. This article presents a review of current nursery production practices of blueberry and explores the challenges and opportunities for nursery crop producers, including pesticide use during nursery production of an edible crop, and discusses current research relevant to the green industry. Needs for additional research and opportunities for breeding are presented. Blueberries are Ericaceous plants and have very specific cultural requirements. This review presents the culture, as well as insect, mite, and disease control from an integrated pest management (IPM) approach for several blueberry species. A serious threat to the blueberry market, spotted wing drosophila (*Drosophila suzukii* Matsumura) is discussed to provide information needed by commercial producers and landscape managers to address client and customer questions. This review also highlights the most relevant blueberry selections for container production in the southeastern United States.

Index words: arthropod, edible landscape, IPM, nursery crop, ornamental, *Vaccinium*.

Species mentioned in this review: lowbush blueberry (*V. angustifolium* Ait.); farkleberry (*V. arboreum* Marsh); highbush or northern highbush blueberry (*V. corymbosum* L.); half-high blueberry (*V. corymbosum* L. ×*V. angustifolium* Ait.); southern highbush blueberry [complex hybrids of *V. corymbosum* L. with *V. darrowi* Camp, *V. virgatum* (syn. *V. ashei*) Reade, *V. elliottii* Chapm. and others]; Darrow's blueberry (*V. darrowi* Camp); Elliott's blueberry (*V. elliottii* Chapm.); cranberries (*V. macrocarpon*, *V. oxycoccus* Ait.); rabbiteye blueberry [*V. virgatum* (syn. *V. ashei*) Reade] and lingonberries (*V. vitis-idaea* var. *majus* L.).

Significance to the Horticulture Industry

The genus *Vaccinium* contains several species and selections that are becoming important to the nursery industry within the southeastern United States. This review provides a comprehensive overview of the species and their characteristics as well as cultural requirements, abiotic (environmental) issues and biotic (insect, mite, and disease) factors to consider during nursery production. The article presents an Integrated Pest Management approach and specifically focuses on cultural practices and insect, mite, and disease pests that influence plant health, aesthetics, and ultimately plant marketability rather than fruit production. This review directly applies to commercial producers and landscape management professionals who grow or sell blueberry plants in the southeastern U.S. and will also be useful to those who install or maintain blueberries in landscapes.

Blueberry Consumption and Health Benefits

From 1994 to 2003 there was a 160% increase in blueberry consumption among U.S. consumers (USDA 2012). This

[1]Received for publication September 20, 2014; in revised form March 11, 2015. The authors wish to acknowledge the Southern Region IPM Center for funding the project titled *IPM for Shrubs in Southeastern U.S. Nursery Production (Vol. I), a SNIPM Working Group Effort* that led to the development of this manuscript and express their appreciation to Diana R. Cochran and Justin Hawkersmith for their review of an earlier version of this manuscript and Ms. Cheryl Kaiser, Ms. Whitney Yeary, and two anonymous reviewers for their critical feedback on many topics within the manuscript. The use of trade names in this publication is solely for the purpose of providing specific information. The authors do not guarantee or warranty the products named, and references to them in this publication do not signify our approval to the exclusion of other products of suitable composition.

Discussion of cranberry rootworm (*Rhadopterus picipes)* is largely reprinted from text prepared for Management of Pests, Plant Diseases and Abiotic Disorders of Magnolia Species in the Southeastern U.S.: A Review (Knox et al. 2012. J. Environ. Hort. 30:223-234). Reprint of this content herein is made possible by permission of the original content authors.

Discussion of Japanese beetles (*Popillia japonica)* is largely reprinted from text prepared for Optimizing Plant Health and Pest Management of *Lagerstroemia* spp. in Commercial Production and Landscape Situations in the Southeastern U.S.: A Review (Chappell et al. 2012. J. Environ. Hort. 30:161-172). Reprint of this content herein is made possible by permission of the original content authors.

Discussion of twospotted spidermite (*Tetranychus urticae)* is largely reprinted from text prepared for Chong et al. 2012. Cherry – *Prunus* spp., p. 79-108. In: A.F. Fulcher and S.A. White (eds.). IPM for select deciduous trees in southeastern US nursery production. Southern Nursery IPM Working Group, Knoxville, TN. Reprint of this content herein is made possible by permission of the original content authors.

Discussion of blueberry diseases is adapted from content originally developed by the Midwest Fruit Workers [Blueberry Diseases, Ch 11. *in*: Barnes et al. 2013. Midwest blueberry production guide. Ward Gauthier, N.A. and C. Kaiser (eds.). Univ. Ky.]. Reprint of this content herein is made possible by permission of the original content authors.

[2]Department of Plant Sciences, 2431 Joe Johnson Drive, Ellington Plant Science Building rm. 252, University of Tennessee, Knoxville, TN 37996.

[3]Corresponding author: afulcher@utk.edu.

[4]Department of Plant Pathology, University of Kentucky, 1405 Veterans Drive, Lexington, KY 40546-0312.

[5]University of Tennessee, Entomology and Plant Pathology Department, 5201 Marchant Drive, Nashville, TN 37211-4571.

[6]Clemson University, School of Agricultural, Forest, and Environmental Sciences, 167 Poole Agricultural Center, Clemson, SC 29634.

increase was fueled by a greater understanding of the health benefits of antioxidants and increased public awareness of blueberries as a ‘superfood’, containing high levels of the naturally-occurring antioxidants. Putative health benefits of the high anthocyanin content of some species include anti-inflammatory (Wang et al. 1999), antitumor (Adams et al. 2010, Chen et al. 2008b, Kamei et al. 1995), antiulcer (Cristoni and Magistretti 1987), decreased cardiovascular risk (Basu et al. 2010), and slowing the aging of motor skills and memory function (Krikorian et al. 2010; XianJun et al. 2011). Blueberry consumption is also linked to lowering low-density lipoprotein cholesterol (Chen et al. 2008a, Qin et al. 2009).

Commercial blueberry production and use in residential landscapes is increasing with recognition of the health benefits of blueberry consumption, as well as increased interest in edible landscapes. There are now over 77,000 acres of blueberries harvested each year in the U.S., an 86% increase from 2002 (USDA 2012). As a result of the increasing interest in blueberries, nurseries that traditionally grew ornamental plants exclusively are now producing blueberry plants in containers to meet the retail and commercial market demand throughout the nation (Table 1). Container nursery production and IPM of insects, mites, and diseases of blueberry plants is the focus of this review article.

Blueberry Species

Vaccinium is in the Ericaceae family and also includes cranberries and lingonberries in addition to blueberries. There are approximately 450 species of blueberry worldwide (Dirr 2009). Some of the most relevant species native to North America include: lowbush blueberry, highbush or northern highbush blueberry, half-high blueberry, and rabbiteye blueberry (Barnes et al. 2013). Southern highbush blueberries are interspecific hybrids of northern highbush and blueberry species native to more southern locations, including Darrow’s evergreen blueberry, rabbiteye, and Elliott’s blueberry, as well as some lowbush blueberry parentage (NeSmith and Ehlenfeldt 2010) (Table 2). Half-high blueberries are hybrids of northern highbush blueberry and lowbush blueberry.

With coastal, inland, and mountainous areas, the southeastern U.S. (roughly North Carolina west to Kentucky, south to Mississippi and east to Florida, including U.S. Plant Hardiness Zones 6a to 10b) has a variety of blueberry species that are suited to nearly every climate and USDA Plant Hardiness Zone. While adaptability to the climate in which the nursery is located is important, it is essential to also consider in what markets and regions various blueberry species sell best when deciding what plants to produce. Species not discussed in this review article do not currently contribute significantly to U.S. nursery commerce. However, with over 450 *Vaccinium* species worldwide, additional species are undoubtedly suited to horticultural use in the southeastern U.S. Therefore, there is opportunity for observant nursery growers and fruit producers to work together to explore the germplasm and develop lesser-known species for the trade as well as use in breeding programs to develop improved cultivars.

Propagation

Highbush and rabbiteye blueberry plants can be propagated by softwood terminal cuttings taken in the spring prior to flower bud development without rooting hormone (Ferree and Krewer 2012, Schulte and Hancock 1983). Lowbush blueberry plants can be propagated successfully by softwood cuttings (99% rooting without hormone) during a window of active shoot growth in late spring to early summer (late June and early July) before terminals dieback (Kender 1965). Softwood cuttings of highbush blueberries taken in June also root readily when dipped in 8,000 ppm indole-3-butyric acid (IBA) talc (Hartmann et al. 1997) prior to being stuck in a 1:1 perlite:peat mix and placed under shade with intermittent mist. Rabbiteye blueberries can also be rooted as stem cuttings taken midsummer, treated with 10,000 ppm IBA, and placed under intermittent mist (Hartmann et al. 1997). Providing a 16 h photoperiod to rabbiteye cuttings can improve root growth compared with an 8 h photoperiod (Couvillon

Table 1. Number of production nurseries growing various blueberry species and cultivars reported for twelve southern states[z].

Common name	Scientific name	Number of nurseries
Blueberry	*Vaccinium* sp. – assorted varieties	15
Lowbush	*V. angustifolium* and cultivars[y]	15
Farkleberry	*V. arboreum*	7
Northern highbush	*V. corymbosum* and cultivars[x]	36
Darrow’s	*V. darrowi* and cultivar[w]	21
Rabbiteye	*V. virgatum (syn. V. ashei)* and cultivars[v]	48
Blueberry hybrids	*V.* ×[u]	18
Half-high	*V. corymbosum* ×*V. angustifolium* cultivars[t]	8
Southern highbush	*V. corybosum* ×*V. darrowi*, *V. virgatum* (syn. *V. ashei*), *V. elliottii*, and others[s]	15

[z]Plant and Supply Locator, 2015, PlantAnt.com, 2015.

[y]Lowbush cultivars: ‘Cumberland’, ‘Tophat’.

[x]Northern highbush cultivars: ‘Abundance’, ‘Bluecrop’, ‘Bluegold’, ‘Bluejay’, ‘Blueray’, ‘Coville’, ‘Duke’, ‘Earliblue’, ‘Elliot’, ‘Hardiblue’, ‘Herbert’, ‘Jersey’, ‘Jubilee’, ‘Misty’, ‘Northland’, ‘Patriot’, ‘Reka’, ‘Springwide’, ‘SunshineBlue’, ‘Toro’, BountifulBlue® (‘FLX-2’).

[w]Darrow’s blueberry cultivar: ‘Rosa’s Blush’.

[v]Rabbiteye blueberry cultivars: ‘Alapaha’, ‘Austin’, ‘Baldwin’, ‘Bluebell’, ‘Bonita’, ‘Brightwell’, ‘Climax’, ‘Delite’, ‘Homebell’, ‘Ochlocknee’, ‘Powderblue’, ‘Premier’, ‘Southland’, ‘Springhigh’, ‘Tifblue’, ‘Vernon’, ‘Woodard’.

[u]Hybrid cultivars, varied parentage: ‘Corablue’, ‘Dod’sBlue’, ‘LittleGiant’, ‘Pink Lemonade’.

[t]Half-high blueberry cultivars: ‘Chippewa’, ‘Northblue’, ‘Northcountry’, ‘Northsky’.

[s]Southern highbush blueberry cultivars: ‘Emerald’, ‘Farthing’, ‘Gulfcoast’, ‘Jewel’, ‘Legacy’, ‘O’Neal’, ‘Palmetto’, ‘Primadonna’, ‘Rebel’, ‘Scintilla’, ‘Sharpblue’, ‘Snowchaser’, ‘Southern Belle’, ‘Sweetcrisp’, ‘Windsor’.

Table 2. **Growth characteristics of blueberry selections suitable for nursery production in the southeastern US[z,y].**

Cultivar/selection	Type[x]	Growth rate and habit	USDA Plant Hardiness Zones	Pest resistance, notes
‘Darrow’	DB	Upright, vigorous	5–7	Mummy berry and shoestring virus resistance.
‘Bluecrop’	NHB	Upright, open	4–7	Very susceptible to anthracnose, highly resistant to shoestring virus, moderately resistant to mummy berry, red ringspot virus and powdery mildew.
‘Blueray’	NHB	Upright, open	3–8	Susceptible to anthracnose, red ringspot virus, and mummy berry.
‘Duke’	NHB	Upright, stocky	4–7	Requires pruning to avoid over-cropping. Moderately susceptible to mummy berry, susceptible to botryosphaeria stem blight, moderately resistant to twig blight.
‘Echota’	NHB	N/A	4–7	NC[w] State Univ. release for western NC. No field grown plants survived in West Kentucky.
‘Elliot’	NHB	Upright	4–7	Anthracnose resistant.
‘Jersey’	NHB	Upright, vigorous	4–7	Some mummy berry resistance, moderately resistant to red ringspot virus and anthracnose.
‘Nelson’	NHB	Upright, spreading	(3)4–7	Firm fruit, good yield. Moderate yields.
‘Patriot’	NHB	Short, spreading	3–7	Moderate resistance to phytophthora root rot and mummy berry.
‘Sierra’	NHB	Upright, spreading	4–7	Moderately resistant to anthracnose, some susceptibility to mummy berry.
‘Spartan’	NHB	Upright, vigorous	5–7	Susceptible to anthracnose, moderately resistant to mummy berry.
‘Toro’	NHB	Spreading, stocky	4–7	Moderately resistant to anthracnose, some resistance to mummy berry. Consistent high yields.
‘Briteblue’	RE	Spreading	7–9	Large, firm berries. Lacked necessary plant growth in some plantings.
‘Gardenblue’	RE	Upright, vigorous	7–9	Small, light blue fruit with good quality.
‘Premier’	RE	Upright, vigorous	7–9	Extremely high-yielding selection, large, good quality berries. Canes may be too flexible when heavy fruit load. Orange-red fall color.
‘Powderblue’	RE	Upright, vigorous	7–9	Good quality medium to large fruit.
Summer Sunset™	RE[v]	Upright, vigorous, 1.2 m (4 ft) tall by 0.6 m (2 ft) wide after 3 years	7–9	Ornamental landscape selection. Multi-colored berries. Long fruit-bearing period. Propagates easily by softwood cuttings.
‘Tifblue’	RE	Upright, vigorous	7–9	Dominant in southeastern U.S. Medium to large berries with good quality.
Blue Suede™	SHB	Semi-upright, vigorous, open strong canes	6a–9a	Bears over a long period. Large fruit with good flavor. High yield bearing. Deep red color in fall. Moderately easy propagation by softwood cuttings.
‘Cape Fear’	SHB	Semi-upright, vigorous	7a–8a	Precocious. Ripens slightly before ‘Blue Ridge’. Susceptible to cane canker, field resistant to stem blight. Has problems with soft fruit, not recommended.
‘Blue Ridge’	SHB	Erect, vigorous, widely adapted	7a–8a	Ripens slightly after ‘Cape Fear’ (late). Very high yields. Susceptible to cane canker and mummy berry. Field tolerant to stem blight.
‘Legacy’	SHB	Upright, vigorous, spreading	5–10	Some resistance to anthracnose and both mummy berry. Extremely adaptable to various soil types.
‘Ozarkblue’	SHB	Upright, vigorous, spreading	(4)5–9	Susceptible to botryosphaeria canker

[z]Adapted from Barnes et al. 2013, Bratch and Pattison 2009, and D. Lockwood, University of Tennessee, personal communication.

[y]USDA Plant Hardiness Zone ratings are for acclimated plants growing in soil. Cold damage to roots generally occurs at warmer temperatures than other plant parts. Roots in unprotected or inadequately protected containers can be more easily damaged. See *Overwintering* section.

[x]DB = Darrow’s, NHB = northern highbush, RE = rabbiteye, SHB = southern highbush.

[w]North Carolina.

[v]Complex hybrid, mostly rabbiteye (NeSmith and Ehlenfeldt 2011).

and Pokorny 1968). Plant growth following softwood cutting-propagation of lowbush blueberry plants can be influenced by an IBA powder dip just prior to sticking cuttings. Increasing the IBA concentration (up to a 20 μmolar concentration) applied to lowbush blueberry cuttings led to increased branch development following rooting (Debnath 2007). It is unknown if IBA treatment to softwood cuttings elicits the same response from other commercially important blueberry species, but the possibility warrants investigation as understanding the influence of rooting hormone on shoot growth following rooting has the potential to decrease production time and increase profitability for nursery producers.

Highbush blueberries are commonly propagated by hardwood cuttings. Utilizing hardwood cuttings is beneficial because they can be kept in cold storage [1.7 to 3.3 C (35 to 38 F)] for up to 90 days at near 100% relative humidity (D. Bryan, Freedom Tree Farms, personal communication), allowing propagators to take advantage of a slower time during production and more flexibility working around inclement weather. Additionally, hardwood cuttings are not as perishable. Hardwood cuttings are collected in February and March from the previous season’s growth and cut into 13 to 15 cm (5 to 6 in) sections. Cuttings are pencil diameter [6 to 7 mm (0.23–0.27 in)] and have four to six buds (Barnes et al. 2013). After the last freeze, cuttings are stuck with two nodes above the substrate surface in outdoor beds, in flats in a greenhouse, or in high tunnels. Cuttings are kept moist but not damp during rooting and then transplanted. Rooting typically requires 2 to 2.5 months (D. Bryan, Freedom Tree Farms, personal communication). Cultivars vary in ease of rooting: easy ('Blueray' and 'Patriot'), easy to moderate ('Jersey'), moderate ('Elliot'), and hard to root ('Bluecrop', 'Darrow', and 'Spartan') (Strik 2006).

Propagation by single node cuttings (single bud or leaf-bud cuttings) was the standard method for quickly increasing plant numbers when a new cultivar was released. However, it can result in unpredictable and inconsistent rooting percentages and canopy growth, in particular for half-high blueberry (Parliman et al. 1974, Toivio 1976). In addition, slow establishment of cutting-produced plants has been documented, which is attributed to extremely precocious flowering (Galletta and Ballington 1996). As a result, interest in propagating blueberry plants by tissue culture to rapidly commercialize new cultivars has increased. Tissue culture has some disadvantages (requires highly trained staff, specialized equipment, etc.), but research has shown that tissue culture-propagated plants can have growth advantages. For example, 'Herbert' highbush blueberry plants are more uniform, grow more vigorously, and produce more and longer shoots than cutting-derived plants (Litwińczuk et al. 2005). Increasing blueberry shoot growth during tissue culture has been linked to manipulating red/far red ranges during culture (Read et al. 1988). Unlike cutting-produced plants, tissue culture-propagated blueberry plants are not generally prone to precocious flowering and tend to have consistent rooting percentages (Galletta and Ballington 1996).

There are additional growth benefits to propagating blueberries by tissue culture. Benefits measured in half-high blueberry plants include increased growth rates until 34 weeks after planting (Grout et al. 1986), a two-fold increase in lateral branching at 27 weeks (Grout et al. 1986), and enhanced yield for the first three years (El-Shiekh et al. 1996). The researchers found that the higher yield was a direct result of increased branching. Marino et al. (2014) found that tissue-cultured southern highbush interspecific hybrids 'Emerald', 'Jewel', and 'Primadonna' planted in Florida had more major canes for two seasons, during which time 'Emerald' and 'Jewel' also had greater canopy dry weight. Lowbush blueberries propagated by tissue culture have more and longer stems and a greater number of leaves per stem than cutting-propagated plants (Debnath 2007).

Tissue culture of blueberry plants generally follows the methods of Cohen and Elliott (1979) and Cohen (1980), described as follows: recently formed shoots are pruned, leaves are removed, and stems are cut into six node sections. Surface contaminants are removed by rinsing stem sections in 95% ethanol, then soaking them for 30 min in 10% hypochlorite solution. Stem sections are then rinsed three times with distilled water. Shoots are cut into single node sections and placed on half-strength minerals initiation medium (Murashige and Skoog 1962) with five to seven shoots per culture vessel. Cytokinin at 5 $mg \cdot L^{-1}$ (ppm) isopentenyladenine (not benzyladenine or kinetin) is ideal for shoot proliferation (Cohen 1980). Shoots are incubated at 25 C (77 F) with cool-white fluorescent tubes at 350 $\mu E \cdot m^{-2} \cdot s^{-1}$ with a 16 h photoperiod (Miller and Rawnsley 2002). Shoots that initiate from the buds are excised, cut into two- to three-bud segments and transferred to an elongation medium and incubated. For rooting, excised microcuttings are placed under a double layer of 50% shade or equivalent in a high humidity environment and mist is applied after one week. Use of IBA can be toxic to blueberries in tissue culture. Blueberry microcuttings exposed overnight to 50 ppm IBA aqueous solution or a 400 ppm IBA in 10% alcohol quick dip were damaged by the growth regulator (Cohen 1980). Shoots excised from culture can be rooted at 90 to 95% within four weeks for most cultivars.

Container Production

Blueberry plants can be somewhat slow to establish in a container compared to many common ornamental woody plants. In retail settings, #1 to #3 container sizes are common. For lining out in fields for blueberry fruit production, most plants are sold as 2-year-old plants from rooted cuttings in a #1 container, which is desirable because the smaller container size facilitates transporting large quantities of plants and maximizes plant size and establishment success while minimizing plant cost (E. Hanson, Michigan State University and J. Strang, University of Kentucky, personal communication). Ruter and Austin (1993) reported that rabbiteye blueberries grow best after seven months in a stepped-pyramid style container designed to increase root branching and reduce root circling compared with a traditional solid walled round container. Both plant biomass and root dry weights were greater in the alternative container design. During the time frame of this experiment, root circling only occurred in the round container and only when a 3:1:1 pine bark, sphagnum peat moss, and sand substrate was used.

Substrate, irrigation, and fertilization. As an Ericaecous plant, blueberry needs a low substrate pH, approximately 4.5 to 5.5 (Dirr 2009). Blueberry growth is reduced at pH $\geq$ 6.0, and chlorosis is likely due to nutrient deficiencies, primarily iron and manganese (Haynes and Swift 1985). Substrate pH also affects the ability of mycorrhizae to infect host plant roots (Haynes and Swift 1985). Blueberry is considered inefficient at absorbing nutrients from the soil because root systems tend to be shallow and lack root hairs, making mycorrhizal association particularly important to blueberry (Eck 1966). In the wild, blueberry roots tend to be infected with Ericaceous endomycorrhizal fungi that increase the volume of soil that is exploited and the efficacy with which nutrients are absorbed (Boyer et al. 1982). In container production, the shallow root system is less likely to be an issue than is the lack of root hairs. Blueberry plants grown in containers filled with peat-based substrates have greater growth when inoculated with the mycorrhizal fungus *Pezizella ericae* (D.J. Read) (Powell 1981, Powell 1982).

In Tennessee, highbush blueberry plants are successfully produced in 85:15 pine bark:peat with the addition of sulfur [14.8 ml (1 tbsp)] per #1 container size) (Yeary 2014). In a 60 day study by Libby (2011), lowbush blueberry plants were larger in 3:1 and 1:1 (v/v) sphagnum peat moss to sharp sand, compared with a bark-based substrate [80:20 processed pine bark to sphagnum peat moss (v/v)] and pine bark amended with sphagnum peat moss and coconut coir [64:16:20 pine bark to sphagnum peat moss to coir (v/v)]. Plants also grew better when grown in a shallow mum pot [XL-350 mum pan, 20 cm wide by 13 cm tall (7.8 by 5.1 in), 3.0 liter volume (0.8 gal), Nursery Supplies Inc., Chambersburg, PA] rather than a traditional #1 container [XL-300, 17 cm wide by 18 cm tall (6.7 by 7.0 in), 2.8 liter volume (0.74 gal), Nursery Supplies Inc., Chambersburg, PA] (Libby 2011). Growers and extension educators should note that the experiment was of a short duration and conducted in a cool climate; plants may not fare as well in a study more representative of a typical production season or climate in the southeastern U.S. due to peat degradation. Numerous researchers in a range of climates have reported peat degradation during production, which increases the water holding capacity of the substrate and suggests that growers modify irrigation scheduling during the production cycle (Aendekerk 2001, Owen et al. 2010, Prasad and O'Shea 1999).

In many parts of the southeastern U.S., irrigation water may have a pH ≥ 7.5 and be highly alkaline, especially in soils with limestone parent material. The alkalinity of irrigation water influences how difficult it is to change container substrate solution pH. Test water at least twice a year as extremes in weather, especially rainfall and drought, can influence the chemical properties of water, necessitating changes in management practices to adjust pH. A detailed discussion of water quality, pH, and alkalinity are beyond the scope of this review but can be found in Bailey and Bilderback (1998). Not only are the chemical properties of irrigation water important but so are the biological properties. Blueberry plants are susceptible to Phytophthora root rot caused by a pathogen that can be spread in irrigation water, see the **Diseases of Blueberry Plants with Emphasis on Those Occurring during Container Production** section. Sanitize irrigation water collected in a retention pond before reuse because water molds, fungi, bacteria, viruses, and nematodes can easily spread through irrigation water (Hong and Moorman 2007). This is especially important with irrigation water to be used in propagation houses. Managing irrigation scheduling (volume and timing of irrigation) is another important practice to ensure that blueberry plants do not stay too wet. As noted, the physical properties of substrates can change over the course of a production season as the substrate components degrade. In containers, the rhizosphere can be prone to over- and under-watering (Hagen et al. 2014). Irrigation research for container-grown blueberries is needed, but anecdotal information suggests that the water requirements are low to medium, generally less than the irrigation requirements for blueberry plants in field or landscape settings. Detailed information on nursery irrigation practices is beyond the scope of this review but is available [see Bilderback et al. 2013]. Research is needed to identify substrate moisture levels to support maximum growth rates during production and cultural practices that can be used as part of an IPM program to reduce root rot incidence of blueberry plants while in container production. Specifically, research and breeding are needed to identify cultivars with host plant resistance, as well as identify a holistic approach to managing the irrigation scheduling/substrate physical properties/container dimensions complex that can limit root rot and optimize growth during blueberry plant production.

Once established, blueberry plants grow well in containers with a medium to high rate of controlled release fertilizer (Yeary 2014). Like most woody plants, 3 g (0.11 oz) of actual nitrogen per #1 container size per season is an appropriate general recommendation. A slow- release ammonium or urea form of nitrogen are preferred for blueberry plants as they promote the best growth (Krewer and Ruter 2012). Use of the ammonium form of nitrogen also aids in maintaining a low pH and promoting iron uptake. Excess fertilizer, especially nitrogen, should be avoided because excessive nitrogen can result in salt stress as well as dense foliage that increases plant canopy drying time and can exacerbate foliar plant pathogens. Routine foliar testing for nutrient levels can provide valuable information and facilitate refining blueberry fertilization regimes during production, especially when conducted in tandem with substrate or leachate analysis. Detailed directions for foliar analysis sampling can be found in Hanson and Hull (1994). In brief, during mid-summer, collect 50 to 100 fully expanded leaves from the middle of the current season's growth using as many plants as possible. Avoid leaves from vigorous first year shoots and leaves close to fruit clusters, if present. Wash and rinse leaves with tap water to remove foliar fertilizer and pesticide residue. Dry leaves at room temperature before submitting. Putative sufficient macronutrient concentrations for foliage of highbush blueberry (on a percent of dry weight basis) are nitrogen 1.7 to 2.1, phosphorus 0.08 to 0.40, potassium 0.40 to 0.65, calcium 0.30 to 0.80, magnesium 0.15 to 0.30, and sulfur 0.12 to 0.20 (Hanson and Hancock 1996). Putative sufficiency levels for micronutrients (on a parts per million basis) are iron 6 to 200, manganese 50 to 350, boron 25 to 0, copper 4 to 15, zinc 8 to 30, and molybdenum 0.12 (Barnes et al. 2013, Hanson and Hancock 1996, Mills and Jones 1996). It is unknown if ranges established for fruiting plants are directly applicable to production of ornamental blueberry plants in containers. Additionally, the foliar concentration of iron is often not linked to deficiency symptoms, therefore foliar iron analysis has limited utility in diagnosing iron deficiency.

Blueberry plants can accumulate manganese to toxic levels, particularly when plants are produced in a bark-based substrate (Krewer and Ruter 2012). Pine bark contains manganese and has a low pH, which, while desirable for blueberry plant growth, makes manganese more available. Certain fertilizers and fungicides can also supply manganese (Krewer and Ruter 2012). Growers should monitor foliar manganese levels and avoid fertilizers and fungicides containing manganese if foliar levels are above optimal. If necessary, the pH can be increased slightly to make the manganese less available (Krewer and Ruter 2012).

As noted, blueberry plants do not tolerate excess salt, especially as rooted cuttings and young plants (Krewer and Ruter 2012). Thus, it is very important to monitor substrate electrical conductivity (EC) regularly during container production using the Virginia Tech Extraction Method (Wright 1986). When using bark-based substrates, the desired EC range is 0.50 to 0.75 $mS \cdot cm^{-1}$ (Krewer and Ruter 2012). Do not apply high levels of potassium chloride as blueberry plants are not tolerant of chloride (Krewer and Ruter 2012).

Pruning and mitigating risk from pesticide exposure to fruit. Blueberries can have three or more growth flushes per year, the first being the most vigorous (Barnes et al. 2013). Therefore, plants should be pruned once during the growing season and once during the dormant season. This promotes branching, increasing the number of canes that will produce fruit in the future.

Extra care must be taken to ensure that management practices are adjusted for a fruit-bearing crop and that all pesticide laws are being followed. Pesticides traditionally used during nursery crop production may not be labeled for use on fruit-bearing plants. This is a growing area of concern not only as producers who have traditionally grown ornamental plants grow more fruit-bearing crops but also for landscape managers, as edible plantings have become increasingly popular. A coordinated research and extension effort is needed to raise awareness and to develop more IPM strategies for fruit-bearing crops during production in ornamental plant nurseries and following installation in the landscape. For wholesale ornamental plant producers and retailers, products that do not have a food-use label generally cannot be applied within 1 year of fruit harvest (see individual pesticide labels for specific use instructions and restrictions). The most risk-averse approaches for avoiding dietary risks are to not apply pesticides during production or ensure plants are devoid of fruit prior to entering the sales yard, either by scheduled pruning to remove flower-bearing wood (i.e., pruning the winter before sale) or by manually removing fruit. However, having plants in flower or with fruit is a significant marketing advantage for retail sales. Market research is needed to better understand the implications of this risk management approach and how to compensate for lack of fruit with sales tags and other point of purchase information. Removing flowers/fruit during container production can be beneficial as it diverts more carbohydrates to vegetative growth. Also removing and destroying winter damaged or infected branches and other plant parts (e.g., fruit mummies) limits the amount of fungal inoculum present in the production area.

Plant growth regulators. Plant growth regulators (PGRs) can alter plant architecture and thereby reduce labor costs as PGRs can be more effective than pruning to stimulate branching (Cochran and Fulcher 2013, Cochran et al. 2013). PGRs used to promote branching during the production of woody plants are generally either a chemical pinching agent (i.e. dikegulac sodium) or a branch inducer (i.e. benzyladenine). 'Duke' highbush blueberry plants grown in 4 L (1 gal) containers treated with dikegulac sodium (Augeo®, OHP, Mainland, PA) had on average 12 more branches per plant than plants that were either hand-pruned, treated with a branching agent (cytokinin, Configure, Fine Americas, Inc., Walnut Creek, CA), a compound to reduce internode length (gibberellin biosynthesis inhibitor, Topflor, SePRO Corp., Carmel, IN), or water (Yeary 2014). PGRs that enhance branch architecture are commonly applied, both during nursery production and in the orchard, to other fruiting crops including apple (*Malus* sp.), peach (*Prunus* sp.), pear (*Pyrus* sp.), and sweet cherry (*Prunus* sp.) to enhance yield (Bubán 2000, Elkner and Coston 1986). The opportunity exists for researchers to investigate how PGR application during nursery production can enhance plant quality by increasing branching, decreasing production time, and increasing nursery profitability.

Overwintering. The southeast U.S. encompasses U.S. Plant Hardiness Zones 6a to 10b. In the colder areas of the Southeast, winter injury can kill blueberry plants or render them unmarketable, as well as place surviving plants at risk to diseases such as Botryosphaeria canker and Phomopsis twig blight. Rabbiteye selections are known for rapid cold deacclimation (Ehlenfeldt et al. 2006), which can lead to winter damage under otherwise suitable overwintering conditions. Ericaceous plants, in general, have root hardiness to –12.2 to –6.7 C (10 to 20 F). A major problem with container blueberry production in the mid-south is winter damage to the root system due to lack of proper overwintering (C. Smigell, University of Kentucky, personal communication). In the deep south (AL, FL, MS), container-grown blueberries can be overwintered outdoors; however, in Kentucky, Tennessee, Virginia, and mountainous regions of the southern Appalachian states, overwintering protection is necessary. Overwintering protection can be provided by a Quonset-style house, or containers can remain outdoors, placed next to one another and mulched or covered with a thermal blanket. LeBude et al. (2012) provide a thorough guide on overwintering woody container-grown crops for various regions of the southeastern U.S.

Arthropod Pests Limiting Blueberry Growth and Aesthetics in Nurseries

Information provided is intended to facilitate the identification and control of foliage- and stem-feeding pests that negatively affect plant growth and aesthetics during plant production and marketing, rather than pests that infest fruit (Tables 3 and 4). We make a key exception for spotted wing drosophila (SWD), *Drosophila suzukii* Matsumura, so that commercial growers and landscape management professionals, as well as extension educators, become familiar with SWD and its injury. This newly introduced, non-native pest is expected to cause significant management concerns for commercial production and landscape culture of ornamental and edible blueberry cultivars.

Blueberry aphids. Blueberry aphids, *Illinoia pepperi* MacGillivray, are about 2 to 4 mm (0.08 to 0.16 in) long and green at maturity. These pests are commonly encountered in the northeastern, mid-Atlantic and upper midwestern U.S. Aphid nymphs hatch from overwintering eggs during early flowering of blueberries (Table 3). Aphid populations increase slowly with peak reproduction underway by May and June (Hancock et al. 1993, Kriegel 1985).

Aphids can vector blueberry shoestring virus among production stock when feeding on foliage. The virus is most prevalent in native stands of *Vaccinium* that can also serve as refuge for blueberry aphids, which may subsequently migrate into production areas (Hancock et al. 1993). Typical aesthetic feeding injury occurs when piercing-sucking mouthparts are inserted into leaf undersides on newly-expanded foliage, particularly among heavily fertilized plants. Phloem contents are removed with excess excreted as honeydew that may become evident by sooty mold outbreaks on foliage and fruit. Heavily infested foliage may become deformed and may wilt.

Scout for actively feeding aphid populations by looking for ants that are tending aphids for their honeydew. Natural enemies of blueberry aphids include anthocorid pirate bug (*Orius* sp.), chrysopid lace wings, including *Chrysopa carnea* Stephens, coccinellid lady beetles, and larvae of cecidomyiid flies, including *Aphidoletes aphidomyza* Rondani, and syrphid flies (Whalon and Elsner 1982).

Because blueberry aphids are infrequently encountered on blueberry shrubs in production systems in the southern U.S., chemical controls are seldom warranted. For occasions where an aphid outbreak requires chemical management, particularly when blueberry shoestring virus is present, active ingredient options for control are included within Table 4.

Table 3. Seasonal activities of arthropod pests that may limit growth and can result in aesthetic or foliar injury to blueberry crops in commercial nurseries in USDA Plant Hardiness Zone 7. Activities represented in the table are scale insect crawler emergence, as well as adult and/or nymphal activity of the most common insect and mite pests.

Arthropod pest	Jan[z]	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spotted wing drosophila[y]				■	■	■	■	■	■			
Japanese beetle					■	■	■	■				
Cranberry rootworm				■	■							
Caterpillar defoliators			■	■	■	■	■	■	■	■	■	
Long-horned beetle borers					■	■						
Azalea bark scale					■				■			
Twospotted spider mite				■	■	■	■	■	■	■		

[z]The depicted activity may be early or later than shown depending on location.

[y]Spotted wing drosophila primarily infests and damages blueberry fruits (rather than causing aesthetic injury or limited growth to shrubs). This new non-native pest is included within the table to expand awareness about the seasonal flight activity of the adult flies.

Caterpillar defoliators. Several caterpillar pests may defoliate small canopy portions in a blueberry shrub. Lepidopteran caterpillar pests include bagworms (*Thyridopteryx ephemeraeformis* Haworth), azalea caterpillars (*Datana major* Grote & Robinson), yellownecked caterpillars (*Datana ministra* Drury), eastern tent caterpillars (*Malacosoma americanum* Fabricius), fall webworms (*Hyphantria cunea* Drury), whitemarked tussock moths (*Orgyia leucostigma* J.E. Smith), and obliquebanded leafrollers (*Choristoneura rosaceana* Harris) (Barnes et al. 2013). Early caterpillar instars initiate feeding on top layers of the leaf and chew small holes in the leaves during early development. As larvae grow, they can devour entire leaves, leaving sections of the midvein. Obliquebanded leafrollers form the leaf into a tube and then feed inside the leaf. Damage from caterpillars can occur throughout the growing season (Table 3).

Because feeding in commercial production systems is generally limited to small portions of the canopy on individual plants, preventative chemical management is seldom necessary. Periodic scouting is sufficient to enable early detection of caterpillar feeding damage. Where pest populations are atypically large or aesthetic decline warrants active treatment, infested plants can be spot sprayed with insecticides (Table 4).

Cranberry rootworm. Cranberry rootworm, *Rhadopterus picipes* Olivier, is a chrysomelid leaf-feeding beetle widely distributed east of the Mississippi River. Adults and larvae feed on an extremely broad range of nursery and landscape host plants, including blueberry shrubs. Larvae are active root feeders (Oliver and Chapin 1980). Adults, which are about 5 mm (0.2 inches) long, dark brown, and shiny, emerge late April to mid-May in Mississippi (USDA Plant Hardiness Zones 7 to 8) (Table 3), completing one generation per year (Harman 1931, Oliver and Chapin 1980). Adults are nocturnal feeders, hiding in leaf litter and debris during the day. Adults feed for about 2 weeks after emergence and then seek refuge in leaf litter to deposit their eggs.

Recommended pesticides may be applied when beetles are actively feeding, and applications should be directed to leaf litter and debris beneath the affected plant where nocturnal beetles hide (Table 4). Entomopathogenic nematodes including *Heterorhabditis bacteriophora* (Poinar) (no official common name) and *Steinernema scarabei* (Stock & Koppenhöfer) (no official common name) have shown some potential for cranberry rootworm control (Polavarapu 1999, van Tol and Raupp 2005).

Japanese beetle. Adult Japanese beetles (*Popillia japonica* Newman) attack flowers, fruit and foliage of more than 300 species of plants, including blueberry. 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). Larvae feed on the roots of turfgrass and other susceptible host plants. Adult beetles are 8 to 11 mm (0.3 to 0.4 in) long, metallic green and copper-brown in color, and emerge from the ground in early summer, usually following a rainfall event (Table 3). Adults, which are highly mobile and capable of flying long distances, are also gregarious feeders, capable of rapidly defoliating susceptible plants.

Japanese beetle traps use both a floral lure and sex attractant and will indicate first flight of Japanese beetle adults. Attractants in the commercial lure combination not only attract beetles to the trap but to nearby plants as well; therefore, traps should be placed at least 61 m (200 ft) away from the plants that you are trying to protect. Predation by birds, small mammals, and generalist insect predators can reduce populations of immature Japanese beetles. Two wasp species, *Tiphia vernalis* (Rohwer) and *T. popilliavora* (Rohwer), (no official common name for either organism), parasitize larvae, and a tachinid fly, *Istocheta aldrichi* (Mesnil), attacks adult beetles. Milky spore disease (causal organism *Bacillus popilliae* Dutky) exclusively attacks Japanese beetle but is recommended 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 grubs by means of septicemia. Nematodes effective against Japanese beetle grubs include *Steinernema glaseri* (no official common name) (Steiner) and commercially available *Heterorhabditis bacteriophora* (no official common name) (Poinar).

Adult Japanese beetles on susceptible plants can be controlled with foliar applications of short-residual insecticides that require repeated applications to maintain uninjured

Table 4. Pest-directed insecticidal activity and Insecticide Resistance Action Committee (IRAC) codes can be used to develop a pesticide rotation plan to manage key pests of non-bearing blueberry for nursery (N) and greenhouse (G) management systems. Check current pesticide labels for legal use sites, plant safety[z], and efficacy on pest species. Products listed in Table 4 are currently labeled for use on non-food crops i.e., ornamental nursery crops, and include several available only to certified professional applicators (check for more current guidelines in regularly up-dated resources, e.g., Hale, 2013). Sites approved for use, application conditions, phytotoxicity information and available formulations are also subject to annual revision; therefore, recommendations from this table should be validated by consulting the most current product labels.

Active ingredient (Use sites[y])	IRAC Code[x]	Adult Japanese beetle, Cranberry rootworm	Blueberry aphids	Soft scales	Caterpillar defoliators	Woodboring beetles	Spider mites
Abamectin (N, G)	6	Y[w,v]	Y	*N/A*	*N/A*	*N/A*	Y
Acephate (N, G)	1B	Y	Y	Y	Y	*N/A*	*N/A*
Acequinocyl (N, G)	20B	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Y
Acetamiprid (N, G)	4A	Y	Y	Y	Y	*N/A*	*N/A*
Azadirachtin (N, G)	*unk.*	Y	Y	Y	Y	Y	Y
Bacillus thuringiensis subsp. *aizawai* (N, G)	11	*N/A*	*N/A*	*N/A*	Y	*N/A*	*N/A*
Bacillus thuringiensis subsp. *kurstaki* (N, G)	11	*N/A*	*N/A*	*N/A*	Y	*N/A*	*N/A*
Beauveria bassiana (N, G)	*nr*	Y[v]	Y	*N/A*	*N/A*	*N/A*	Y
Bifenazate (N, G)	*unk*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Y
Bifenthrin (N, G)	3A	Y	Y	Y	Y	*N/A*	Y
Buprofezin (N, G)	16	*N/A*	*N/A*	Y	*N/A*	*N/A*	Y
Carbaryl (N, G)	1A	Y	Y	Y	Y	Y[u]	*N/A*
Chlorpyrifos (N, G)	1B	Y	Y	Y	Y	Y	Y
Clofentazine (N, G)	10A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Y
Clorfenapyr (N, G)	13	*N/A*	*N/A*	*N/A*	Y	*N/A*	Y
Cyfluthrin (N, G)	3A	Y	Y	Y	Y	*N/A*	*N/A*
Cyfluthrin + imidacloprid (N)	3A+4A	Y	Y	Y	Y	Y	*N/A*
Deltamethrin (N)	3A	Y	*N/A*	*N/A*	Y	*N/A*	*N/A*
Diflubenzuron (G)	15	*N/A*	*N/A*	*N/A*	Y	*N/A*	*N/A*
Dimethoate (N)	1B	Y[v]	Y	Y	Y	*N/A*	Y
Dinotefuran (N, G)	4A	Y	Y	Y	*N/A*	Y[t]	*N/A*
Etoxazole (N, G)	10B	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Y
Fenazaquin (N, G)	21A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Y
Fenbutatin-oxide (N, G)	12B	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Y
Fenoxycarb (G)	7B	*N/A*	Y	Y	Y	*N/A*	Y
Fenpropathin (N, G)	3A	Y	Y	*N/A*	Y	*N/A*	Y
Fenpyroximate (N, G)	21A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Y
Flonicamid (N, G)	9C	*N/A*	Y	Y	*N/A*	*N/A*	*N/A*
Hexathiazox (N, G)	10A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Y
Horticultural oil (N, G)	*nr*	*N/A*	Y	Y	Y	*N/A*	Y
Imidacloprid (N, G)	4A	Y	Y	Y	*N/A*	Y	*N/A*
Insecticidal soap (N, G)	*nr*	Y	Y	Y	Y	*N/A*	Y
Isaria fumosorosea (N, G)	*nr*	*N/A*	Y	*N/A*	Y	*N/A*	*N/A*
Lambda-cyhalothrin (N, G)	3A	Y	Y	Y	Y	*N/A*	Y
Methadiathon (N)	1B	*N/A*	*N/A*	Y	*N/A*	*N/A*	*N/A*
Methiocarb (N, G)	1A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Y
Milbemectin (N)	6	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Y
Neem oil (N)	*nr*	*N/A*	Y	Y	*N/A*	*N/A*	Y
Novaluron (N, G)	15	*N/A*	*N/A*	*N/A*	Y	*N/A*	*N/A*
Oxydemeton methyl (N)	1B	Y[v]	Y	Y	Y	Y	Y
Permethrin (N)	3A	Y	Y	*N/A*	Y	*N/A*	*N/A*
Pymetrozine (N, G)	9B	*N/A*	Y	*N/A*	*N/A*	*N/A*	*N/A*
Pyrethrins (N, G)	3A	*N/A*	Y	Y	Y	*N/A*	Y
Pyridaben (N, G)	21A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Y
Pyridaryl (G)	*unk.*	*N/A*	*N/A*	*N/A*	Y	*N/A*	*N/A*
Pyriproxifen (N, G)	7C	*N/A*	Y	Y	*N/A*	*N/A*	*N/A*
s-kinoprene (G)	7A	*N/A*	Y	Y	*N/A*	*N/A*	*N/A*
Sodium tetraborate (N, G)	8D	*N/A*	Y	Y	*N/A*	*N/A*	Y
Spinosad (N, G)	5	Y[v]	*N/A*	*N/A*	Y[s]	*N/A*	Y
Spiromesifen (N, G)	23	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Y
Spirotetramat (N, G)	23	*N/A*	Y	Y	*N/A*	*N/A*	Y
Tau-fluvalinate (N, G)	3A	Y[v]	Y	*N/A*	Y	*N/A*	Y
Tebufenozide (G)	18	*N/A*	*N/A*	*N/A*	Y	*N/A*	*N/A*
Thiamethoxam (N, G)	4A	Y[v]	Y	Y	*N/A*	*N/A*	*N/A*
Tolfenpyrad (G)	21A	*N/A*	Y	Y	Y	*N/A*	Y

[z]Check labels carefully to determine if any ornamental phytotoxity has been reported. It is always sound management practice to test for pesticide safety to plants on a small portion of ornamental plants before spraying the entire nursery crop or range.

[y](N) = labeled for use in commercial nurseries; (G) = labeled for use in commercial greenhouses.

[x]IRAC Chemical class (mode of action): 1A Carbamates and 1B Organophosphates (acetylcholinesterase inhibitors); 3A Pyrethrins and Pyrethroids (sodium channel modulators); 4A Neonicotinoids (acetylcholine receptor agonists); 5 Spinosyns (nicotinic acetylcholine receptor channel agonists); 6 Avermec-

Footnotes continued …

plants during active flight periods. Systemic insecticides can provide longer residual control (Table 4). 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 (National Plant Board 2013).

Oberea long-horned beetles. Dogwood twig borer (*Oberea tripunctata* Swederus) is a species of long-horned wood-boring beetle. While dogwood is the preferred host plant, dogwood twig borers also attack numerous other species, including blueberry. These larval roundheaded borers are cylindrical in shape and chew round exit holes through the wood and bark just prior to pupation and adult emergence. Adult dogwood twig borers are slender beetles about 3 mm wide (0.12 in) and 10 to 15 mm (0.4–0.6 in) long. They have a dark to almost black head. The top of the rust-red thorax has three black spots forming a triangle. Yellow to tan wing covers have a thin black line on their inner edge running down the middle and a wider black line along the outer edge or side (Carter et al. 1980).

In early to mid-June, the adult female dogwood twig borer makes two girdling cuts about 13 to 25 mm (0.5 to 1.0 in) apart encircling a branch near the tip. The female then makes a lengthwise slit between the girdles in which a single egg is inserted under the flap of bark (Solomon 1995). When the egg hatches, the larva chews through the bark between the girdles to enter the branch. The larva then starts tunneling toward the branch tip for a short distance before turning around and boring down the center of the branch toward the main trunk (Solomon 1995). As larvae tunnel through the branch, woody excrement (frass) is expelled from the closely-spaced holes. The portion of the branch containing tunnels will die and larvae overwinter in the hollowed branch between two frass plugs (Solomon 1995). In the spring, mature larvae girdle the branch from the inside out, weakening affected branches (Table 3). Many of these branches break, after which the larva plugs the opening with frass and pupates between April and May within small chambers (Solomon 1995). There is one generation per year in the South (Solomon 1995).

The azalea stem borer (*Oberea myops* Haldeman) is a pest of azalea and rhododendron (*Rhododendron* sp.), blueberry, and mountain laurel (*Kalmia* sp.) (Baker 1994). This slender longhorned beetle is 12.5 to 15.6 mm (0.5 to 0.625 in) long with a yellowish brown head and thorax. This species has two black spots on the thorax, and yellowish gray wing covers with dark outer margins (Baker 1994). The azalea stem borer has a similar life cycle to the dogwood twig borer. The azalea stem borer adult emerges from mid-May through June, chews two rows of holes about 12.5 mm (0.5 in) apart on a twig, and inserts an egg under the bark (Baker 1994). The resulting larva bores down the twig into the main stem and then continues to tunnel into the crown and eventually into the roots to spend the winter (Baker 1994). Like the dogwood twig borer, twigs and stems wilt as larvae move downward making a series of holes in the bark from which frass is pushed out (Baker 1994).

Oberea sp. borers can be removed by pruning below where the larva is tunneling and disposing or burning the twig. If populations and injury warrant insecticides, sprays of bifenthrin or permethrin in mid-May and late June can control azalea stem borer (Tables 3).

Soft scale insects. The azalea bark scale (*Eriococcus azalea* Comstock) is a soft scale pest of blueberry, andromeda (*Pieris japonica* Thunb.), azalea and rhododendron (*Rhododendron* sp.), and other species (Rosetta 2006). The adult female azalea bark scale is a tiny red insect with short legs and antennae and long, slender sucking mouthparts. The adult body is covered by a white ovisac (egg sac) made of matted waxy filaments (Carter et al. 1980). Like all soft scales, the waxy coverings of azalea bark scales (or 'test') cannot be separated from the insect body.

There are two generations in the southeastern U.S. (Carter et al. 1980). In North Carolina, the adult female lays its red eggs, filling the ovisac, in late April (Table 3). The eggs hatch in approximately 3 weeks. The nymphs mature during the summer and produce eggs for a second generation in September. The resulting nymphs overwinter and mature into adults in the spring (Carter et al. 1980).

Azalea bark scale feed in the crotch of branches (Carter et al. 1980). They produce copious amounts of honeydew on which black sooty mold grows. Sooty mold associated with honeydew reduces the aesthetic value of trees but also reduces plant photosynthesis, thereby reducing plant growth rate leading to crown thinning and branch dieback under heavy infestations (Carter et al. 1980).

Soft scale management is most successful when contact insecticide applications coincide with crawler activity. Scout trees by surveying the trunk and scaffold branches, especially at branch collars. Double-sided sticky tape traps can be used to detect crawler activity. Contact insecticide use, includ-

Table 4. Footnotes continued

tins (chloride channel activators); 7A, B, C (juvenile hormone mimics); 8D Miscellaneous non-specific (multi-site) inhibitors; 9B, C (Compounds of non-specific modes of action (selective feeding blockers); 10A and 10B Mite growth inhibitors; 11 Microbial endotoxins; 12B Organotin miticides (inhibitors of mitochondrial ATP synthesis); 13 (Uncouplers of oxidative phosphorylation via disruption of proton gradient); 15 Benzoylureas (inhibitors of chitin biosynthesis, type 0); 16 (inhibitors of chitin biosynthesis, type 1); 18 Diacylhydrazines (Ecdysone receptor agonists); 20B (Mitochondrial complex III electron transport inhibitors); 21A MET I acaricides (Mitochondrial complex I electron transport inhibitors); 23 Tetronic and tetramic acid derivatives (inhibitors of acetyl CoA carboxylase); *nr* = products not required to have an IRAC code; *unk*. = Compounds with unknown mode of action. Insecticide Resistance Action Committee (IRAC) 2014 database [http://www.irac-online.org].

[w]Y = a product with this active ingredient is labeled for use on the pest indicated; *N/A* = Not available for use. Labels for these active ingredients may include allowable landscape uses on other ornamental crops. Because blueberries produce edible fruit that may be consumed by humans, these products may not be legal for landscape use when applied to a fruiting edible plant (like blueberry) even when no fruit are present. Consult the label to determine if situations like these apply.

[v]Not labeled for Japanese beetle adults. Cranberry rootworm is a chrysomelid leaf-feeding beetle that is listed on the label.

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

[t]Roundheaded borers are listed on label.

[s]Use when spider mite populations are not present, or are not increasing in number.

ing pyrethroids and organophosphates, can result in scale outbreaks because these broad-spectrum pesticides often kill natural enemies while not controlling mature armored scales (McClure 1977, Merritt et al. 1983, Raupp et al. 2001). Reduced-risk insecticides such as insect growth regulators and some neonicotinoids, including imidacloprid, are alternatives to pyrethroid and organophosphate insecticides (Frank and Sadof 2011, Raupp et al. 2006, Rebek and Sadof 2003). Soft scale species can be controlled with imidacloprid, whereas imidacloprid does not kill armored scale and can actually increase its abundance (Table 4) (Rebek and Sadof 2003, Sadof and Sclar 2000).

Spotted wing drosophila (SWD). The recent introduction of this serious invasive pest into North America is making the production of blueberry, and many other fruits, more difficult. Since first being detected in California in 2008, SWD has quickly spread across the U.S. (Addesso 2013). The adult fly lays its eggs in developing fruit where larvae feed. Current control recommendations are to start spraying the plant with an insecticide on at least a weekly schedule beginning when the fruit first show color during ripening. If the pest is present (Table 3 shows approximate period of activity) and protective insecticide sprays are not made, 100% of the fruit could be ruined as one or more larvae develop inside the blueberries. This development is problematic for the nursery industry. Because insecticides are needed for SWD control and the weekly sprays required may not provide 100% control, there is a good possibility that even treated plants will have some damaged or infested fruit. Nursery growers can expect higher production costs, as well as increased exposure to consumer-based risk, if fruit is to be left on the plant for retail sale. See discussion in *Pruning and mitigating risk from pesticide exposure to fruit.*

Twospotted spider mite. Twospotted spider mite, *Tetranychus urticae* Koch, is one of the most common and destructive mite species in both production and landscape settings, attacking over 200 ornamental plant species, including blueberry (Johnson and Lyon 1988). Adult and immature twospotted spider mites are 0.05 cm (0.02 in) long. Both life stages are pale-green to yellow or cream colored and have two dark green-black patches of spotting on the body. Eggs are spherical and translucent. Injury from foliar feeding becomes evident on susceptible host plants as twospotted spider mites feed on the undersides of leaves and empty leaf cell contents to affect a silvery stippling damage visible on the leaves. Twospotted spider mites spin silken threads that can aid in dispersal, and webbing can cover branches when infestations become severe.

Twospotted spider mites overwinter as adult females either in bark crevices or in the soil (Johnson and Lyon 1988) and may persist throughout the season within protected nursery structures, provided that plant food resources, including weed species, remain present. Eggs of subsequent seasonal populations are deposited directly on leaf undersides. Spider mite populations begin to expand in April and pass through several generations per year, with peak activities occurring in June and July (Potter 2008). Twospotted spider mites become increasingly active as localized conditions become hot and dry and during warmer seasons of the year (Table 3). In tree fruit systems, twospotted spider mites migrate from groundcovers onto trees, which may help trigger higher levels of summer activity (Gotoh 1997). Development of twospotted spider mite on raspberry (*Ribes idaeus* L.) can be completed in about 7 days at 30 C (86 F), 14 days at 25 C (77 F), 16 days at 16 C (60.8 F), and 25 days at 15 C (59 F) (Bounfour and Tanigoshi 2001). Each female can produce 38 to 125 eggs (Bounfour and Tanigoshi 2001). Populations remain active as long as environmental conditions and plant quality are favorable for reproduction and growth.

Incipient populations of twospotted spider mites are easy to overlook due both to their small size and their overwintering habits. Scouts can monitor susceptible crops and weed refuges by looking for the characteristic stippling injury to leaf surfaces. In outdoor container operations and landscapes, overhead irrigation and hand watering can limit mite population growth (Drees 2004). Susceptible plants can be repositioned away from dry, dusty roads and also away from doorways and exhaust fans within production structures. Many natural enemy organisms feed on twospotted spider mites. In Oregon, commercially available *Neoseiulus fallacis* (no official common name) (Garman) predatory mites successfully suppressed twospotted spider mites in ornamental nurseries (Pratt 1999). Once introduced, some predatory organisms can persist by foraging on prey present on alternate host plants, like crabapple (*Malus* sp. Mill.) and ground covers (Stanyard et al. 1997).

Several key factors should be considered when using chemical miticides for population management. Because twospotted spider mites reproduce rapidly and can quickly develop pesticide resistance, it is critical to rotate between different modes of action (Table 4). Select a miticide that is most effective against the life stages detected during scouting. Conserve beneficial arthropods, which can provide long-term biological control of twospotted spider mites, by selecting miticides that are compatible with the natural enemies that are already present. Pyrethroids that are registered for spider mite management are generally not effective.

Diseases of Blueberry Plants with Emphasis on Those Occurring during Container Production

Fungal leaf spots. Foliar leaf spots caused by fungal pathogens are generally considered minor diseases of highbush blueberries in the Southeast (Brannen 2001, Scherm et al. 2003). They may be caused by a variety of fungi, including double spot (*Dothichiza caroliniana* Demaree & M.S. Wilcox), Gloeosporium leaf spot and dieback (*Gloeosporium minus* Shear), Gloeocercospora leaf spot (*Gloeocercospora inconspicua* Demaree & M.S. Wilcox ex Deighton), Phomopsis leaf spot (*Phomopsis vaccinii* Earle), and Phyllosticta leaf spot (*Phyllosticta vaccinii* and *P. elongate* Weid) (Caruso and Ramsdell 1995). Foliar leaf spot symptoms range from small brown leaf spots with reddish or purplish margins to larger irregular lesions. Spots may develop during mid- to late-summer, a few weeks after periods of frequent rainfall, and in severe cases, defoliation may occur. Fungi that cause leaf spots may also infect and kill succulent stems, causing severe dieback. Leaf spot fungi overwinter in infected tissue that falls to container pad floors. Rain and overhead irrigation disperse spores as temperatures warm. Infection occurs during mid-season, but symptoms are not visible until mid- to late- season, or one month after infection.

Foliar leaf spot diseases can be reduced by limiting overhead irrigation, spacing containers, and pruning bushes so that humidity is reduced within the canopy, thus promoting more rapid leaf drying. Sanitation efforts, including maintaining a clean container pad floor and raking and burning fallen diseased leaves, are also critically important for mitigating spread of foliar plant pathogens. Plant infection incidence can be limited in subsequent seasons by applying protective fungicides (Table 5).

Phytophthora root rot. Phytophthora root rot, caused by the water mold *Phytophthora cinnamomi (*Rands), is the most important disease of blueberry (Milholland 1975, Smith 2006). The disease causes root decay in warm, wet substrates (and soils). *Phytophthora cinnamomi* is a soil-borne pathogen that attacks small feeder roots, spreads to main roots, and eventually invades crowns (Sinclair and Lyon 2005). Above-ground symptoms begin with leaves yellowing or reddening. Fewer functioning roots allow less water and nutrient uptake, eventually leading to stunting, lack of new growth, and plant death. Highbush blueberry is extremely susceptible to Phytophthora root rot (Caruso and Ramsdell 1995). While highbush blueberry can tolerate a period of flooding (Lin et al. 2002), it is intolerant of poorly drained conditions, which are also conducive to infection (de Silva et al. 1999). Such conditions can occur on a poorly constructed or uncrowned container pad, when irrigation is over-applied, or when a poorly draining container substrate is used. Rabbiteye blueberry is less susceptible to infection by *P. cinnamomi* than highbush blueberry (Austin 1994); it has fewer root rot symptoms following inoculation than highbush blueberry (Milholland 1975). Southern highbush selections, which include some *V. corymbosum* parentage, are generally susceptible to *P. cinnamoni*; however in field studies, 'Gulfcoast' had comparable resistance to 'Tifblue' and 'Premier' rabbiteye cultivars (Smith 2002). In preliminary research using plants in containers filled with potting substrate, the southern highbush cultivar 'Biloxi' had a 31 to 80% mortality rate while just 2% for 'Star', and 3% for the rabbiteye cultivar 'Tifblue' (Smith et al. 2014).

Once established, Phytophthora water molds persist in soil and substrate as overwintering structures that can survive in a variety of climate extremes (Sinclair and Lyon 2005). *Phytophthora* sp. require free water to survive and reproduce. Spores have long whip-like structures (flagella) that assist in their 'swimming' movement. Wet substrates provide a medium for pathogens to move into blueberry root zones. When environmental conditions reach optimal levels (20 to 32 C [(68 to 90 F]) and substrate is saturated, the pathogen breaks out of dormancy and can infect susceptible blueberry plants.

Selecting a container substrate with desirable physical properties and constructing container pads with good drainage are critical for preventing Phytophthora root rot outbreaks. Ownley et al. (1990) found substrate characteristics less conducive to Phytophthora root rot infection included lower bulk density [0.15 to 0.53 $g{\cdot}cm^{-3}$ (0.09 to 0.31 $oz{\cdot}in^{-3}$)] and lower volumes of water held in the 0.05 to 0.10 bar (5.0 to 10.0 kPa) matric tension range (3 to 6%), and higher total porosity (68 to 86%) and air space (25 to 36%). Drainage from production areas can be improved by installing drainage systems beneath the pads and overwintering houses. During the growing season, avoid excess irrigation especially when conditions favor plant pathogen development. Fungicides such as mefenoxam and phosphorus acid are effective in suppressing disease spread and development of Phytophthora root rot (Table 5).

Table 5. Fungicidal activity arranged by Fungicide Resistance Action Committee (FRAC) codes to facilitate development of a fungicide rotation plan for managing key plant pathogens of blueberry. Blueberries are edible plants and should be treated with products labeled for blueberry (food use label). Do not use fungicides labeled solely for ornamental plants. Check current product labels to ensure they are legal pesticides for use on blueberry, list valid use sites for control, and are safe for plants and effective against the causal fungal species[z] e.g., Ward Gauthier, 2014.

Active ingredient	FRAC code[y]	Management note(s)[x]	Botryosphaeria stem canker & stem blight	Leaf spots	Stem/root rots by water molds[w]	Phomopsis cane and twig blight
Causal organism			***fungal***	***fungal***	***oomycetes***	***fungal***
Azoxystrobin	11	LS, H	Y[v]	Y	*N/A*	Y
Calcium polysulfides	*nr*	NS, L	*N/A*	*N/A*	*N/A*	Y
Captan	M	NS, L	Y	*N/A*	*N/A*	*N/A*
Cyprodinil + fludioxonil	9 + 12	NS, H	*N/A*	Y	*N/A*	Y
Fosetyl-Al	33	FS, Rf, L	*N/A*	*N/A*	Y	*N/A*
Mefenoxam	4[u]	FS, Rf	*N/A*	*N/A*	Y	*N/A*
Mono- and di-potassium salts of phosphorous acid	33	FS, Rf, L	*N/A*	Y	Y	*N/A*
Potassium phosphate	33	FS, Rf, L	*N/A*	Y	Y	*N/A*
Sodium tetraborate	*nr*	NS, L	*N/A*	Y	*N/A*	*N/A*
Ziram	M	NS, L	Y	Y	*N/A*	*N/A*

[z]This table reports information on fungicide labels and does not necessarily reflect product efficacy.

[y]FRAC Chemical class (mode of action): 4 Phenylamides; 9 Anilo-pyrimidines (methionine biosynthesis inhibitors); 11 Quinone outside inhibitors (also known as Strobilurins); 12 Phenylpyrroles (Osmotic signal transducers); 33 Phosphonates, phosphorous acids, ethyl phosphonates (unknown mode of action); M Multi-site inhibitors; *nr* = not required to have a FRAC classification (FRAC, 2013). Fungicide formulations that contain more than one active ingredient may be listed to have more than one FRAC code designation.

[x]NS, non-systemic; LS, locally systemic; FS, fully systemic; Rf, Rainfast; H, High or Low (L) risk of fungicide resistance development.

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

[v]Y = a product with this active ingredient is labeled for legal use against the listed pathogen type; *N/A* = not applicable or not currently labeled for use against the listed plant pathogen.

[u]Not for use in greenhouses and certain uses restricted for nursery crop sites. Primarily for applications to soil around established in-ground plantings.

Stem diseases. Botryosphaeria stem canker is caused by the fungus *Botryosphaeria cortices* (Demaree & Wilcox) and is an important disease of highbush blueberry in the Southeast (Smith 2006). The first symptoms appear as small red lesions on succulent stems, which often resemble winter injury on new wood. These lesions develop into cankers (Caruso and Ramsdell 1995).

Optimal conditions for spore production and infection coincide with wet conditions when temperatures range from 25 to 28 C (77 to 82 F). Upon infection, the pathogen grows slowly and does not seriously affect plants the first year (Caruso and Ramsdell 1995). Without managing the disease, it becomes increasingly more severe each year.

Botryosphaeria stem blight (or dieback) is caused by the fungus *Botryosphaeria dothidea* (Moug. ex Fr.). Symptoms include yellowing, reddening, or drying of leaves on one or more branches. As symptoms progress, leaves turn brown and remain attached for a period of time. Diseased young plants can die within 1 to 2 years. Symptoms often resemble winter injury (Smith 2006). Young plants are more susceptible than older, well-established plants. Infections occur in May to June when temperatures reach 28 to 31 C (82 to 88 F). The pathogen enters host tissue primarily through wounds, such as mechanical damage or in association with Phomopsis infections (Caruso and Ramsdell 1995). Infected stems may provide overwintering sites for the fungus (Sinclair and Lyons 2005). Disease susceptibility decreases as plants age.

Phomopsis twig blight or stem canker, caused by *Phomopsis vaccinii* (Shear), is the most common canker disease in blueberry and is one of the first diseases to develop in spring (Milholland 1982). Early symptoms occur shortly after green-tip, at which time buds begin to turn brown and die. Eventually stems also die, and sudden wilting and flagging of stems occur as warm summer weather progresses (Parker and Ramsdell 1977). Leaves on infected twigs often turn reddish and remain attached to stems (Caruso and Ramsdell 1995). Infection by this fungus occurs through opening buds. During the second year, twigs become blighted and bud loss is more severe. The fungus overwinters in dead or infected twigs. These spores can also infect through wounds on young woody stems, causing cankers (Caruso and Ramsdell 1995). Infection through stems is most common on those damaged or wounded by freezing temperatures.

Stem diseases are most readily avoided by selecting and growing disease-resistant blueberry cultivars (Table 2) and sustaining vigorous plant growth. Select container production sites that are not prone to spring frost (e.g., downhill and low-lying areas where moist cold air can accumulate). Limit late-season fertilizer and irrigation applications in order to restrict late-season growth and to facilitate early hardening-off prior to winter. Winter-injured tissues are most susceptible to infection. Avoid overhead irrigation particularly late in the day in order to limit the hours leaves are wet, minimize humidity within the canopy, and reduce water-splashed spores. Avoid management actions that can induce stem wounds and prune branches during dormancy. When cankers are found, remove infected and blighted twigs, including those that develop during the growing season, by cutting at least 15.2 cm (6 in) below infected tissue. Blueberry plants are among the most disease-free fruit crops in the Southeast; therefore, fungicides are not extensively used to manage diseases. However, a fungicide program may be required if certain stem diseases become established (Table 5).

Viruses and phytoplasmas. Several diseases in infected blueberry shrubs are attributed to viruses. Some virus-caused diseases are spread by insects while others are vectored by mechanical means, such as tools. Once plants become infected there is no cure, and plants must be destroyed.

Shoestring virus (BSSV) is pervasive in the Eastern U.S. and is transmitted by the blueberry aphid (Morimoto et al. 1985, Ramsdell 1979). Symptoms, including reddish to purple coloration along leaf midribs and bases and strap-like leaves with intense reddish-purple coloration, may take up to 4 years to appear. Fruit may remain reddish-purple instead of turning blue at ripening. Many cultivars of highbush and lowbush blueberry are susceptible to shoestring virus, but contrary to previous reports, some cultivars of rabbiteye blueberry may also become infected (Acquaah and Ramsdell 1995). This virus is transmitted by aphids throughout the growing season, but management of early-season aphid populations is most effective to prevent spread (Morimoto et al. 1985).

Red ringspot virus (RRSV) is common in the Eastern U.S. and is vectored by mealybugs. Symptoms include formation of reddish spots on both the stems and upper sides of mature leaves. Young leaves do not develop symptoms. Fruit are also susceptible to infections. Disease symptoms develop one year after infection occurs (Caruso and Ramsdell 1995). Various *Vaccinium* sp. have been reported to be susceptible; a few highbush cultivars such as 'Jersey' and 'Bluecrop' are known to be immune or resistant.

Blueberry stunt phytoplasma, once thought to be a virus, induces dwarfing via shortened internodes. Leaf cupping and marginal chlorosis and/or interveinal chlorosis are also common. Disease symptoms, which are most apparent from June through September, vary depending on blueberry cultivar, plant growth stage, severity of infection, and across seasons. Blueberry stunt is transmitted primarily by the sharpnosed leafhopper (*Scaphytopius magdalensis* Provancher), but other leafhopper species have been reported as vectors. Because vectors are also prominent in various wild and domesticated brambles, vector management is difficult (Tomlinson et al 1950, Whitney and Meyer 1988). Blueberry stunt is also transmitted via grafting.

The most obvious and effective way to limit virus infection during blueberry plant production is to purchase virus-indexed (virus free) plants from a reputable propagator, because once infected by viruses, diseased shrubs cannot be cured. Inspect plants frequently, then remove and destroy infected plants as soon as they are diagnosed to avoid spread of the virus. Although plants cannot be treated for viruses, insecticides can be applied to manage arthropod vectors, including aphids, mealybugs, and leafhoppers (numerous genera for all three insects), once they are detected in the production system. Weeds that serve as refuge and alternative host plants for pests should also be controlled.

Interest in the health benefits of consuming blueberry fruit has led to a dramatic increase in demand for blueberry plants. Container production of blueberry plants is an expanding opportunity for nursery crop producers who have traditionally produced ornamental plants. Blueberry can be a low input crop, but research is needed to better understand the specific cultural requirements of the crop especially with respect to maximizing branching potential, container irrigation requirements, and related cultural practices as part of an IPM program to minimize the occurrence of root rot and optimize growth. Similarly, blueberry plants have few insect and mite pests but the emergence of SWD has raised awareness of the need to carefully manage pesticide use on a fruit-bearing nursery crop as well as implications for marketing a fruit-bearing crop when pesticides are used during nursery production. Members of the nursery crop industry, allied industries, researchers, and extension educators must continue to work together to develop production methods and marketing strategies that support this important crop.

Literature Cited

Acquaah, T. and D.C. Ramsdell. 1995. Resistance to blueberry shoestring virus in southern highbush and rabbiteye cultivars. HortScience 30:1459–1460.

Adams, L.S., S. Phung, N. Yee, N.P. Seeram, L. Li, and S. Chen. 2010. Blueberry phytochemicals inhibit growth and metastatic potential of MDA-MB-231 breast cancer cells through modulation of the phosphatidylinositol 3-kinase pathway. Cancer Res. 70:3594–3605.

Addesso, K. 2013. Spotted wing drosophila and the green industry. Tennessee Greentimes 14(4):14–18.

Aendekerk, T.G.L. 2001. Decomposition of peat substrates in relations to physical properties and growth of *Skimmia*. Acta Hort. 548:261–268.

Austin, M.E. 1994. Rabbiteye blueberries: Development, production, and marketing. AgScience, Inc. Auburndale, FL

Bailey, D. and T. Bilderback. 1998. Alkalinity Control for Irrigation Water Used in Nurseries and Greenhouses. NC State Univ. HIL 558. http://www.ces.ncsu.edu/hil/hil-558.html. Accessed March 29, 2014.

Baker, J.R. 1994. Azalea Stem Borer. NC State Univ. ENT/ort-76. http://www.ces.ncsu.edu/depts/ent/notes/O&T/shrubs/ort076e/ort076e.htm. Accessed January 5, 2015.

Barnes, T., G. Gao, R. Isaacs, D. Johnson, C. Smigell, E. Stafne, N. Ward Gauthier, D. Wolfe, and S. Wright. 2013. Midwest blueberry production guide. N.A. Ward Gauthier and C. Kaiser (eds.). Univ. Kentucky, Lexington, KY. p. 1–58.

Basu, A., M. Du, M.J. Leyva, K. Sanchez, N.M. Betts, M. Wu, C.E. Aston, and T.J. Lyons. 2010. Blueberries decrease cardiovascular risk factors in obese men and women with metabolic syndrome. J. Nutr. 140:1582–1587.

Bilderback, T., C. Boyer, M. Chappell, G. Fain, D. Fare, C. Gilliam, B.E. Jackson, J. Lea-Cox, A.V. LeBude, A. Niemiera, J.S. Owen, J. Ruter, K. Tilt, S. Warren, S.A. White, R. Wright, and T. Yeager (eds.). 2013. Irrigation management practices. p. 6–50, 85–87. *In*: Best Management Practices: Guide for Producing Nursery Crops. 3rd ed. Sou. Nur. Assn., Atlanta, GA.

Bounfour, M. and L.K. Tanigoshi. 2001. Effect of temperature on development and demographic parameters of *Tetranychus urticae* and *Eotetranychus carpini borealis* (Acari: Tetranychidae). Proc. Annu. Entomol. Soc. Amer. 94:400–404.

Boyer, E.P., J.R. Ballington, and C.M. Mainland. 1982. Endomycorrhizae of *Vaccinium corymbosum* L. in North Carolina. J. Amer. Soc. Hortic. Sci. 107:751–754.

Brannen, P. 2001. Leaf spots of blueberry — How to identify and control them. Proc. Biennial Southeast Blueberry Conf. 10:18–19.

Bratch, A. and J. Pattison. 2009. Specialty Crop Profile: Blueberry. Virginia Coop. Ext. Serv. Pub. 438-103. http://pubs.ext.vt.edu/438/438-103/438-103.html. Accessed April 19, 2014.

Bubán, T. 2000. The use of benzyladenine in orchard fruit growing: A mini review. Plant Growth Regulat. 32:381–390.

Carter, C.C., K.F. Horn, D. Kline, J.R. Baker, J. Scott, and H. Singletary, with the collaboration of D.L. Stephan. 1980. Insect and related pests of shrubs. http://ipm.ncsu.edu/AG189/html/Dogwood_Twig_Borer.HTML. Accessed January 5, 2015.

Caruso, F.L. and D.C. Ramsdell. 1995. Compendium of blueberry and cranberry diseases. American Phytopathological Society, Minneapolis, MN. p. 7–11, 19, 28–29, 33, 35.

Chappell, M.R., S.K. Braman, J. Williams-Woodward, and G. Knox. 2012. Optimizing plant health and pest management of *Lagerstroemia* spp. in commercial production and landscape situations in the southeastern U.S.: A review. J. Environ. Hort. 30:161–172.

Chen, Z.Y., R. Jiao, and K.Y. Ma. 2008a. Cholesterol-lowering nutraceuticals and functional foods. J. Agric. Food Chem. 56:8761–8773.

Chen, Z.Y., R. Jiao, and N.P. Seeram. 2008b. Berry fruits for cancer prevention: current status and future prospects. J. Agric. Food Chem. 56:630–635.

Chong, J.-H., S.A. White, and N. Ward. 2012. Cherry — *Prunus* spp. p. 79–108. *In*: A.F. Fulcher and S.A. White (eds.). IPM for Select Deciduous Trees in Southeastern US Nursery Production. Southern Nursery IPM Working Group, Knoxville, TN.

Cochran, D. and A. Fulcher. 2013. Type and rate of plant growth regulator influence vegetative, floral growth, and quality of Little Lime™ hydrangea. HortTechnology 23:1–6.

Cochran, D., A. Fulcher, and G. Bi. 2013. Efficacy of dikegulac sodium applied to pruned and unpruned 'Limelight' hardy hydrangea grown at two locations in the southeastern U.S. HortTechnology 23:836–842.

Cohen, D. and D. Elliott. 1979. Micropropagation methods for blueberries and tamarillos. Comb. Proc. Intl. Plant Prop. Soc. 29:177–179.

Cohen, D. 1980. Application of micropropagation methods for blueberries and tamarillos. Comb. Proc. Intl. Plant Prop. Soc. 30:144–146.

Couvillon, G.A. and F.A. Pokorny. 1968. Photoperiod, indolebutyric acid, and type of cutting wood as factors in rooting in rabbiteye blueberry. (*Vaccinium ashei* Reade), cv. Woodward. HortScience 3:74–75.

Cristoni, A. and M.J. Magistretti. 1987. Antiulcer and healing activities of *Vaccinium myrtrillus* anthiocyanosides. Farmaco (Pratica) 42:29–43.

Debnath, S.C. 2007. Influence of indole-3-butyric acid and propagation method on growth and development of in vitro- and ex vitro-derived lowbush blueberry plants. Plant Growth Regulat. 51:245–253.

de Silva, A., D. Patterson, C. Rothrock, and R. McNew 1999. Phytophthora root rot of blueberry increases with frequency of flooding. HortScience 34:693–695.

Dirr, M. 2009. Manual of Woody Landscape Plants. Stipes, Champaign, IL. p. 1180–1187.

Drees, B.M. 2004. Water wands: High pressure water spray devices for insect and mite control. Texas AgriLife Ext. EEE-00006. http://insects.tamu.edu/extension/publications/epubs/eee_00006.cfm. Accessed January 5, 2015.

Eck, P. 1966. Botany. p. 14–44. *In*: P. Eck and N.F. Childers (eds.). Blueberry Culture. Rutgers Univ. Press, New Brunswick, NJ.

Ehlenfeldt, M.K., E.L. Ogden, L.J. Rowland, and B. Vinyard. 2006. Evaluation of midwinter cold hardiness among 25 rabbiteye blueberry cultivars. HortScience 41:579–581.

Elkner, T.E. and D.C. Coston. 1986. Effect of BA + GA4 + 7, BA and daminozide on growth and lateral shoot development in peach. J. Amer. Soc. Hort. Sci. 111:520–524.

El-Shiekh, A., D.K. Wildung, J.J. Luby, K.L. Sargent, and P.E. Read. 1996. Long-term effects of propagation by tissue culture or softwood single-node cuttings on growth habit, yield, and berry weight of 'Northblue' blueberry. J. Amer. Soc. Hort. Sci. 121:339–342.

Ferree, M.E. and G. Krewer. 2012. Propagating deciduous fruit plants common to Georgia. GA Bul. B 818. p. 13.

Fungicide Resistance Action Committee (FRAC) database. 2013. http://www.frac.info/index.htm. Accessed January 5, 2015.

Frank, S.D. and C.S. Sadof. 2011. Reducing insecticide volume and non-target effects of ambrosia beetle management in nurseries. J. Econ. Entomol. 104:1960–1968.

Galletta, G.J. and J.R. Ballington. 1996. Vine and small fruit crops: Blueberries, cranberries, and lingonberries. p. 1–107. *In*: J. Janick and J.N. Moore (eds.). Fruit Breeding. Vol. 2. Wiley, New York, NY.

Gotoh, T. 1997. Annual life cycles of populations of the two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) in four Japanese pear orchards. Appl. Entomol. Zoology 32:207–216.

Grout, J.M., P.E. Read, and D.K. Wildung. 1986. Influence of tissue culture and leaf-bud propagation on the growth habit of 'Northblue' blueberry. J. Amer. Soc. Hort. Sci. 111:372–375.

Hagen, E., S. Nambuthiri, A. Fulcher, and R. Geneve. 2014. Growth and water consumption of *Hydrangea quercifolia* irrigated by on demand and daily water use irrigation regimes. Scientia Horticulturae 179:132–139.

Hale, F.A. 2013. Commercial insect and mite control for trees, shrubs and flowers. PB1589. Tenn. Coop. Ext. Serv. Knoxville, TN. p. 1–78. https://utextension.tennessee.edu/publications/Documents/PB1589.pdf. Accessed January 5, 2015.

Hancock, J.F., P.W. Callow, S.L. Krebs, D.C. Ramsdell, J.R. Ballington, M.J. Lareau, J.J. Luby, G.P. Pavilis, M.P. Pritts, J.M. Smagula, and N. Vorsa. 1993. Blueberry shoestring virus in eastern North American populations of native *Vaccinium*. HortScience 28:175–176.

Hanson, E. and J. Hancock. 1996. Managing nutrition of highbush blueberries. MI State Univ. Bul. E-2011. p. 1–4.

Hanson, E. and J. Hull. 1994. Plant tissue sampling for determining fertilizer needs of fruit crops. MI State Univ. Bul. E-2482. p. 1–8.

Harman, S.W. 1931. The cranberry rootworm as an apple pest. J. Econ. Entomol. 24:180–182.

Hartmann, H.T., D.E. Kester, F.T. Davies, and R.L. Geneve. 1997. Plant Propagation: Principles, and Practices. Prentice Hall, Upper Saddle River, NJ. p. 656–657.

Haynes, R.J. and R.S. Swift. 1985. Growth and nutrient uptake by highbush blueberry plants in a peat medium as influenced by pH, applied micronutrients and mycorrhizal inoculation. Sciencia Hort. 27:285–294.

Held, D. 2004. Relative susceptibility of woody landscape plants to Japanese beetle (Coleoptera: Scarabaeidae). J. Arboriculture 30:328–334.

Hong, C.X. and G.W. Moorman. 2007. Plant pathogens in irrigation water: Challenges and opportunities. Crit. Rev. Plant Sci. 24:189–208.

Johnson, W.T. and H.H. Lyon. 1988. Insects that Feed on Trees and Shrubs. 2nd ed. Comstock University Press, Ithaca, NY. p. 1–560.

Kamei, H., T. Kojima, M. Hasegawa, T. Koide, T. Umeda, T. Yukawa, and K. Terabe. 1995. Suppression of tumor cell growth by anthocyanin in vitro. Center Invest. 13:590–594.

Kender, W.J. 1965. Some factors affecting the propagation of lowbush blueberries by softwood cuttings. Proc. Amer. Soc. Hort. Sci. 86:301–305.

Knox, G.W., W.E. Klingeman, M. Paret, and A. Fulcher. 2012. Management of pests, plant diseases and abiotic disorders of *Magnolia* species in the southeastern U.S.: A review. J. Environ. Hort. 30:223–234.

Kriegel, R.D. 1985. The population dynamics and dispersal of the blueberry aphid, *Illinoia pepperi* (MacG.) MS Thesis. Michigan State Univ., East Lansing. p. 1–154.

Krikorian, R., M.D. Shidler, T.A. Nash, W. Kalt, M.R. Vinqvist-Tymchuk, B. Shukitt-Hale, and J.A. Joseph. 2010. Blueberry supplementation improves memory in older adults. J. Agric. Food Chem. 58:3996–4000.

Krewer, G. and J. Ruter. 2012. Fertilizing blueberries in pine bark beds. Univ. GA Bul. 1291. p. 1–8.

LeBude, A.V., T.E. Bilderback, H.T. Kraus, S.A. White, M. Chappell, and J. Owen. 2012. Preparing nursery plants for winter in the Southeastern United States. N.C. State Univ. AG-454. http://www.nurserycropscience.info/cultural-practices/overwintering/extension-publications/preparing-nursery-crops-for-winter-ag-454.pdf/view. Accessed January 5, 2015.

Libby, B.A. 2011. Propagation, nursery container production, and rhizome growth studies of *Vaccinium angustifolium* Ait. and *Vaccinium vitis-idaea* L. subsp. *minus* (Lodd.) Hultén. Univ. Maine, Orono, M.S. Thesis. p. 1–140.

Lin, W., L. Yadong, Z. Zhidong, H. Rui, and K. Pliszka. 2002. Comparison of flooding tolerance ability among different blueberry cultivars in China. Acta Hort. 574:261–266.

Litwińczuk, W., G. Szczerba, and D. Wrona. 2005. Field performance of highbush blueberries (*Vaccinium ×corymbosum* L.) cv. 'Herbert' propagated by cuttings and tissue culture. Scientia Hort. 106:162–169.

Marino, S.R, J.G. Williamson, J.W. Olmstead, and P.F. Harmon. 2014. Vegetative growth of three southern highbush cultivars obtained from micropropagation and softwood cuttings in two Florida locations. HortScience 49:556–561.

McClure, M.S. 1977. Resurgence of the scale, *Fiorinia externa* (Homoptera: Diaspididae) on hemlock following insecticide application. Environ. Entomol. 6:480–484.

Merritt R.W., M.K. Kennedy, and E.E Gersabeck. 1983. Integrated pest management of nuisance and biting flies in a Michigan resort: Dealing with secondary pest outbreaks. p. 277–299. *In*: G.W. Frankie and C.S. Koehler (eds.). Urban Entomology: Interdisciplinary Perspectives. Preager, New York, NY.

Milholland, R.D. 1975. Pathogenicity and histopathology of *Phytophthora cinnamomi* on highbush and rabbiteye blueberry. Phytopathology 65:789–793.

Milholland, R.D. 1982. Blueberry twig blight caused by *Phomopsis vaccinii*. Plant Dis. 66:1034–1036.

Miller, S.A. and E.K. Rawnsley. 2002. Tissue culture techniques with New Zealand blueberry selections©. Comb. Proc. Intl. Plant Prop. Soc. 52:211–213.

Mills, H.A. and J.B. Jones Jr. 1996. Plant Analysis Handbook II. MicroMacro Publishing, Athens, GA. p. 159.

Morimoto, K.M., D.C. Ramsdell, J.M. Gillett, and W.G. Chaney. 1985. Acquisition and transmission of blueberry shoestring virus by its aphid vector *Illinoia pepperi*. Phytopathology 75:709–712.

Murashige, T. and F. Skoog, 1962. A revised medium for rapid growth and bioassays with tobacco tissue cultures. Physiologia Plantarum. 15:473–497.

National Plant Board (NPB). 2013. U.S. Domestic Japanese Beetle Harmonization Plan. http://www.nationalplantboard.org/docs/jbcolumn.pdf. Accessed January 5, 2015.

NeSmith, D.S. and M.K. Ehlenfeldt. 2011. 'Summer Sunset™': A new ornamental blueberry. HortScience 46:1561–1561.

NeSmith, D.S. and M.K. Ehlenfeldt. 2010. 'Blue Suede™': A Southern highbush blueberry for the home gardener. HortScience 45:302–303.

Oliver, A.D. and J.B. Chapin. 1980. The cranberry rootworm: Adult seasonal history and factors affecting its status as a pest of woody ornamentals in Louisiana. J. Econ. Entomol. 73:96–100.

Owen, J.S., M. Zazirska-Gabriel, D. Sullivan, J.E. Altland, and J.P. Albano. 2010. Water use and growth of two woody taxa produced in varying indigenous Douglas fir based soilless substrates. HortScience 45:S111 (Abstr.).

Ownley, B.H., D.M. Benson, and T.E. Bilderback. 1990. Physical properties of container media and relation to severity of Phytophthora root rot of rhododendron. J. Amer. Soc. Hort. Sci. 115:564–570.

Parliman B., M. Toivio, and C. Stushnoff. 1974. Propagation procedures for new half-high blueberry hybrid. Proc. N. Amer. Blueberry Res. Workers Conf., Mich. Agric. Ext. Sta. Rpt. 3:17–33.

Parker, P.E. and D.C. Ramsdell. 1977. Epidemiology and chemical control of Phomopsis canker of highbush blueberry. Phytopathology 67:1481–1484.

Plant and Supply Locator. 2014. Hutchison Publishing Corporation, Taylors, SC. http://www.plantlocator.net. Accessed March 29, 2014.

PlantANT. 2014. PlantANT Free Wholesale Plant & Nursery Directory, Davie, FL. http://www.plantant.com. Accessed March 29, 2014.

Polavarapu, S. 1999. Insecticidal nematodes for cranberry pest management. p. 79–90. *In*: Proc. Wkshp. Optimal Use Insecticidal Nematodes in Pest Mgt. Rutgers University, Chatsworth, NJ. http://www.rci.rutgers.edu/~insects/nematodeproceed.pdf. Accessed January 5, 2015.

Potter, M.F. 2008. Spider mites on landscape plants. Univ. Ky. ENTFACT-438. http://www2.ca.uky.edu/entomology/entfacts/ef438.asp. Accessed January 5, 2015.

Powell, C.L. 1981. Mycorrhizal fungi and blueberries — how to introduce them. N.Z. J. Agric. 143:33–35.

Powell, C.L. 1982. The effect of the ericoid mycorrhizal fungus *Pezizella ericae* (Read) on the growth and nutrition of seedlings of blueberry (*Vaccinium corymbosum* L.). J. Amer. Soc. Hort. Sci. 107:1012–1015.

Prasad, M. and J. O'Shea. 1999. Relative breakdown of peat and non-peat growing media. Acta Hort. 481:121–128.

Pratt, P.D. 1999. Biological control of spider mites by the predatory mite *Neoseiulus fallacis* (Acari: Phytoseiidae) in ornamental nursery systems. Oregon State Univ., Corvallis, PhD Dis. p. 1–202.

Qin Y., M. Xia, J. Ma, Y. Hao, J. Liu, H. Mou, L. Cao, and W. Ling. 2009. Anthocyanin supplementation improves serum LDL- and HDL cholesterol concentrations associated with the inhibition of cholesteryl ester transfer protein in dyslipidemic subjects. Amer. J. Clin. Nutr. 90:485–492.

Ramsdell, D.C. 1979. Physical and chemical properties of blueberry shoestring virus. Phytopathology 69:1087–1091.

Raupp, M.J., J.J. Holmes, C.S. Sadof, P.M. Shrewsbury, and J.A. Davidson. 2001. Effects of cover sprays and residual pesticides on scale insects and natural enemies in urban forests. J. Arboriculture 27:203–214.

Raupp, M.J., A.B. Cumming, and E.C. Raupp. 2006. Street tree diversity in Eastern North America and its potential for tree loss to exotic borers. Arboriculture Urban For. 32:297–304.

Read, P.E., A.S. Economou, C.A. Hartley, J.M. Grout, and C.D. Fellman. 1988. A summary of stock plant influences on woody plant tissue culture success with special emphasis on the Ericaceae. Acta Hort. 227:476–478.

Rebek, E.J. and C.S. Sadof. 2003. Effects of pesticide applications on the euonymus scale (Homoptera: Diaspididae) and its parasitoid, *Encarsia citrina* (Hymenoptera: Aphelinidae). J. Econ. Entomol. 96:446–452.

Rosetta, R. 2006. Azalea bark scale. Pacific Northwest Nursery IPM, Oregon State University, Corvallis. http://oregonstate.edu/dept/nurspest/azalea_bark_scale.htm. Accessed January 5, 2015.

Ruter, J.M. and M.E. Austin. 1993. Influence of container design and potting media on growth and root circling of 'Tifblue' and 'Brightwell' rabbiteye blueberries. J. Small Fruit Viticult. 1:27–34.

Sadof, C.S. and D.C. Sclar. 2000. Effects of horticultural oil and foliar or soil-applied systemic insecticides on Euonymus scale in pachysandra. J. Arboriculture 26:120–125.

Scherm, H., P.M. Brannen, P.S. Ojiambo, A.T. Savelle, G. Krewer, and M.D. Bruorton. 2003. Blueberry leaf spots: Epidemiology, yield losses, and control. Proc. Southeastern Blueberry Conf. 57–66.

Schulte, N. and J. Hancock. 1983. Propagating highbush blueberries. Mi. State Univ. Ext. Pub. E-1680. p. 4.

Sinclair, W.A. and H.H. Lyon. 2005. Diseases of Trees and Shrubs. 2nd ed. Cornell Univ. Press. Ithaca, NY. p. 1–660.

Smith, B.J. 2002. Susceptibility of Southern highbush blueberry cultivars to phytophthora root rot. Acta Hort. 574:75–79.

Smith, B.J. 2006. Phytophthora root rot and botryosphaeria stem blight: Important diseases of southern highbush blueberries in the southern United States. Acta Hort. 715:473–480.

Smith, B.J., M. Miller-Butler, and K.J. Curry. 2014. Phytophthora root rot mortality of container-grown rabbiteye and Southern highbush blueberry plants. Phytopathology 104(S3):111–112 (Abstract).

Solomon, J.D. 1995. Guide to insect borers in North American broadleaf trees and shrubs. USDA For. Serv. Agric. Hdbk. AH-706. p. 1–735.

Stanyard, M.J., R.E. Foster, and T.J. Gibb. 1997. Effects of orchard ground cover and mite management options on the population dynamics of European red mite (Acari: Tetranychidae) and *Amblyseius fallacis* (Acari: Phytoseiidae) in apple. J. Econ. Entomol. 90:595–603.

Strik, B., G. Fisher, J. Hart, R. Ingham, D. Kaufman, R. Penhallegon, J. Pscheidt, R. William C. Brun, M. Ahmedullah, A. Antonelli, L. Askham, P. Bristow, D. Havens, B. Scheer, C. Shank, and D. Barney. 2006. Highbush blueberry production. Oregon State Univ. Ext. Pub. PNW215. p. 1–78.

Toivio. M. 1976. Propagation of blueberries and azaleas from leaf-bud cuttings. Univ. Minn., Minneapolis, M.S. Thesis. p. 1–117.

Tomlinson, Jr. W.E., P.E. Marucci, and C.A. Doehlert. 1950. Leafhopper transmission of blueberry stunt disease. J Econ. Entomol. 43:658–662

USDA. 2012. U.S. Blueberry Production and Utilization (Cultivated and Wild), Selected States, 1980–2012. Economic Research Service. USDA. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1765. Accessed March 29, 2014.

van Tol, R.W.H.M. and M.J. Raupp. 2005. Nursery and tree application. p. 167–190. *In*: P.S. Grewal, R.-U. Ehlers, and D.I. Shapiro-Ilan (eds.). Nematodes as Biocontrol Agents. CAB Intl. London, UK.

Wang, H., M.G. Nair, M. Strasburg, Y.C. Chang, A.M. Booren, and J.I. Gray. 1999. Antioxidant and anti-inflammatory activities of anthocyanins and their aglycon, cyanidin, from tart cherries. J. Natural Prod. 62:294–296.

Ward Gauthier, N. 2014. Fungicides for management of landscape woody ornamental diseases. Univ. Ky. PPFS-OR-W-14. http://www2.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/PPFS-OR-W-14.pdf. Accessed January 5, 2015.

Whalon, M.E. and E.A. Elsner. 1982. Impact of insecticides on *Illinoia pepperi* and its predators. J. Econ. Entomol. 75:356–358.

Whitney, S.P. and J.R. Meyer. 1988. Movement between wild and cultivated blueberry by two species of sharpnosed leafhoppers. J. Entomol. Sci. 23:88–95

Wright, R.D. 1986. The pour-through nutrient extraction procedure. HortScience 21:227–229.

XianJun, M., Y. XinLing, S. RenYan, and Z. Rui. 2011. Impacts of blueberry extract on the memory and anti-aging role of laboratory mouse. J. Shenyang Agric. Univ. 42:740–742.

Yeary, W. 2014. Increasing nursery crop canopy density: Implications for sustainable insect pest management. Univ. Tenn., Knoxville, M.S. Thesis. p. 1–175.