

# Pest Management Strategic Plan for Container and Field-Produced Nursery Crops in FL, GA, KY, NC, SC, TN, and VA: Revision 2015

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*This revision is based on a Focus Group Meeting held February 25-26, 2014, at the  
North Florida Research and Education Center, Quincy, FL*

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[www.go.ncsu.edu/NurseryCropsIPM2015](http://www.go.ncsu.edu/NurseryCropsIPM2015).

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# Executive Summary

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## *About the Focus Group Meeting*

Nursery crop producers from five states (GA, FL, NC, TN, and VA) were identified and contacted about participating in an effort to identify pest priorities for nursery production. Growers ranked insect, disease, and weed pests prior to meeting as a focus group. Nursery crop growers and university personnel met over a two-day period to discuss pest problems of trees and shrubs in container and field production. The group further prioritized insect, disease, and weed pests and identified regulatory, Extension, and research needs.

### *Agenda*

Southern Region Nursery Crop Pest Management Meeting  
North Florida Research and Extension Center, Quincy, FL,  
February 25-26, 2014

Moderator: Anthony LeBude

Recorder: Sarah White

### **Tuesday, February 25, 2014**

#### *Morning*

- 8:00-8:15 Load talks, welcome, and objectives for the day.
- 8:15-8:55 Current perspective on weed control in field and container nurseries: Joe Neal, NC State, Weeds Science.
- 9:00-9:40 Current perspective on arthropod control in field and container nurseries: Kris Braman, University of Georgia, and J.C. Chong, Clemson, Entomology
- 9:45-10:25 Current perspective on plant disease in field and container nurseries: Nicole Ward, University of Kentucky, Plant Pathology
- 10:30-11:10 Current perspective on irrigation in field and container nurseries: Matthew Chappell, University of Georgia
- 11:15-12:00 Current perspective on Cooperative Extension in the Southeast U.S.:  
Dr. Steve Brown, Assistant Dean of Extension, University of Georgia
- 12:00 Lunch on-site

#### *Afternoon*

- 12:15-1:00 Lunch presentation (Technology in IPM: Joe LaForest, Assistant Director, Southern Region IPM Center)  
*Joe LaForest will discuss the new Pest Management Strategic Plan and Crop Profile system, mobile device applications available across the region, and update on the SR-IPM center, and pest reporting and mapping across the region.*
- 1:00-1:30 Each grower present provides a brief overview (5 minutes) of their production and pest management practices.
- 1:30-6:30 Present and discuss the pre-ranking of arthropods, plant diseases and weeds. Each discipline lead revisited existing research and extension priorities and developed new overall priorities through facilitation of grower's comments. Growers present voted on importance of priorities, pests, plant diseases, or weeds using a sticker caucus. For each voting

opportunity, growers distributed 24 stickers among the candidate priorities, initiatives or pests, etc. They could place more than one sticker on a priority/pest to emphasize its importance.

- 1:30-2:15 Weeds
- 2:15-2:30 Ranking weed priorities (sticker caucus)
- 2:30-3:15 Arthropods
- 3:15-3:30 Ranking arthropod priorities (sticker caucus)
- 3:30-3:45 Break
- 3:45-4:30 Plant Disease
- 4:30-4:45 Ranking disease priorities (sticker caucus) - disease
- 4:45-5:30 Horticulture and Technology
- 5:30-5:45 Ranking disease priorities (sticker caucus) – extension and research
- 5:45-6:15 Open Discussion and General priorities
- 6:15-6:30 Ranking of Horticultural priorities (sticker caucus)
- 6:30-6:45 Curriculum development and evaluation of experiential learning. Anthony LeBude, NC State  
Focus group discussion on workshop content for June 2014, learning preferences, and the survey methodology used to evaluate both short and long-term knowledge change
- 6:45-7:00 Concluding remarks and reimbursement instructions
- 7:00 Depart for dinner in Tallassee (two mini-vans). Growers attend dinner, depart, or both.

Growers will be departing after the first day but might stay overnight in order to catch flights on 2/26.

### **Wednesday, February 26, 2014**

#### *Morning*

- 8:00-9:30 Working Session I: Group discussion of priorities and format for updated PMSP tables.
- 9:30-11:45 Working Session II: Each discipline breaks into groups to organize their priorities from the previous day and prepare draft priorities.

#### *Afternoon*

- 11:45-1:30 Working Lunch – Working Session III  
Finalize pesticide table updates in PMSP document.  
Evaluate the amount of work necessary to finish updates of PMSP  
Revisit deadlines from proposal  
Discuss content to be administered at workshops  
Develop teaching outlines for each discipline  
Discuss responsibilities for workshops
- 2:00 SNIPM members depart

# Outcomes from Priorities Since 2009

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SNIPM took an integrated approach to creating outcomes that met several stakeholder priorities listed in the 2009 PMSP. Some priorities are a continuous process, that is, more work is needed to show that IPM is profitable for nursery growers in the southeast, as well as, to determine efficacy of new chemicals introduced and their subsequent effect on target pests or plant diseases and non-target organisms.

**Priority: 1) Make IPM profitable and viable for nursery crop production. 2) Develop and adapt new technology and technology transfer to practitioners.**

Outcome: SNIPM developed and introduced the first ever mobile device applications (apps) utilizing IPM for the green industry and homeowner use. *IPMPro* and *IPMLite* version 1.0 were released in May 2012 and July 2012, respectively. These apps contain major pest and cultural practices references, automatic text-like alerts specific to user location for time-sensitive pest issues and cultural practices, action items viewable as a calendar or chronological list for easy reference, images, pest life cycle, and management options for major pests of woody plants, and pesticide recommendations for major diseases and insects, as well as built-in pesticide record keeping to make outdoor and on-the-go record keeping easy. Based on survey evaluation, reminders for scouting and plant care have saved an average of \$3,367 per user, resulting in a total impact of \$1,703,702 based on 506 downloads.

**Priority: 3) Improved monitoring tools, protocols, and educational programs (e.g., improved guides for identifying “emerging weeds of concern”).**

A website containing a multi-character key, taxa, and images for identifying weeds in container nurseries was created by the Container Nursery Weed Research Group (Bernard et al. 2012). By selecting various morphology traits including root type, flower color, and leaf arrangement, users can narrow down choices to identify weeds. Images and descriptions of weeds aid identification and emerging weeds are added.

**Priority: 4) Apply nursery IPM within a whole-systems approach. 5) Group (scale) insects and develop management guidelines for each group. 6) Determine insect biology, host preference and overwintering host preference and how production practices might affect both. 7) Emphasize scouting and early detection to be able to act on thresholds. 8) Emphasize the importance of decreasing stress on plants and using appropriate production practices to do so.**

Outcome: SNIPM published two electronic books (e-books) with limited edition print copies, one titled *IPM for Select Deciduous Trees in Southeastern US Nursery Production*, and the other titled *IPM for Shrubs in Southeastern US Nursery Production: Vol I*. Both are available via iTunes or on the web to download at <http://wiki.bugwood.org/SNIPM>. The books contain scouting, key pest (including both classes of scales) and plant disease identification, pesticide recommendations, and cultural practices to reduce pest attack and maintain plant quality for 10 tree genera and five common shrubs, and their myriad cultivars, in the Southeast U.S. Users of *IPM for Select Deciduous Trees* self-reported in 2013 an increased savings or earnings by an average of \$3,313 because of reduced pesticide use or more refined pesticide applications. As of January 2015, the book was downloaded by 928 separate users in the United States for a total benefit of \$3,074,464.

**Priority: 9) Focus on key pest biology to optimize pest monitoring and management tactics. 10) Encourage the support and use of county Extension personnel (serving the green industry) in the dissemination of information.**

Outcome: SNIPM developed hands-on, experiential training for pest scouting, early disease detection and development, and use of action thresholds for both ornamental nursery growers and Extension agents. Three, two-day workshops were delivered to growers and Extension Agents in Quincy, FL, Decherd, TN, and Raleigh, NC, June 2014. Live samples of pests, plant diseases and weeds, as well as host plant damage, were used to help identify key pests and damage to key plants. Cultural practices were shown.

**Priority: 11) Evaluate products that control pests with minimal negative effects on natural enemies and pollinators.**

Frank and Sadoff (2012) found that 5 times more insecticide was released by airblast sprayers than a manual spray wand and backpack sprayer. The extra insecticide from airblast applications landed on tree canopies, between rows, and left the nursery beds as drift. As a consequence of not spraying tree canopies, 50% *more* natural enemies and 50% *fewer* spider mites were captured in nursery beds treated with a manual spray wand than beds treated with an airblast sprayer.

Bifenthrin and carbaryl, and imidacloprid and dinotefuran are, respectively, contact and systemic insecticides commonly used to manage insect pests in commercial nursery production. Exposure to pesticide residues following treatment may have detrimental effects on non-target arthropods entering a treated area. To assess this concern, beneficial insects including adult lacewings (*Chrysoperla rufilabris*), convergent lady beetles (*Hippodamia convergens*) and insidious flower bug (*Orius insidiosus*) were confined in experimental arenas and exposed to insecticide residues across time. Yeary et al. (2015) found that direct mortality or diminished behavioral capabilities were observed for all three species, with contact insecticide bifenthrin least harmful to adult lacewings and dinotefuran not harmful to lady beetles. By contrast, broad spectrum carbaryl was most harmful to these species. Bifenthrin was most harmful to insidious flower bug, yet all insecticides caused mortality to this species.

**Priority: 12) Improve borer identification technique, distinguish between various borers.**

Outcome: A number of technical and Extension publications were published to describe monitoring techniques and identification characteristics for a number of borers in the Southeast. Examples include, Hansen et al. (2011), which addressed monitoring, identification, and damage caused by *Buprestid* species that are attracted to purple panel traps in Tennessee. In collaboration between Universities of Tennessee and Kentucky, Bowers and Fulcher (2012 a, b) created an award-winning Extension publication series titled IPM Quick Facts, which covered many pests of ornamentals, but particularly flatheaded apple tree borer and its related species, and granulate ambrosia beetle. Oliver et al. (2012) highlighted an emerging pest, camphor shot borer, and provided characteristics to distinguish it from similar borers.

**Priority: 13) Develop and make available efficacy tables to include REI and mode of action group**

Outcome: These tables were created or updated for fungicides, insecticides, and herbicides and are included within this PMSP under their respective sections.

# Overall Priorities 2015

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The Research, Extension, and Regulatory themes below are based on stakeholder focus groups held in 2009, 2011, and 2014. After discussion among members of the Southern Nursery IPM (SNIPM) working group and stakeholders, the caucus could not define the separation between the three main categories of Research, Extension, and Regulatory. Indeed, many of the priorities in nursery crops require an integrated effort of all three areas to meet the challenges posed by the focus group members. Moreover, the combination of numerous nursery plant species, their subsequent pest and plant disease complexes, and varied production environments, i.e., field and container nurseries, full sun and shade structures, created a lengthy list of initiatives. The framework and presentation of the themes and their initiatives below is based on that organized and published in Fulcher et al. (2012). In that publication, four main themes were used to organize the overall Research, Extension and Regulatory initiatives or priorities. The framework has been updated to account for the most recent focus group meeting in 2014. A table of the high priority pests, plant diseases, and weeds is also provided below (Table 1). The pests were organized by focus group members who considered prevalence, difficulty to control, damage potential, and severity of injury into their final choices. Therefore, use the priorities outlined below combined with a pest or pest complex from Table 1 to produce a research or extension priority. For more discipline-specific priorities, and scores for the various metrics of each pest, please visit each section in the strategic plan for cultural practices and technology, arthropods, plant diseases, and weeds.

## *General Operational Initiatives for Four Research and Extension Themes for Nursery IPM.*

The initiatives within each theme are listed in order of highest priority as voted by focus group attendees in 2014.

1. Apply nursery IPM within a whole-systems approach
  - a. Promote efficient pesticide applications directed at susceptible pest life stages to minimize risks and increase effectiveness.
  - b. Demonstrate relationships between production practices (e.g., pruning, fertilization, water quality, irrigation, leaf wetness, potting, planting, spacing, sanitation, and use of cover crops and living mulches) and pest population dynamics.
  - c. Optimize monitoring, scouting, and pesticide application timing to manage the pest complex (weeds, arthropods, plant disease) rather than individual species.
  - d. Screen insecticides and formulations with reduced impacts on secondary pests and nontarget species (e.g., natural enemies and pollinators).
  - e. Increase use of plant phenology indicators to predict seasonal pest activity.
  - f. Quantify differences in container- and field-grown plants for pest susceptibility and pesticide efficacy.
2. Key Pest Biology; Optimize pest monitoring and management tactics
  - a. Develop training on pest, plant disease, and weed scouting; utilize manual and digital recognition techniques; early pest, disease and weed detection and development; and use of action thresholds.

- b. Develop improved management guidelines, identification techniques and outreach literature.
3. Develop and adapt new technology and technology transfer to practitioners.
  - a. Develop decision aids to improve pesticide, fungicide, and herbicide selection by improving access to product label information including pests, plant diseases, or weeds controlled, crop tolerances, application doses, mode of action, worker protection standards, rotations, rainfastness, and guidelines for effective use.
  - b. Develop a regional website to effectively distribute nursery IPM news and information.
  - c. Develop a nursery scouting certification program delivered ideally via distance education.
  - d. Increase use and access to digital diagnostic resources through county Extension offices.
  - e. Design and develop a mobile device application to aid scouting and monitoring.
  - f. Use of unmanned aerial vehicles (drones) or similar technology for scouting for pests, weeds, and diseases; detecting blow over; targeted spray applications; worker productivity management; and sales and inventory management.
4. Assess economics and actual costs; validate benefits of adopting IPM
  - a. Pesticide, fungicide and herbicide efficacy trials should include cost analysis and include generic products and formulations as alternatives.

### *Regulatory Priorities*

- Address immigration reform and workers in the green industry.
- Evaluate the sustainability of oak production regarding Sudden Oak Death.
- Resolve questions on required quarantined treatments for fire ants and Japanese beetles.
- Address use of hydrogen peroxide for water filters.
- Address chlorine concerns (Homeland Security).
- Numerous water issues (availability, quality, runoff, regulations, etc.).
- Identification of ornamental production as an agriculture industry.

Pests were identified by focus group members as key management priorities and listed in order chosen in Quincy, FL, in February 2014. Members completed a pre-survey of these pests based on prevalence, difficulty to control, damage potential, and severity of injury. During the focus group meeting, SNIPM members and focus group participants discussed the pests and then focus group members only produced a final reorganization by vote using a sticker caucus.

*Table 1. Key management arthropods, plant diseases, and weed pests.*

<b>Arthropods</b>	<b>Plant Diseases</b>	<b>Weeds<sup>z</sup></b>
Eriophyid mites	Boxwood blight	Spurge (C)
Flea beetles	Rose rosette virus	Oxalis/woodsorrel (C)
Spider mites, <i>incl.</i> red spider mite	Stem cankers, <i>incl.</i> <i>Seridium</i> , <i>Fusarium</i> /cold injury, and others	Liverwort (C)
Fire ants	Bacterial leaf spot/blights	Eclipta (C)
Armored scales: Japanese maple scale, tea, white peach	Powdery mildew	Bittercress (C)
Soft scales: calico, lecanium, wax	Conifer tip blights ( <i>Phomopsis</i> and others)	Groundsel (F, C)
Aphids	Fireblight	Crabgrass (F)
Granulate ambrosia beetle	Foliar nematodes	Nutsedge (F)
Thrips ( <i>incl.</i> chilli thrips)	Crown gall of rose	Bermudagrass (F)
Root grubs/weevils	Black root rot ( <i>Thielaviopsis</i> )	Horseweed (marestail) (F, C)
Clearwing moth (e.g., dogwood, peachtree, lilac/ash borer)	Fungal leaf spots, <i>incl.</i> black spot	Chickweed (F, C)
Broad mites	<i>Cercospora</i>	Glyphosate resistant horseweed (marestail) (F, C)
Brown marmorated stink bug	Vascular wilts	Henbit (F)
Japanese beetle	Anthracnose	Glyphosate resistant pigweed (F)
Leafhoppers	<i>Pythium</i> and <i>Phytophthora</i>	Morningglory (F)
Bagworm	Bacterial leaf scorch	Pigweed (F)
Maple tip borer	Rust ( <i>Passilora</i> )	Annual bluegrass (C)
FHAB ( <i>incl.</i> emerald ash borer)	Target spot	Mulberryweed (F, C)
Crape myrtle bark scale	Rhizoctonia root rot and web blight	Ragweed (F)
Black twig borer	<i>Botrytis</i>	Chamberbitter (F, C)
Kudzu bug		Bindweed (F)
		Johnsongrass (F)
		Horsenettle (F)
		Glyphosate resistant johnsongrass (F)

<sup>z</sup>Weed species are listed by perceived abundance and management difficulty but the list does not represent a complete listing of important species or current abundance. For example, glyphosate resistant johnsongrass is listed as a species of concern but is currently documented to be present in agronomic crop fields in only 3 states in the lower Mississippi River valley. C=Container; F=Field.

# Nursery Crop Production

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## *Introduction*

Nursery crop production is the art and science of growing woody plants (trees, shrubs, vines and groundcovers). Nursery crops are grown in containers and in the field. Plants sold by nurseries range in size from small “liners” or transplants to large caliper (6” and larger) trees. Nursery crops are sold to re-wholesalers, brokers, landscape contractors, nurseries, independent retail garden centers, and mass merchandisers. Nursery crops are also sold via direct marketing through mail order catalogues and the internet. Woody ornamentals are planted in residential and commercial landscapes, parks, golf courses, cemeteries, urban forests, neighborhoods, arboreta, reclamation sites, and green spaces and other municipal sites and right of way areas.

Nursery production is an important sector of US agriculture, especially in the Southern US. Nursery crops production in the United States takes place on over 369,000 acres, is responsible for 6.6 billion dollars in sales annually, and employs tens of thousands of workers (USDA, 2009). Nursery crops production is a high input form of production; often liners are \$7-25 each. Nursery crop production requires a significant amount of manual labor and management. An individual nursery may grow just a few to a few hundred types of plants, with nearly 400 different genera produced industry-wide (Yeager et al., 2007). Each type of plant must be managed for both cultural requirements and pest control.

Field production was the earliest form of nursery production in the US. The first crops were mainly fruit trees. Early production soon expanded to include ornamental plants. Current centers of production include the South, the Lake County Ohio Area, portions of the East Coast, the Pacific North West, and southern West Coast, although nurseries exist in every state. The location of field production nurseries is dependent on high quality soils and acceptable climate conditions. Field-grown plants are lined out in rows, generally with mechanical setters. After one or more years, the trees are mechanically harvested and sold as bareroot or are balled and burlapped. Some aspects of managing field-produced plants, i.e., harvesting, transportation, and storage, require precise care. Digging generally must be accomplished during the dormant season. For bareroot plants, fairly precise storage conditions are necessary upon harvest. For balled and burlapped plants, root balls must be handled carefully to avoid breaking. Considerable field soil is removed when balled and burlapped plants are harvested, which makes plants extremely heavy, often requiring specialized equipment to move plants. Field production can be accomplished without overwintering structures and does not necessitate irrigation. In a holding

yard and while being marketed, balled and burlapped plants often have lower irrigation requirements than container-grown plants.

Since the mid 20<sup>th</sup> century, container production of ornamental plants in the southeastern United States has grown to meet the burgeoning public demand. Inventory and availability of container grown trees, shrubs, perennials and annuals is unmatched by field-grown production. Caliper size limitations to container-grown tree production are also being challenged, as container sizes are available up to 500 gallons. Container-grown plants offer growers greater control of cultural and environmental conditions, can be planted and sold year round, are easy to manage by all consumers, and lend themselves to creative marketing. Over 60% of consumers purchase their plants from mass merchants compared to 30% who purchase from garden centers (McClellan et al., 2003). Due to ease of handling, shipping and displaying/moving in a retail setting, mass merchants, as well as independent retail garden centers, predominately sell plants in containers.

Production of container-grown plants is less coupled to soil conditions than field production nurseries. As a result, container production nurseries can be found in all parts of these five states, whereas field growing operations are usually centralized around specific growing regions where adequate native soils and specific environmental conditions exist (e.g. precipitation frequency and amount). Poorer soils not suited for field production can be developed as sites used for container production, provided irrigation water, skilled labor, and markets for sale are available. For example, over 75% of nursery sales in Georgia are container producers localized in the Thomson, Cairo, and Athens, GA areas. In contrast, most nurseries in Kentucky are field grown operations located in central and northern Kentucky, and to a lesser extent in far western Kentucky.

In all seven states (FL, GA, KY, NC, SC, TN and VA) represented by this PMSP, nursery producers are only 24-48 hours away from half the population of the United States. These same seven states collectively produced 25% of the value in nursery crops in 2007 in the United States (Table 4) (USDA, 2009).

*Table 2. Number of producers, total acreage and value of nursery crops for seven southern states.*

State	Number of producers <sup>1</sup>	Total acreage	Value in million \$
Florida	3184	45,134	844.3
Georgia	501	8,074	125.2
Kentucky	332	3,976	23.6
North Carolina	1250	23,443	251.8
South Carolina	314	7,375	91.4
Tennessee	793	33,591	177.2
Virginia	392	11,955	96.6
Totals	6766	133,548	1,610.1
Percent of U.S. total	30%	30%	25%

<sup>1</sup>All values in table based on USDA 2009, Census of Agriculture.

Plant damage by pests is a predominant source of revenue loss for the nursery industry. In North Carolina, the green industry reported annual losses of \$91M due to insects and diseases (NCDA 2005). Losses due to plant disease and cost of control in Georgia nurseries were estimated to be \$39.3M in 2011 (Williams-Woodward 2011).

Plant health is an important aspect of Integrated Pest Management (IPM). In many cases, healthy plants experiencing low levels of stress have fewer pest concerns than similar plants experiencing higher stress levels. Stresses can be categorized into biotic and abiotic stresses. Abiotic stresses include the quality of the substrate and its pH, water quality, irrigation timing and quantity, light, temperature, growing area design, mineral nutrient concentrations and availability, and environmental events (e.g., hail and wind). Biotic stresses can be caused by weeds, insects, nematodes, pathogens (e.g., fungi, bacteria, phytoplasmas, oomycetes, and viruses) and vertebrates. Stresses can be cumulative over the production cycle, such that small problems early in production can become larger problems later during time of sale.

Identifying and acting, or preventing these stress problems early, is the best strategy to maintain plant health. Always try to eliminate which “normal” production practices might contribute to overall poor plant health, while simultaneously identifying and developing practices that improve plant health.

## ***Sanitation in Nursery Production***

Many pests and diseases are difficult to eradicate once established in a nursery. Thus, sanitation/hygiene management practices should be introduced and followed assiduously in nurseries to prevent infection and reduce pressure from diseases enhanced by poor sanitation. Once a disease becomes established in nursery soils or substrates, growing surfaces, equipment, or alternate hosts, reinfection is difficult to prevent. Prevention is the best way to reduce pest management costs.

New plants entering the nursery site should be quarantined for a suitable time period to determine if disease, insect, or weed pests are present. If present, proper chemical treatment should occur to eradicate pests. If a disease/pest is invasive or especially virulent, plant material should be disposed of properly to prevent spread of the disease/pest to plant material at other nurseries or throughout the state or region. Sanitation methods for existing nursery areas should include disinfestation of equipment between production areas to prevent spread of disease, insect, or weed pests from one infected area to another. Weeds in areas adjacent to production areas should be controlled by mowing or herbicides. Hedges can also be used as windbreaks to impede weed seeds from blowing in from neighboring property.

Potting and propagation surfaces should be free of potting substrate and plant debris to reduce the potential for harboring weed seeds, pathogens, or nematode contaminants. After surfaces are cleaned of organic waste, they should be washed and treated with the appropriate concentration of disinfectant for the recommended contact time for a particular surface type to insure disinfestation (Copes, 2004). Anecdotal evidence suggests that nurseries using appropriate sanitation practices spend less money on chemical treatment and are less likely to have recurring pest infestations.

## ***Field Production***

### *Site Selection*

A number of factors influence the success of a field nursery. This includes soil type, topography (slope) and access to irrigation water (Bilderback et al., 2008). Soil type is the most important factor and

includes characteristics such as soil texture, tilth, drainage, and profile. Field nurseries are often located on a clay loam, loam or sandy loam soil. Soil types determine whether or not the field soil will produce a root ball with enough cohesion to remain intact around the roots when dug. Root balls from sandy soils often fall apart during the handling process.

Soils that have poor internal drainage or are subject to flooding should be avoided. Fields should have a well-drained profile of at least 8 to 10 inches. Mottled yellow, gray or blue, or sour smelling soil indicates poor internal drainage or a standing water table at some time during the year. Soils with mottled characteristics are often found to be saturated during winter months.

Field nurseries are often located in flat to slightly sloped, non-flooding areas near rivers (bottomlands). Bottomlands are generally close to irrigation water; flat enough to allow easy working with equipment, and relatively rock free. Properly located upland soils with similar characteristics are often utilized as long as slope is not too great, topsoil too thin, or erosion too severe. Slope also plays a role in air drainage. Bottomland sites may be more susceptible to cold pockets resulting in damage to sensitive crops from cold air pooling in these lowlying areas. Cold sensitive species should be sited on upland soils with better air drainage.

Access to a large quantity of irrigation water that is also of high quality is essential to a healthy nursery. Water is required to get newly planted liners established, to keep plants alive during drought periods and to promote growth since the objective is to get the plant to market as quickly as possible.

#### *Land/Soil Preparation*

When selecting and preparing a site for a field nursery take into account the natural features of the land, the equipment to be used, and cultural requirements of crops to be grown. Planting rows should always follow the proper contour. Best Management Practices (BMPs) for field nurseries that reduce erosion and sedimentation should be implemented. These include cover crops during all seasons of production, as well as vegetated waterways, row middles, and field edge buffer strips.

A field nursery site should first be soil tested to determine the soil's fertility. The number of soil samples taken per field will vary with the size and uniformity of the field and variety of crops being planted. Soil tests should be conducted well in advance of cultivation. Practices such as liming and the application of superphosphate should be completed prior to planting so that these materials can be thoroughly mixed with the top 6 to 8 inches of soil during normal soil preparation practices.

Some sites selected for field nursery production may benefit from the addition of organic matter. Benefits include an improved soil structure, water retention and drainage, aeration and quality of nursery stock grown. Plant digging is often easier in mineral soils amended with organic matter, and plants develop a more fibrous root system in amended soil. Nursery fields may be amended with bark, compost, municipal yard wastes or organic amendments like cattle manure or poultry liter. Traditional methods to increase organic matter in fields include green manure crop rotation utilizing a double cropping system of minor cereals, small grains, legumes, and mustards. Cereals, such as wheat, rye, barley, or oats, may be sown in the fall, killed with a herbicide, mowing, or rolling prior to producing seeds in the spring, and either plowed under or left on top of the soil. Small grains like the hybrid sorghum-sudan grass, millets, and buckwheat are commonly used as summer cover crops, which are sown when the soil is warm in April or May. Some summer cover crops may need to be mowed to prevent seed formation or control height, yet virtually all of them are killed by frost. Stubble can be mowed and either left on top or plowed under in fall for the next crop. Cover crop combinations of cereal grains and legumes, for example, a fall planting of barley and crimson clover, or a planting of cereal rye (not ryegrass) and hairy vetch, work well together because the cereal takes up nitrogen left over from the previous crop while the legume assimilates nitrogen into the soil from the atmosphere. When mowed over and plowed under, legumes release quickly available nitrogen (90% after 4 months), while the cereal releases nitrogen more slowly (50% after 8 months)

Any existing crop stubble and fertilizer, lime and soil amendments will need to be incorporated and mixed prior to planting. A chisel plow will efficiently mix materials into the soil profile ensuring an even distribution of materials and rapid root development. Rotovating can also prove effective, but often does not mix the soil as deeply when compared to chisel plowing. Use of a mold board plow should be avoided as it does not uniformly mix the material into the soil but rather deposits it in a layer beneath the soil. If a moldboard plow is the only option, consider discing afterward to blend soil profiles as much as possible. Best results are obtained by chisel plowing twice. Where slope and erosion are not a problem, the field should first be plowed in one direction and then plowed at right angles to the first path. Destruction of field terraces or contours should be avoided when chisel plowing.

### *Planting*

While field layout is often determined well in advance of planting, the actual distribution of plants in the field is determined at planting. Transplants or liners are graded prior to planting since plants of the same size and grade are expected to grow at the same rate and should be planted together to ensure

uniformity in production stands. The quality of liner used will impact plant growth and health, perhaps for the remainder of production.

Plants may be transplanted using mechanical transplanters or planted by hand. Grading transplants and ensuring the field is relatively level and uniform will better facilitate mechanical transplanting.

Plant spacing is determined by the final size of the plant at sale or the market for the crop. Plants sold as municipal trees or to professional landscapers are spaced wider to allow for more growth and better access during harvest. When the future market is uncertain, wider spacing also allows more opportunity for finding a market prior to the trees becoming overgrown.

Field-ready transplants should be kept moist and shaded prior to being planted, with care given to ensure that roots do not dry out. Many are healed-in in moist pine bark or sawdust until planting. If many liners are to be transplanted over a long period while the weather is volatile, consider cold storage or inquire about leasing cold storage facilities. To prevent desiccation of newly planted liners and improve their chance of survival, roots may be soaked for 1 to 2 hours within 24 hours of planting. Roots may also be treated with starch-based hydrogel dips to avoid drying out at planting.

Transplants may be set in the ground in late winter to early spring and/or late fall to early winter depending on the geographical region. In some regions, late fall to early winter plantings have been less successful as a result of freeze-thaw cycles that heave plants out of the ground. Transplants set in spring have the opportunity to establish a root system prior to flushing foliage, aiding in the uptake of water lost from tender foliage and anchoring before winter to prevent frost heaving.

It is a good practice to water recently set transplants within 24 hours after planting even if the liners were set into moist soil or water is applied to the planting hole by a mechanical transplanter. Water from a sprinkler truck, irrigation system or rain will help to firm soil around roots, which eliminates air pockets that might dry-out plants.

Liners should be set at the same level as they were growing in the transplant bed. The root flare (area where stem meets the first primary lateral root) is even with or less than 3 inches below the soil surface. If the soil is soft from cultivation, liners may be set slightly higher to allow for settling. If liners are planted or settle too deep, plants may be stunted or be killed.

### *Fertilization*

Soil test results will indicate lime and superphosphate rates and any other soil nutrients that need to be incorporated prior to planting. Best Management Practices for fertilizer applications focus on minimizing nutrient runoff and impacts to water quality while maintaining maximum growth. To minimize surface run-off following new field preparation, incorporate to a depth of 6 to 8 inches 50 lbs. per acre nitrogen (N) and all other nutrients at appropriate rates according to soil tests..

In subsequent years, N application rates should be based on the amount of N per plant rather than pounds of N per acre. Fertilizer should be placed within the root zone as a side dress at the rate of 0.25 to 0.5 oz. N per plant rather than previous recommendations of 100 to 200 lbs. N per acre. Doing so maximizes growth with a minimum amount of fertilizer. If supplemental fertilizer is required the first year for fall-transplanted plants, each plant should receive 0.25 to 0.5 oz. N before bud break.

During the second year, each plant should receive 0.5 to 1.0 oz. N distributed in split applications: the first two-thirds of the total amount applied before bud break, and the second application applied by mid-June. During the third and following years, each plant should receive 1.0 to 2.0 oz. N in split applications as described for the second year. Slower growing cultivars or species should be fertilized at the lower application rates, whereas vigorous plants will have increased growth if the higher application rate is used. Rates greater than those recommended are not warranted as they have been shown to reduce growth and may contribute to nutrient runoff that impacts water quality. Controlled release fertilizers (CRF) have been developed specifically for field-use. Although they are more expensive, one application of CRF will last the entire growing season.

If fertilizer is applied to crops through drip irrigation (fertigation), the amount of fertilizer can be reduced because applications can be proportioned during the growing period and each application is directed at the root zone. During fertigation, the amount of fertilizer used is one-half that of granular top-dress. Less fertilizer can produce more growth during fertigation because nutrients are more likely to reach the plant and less fertilizer is leached from the soil. Additionally, fertigation is designed to combine nutrient availability with plant demand because rates can be increased during times of growth (Spring/early summer/Fall) and decreased during pseudo-dormancy in summer or dormancy and its onset in late fall or winter.

### *Irrigation*

Field nurseries utilize either hose reel irrigation equipment or a low volume application method. In general, hose reel and gun types of irrigation are cost effective for watering large fields of transplanted trees, yet extremely inefficient because large quantities of water are applied to row middles and non-

planted areas. Wide plant spacing further decreases irrigation efficiency. This is the irrigation method of choice for most field nurseries because nurseries are near lakes or streams or have access to high output wells. An acre of newly planted nursery stock may need an inch of irrigation (acre-inch) applied 1 to 2 times per week for the first growing season. An acre-inch of water is 27,000 gallons, therefore a large water supply is required. Though high volume is applied, hose and reel systems with gun application can be calibrated to provide the correct volume of water and apply it efficiently. Contact the irrigation distributor or a Cooperative Extension agent to obtain information about calibration technique or tables that provide crude calibration from known pressure and travel times. Additionally, when deciding on the amount of water to apply take into consideration the amount of rainfall for the area and the water holding capacity of the soil. Saturated soils lead to runoff, which leaches nutrients both overland directly into streams and underground into water tables.

Drip irrigation is a highly efficient system that uses low water volume and low pressure to deliver water directly to the root zone. With this method, roots tend to concentrate in the wet zone, resulting in easier harvest of root balls and increased survivability after sale when plants are transplanted correctly. With drip irrigation, water is applied within rows, directly to the soil surface, and gradually over extended periods of time (e.g., 1, 2, or 5 gallons per hour). Direct placement associated with drip irrigation allows less water lost to evaporation or runoff. In addition, weed seeds are not irrigated by water distributed over large areas, which results in fewer weeds in the nursery.

Drawbacks to drip irrigation include the inability to protect flower buds and flowers from frosts or freezes by irrigating lightly overhead. It becomes more difficult to water in newly transplanted liners and preemergence herbicides after planting with drip irrigation. Rodents can be a problem as they can chew holes in drip lines and spaghetti tubes.

Drip irrigation requires clean water free of sediment and minerals that can clog emitters. Well water or county water requires only minimal filtration and is optimal for drip irrigation, but may fall under municipal water restrictions during times of drought. Surface waters from rivers or ponds generally require more intensive filtration to prevent plugged or reduced water flow through drip emitters. Due to additional costs for intensive filtration, surface water is more effective for overhead irrigation than drip irrigation. Nevertheless, drip irrigation is a better use of the resource.

### *Pruning*

Pruning during nursery production increases plant quality and controls plant size. Trees are usually pruned in winter (dormant pruning) and summer, and shrubs are pruned several times during the

summer. The timing of summer pruning can coincide with herbicide, fungicide and insecticide applications. Pruning tools include hand pruners, loppers, manual and power shears, and use of workers' hands without an implement.

Winter pruning generally consists of improving canopy architecture by removing lateral branches that are acutely (< 30 degrees) attached to the tree, are closely spaced together, or are crossing. . Dead, damaged, or diseased branches, such as from black knot or fireblight, are also removed at this time. Co-dominant leaders are removed during dormant and summer pruning. Summer pruning often includes thinning cuts to reduce the canopy volume and increase air circulation. This decreases the risk of storm damage and improves deposition of pesticides and penetration of air and sun to the interior canopy.

Training a central leader can be done in the dormant season or the growing season. Techniques to train a leader include taping, stapling, bud clip, or tying a bud or new growth to an existing branch or stub. On maples and ornamental fruit trees, buds or growth from two or more nodes below the tip of the leader are often removed to reduce the occurrence of co-dominant leaders.

Branches growing low on the trunk are removed at least annually, often in the summer. For deciduous shade trees, this means removal of limbs up to 60" or higher on the trunk if final use is for street trees. Ornamental trees and smaller caliper trees may have substantially lower permanent branches unless they are also destined for municipalities that have minimum branch height requirements. Ideally, branches are removed before attaining 1/3 or greater the diameter of the trunk in order to minimize time to cover the wound. This generally means that low branches are removed when the branches are smaller than 1/2" in diameter. For trees such as honeylocust and hedge maple, which have leaves that grow in abundance from the trunk, nursery workers often grip the trunk and run their hand down the trunk removing tender new leaves early in the season. Suckers (sprouts from the roots) and watersprouts (vigorous, vertical shoots from lateral branches or main truck), are usually removed once or twice during the growing season by hand pruning. Current research is examining the effects of post emergence herbicides, i.e., glyphosate on plant growth after suckers are removed. The relationship is not fully understood at this time, and care must be taken in scheduling sucker removal and glyphosate application. Some species such as crabapples are more prone to developing suckers and watersprouts, therefore ask the nursery providing the liners if the understock used for the cultivar is less prone to suckering. Pruning tasks constitute additional worker contact with plant surfaces that may contain pesticide residue.

### *Flexing and Staking*

Flexing is a manual technique that is used to straighten tree trunks. Flexing is most commonly done in the spring and less commonly in the fall. Some growers flex 100% of their trees, while other growers do not flex at all. Some growers flex in lieu of using a stake, while others use fiberglass stakes and flex with the stake on. Flexing must be done when trees are 1" or less in caliper, before flexibility is lost. To flex a tree, nursery workers hold the trunk in both hands and bend the trunk in the opposite direction of a crook or bend in the trunk. This is repeated two or more times until the tree is straight and is repeated in a few days for best results. If stakes are used, they are commonly installed following flexing. Ash and locust do not flex.

If stakes are used, they are generally installed within a few weeks of planting. With new planting guidelines suggesting that the first order lateral root be within three inches of the surface, staking is imperative since small wind gusts can blow the tree over. At time of stake installation, trees are straightened and excess soil is removed from the base of the trunk. Bamboo, metal conduit, rebar, and more recently, fiberglass rods, have all been used for staking trees. Bamboo stakes are inexpensive, but the underground portion normally rots during the first year causing them to break in high wind. Also, bamboo stakes are rigid and do not allow trunk movement. Metal conduit (5/16") stakes are usually flexible enough to withstand wind but can bend in high wind, especially when used on larger trees with heavy canopies. Metal conduit stakes are generally long-lasting and allow trees to move, building trunk caliper. However, these stakes rust and can create wounds by rubbing the trunk or branches. Rebar generally has the same characteristics as metal conduit except that it is not flexible. Fiberglass rod stakes are the most expensive stakes to purchase. However, they are highly flexible, will not bend or break in high wind, allow movement, and are reported to last for decades. Trees are hand-tied or stapled to stakes. Stakes are often removed after the first year. Later in production, stakes may be used as splints, with one stake overlapping another for additional height, or a single stake placed about 12" from the ground, to straighten the upper portion of the leader. Some plants, such as Callery Pears and other ornamental fruit trees, are frequently grown without stakes. However, some growers stake every tree. Like pruning, staking is an activity that can coincide with the timing of pesticide applications. Many growers install or adjust stakes when pruning.

### *Floor Management: Driveways and Middles*

Driveways and middles may be kept bare, planted with fescue, or planted with a non-fescue cover crop. Bare soil driveways are inexpensive but expose soil to erosion and do not dry as quickly following

precipitation, which creates challenges for spraying and digging and transporting balled and burlapped (B&B) trees. Tall fescue middles and driveways are relatively inexpensive to install and maintain. Endophyte-free fescue is recommended because it is less competitive than endophytic fescue. Following spring planting, soil is tilled, fescue seed is sown, and grass is mowed periodically. Some growers mow to turf height (3-5" tall), while other growers allow considerable growth between mowing. Crimson clover is one of the more common non-fescue cover crops (Halcomb, 2009). It is a nitrogen-fixing legume and may reduce nitrogen fertilization requirements for subsequent crops. Crimson clover grows rapidly during cool weather, has shade tolerance and some reseeding potential. Crimson clover can be planted from approximately early-August to mid-October for weed control. Crimson clover, like all clovers, may attract deer, and the additional height and cover may create habitat for voles. Crimson clover seed is relatively expensive. Other options are winter wheat and rye which can be sown in September and October (Halcomb, 2002). Winter wheat and rye will support traffic and suppress weeds and reduce erosion, but will not fix nitrogen like crimson clover. 'Poco' Barley, a dwarf variety created for relatively short growing seasons of the desert south west, has also been used as a row cover because it stays low and does not shade trunks.

#### *Floor Management: Clippings*

Nursery workers should collect and dispose of pruned clippings. This extends the blade-life of mowing implements. Additionally, it makes a more level driveway, allowing equipment such as the EnviroMist and mechanical weeders to operate optimally, and provides an area for better contact with soil by preemergence herbicides. Nursery workers often rake and pick up the clippings, which is a potential exposure to chemical residue on plant material.

#### *Tagging and Inventory*

Each grower approaches inventory differently. Approaches range from measuring every tree every year to measuring a random sampling of trees as digging approaches. Inventory often begins in August or September for fall and spring sales with some gain in caliper accounted for in the time between inventory and digging. Some growers use flagging tape to label individual trees according to size and grade at the time of inventory. Nursery standards (ANLA, 2004) dictate measuring caliper at 6" above the soil line for trees up to and including 4" in caliper and at 12" above the ground for greater caliper sizes. Tagging constitutes additional contact with trunk surfaces that may contain pesticide residue.

### *Harvest*

With few exceptions, field-produced trees are harvested in the dormant seasons (spring, fall, or winter). Individually tagged trees are dug selectively or the fields are harvested as a row run. Trees are usually dug with hydraulic spades, but shrubs may be dug mechanically or by hand. The root zone may be irrigated within a week of digging to make it easier for the blades to penetrate the earth. For trees, a trunk guard is placed around the bottom 3' of trunk. Blades (3-4 depending on brand) sever roots and pull the root ball from the ground. The bottom is leveled off with a hand spade, and any stray roots are pruned. The root ball is placed into a burlap-lined wire basket. The burlap is wrapped around the root ball and nailed or stapled into place. Rope is used to secure the top of the wire basket around the base of the trunk. The wire basket is crimped around the circumference of the root ball to tighten it. Either before or after digging, limbs are tied up around the leader to keep them out of the way, condense the canopy for shipping, and to prevent breakage. For shrubs, branches are first tied. If the shrub has a standard (a trunk), a trunk wrap is placed around the trunk. Then the outer edge of the root ball is hand dug. A loop of twine may be placed over the root ball and pulled from both sides to slice through the bottom of the root ball, separating it from the soil below, or a spade can be used to cut the bottom of the root ball from the ground. The root ball is removed from the hole and placed on a square of burlap. The burlap is pinned around the root ball and at the base of the trunk if it is a standard. The twine is wrapped around the root ball and the burlap at the base of the trunk.

## ***Container Production***

### *Substrates*

Aged pine bark is the predominant soilless substrate chosen for container production in the southeast. Properly aged pine bark, sieved to 5/8 to 3/4 inch particle size, retains physical properties that typically provide an adequate combination of pore space for drainage and water holding capacity, enabling growth of a wide range of woody ornamental species in containers. A consistent, quality supply of pine bark is necessary to base nutrient and irrigation management decisions. If a local bark producer has recently been sold to a new company, or if regional supplies are low, pine bark quality can change without notice to growers. In the former case, new pine bark pile management techniques may be administered by the new company, and in the latter case, insufficient aging may occur because bark demand is high and supplies are low. Plants potted in poor quality substrates can be more susceptible to pests and plant disease, as well as need more nutrient and irrigation management. The pH and electrical

conductivity of pine bark deliveries needs to be checked seasonally and especially if the scenarios above occur.

Testing the pH and EC of potting substrates (such as aged pine bark) and other organic substrate amendments (including compost, animal manures, and alfalfa meal) before potting can prevent poor growth and plant loss (LeBude and Bilderback, 2009). If moisture, temperature, and oxygen are not managed correctly in substrate inventories, substrates can become anaerobic (no oxygen). Anaerobic conditions are usually accompanied by extremely low pH and high EC. This combination can damage or kill nursery crops. For example, a pH of 4.0 to 4.2 is expected for aged pine bark from loblolly or slash pine. If pine bark has some sand or grit in it, the pH may be higher, such as 4.8 to 5.0. If pine bark pH is below 3.8, the inventory may recently have been decomposing under anaerobic conditions and is not sufficiently aged. In this case, inventory should not be used until the pine bark is aged properly and pH increases.

Anaerobic bark supplies may also have very high EC readings—for example, 1.5 mS/cm to 2.5 mS/cm have been recorded. Substrates with high pH and EC characteristics should be irrigated to leach out organic acids and salts. The inventory should also be turned to promote aerobic (oxygen-rich) conditions, which promote aging. Inventory use should be delayed for several days or a week until an acceptable pH range (4.0 to 4.2) is reached and EC readings below 0.5 mS/cm are measured. In some cases, where pH and EC readings are only marginally out of this desired range, growers can blend the affected inventory with other “good” inventories in a volume of 50:50 to reduce risk of damaging nursery crops.

Organic amendments, if properly composted, should have a pH near 7.0 when added to substrates. If pH is lower than 7.0, the composting process may be incomplete. The amendment may be used if mixed with other organic materials that are completely composted. Composts with a very high EC can be blended safely only at volumes of 5 to 10% to avoid plant damage. High EC levels may indicate an overabundance of readily available nutrients that can burn new plants when potted.

Bulk substrate inventories should be placed on the highest areas in the nursery on level ground. Drainage from nursery crops should not be allowed to penetrate and saturate the substrate inventory or disease causing organisms may spread from production to the stored substrate. The inventory supply, however, should be moistened and turned periodically if it will be stored for a long time, especially if steam or mold spores rise from the pile. Turning regularly will help prevent fungal colonization of bark

medium. Inventories should be stored in windrows or mounds less than eight feet high (preferably six feet high) to increase air penetration and make turning more manageable. Plant windbreaks nearby or enclose piles to prevent weed seeds from blowing onto bark and becoming introduced into production.

### *Irrigation*

Due to the limited volume of containers, plants require frequent irrigation. Pine bark-based substrates can withstand substantial overwatering without severe short-term concerns. During summer, overwatering occurs frequently due to the need to reduce heat load of the substrate, yet this practice can be detrimental if sustained. Over time, overwatering leaches nutrients from containers causing growth reductions and increased nutrients in nursery effluent. Excessive irrigation uses more resources such as electricity for pumps, fertilizer inputs, and the water resource itself. Additionally, overwatering can increase the chances of root rot diseases caused by *Phytophthora* or *Pythium*, thus leading to increased preventative fungicide use during production. A strategy for using water effectively is to designate a person solely for irrigation management (Garber et al., 2002), who monitors environmental conditions (such as evapotranspiration and rainfall) to maximize irrigation efficiency.

### *Irrigation: Frequency and uniformity*

Standard irrigation practices for container-grown plants include 0.6" water per day during the summer (Yeager et al., 2007). Cyclic irrigation, applying the total amount of irrigation for the day in small, incremental applications instead of in one application continuously, has several benefits compared to a single application. For example, incremental applications repeatedly re-wet the substrate during the day, which dissolves mineral nutrients periodically and carries them down the container column. One continuous application saturates the substrate, causing excess run-off and leaching of nutrients. Using cyclic irrigation can reduce runoff by 30% and nitrogen leaching by 41% compared with continuous irrigation (Fare et al., 1994). Applications during mid-day into mid-afternoon cool the plant canopy and also cool substrate temperatures, alleviating high temperature stress (Warren and Bilderback, 2002). Evaporation of irrigation water may be greater at mid-day than at other times, but the plant will use water applied more efficiently, and less water will run off the nursery compared to a one-time continuous application.

Irrigation efficiency is monitored by measuring the leaching fraction from containers and irrigation uniformity is monitored by measuring the distribution of water applied over a growing area. Leaching fractions for growing plants should be between 0.10 and 0.20. Leaching fractions are calculated by dividing the amount of irrigation water that leaches from the container by the total volume of irrigation water applied. For example, if 1 liter (1000 ml) (33.8 fl oz) of irrigation is applied to container plants by

either overhead or drip irrigation, then only 100 ml (3.4 fl oz) to 200 ml (6.8 fl oz) should leach from the containers (100 ml / 1000 ml = 0.10 or if 200 ml leaches from the container, then 200 ml/ 1000 ml= 0.20 leaching fraction) (3.4 fl oz / 33.8 fl oz=0.10 or 6.8 fl oz / 33.8 fl oz = 0.20 leaching fraction). To determine the leaching fraction, use two empty containers that are the same size as containers used in the growing area. Put a plastic bag in each container so it will hold water. Leave one container out in the growing area (container 1 or C1). In the other container, place a container plant from the growing area (container 2 or C2). Container C1 placed in the open will capture the amount of irrigation water applied, while the second container, C2, will capture the amount of water that leaches from a plant. Make sure that the seal between the pot with a growing plant and C2 is tight enough to exclude water applied from overhead that drips outside the container line. Usually this is achieved by using two similarly sized pots. Thirty minutes after the irrigation cycle has been completed for the day, collect and measure the volume of water in each container. The water in C1 is the total volume applied and the water in C2 is the volume leached from the container. When C2 is divided by C1, this number equals the leaching fraction ( $C2/C1$ =leaching fraction).

Water output often varies considerably across an individual irrigation zone (Yeager et al., 2007) and by as much as 300% variability within a single zone (Niemiera, 1994; Yeager et al., 2007). To measure distribution uniformity (DU) of irrigation application in the growing area, place a number of C1 pots randomly in the growing area and measure their volume 30 minutes after the irrigation cycle ends. Calculate the average volume of all containers ( $V_m$ ). Then calculate the average volume of 25% of the lowest C1 volumes ( $q$ ). Then divide the average 25% driest volumes ( $q$ ) by the overall average ( $V_m$ ) and multiply by 100 to get a percent [ $DU\%=(q/V_m)*100$ ]. Distribution uniformities of 80% or better are preferred. Values outside this range mean that irrigation is applied unevenly and there are a number of dry spots. Cracked, clogged or worn orifices on irrigation risers or perhaps the design and layout of the entire system may be the cause of uneven distribution. Simply compensating for drier areas by overwatering all plants is not an effective or efficient strategy. Repair broken risers and nozzles, adjust plant layout, or design and retrofit a new irrigation system to apply irrigation more uniformly over the growing area.

#### *Irrigation: Water quality, retention basins, and recycling*

Water quality not only affects plant growth, but also influences fertilizer, pesticide, and growth regulator effectiveness. Salt levels [Sodium (Na) and Chlorine (Cl)], mineral concentrations, pathogen load, pH, electrical conductivity (EC), alkalinity (carbonates and bicarbonates), and turbidity (sediment) are all factors that influence irrigation water quality. Whether of municipal, well, surface, or retention

pond origin, irrigation water needs to be frequently monitored and tested periodically to ensure efficient use of fertilizer, chemical, and water resources while maintaining plant quality.

Water used for irrigation, ideally, should have a pH ranging from 5.8 to 7.0. Other factors need to be considered when choosing a source for irrigation water, for example, alkalinity, dissolved nutrients in the water, particularly calcium (Ca), magnesium (Mg) or sodium (Na), and turbidity. Adequate levels of alkalinity (60 to 100 ppm) will neutralize acidity in the substrate, which will raise the pH slightly in pine bark substrates. However if alkalinity is too high (>100 ppm), pH will increase to levels that are detrimental to plant growth because nutrients may be bound and unavailable. Many irrigation sources contain dissolved calcium, magnesium, and sodium. If calcium and magnesium levels approach 20-40 ppm in the water source and alkalinity is adequate, then liming of the substrate may not be necessary. This is particularly true if the plant material being grown is intolerant of high pH (e.g., Ericaceous species). If lime is necessary, many growers add between 4 to 6 lbs of dolomitic limestone per cubic yard of mixed substrate. Depending on the quality of substrate and water used for irrigation, nurseries may need to modify this standard to meet their needs rather than traditionally continuing the same practices. Water quality can change over time in wells and especially if recaptured water is used for irrigation. Without testing, resources may be wasted unknowingly. A complete water test from a state department of agriculture or a private laboratory will determine the levels and possible remedies if the irrigation source poses a challenge. Acid injection may also be necessary to reduce alkalinity and lower irrigation water pH. Acidification of alkaline irrigation water increases the availability of dissolved mineral nutrients in containers and enhances pesticide efficacy.

Many chemicals perform optimally when mixed with acidic water while a few others perform best with neutral or higher pH water (Smith, 2004). If the pH of irrigation water is too high (> 7.0) and alkalinity excessive (>100 ppm), many pesticides (organophosphates, synthetic pyrethroids, carbamates, chlorinated hydrocarbons, ethephon – a plant growth regulator, and others) and herbicides (glyphosate, paraquat) undergo alkaline hydrolysis, a reaction with bicarbonates in water that causes chemical breakdown. The higher the pH and alkalinity the quicker the breakdown, and for every unit increase in pH, the rate of hydrolysis increases 10 times. Some chemicals break down more quickly than others, dependent upon chemical sensitivity to pH and susceptibility to hydrolysis. Chemical companies provide information about the hydrolysis rate (or half-life) of chemicals in their literature. Warm water temperature and long pesticide contact times with poor quality water also increases the hydrolysis rate. Therefore, if water pH is too high, temperature too high, or contact time between poor quality water and the chemical is excessive, the pesticide, growth regulator, or herbicide mixture/dilution will begin to

degrade, effectively reducing the chemical application rate. Many nurseries use well water, their most sediment free water source, to mix spray applications. Many wells in North Carolina contain some bicarbonates and therefore have alkalinity even with a pH near 7.0, thus monitoring these sources frequently is imperative to adjust and maintain correct pH in spray tanks. Because poor water quality is not easily identifiable (i.e. no colors, no smells, no tastes), this problem can persist for years without recognition. Additionally, spray tank applications, especially for herbicides, might be prepared in the morning and sprayed in the afternoon or the next day, thus allowing poor quality water and high temperature to remain in contact with the chemical longer, rendering it less effective. As a result, excessive spray applications with more toxic chemicals might occur as compensation for poor control, even without grower intention. This scenario can create pesticide resistance in some insects and pathogens, as well as increase pesticide application costs by using more chemicals. To prevent these problems and enhance pesticide, growth regulator, and herbicide effectiveness and residual control, obtain buffering agents to adjust pH. These are located at agriculture distributors or the chemical manufacturer. .

If the water used for irrigation routinely has high pH and alkalinity, consider acidifying it to control many issues directly at the source. The pH of small volumes of water used to dilute pesticides or growth-regulating chemicals can be adjusted down with various amendments or buffering agents. If irrigation water is recycled and recurring problems are present like high pH, alkalinity, plant growth issues, and pest infestations, then additional treatment options such as acid injection or dilution with a better quality water source should be considered to reduce plant stress from both abiotic and biotic factors. Acidification immediately at the source solves many other “downstream” problems. For example, high pH (> 7.0) also reduces the efficacy of chlorine dioxide treatment and disinfestation of irrigation water. Higher concentrations of chlorine dioxide are needed to achieve similar pathogen control rates with water at pH 8.0 compared with water at pH 5.0 (Copes et al., 2004). Acidification is less expensive than using higher rates of chlorine dioxide, adding buffering agents, applying more nutrients, and compensating for poor plant growth after the water is used for irrigation.

Best management practices (BMPs) are implemented in nurseries to keep plants healthy and to promote resource use efficiency. BMPs were first developed in the nursery industry for Alabama in the late 1980's to improve effluent water quality from nurseries. Research- and industry-based BMPs for all aspects of nursery production in the southeast were based on these nascent BMPs and published by the Southern Nursery Association in 1997 and revised in 2007 and 2013 (Bilderback et al., 2013). In the interim, most nurseries in Alabama with more than 11 acres in production developed retention basins to capture effluent to re-use as irrigation water or to slowly capture sediments, nutrients, or pesticide

residues prior to discharge from the nursery (Fain et al., 2000). Over 48% of nurseries in Georgia captured effluent in a pond or retention basin. Those nurseries that collected runoff captured runoff water from over 75% of the nursery (Garber et al., 2002). Since the early part of the 21<sup>st</sup> century, anecdotal evidence suggests that nurseries have developed and installed many retention basins that serve both as effluent capture and irrigation water recycling ponds. In some regions, it is mandatory that runoff from agricultural production areas be captured and stored to retain nitrogen, phosphorus, and pesticides. Retention basin installation is a conservation-minded approach to protecting ground and surface water around nurseries. However, the practice might produce other challenges in the nursery when the water is recycled for irrigation.

In the event that captured runoff water is re-used for irrigation, there is the possibility of 1) salt build up in the retention pond over time, 2) low dissolved oxygen conditions in the water column that inhibit microbial processing, 3) pH increases caused by increasing alkalinity, and 4) accumulation of pathogen or weed inoculum that can be redistributed over the nursery (Hong and Moorman, 2004; Kong et al., 2004; Maurer et al., 1995). Retention basins can be aerated to improve uniformity of irrigation water, prevent temperature stratification in ponds, moderate pH, and promote greater processing of carbon from decaying algae and plant material (Leach, 2005). Aeration does not have to occur continuously throughout a 24-hour period. Nightly aeration of retention basins results in the aforementioned benefits, with the added bonus of irrigation water that is adequately aerated so that low dissolved oxygen concentrations in water do not negatively impact plant growth.

In Georgia, few nurseries treat water either for pathogens or to reduce alkalinity before reuse, and only 30% of nurseries check water quality before reuse (Garber et al., 2002). In a recent survey of growers in five states (GA, KY, NC, SC, and TN), approximately 30% of respondents treated irrigation water with chlorine (LeBude et al., 2012). If water is being re-used for irrigation from collection ponds or retention basins, treating the water to reduce pathogens may be necessary. Sanitizing irrigation water can be accomplished using copper ionization, ultra-violet light, or chlorination. Monitoring is necessary to determine water quality and to track any changes that occur during times of increased or reduced rain frequency. This tracking will determine changes to water quality over the life of the nursery also.

#### *Irrigation: Water treatment technologies*

Various water quality issues may emerge over time at a nursery because of changing personnel, water sources, weather, and development and urbanization. Many options are available for treating water, but all depend upon a basic knowledge of important water quality factors. Various physical, chemical,

and biological contaminants need to be managed within irrigation water. Water source (municipal, well, surface, or recycled) influences the treatment regimen necessary before water can safely be used for irrigation. Do not simply adopt a treatment technology without carefully monitoring the quality of current source water for irrigation. Water quality monitoring should be consistent over seasons and years. Work closely with an Extension agent, university faculty member, or treatment representative to determine which physical, chemical, or microbial contaminants are present in irrigation water, before deciding on a treatment methodology system. These factors can fluctuate seasonally and still not be a potential problem to plant quality. If a treatment technology is adopted, continue monitoring seasonally to determine if the contaminant identified pretreatment was adequately controlled and to verify that the efficacy of the treatment technology continues over time.

*Filtration* or removal of unwanted particles is the most common and necessary treatment technology used to improve irrigation water quality. Granular media filtration (slow sand filters or multi-media filters) is common for larger particles (suspended solids), while bag and cartridge filters can remove particles ranging in size from 5 to 100 microns. Growers seeking to more effectively filter water (especially for propagation houses) should consider a minimum filter target range of 50 microns. Bag and cartridge filters are not effective at removing most microorganisms, but micro- and ultra-filtration systems can remove most bacteria. However, these systems are ineffective at removing viral pathogens. Using staged filtration to reduce biological loads (duckweed, bacteria, fungi, crop debris, and substrate components) from recycled irrigation water before disinfection is recommended to increase the effectiveness of the chemical treatment. The biofilms that form on slow-sand filtration media are responsible for much of the bacteria, phytopathogen and virus removal potential (Ehret et al., 2001), but these biofilms also promote clogging that limit the use of filtration alone for removing various pests from recirculated water.

*Disinfection (disinfestation)* is used to inactivate various microorganisms in the water column (viruses, bacteria, fungi, nematodes, cysts, as well as algae). Disinfection type depends upon the microorganism of interest. Oxidants are highly reactive with organic material, and these reactions reduce the efficacy of the oxidant-aided disinfestation (Ehret et al., 2001). Ozone is a strong oxidizing agent, is relatively unstable, and decomposes completely; it can be used to disinfest recirculated irrigation water without potential for phytotoxicity. Graham et al. (2009) evaluated the phytotoxicity potential of aqueous ozone to *Spiraea japonica* ‘Goldmound’, *Hydrangea paniculata* ‘Grandiflora’, *Weigela florida* ‘Alexandra’, *Physocarpus opulifolius* ‘Summer Wine’, and *Salix integra* ‘Hakura Nishiki’ exposed via

overhead irrigation for six weeks. They concluded that ozone residuals at rates of 31.2  $\mu\text{mol/L}$  applied during irrigation were adequate to disinfect the water while resulting in no negative plant growth effects.

Disinfectants such as chlorine, chlorine dioxide, chloramine, and sodium hypochlorite are chemical treatments that effectively disinfect water if properly used (Gurol, 2005; Ehret et al., 2001). *Spiraea japonica* 'Goldmound', *Hydrangea paniculata* 'Grandiflora', *Weigela florida* 'Alexandra', *Physocarpus opulifolius* 'Summer Wine', and *Salix integra* 'Hakura Nishiki' all exhibited signs of chlorine injury, including foliar chlorosis and necrosis, necrotic mottling of leaves, stunted plant growth, and premature leaf abscission as a result of exposure to free chlorine in irrigation water. The critical free chlorine threshold for *S. japonica*, *H. paniculata*, *W. florida*, and *S. integra* was 2.5 ppm, while the critical free chlorine threshold for *P. opulifolius* was 5.0 ppm (Cayanan et al., 2008). However, Cayanan et al. (2009) found that free chlorine concentrations necessary to kill five common pathogens (*Phytophthora infestans*, *Phytophthora cactorum*, *Pythium aphanidermatum*, *Fusarium oxysporum*, and *Rhizoctonia solani*) ranged from 0.3 to 14 ppm. Therefore, depending upon the pest of concern, free chlorine concentrations needed to disinfect recycled water may exceed threshold concentrations that induce toxicity symptoms. Several methods exist for removing chlorine from irrigation water after treatment and include aeration, active carbon (charcoal), or chemical treatment with sodium dioxide, sodium sulfite, or sodium metabisulfite (Cayanan et al., 2009).

Hydrogen peroxide and peroxide containing salts are somewhat weaker disinfectants than chloride and oxidant-based disinfectants, while essential elements [iodine (I), silver (Ag), copper (Cu), and zinc(Zn)] are weak disinfectants (Runia, 1995). Electrolytically generated copper (copper ionization treatment) is commonly used to control pathogens and algae in greenhouse culture, but less work has evaluated its potential for use in ornamental crop production. Zheng et al. (2004) evaluated  $\text{Cu}^{2+}$  toxicity thresholds for three ornamental crops, *Dendranthema x grandiflora* 'Fina', *Rosa x hybrida* 'Lavlinger', and *Pelargonium xhortorum* 'Evening Glow', and found that  $\text{Cu}^{2+}$  concentrations  $> 2.4 \mu\text{molar}$  resulted in visible plant injury. Care should be taken that  $\text{Cu}^{2+}$  ionization concentrations do not exceed this concentration to reduce risk of foliar and root injury to sensitive species.

Ultra-violet (UV) light is electromagnetic radiation with a wavelength between 100 and 400 nm. UV light does not change the physical or chemical characteristics of water during treatment. A minimum of 60% UV light transmission effectively disinfects water (Mebalds et al., 1996), but slow flow rates, used to achieve adequate treatment levels, reduce its applicability for rapidly treating water at nurseries with high irrigation volume applications. Water quality influences the efficacy of UV treatment with high total dissolved solids, iron ( $> 1.0 \text{ ppm}$ ), manganese, calcium, and suspended solids inhibiting proper UV

function (Roberts, 1999). Some nurseries are altering drainage (runoff) flow routes by widening the drainage path and decreasing its slope to form a wide, thin film of drainage that maximizes pathogen exposure to natural UV light and improves UV aided disinfection of recycled water.

Retention ponds used for irrigation should be sited to avoid runoff from roadways, industrial sites or pastures as the herbicides often used in these sites can be very injurious to nursery crops at very low doses. If applicable, site the intake pump used for irrigation or water transfer between ponds as far away as possible from the area of the pond that receives production runoff from the nursery (Ghimire et al., 2011).

### *Fertilization*

Controlled release fertilizers are the standard for supplying macro- and micronutrients over an extended period of time in containers. Sometimes label rates may be higher than necessary for crops. A good rule of thumb is to provide 3 g nitrogen (N) per gallon container size. For example, if an 18-6-12 controlled release fertilizer is being used to provide nutrients to a 3 gallon plant, then 50 g of the product would be applied. Multiplying 3 g nitrogen by 3 gallon size=9g nitrogen needed. There is 18% nitrogen in the fertilizer, so divide  $9 \text{ g} / 0.18 = 50 \text{ g}$ . The goal is to provide the minimal amount of nutrients to produce the desired growth. Nutrients from CRFs are released slowly and usually do not cause plant damage. However, if containers are consistently overwatered, quicker release of the nutrients may occur. These excessive nutrient levels could burn tissues in sensitive plant species, but will more likely leach from the substrate and be unavailable for uptake when needed. Plants do not absorb excess nutrients, so over-application results in nutrient leaching and loss with nursery runoff. Temperature can also influence nutrient release; under warmer conditions, fertilizers will release more rapidly than under cooler conditions.

Growers frequently do not know when adequate levels of fertilizers for sustained plant growth remain in the substrate. Growers can determine when to fertilize during production by monitoring the pH and electrical conductivity of container leachates (LeBude and Bilderback, 2009). Each nursery needs to develop nutrition diagnostic tools based on acceptable plant growth and appearance to determine when to fertilize. Developing these tools requires collecting irrigation, leachate, and tissue samples (from plants that are growing well) once or twice per growing season. These samples are sent to a laboratory, and results can be used to build a diagnostic tool that can help with adapting production strategies to changes in substrate, irrigation water, and/or fertilizer brands. It is important to note that adequate nutrient levels to sustain plant growth not only vary by species but also by cultivar within a species (Jiang et al., 2000; LeBude and Bilderback, 2009; Marschner, 1995; Rose and Biernacka, 1998).

Many factors contribute to optimal plant growth, yet pests may still attack perfectly healthy plants. Revisit all nursery inputs including substrate and amendments, water and any additives for pH correction, nutrients and lime, as well as preventative sprays for pests and plant disease. Determine for each additive or action, 1) why was this incorporated into the nursery production system; 2) what benefit does it contribute to plant growth; 3) can the same plant quality be achieved without this additive or action, or can a lesser amount be used? Ask these questions prior to the addition of anything new to the production system. Many things are added to the system because a nearby grower has done it, or it is recommended by a sales representative, Extension agent, plant pest or disease clinic employee, a faculty member at a trade show, or it was read about in a trade journal. Getting information from all those sources is very reasonable and trustworthy, just ensure that the underlying problem the corrections are purported to improve or solve are actual problems in the nursery system currently. False positives in nursery production, that is, finding a difference when one does not exist is common. For example, something could be added to the substrate that is claimed to increase growth or decrease pathogens. If it is added and nothing happens, that is, the same quality growth from last year is obtained, it might be reasonable to suggest that it is a good additive because it did not decrease plant growth. Even though it did not change growth substantially, it might now become thought of as “additive insurance,” and once it becomes entrenched in the regular nursery production system, it might be difficult to get rid of since it is what has always been done. Choose additives and actions wisely, more is not always better when it comes to plant growth. Add just enough to obtain optimal plant growth when the plant is growing. Otherwise, excesses are leached or lost, or utilized for other possibilities, like pest and plant disease growth.

### ***Systems-Based Pest Management***

A systems approach to pest management, which is an audit-based method to certify plants as pest free for shipment, has recently been used on a limited basis in the US and internationally (Griesbach et al., 2012)<sup>1</sup>. A systems approach was created to reduce pressures on federal and state regulators completing end-point inspections of nursery crops and engage stakeholders to work together to mitigate plant pests and pathogen risks associated with nursery production. Further adoption of this approach by US and international regulatory agencies is expected and has the potential to dramatically change nursery pest management and certification. A systems approach to pest management is compatible with IPM and shares an emphasis on prevention and knowledge-based decision-making. Conducting a risk analysis is inherent to a systems approach to pest management. Hazard Analysis and Critical Control Points (HACCP) has been adapted from the food processing industry to identify and evaluate risk in nurseries.

HACCP focuses on preventing hazards, rather than identifying and containing them as a finished product (conventional inspection at shipping point) (Osterbauer et al., 2014). Critical control points are identified that can be used to install independent methodologies to prohibit the entrance and reproduction of pests, plant diseases, and weeds into the nursery production system (Dixon et al., 2012).

A systems approach to nursery certification requires redundant and overlapping measures to create cumulative protection and depends on early pest detection (Griesbach et al., 2012). Specifically, at least two independent measures of control are required to manage pests. Installing at least two independent measures decreases the likelihood of both failing simultaneously, thus growers decrease the likelihood of pest or pathogen infestation. For example, growers can adopt three independent measures to prevent a pathogen from being introduced into a nursery when the pathogen can be on plants, but the plants appear asymptomatic. First, all liners purchased from an outside source would be inspected thoroughly upon arrival to detect any symptoms. Secondly, the plants could be quarantined for at least two weeks in an area of the nursery surrounded by plants that are not susceptible to the pathogen. Lastly, rigid scouting of that block of plants could occur for the next six months to detect any early symptoms of the pathogen. Additionally, growers could keep track of all suppliers of those liners and any end users that might purchase finished plants from them. All of these independent measures work together to create a systematic approach to detecting and eradicating any pathogens introduced into a nursery. If one measure fails, for example, the initial scouting when plants are received, the pathogen might still be detected in quarantine two weeks later and the pathogen or plants can be eradicated. Below is a checklist for systems based pest management. A systems approach emphasizes pest avoidance and prevention, however, it does not eliminate pesticide use (Griesbach et al., 2012).

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<sup>1</sup>**Canadian Nursery Certification Program (CNCP).** The CNCP mirrors the USNCP requirements and is a reciprocal program.

**Clean Plants Program.** The Clean Plants Program was developed by the Canadian Nursery and Landscape Association to assist growers in transitioning to the CNCP program.

**Grower Assisted Inspection Program (GAIP).** GAIP was created by Oregon Department of Agriculture to help control Phytophthora species in nursery plants transported within the US (Lujan et al., 2010).

**Systems Approach to Nursery Certification (SANC).** SANC is described in the Framework for a Systems Approach to Nursery Certification by the National Plant Board (Dixon et al., 2012).

**United States Nursery Certification Program (USNCP).** The USNCP is a trial certification system described in Regional Standard for Phytosanitary Measures (RSPM) No. 24. This regional standard for Canada, Mexico, and the United States was developed by the North American Plant Protection Organization (NAPPO).

### *Systems-Based Pest Management Check List*

- Unused containers are stored off ground and above the rain splash zone
- Sterilize all used containers and flats before planting
- Disinfect surface water that is used for irrigation
- Sanitize hands and shoes before entering a propagation area
- Keep clear records that allow plant history to be traced
- Quarantine new plants before moving them into the nursery
- Plants are grouped and spaced appropriately
- Plants are scouted weekly or bi-weekly during production
- Sanitize pruning equipment regularly when pruning or shearing
- Cull piles and plant debris are kept out of the production area

(Cochran et al., 2014)

### *Calendar of Worker Activities in Field Nurseries*

#### *January*

- \* Take advantage of good weather. Grade and apply gravel to tractor roads. Inspect and replace worn irrigation equipment and nozzles. Calibrate sprayers and spreaders.
- \* Conduct maintenance on equipment: replace tires, repack bearings on trailers, repair tractors, and sharpen maintenance equipment. Clean out, inspect, and inventory storage areas. Order crop protection chemicals, fertilizers, and amendments for growing season.
- \* Dig trees when weather permits. Protect root balls and tops on dug B&B crops.
- \* If necessary, apply Casoron when daytime high temperatures are below 50°F.
- \* Prune trees to establish a single leader and scaffold branches, and lift canopy; remove crossed or damaged branches. Remove basal and water sprouts, and direct the growth of multiple stemmed crops.
- \* Take soil samples and prepare remaining ground beds and fields for planting.
- \* Review IPM and pesticide records from the past year to determine success of IPM and pest control program.
- \* Schedule and write on calendar IPM monitoring and scouting visits for coming year.
- \* Scout nursery fields, sites or blocks of ornamental plants at least once in January. Periods of key pest emergence may require weekly scouting.
- \* Develop professionally by attending trade shows and Extension workshops.

### *February*

- \* Conduct any unfinished maintenance and inventory activities on growing and non-growing areas, equipment and storage compartments.
- \* Dig trees when weather permits. Protect root balls and tops on B&B crops.
- \* Prune to establish leaders, scaffold branches, canopy height and conflicting/damaged branches. Cut any seedlings or liners to the ground if planned. Shear plants being grown for screening purposes.
- \* As orders arrive, keep liners moist: place in sand, bark or sawdust and store in shaded areas or place in coolers under mist/fog.
- \* Plant liners as soon as weather permits. Install drip irrigation in new plantings.
- \* Apply preemergence herbicides on new crops and in rows of field stock.
- \* Take soil samples and prepare remaining ground beds and fields for planting.
- \* Treat newly planted crops with preemergence herbicides within 48 hours of planting or as soon as label instructions permit, record application dates, rates and products.
- \* Plan to scout for insect, mite, disease, weed and vertebrate pests at least once in February. Periods of key pest emergence may require weekly scouting.
- \* Process orders, tag and assemble orders for shipment.
- \* Attend trade shows and Extension workshops.

### *March*

- \* Maintain roads and drives as needed to avoid impeding shipping activities.
- \* Conduct any needed maintenance for pumps and irrigation systems.
- \* Dig trees and ship harvested nursery stock; store dug crops in cool/shaded area. Keep root balls moist and protected from freezing.
- \* Hold liner stock in cool, shaded location; keep roots moist. Plant ASAP.
- \* Apply 2/3 of annual nitrogen application to field stock if granular fertilizer is used, using an approximate rate of 0.25 oz. to 2.0 oz. nitrogen/year based upon size and species.
- \* Plan to scout for insect, mite, disease, weed and vertebrate pests at least twice in March. Periods of key pest emergence may require weekly scouting. Record pests identified and select and make record of any pesticides applied.
- \* Scout for spring weeds to determine which weeds escaped the fall herbicide program, as well as which winter annuals are germinating in spring as a result of fall herbicide running out.

- \* Shipping begins to dominate activities at nursery. Most available personnel may be involved in pulling orders and loading trucks.  
Sales personnel account for inventory, process orders, route trucks, drops and billing

#### *April*

- \* Maintain facilities as needed to avoid impeding shipping and production activities.
- \* Dig trees and ship.
- \* Plant new liners ASAP.
- \* Apply fertilizer and preemergence herbicides in new fields.
- \* Weed liner and seedbeds; apply fertilizer and preemergence herbicides.
- \* Apply drip irrigation, wetting soil to a six-inch depth, as needed depending on rainfall. Fertilize crops based on fertigation guidelines.
- \* Plan to scout for insect, mite, disease, weed and vertebrate pests at least twice in April. Periods of key pest emergence may require weekly scouting. Record pests identified and select and record any pesticides applied.
- \* Shipping is in full swing. All available personnel may be needed to pull orders, tag and load trucks.

#### *May*

- \* Check irrigation system uniformity and efficiency on days with high temperatures.
- \* Digging season ends for many nurseries.
- \* Irrigate field-grown crops as needed with overhead or drip irrigation. Consider fertilizing crops through drip lines based on fertigation guidelines.
- \* Scout fields for emerging nutsedge and perennial weeds. Treat with postemergence herbicides and apply preemergence herbicides.
- \* Harvest or till winter cover crops into soil. Plant summer cover crops on fallow strips or fields to improve organic matter in soil.
- \* Plan to scout for insect, mite, disease, weed and vertebrate pests at least twice in May. Periods of key pest emergence may require weekly scouting. Record pests identified and select and record any pesticides applied.
- \* Prune/shear shrubs and screening liner plants. Lightly fertilize if appropriate.
- \* Shipping season winds down for most nurseries.

- \* Summer production schedules begin.

### *June*

- \* Grade and gravel roads from spring digging/shipping.
- \* Review/develop disaster plans for nursery for floods, hurricanes, high winds, and hail. Consider computer backup practices, power failure alternatives for irrigation, employee responsibilities, structural insurance, and inventories for crop insurance.
- \* Re-establish single leaders in trees, prune tips in competing shoots, prune excessive growth of lateral branches.
- \* Maintain weed management with directed postemergence herbicides. Re-apply preemergence herbicides and postemergence nutsedge control as needed. Mow vegetation in aisles and roadways.
- \* Scout fields for mature winter annual weeds not controlled by spring treatments and emerging summer annuals and perennials. Record all species present, highlighting the most prevalent or difficult to control.
- \* Apply final 1/3 of annual nitrogen application to field stock. If field grade fertilizer is applied, annual rate is 1/4 oz nitrogen to 2.0 oz nitrogen/year based upon size and species.
- \* Plan to scout for insect, mite, disease, and vertebrate pests at least twice in June. Periods of key pest emergence may require weekly scouting. Record pests identified and select and record any pesticides applied.

### *July*

- \* Maintain irrigation equipment; assess water supplies compared to irrigation demand.
- \* Irrigate field-grown crops as needed with overhead or drip irrigation. Application of nitrogen fertilizer should be completed by end of July.
- \* Mow aisles and drive roads. Summer cover crops may require mowing.
- \* Make directed applications of post-emergence herbicides as needed.
- \* Check fall digging inventories. Order wire baskets, burlap, twine, pinning nails and other supplies or make a note to see distributors at August trade shows.
- \* Plan to scout for insect, mite, disease, weed and vertebrate pests at least twice in July. Periods of key pest emergence may require weekly scouting. Record pests identified and select and record any pesticides applied.

- \* Trade shows
- \* Shipping continues. New orders are booked for fall.
- \* Daily nursery activities may be accented with visits from customers and nursery tours.

### *August*

- \* Maintain buildings, roads and equipment as needed.
- \* Irrigate field-grown crops as needed with overhead or drip irrigation.
- \* Collect leaf tissue samples of crops showing nutritional disorders and send them to a diagnostic lab. Correct problems based upon the results.
- \* Mow summer cover crops on fallow fields. Begin field preparation for planting.
- \* Mow aisles and drive roads.
- \* Apply preemergence herbicides for winter annual weed control.
- \* Scout all field nursery blocks for weeds. Record all species encountered.
- \* Many perennial weeds are controlled by glyphosate applications in late August or September.
- \* Prepare digging and shipping schedules for fall digging season.
- \* Plan to scout for insect, mite, disease, weed and vertebrate pests at least twice in August. Periods of key pest emergence may require weekly scouting. Record pests identified and select and record any pesticides applied.
- \* Seed winter cover crops.

### *September*

- \* Prepare fields by tilling or plowing cover crops and amend according to soil test.
- \* Begin planting broadleaved and coniferous liners. Apply preemergence herbicides within 48 hours after planting or as soon as label instructions permit.
- \* Digging season begins with harvest of crape myrtle, broadleaved evergreens and conifers.
- \* Plan to scout for insect, mite, disease, weed and vertebrate pests at least twice in September. Periods of key pest emergence may require weekly scouting. Record pests identified and select and record any pesticides applied.
- \* Autumn seasonal production, shipping and harvesting seasons begin.

### *October*

- \* Repair driveways and roads in fields before cold weather.
- \* Plant fall liners in prepared fields. Install drip irrigation to reduce winter desiccation mortality. Irrigate weekly and before cold fronts to increase turgor in newly planted liners.
- \* Harvest broadleaved evergreens and conifers. Wait until leaf drop is complete before digging deciduous crops.
- \* Plan to scout for insect, mite, disease, weed and vertebrate pests at least once in October. Periods of key pest emergence may require weekly scouting. Record pests identified and select and record any pesticides applied.
- \* Fall shipping sales are booked and orders processed upon availability.

### *November*

- \* Turn attention to winterizing the nursery.
- \* Finish planting broadleaved liners. Irrigation will reduce mortality of evergreen crops, due to winter desiccation. Irrigate before cold fronts and drain lines.
- \* Digging season begins full season. Protect root balls from freezing and evergreen tops from wind and sun to prevent desiccation during holding and shipping harvested crops.
- \* Plan to scout for insect, mite, disease, weed and vertebrate pests at least once in November. Periods of key pest emergence may require weekly scouting. Record pests identified and select and record any pesticides applied.
- \* Fall shipping is in full swing.

### *December*

- \* Finish winterizing the nursery before the holiday season.
- \* Dig when weather is permitting. Protect root balls from freezing and evergreen tops from wind and sun to prevent desiccation during holding and shipping harvested crops.
- \* Plan to scout for insect, mite, disease, weed and vertebrate pests at least once in December. Periods of key pest emergence may require weekly scouting. Record pests identified and select and record any pesticides applied.
- \* Fall shipping for field stock continues.

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# Nursery Crop Production Critical Issues: *IPM Technology*

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Technology to aid nursery growers with IPM was included in 2014 because many platforms now exist that enable growers to obtain information about pests in the nursery, monitor real time how irrigation and nutrients are being utilized in production, and gather information about possible tactics, cultural practices and interventions to manage these plant diseases, pests, and weeds.

Focus group attendees were asked to imagine uses of technology for horticulture without regard to total costs.

Unmanned aerial vehicles (Drones) or other forms of technology that can meet the needs specified.

- Aiding scouting for pests, weeds, and diseases
- Detecting blow over of plant material on nursery margins
- Targeting spray applications
- Monitoring worker productivity management
- Completing inventory tasks, for example, maintaining inventory updates on nursery that automatically update a database in real-time so nursery sales people and regional sales representatives do not double book the same plant material.
- Confirm location or get an image representative of the crop for customers.

Radio-frequency identification (RFID)

“RFID is the wireless use of electromagnetic fields to transfer data, for the purposes of automatically identifying and tracking tags attached to objects. The tags contain electronically stored information. Some tags are powered by electromagnetic induction from magnetic fields produced near the reader. Some types collect energy from the interrogating radio waves and act as a passive transponder. Other types have a local power source such as a battery and may operate at hundreds of meters from the reader” (Wikipedia, 2014).

- Use RFID to track production history for each crop
  - Have responder carry all information for cultural practices, pesticide applications, and plans for that crop
- Use the technology to track emerging significant pests, for example, boxwood blight, giving someone trace forward and trace backward capabilities.

Prescription nutrient and pesticide delivery

- Ability to determine which nutrients are available to the plant and which ones have been absorbed by roots to reduce delivery of abundant nutrients.
- Enclose pesticides in small enough containers that once inserted into a mixing mechanism on a spray rig, they mix automatically without exposing the operator in the process.

### Mobile device applications (Apps)

- Provide various scenarios for new crop placement on nursery using the desired finished crop spacing and grower-identified field or production area sizes.
- Must integrate with country wide platforms to account for multiple locations of larger nurseries.
- Send weekly updates with pictures of plant locations and blocks geotagged.
- Must be able to work across all mobile platforms (handheld, ipad/notebooks, desktop computer).
- Provide it in a Spanish version.
- Easy to read in sunny locations like gravel pads, greenhouses, trucks, and field situations.
- Consider that not all nurseries have high bandwidth capabilities or extensive wireless coverage.

# Key Pest Profiles, Focus Group Rankings, and Critical Issues: *Insect Pests*

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## *Pre-Meeting Survey and Focus Group Results*

Growers participating in the PMSP focus group meeting were asked to complete a pre-survey about important arthropods to determine their prevalence, difficulty to control, damage potential, and severity of injury (Table 3). These preliminary results were used to focus discussion during the meeting. Each attendee then distributed 24 votes among the various arthropod pests to create an Overall Focus Group Ranking to indicate which ones were most important. More than one vote could be cast for each pest, but SNIPM working group members did not cast ballots. New and or emerging pests discussed at the focus group were included below in the Key Pest Profiles. Compared to the 2009 PMSP, the 2014 survey included individual insect pests rather than combining them together under one heading. For example, in 2009, scales and borers were ranked as the top two insect pests after the focus group discussion, whereas in 2014, flea beetles and eriophyid mites, which were not included in 2009, were perceived overall as causing the most problems. Scales and borers are still considered important pests in these rankings, because armored scales are somewhat difficult to control (armored scales, score of 5.0) or as in the case of granulate ambrosia beetle make current seasonal sale unlikely (granulate ambrosia beetle, score=3.3) (Table 3). These two examples also highlight some aspects of using focus groups. For example, focus groups are intended to be a random sampling of a population and are thought to reflect similar perceptions of that larger population. In this case, it is not feasible to obtain such a true focus group population of the entire southeast, so a select few are chosen to represent the remainder. Additionally, climatic factors and region of the country affect each grower's perceptions of important pests. For example, in 2007, a drought affected the southeast and borer damage was likely the following growing season in 2008. When the focus group met in 2009, borers may have been a very important pest based on the recent events. Recently rose rosette virus and its vector, eriophyid mites, has become an emerging plant disease and pest issue. This is reflected in those two pests being ranked highly in both Tables 1 and 2. Additionally, the area near South Georgia and Northern Florida, where this focus group was held, is also a large production area for Knockout™ and other everblooming shrub roses. Therefore, a number of subjective factors are included in the rankings of importance for arthropod, plant disease, and weed pests.

Table 3. Pre-meeting survey of arthropods and overall importance of pests after discussion by a focus group of nursery crop growers from FL, GA, NC, TN, and VA.

Arthropod Pests	Overall Focus Group Ranking <sup>1</sup>	Prevalence <sup>2</sup>	Difficulty to Control <sup>3</sup>	Damage Potential <sup>4</sup>	Severity of Injury <sup>5</sup>
Eriophyid mites	17	4.2	5.5	4.6	3.0
Flea beetles	17	5.5	4.8	4.8	2.0
Spider mites, <i>incl.</i> red spider mite	14	5.4	3.7	4.4	1.8
Fire ants	10	4.9	3.4	3.8	2.3
Armored scales: Japanese maple scale, tea, white peach	9	4.9	5.0	3.7	2.3
Soft scales: calico, lecanium, wax	8	4.7	4.7	3.7	1.8
Aphids	8	5.1	3.0	3.7	1.6
Granulate ambrosia beetle	7	3.9	4.4	3.5	3.3
Thrips ( <i>incl.</i> chilli thrips)	7	3.7	3.4	3.4	2.2
Root grubs/weevils	7	3.3	3.3	3.3	1.0
Clearwing moth (e.g., dogwood, peachtree, lilac/ash borer)	6	3.3	4.7	3.3	3.2
Broad mites	6	4.6	3.7	3.3	1.7
Brown marmorated stink bug	5	2.8	3.0	3.0	1.7
Japanese beetle	4	3.7	3.0	3.0	2.0
Leafhoppers	3	4.1	3.6	3.0	2.0
Bagworm	3	3.7	3.6	3.0	2.3
Maple tip borer	3	3.0	2.5	3.0	2.3
Flatheaded appletree borer ( <i>incl.</i> emerald ash borer)	2	2.3	3.0	2.5	2.6
Crape myrtle bark scale	1	2.7	3.3	2.3	2.3
black twig borer	0	2.4	1.0	2.0	2.5
Kudzu bug	0	2.5	1.0	1.0	1.0
Eastern tent caterpillar (and others)	<i>n.r.</i> <sup>6</sup>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Lacebug	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Leafminers	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Midge larvae clogging filters	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Snails	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Strawberry root weevil	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Twig girdler	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Whiteflies	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>

<sup>1</sup>Overall focus group ranking = number of votes, greater number of votes indicates more participants found this to be a problem arthropod at the focus meeting. Each attendee had 24 votes to cast and could vote more than once for each pest. There were n=9 growers present.

<sup>2</sup>Prevalence; 1=Don't know the pest; 2=Not found at site; 3=Rare; 4=Occasional (spot treat only if found); 5=Common (part of regular monitoring effort); 6=Actively managed every year. n=8. Means of the scale, not including "1=Don't know the pest," are presented. n=8.

<sup>3</sup>How easy or difficult is the pest to control. 1=Not applicable; 2=Easy; 3=Somewhat easy; 4=Moderate; 5=Somewhat difficult; 6=Difficult. n=8. Means of the scale, not including "1=Not Applicable," are presented. n=8.

<sup>4</sup>Estimated proportion of grower's most susceptible crop that is commonly injured by the pest. 1=Not applicable; 2=0%; 3=1-5%; 4=6-15%; 5=16-25%; 6=>25%. Means of the scale, not including "1=Not Applicable," are presented. n=8.

<sup>5</sup>Please indicate the best description of injury associated with each arthropod pest. 1=Salable crop (no visible injury or injury acceptable); 2=Seasonal sale delayed until new growth flush or hand pruning; 3=Seasonal sale unlikely, crop leaf drop & new leaf protection needed; 4=Quality of sale lost (grade reduced); 5=Total crop loss. Means of the scale are presented. n=8.

<sup>6</sup>n.r. – listed pest was not specifically identified nor assessed in the given year's focus group roundtable.

## Key Pest Profiles: Insects

### Aphids and Adelgids

#### Common species:

**Aphids** (Hemiptera: Aphididae): Crapemyrtle aphid, *Tinocallis kahawaluokalani* (Kirkaldy); Balsam twig aphid, *Mindarus abietinus* (Koch); Melon aphid, *Aphis gossypii* (Glover); Apple aphid, *Aphis pomi* (De Geer); Rose aphid, *Macrosiphum rosae* (L.); Spirea aphid, *Aphis spiraecola* (Patch); Tulip tree aphid, *Illinoia liriodendri* (Monell); Green peach aphid, *Myzus persicae* (Sulzer); Woolly alder aphid, *Paraprociophilus tessellates* (Fitch); Woolly elm aphid, *Eriosoma americana* (Riley); Woolly apple aphid, *Eriosoma lanigerum* (Hausmann); etc.

**Adelgids** (Hemiptera: Adelgidae): Balsam woolly adelgid, *Adelges piceae* (Ratzeburg); Eastern spruce gall adelgid, *Aldelges abietis* (L.); Pine bark adelgid, *Pineus strobi* (Hartig); Hemlock woolly adelgid, *Adelges tsugae* (Annand); etc.

#### Host Plants:

- Aphids can infest virtually all woody and herbaceous ornamental plants grown in nurseries.

- Some of the plants most commonly infested by aphids are *Rosa*, *Lagerstroemia*, *Liriodendron*, and *Prunus* spp.
- Adelgids infest many genera of conifers including *Abies*, *Picea*, *Pseudotsuga*, *Pinus*, and *Tsuga*.

### **Distribution, Damage and Importance:**

- Most of the common species have a cosmopolitan distribution in the Southeast.
- All aphid species feed by sucking plant sap from vascular or other tissue with piercing mouthparts.
- Feeding results in deformed and/or small leaves, discoloration, defoliation, and in some cases plant death from reoccurring or large infestations.
- Aphids produce large amounts of honeydew as a by-product of feeding on phloem. Honeydew forms a sticky layer on leaves and objects below the infested plants. Honeydew is also a substrate for black sooty mold, which (although not pathogenic) is unattractive when grown on leaves and reduces photosynthesis.
- Many aphid species are also important as vectors of plant disease.
- Adelgids occur with host species, which are always coniferous trees. Thus, most occur in cooler parts of the region and at higher elevations where hemlock, spruce, and other hosts are common.
- Hemlock woolly adelgid is the most damaging species in this group. It is an invasive species from Asia that has devastated forests and curtailed nursery production and shipment in the Eastern US.

### **Life Cycle:**

- The life cycles of aphids vary by species, but all species are partially or fully parthenogenic.
- Aphids can have many parthenogenic 'generations' per year.
- Many species have a sexual stage on alternate host plants.
- Typically this involves a fall migration to the alternate host where mating occurs and eggs are laid.
- Aphids typically overwinter as eggs on plant tissue or bark.
- Development time is generally short. Parthenogenically produced nymphs can develop into adults in a few days depending on species and temperature.
- Adelgids have more complex life cycles involving alternate hosts. For example, hemlock woolly adelgid has 2 generations per year. Adults overwinter on hemlock and oviposit in the spring. Then some nymphs move to spruce as an alternate host for sexual reproduction while others stay on

hemlock to mature and oviposit there. Nymphs enter aestivation during hot summer months, then begin feeding and mature in the fall.

### **Control Measures:**

#### **Monitoring:**

- Inspect foliage and stems of crops for the presence of the aphids, shed skins, honeydew and sooty mold.

#### **Cultural/Mechanical:**

- The most important cultural control tactic is to maintain the health of nursery crops through proper cultural practices.
- Plant stress from drought or other sources can make plants more susceptible to aphid infestations by reducing plant defenses or promoting aphid growth via an increase in free nitrogen in the vascular fluid.
- Fertilizer, particularly nitrogen, makes plants more nutritious for aphids and can substantially increase aphid population growth by reducing development time and increasing fecundity.
- Some plant varieties are more resistant to aphids than others. For example, crapemyrtle varieties have a great range of resistance to crapemyrtle aphid, so resistant varieties can be selected.

#### **Biological:**

- Aphid and adelgid populations in field production are subjected to predation and parasitism by existing populations of parasitoids and predators. In many cases, aphid and adelgid populations are fully controlled by existing natural enemies.
- A number of biological control agents can be purchased to control aphids. Predators include lady beetles, minute pirate bugs (*Orius insidiosus*), aphid gall midge (*Aphidoletes aphidimyza*), and syrphid fly larvae. Parasitoids include *Aphidius colemani*, other *Aphidius* spp., and *Aphelinus* spp.
- Entomopathogenic fungi, such as *Beauveria bassiana* and *Isaria formosorosea*, are also available for the management of aphids.

- Conservation biological control may be achieved by diversifying the plant species in a habitat and, in particular, providing floral resources and alternative hosts for predators and parasitoids.
- The effectiveness of biological control (conservation or augmentative) in field productions is unknown.
- Existing biological control can be disrupted by the use of broad-spectrum insecticides.

**Chemical:**

- Aphids are susceptible to a number of products. A smaller number of products are registered for the management of adelgids.
- Many species feed on the undersides of leaves, so coverage of these areas is important.
- Systemic products can improve efficacy by killing aphids that feed on the plant even if they were not contacted by the insecticide.
- Chemicals used in nurseries include:

Chemical Class	Common Name
Carbamates	carbaryl, methiocarb
Organophosphates	acephate, chlorpyrifos
Pyrethroids	bifenthrin, cypermethrin, $\lambda$ -cyhalothrin, deltamethrin, fenpropathrin, tau-fluvalinate, permethrin, pyrethrin
Neonicotinoids	acetamiprid, clothianidin, dinotefuran, imidacloprid, thiamethoxam
Avermectins	abamectin
Juvenile hormone mimics	pyriproxyfen
Feeding blockers	pymetrozine, flonicamid
Buprofezin	buprofezin
Tetramic acid derivatives	Spirotetramat
Azadirachtin	azadirachtin
Horticultural oil and neem oil	
Insecticidal soap	

### **Federal/State/Local Regulations and Pesticide Restrictions:**

- Many states restrict the importation of hemlocks due to potential infestation with hemlock woolly adelgid.

### **Critical Issues and Needs:**

- A better understanding of the life history of aphids for effective management.
- Improvement in predicting important life history events using degree-day models or plant phenological indicators.
- Development of thresholds that include natural enemy abundance to help growers determine if pesticides are necessary or if the population is under natural control.
- Because of the variation in phenology and management strategies, Extension personnel and grower training is needed to improve monitoring and management efficiencies.
- Assessment of the efficacy and the cost-benefit ratio of augmentative biological control and development of improved implementation methods.
- Development of conservation biological control tactics, such as habitat manipulation with flowering plants, to increase the abundance, diversity, and efficacy of naturally occurring predators and parasitoids.
- Development of banker plant systems for use in outdoor nurseries to support natural enemies and suppress aphids.

### *Borers*

#### **Common species:**

**Flatheaded borers** (Coleoptera: Buprestidae): Flatheaded appletree borer, *Chrysobothris femorata* (Oliver); Bronze birch borer, *Agrilus anxius* (Gory); Twolined chestnut borer, *Agrilus bilineatus* (Weber); Emerald ash borer (EAB), *Agrilus planipennis* (Fairmaire); etc.

**Roundheaded borers** (Coleoptera: Cerambycidae): Twig pruner, *Anelaphus villosus* (F.); Twig girdler, *Oncideres cingulata* (Say); Roundheaded appletree borer, *Saperda candida* (Fabricius); Dogwood twig borer, *Oberea tripunctata* (Swederus); Locust borer, *Megacyllene robiniae* (Forster); Asian longhorn borer, *Anoplophora glabripennis* (Motschulsky)

**Weevils** (Coleoptera: Curculionidae): Cypress weevil, *Eudocimus mannerheimii* (Boheman)

**Lepidopteran borers** (Lepidoptera: Sesiidae): Dogwood borer, *Synanthedon scitula* (Harris); Lilac borer, *Podosesia syringae* (Harris); Banded ash clearwing borer, *Podosesia aureocincta* (Purrington & Nielsen); Peachtree borer, *Synanthedon exitiosa* (Say); Lesser peachtree borer, *Synanthedon pictipes* (Grote & Robinson)]; Rhododendron borer, *Synanthedon rhododendri* (Beutenmüller)

#### **Host Plants:**

- Many species of trees and woody ornamentals are attacked by borers of one type or another.
- The genera of trees most commonly damaged by borers are *Acer*, *Betula*, *Cornus*, and *Fraxinus*, and ornamentals in Rosaceae.

#### **Distribution, Damage and Importance:**

- Most of the common species have a cosmopolitan distribution in the Southeast.
- The beetle borers (flatheaded borers, roundheaded borers and weevils) have chewing mouthparts that are used by adults or larvae to bore into woody plants.
- Only the larvae of the clearwing borers tunnel into woody tissues.
- Damage by some species, such as the flatheaded apple tree borer and clearwing borers, occurs to the vascular layer just below the bark. Thus, the bark has a blistered and gnarled appearance as larvae produce galleries below.
- Vascular damage results in girdling of the tree and interrupted vascular transport. As a result, trees exhibit chlorotic leaves, sparse foliage, branch dieback, and sometimes plant death.
- Other species, such as locust borer, bore into the center or heartwood of the tree, which interrupts vascular flow and weakens the tree.
- Borers produce frass, which is sometimes pushed out of the holes they bore.
- Boring by insects also opens the tree to secondary infection by a pathogen or other insects.
- Trees or other woody plants with boring damage are unsalable because of their appearance and because they are unlikely to flourish in the landscape.
- Emerald ash borer is important as an exotic invasive species that has the potential to eliminate ash trees from forests and landscapes. Current distribution includes AR, CO, CT, GA, IA, IL, IN, KY, KS, MA, MD, MI, MN, MO, NY, NC, NH, NJ, NY, OH, PA, TN, VA, WI and WV, as well as ON and QC in Canada (USDA, 2014).

- Asian longhorned beetle is NOT currently in the Southeast but is important for growers to be aware of when inspecting nursery stock coming from New York, New Jersey, Massachusetts, or Illinois.

### **Life Cycle:**

- Lifecycles vary by family and species.
- Typically, the generation time is one to two years.
- Flatheaded borers generally have a similar life history. For example:
  - Bronze birch borer overwinters as mature larvae in galleries and pupates in early spring. Adults emerge in early summer and lay eggs on the tree bark.
  - Flatheaded appletree borer adults emerge in summer and lay eggs on the bark. Larvae bore into the tree from that point and overwinter as larvae.
- Round headed borers such as roundheaded appletree borer may take two years to develop, whereas the locust borer takes one year.
- Lepidopteran borer adults emerge in spring and summer and live just long enough to deposit eggs on bark. Adults do not damage trees. Larvae feed in the sapwood all summer, overwinter as larvae and pupate the following spring.

### **Control Measures:**

#### **Monitoring:**

- Monitoring is extremely important because prevention of oviposition by adults and boring activity by young larvae is more effective than curative treatment against older larvae.
- Flatheaded borers may be monitored with purple stick cards.
- Clearwing (lepidopteran) borers may be monitored with pheromone traps.
- Monitoring methods for the roundheaded borers and weevils are not well established.

#### **Cultural/Mechanical:**

- The most important cultural control tactic is to maintain and promote the health of nursery crops through proper cultural practices.
- Stressed trees are often targeted by borers, less able to fend off attacks with sap, and less able to recover from borer damage.

- Mechanical damage to bark is generally a preferred oviposition site for borers, so avoiding damage to bark is important.

**Biological:**

- Borers are subject to parasitism by a number of parasitoids.
- No parasitoids are commercially available for release.
- Nematodes, *Steinernema carpocapsae*, can be used with success to kill borer larvae.

**Chemical:**

- Borers can be targeted as adults by spraying the bark to prevent oviposition and successful entry by young larvae.
- Many species can be monitored with pheromone traps or purple sticky traps to determine when adults are active.
- Systemic products can be effective on species that spend a significant amount of time feeding on the vascular tissue.
- Chemicals used in nurseries include:

Chemical Class	Common Name
Carbamates	carbaryl
Organophosphates	chlorpyrifos
Pyrethroids	bifenthrin, permethrin
Neonicotinoids	acetamiprid, dinotefuran, imidacloprid

**Federal Restrictions:** Areas infested with emerald ash borer or Asian longhorn borer are subject to quarantine (UDSA, 2014).

**Critical Issues and Needs:**

- A better understanding of life history of borers is important to effective management.

- Increased availability of pheromones and other monitoring tools.
- Research on how nutrition, water, and other cultural practices affect susceptibility to and preference of borers.
- Research into how pruning may affect tree susceptibility and how to time pruning to expose trees to the least borer risk.
- Research on how suckers and adventitious growth affects susceptibility to and preference of borers, including how to prune/remove suckers without exposing trees to risk.
- Research on the efficacy of current insecticides is critical including comparisons of old products such as chlorpyrifos and permethrin to new products such as neonicotinoids and chlorantraniliprole that have lower vertebrate toxicity and impact on natural enemies.
- Research on how to make products more effective with surfactants, stickers, or other products.
- Research on curative applications to kill borers once they are inside trees.
- Impact of insecticide applications targeting borers on natural enemies and secondary pest outbreaks such as mites.

### *Brown Marmorated Stink Bug*

**Species:** *Halyomorpha halys* Stål

**Host Plants:**

Many ornamental plants are reported as host plants of BMSB, including *Acer*, *Betula*, *Cornus*, *Ilex*, *Malus*, *Phalaenopsis*, *Prunus*, and *Pyrus*.

**Distribution, Damage and Importance:**

- BMSB was first detected in Allentown, PA in 1996 (Hoebeke and Carter 2003) and is now detected in 40 states (Stop BMSB 2012).
- BMSB is polyphagous. Feeding by BMSB cause fruit (e.g., apples and pears) malformation, discoloration, pitting and scaring. In its native range of eastern Asia, BMSB is also a pest of soybeans. In all its distribution range, BMSB becomes a nuisance pest that enters houses to overwinter.
- There are no confirmed reports of ornamental plants in southern U.S. nurseries by BMSB. In the mid-Atlantic states where BMSB have caused significant damage, the pest is observed to feed on fruit

trees in urban landscape, as well as butterfly-bush (*Buddleia* sp.) and the princess tree (*Paulownia tomentosa*) (Hoebeker and Carter 2003, Bernon et al. 2004). 56 genera and more than 80 ornamental plant species are known hosts of BMSB (Shrewsbury et al. 2011).

- The presence of BMSB may be considered a nuisance.

#### **Life Cycle:**

- BMSB overwinters as adults and generally emerge in early spring to mate. After multiple mating, a female BMSB produces as many as 400 eggs in her lifetime. Eggs are deposited in clusters of 20-30 eggs in June to September.
- Eggs hatch after 4-5 days and the nymphs disperse from the egg cluster to feed on fruits, buds and seedpods. The nymphs develop through 5 instars before becoming adults. There is only one generation per year.

#### **Control Measures:**

##### **Monitoring:**

- BMSB may be monitored with black pyramid traps baited with commercial stink bug lures. The use of commercial stink bug lure necessitate the identification of different stink bug species that are attracted to the general lure. Pheromone lure specific to BMSB is currently under evaluation.
- Stink bugs are attracted to white, blue and black light. Light trap designed specifically to monitor BMSB activity is currently under development.

##### **Cultural/Mechanical:**

- No viable cultural or mechanical control option available at the moment.

##### **Biological:**

- Several parasitoid species (including *Trissolcus* spp.) and entomopathogenic fungi (e.g., *Ophiocordyceps* sp.) are currently evaluation. No viable biological control option is currently available.

##### **Chemical:**

- Insecticide applications should target both adults and nymphs.
- No insecticide is currently labeled for stink bug (general) management in ornamental nurseries. Research conducted in PA and VA reported good efficacy with applications of acephate, acetamiprid, bifenthrin, chlorpyrifos, cypermethrin, domethoate, endosulfan, malathion,

methidation, methomyl, pemethrin and combinations of pyrethroids and neonicotinoids (Wainwright-Evans and Palmer 2011).

**State/Local Regulations:**

- None

**Critical Issues & Needs:**

- Identify ornamental plant species susceptible to BMSB infestation and damage.
- Assess risk of, and quantity damage by, BMSB on ornamental and shade trees/plants.
- Develop and evaluate chemical control options for BMSB.

*Caterpillars (Lepidoptera)*

Bagworm, *Thyridopteryx ephemeraeformis* (Haworth); Eastern tent caterpillar, *Malacosoma americanum* (Fabricius); Maple shoot borer, *Proteoteras aesculana* (Riley); Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock); European pepper moth, *Duponchelia fovealis* (Zeller); etc.

**Host Name:**

- Bagworm feeds on a total of 128 plant species. Preferred hosts of bagworm include *Acer*, *Aesculus*, *Juniper*, *Platanus*, *Robinia*, *Thuja* and *Ulmus*.
- Eastern tent caterpillars feed on *Prunus*, *Malus*, and occasionally on *Acer*, *Betula*, *Nyssa*, *Fraxinus*, *Hamamelis*, *Populus*, *Salix*, and *Quercus*.
- Nantucket pine tip moth is a pest of all two- and three-needle pines except slash pine and long-leaf pine.
- Maple shoot borer is a pest of maple, especially *Acer rubrum* and *Acer x freemanii*.

**Distribution, Damage and Importance:**

- All caterpillars species mentioned above are widely distributed in the eastern United States.
- There are many caterpillar species (Order Lepidoptera: moths, butterflies, skippers) that attack ornamental plants in nurseries. Leaf-feeding caterpillars include leafminers, leaf tiers, leafrollers, and defoliators. While leaf feeding is most commonly attributed to caterpillars, there are also many common species that bore into shoots, trunks and roots.

- The larvae of Nantucket pine tip moth tunnel into buds and shoots. They can cause up to 12 inches of dieback, which turns needles reddish. The maple shoot moth bores into the new shoot growth in the spring and causes die-back. Since maples have opposite branching, the die-back of the new shoot will cause an undesirable forked leader.

### **Life Cycle:**

- Eggs are laid singly or in egg masses depending on the species. Several (usually 4-5) larval instars (stages) occur followed by the pupal and adult stages. Some late instar larvae spin a silken cocoon just prior to pupation, which is often attached to foliage, bark, plant debris on the ground or within an earthen cell in the soil. The pupae of many species lack a silken cocoon.
- Some species, such as bagworm and eastern tent caterpillar, overwinter in the egg stage. Many others overwinter as pupae with or without a cocoon. Others overwinter as adults in protected locations such as beneath tree bark.
- Some, such as bagworm and eastern tent caterpillar, have one generation per year. Others, such as fall webworm, have multiple generations in the South.

### **Control Measures:**

#### **Monitoring:**

- The goal of monitoring is to detect the damaging stages and make control decisions before significant defoliation has occurred.
- Pheromone traps can be used in conjunction with degree-day models to better time insecticide applications.
- Larval stages are best controlled soon after egg hatch when they are still small and before much feeding damage has occurred.
- Visually inspect foliage.

#### **Cultural/Mechanical:**

- Resistant cultivars are not known.

- Managing plant stress and mechanical trunk damage are important cultural factors in preventing infestations by clearwing borers and many other wood-boring insects.
- Some damage from Nantucket pine tip moth can be removed by pruning of Christmas trees.

**Biological:**

- Some level of predation and parasitism occurs in commercial nurseries although this predation generally does not control pest species once outbreaks occur.
- Predators include lady beetles, lacewings, predacious bugs, and spiders.
- *Bacillus thuringiensis* (Bt), *Beauveria bassiana* and *Isaria formosorosea* are most effective against small larvae.

**Chemical:**

- Since insecticides are most effective on the first and second instar larvae, insecticide applications made just prior to egg hatch are the most effective for controlling larvae. This is especially critical for clearwing borers and many other wood-boring insects. This type of precise timing requires regular field scouting or trapping.
- Most insecticide applications are made after larval feeding has caused noticeable feeding damage.
- Insecticides used in the nursery for caterpillars include:

Chemical Class	Common Name
Organophosphate	acephate, chlorpyrifos
Carbamate	carbaryl
Microbial	<i>Bacillus thuringiensis</i> (Bt), subspecies <i>aizawai</i> and <i>kurstaki</i> ; <i>Beauveria bassiana</i> ; <i>Isaria formosorosea</i>
Spinosyn	spinosad
Chemical Class	Common Name
Benzoylureas	novaluron
Diacylhydrazines	tebufenozide
Pyrethroids	bifenthrin, cyfluthrin, $\lambda$ -cyhalothrin, deltamethrin, fenpropathrin, tau-fluvalinate, permethrin, pyrethrin
Avermectins	abamectin

**Federal/State/Local Regulations:**

- None noted.

**Critical Needs:**

- Evaluate resistant plant species or cultivars.

*European Pepper Moth*

**Species:** *Duponchelia fovealis* (Zeller)

**Host Plants:** European pepper moth (EPM) larvae are an emerging pest of cut flowers, vegetables, aquatic plants, *Lisanthus*, strawberries, and Chrysanthemum sp. foliage, as well as injury reported to

leaves and new stem growth of blackberry, pomegranate, roses, rhododendrons, and elm woody host plants

### **Distribution, Damage and Importance:**

- European pepper moth is native to fresh and saltwater marshlands of southern Europe, the eastern Mediterranean region, and north Africa (Syria and Algeria). It has spread across Europe, into the United Kingdom, Canada, and the U.S. In the U.S., European pepper moth has been reported from AL, AZ, CA, CO, FL, GA, MS, NC, NY, OK, OR, SC, TN, TX and WA
- EPM larvae feed on roots, leaves, flowers, buds, and fruit and may tunnel into stem and fruit tissues as the larvae mature.
- EPM are strong fliers (exceeding 100 km/62 mi) and can also be dispersed on infected plant material, as well as infested soil and potting substrates.

### **Life Cycle:**

- At 68F/20C, EPM eggs hatch in 4-9 d. Larvae mature in 3-4 wk. Pupation lasts 1-2 wk and adults survive 1-2wk. Females can lay up to 200 eggs. In greenhouses, 8-9 generations of EPM per year have been recorded.
- EPM is primarily a greenhouse pest. Its ability to overwinter outdoors in USDA Plant Hardiness Zones 7 and 8 undetermined.

### **Control Measures**

**Monitoring:** Adult European pepper moths are nocturnal and during daytime, they rest beneath sheltered vegetation and on the outsides of containers. When disturbed, adults drop to the ground or make short, irregular flights. Light trapping and sticky traps with pheromone lures are available and effective for detecting adults. Larvae spin feeding tunnels of webbing across substrate surfaces. Larvae may be found feeding on lower portions of foliage and on stems at the crown, using protected locations beneath leaf litter. Later instar larvae may feed within stems causing wilt and stem collapse. Secondary fungal pathogens, including *Botrytis*, are common.

**Biological:** Larvae may be controlled using *Bacillus thuringiensis* (Bt) and entomopathogenic nematodes (*Heterorhabditis bacteriophora* and *Steinernema* sp.). Predatory mites including *Gaeolaelaps aculeifer* (= *Hypoaspis*) and *Stratiolaelaps scimitus* (sold as *Hypoaspis miles*), and

Trichogrammatidae (*Trichogramma evanescens*, *T. cacoeciae*, and *T. brassicae*) parasitoid wasps are available to control the egg stage.

**Chemical:** European pepper moth has been controlled with acephate, azadirachtin, bifenthrin, chlorantraniliprole, deltamethrin, ethoprop, emamectin, esfenvalerate, fluvalinate, lambda-cyhalothrin, orthene, permethrin, spinosad and growers need to confirm label registration of these products on the specific crop and site where infestation occurs. Larvae may burrow into fruits, and can form protective webbing within leaves and in soil. Targeted sprays are likely to be more effective than broadcast treatments.

**State/Local Regulations:** EPM regulatory status remains under review

**Critical Issues & Needs:**

- Survey detection for information on spread/current status of EPM in the U.S. Greater awareness needed of EPM among growers and growers state desire for resources that facilitate scouting, monitoring and ID efforts.
- Research needed to determine cold hardiness capability of EPM in USDA PHZ 7-8.

## *Flea beetles and leaf beetles (Coleoptera: Chrysomelidae)*

### **Common Species:**

Redheaded flea beetle, *Systema frontalis* (F.); Apple flea beetle, *Altica foliacea* (LeConte); Grape flea beetle, *Altica chalybea* Illiger; *Altica litigata* Fall; Cranberry rootworm, *Rhabdopterus picipes* (Olivier); Strawberry rootworm, *Paria fragariae* Wilcox; *Colaspis pseudofavosa* Riley; Elm leaf beetle, *Pyrrhalta luteola* (Müller); Larger elm leaf beetle, *Monocesta coryli* (Say); Imported willow leaf beetle, *Plagioderma versicolora* (Laicharting); Cottonwood leaf beetle, *Chrysomela scripta* Fabricius; and *Chrysomela interrupta* Fabricius.

### **Host Plants:**

- Redheaded flea beetles feed on foliage of many ornamental plant species, including *Abelia*, *Hydrangea*, *Ilex*, *Itea*, *Rosa*, *Vaccinium*, among others.
- Apple flea beetle adults feed on the foliage of *Malus*, *Rosa*, *Salix*, and *Vitis*. *Altica litigata* is a foliage feeder on *Lagerstroemia*.
- Grape flea beetle feeds on *Vitis*, *Malus*, *Fagus*, *Ulmus*, and *Prunus*.
- Cranberry rootworm adults feed on *Camellia*, *Photinia*, *Rhododendron*, and other shrubs.
- Strawberry rootworm adults feed on *Vaccinium* and *Rhododendron*.
- *Colaspis pseudofavosa* feed primarily on azalea and *Photinia* spp.
- Elm leaf beetles and larger elm leaf beetles feed on elm foliage.
- Imported willow leaf beetles feed on *Salix*, *Populus nigra* 'Italica', and *Populus deltoides*.
- Cottonwood leaf beetles feed on *Populus deltoides* and *Populus alba*.
- *Chrysomela interrupta* larvae and adults prefer willow but also feed on poplar and alder.

### **Distribution, Damage and Importance:**

- Most flea beetles and leaf beetles mentioned herein are widely distributed in the South.
- Redheaded flea beetles are becoming a significant pest in many nurseries in the South and Northeast. Adults feed on the foliage, creating shot holes throughout the tissues. Larvae feed on the roots and

underground stems. Focus group attendees recognized the seasonal nature of damage by this pest compared to borers by stating that beetles delay seasonal sales until a new growth flush or hand pruning occurs (2.0; Table 3), whereas borers cause unlikely seasonal sales, crop leaf drop & protection of new leaves (3.3; Table 3).

- Apple flea beetle adults and larvae feed on foliage.
- Grape flea beetle adults of the first generation tunnel in the buds while leaves are skeletonized by larvae later in the season.
- Cranberry rootworm adults are nocturnal feeders on emerging foliage. This feeding causes elongated or crescent-shaped holes in mature leaves.
- Strawberry rootworm adults are nocturnal feeders that can riddle the foliage.
- Elm leaf beetle adults chew circular holes in the leaf while the larvae skeletonize the underside of the leaf.
- Larger elm leaf beetle is less damaging than the elm leaf beetle.
- Imported willow leaf beetle larvae skeletonize the underside of leaves while adults chew small holes in leaves.
- Cottonwood leaf beetle and *Chrysomela interrupta* larvae skeletonize and chew holes in leaves. The adults feed on young twigs and skeletonize leaves but to a lesser extent than the larvae.
- The larvae of *Colaspis pseudofavosa* are root feeders, and adults can be found feeding on the foliage of host plants year-round in Florida.

#### **Life Cycle:**

- Because of the diverse groups of flea beetles and leaf beetles, generalization of their life cycles is difficult. The larvae of some species such as cranberry rootworm feed on roots, although the more damaging stage is the adult stage that feeds on the foliage. Both the larvae and adults of most of the listed species feed on the foliage.
- Examples of a leaf beetle life cycle follow:

- Redheaded flea beetles likely overwinter as eggs in the soil. Larvae hatch in the spring and pupate in the soil. Adults emerge from the soil from May to August; many move into the production areas from the surrounding weeds. As many as three generations are reported in New Jersey.
- Imported willow leaf beetles hibernate on the tree trunk in protected places such as under loose bark. The adults move to the opening buds in the spring to feed. Masses of shiny yellow eggs are laid on the underside of leaves. The eggs hatch in a few days. The black larvae feed on the leaves for 3-4 weeks. The yellowish brown pupae molt into adults after a short time. The adults are small, oval-shaped shiny black to greenish blue beetles. There are usually four generations per year in the South.
- The cottonwood leaf beetle has four or more generations in the South.

**Control Measures:**

**Monitoring:**

- The goal of monitoring is to detect the damaging stages and make control decisions before significant defoliation has occurred.
- Larval stages are best controlled soon after egg hatch when they are still small and before much feeding damage has occurred.
- Control of adults will reduce their feeding damage and egg production. Consequently, fewer of the potentially more damaging larvae will be produced.
- Visually inspect foliage on a 10-day schedule.
- Redheaded flea beetle activity can be monitored with growing degree-days (GDDs) and plant phenological indicators. In Delaware, larval activity begins around 260-480 GDD (base temperature of 50°F), and when black locust trees are in bloom. Adult activity begins at 590-785 GDDs and when winterberry holly is in bloom.

**Biological:**

- Some level of predation and parasitism occurs in commercial nurseries, although this predation generally does not control pest species once outbreaks occur.

- Predators include lady beetles, lacewings, predacious bugs, and spiders. The chalcidoid wasp, *Schizonotus seiboldi*, is a very effective parasitoid of imported willow leaf beetle pupae.
- The use of broad-spectrum insecticides can kill beneficial predators and parasitoids which can lead to pest resurgence.

**Cultural/Mechanical:**

- Resistant plants are not known.
- Removal of plant debris may help to reduce pupation or overwintering sites.

**Chemical:**

- Insecticide applications to the foliage may target either adults or larvae of most species.
- Targeting adults early in the season will reduce egg lay and subsequent larvae.
- Insecticides used in the nursery against flea beetles include:

Chemical Class	Common Name
Organophosphates	chlorpyrifos
Carbamates	carbaryl
Microbial	<i>Beauveria bassiana</i> ; <i>Isaria formosorosea</i>
Pyrethroids	bifenthrin, cyfluthrin, $\lambda$ -cyhalothrin, deltamethrin, fenpropathrin, tau-fluvalinate, permethrin, pyrethrin
Neonicotinoids	acetamiprid, dinotefuran, imidacloprid
Spinosyn	spinosad

**Federal/State/Local Regulations:**

- None noted.

**Critical Needs:**

- Evaluate resistant plant species or cultivars.
- Better understand the life cycle of various species (particularly overwintering ecology of the redheaded flea beetle) to develop the most effective monitoring and management tools and to identify the most efficacious application timing in the southern US.
- Determine the dispersal of adults from weeds to ornamental plants.

*Granulate Ambrosia Beetle***Species:**

*Xylosandrus crassiusculus* (Motschulsky); occasionally *Xylosandrus germanus* (Blandford) and *Cnestus mutilatus* (Blandford)

**Host Plants:**

The granulate ambrosia beetle attacks 124 plant species. Common hosts in the Southern region: *Acer palmatum*, *Acer rubrum*, *Carya illinoensis*, *Cercis canadensis*, *Cladrastis lutea*, *Cornus*, *Diospyros virginiana*, *Lagerstroemia*, *Liquidambar*, *Magnolia*, *Prunus*, *Pyrus calleryana* 'Bradford', *Quercus*, *Styrax*, *Ulmus parvifolia*, *Zelkova*, etc.

**Distribution, Damage & Importance:**

- Introduced to South Carolina in the early 1970s.
- Reported distribution in the US: AL, DE, FL, GA, HI, IN, KS, KY, LA, MD, MS, NC, OR, SC, TN, TX, VA.
- Also in Africa, Asia, and the Pacific Islands.
- Primary damage to the trees is not by the beetle tunneling inside the wood but by the ambrosia fungi introduced by the beetles.
- Fungi block the vascular system and cause tree death.

- Death caused by the fungi introduced by first generation usually occurs before bud-break. It is often believed that the second generation does not contribute to tree death but recent reports have suggested otherwise.
- Camphor shoot borer (*C. mutilatus*) is noted to cause damage on larger trees in GA, SC and TN, as well as B&B in TN. Damage is restricted to some smaller branches (< 1 cm in diameter) on the top of canopy, causing canopy wilt.

### **Life Cycle:**

- There are two generations in the South. The first generation begins with the flight of adult beetles from surrounding woods into the nursery. Flight usually begins in February and peaks in April and June. The offspring of the first generation emerge in June to August.
- Adults bore into the thin barked, deciduous trees and produce tell-tale frass tubes. Frass tubes are often dislodged by rain or wind. The adults create galleries in the heart wood and reproduce.
- Both the adults and larvae feed on introduced ambrosia fungi.
- It takes about 55 days to complete one generation in middle Tennessee (Oliver and Mannion, 2001).

### **Control Measures:**

#### **Monitoring:**

- The goal of monitoring is to pinpoint the timing of adult emergence in late winter and early spring.
- Adult flight can be monitored with ethanol-baited traps. The traps can be purchased from commercial sources or made by growers using soda bottles.
- Attacked trees are indicated by the frass tubes and oozing sap from boring holes.

#### **Cultural/Mechanical:**

- Growers are often advised to retain infested trees in the nursery for 3-4 weeks to act as a magnet for flying beetles. Afterward, all attacked trees should be destroyed and discarded.

#### **Biological:**

- None noted.

**Chemical:**

- There is currently no control for the ambrosia fungi.
- Current management programs use a pyrethroid on susceptible hosts (*Acer*, *Prunus*, *Ulmus*, *Zelkova*, etc.) to repel and prevent adult beetles from boring into the trees. This can be done as soon as the spring flight is detected with ethanol traps.
- Because of rapid degradation of the insecticides in the field, reapplication every 10-14 days may be needed until the trees flush out.
- Once inside the wood, no insecticides (including the systemic neonicotinoids) are known to have any effect on the adults and larvae.
- Chemicals used in the nurseries:

Chemical Class	Common Name
Pyrethroids	bifenthrin, permethrin

**Federal/State/Local Regulations:**

- None.

**Critical Issues & Needs:**

- Improve prediction of adult flight across the South using growing degree-days or plant phenological indicators.
- Better understand the factors associated with cultural practices or plant health that influence plant susceptibility to the ambrosia beetle.
- Improve the residual longevity of bifenthrin and permethrin.
- Determine if surfactants or other spray additives increase pesticide residual and efficacy on bark.
- Explore the potential of systemic insecticides in killing adults and larvae and fungicides in killing fungi once they are in the wood.
- Make biological and management information and guidelines more readily available.

## *Kudzu Bug, Bean Plataspid*

**Species:** *Megacopta cribraria* (F.)

**Host Plants:** Numerous ornamental plants are resting or feeding hosts for the kudzu bug. Kudzu and soybean are its two main hosts. Few ornamental plants serve as known reproductive hosts at the present time. Wisteria can support growth and development of kudzu bug.

**Distribution, Damage and Importance:** Asian in origin, and found in Georgia in 2009, the kudzu bug is now reported as established in seven states in the southeastern U.S.

**Life Cycle:** Kudzu bug overwinters as an adult and emerges in the spring. Adult females lay eggs that hatch and develop through five nymphal instars. Development from egg to adult may take 6-8 weeks. They feed extensively on kudzu and other leguminous hosts. In summer adults move into bean fields where they continue to lay eggs and develop. Adults become active again in the fall as they seek overwintering sites. They can be a tremendous nuisance pest on buildings, vehicles, etc.

### **Control Measures.**

**Monitoring:** Adults are about ½ inch long, olive green/brown with spots. They can be directly observed in large congregation on plant, stems and new shoots. They can be sampled with a sweep net, but are readily observed by direct visual examination. There are no thresholds for ornamental plants.

**Biological:** There are some generalist predators, assassin bugs, etc. *Beauveria bassiana* attacks the kudzu bug. A parasitoid has been reported attacking the eggs in several states.

**Chemical:** Pyrethroid insecticides have been effective.

**Critical Issues & Needs:** Little is known about the potential impact on native ornamental plants in the same host family such as red bud, yellowwood, etc. Damage impact relations as well as control measures need to be understood.

## Leafhoppers (*Homoptera: Cicadellidae*)

### Common Species:

Potato leafhopper, *Empoasca fabae* (Harris); White apple leafhopper, *Typhlocyba pomaria* McAtee; Rose leafhopper, *Edwardsiana rosae* (Linnaeus)

### Host Name:

- While potato leafhoppers are primarily a pest of *Acer* (especially *Acer rubrum*), they also feed on *Betula*, *Castanea*, *Juglan regia*, and *Malus*.
- White apple leafhopper is a pest of *Craetegus*, *Malus*, *Prunus*, and *Rosa*.

### Distribution, Damage and Importance:

- Potato leafhopper, white apple leafhopper, and rose leafhopper are widely distributed in the US and Canada.
- Potato leafhoppers inject toxins and cause mechanical damage to the vascular tissue of the plant while feeding. The result is a downward curling and browning of the edge of the leaves called hopperburn. Stunting of shoot growth and a reduced survival rate for shoots also occurs.
- White apple leafhopper feeding causes tiny white spots on the leaves. They deposit spots of excrement that turn dark brown (tarspots) on the underside of the leaf.

### Life Cycle:

- Potato leafhoppers overwinter in the Gulf Coast states and fly north in the spring on prevailing winds.
- Most leafhopper species lay their eggs in slits they make in the underside of leaves or in the leaf petiole. The nymphs have five instars, and six or more generations occur in the South.

### Control Measures:

#### Monitoring:

- The goal of monitoring is to detect the damaging stages and make control decisions before significant defoliation has occurred.

- Very little feeding is required for hopperburn (two adults per leaf) to occur, so the action threshold can be as low as one adult (Chris Ranger, personal communication).
- Larval stages are best controlled soon after egg hatch when they are still small and before much feeding damage has occurred.
- Control of adults will reduce their feeding damage and egg production. Consequently, fewer of the potentially more damaging larvae will be produced.
- Make visual inspections of foliage. Note that potato leafhopper nymphs walk sideways while the white apple leafhopper nymphs walk to the front or backward.

**Biological:**

- Some level of predation, parasitism, or entomopathogenic fungi occurs in the commercial nursery although this predation generally does not control pest species once outbreaks occur.
- Predators include lacewings, predacious bugs, and spiders.
- The wasp egg parasitoid, *Anagrus armatus* (Ashmead), can be a very effective natural control of rose leafhopper populations.
- The use of broad-spectrum insecticides can kill beneficial predators and parasitoids, which can lead to pest resurgence.

**Cultural/Mechanical:**

- Resistant plants are unknown.

**Chemical:**

- Insecticide applications to the foliage may target either adults or larvae of most species.
- Targeting adults early in the season will reduce egg lay and subsequent larvae.
- Insecticide resistance to organophosphate insecticides has been documented in apple orchards.

- Insecticides used in the nursery for leafhoppers include:

Chemical Class	Common Name
Organophosphate	acephate, chlorpyrifos
Carbamate	carbaryl
Neonicotinoid	acetamiprid, dinotefuran, imidacloprid, thiamethoxam
Pyrethroid	bifenthrin, cyfluthrin, $\lambda$ -cyhalothrin, deltamethrin, fenpropathrin, tau-fluvalinate, permethrin, pyrethrin
Buprofezin	buprofezin
Tetramic acid derivatives	spirotetramat
Azadirachtin	azadirachtin
Entomopathogenic fungi	<i>Beauveria bassiana</i> , <i>Isaria formosarosea</i>

#### **Federal/State/Local Regulations:**

- None noted.

#### **Critical Needs:**

- Evaluate resistant plant species or cultivars.
- Develop integrated pesticide protocols that target leafhoppers without causing mite outbreaks.

#### *Mites*

##### **Common Species:**

##### **Spider mites (Tetranychidae):**

Twospotted spider mite, *Tetranychus urticae* (Koch); European red mite, *Panonychus ulmi* (Koch);

Spruce spider mite, *Oligonychus ununguis* (Jacobi); Southern red mite, *Oligonychus illicis* (McGregor);

Maple spider mite, *Oligonychus aceris* (Shimer).

### **Eriophyid mites (Eriophyidae):**

There are many eriophyid mite species, many of which are not named. Eriophyid mites are often referred to by the type of damage they cause, such as blister mites, rust mites, gall mites, and bud mites. Many also lack common names. *Phyllacoptes fructiphylus* vectors rose rosette virus that cause rose rosette disease; Hemlock rust mite, *Nalepella tsugifoliae* (Keifer); *Vasates aceriscrumena* (Riley) produces maple spindle gall; *Vasates quadripedes* (Shimer) produces maple bladder galls; *Phytoptus emarginated* (Keifer) produces a green pouch gall on *Prunus* spp.; *Eriophyes parulmi* (Keifer) produces spindle galls on *Ulmus* spp. Similar galls caused by eriophyid mites occur on *Fagus*, *Populus*, *Prunus*, and *Tilia*.

### **Thread-footed mites (Tarsonemidae):**

Historically, the cyclamen mite [*Phytonemus pallidus* (Banks)] and broad mite [*Polyphagotarsonemus latus* (Banks)] are pests of greenhouse-grown ornamental plants. Recently, infestations of woody ornamental plants in outdoor production by broad mite have been reported in TN.

### **Host Plants:**

- Many species of trees and woody ornamentals are attacked by spider mites, broad mite and eriophyid mites of one type or another.
- Twospotted spider mites are generalist feeders that are widely distributed in the United States and feed on over 180 host plants, including over 100 cultivated species.
- Southern red mites feed on evergreen broadleaf plants such as *Camellia*, *Ilex crenata*, *Rhododendron*, and many plants in Ericaceae and Aquifoliaceae.
- Spruce spider mites feed on most coniferous evergreens such as *Juniper*, *Picea*, and *Thuja*.
- Maple spider mites feed heavily on *Acer* in nurseries.
- Most plant species are susceptible to at least one species of eriophyid mite.
- Broad mite attacks a wide range of plant species. Species most impacted in TN include *Cryptomeria* and *Viburnum*.

### **Distribution, Damage and Importance:**

- Most of the common species have a cosmopolitan distribution in the Southeast.
- Mites have piercing mouthparts they use to suck the contents out of cells.
- Many mites prefer the undersides of leaves.

- Infested leaves have a stippled appearance where chlorophyll has been removed from cells.
- Spider mites also cover the underside of leaves with silk webbing, shed skins, eggs, and feces which is cosmetically unpleasing.
- Eriophyid mites produce many types of damage to leaves and buds, in particular: blisters, rust, galls, and bud deformation.
- Broad mites cause permanent brittle-like deformation on growing buds, flowers and leaves.
- Spider mites are important because they are among the most damaging arthropod pests of nurseries. They are also difficult to control and detect which contributes to the extent of their damage.

### **Life Cycle:**

- The life cycles vary by family and species.
- Twospotted spider mites have many generations per year and thrive in hot weather.
- From egg hatch to the adult stage takes only 5 days. Adult females live 2-4 weeks and produce 100-300 eggs. They overwinter as females in leaf litter or under bark.
- Spruce and Southern red mites have several generations per year and are active in the spring and fall but are dormant as eggs in the summer. They overwinter as eggs.
- Maple spider mites overwinter as eggs on the trees and have many generations throughout the spring and summer.
- Eriophyid mites have many different life history strategies.
- Broad mites complete development in 4-6 days and each female produces about 20 eggs.

### **Control Measures:**

#### **Monitoring:**

- Inspect foliage and buds of plants that show the stippling or deformation symptoms with handlens. Because of their small sizes, handlens or microscopes of higher power may be needed to inspect eriophyid mites.
- Tap leaves and branches sharply to dislodge mites onto a piece of white paper placed under the leaves or branches. Examine the paper for mites.

#### **Cultural/Mechanical:**

- The most important cultural control tactic is to maintain and promote healthy plants through proper cultural practices.

- Plant stress from drought or other abiotic sources can make plants more susceptible to mites by reducing plant defenses.
- Fertilizer, particularly nitrogen, makes plants more nutritious for mites.
- Resistant varieties can be used to reduce mite damage. Maple taxa resistant to maple spider mites have been reported (Seagraves, 2006)

**Biological:**

- Mites are eaten by many natural enemies present in the nursery such as predatory mites (Phytoseiidae), lady beetles, minute pirate bugs, lacewings, and others.
- Phytoseiid mites are available to purchase as an augmentative biological control agent, although efficacy is unpredictable.
- It is important not to kill endemic natural enemies with insecticide applications because this causes mite outbreaks.

**Chemical:**

- Mites can be managed with a number of insecticides and miticides.
- Miticides used in nurseries include:

Chemicals Class	Common Name
Carbamates	carbaryl
Pyrethroids	bifenthrin, $\lambda$ -cyhalothrin, deltamethrin, fenpropathrin, tau-fluvalinate
Spinosyns	spinosad
Avermectins, Milbemycins	abamectin, milbemectin
Clofentezine, Hexythiazox	clofentezine, hexythiazox
Etoxazole	etoxazole
Organotin miticides	fenbutatin-oxide

Chemicals Class	Common Name
METI acaricides	fenazaquin, fenpyroximate, pyridaben
Tetronic and tetranic acid derivatives	spiromesifen, spirotetramat
Beta-ketonitrile derivatives	cyflumetofen
Bifenazate	bifenazate
Horticultural oil and neem oil	
Insecticidal soap	
Entomopathogenic fungi	<i>Beauveria bassiana</i> , <i>Isaria formosarosea</i>

### **Federal/State/Local Regulations and Pesticide Restrictions:**

- None.

### **Critical Issues and Needs:**

- Biology and management of rose rosette-associated disease and its eriophyid mite vector.
- Biology and management of eriophyid mites on *Echinacea*, rose, hydrangea, *Ligustrum*, and juniper.
- Biology and management options for broad mite on woody ornamental plants.
- Better understanding of life histories of mites is important for effective management.
- Plant phenology and other tools for monitoring and predicting mite activity.
- Action thresholds are needed to help growers know when to treat. Thresholds should include natural enemy activity and pest activity.
- Compare efficacy of older products to newer ones that have lower vertebrate toxicity and less negative impact on natural enemies.
- Impact of insecticides on mite population dynamics, resurgence, and outbreaks due to hormoligosis, i.e., favorable effects of pesticides on arthropod physiology and behavior and effects on natural enemies.
- Impact of mite management practices on other pests and vice versa.
- Research to manage mites as part of a pest complex that is affected and can be affected by management of other pests, diseases, and management tactics.
- Research on the effect of plant cultural practices such as fertilization and watering on mite populations.

### *Red Imported Fire Ant (RIFA)*

#### **Species:**

*Solenopsis invicta* Buren

#### **Distribution, Damage & Importance:**

- Introduced into the United States in the 1930's near Mobile, AL.

- RIFA infestations are confirmed and quarantined in the following states/territories: AL, AR, CA, FL, GA, LA, MS, NC, NM, OK, PR, SC, TN and TX. Infestations have also been reported in VA (USDA, 2009).
- A significant quarantined pest of ornamental plants and turfgrass.
- Painful stings pose human and veterinarian health hazards and a liability to growers.
- Infestations in utility facilities can cause damage to equipment.

### **Life Cycle:**

- An average colony contains 100,000 to 500,000 workers. Winged individuals (the reproductive form) emerge after a rainy period.
- Queens can live for 7 or more years and produce 800 to 1,000 eggs per day.
- Larvae develop in 6-10 days and then pupate. Adults emerge 9-15 days after pupation. Workers typically live 5-8 weeks.
- Sexually reproductive hybrid imported fire ants (hybrids of the red and black species) occur in some parts of the country.
- Colonies can be single-queen (monogyne) or multiple-queen (polygyne) forms.
- Colonies frequently migrate from one site to another depending on the environmental conditions and food availability.

### **Control Measures:**

#### **Cultural/Mechanical:**

- Proactive prevention of colony establishment using chemicals is recommended.
- Removal of food sources, such as trash cans and aphids, also help to reduce invasion or attraction of foraging ants.

#### **Biological:**

- Biological control agents, such as the ant decapitating flies, *Pseudacteon* spp. (Phoridae), and the microsporidian pathogen, *Kneallhazia solenopsae*, are under evaluation.

**Chemical:**

- Due to quarantine requirements for field-grown and container nurseries, insecticides applied as topical granule or baits, container substrate mix granules, immersion, or container substrate drenches are currently the only options.
- Applications are often aimed at prevention immediately before planting or curative treatment before shipment.
- Nursery production should follow USDA-APHIS guidelines on RIFA quarantine treatments (USDA, 2007, USDA-APHIS, 2009):
- Insecticides used against red imported fire ants in nursery:

<b>Chemical class</b>	<b>Common Name</b>
Organophosphates	acephate, chlorpyrifos
Pyrethroids	bifenthrin, $\lambda$ -cyhalothrin, deltamethrin, tau-fluvalinate, permethrin, pyrethrin
Neonicotinoids	thiamethoxam
Spinosyns	spinosad
Juvenile hormone mimics	s-methoprene, fenoxycarb, pyriproxyfen
Hydramethylnon	hydramethylnon
Metaflumizone	metaflumizone

**State/Local Regulations:**

- RIFA is under state and federal quarantine. See the list under 'Distribution' for the states currently under quarantine.

**Critical Issues & Needs:**

- Increase residual control or longevity of chemicals applied.
- Understand how RIFA treatments affect natural enemies, other non-targets, and pests.
- Develop alternative application method to drench and medium incorporation.

## Scale Insects

### Common Species:

**Armored scales** (Diaspididae, 261 species in the South): False oleander scale, *Pseudaulacaspis cockerelli* (Cooley), formerly known as magnolia white scale; Tea scale, *Fiorinia theae* (Green); Obscure scale, *Melanaspis obscura* (Comstock); Gloomy scale, *Melanaspis tenebricosa* (Comstock); Euonymus scale, *Unaspis euonymi* (Comstock), etc.

**Soft scales** (Coccidae, 65 species in the South): Wax scales (*Ceroplastes* spp.); Oak lecanium scale, *Parthenolecanium quercifex* (Fitch); Calico scale, *Eulecanium cerasorum* (Cockerell); hemispherical scale, *Saissetia coffeae* (Walker); brown soft scale, *Coccus hesperidum* L.; Cottony maple scale *Pulvinaria innumerabilis* (Rathvon); etc.

**Felt scales** (Eriococcidae): Crape myrtle bark scale, *Eriococcus lagerstroemiae* Kuwana; azalea bark scale, *Eriococcus azaleas* Comstock

### Host Plants:

- Scale insects can infest virtually all woody and herbaceous ornamental plants grown in nurseries.
- Some of the most commonly infested plants are *Acer*, *Camellia*, *Euonymus*, *Ilex*, *Magnolia*, *Quercus* and *Pinus*.
- Crape myrtle bark scale is known to infest at least 18 species in 13 families. In the US, this species only infests *Lagerstroemia* spp.

### Distribution, Damage and Importance:

- Most of the common species have a cosmopolitan distribution.
- Trades of horticultural crops have facilitated the spread of some scale insect and mealybug species.
- All scale insects feed by sucking plant sap from vascular tissue or contents from individual cells through a modified, straw-like mouthpart.
- Long-term feeding can significantly weaken the plants and cause dieback on branches and eventual death of the entire plant.
- Soft scales and mealybugs, which feed on plant sap, produce copious amounts of honeydew. Honeydew forms a sticky layer on the surfaces of infested plants or structures below infested plants, and becomes an excellent medium for the growth of black sooty mold.

- The potential for scale insects to act as vectors of plant pathogens is not considered important in ornamental productions.
- As of 2013, infestations of crape myrtle bark scale are known from AR (Little Rock), LA (Shreveport, Houma), OK (Ardmore), TN (Germantown) and TX (Dallas/Ft. Worth, Tyler).

### **Life Cycle:**

- Life cycle of scale insects vary by species.
- Crape myrtle bark scale has two generations (adults appear in late April and late August) in Korea and three generations in China. Life cycle in the U.S. is not known.
- Armored scales have 4 female life stages (egg, crawler, 2<sup>nd</sup>-instar nymph, adult, sometimes with an additional nymphal instar) and 5 male life stages (an additional ‘pupal’ stage).
  - There can be 1 to 6 (or more) generations per year, depending on species and climate.
  - Overwintering of females can be accomplished by any life stage. Males generally do not overwinter as older instars.
  - Eggs generally hatch in the spring (first generation), and the crawlers disperse either passively by air movement or actively by crawling.
  - Armored scales can be either parthenogenic or obligately biparental.
  - Some species are host specific, but most pestiferous species are highly polyphagous.
- Soft scales generally have 4-5 female life stages (egg, crawler, 2<sup>nd</sup>-instar nymph, adult, with some species having an additional nymphal instar) and 6 male life stages (additional ‘pre-pupal’ and ‘pupal’ instars).
  - Most species have one annual generation.
  - Overwintering is often accomplished by late-instar nymphs on twigs or branches.
  - Eggs generally hatch in the spring. Crawlers feed on the leaves in spring and summer, molt into 2<sup>nd</sup>-instar nymphs, and move back onto the twigs to overwinter just before leaf drop. Bodies of adult females swell dramatically in early spring.
  - Many are known to be parthenogenic (although males are sometimes detected) but some are also known to be obligately biparental.

## **Control Measures:**

### **Monitoring:**

- Visual inspection in the spring is important in confirming the emergence of crawlers.
- Double-sided sticky tape wrapped around a twig can be used to trap dispersing crawlers. Inspection of the tape using handlens is needed.
- Degree-day and plant phenological models are being developed for some species. Details of the models will likely vary greatly among species.

### **Cultural/Mechanical:**

- The most important cultural control tactic is to maintain and promote the health of nursery crops through proper planting, irrigation and fertilization practices.
- Healthy shrubs and trees can better withstand and recover from scale infestations.
- Removal and immediate disposal of infested plant materials and alternative host plants in the production areas are important in preventing the introduction and spread.
- The trunk and reachable limbs on heavily infested plants in landscapes can be brushed with mild soap solution to remove female scales and egg masses. Brushing will remove some loose bark helping with dormant oil and insecticide coverage.
- Little information is available on resistant plant taxa. Some *Acer* taxa resistant to calico scale have been reported (Seagraves, 2006).

### **Biological:**

- Scale insect populations in field production are constantly under predation and parasitism. Many existing populations of parasitoids and predators attack scale insects of all stages.
- The effectiveness of biological control (conservation or augmentative) in field productions is unknown.
- Existing biological control can be disrupted by the use of broad-spectrum insecticides.
- No biological control of the crape myrtle bark scale is known.

### **Chemical:**

- Because of the cryptic nature of scale insects, infestations are often not detected until severe. Insecticides are often needed to reduce the scale insect populations.

- Scale insects have a shell composed of wax and exuviae produced by the insects. Armored scales have a covering which is not part of their body. Soft scales have a waxy coating on their integument, not removable.
- The waxy layer interferes with the penetration of most contact insecticides. Crawlers do not have such a thick waxy layer. Therefore, insecticide applications should be timed for crawler emergence.
- Addition of sticker or spreader in the insecticidal solutions can improve efficacy.
- Complete coverage of the entire plant, particularly of the branches and undersides of leaves, are essential for effective control.
- For crape myrtle bark scale, application of dormant oil to the bark and crotches of crape myrtle plants may be beneficial. Sufficient volume is needed to penetrate behind loose bark and into cracks and crevices where overwintering scales are clustered. Systemic insecticides like imidacloprid, thiomethoxam and dinotefuran, have given the best control when applied as a drench to the root zone between May and July. Soil drenches using systemic insecticides may require several weeks before the product is distributed throughout the plant.
- Chemicals used in the nurseries include the following:

<b>Chemical Class</b>	<b>Common Name</b>
Carbamates	carbaryl
Organophosphates	acephate, chlorpyrifos, dimethoate
Pyrethroids	bifenthrin, cyfluthrin, $\lambda$ -cyhalothrin, deltamethrin, fenpropathrin, pyrethrin
Neonicotinoids	acetamiprid, dinotefuran, imidacloprid, thiamethoxam
Juvenile hormone mimics	pyriproxyfen
Buprofezin	buprofezin
Tetramic acid derivatives	spirotetramat
Azadirachtin	azadirachtin
Entomopathogenic fungi	<i>Beauveria bassiana</i> , <i>Isaria formosarosea</i>
Horticultural oil and neem oil	
Insecticidal soap	

## **Federal/State/Local Regulations and Pesticide Restrictions:**

None noted.

## **Critical Issues and Needs:**

- Better understanding of life histories of scale insects is important for effective management.
- Improvement in predicting important life history events, such as the emergence of crawlers, using degree-day models or plant phenological indicators.
- Because of the variations in phenology and management strategies, training Extension personnel and growers is needed to improve monitoring and management efficiencies.
- Improvement of neonicotinoids and other insecticides in field efficacy, residual control, and reduced production, labor and material costs.
- Improvement in the use of neonicotinoids and other insecticides against scale insects feeding on the trunks or branches.
- Determine the efficacy of various surfactants in providing control.
- Assessment of the efficacy and the cost-benefit ratio of biological control and the manipulation of the field characteristics to improve the effectiveness of natural enemies.
- Determine distribution and assess risk of expanding distribution of invasive scale insect species, such as the crape myrtle bark scale.

## *Scarab and Weevil Grubs*

### **Common Species:**

#### **Scarab beetles (Scarabaeidae):**

Japanese beetle, *Popillia japonica* Newman; Oriental beetle, *Anomala orientalis* Waterhouse; more species in northern latitudes

#### **Weevils (Curculionidae):**

Black vine weevil, *Otiorhynchus sulcatus* (Fabricius)

### **Host Plants:**

- White (scarab) grubs typically attack roots of grasses. A variety of containerized nursery plants are also being attacked, e.g. *Rhododendron*, *Rosa*, and *Thuja*.

- Black vine weevil attacks more than 100 species of plants, with *Euonymus*, *Ilex crenata*, *Kalmia*, *Pieris*, *Rhododendron*, *Taxus*, and *Tsuga* being the most common hosts.

### **Distribution, Damage & Importance:**

- Japanese beetle was introduced to New Jersey in 1916. The current distribution includes much of the US east of the Mississippi River (with the exception of Florida), as well as AR, IA, KS, MN, MO, NB, OK, TX, and WI.
- Oriental beetle was introduced from Japan and first detected in Connecticut in the 1920's. This species is currently distributed from New England to OH and SC.
- Black vine weevil was introduced from Europe in the early 1900s and is currently distributed from ME to the Carolinas and west to WA and OR.
- Scarab and weevil grubs are serious pests of the roots of turfgrass and field-grown or containerized shrubs. Feeding damage on the roots reduces uptake of water and nutrients, weaken the plants, reduces plant growth, and may open wounds for the invasion of pathogens.

### **Life Cycle:**

- Because of the diverse groups of root-feeding scarab and weevil grubs, generalization of their life cycles is difficult.
- Japanese beetle, oriental beetle and black vine weevil have one annual generation.
- Adults generally emerge in late spring or early summer, depending on the species. Adults of Japanese beetle and black vine weevil will feed on foliage and flowers of host plants and produce several broods of eggs between feeding bouts. Adult Oriental beetles do not feed.
- Eggs hatch in 2-3 weeks, and the neonate feed on the root hairs.
- As the grubs mature, they will feed on larger roots and stems.
- Overwintering is typically accomplished by the late-instar grubs deeper in the soil or container substrate. Late-instar grubs will resume feeding in the early spring until pupation.

### **Control Measures:**

#### **Cultural/Mechanical:**

- Removal of adults with pheromone traps is generally considered counterproductive.

- Practices that help to reduce moisture in the container substrate or soil, such as the removal of excessive mulch, the reduction of irrigation frequency and volume and termination of irrigation during peak adult flight period, also help to reduce survival of grubs.
- Removal of grasses that may be used for grub development.
- No plant species resistant to the larval stage has been identified.

**Biological:**

- The nematodes, *Steinernema* spp. and *Heterorhabditis* spp., have been shown to be effective against scarab and weevil grubs in container nurseries when the moisture in the substrate is kept high.
- Milky spore pathogen, *Bacillus popilliae* (Dutky), has been used against Japanese beetle grubs with inconsistent results.
- Naturally occurring, native predators and parasitoids, such as species of *Tiphia* wasp that attack Japanese beetle grubs, are active in the field but their efficacy in nurseries is unknown.

**Chemical:**

- Management of grubs is more effective when the grubs are still in the early developmental stages.
- Chemicals used in the nurseries include (National Plant Board, 2009):

Chemical Class	Common Name
<i>Dip treatment for B&amp;B and container plants:</i>	
Organophosphate	chlorpyrifos
Pyrethroid	bifenthrin
<i>Drench treatment for container plants:</i>	
Pyrethroid	bifenthrin
Neonicotinoid	imidacloprid, thiamethoxam

<i>Media incorporation for container plants:</i>	
Pyrethroid	bifenthrin, tefluthrin
Neonicotinoid	imidacloprid
<i>Methyl bromide fumigation:</i>	
Methyl bromide	
<i>Pre-harvest soil surface treatment:</i>	
Neonicotinoid	imidacloprid, imidacloprid+cyfluthrin, thiamethoxam

**State/local Regulations:**

- Federal quarantine for Japanese beetle is currently in effective in the following states: ME, NH, VT, MA, CT, RI, NY, PA, NJ, DE, DC, MD, VA, WV, OH, KY, IN, MI, IL, WI, MN, IA, MO, AR, TN, AL, GA, SC, and NC.
- No federal quarantine for oriental beetle and black vine weevil is noted.

**Critical Needs:**

- Evaluate more effective insecticides for quarantine treatment.

- Improve biological control of white grubs in containerized nurseries.

### *Japanese Beetle Adult (Coleoptera: Scarabaeidae)*

Japanese beetle, *Popillia japonica* Newman

#### **Host Name:**

Adult Japanese beetles feed on foliage, flower and fruit of more than 300 plant species. *Acer palmatum*, *Acer platanoides*, *Aesculus*, *Althea*, *Betula populifolia*, *Castanea*, *Juglans nigra*, *Lagerstroemia*, *Malus*, *Platanus*, *Populus nigra*, *Prunus*, *Salix*, *Sassafras*, *Sorbus americana*, *Tilia americana*, *Ulmus americana*, are the most susceptible trees and shrubs to Japanese beetle attack. Foliage feeding is characterized by skeletonized leaves.

#### **Distribution, Damage and Importance:**

- Japanese beetle was introduced into New Jersey in 1916.
- The current distribution includes much of the United States east of the Mississippi River (with the exception of FL), as well as MN, WI, IA, MO, NE, KS, OK, AR, and TX.

#### **Life Cycle:**

- Japanese beetles have one annual generation.
- They pupate in the soil, and adults emerge in late spring through Jun or July depending on location.
- Eggs are laid in mid-summer.
- There are three larval instars (white grub stages) that feed on turfgrass roots in the top two inches of the soil.
- In late fall when soil temperatures drop to about 60°F, the third instar larvae move downward and remain at a depth of 4 to 6 inches throughout the winter.

#### **Control:**

#### **Monitoring:**

- Adult Japanese beetles are typically monitored by feeding aggregation or by commercially available lure traps.
- The goal of monitoring is to visually detect the adult Japanese beetles on the foliage and make control decisions before significant defoliation has occurred.

**Biological:**

- Some level of predation and parasitism occurs in nurseries although natural enemies generally do not control pest species once economic outbreaks occur.
- Predators include predacious bugs and spiders.

**Cultural:**

- Trapping with a lure trap is considered counterproductive.
- Hand removal of adults is not practical on a large scale but will limit aggregation and feeding damage when practiced each day. Crapemyrtle cultivars with *Lagerstroemia fauriei* Koehne in their parentage and crabapple cultivars 'Adirondack,' 'Bob White,' 'David,' 'Lousia,' and 'Red Jewel' are less susceptible to feeding by adult Japanese beetle (Pettis, 2004).
- Plants resistant to adult Japanese beetle feeding include *Acer negundo*, *Acer rubrum*, *Acer saccharinum*, *Buxus*, *Cercis*, *Chamaecyparis*, *Cornus*, *Euonymus*, *Forsythia*, *Fraxinus*, *Ilex*, *Juniper*, *Liriodendron*, *Liquidambar*, *Magnolia*, *Picea*, *Pinus*, *Quercus alba*, *Quercus rubra*, *Quercus velutina*, *Syringa*, *Thuja*, *Tsuga*, *Taxus*, and certain *Malus* cultivars (Held, 2004).

**Chemical:**

- Insecticide applications applied to the foliage target adults.
- Targeting adults early in the season will reduce aggregation on the foliage and subsequent feeding damage.
- Because of the extended adult activity period, reapplications every 7-10 days after the initial application are often required.

- Insecticides used in nurseries for Japanese beetle adult control:

<b>Soil applied in early spring:</b>	
<b>Chemical Class</b>	<b>Common Name</b>
Neonicotinoid plus pyrethroid	imidacloprid plus cyfluthrin
<b>Foliar application:</b>	
Carbamate	carbaryl
Pyrethroid	bifenthrin, cyfluthrin, deltamethrin, ambda-cyhalothrin

**Federal/State/Local Regulations:**

- Federal quarantine for Japanese beetle is currently in effect in the following states: ME, NH, VT, MA, CT, RI, NY, PA, NJ, DE, DC, MD, VA, WV, OH, KY, IN, MI, IL, WI, MN, IA, MO, AR, TN, AL, GA, SC, and NC.

**Critical Needs:**

- Evaluate resistant plant species or cultivars.
- Evaluate more effective insecticides and repellants.
- Determine how plant quality due to cultural practices, cultivar resistance, or other herbivores affects Japanese beetle behavior and damage.

*Thrips*

**Common Species:**

Several thrips species damage ornamental plants, with damage more heavy in greenhouses and protected cultures. Thrips are only occasional pests of outdoor ornamentals. Infestation and damage are often associated with migration from field crops and attacks on flowering plants. The most common species is the western flower thrips (*Frankliniella occidentalis*). Other occasional pestiferous thrips species include

onion thrips (*Frankliniella tabaci*), gladiolus thrips (*Thrips simplex*), red-banded thrips (*Selenothrips rubrocinctus*), and ‘weeping ficus’ thrips (*Gynaikothrips uzeli*).

Chilli thrips (*Scirtothrips dorsalis*) has emerged as an important thrips pest species of outdoor ornamentals in recent years.

### Chilli thrips

**Species:** *Scirtothrips dorsalis* (Hood)

#### Host Plants:

- Host plant range includes more than 112 plant species in 40 families (Kumar et al., 2013).
- Reproduction can be completed on 36 common annual and perennial ornamental plant species (Kumar et al., 2013), with roses, schefflera, Indian hawthorn, pittosporum and viburnum being the most impacted.

#### Distribution, Damage and Importance:

- Chilli thrips is native to the Indian subcontinent. This species was first detected in Florida in 1991. Since its first establishment in urban landscapes was confirmed in Florida and Texas in 2005, this species has been detected as far north as New York (Kumar et al., 2013).
- Permanent establishment of chilli thrips may be limited to regions in the U.S. where winter temperature does not fall below 25°F for five consecutive days (Kumar et al., 2013).
- Chilli thrips feed on leaves and buds with a rasping-sucking mouthpart. Feeding by chilli thrips on growing tissues cause scarring, distortion and stunting of fruits, flowers and leaves. Feeding on expanded leaves cause bronzing and chlorosis. Severe feeding can cause defoliation and premature abortion of flower buds.
- Chilli thrips is a vector of several viruses. However, its role as a disease vector may be of minor importance in ornamental production.

#### Life Cycle:

- Female inserts small, kidney-shaped eggs into the plant tissues using a modified ovipositor.
- Eggs hatch in 2-7 days, depending on the temperature. Chilli thrips develop through 2 nymphal instar before becoming adults and the duration of development depends on temperature and host plant species. The nymphs pupate on the concealed places on leaves and flowers instead of in the soil.

- Based on degree-day modeling (281DDF at 40.5°F base temperature), multiple generations of chilli thrips may occur in the southern U.S. (Holtz, 2006). In Japan, chilli thrips begin reproduction in late March when temperature becomes favorable.

**Control Measures:**

**Monitoring:**

- Chilli thrips prefers to inhabit dense plant tissues and concealed locations, which makes its detection and monitoring very difficult.
- Visually inspect plants to detect damaged (distorted, chlorotic, bronzing) plant tissues. Beat the plant tissues on a white board or a white paper and identify the dislodged thrips.
- Infested plant tissues can also be collected, put in a plastic zip-lock bag or preserve in 70% ethanol, and send for further microscopic identification by diagnostic services or extension personnel.
- Yellow sticky cards are effective in collecting and monitoring for the chilli thrips; other thrips species prefer blue cards.

**Cultural/Mechanical:**

- Viable cultural and mechanical control option is not available currently.

**Biological:**

- Natural enemies include the minute pirate bug (*Orius* spp.), predatory mites (*Neoseiulus cucumeri*, *Amblyseius swirskii* and *Euseius* spp.), predatory thrips species, lacewings (*Chrysoperla* spp.), ladybeetles and predatory mirid bugs.
- Biological control of chilli thrips is more widely practiced in protected cultures than outdoor production.

**Chemical:**

- Chemical control is the primary method of management against the chilli thrips.
- Because of the thrips habit of inhabiting concealed places, the addition of sticker/spreader and the use of high volume sprays may improve efficacy.
- Chemical used in the nurseries for (general) thrips management include:

Chemical Class	Common Name
Carbamates	carbaryl

Organophosphates	acephate, chlorpyrifos
Pyrethroids	bifenthrin, cyfluthrin, $\lambda$ -cyhalothrin, deltamethrin, fenpropathrin, tau-fluvalinate, permethrin, pyrethrin
Neonicotinoids	acetamiprid, dinotefuran, imidacloprid, thiamethoxam
Spinosyns	spinosad
Avermectins	abamectin
Benzoylureas	novaluron
Tetramic acid derivatives	spirotetramat
Horticultural oil	
Azadirachtin	azadirachtin
Entomopathogenic nematodes	<i>Beauveria bassiana</i> , <i>Isaria formosorosea</i> , <i>Metarhizium anisopliae</i>

**State/Local Regulations:**

- None.

**Critical Issues & Needs:**

- The dynamics and impacts of thrips migrating from agricultural fields surrounding the nursery need to be understood.

## Whiteflies

### Common Species:

- The sweetpotato whitefly, *Bemisia tabaci* (Gennadius), is the most common pest of greenhouse ornamental production. It is also a pest of multiple row crop species, e.g., cotton and vegetables. In the nurseries, infestation by the sweetpotato whiteflies is often associated with migration of adults from surrounding fields when the row crops senesce or are harvested.
- The citrus whitefly, *Dialeurodes citri* (Ashmead), is a frequent pest of gardenia in the landscapes and nurseries.
- Several species (e.g., rugose spiraling whitefly and ficus whitefly) have recently been introduced and may pose threats to ornamental plant productions in the southern U.S.

### Host Plants:

- Sweetpotato whitefly feeds on more than 500 plant species in 74 families. Outdoor grown hibiscus, chrysanthemums, verbena and other plants have been attacked by adult whiteflies invading from surrounding fields.
- While citrus is its preferred host, the citrus whitefly also infest several ornamental species, e.g., gardenia, crape myrtle, English ivy, lilac, trumpet vine and water oak.

### Distribution, Damage & Importance:

- The sweetpotato whitefly is distributed worldwide and considered one of the most important pests of greenhouse grown ornamentals and vegetables.
- The citrus whitefly is distributed in AL, CA, CO, FL, GA, IL, LA, MS, NC, SC, TX, VA and DC.
- Whiteflies use piercing-sucking mouthpart to remove plant sap from the phloem. Prolonged feeding will lead to stunting of the plants, and distortion of the growing tissues.
- Feeding also produces a large amount of honeydew. When the honeydew lands on leaf surface, it leaves behind a shiny sticky surface and an excellent growing medium for the black sooty mold. The honeydew and sooty mold interfere with photosynthesis and reduce aesthetic value of the infested plants.
- The presence of adults can become a nuisance.

### Life Cycle:

- Adults deposit about 150 eggs within 2 weeks. The eggs are typically deposited on the underside of the leaves.

- Eggs hatch in about 4 to 14 days, depending on the temperature. Nymphs feed on the underside of the leaves and become adults after 30-60 days. Multiple overlapping generations are present from spring to fall.

**Control Measures:**

**Monitoring:**

- Monitoring of nymph population is achieved by visual inspection of the underside of leaves, whereas adult population is achieved by visual inspection and the deployment of yellow sticky cards.

**Cultural/Mechanical:**

- Infested should be removed and discarded as soon as infestation is detected.

**Biological:**

- Most whitefly species are heavily attacked by existing parasitic wasps, predators (e.g., ladybeetles, lacewings, predatory bugs, etc.), and entomopathogenic fungi. Conserving these natural enemies will help in suppressing the whitefly population.
- Several species of parasitoids (e.g., *Encarsia* and *Eretmocerus* spp.) and predators (e.g. *Delphastus pusillus* and *Chrysoperla* sp.) are commercially available for releases against the whiteflies. However, their efficacies in outdoor production have not been demonstrated.

**Chemical:**

- Because whiteflies feed on the underside of leaves, complete coverage of the canopy is necessary to achieve successful control.
- Chemicals used in the nursery for control of (general) whiteflies include:

Chemical Class	Common Name
Carbamates	carbaryl
Organophosphates	acephate, chlorpyrifos
Pyrethroids	bifenthrin, cyfluthrin, $\lambda$ -cyhalothrin, fenpropathrin, fluvalinate, permethrin, pyrethrin
Neonicotinoids	acetamiprid, dinotefuran, imidacloprid, thiamethoxam
Avermectins	abamectin

<b>Chemical Class</b>	<b>Common Name</b>
Pyriproxyfen (IGR)	pyriproxyfen
Buprofezin (IGR)	buprofezin
Benzoylureas	novaluron
Tetronic and tetramic acid derivatives	spiromesifen, spirotetramat
METI acaricides and insecticides	fenazaquin, pyridaben
Pymetrozine	pymetrozine
Horticultural oil and neem oil	
Insecticidal soap	
Azadirachtin	azadirachtin
Entomopathogenic fungi	<i>Beauveria bassiana</i> , <i>Isaria formosorosea</i>

**State/local Regulations:**

- None.

**Critical Needs:**

- Determine the dynamics and impacts of migration of whiteflies from surrounding agricultural fields.
- Develop collaboration between horticultural and agronomic productions to better manage migrating whiteflies.

# Extension Priorities: Entomology

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- Monitor the presence and populations of insects and establish action thresholds.
- Group scale insects and develop management guidelines for each group.
- Emphasize scouting and early detection to be able to act on thresholds.
- Use oils early when thresholds are reached to avoid using products that might be more expensive, more toxic, or both.

# Research Priorities: Entomology

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- Use of water conditioner for pH
- Determine if improved nutrition in the fall will reduce attacks by the flatheaded appletree borer in field and container-grown plants. Some growers use 25 ppm K- or Mg-nitrate late in summer to gradually slow the plants down.
- Increase chemical efficacy by determining correct surfactants, penetrants, and their rates.
- Determine possibilities for management of granulate ambrosia beetle after they enter trees.
- Develop more cost effective management of fire ants
- Develop systemic controls of borer and scale insects



Table 4 (cont'd). Insecticides labeled for management of selected pests of ornamental plants\*

IRAC No. <sup>1</sup>	Mode of Action	Chemical subgroup	Active Ingredient	Selected Trade Names <sup>2</sup>	Use Site <sup>3</sup>	REI (hours) <sup>4</sup>	Aphids	Armored scales	Soft scales	Leafhoppers &/or planthoppers <sup>5</sup>	Flea beetles	Japanese beetles (adult)	Caterpillars	Clearwing borers	Flatheaded borers	Ambrosia beetles	Spider mites				
3A	Sodium channel modulators	Pyrethroids	cyfluthrin	Decathlon	L, N, G, I	12	x	x	x	x	x	x	x								
				Tempo	L, I	N/A	x	x	x	x	x	x	x								
			lambda-cyhalothrin	Scimitar CS; Scimitar GC	L; L, N, G	24; 24	x	x	x	x <sup>lh</sup>	x	x	x							x	
				beta-cypermethrin	Demon WP	L, I	N/A	x	x	x	x	x	x	x	x					x	
			deltamethrin	DeltaGard G <sup>11</sup>	L, I	N/A					x <sup>lh</sup>	x	x	x							
			fenpropathrin	Tame 2.4 EC	N, G, I	24	x	x			x		x	x						x	
			tau-fluvalinate	Mavrik Aquaflo	L, N, G, I	12	x				x	x			x					x	
			permethrin	Astro	L, G, I	12	x				x		x	x	x	x	x				
				Permethrin Pro	L, I	N/A	x					x		x	x	x	x				
			pyrethrins	Perm-Up 3.2 EC	L, N, G, I	12	x					x		x	x	x	x				
				Tersus	N, G	12	x	x	x	x	x <sup>lh, ph</sup>	x	x	x	x	x	x	x	x	x	x
							Pyganic. Pyrethrum TR	N, G	12	x	x	x	x	x		x					x
3A + 4A		Pyrethroids + Neonicotinoids	bifenthrin + clothianidin	Aloft LC G, LC SC	L	N/A	x	x	x	x	x	x	x								
				bifenthrin + imidacloprid	Allectus G, SC	L	N/A	x	x	x	x	x	x	x			x			x	
				cyfluthrin + imidacloprid	Discus N/G	N, G, I	12	x	x	x	x		x	x			x				
				lambda-cyhalothrin + thiamethoxam	Tandem	L	N/A	x	x	x	x	x	x	x	x						
3A + 27A		Pyrethroids + Piperonyl butoxide (PBO)	pyrethrins + piperonyl butoxide	Pyreth-It	N, G	12	x			x	x		x								

Table 4 (cont'd). Insecticides labeled for management of selected pests of ornamental plants\*

IRAC No. <sup>1</sup>	Mode of Action	Chemical subgroup	Active Ingredient	Selected Trade Names <sup>2</sup>	Use Site <sup>3</sup>	REI (hours) <sup>4</sup>	Aphids	Armored scales	Soft scales	Leafhoppers &/or planthoppers <sup>5</sup>	Flea beetles	Japanese beetles (adult)	Caterpillars	Cleanwing borers	Flatheaded borers	Ambrosia beetles	Spider mites			
4A	Nicotinic acetylcholine receptor agonists	Neonicotinoids	acetamiprid	TriStar 8.5 SL <sup>11</sup>	L, N, G	12	x	x	x	x <sup>lh</sup>		x	x		x					
			clothianidin	Arena 0.25 G	L, I	12	x													
				Arena 50 WDG	L, I	12	x													
			dinotefuran	Safari 2G	L, N, G, I	12		x	x	x							x			
				Safari 20 SG	L, N, G, I	12	x	x	x	x			x				x			
				Zylam Liquid	L	N/A	x	x	x	x				x			x			
				Transtect	L	N/A	x	x	x	x			x	x	x	x	x			
				Xytect 75WSP; 2F	L, N, G, I	12	x	x <sup>12</sup>	x	x <sup>lh,ph</sup>			x				x			
			imidacloprid <sup>6</sup>	Marathon II	N, G, I	12	x	x <sup>12</sup>	x				x				x			
				Marathon 60WP	N, G, I	12	x	x <sup>12</sup>	x	x <sup>lh</sup>			x							
				Merit	L, I	N/A	x	x <sup>12</sup>	x	x			x				x			
				CoreTect	L, I	N/A	x	x <sup>12</sup>	x	x			x				x			
				Discus Tablets	N, G, I	12	x	x <sup>12</sup>	x	x			x				x			
				thiamethoxam	Flagship 25WG	N, G, I	12	x		x	x									
		Meridian 0.33G	L, I	N/A	x		x			x	x	x								
		Meridian 25WG	L, I	N/A	x		x			x	x	x								
4C + 5		Sulfoxaflor + Spinosyns	sulfoxaflor + spinetoram	XXpire <sup>13</sup>	L, N, G	12	x	x					x				x			

Table 4 (cont'd). Insecticides labeled for management of selected pests of ornamental plants\*

IRAC No. <sup>1</sup>	Mode of Action	Chemical subgroup	Active Ingredient	Selected Trade Names <sup>2</sup>	Use Site <sup>3</sup>	REI (hours) <sup>4</sup>	Aphids	Armored scales	Soft scales	Leafhoppers &/or planthoppers <sup>5</sup>	Flea beetles	Japanese beetles (adult)	Caterpillars	Clearwing borers	Flatheaded borers	Ambrosia beetles	Spider mites		
5	Nicotinic acetylcholine receptor allosteric activators	Spinosyns	spinosad	Conserve SC	L, N, G	4							x		x		x		
				Entrust	L, N, G	4								x		x		x	
6	Chloride channel activators	Avermectins, Milbemycins	abamectin	Avid, Flora-Mek, Lucid	L, N, G	12	x										x		
				Aracinate TM <sup>9</sup>	L, N, G, I	N/A	x	x	x					x	x	x		x	
				emamectin benzoate	Arbormectin	L	N/A	x	x				x	x		x	x		x
					Tree-äge	L	N/A		x					x	x	x			
			milbemectin	Ultiflora	N	12											x		
6 + un			abamectin + bifenazate	Sirocco <sup>14</sup>	L, N, G, I	12	x										x		
7A	Juvenile hormone mimics	Juvenile hormone analogues	s-kinoprene	Enstar AQ	G, I	4	x	x	x	x									
7B		Fenoxycarb	fenoxycarb	Preclude TR	G	12	x	x	x				x				x		
7C		Pyriproxyfen	pyriproxifen	Distance IGR	L, N, G, I	12	x	x	x										
	Fulcrum			L, N, G, I	12	x	x	x											
8D	Miscellaneous non-specific (multi-site) inhibitors	Borates	sodium tetraborohydrate decahydrate	Prev-AM Ultra	N, G	12	x	x	x								x		

Table 4 (cont'd). Insecticides labeled for management of selected pests of ornamental plants\*

IRAC No. <sup>1</sup>	Mode of Action	Chemical subgroup	Active Ingredient	Selected Trade Names <sup>2</sup>	Use Site <sup>3</sup>	REI (hours) <sup>4</sup>	Aphids	Armored scales	Soft scales	Leafhoppers &/or planthoppers <sup>5</sup>	Flea beetles	Japanese beetles (adult)	Caterpillars	Clearwing borers	Flatheaded borers	Ambrosia beetles	Spider mites				
9B	Selective homopteran feeding blockers	Pymetrozine	pymetrozine	Endeavor <sup>14</sup>	L, N, G, I	12	x														
9C		Fonicamid	flonicamid	Aria	L, N, G	12	x	x	x	x <sup>lh</sup>											
10A	Mite growth inhibitors	Clofentezine	clofentazine	Ovation SC	N, G	12												x			
		Hexythiazox	hexythiazox	Hexygon DF <sup>11</sup>	L, N, G, I	12													x		
10B		Etoxazole	etoxazole	Beethoven TR	G	24														x	
				TetraSan 5 WDG	L, N, G, I	12													x		
11	Microbial disruptors of insectmidgut membranes	<i>Bacillus thuringiensis</i> & insecticidal proteins	<i>Bt</i> subsp. <i>aizawai</i>	XenTari	N, G	4							x								
			<i>Bt</i> subsp. <i>kurstaki</i> <sup>6</sup>	Dipel Pro DF	L, N, G	4								x							
12B	Inhibitors of mitochondrial ATP synthase	Organotin miticides	fenbutatin-oxide	ProMITE 50WP, Meraz	L, N, G	48													x		
13	Uncouplers of oxidative phosphorylation via disruption of the proton gradient	Chlorfenapyr	chlorfenapyr	Pylon	G	12							x						x		
15	Inhibitors of chitin biosynthesis, type 0	Benzoylureas	diflubenzuron	Adept	G	12							x								
				Dimilin 25W	L, N	12								x							
				Dimilin 4L	L, N	12									x						
				novaluron	Pedestal	N, G	12								x						

Table 4 (cont'd). Insecticides labeled for management of selected pests of ornamental plants\*

IRAC No. <sup>1</sup>	Mode of Action	Chemical subgroup	Active ingredient	Selected Trade Names <sup>2</sup>	Use Site <sup>3</sup>	REI (hours) <sup>4</sup>																	
							Aphids	Armored scales	Soft scales	Leafhoppers &/or planthoppers <sup>5</sup>	Flea beetles	Japanese beetles (adult)	Caterpillars	Clearwing borers	Flatheaded borers	Ambrosia beetles	Spider mites						
16	Inhibitors of chitin biosynthesis, type 1	Buprofezin	buprofezin	Talus 70DF	L, N, G	12		x	x		x <sup>h, ph</sup>												
18	Ecdysone receptor agonists	Diacylhydrazines	methoxyfenozide	Intrepid 2F	L, N, G, I	4									x								
			tebufenozide	Confirm 2F	N	4										x							
20B	Mitochondrial complex III electron transport inhibitors	Acequinocyl	acequinocyl	Shuttle 15 SC	L, I	12															x		
				Shuttle O	N, G	12																x	
21A	Mitochondrial complex I electron transport inhibitors	METI acaricides and insecticides	fenazaquin	Magus	L, N, G, I	12															x		
			fenpyroximate	Akari 5SC	N, G, I	12																x	
			pyridaben	Sanmite	N, G	12																	x
			tolfenpyrad	Hachi-Hachi	G	12	x	x	x	x						x							
22A	Voltage-dependent sodium channel blockers	Indoxacarb	indoxacarb	Provaunt	L	N/A					x												
23	Inhibitors of acetyl CoA carboxylase	Tetronic and Tetramic acid derivatives	spiromesifen	Forbid	L	N/A															x		
				Judo	N, G	12																x	
			spirotetramat	Kontos	N, G, I	24	x	x	x	x													x

Table 4 (cont'd). Insecticides labeled for management of selected pests of ornamental plants\*

IRAC No. <sup>1</sup>	Mode of Action	Chemical subgroup	Active Ingredient	Selected Trade Names <sup>2</sup>	Use Site <sup>3</sup>	REI (hours) <sup>4</sup>	Aphids	Armored scales	Soft scales	Leafhoppers &/or planthoppers <sup>5</sup>	Flea beetles	Japanese beetles (adult)	Caterpillars	Clearwing borers	Flatheaded borers	Ambrosia beetles	Spider mites		
25	Mitochondrial complex II electron transport inhibitors	Beta-ketonitrile derivatives	cyflumetofen	Sultan	L, N, G, I	12											x		
28	Ryanodine receptor modulators	Diamides	chlordantraniliprole	Acelepryn	L, I	4	x		x <sup>7</sup>			x <sup>7</sup>	x	x					
			cyantraniliprole	Mainspring	G, I	4	x		x			x	x						
Unkn-own	Unknown	Azadirachtin	azadirachtin <sup>6</sup>	Azatin O	L, N, G	4	x	x	x	x	x	x	x	x	x				
			Azatin XL	N, G, I	4	x				x	x	x	x						
			Azatrol	L, N, G	4	x	x	x	x	x	x	x	x					x	
			Ornazin	L, N, G, I	12	x	x	x	x	x	x	x	x	x					
			TreeAzin <sup>9</sup>	L, N, G	until dry								x	x		x			
			Bifenazate	bifenazate	Floramite SC	L, N, G, I	12												x
			Cryolite	cryolite (sodium aluminofluoride)	Kryocide	L	12						x		x				
			Dicofol	dicofol	Kelthane <sup>15</sup>	L, N, G	48												x
	Pyridaryl	pyridaryl	Overture	G	12								x						
	Pyrifluquinazon	pyrifluquinazon	Rycar	G	12	x			x										

Table 4 (cont'd). Insecticides labeled for management of selected pests of ornamental plants\*

IRAC No. <sup>1</sup>	Mode of Action	Chemical subgroup	Active Ingredient	Selected Trade Names <sup>2</sup>	Use Site <sup>3</sup>	REI (hours) <sup>4</sup>	Aphids	Armored scales	Soft scales	Leafhoppers &/or planthoppers <sup>5</sup>	Flea beetles	Japanese beetles (adult)	Caterpillars	Clearwing borers	Flatheaded borers	Ambrosia beetles	Spider mites				
Unclassified	Various		<i>Beauveria bassiana</i> <sup>6</sup>	BotaniGard	L, N, G, I	4	x			x								x			
				Naturalis-L	L, N, G	4	x				x	x		x						x	
			<i>Chromobacterium subtsugae</i>	Grandevo PTO	L, N, G	4	x									x					x
				<i>Heterorhabditis bacteriophera</i>	NemaShield HB	L, N, G, I	N/A									x					
			<i>Isaria formosorosea</i> (=Paecilomyces fumosoroseus)	NoFly	G	4	x					x									
				Preferal	N, G	4	x									x					x
			<i>Steinernema carpocapsae</i>	Millenium	L, N, G, I	N/A										x	x				
				Exhibitline SC	N	N/A										x					
			horticultural oil <sup>6</sup>	Ultra-Pure Oil, TriTek	L, N, G, I	4	x	x	x							x					x
			insecticidal soap <sup>6</sup>	M-Pede	L, N, G, I	12	x	x	x	x	x			x	x						x
			neem oil <sup>6</sup>	Trilogy	L, N	4	x	x	x	x											x
				Triact 70	L, N, G	4	x	x	x	x											x

*\*This chart represents a small fraction of information compiled by J.-H. Chong, F. Hale and W. Klingeman for insecticide/miticide products and pests labeled for control in ornamental plant management. For a comprehensive publication listing pesticide products and pests controlled, visit "Publications", at <https://extension.tennessee.edu> for "An Ornamental Plant Pest Management Guide and Pesticide Rotation Planning Aid".*

**Information including restrictions, notes on sensitive plant species, usage sites and pests listed on pesticide labels are subject to change. Before making pesticide applications, check the product labels to determine if changes have been made.**

**Explanations and Supplemental Notes:**

1. IRAC Code designations and Related Modes of Action are explained at the Insecticide Resistance Action Committee Database 2014 (IRAC 2013; <http://www.irac-online.org/teams/mode-of-action/>).
2. Trade names of products are provided as examples only. No endorsement of mentioned product or criticism of unmentioned products is intended.
3. Use site information is provided for reference only: L = landscape; N = nursery; G = greenhouse; I = interiorscape. \*Products listed for use in L, N, G or I sites may include active ingredients in differently labeled products that are designated for use in turfgrass or sod production use sites. Mention of those products is beyond the scope of this table, and products listed herein may not be legal or appropriate for site uses in turfgrass or sod production.
4. Within the Re-Entry Interval (REI) designation, 'N/A' is used to indicate products with Landscape and/or Interiorscape site uses and that present Non-Agricultural Use Requirements. Thus, these do not include a REI listing relative to Agricultural Use Requirements. Additionally, some product labels may list site uses that are beyond the scope of this publication (e.g., sod farms, pastures, rights-of-way, etc.). These site uses may involve Agricultural Use Requirements that list an REI not presented here. Consult the product labels for specific details required for compliance within those application conditions.
5. lh = leafhopper; ph = planthopper
6. Multiple formulations and trade names of the same active ingredients are available; representative example(s) presented.
7. See product label for information about potential crop phytotoxicity, known plant sensitivity, and how to test for phytotoxicity.
8. Check label for restrictions on the number of times the product can be applied in a growing season or year.
9. Product formulated for tree or shrub injection; specialized equipment may be required.
10. Use of handheld application equipment is prohibited. For use only on seedling trees and non-bearing fruit trees in commercial nurseries.
11. Intended for commercial use only.
12. Label-indicated efficacy against target pest group is primarily by population suppression.
13. XXpire label restricts landscape uses only to commercial landscapes. Residential landscapes are not a permitted application site.
14. Not intended for homeowner use.
15. Kelthane (dicofol): Use of existing stocks of any end-use product shall be allowed until October 31, 2016, and thereafter only for purpose of proper disposal.

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# Key Pest Profiles and Critical Issues: *Plant Diseases*

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## *General Disease Control Practices for Nursery Ornamentals*

Controlling most ornamental diseases is much easier when done *preventatively*. To lessen the impact of plant diseases, an integrated approach to pest management must be followed; this includes the use of disease-resistant cultivars, cultural and sanitation practices, and chemical applications. Diseases are often associated with stressed plants grown under suboptimal conditions. In container nursery production, careful consideration must be given to the layout of the production beds in terms of surface coverings, drainage, plant spacing, and to the source and treatment of irrigation water. Good sanitation practices are extremely important in nursery production.

### *Cultural Control Practices*

The foundation of any integrated pest management program should always include cultural and sanitation practices. Cultural management involves avoiding the onset of disease by creating an environment unfavorable to pathogens. When abiotic factors are deficient or in excess, for example, water, light, temperature, air pollution, pesticides or nutrients, they can predispose a plant to disease or directly cause plant injury. To prevent disease onset, growers are advised to:

- Provide adequate spacing for plants. Air movement is limited when plants are grown too close together, which allows moisture to remain on leaves for longer periods of time. Decreased spacing fosters upright, succulent growth, which can be predisposed to disease. Wider spacing in beds and container areas promotes faster drying after wet periods and promotes lateral branching.
- Avoid excessive soil moisture. Overwatering enhances damping-off and root rot diseases. Do not plant in areas or rooting medium that has poor drainage or where water stands following precipitation.
- Fertilize plants properly based on soil nutrient analyses or monthly EC/pH readings of containers.
- Remove plant debris or infected plant parts after each growing season. Prune or remove twigs and branches affected with fire blight and other bacterial or fungal canker diseases.

- Keep production areas weed-free. Weeds are often pathogen reservoirs. Weed removal also increases air movement and thus decreases conditions that favor disease development.
- Always disinfest equipment and other tools (refer to Table 5).
- Maintain calendar records of disease problems. Scout for disease symptoms during specific times of the year based on previous history.

### *Disease Resistance*

Host plant resistance is one of the most important strategies for managing plant diseases. Plant selection and traditional plant breeding methods are two of the common methods of developing disease resistant plant material for the green industry. In areas where certain plant diseases are endemic, disease resistance can be a viable option to avoid long term losses from a pathogen. Many disease resistant plants are not immune to plant disease, but perform very well with few signs or symptoms of the disease. Resistance can be broken by mutations in the pathogen, or in some cases by placing the plant in an environment that is more conducive for disease. For instance, roses that are resistant to powdery mildew when grown in full sun may be susceptible when planted in shade.

Plant selection involves looking at a population of one or more seedlings, cultivars or species to evaluate susceptibility to common plant diseases. Examples discovered through selection include disease resistant dogwoods (powdery mildew and anthracnose), crape myrtle (powdery mildew), crab-apple (mildew, scab, fire blight, rust), holly (black root rot), rhododendron (phytophthora root rot), rose (blackspot, cercospora leaf spot, powdery mildew, rust), and lilac (powdery mildew).

Plant breeding is used to cross plants of the same species or of different species (interspecific crosses) with the intent of combining desirable traits or developing new or superior horticultural traits. On occasion, unintended outcomes occur and resistance is found to a troublesome disease such as powdery mildew along with dogwood anthracnose resistance. The Stellar series of dogwoods (*Cornus florida* x *C. kousa*) have horticultural traits such as larger and more numerous flowers than either parent species, but trees are also resistant to powdery mildew and dogwood anthracnose. In recent years, no-spray, disease resistant roses in the Knockout™ series have become one of the most popular groups of roses in the green industry primarily due to their disease resistance. This has not gone unnoticed by rose breeders, as they have made many crosses in hopes of developing a rose with desirable form, fragrance and flower color, as well as disease resistance.

In the future, genetic engineering will play a larger role in developing plant material for the green industry. Techniques that have been widely used to develop field crops will be used to develop ornamentals with disease resistance and novel horticultural traits.

Table 5. Products or treatments used for sanitizing tools, equipment, pots, flats, and surfaces.

Treatment	Trade Name	Formulation	Remarks	Contact Time
Alcohol, ethyl and isopropyl (grain, rubbing, wood) (70-100%)	Various commercial brands; Lysol Spray (also includes quaternary ammonium)	Full strength	Evaporates quickly, so adequate contact time may not be achieved; high concentrations of organic matter diminish effectiveness; flammable. Not as effective as other products.	10 min for equipment, pots, flats and surfaces. Tools can be dipped for 10 seconds and allowed to dry. Do not rinse.
Phenolics	Pheno-Cen Spray Disinfectant. Lysol Concentrate (contains 5.5% O-benzyl-p-chlorophenol)	Full strength  1.25 fl oz. (2.5 tsp) to one gallon of water	Phenol penetrates latex gloves; eye/skin irritant; remains active upon contact with organic soil; may leave residue. Wear gloves and eye protection when working with concentrated solution.	10 min for equipment, pots, flats and surfaces. Tools can be dipped for 10 seconds and allowed to dry. Do not rinse.
Peroxyacetic acid and hydrogen peroxide mixture	ZeroTol 2.0.  SaniDate 5.0	2.5 fl. oz per gallon of water. 0.5 fl. oz. per gallon of water	Corrosive; causes irreversible eye damage; eye/skin irritant. Low odor. Use according to label.	1-10 min
Quaternary ammonium	Consan Triple Action 20; Physan 20; GreenShield 20;	1 tablespoon per gallon of water	Effective for non-porous surface sanitation, e.g. floors, walls, benches, pots. Low odor, irritation. Use according to label.	10-15 min
Sodium hypochlorite (8.25% - 5.25%; almost all current formulations are 8.25%)	Clorox; Commercial bleach	If using a 5.25% conc., use 10% or a 1:9 ratio of bleach : water; If 8.25%, use 1:14 ratio bleach:water	Inactivated by organic matter; fresh solutions should be prepared every 8 hr or more frequently if exposed to sunlight; corrosive to metal; irritating to eyes and skin; Exposure to sunlight reduces efficacy. Keep solution in opaque container.	10-15 min for equipment, pots, flats and surfaces. Tools can be dipped for 10 seconds and allowed to dry. Do not rinse.
Steam	NA	Cover or seal	For plastic pots/trays, heat center of steamer between 150°F and 160°F; For less heat-sensitive objects, heat to 180°F.	60 min; 15 min.
Solarization	NA	Place clean items on solid surface, cover tightly with CLEAR plastic.	Clear plastic works very well.	140°F, 4 to 8 hr/day for 7 days

**\*\*All items should be free of organic debris before exposing to the treatments.\*\***

## *Chemical Control*

Chemical control reduces a pest population through the application of pesticides. The decision to incorporate pesticides into an IPM program should be based on economic thresholds associated with both the particular disease and the chemical. Effective use of fungicides and bactericides requires that the grower be familiar with commonly occurring diseases of plants and the factors that influence their development. Growers should consult disease guidebooks or take advantage of diagnostic services offered by state and/or private labs for accurate disease identification.

Fungicides are most effective at protecting plants from foliar and soilborne infections when used preventatively and in combination with other practices. Fungicides used to control ornamental crop pathogens are applied to the soil or plant foliage as sprays, sprenches, or drenches. Sprays are applied to all above-ground plant tissues for controlling diseases that occur aerially like leaf spots and powdery mildew. Sprenches are applied to the stem or crown of the plant with enough volume to wet at least the first inch of the potting medium, and are typically used to manage diseases that attack the base of the plant. Drenches are typically used to manage root diseases, and should be applied with enough volume to thoroughly wet the entire pot, often allowing a small amount to run through.

There is no single product that is effective against all important pathogens. Most diseases have more than three chemical choices available for control, including biological products in some cases. Although efficacy is usually the first factor considered when selecting a fungicide, another important consideration is fungicide resistance management. Fungicides are numerically grouped by similarities in chemical structure and mode of action by the Fungicide Resistance Action Committee (FRAC). Highly effective compounds like the triazoles and QoI fungicides (e.g., strobilurins) with specific modes of action are available. These site-specific fungicides disrupt single metabolic processes or structural sites of the target organism and are more prone to resistance development because of their specificity. When growers need to repeatedly spray fungicides to manage a problem, it is best to use fungicides that have different modes of action. The potential for the development of fungicide resistance will be minimized if growers use tank mixes when possible, or alternate sprays/drenches with a fungicide from a different mode of action group designated by a different numerical FRAC code.

Timing of application is critical to achieve the best efficacy. For optimal results, applications should be applied before infections become established and in sufficient volume for complete coverage of all plants. It is recommended for curative disease control to apply the highest specified rate of a product at the shortest treatment interval. Once unfavorable conditions occur for further disease spread, these curative treatments can stop being applied to new growth. It is important to note that fungicides will not “cure” an already infected plant.

## Pre-Meeting Survey and Focus Group Results

Growers participating in the PMSP focus group meeting were asked to complete a pre-survey regarding important plant diseases in order to determine their prevalence, difficulty to control, damage potential, and severity of injury (Table 6). These preliminary results were used to focus discussion during the meeting. Each attendee then distributed 24 votes among the various plant diseases in efforts to create an Overall Focus Group Ranking to indicate importance. More than one vote could be cast for each pest, but SNIPM working group members did not cast ballots. New or emerging plant diseases discussed at the focus group meeting were included below in the Key Plant Disease Profiles.

Table 6. Pre-meeting survey and overall ranking of plant diseases after discussion by a focus group of nursery crop growers from FL, GA, NC, TN, and VA.

Diseases	Overall Focus Group Ranking <sup>1</sup>	Prevalence <sup>2</sup>	Difficulty to Control <sup>3</sup>	Damage Potential <sup>4</sup>	Severity of Injury <sup>5</sup>
Boxwood blight	18	2.0	4.0	2.0	3.5
Rose rosette virus	16	2.7	6.0	3.5	4.3
Stem Cankers, incl. <i>Seiridium</i> , <i>Botryosphaeria</i> , and others	12	3.2	6.0	2.8	4.2
Powdery mildew	12	4.7	4.3	4.0	1.9
Bacterial leaf spots/blights	8	5.0	5.0	4.3	2.7
Foliar nematodes	5	<i>n.r.</i> <sup>6</sup>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Fireblight	5	3.6	4.6	3.8	4
Crown Gall	5	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Conifer tip blights incl. ( <i>Phomopsis</i> and others)	5	4.9	4.3	4.0	2.3
Vascular wilts (listed in 2009 as <i>Verticillium</i> wilt)	3	3.0	5.4	2.8	4.3
Sudden oak death ( <i>Phytophthora ramorum</i> )	3	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Leaf spot, incl. black spot	3	5.3	4.3	4.3	2.2
Passalora needle blight	3	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Black root rot ( <i>Thielaviopsis</i> )	3	3.7	4.8	3.4	3.4
Anthracnose	3	4.7	4.3	3.4	2.2
Pythium and Phytophthora root rot	2	4.6	4.9	3.7	3.7
Bacterial leaf scorch	2	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Cedar Rusts	1	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Rhizoctonia root rot and web blight	0	4.0	4.4	3.4	3.4
<i>Ralstonia solanacearum</i> bacterial wilt	0	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
<i>Botrytis</i> gray mold	0	3.5	3.0	3.0	2.3
<i>Bryozoa</i> control on ponds	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Southern blight	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>
Tip blight on <i>Cryptomeria</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>	<i>n.r.</i>

<sup>1</sup>Overall focus group ranking = number of votes, greater number of votes indicates more participants found this to be a problem plant disease at the focus meeting. Each attendee had 24 votes to cast and could vote more than once for each plant disease.

<sup>2</sup>Prevalence; 1=Don't know the plant disease; 2=Not found at site; 3=Rare; 4=Occasional (spot treat only if found); 5=Common (part of regular monitoring effort); 6=Actively managed every year. Means of the likert-type scale are presented. n=8 for all.

<sup>3</sup>How easy or difficult is the plant disease to control. 1=Not applicable; 2=Easy; 3=Somewhat easy; 4=Moderate; 5=Somewhat difficult; 6=Difficult. Means of the likert-type scale, not including the response for "1=Not applicable," are presented.

<sup>4</sup>Estimated proportion of grower's most susceptible crop that is commonly injured by the plant disease. 1=Not applicable; 2=0%; 3=1-5%; 4=6-15%; 5=16-25%; 6=>25%. Means of the likert-type scale, not including the response for "1=Not applicable," are presented.

<sup>5</sup>Please indicate the best description of injury associated with each plant disease. 1=Salable crop (no visible injury or injury acceptable); 2=Seasonal sale delayed until new growth flush or hand pruning; 3=Seasonal sale unlikely, crop leaf drop & new leaf protection needed; 4=Quality of sale lost (grade reduced); 5=Total crop loss. Means of the likert-type scale are presented.

<sup>6</sup>*n.r.* – listed plant disease was either not specifically identified on the pre-survey, not assessed in the given year's focus group roundtable, or both.

## Plant Disease Profiles

### Bacterial Leaf Spots and Blights

#### Pathogen:

*Pseudomonas syringae*, *Pseudomonas cichorii*, *Xanthomonas campestris*, *Acidovorax* spp.

#### Hosts:

These bacteria generally have wide host ranges that can include herbaceous and deciduous woody ornamentals, and fruit trees; *P. syringae* has many pathovars that can be host-specific.

Hosts include species of *Acer*, *Begonia*, *Cornus*, *Dahlia*, *Gerbera*, *Hibiscus*, *Impatiens*, *Magnolia*, *Pelargonium*, *Poinsettia*, *Prunus*, *Syringa*, and *Viburnum* to name a few.

#### Distribution and Importance:

- The bacteria are widespread and likely endemic to every nursery.
- Bacteria reproduce rapidly under warmer wet conditions (rain, irrigation, or high humidity) and can quickly spread to susceptible hosts.
- Symptoms vary depending upon pathogen and host susceptibility, but can include leaf spotting, bud and blossom blight, stem rot, stem cankers, wilt, and dieback.

#### Disease Cycle:

- Bacterial pathogens can survive on infected plants, debris from infected plants, weeds, healthy plants (e.g. on dormant buds), on or in seed, and in infested soil.
- Inoculum can be spread via splashing water, tools, and human hands.
- Infection generally occurs through wounds or natural openings (e.g. stomata) in plant tissue.
- Bacterial diseases are favored by moist conditions.

#### Control Measures:

##### Cultural Control:

- Purchase certified disease-free plants.
- Remove and destroy diseased leaves and infected plant material.
- Follow strict sanitation practices (e.g. destruction of diseased material, sanitize benches, pots, flats, etc.)
- Thin plants and increase spacing to improve air circulation and rapid drying.
- Eliminate overhead irrigation to prevent moisture accumulation on foliage and dispersal of the pathogen.
- Avoid handling wet plants to reduce spread of bacterial pathogens.

##### Biological Control:

- None noted.

**Chemical Control:**

- Copper-based fungicides and bactericides can be used to limit disease spread.
- Streptomycin-based bactericides are labeled for commercial use only on select crops; however the development of resistant bacteria can become an issue.

**Critical Issues and Needs:***Black Root Rot***Pathogen:**

*Thielaviopsis basicola*

**Hosts:**

*Ilex crenata* cvs: 'Compacta', 'Convexa', 'Green Lustre', 'Helleri', 'Highlander', 'Hoogendorn', 'Microphylla', 'Rotundifolia', 'Sky Pencil', 'Soft Touch'; *Ilex xmeserveae* cvs: Blue Prince®, Blue Princess®; *Ilex glabra* cvs: 'Shamrock', 'Densa'; *Catalpa speciosa*; *Robinia pseudoacacia*; *Stewartia pseudocamellia*; *Viburnum*; *Buxus sempervirens* 'Suffruticosa'; *Illicium* spp., numerous herbaceous perennials and annual bedding plants; may also cause graft failure of *Camellia*.

**Distribution and Importance:**

- *Thielaviopsis* is wide-spread in native soils and has been associated with root rot diseases of over 100 genera, mostly herbaceous plants.
- In woody ornamentals, black root rot has been associated with chlorosis in container nurseries and with declining plants in landscape beds.
- In nurseries, infected plants may have one or more of the following symptoms: stunted growth, chlorotic foliage, necrotic roots, branch dieback, or death.
- Some regulatory agencies see this disease as a quality problem and do not attempt to regulate infected plants.
- Many nurseries do not recognize black root rot as a problem and employ no specific management strategies to combat this disease. As it rarely kills plants in a nursery setting, it is overlooked by many growers.
- The number of declining holly specimens from landscape beds that arrive at diagnostic labs with black root rot indicate that the disease is more than a quality issue.

- In a recent survey of garden centers in Middle Tennessee, up to 93% of specimens of certain holly species from wholesale container nurseries in four states were infected with black root rot.
- Plants with chlorotic and healthy foliage were equally infected.
- It was difficult, if not impossible, to determine if a plant's root system was healthy when visually inspected in the field.
- Root assays for *Thielaviopsis basicola* are the best way to determine if a suspect plant is infected.

#### **Disease Cycle:**

- *Thielaviopsis basicola* is a dematiaceous hyphomycete.
- *Thielaviopsis* produces two distinct spores: cylindrical, dark brown, multi-septate chlamydospores and unicellular, cylindrical, hyaline endoconidia.
- Endoconidia are extruded in chains endogenously from conidiophores.
- Chlamydospores may be observed in infected roots.
- *Thielaviopsis basicola* may be spread in infested irrigation water, in substrate, by insects such as shore flies and fungus gnats, and long distance via infected plants.
- Chlamydospores may serve as survival structures in soil and will germinate in the presence of root exudates.

#### **Control Measures:**

##### **Cultural Control:**

- Take cuttings for propagation from disease-free plants
- Inspect shipments for symptoms of black root rot
- Root cuttings on raised benches in a soil-less mix to minimize contamination with soil
- Avoid excessive irrigation that could attract fungus gnats and shore flies
- Adjusting pH of rooting medium to 5.5 and using certain nitrogen sources are only marginally effective.
- Resistant species are used in the landscape industry where black root rot has been a problem.
- Many landscape contractors use dwarf yaupon holly (*Ilex vomitoria*) as a replacement plant for many compact forms of *Ilex crenata*.

**Biological Control:**

- In other cropping systems, *Pseudomonas fluorescens* and mycorrhizal fungi have been used to suppress *Thielaviopsis*.

**Chemical Control:**

- The most commonly used fungicides for protective drenches are thiophanate methyl and triflumizole. Polyoxin-D and fludioxinil are marginally effective.
- There are no curative treatments for black root rot.

**Critical Issues and Needs:**

- Identify additional hosts of *Thielaviopsis basicola*.
- Determine factors that lead to decline of landscape plants infected with black root rot.
- Identify reliable cultural practices and biological control agents for managing black root rot.
- Identify additional fungicides that may be used for preventative treatment.

*Boxwood Blight***Pathogen:**

*Calonectria pseudonaviculatum* (syn. *Cylindrocladium pseudonaviculatum*; *C. buxicola*).

**Hosts:**

Most species of *Buxus*, including *B. sempervirens* ('American' and 'Suffruticosa' are highly susceptible), *B. microphylla*, *B. sinica*; *Sarcococca* spp.; *Pachysandra* spp.

**Distribution and Importance:**

- First identified in the U.S. in 2011.
- Identified in nurseries and landscapes in the following states as of Feb. 2015: AL, CT, DE, GA, KS, KY, MA, MD, MO, NC, NJ, NY, OH, OR, PA, RI, TN, VA.
- There are no regulator restrictions at this time; however, ANLA has produced "Nursery Industry Voluntary Best Management Practices for *Cylindrocladium pseudonaviculatum*."
- Tolerant cultivars of *Buxus* have been identified in NC State research trials; however, it has also been found that apparently healthy tolerant cultivars can carry and transmit the pathogen.
- Infects leaves and branches; roots are not affected.

- Symptoms include circular leaf spots and elongated black lesions on stems.
- Causes severe defoliation and death of young plants.
- Repeated defoliation of older plants results in dieback and decline, predisposing plants to infection from other diseases, and possible plant death.
- Can affect healthy plants.
- Diseased plants are unmarketable.

#### **Disease Cycle:**

- *C. pseudonaviculatum* spores are dispersed short distances by splashing water, wind-driven rain, worker activity (clothing, tools), and possibly animals/pets, birds and insects.
- Long distance dispersal occurs from movement of infected plant material, infested plant debris, soil, and tools/equipment.
- Clusters of spores are produced on infected tissues in humid, wet weather with cool to moderate temperatures. Hot, dry weather can suppress fungal growth and mask symptoms.
- Disease cycle can be completed in 1 week.
- The fungus may overwinter as chlamydospores and/or microsclerotia within infected tissues.
- The pathogen can survive for several years in leaf debris on the soil surface or buried.

#### **Control Measures:**

##### **Cultural Control:**

- Inspect newly purchased plants for symptoms of boxwood blight.
- Isolate new planting stock from other boxwoods for at least 3 weeks.
- Remove and destroy diseased plants, as well as other boxwoods within 10 feet of infected plants. Bag plants on-site for disposal, then burn or bury them.
- Good sanitation practices are essential to reduce inoculum levels.
- Burn fallen leaf litter with a propane torch to reduce inoculum reservoir and survival.
- Do not compost infected plant material.
- Avoid overhead irrigation.
- Sanitation is critical. Spores and spore-infested soil spread by sticking to tools, clothing, and gloves

##### **Biological Control:**

- None noted.

**Chemical Control:**

- There are no curative fungicides available for this disease.
- Preventative fungicide sprays can be used on unaffected plants that have been located near infected plants.
- Pathogens in this genus can be difficult to control with fungicides.
- The most effective fungicides in NC State research trials were: chlorothalonil, chlorothalonil + thiophanate methyl, chlorothalonil + propiconazole, tebuconazole, fludioxonil, and metconazole.
- Be sure the host is included on the label before applying any fungicide.

**Critical Issues and Needs:***Cedar Rusts*

**Pathogens:** *Gymnosporangium juniperi-virginianae*, *Gymnosporangium clavipes*, *Gymnosporangium globosum*.

**Hosts:**

*Amelanchier* sp., *Crataegus* spp., *Malus* spp., *Juniper* spp., *Pyrus* spp.,

**Distribution and Importance:**

- Cedar rusts are important plant pathogens wherever junipers and susceptible hosts are grown in close proximity.
- Many crabapple cultivars in the nursery trade have been selected and noted for resistance to cedar-apple rust (*G. juniper-virginianae*), but may be susceptible to quince rust (*G. clavipes*).
- Quince rust is a growing problem on several woody ornamentals, especially *Crataegus* spp., which may be due to the increased use of hawthorn.
- Crabapple infected with cedar-apple rust may have yellow-to-gold lesions on leaves and fruit; whereas hawthorn or quince infected with hawthorn or quince rust may have leaf lesions, stem galls, twig dieback, and swollen, discolored fruit.

- Washington hawthorn (*C. phaenopyrum*) may have severe twig dieback from cedar-quince rust infection; *C. viridis* 'Winter King' may have all of its fruit destroyed by quince rust and a substantial number of stem galls, including on the central leader.
- If conditions are favorable for infection, infected shoots may be observed on pear, crabapple and serviceberry.

### **Disease Cycle:**

- Junipers serve as the primary hosts for cedar rusts.
- Eastern red cedar (*Juniperus virginiana*), as well as some cultivated ornamental junipers, are hosts of cedar rusts.
- Alternate hosts include plants in the Rosaceae family.
- Cedar rusts complete their life cycle in 1 to 2 years.
- In the spring, when warm, moist conditions exist, gelatinous horns or matrix appear on juniper galls or swollen twigs and trunks of cedars.
- These telia produce teliospores that germinate to form basidia on which basidiospores are produced. Basidiospores are borne by air currents to succulent parts of the alternate hosts (apple, crab-apple, hawthorn, pear).
- Once infection takes place, spermogonia form on the leaf, fruit or twig depending on the rust species.
- Spermogonia formation is followed by aecia in which aeciospores are produced.
- Aeciospores are wind-borne and infect juniper needles or cedar twigs.
- Cedar rusts generally overwinter on the evergreen (juniper/cedar) host and do not survive on the aecial host.

### **Control Measures:**

#### **Cultural Control:**

- Pruning out rust galls and infected twigs on junipers is effective when infection is limited to outer branches, but it is time consuming.
- Removing junipers/cedars from close proximity can reduce infection, but is usually not deemed practical.
- Use of resistant species and cultivars is one of the few cultural control measures.

- There are crabapple cultivars resistant to cedar-apple rust, as well as some juniper species and cultivars that are resistant (Durham et al., 1999; Wallis and Lewandowski, 2008).

**Biological Control:**

- None noted.

**Chemical Control:**

- Fungicides in the dithiocarbamate (mancozeb), sterol biosynthesis inhibitor (myclobutanil, propiconazole, triadimefon) and strobilurin/quinone outside inhibitor (trifloxystrobin, azoxystrobin) groups are used to protect susceptible plants from rusts.

**Critical Issues and Needs:**

- Evaluate plant species and cultivars for resistance to cedar rusts.
- Evaluate the timing of fungicide sprays to protect alternate hosts from infection by basidiospores.
- Evaluate new chemicals and biological control materials with efficacy against cedar rusts.

*Crown Gall*

**Pathogen:**

*Agrobacterium tumefaciens*

**Hosts:**

*Rosa spp.*, *Euonymus spp.*, *Salix spp.*, *Forsythia spp.*, and many other species of ornamental trees, shrubs, and vines, as well as woody fruit crops. Crown gall has been reported on members of 93 plant families.

**Distribution and Importance:**

- Crown gall is widely distributed and present throughout the temperate regions of the world.
- Causes the formation of somewhat spherical, lumpy galls on roots, lower trunk, and lower branches.
- Affected plants may be stunted, produce small chlorotic leaves, and become more sensitive to environmental stresses.
- Severely infected plants may decline and ultimately die.

**Disease Cycle:**

- *Agrobacterium tumefaciens* is a soil-borne bacterium.
- Galls from infected plants release the bacterium into the soil where it can survive in a free-living state and on the outer surface of weedy plant roots.
- The bacterium enters through fresh wounds.
- The pathogen can be transmitted on pruning tools and through grafts.

**Control Measures:****Cultural Control:**

- Plant only disease-free stock.
- Visually inspect plants for tumors; however, since the bacterium can be present systemically or on roots in the absence of visual symptoms, this is no guarantee that symptomless plants are free of crown gall.
- Long rotations with cereal crops can help reduce pathogen survival in the soil.
- Prune infected galls from branches, cutting back into healthy tissues. Disinfest pruning tools between cuts.
- Remove and destroy infected plants that have galls on roots, main trunk, or lower stem.

**Biological Control:**

- Root systems of some plant species may be dipped into a suspension of *A. radiobacter* K84 (sold as Galltrol-A) before planting into infested sites.

**Chemical Control:**

- Chemical control is rarely used as it is labor intensive and economically costly.
- Gallex is registered for certain hosts and can be “painted” onto exposed galls to eradicate tumors.
- Reapplication 4 to 6 months later may be necessary.
- See the label for specific application method details and a listing of hosts.

**Critical Issues and Needs:**

## Downy Mildew

### Pathogens:

*Peronospora* spp., *Pseudoperonospora* spp., *Plasmopara* spp., and *Bremia* spp. The different species causing downy mildew are typically host specific.

### Hosts:

Downy mildew attacks a number of container and bedding crops, including *Arabis*, *Anemone*, *Buddleia*, *Centaurea*, *Coreopsis*, *Cynoglossum*, *Delphinium*, *Dianthus*, *Dicentra*, *Dimorphotheca*, *Erigeron*, *Eustoma*, *Geranium*, *Gerbera*, *Geum*, *Godetia*, *Helianthus*, *Hesperis*, *Iberis*, *Impatiens*, *Labularia*, *Lathyrus*, *Linaria*, *Matthiola*, *Meconopsis*, *Mimulus*, *Nicotiana*, *Ocimum*, *Oenothera*, *Osteospermum*, *Primula*, *Ranunculus*, *Rosa*, *Rosmarinus*, *Rudbeckia*, *Salvia*, *Scabiosa*, *Verbena*, *Veronica* and *Virburnum* spp.

### Distribution and Importance:

- Downy mildew has become a serious problem throughout the southeastern and western United States. Roses are typically the most important woody ornamental plants affected. Although often described as “no-spray roses”, most varieties of Knock-Out roses are very susceptible to downy mildew.
- Symptoms include irregular, purplish-red to dark brown spots on leaves, stems and flowers. Leaflets may yellow but retain some green areas.
- Leaf lesions typically become angular as they enlarge and are delimited by major leaf veins.
- A grayish ‘downy’ spore mass on the underside of leaflets is sometimes observed during humid conditions. However, sporulation is not always visible and may disappear if conditions become dry.
- The rose downy mildew pathogen typically produces very sparse sporulation.
- Rapid defoliation may occur under severe disease pressure.
- When young vegetation gets infected, the pathogen may become systemic, resulting in stunted, malformed, and discolored new growth.

### Disease Cycle:

- The pathogens responsible for downy mildew overwinter on infected plant tissue.
- When temperatures range between 50° and 75°F during humid (>85%) conditions, the pathogen begins to produce spores that infect new growth.

- Once conditions become warm (>85°F) and dry, the pathogen becomes latent until the next cool, humid period.
- Cuttings taken from infected stock plants will carry the disease.

### **Control Measures:**

Management depends primarily on preventative fungicide applications.

#### **Cultural Control:**

- Scout carefully for symptoms of the disease, especially on stock plants or plants held over from the previous year.
- Increase air movement in plant canopy by selectively pruning new growth and increasing container spacing.
- Rake leaves and prune out old flowers and stems. Remove and destroy all infected material.
- Take cuttings from plants with no history of the disease.

#### **Biological Control:**

- None noted.

#### **Chemical Control:**

- The most effective fungicides for managing downy mildew include mefenoxam (Subdue Maxx), Fosetyl aluminum (Aliette), Dimethomorph (Stature), Cyazofamid (Segway) and the phosphoric acid compounds (Alude, Agri-Fos, Fosphite, Vital, and Biophos).
- Rotation between chemical classes is important to prevent fungicide resistance.
- Resistance to mefenoxam has been detected among some species of downy mildew.

### **Critical Issues and Needs:**

- Research is needed to identify ornamental plant varieties that are tolerant or less susceptible to downy mildew.
- As fungicides are the primary means of management, additional fungicides need to be evaluated against the downy mildews.
- More information on the biology and life cycle of the pathogens causing downy mildew diseases is needed.

## Fire Blight

### Pathogen:

The bacterium, *Erwinia amylovora*.

### Hosts:

Many ornamental plants in the Rosaceae family are susceptible to fire blight. The known host range of the pathogen includes nearly 130 plant species in 40 genera, including certain species and varieties of *Amelanchier*, *Aronia*, *Aruncus*, *Chaenomeles*, *Cotoneaster*, *Cowania*, *Crataegus*, *Cratnegomespilus*, *Cydonia*, *Dichotomanthes*, *Docynia*, *Dryas*, *Eriobotrya*, *Exochorda*, *Fragaria*, *Geum*, *Heteromeles*, *Holodiscus*, *Kageneckia*, *Kerria*, *Malus*, *Mespilus*, *Osteomeles*, *Peraphyllum*, *Photinia*, *Physocarpus*, *Potentilla*, *Prunus*, *Pyracantha*, *Pyrus*, *Rhodotypos*, *Rhaphiolepis*, *Rosa*, *Rubus*, *Sorbaria*, *Sorbus*, *Spiraea*, and *Stranvaesia*.

### Distribution and Importance:

- Fire blight is a common and destructive disease of many ornamental plants.
- The causal bacterium is ubiquitous on plant surfaces. However infection only occurs under the proper environmental conditions.
- Development of the disease is favored by a combination of warm temperatures and high humidity caused by dew, rain, fog, or irrigation, especially overhead irrigation.
- Fire blight is most damaging in years when spring temperatures are above normal with frequent rains.
- The disease is characterized by sudden wilting, followed by shriveling and blackening of blossoms, tender shoots, and young fruits.
- The damaged flowers, twigs, and foliage look as though they were scorched by fire, hence the name 'fire blight'.
- A characteristic symptom of fire blight is bending of the blighted terminal, often referred to as a 'shepherd's crook'.
- Sunken cankers can form on large limbs and may eventually girdle the limb.
- Severely infected plants are usually disfigured and can die from fire blight.

### Disease Cycle:

- Rod-shaped bacterium overwinters in tissues around the edge of perennial branch cankers.
- Fire blight development is influenced primarily by seasonal weather.

- Temperatures in the range of 70° to 85°F accompanied by rain and hail are ideal conditions for disease development.
- A milky, cream- to amber-colored slime containing millions of bacterial cells often oozes from cankers during warm, humid weather in spring.
- This bacterial ooze can be dispersed by pruning tools, insects, splashing rain, and even wind to blossoms, leaves, and shoots.
- Initial infections usually occur through the flowers at bloom, but bacteria can quickly spread to twigs and leaves.
- Bees and flies play a role in spreading fire blight from blossom to blossom.
- The bacteria often invade wounds, and infection can be especially severe after hail storms.

### **Control Measures:**

Management of fire blight requires an integrated approach. Fire blight is more severe when plants are vigorous.

#### **Cultural Control:**

- Cankers on twigs, branches and trunks should be pruned out during winter; the cut should be made through healthy wood 6 to 8 inches below the point of visible infection.
- Pruning tools should be sterilized frequently to prevent spreading the bacterium.
- Trees should not be irrigated overhead during bloom.
- The disease is worse on succulent tissues.
- Avoid excess nitrogen fertilization and heavy pruning, which promotes succulent growth that is more susceptible to infection.
- Remove water sprouts that form on susceptible hosts, as they are especially susceptible to the pathogen.
- Space container plants to promote air movement and lateral branching.
- Remove severely infected plants.
- Varying levels of resistance to fire blight have been found among cultivars of some common ornamentals (Bell et al., 2005).

#### **Biological Controls:**

- None noted.

#### **Chemical Control:**

- Unfortunately, under high disease pressure, chemical applications will not be 100% effective.

- Chemical control consists of spraying the antibiotic streptomycin sulfate (e.g. Agri-Mycin), or copper (Nu-Cop, Cu-PRO, Champion, Camelot, Phytan 27) during the bloom period as flower buds show color.
- Sprays applied after blooming are not effective.
- Blossoms are the most susceptible part of the plant.
- The number of applications depends on the blooming period.
- Rotate at 4 to 7 day intervals during periods of high humidity and until petal fall and at shorter intervals under extreme infection conditions.
- Plants pruned in late spring that put on new growth may need additional applications.
- Some varieties of crabapple are sensitive to copper sprays; phytotoxic reactions may occur.
- Continued use of streptomycin may lead to resistant bacterial strains.

### **Critical Issues and Needs:**

- Develop chemical control products to increase options for rotation and reduce resistance since there are a limited number of products for managing bacterial diseases. Products that are available have higher risks associated with their use due to resistance development in the pathogen population.

## *Foliar Nematodes*

### **Pathogens:**

*Aphelenchoides* spp.; *A. fragariae* and *A. ritzemabosi* most commonly affect ornamentals.

### **Hosts:**

A wide variety of plants can become infected, mainly herbaceous ornamentals (e.g., ferns, bedding plants, and perennials), but also some woody ornamentals (e.g., *Abelia* spp., *Buddleja* spp., *Paeonia* spp., *Rhododendron* spp.) and strawberry.

### **Distribution and Importance:**

- Foliar nematodes are becoming more common with the lack of systemic nematicides available for treatment; increased nursery production of vegetatively propagated susceptible plants; and long distance movement of plant material.
- Host plants can be symptomless carriers; that is, infected but initially without visible symptoms.

- Foliar lesions are generally angular (nematode feeding is often limited to areas between leaf veins) and may be brown, black, or chlorotic (yellow) in color. Leaves with parallel veins appear “striped.”
- Nematodes rarely kill their host, but they reduce plant vigor and plant quality.

**Disease Cycle:**

- Nematodes enter leaf tissue through stomata and may emerge in the same manner.
- The nematodes feed and reproduce within leaf tissue.
- Adult and fourth-stage juvenile foliar nematodes overwinter in dried leaves and dormant buds, but not plant roots.
- Nematodes can survive several years in a dormant state.

**Control Measures:**

**Cultural Control:**

- Remove and destroy infected plants.
- Do not discard infected plants into a compost pile as the nematodes will still survive and reproduce.
- Good sanitation in the greenhouse and nursery is critical.
- Avoid overhead irrigation to prevent splash dispersal of nematodes.

**Biological Control:**

None noted.

**Chemical Control:**

None noted.

**Critical Issues and Needs:**

## Fungal Canker Diseases

### Pathogens:

*Botryosphaeria dothidea*, *B. ribis*, *B. rhodina*, *Seiridium cardinal*, *S. unicorn*, *S. cupressi*, *Phomopsis spp.*

### Host Name:

*Rhododendron spp.*, x *Cupressocyparis leylandii*, many woody ornamental species are susceptible to *Botryosphaeria* canker.

### Distribution, Damage and Importance:

- A canker is a localized infection of a stem, trunk, branch or twig.
- Canker diseases are widely distributed wherever woody ornamental plants are produced. These diseases may be found in mature container stock, but are more likely to be observed in field-grown woody ornamentals.
- Canker diseases are most common in landscape beds and field nurseries, especially on those plants that have been subject to drought stress.
- The most common symptoms associated with canker diseases are wilting and branch dieback.
- Other symptoms include resin flowing from cankers on juniper and cypress and discolored sapwood on *Rhododendron*.

### Life Cycle:

- Fungi, such as *Botryosphaeria*, produce spores in abundance during wet weather in late spring and early summer.
- Spores are wind-blown and may be splashed from plant to plant during irrigation or a rain event.
- Infection may occur at wounds caused by pruning, insect feeding, leaf scars, freeze damage, etc. In general, plants exposed to significant water stress are more susceptible to infection.

### Control Measures:

Management depends on pro-active measures such as monitoring plant stress and timely irrigation.

**Cultural/Mechanical Control:**

- Timely irrigation is important to prevent water stress. Stressed plants are more likely to be infected, have more and larger cankers, and significant branch dieback.
- Branches with cankers should be removed by pruning. Flush cuts when limbing up shade trees should be avoided as the wounds are slow to heal and vulnerable to infection by canker-causing fungi.
- Pruners should be disinfected after removing cankered branches.
- Infected plants should be pruned last; prune healthy plants first before moving on to diseased plants.
- Do not prune plants when they are wet and humidity is high as infection is more likely.

**Biological Control:**

- None noted.

**Chemical Control:**

- Fungicides are generally not recommended for the management of canker diseases.

**State/Local Pesticide Restrictions or Limitations, Export Issues, etc.:**

None

**Critical Issues and Needs:**

There has been little research on the biology and management of canker-causing fungi on ornamental plants in production nurseries.

## Fungal Leaf Spots

### Pathogens:

*Diplocarpon rosae*, *Cercospora* spp., *Pseudocercospora* spp., *Mycosphaerella* spp., *Phyllosticta* spp., *Septoria* spp., *Guignardia* spp., *Entomosporium mespili*.

### Hosts:

Species and cultivars of *Acer*, *Aesculus*, *Betula*, *Cornus*, *Hydrangea*, *Kalmia*, *Malus*, *Nandina*, *Rosa*, *Photinia*, *Platanus*, and others.

### Distribution and Importance:

- Pathogens that cause leaf spot diseases are widespread and may cause extensive damage.
- Plants that are infected each year and defoliate prematurely may become stunted and exhibit branch dieback.
- Fungal leaf spot diseases may be serious problems in container and field nurseries.
- Susceptible hosts, tight spacing, overhead irrigation, and frequent rainfall can all be factors in an outbreak of these diseases.

### Disease Cycle:

- In general, it is the asexual stage of the fungus that is observed on leaves infected by a fungal pathogen.
- These fungi may produce spores on stalks or in spherical fruiting bodies.
- In late fall, the sexual stage of the fungus may form in lesions on the leaf and survive the winter in leaf litter to produce primary inoculum the following spring.
- Once infection takes place in the spring, the asexual stage of the pathogen forms, produces spores, and the infection process may repeat itself throughout the season as long as conditions are favorable for disease development.
- Some leaf spot diseases appear in late summer or early fall and cause little harm to the host; however, given that appearance is important with ornamental plants, infected plants may be unacceptable to customers.

## **Control Measures:**

### **Cultural Control:**

- Spacing plants to speed the drying of foliage.
- Removing leaf litter.
- Placing a mulch barrier over leaf litter to act as a physical barrier.
- Pruning to remove diseased foliage and open the canopy.  
Resistant species and cultivars exist for some ornamental plant groups.
- Some rose cultivars have been identified with resistance to black spot and *Cercospora* leaf spot (Mynes et al.).
- There are differential reactions among *Aesculus* spp. to *Guignardia* species that cause leaf blotch.

### **Biological Control:**

- Antagonistic bacteria may be applied preventatively to the foliage of healthy plants to prevent or limit infection.

### **Chemical Control:**

- Fungicides can be an important tool in managing fungal leaf spot diseases.
- Fungicides in the following groups are used: dithiocarbamates, sterol biosynthesis inhibitors, chloronitriles, benzimidazoles, and strobilurins.
- Some of the fungicides used to manage fungal leaf spot diseases are: mancozeb, myclobutanil, propiconazole, triadimefon, chlorothalonil, thiophanate methyl, azoxystrobin, pyraclostrobin, and trifloxystrobin.

## **Critical Issues and Needs:**

- Evaluate plant material for resistance to leaf spot diseases.
- Evaluate biological control agents that prevent the colonization of the leaf surface by plant pathogens.
- Evaluation of soft or biorational fungicides and new synthetic fungicides for efficacy against leaf spot diseases.

## *Passalora Blight*

### **Pathogens:**

*Passalora sequoiae* (syn. *Cercosporidium sequoiae*)

### **Host Name:**

*Cupressocyparis lelandii*, *Cupressus arizonica*, *Cryptomeria japonica*, *Juniperus chinensis*, *Juniperus virginiana*

### **Distribution, Damage and Importance:**

- *Passalora* blight of cypress and juniper has been reported most frequently in the Southeast, but also in the Northeast and Midwest
- Leyland cypress is especially susceptible to *Passalora* blight; large specimens in containers, field nurseries and Christmas tree plantations may be so severely affected that they are not marketable.
- Symptoms are somewhat similar to needlecast diseases as needles are first blighted in the interior of the canopy on the lower portion of the tree.
- Infected needles are first brown to reddish brown and may become gray with time.

### **Life Cycle:**

- *P. sequoiae* survives on needles in the canopy of infected plants
- Research in GA has shown that spore production is greatest during the summer months, with a peak in August through October.
- The fungus may be observed on infected needles with a hand lens or dissecting microscope.
- Infection may occur throughout the year in FL.

### **Control Measures:**

Management depends primarily on preventative fungicide applications.

#### **Cultural/Mechanical Control:**

- For propagation, do not take cuttings from infected plants.
- Do not excessively irrigate during late summer-early fall when spore production peaks.
- Increased plant spacing may help, but this has not been documented.

**Biological Control:**

- None noted.

**Chemical Control:**

- Fungicide applications should coincide with spore production. This may vary depending upon your location. In GA, fungicide applications were initiated in mid-June and continued through early fall.
- Chemicals used: azoxystrobin, chlorothalonil, copper hydroxide, mancozeb, myclobutanil

**State/Local Pesticide Restrictions or Limitations, Export Issues, etc.:**

None noted.

**Critical Issues and Needs:**

- Research is needed to determine when sporulation begins and peaks at several locations in the Southeast.
- As fungicides are the primary means of management, additional fungicides need to be evaluated against *P. sequoiae*.
- Research is needed on cultural practices that can be included in an integrated disease management program.

## *Phytophthora Root Rot and Pythium Root Rot*

### **Pathogens:**

*Phytophthora* spp.; Phytophthora root rot is caused by several species of *Phytophthora*, although in the Southeast *P. cinnamomi* and *P. nicotianae* are the most important. Other species associated with diseased ornamental plants include *P. cactorum*, *P. cambivora*, *P. citricola*, *P. citrophthora*, *P. cryptogea*, *P. dreschleri*, *P. hedraiaandra*, *P. megasperma*, as well as several undescribed *Phytophthora* species. Most common *Pythium* species in the Southeast include *P. aphanidermatum* and *P. irregulare*.

### **Hosts:**

*Phytophthora* and *Pythium* species attack a wide range of woody ornamentals, including species and cultivars of: *Abies*, *Acer*, *Aesculus*, *Aucuba*, *Betula*, *Buddleia*, *Buxus*, *Calluna*, *Camellia*, *Castanea*, *Cedrus*, *Cornus*, *Cotoneaster*, *Craetegus*, *Cupressocyparis leylandii*, *Eleagnus*, *Euonymus*, *Forsythia*, *Gledistia*, *Ilex*, *Juglans*, *Juniper*, *Kalmia*, *Larix*, *Leucothoe*, *Ligustrum*, *Liquidambar*, *Magnolia*, *Malus*, *Nyssa*, *Picea*, *Pieris*, *Pinus*, *Platanus*, *Prunus*, *Pyrus*, *Quercus*, *Rhododendron*, *Salix*, *Syringa*, *Thuja*, *Tsuga*, *Ulmus*, *Vaccinium*, *Wisteria* and others, as well as numerous herbaceous hosts.

### **Distribution and Importance:**

- Phytophthora root rot is a serious, widespread and difficult to control disease affecting a diverse range of ornamental and agronomic plants worldwide.
- Pythium root rot is typically not as common on woody ornamentals.
- *Pythium* species are most well-known for their ability to cause damping-off during seedling production.
- *Phytophthora* and *Pythium* kill the roots and crown of infected plants.
- These pathogens markedly reduce the volume of the roots that the plant uses to absorb water and nutrients.
- Symptoms include yellow or bronze foliage, wilting, branch dieback, poor plant vigor, and sometimes death. Downward rolling of leaves is also an early symptom on rhododendron.
- Liners or container-grown plants can remain symptomless until after transplanting into larger containers or landscape beds.
- Roots of affected plants are cinnamon-red to black in color and lack white growing tips.

- Often, the outer surface of the root can be pulled away from the inner core, also called 'root sloughing', and feeder roots are typically absent or discolored.
- Butterscotch discoloration of the tissues or oozing, water-soaked cankers may be apparent under the bark of the plant around the soil line.
- These symptoms are often not apparent until the roots are heavily infected.
- Many of the symptoms of root rot can be easily confused with those of a nutritional disorder, over- or under- watering, or a number of other factors, hence a confirmation of the pathogen is important.

#### **Disease Cycle:**

- *Phytophthora* and *Pythium* require extended periods of high soil moisture to cause disease.
- During the growing season when temperatures rise, mycelia or chlamydospores germinate and produce sporangia.
- These lemon-shaped sporangia cause new infections, either by germinating directly and colonizing roots, or by releasing zoospores that have formed inside each sporangium into water.
- Zoospores are able to swim using their flagella, and are capable of directional movement to host plants based on chemical attraction.
- *Phytophthora* and *Pythium* species can spread through contaminated substrate or supplies (including re-used media and pots), with infected nursery stock, or by contaminated irrigation water.
- Recent research has found some *Phytophthora* and *Pythium* species can be spread by fungus gnats and shore flies (Hyder et al., 2009).

#### **Control Measures:**

Managing root rot requires an Integrated Pest Management (IPM) approach, as no single control strategy will prevent or control this disease.

#### **Cultural Control:**

- Purchase healthy liners and container-grown plants. Prevention is the key to controlling root rot.
- Avoid excessive irrigation.
- Avoid using fine materials in substrate, such as peat moss or clay, which may settle and slow percolation of water. Substrate can have a significant impact on the occurrence and severity of root rot. Container stock that is grown in compacted, poorly drained media with

little pore space is most likely to suffer from root rot. The substrate should drain rapidly and have about 20 to 30 percent air space (air filled porosity).

- Maintain plants in well-drained areas to prevent water ponding around plants. Field sites and container areas should be crowned or sloped to speed the run-off of water. A drainage system should be designed to quickly move water around or away from production areas. Do not grow shallow-rooted trees and shrubs in areas that flood. Also, container areas should be covered with plastic or weed barrier and topped with a layer of gravel, oyster shell, or similar coarse material.
- Remove infected plants immediately to limit the amount of pathogen inoculum in the growing area.
- Sanitize equipment and supplies between crops (Table 5).
- Components for container potting media should be stored on concrete pads to reduce contamination.
- Avoid reusing cell packs or containers unless they are first cleaned of organic material and then soaked in disinfectant or steamed.
- Evaluate irrigation water to ensure it is not contaminated with the pathogen. Recycled irrigation water should be sanitized with chlorine or other disinfestation methods; recent research has shown that *Phytophthora* and *Pythium* incidence in nurseries is correlated with the use of recycled water (Hong and Moorman, 2005).

**Biological Control:**

- None noted.

**Chemical Control:**

- Chemical control of *Phytophthora* or *Pythium* root rot is successful only when integrated with best management practices.
- Fungicides work better as prophylactic treatments.
- Incorporated fungicides are usually more uniformly distributed throughout the substrate or soil and may provide better protection.
- If a root rot fungicide was not incorporated into the substrate, begin drenches or foliar sprays immediately after plants have been transplanted.
- Soil drenches usually provide better protection from root rot than foliar sprays.

- Treatment schedules and rates will depend on the plant being grown, the level of disease pressure, and the fungicide used.
- Fungicides recommended for *Phytophthora* and *Pythium* root rot control in container- and field-grown plants are listed (Table 7).

*Table 7. Chemicals recommended for Phytophthora and Pythium root rot control.*

Active Ingredient	Trade name	FRAC code*	Sites**	REI
Mefenoxam	Subdue Maxx	4	G, N, L	0 hr
Azoxystrobin;	Heritage;	11	G, N, L	4 hr
Pyraclostrobin;	Pageant;	11	G, N, L	12 hr
Fenamidone;	FenStop;	11	G	12 hr
Etridiazole	Terrazole; Truban	14	G, N, L	12 hr
Dimethomorph	Stature DM	40	G, N	12 hr
Cyazofamid	Segway	21	G, N, L	12 hr
Fosetyl aluminum;	Aliette;	33	G, N, L	12 hr
Phosphorous acid;	Alude; Agri-Fos;	33	G, N, L	4 hr
Potassium phosphate;	Fosphite; Vital;	33	G, N, L	4 hr
Dipotassium phosphonate	BioPhos	33	G, N, L	12 hr

\* Always rotate chemicals with different modes of action.

\*\* G= Greenhouse; N= Nursery; L= Landscape.

#### **Critical Issues and Needs:**

- *Phytophthora* tolerant varieties of rhododendron and azalea have been reported but these varieties are difficult to find and most are not cold-hardy.
- Develop and evaluate plant material for resistance to root rot.
- More research on effective chemicals for *Pythium* root rot is needed.
- Offer research and education on cost-effective water disinfestation methods.

## Powdery Mildew

### Pathogens:

*Erysiphe pulchra*, *Erysiphe syringae*, *Erysiphe euonymi-japonici*, *Erysiphe australiana*, *Erysiphe polygoni*, *Phyllactinia gutta*, *Podosphaera pannosa* var. *rosae*

### Hosts:

*Cornus florida*, *Euonymus japonicus*, *Hydrangea* spp., *Lagerstroemia indica*, *Malus* spp., *Quercus* spp., *Rosa* spp., *Syringa vulgaris*

### Distribution and Importance:

- Pathogens causing powdery mildew are widely distributed wherever ornamental plants are grown.
- Powdery mildew has significant, negative economic impacts on the green industry.
- Nurseries that produce flowering dogwood may spend up to \$1,900/ha/yr to manage powdery mildew (Halcomb, M., personal communication).
- Many nurseries have dropped flowering dogwood from their inventory due to the increased cost of production.
- White, powdery mycelium and brown-to-black ascocarps on foliage are the most common signs of disease.
- Symptomatic plants may exhibit one or more of the following symptoms: stunted growth, distorted leaves and flowers, leaf scorch, and fewer flower buds. Dogwoods treated biweekly for powdery mildew had a 50% increase in caliper and height over non-treated controls (Halcomb, M., personal communication).

### Disease Cycle:

- Powdery mildew fungi are identified by morphological characteristics of the asexual and sexual states.
- On most woody hosts, the asexual stage of the fungus is the stage most commonly observed.
- Asexual spores (conidia) may be produced in chains on stalks (conidiophores).
- In flowering dogwood, the asexual spore produces 1 to 4 germ tubes and infection structures (appresoria and penetration pegs) that penetrate the leaf epidermis.
- Fungal feeding structures (haustoria) develop within epidermal cells.
- A network of white, powdery mycelium forms in circular colonies on the surface of the host.
- In late summer to early fall, the sexual stage of the fungus may be found on infected leaves. The sexual fruiting structure or ascocarp is called a chasmothecium.

- Inside the ascocarp are sac-like structures (asci) in which ascospores are produced. The fungi overwinter in the sexual stage primarily.
- Powdery mildew spores are easily dispersed by air currents and splash dispersal by water. Initial inocula in the spring are usually ascospores that survived in ascocarps on leaf debris.
- Once infection takes place, conidia are formed and are the primary means by which the disease is spread throughout the season.
- Conidial germination is favored by high humidity, but may be slowed when free water is present on leaves.

### **Control Measures:**

#### **Cultural Control:**

- There are few cultural practices that are practical for most nurseries when dealing with powdery mildew.
- Syringing leaves with water may prevent infection by powdery mildew, but may make conditions more favorable for other pathogens.
- Use of resistant cultivars and species is an effective means of control.
- There are mildew resistant cultivars of flowering dogwood, crapemyrtle, crabapple, and lilac available.

#### **Biological Control:**

- There are biological agents (bacteria and actinomycetes) that are labeled for powdery mildew control.

#### **Chemical Control:**

- Fungicides are an important tool for the management of powdery mildew.
- Soft or biorational products such as neem oil, bicarbonates and copper soaps have been used to keep mildew at low levels.
- Biorational products may not perform well in hot, humid climates if disease pressure is high and may have to be applied more frequently than traditional fungicides.
- Important agents for management of powdery mildew include fungicides in the following classes: benzimidazoles, sterol biosynthesis inhibitors, and strobilurins.
- Examples of active ingredients used for powdery mildew management include: copper sulfate pentahydrate, thiophanate methyl, myclobutanil, piperalin, propiconazole, triadimefon, trifloxystrobin, pyraclostrobin, and azoxystrobin.

**Critical Issues and Needs:**

- Continued evaluation of plant material for resistance to powdery mildew is necessary.
- Continued evaluation of biorational products and fungicides is needed, as is the evaluation of proper timing and scope of their application.

*Rose Rosette-Associated Virus (RRaV)***Pathogen:**

Rose rosette-associated virus (RRaV)

**Hosts:**

Virtually all cultivated roses (*Rosa* spp); multiflora roses (*R. multiflora*)

**Distribution and Importance:**

- Rose rosette, first identified in California in 1941, has spread eastward to several states along the Eastern Seaboard; it is prevalent in the Midwest, as well as the South.

**Disease Cycle:**

- Multiflora roses are an important source of the virus.
- RRaV is vectored by the rose leaf curl mite, an eriophyid mite (*Phyllocoptes fructiphylus*).
- The virus can also be transmitted via grafts.
- There is no evidence that the virus can survive outside the plant or be transmitted mechanically via pruning wounds.
- Mites move from plant to plant via air currents or by attaching themselves to insects.
- Adult mites overwinter on rose canes. Mites are well protected in the leaf axil, often found where shoots attach to the cane.
- In spring, mites migrate to developing shoots where they lay their eggs.
- Mites cannot survive in the absence of the host (rose).

**Control Measures:****Cultural Control:**

- Purchase healthy plants from a reliable source.
- Inspect plants prior to purchase and reject any showing symptoms of disease.
- Remove wild multiflora roses within 100 yards of cultivated roses.

- Do not allow foliage or stems to overlap from one plant to the next in nurseries or landscapes; this will prevent the mites from crawling from plant to plant.
- Infected plants cannot be cured and will only serve as a source of inoculum for other plants.
- Once symptomatic roses are detected, infected plants (including roots), must be removed completely.
- Bag diseased plants and remove from the vicinity.
- Remove and destroy any regrowth that occurs from infected roots that might have been left behind in the soil.
- Non-hosts may be used as screens/barriers between rose plantings to slow the spread of the mite, and thus the disease.
- Roses may be replaced with healthy roses almost immediately. However, they will be at risk, if infected roses are growing in the vicinity.

**Biological Control:**

- None noted.

**Chemical Control:**

- Rose rosette-associated virus cannot be prevented or controlled with chemicals.
- Use of a miticide to control the vector is not considered practical at this time. Research continues on the use of miticides to manage rose rosette.

**Critical Issues and Needs:**

- Evaluate rose species and cultivars for susceptibility to rose rosette-associated virus.
- Evaluate rose species and cultivars for mite feeding preference, fecundity.
- Breeding for resistance to rose rosette-associated virus.
- Evaluate miticides for management of rose rosette.
- Educational programs for nursery and landscape professionals on the identification and management of rose rosette.
- Identification of suitable landscape plants with similar horticultural characteristics of Knockout rose for use in areas where rose rosette is endemic.

## Tip and Twig Blights

### Pathogens:

*Phomopsis juniperovora*, *Kabatina juniper*, *Diplodia pinea* (*Sphaeropsis sapinea*)

### Hosts:

*Phomopsis*: Species and cultivars of *Juniperus*, plus *Pseudotsuga menziesii*, *Larix decidua*, *Pinus baltica*, and *Thuja* spp.

*Kabatina*: Species and cultivars of *Juniperus*, plus *Abies* spp., *Cryptomeria japonica*, *Cupressus* spp., *Pseudotsuga menziesii*, *Taxus* spp., and *Thuja* spp.

*Diplodia*: all *Pinus* spp., particularly *Pinus nigra*, *P. sylvestris*, *P. mugo*, *P. ponderosa*, *P. radiata*, *P. resinosa*

### Distribution and Importance:

- These diseases are widespread throughout central and eastern U.S.; some occurrences in California and the western portion of the country.
- Cause damage to nursery stock and transplants in landscape nurseries and Christmas tree plantations; *Diplodia* can also damage older trees.
- *Kabatina* and *Phomopsis* girdle shoots, resulting in death of branch tips.
- Pines affected by *Diplodia* have stunted straw-colored needles and excess resin flow; infected needles may become “trapped” in the excess resin rather than dropping to the ground. Unwounded new shoots can be affected, as well as wounded current-year and older tissues.
- Fungal fruiting bodies appear as black specks in diseased tissues.

### Disease Cycle:

- *Diplodia* spores are released in spring and early summer; spores are spread by wind, splashing rain, animals and pruning equipment. The fungus infects young needles of the current season’s growth, as well as cones, buds, and twigs.
- *Phomopsis* spores are spread via rain splash; spores are spread in summer and symptoms may develop anytime during the growing season. Infection occurs in healthy tissue of young twigs.
- *Kabatina* spores are believed to be disseminated in fall, resulting in symptom development in early spring, before new growth begins. Infection occurs via wounds, not healthy tissues.

## **Control Measures:**

### **Cultural Control:**

- Fertilize and water trees/shrubs as needed to promote plant vigor; stressed pines, in particular, are more susceptible to *Diplodia* tip blight.
- Prune and destroy infected twigs and branches.
- To minimize pathogen spread, do not prune when foliage is wet and disinfect tools between pruning cuts.
- Rake up and destroy fallen diseased material, such as needles and cones.
- Avoid use of overhead irrigation or irrigate early in the day so foliage can dry before sunset.
- Plant host cultivars known to have some resistance to *Phomopsis* twig blight and/or *Kabatina*.

### **Biological Control:**

- None noted.

### **Chemical Control:**

- *Diplodia*: spray trees with an effective fungicide just before or just as buds swell in spring; apply second spray when candles are about half elongated; apply a third spray as needles begin to emerge from needle sheaths.
- *Phomopsis*: apply registered fungicides at 7 to 21 day intervals during spring when rapid growth is occurring and favorable weather (wet, cool, cloudy) prevails.
- *Kabatina*: Use approved insecticides to control insect pests that could create wounds for pathogen entry. Apply fungicides in late summer or fall; however, fungicides registered for this disease may be limited

## **Critical Issues and Needs:**

## *Emerging Plant Diseases*

Emerging plant diseases are those that have increased in incidence within the last 10 to 15 years. Often these pathogens are exotic to the United States and are not well studied in their native habitat, which is often unknown. Nurseries and greenhouses are not isolated geographically, and the movement of both propagation and finished stock occurs across the globe. Due to the increased movement of plant material, ornamental production in the southeastern United States is faced with the constant threat of introduced exotic or regulated pathogens from infested plant material. As examples, *Phytophthora ramorum*, the causal agent of sudden oak death, was introduced into nurseries in several southeastern states in 2004 on infected nursery stock originating from California. Daylily rust was first identified in the United States in Georgia in 2000 and was not known to occur in North Carolina until 2002, but it has appeared in nurseries each year since. Since the 1980's, dogwood anthracnose has spread rapidly in the Appalachians on *Cornus florida* and has been reported on over 12 million acres in 180 counties. It continues to threaten dogwoods in nurseries and throughout their native range. Boxwood blight was first reported in North Carolina in 2011 and has since been reported in 18 other states. Rose rosette-associated virus, first identified in California in 1941, has spread eastward to several states along the Eastern seaboard; it is prevalent in the Midwest, as well as the Southern U.S. More education involving newly emerging plant diseases will be essential for their rapid detection, identification, and control.

## Plant Pathology Priorities: Extension

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- Develop resources that provide information regarding:
  - Cultural practices as related to disease management such as pruning/thinning, plant spacing, leaf wetness, irrigation, and sanitation.
  - Chemical controls with efficacy tables that also include other details such as rainfastness, curative/preventative activity and certain state label restrictions.
  - Pathogen biology that includes overwintering sanitation, and time of infection.
  - Digital scouting guides, macro- and microscope views and identification aides.

# Plant Pathology Priorities: Research

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- Weather alerts and disease models that use short message service (SMS) alerts.
- Biology of secondary diseases, their infection and susceptibility to hosts after stresses, wounds, or sunscald.
- Investigate biology of black root rot.
- Determine cause and treatment of *Cryptomeria* tip disorder.
- Identify effective treatments for foliar nematodes.
- Investigate the biology of downy mildew diseases on ornamentals.
- Evaluate the efficacy of products applied via chemigation

Table 8. Relative effectiveness of various chemicals for disease control of ornamental plants.

Visit [http://www2.ca.uky.edu/agcollege/plantpathology/ext\\_files/PPFShtml/PPFS-GEN-13.pdf](http://www2.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/PPFS-GEN-13.pdf) for a larger version of this table.

Trade name	Active ingredient(s)	FRAC <sup>1</sup>	Sites <sup>2</sup>	Bacterial leaf spots/blights	Black root rot	Cedar rusts	Conifer Tip Blights	Downy mildew	Fire blight	Fungal stem cankers	Fungal leaf spots	Fusarium stem rot	Passalora needle blight	Phytophthora root rot	Pythium root rot	Powdery mildew	Rhizoctonia blight/root rot	Notes
Cleary 3336, OHP 6672, Alban, Transom	Thiophanate methyl	1	G, N, L	G <sup>Dr, D</sup>		F-G <sup>S</sup>			P-F <sup>S</sup>	F <sup>S</sup>	F-G <sup>Dr</sup>	F <sup>S</sup>		F <sup>S</sup>	G <sup>Dr, D</sup>			Do not mix with copper-containing materials or with highly alkaline pesticides such as lime or sulfur.
Banrot	Thiophanate methyl + Etridiazole	1 + 14	G, N, L	F <sup>Dr</sup>							P-F <sup>Dr</sup>		P <sup>Dr</sup>	G <sup>Dr</sup>		F-G <sup>Dr</sup>		
Spectro 90	Thiophanate methyl + Chlorothalonil	1 + M5	G, N, L	F-G <sup>Dr</sup>		F-G <sup>S</sup>				G <sup>S</sup>	G <sup>Dr</sup>	G <sup>S</sup>			F-G <sup>S</sup>	G <sup>Dr</sup>		Do not apply to green or variegated pittosporium or schefflera more than once.
Cleary 26/36	Thiophanate methyl + Iprodione	1 + 2		G <sup>Dr</sup>						G <sup>S</sup>	F-G <sup>Dr</sup>							
Chipco 26019/26 GT, Iprodione	Iprodione	2	G, N, L							F-G <sup>S</sup>	F-G <sup>Dr</sup>					F <sup>Dr</sup>		Do not apply as a soil drench on Impatiens and Pathos. Do not apply on Spathiphyllum.
Banner Maxx, Strider, Fathom <sup>1</sup>	Propiconazole	3	N, L			F <sup>S</sup>	F <sup>S</sup>			G <sup>S</sup>						G <sup>S</sup>	G <sup>Dr</sup>	May cause some growth regulator effects or phytotoxicity, in particular on rose.
Eagle, Hoist	Myclobutanil	3	G, N, L			F <sup>S</sup>				G <sup>S</sup>		F <sup>S</sup>				G <sup>S</sup>		Special use instructions for chrysanthemums. May prevent rooting on some Prunus spp. (e.g. sand cherry).
Fungaflor <sup>i</sup>	Imazalil	3	G													G <sup>S</sup>		
Rubigan	Fenarimol	3	N, L													G <sup>S</sup>		May cause leaf puckering and growth effects on some rose cultivars during cool and overcast conditions.
Strike	Triadimefon	3	Phased Out															Product is being phased out
Strike Plus	Triadimefon + Trifloxystrobin	3 + 11	G, N			F <sup>S</sup>				G <sup>S</sup>						G <sup>S</sup>		Do not apply on petunia, violets, or New Guinea impatiens. Do not apply on bearing fruit trees.
Terraguard <sup>1</sup>	Triflumizole	3	G, N, L	G <sup>Dr</sup>												G <sup>S</sup>		Do not apply on impatiens plugs; phytotoxic to some cultivars of impatiens.
Torque	Tebuconazole	3	N, L			F <sup>S</sup>				G <sup>S</sup>	F-G <sup>Dr</sup>					G <sup>S</sup>	G <sup>Dr</sup>	Not for homeowner use. Do not apply to bearing fruit trees or vegetables.
Tourney	Metconazole	3	N, L							G <sup>S</sup>						G <sup>S</sup>		May cause growth regulation on some ornamentals.
Trinity	Triticonazole	3	G							F <sup>S</sup>						G <sup>S</sup>		Total Release product in cannisters. For use on floricultural crops.
Clevis	Myclobutanil + Mancozeb	3 + M3	G, N, L			F <sup>S</sup>				G <sup>S</sup>						G <sup>S</sup>		
Concert <sup>i</sup>	Propoconazole + Chlorothalonil	3 + M5	N, L <sup>a</sup>			F <sup>S</sup>	F <sup>S</sup>			G <sup>S</sup>						G <sup>S</sup>		Do not apply on African violet, begonia, Boston fern, geranium, variegated and green pittosporium, and schefflera; may cause injury to buds, blooms, or tender new growth.
Subdue Maxx	Mefenoxam	4	G, N, L						G <sup>Dr, R</sup>					G <sup>Dr, R</sup>	P- G <sup>Dr, R</sup>			Some species of <i>Pythium</i> are insensitive to this product. A granular formulation of Subdue can also be mixed into the substrate.
Hurricane WDG	Mefenoxam + Fludioxonil	4 + 12	G, N											G <sup>Dr, R</sup>	P- G <sup>Dr, R</sup>	G <sup>Dr</sup>		
Pipron	Piperalin	5	G													G <sup>S</sup>		For use only in greenhouses and similar enclosed structures. May be phytotoxic on flower buds of some plants, check label.

Relative control rating: G= Good (100-80%); F=Fair (79-50%); P=Poor (49-0%) (Williams-Woodward et al. 2014).

Table 8 (cont'd). Relative effectiveness of various chemicals for disease control of ornamental plants.

Trade name	Active ingredient(s)	FRAC <sup>1</sup>	Sites <sup>2</sup>														Notes
				Bacterial leaf spots/blights	Black root rot	Cedar rusts	Conifer Tip Blights	Downy mildew	Fire blight	Fungal stem cankers	Fungal leaf spots	Fusarium stem rot	Passalora neesle blight	Phytophthora root rot	Powdery mildew	Rhizoctonia blight/root rot	
Pageant	Boscalid + Pyraclostrobin	7 + 11	G, N, L			F <sup>S</sup>		F <sup>S</sup>			G <sup>S</sup>	F-G <sup>Dr</sup>	F <sup>Dr</sup>	F <sup>Dr</sup>	G <sup>S</sup>	G <sup>Dr</sup>	Do not mix with organosilicone adjuvants. Impatiens and petunia flowers may become discolored after application. Do not apply on Ninebark or wintercreeper.
Compass O	Trifloxystrobin	11	G, N, L			F <sup>S</sup>					G <sup>S</sup>		F <sup>Dr</sup>		G <sup>S</sup>	F-D <sup>Dr</sup>	Do not mix with organosilicone adjuvants. May cause phytotoxicity on pansy.
Cygnus	Kresoxim methyl	11	G, N, L								G <sup>S</sup>				G <sup>S</sup>		Do not mix with organosilicone adjuvants; may be phytotoxic to some <i>Prunus</i> spp.
Disarm O	Fluoxastrobin	11	G, N					F <sup>S</sup>		F <sup>S</sup>	F <sup>S</sup>	F <sup>S</sup>	F <sup>Dr</sup>		F <sup>S</sup>	F <sup>Dr</sup>	Limited host plant list; mostly heraceous plants and roses.
FenStop	Fenamidone	11	G					F <sup>S</sup>		G <sup>S</sup>			F <sup>Dr</sup>	F <sup>Dr</sup>	G <sup>S</sup>		Do not apply to Oxalis.
Heritage	Azoxystrobin	11	G, N, L			F <sup>S</sup>		F <sup>S</sup>		G <sup>S</sup>	F-G <sup>Dr</sup>	G <sup>S</sup>	P <sup>Dr</sup>	P <sup>Dr</sup>	G <sup>S</sup>	G <sup>Dr</sup>	Do not mix with organosilicone adjuvants.
Empress	Pyraclostrobin	11	G, N								F-G <sup>Dr</sup>		P <sup>Dr</sup>	P-F <sup>Dr</sup>		G <sup>Dr</sup>	Do not mix with organosilicone adjuvants; Do not apply on Ninebark or Wintercreeper.
Palladium	Cyprodinil + Fludioxonil	9 + 12	G, N, L							F <sup>S</sup>					G <sup>S</sup>		Do not apply to leather leaf fern or field-grown fern harvested for floral arrangements; may leave residue on poinsettia with bracts.
Medallion	Fludioxonil	12	G, N, L		F <sup>Dr</sup>					F <sup>S</sup>	G <sup>Dr</sup>					G <sup>Dr</sup>	Do not apply on leather leaf fern; may cause stunting or chlorosis on impatiens and some varieties of geranium.
Mozart TR	Fludioxonil	12	G							F <sup>S</sup>							
Terraclor 400	PCNB	14	G, N, L											G <sup>Dr</sup>	G <sup>Dr</sup>		
Terrazole, Truban	Etridiazole	14	G, N, L <sup>b</sup>														
Decree	Fenhexamid	17	G, N														Only labeled for <i>Botrytis</i> .
Affirm, Veranda O, Endorse	Polyoxin D	19	G, N, L		G <sup>Dr</sup>			P-F <sup>S</sup>		F-G <sup>S</sup>	F <sup>S</sup>				F-G <sup>S</sup>	F-G <sup>Dr</sup>	
Segway	Cyazofamid	21	G, N, L					G <sup>S, Dr</sup>					G <sup>Dr</sup>	F-G <sup>Dr</sup>			
Agri-Mycin 17	Streptomycin	25	N, L						F <sup>S, R</sup>								Apply in foliar and bud sprays; Do not apply after fruit is visible.
Aliette WDG	Fosetyl AL	33	G, N, L	P-F <sup>S</sup>				G <sup>S</sup>					G <sup>S, Dr, Dr</sup>	G <sup>Dr</sup>	P <sup>S</sup>		Aliette is not compatible with flowable formulations of Daconil, Fore, or copper fungicides as tank mixtures.
Alude, Fosphite, K-Phite, Magellan	Mono- and di- potassium salts of phosphorous acid	33	G, N, L	P-F <sup>S</sup>				G <sup>S</sup>					G <sup>S, Dr, Dr</sup>		F <sup>S</sup>		Do not apply to plants under severe water stress or during very HIGH or very LOW temperatures.
Biophos	Dipotassium salts of phosphorous acid	33	G, N, L												F <sup>S</sup>		Do not tank mix with copper or surfactants.
Vital	Potassium phosphite	33	G, N, L					G <sup>S</sup>					G <sup>S, Dr</sup>		F <sup>S</sup>		Do not apply to plants under severe water stress or during very HIGH or very LOW temperatures.

Relative control rating: G= Good (100-80%); F=Fair (79-50%); P=Poor (49-0%).

Table 8 (cont'd). Relative effectiveness of various chemicals for disease control of ornamental plants.

Trade name	Active ingredient(s)	FRAC <sup>1</sup>	Sites <sup>2</sup>	Bacterial leaf spots/blights	Black root rot	Cedar rusts	Conifer Tip Blights	Downy mildew	Fire blight	Fungal stem cankers	Fungal leaf spots	Fusarium stem rot	Passalora needle blight	Phytophthora root rot	Pythium root rot	Powdery mildew	Rhizoctonia blight/root rot	Notes	
Micora	Mandipropamid	40	G, N															This product can also be used on vegetables sold to the retail market in GH with permanent flooring.	
Orvego	Dimethomorph + Ametoctradin	40 + 45	G, N <sup>c</sup>																
Stature SC	Dimethomorph	40	G, N															Active may settle out of solution; requires agitation if left to sit.	
Adorn	Fluopicolide	43	G, N, L															Adorn MUST be tank mixed for resistance management with another product that is registered for use against the target disease. Do not make more than one application of Adorn per crop on poinsettia--phytotoxicity has been observed with repeat applications.	
Camelot O	Copper octanoate	M1	G, N, L	F <sup>S</sup>						P <sup>S, R</sup>	F <sup>S</sup>							Do not tank mix with Aliette. Avoid contact with metal surfaces. Discoloration of blooms may occur on certain plant varieties: check label. Do not apply to hibiscus plants in flower.	
Cuproxat	Tribasic copper sulfate	M1	G, N	F <sup>S</sup>		F-G <sup>S</sup>	F <sup>S</sup>				F <sup>S</sup>	F-G <sup>S</sup>							
CuPRO, Nu-COP	Copper hydroxide	M1	G, N, L	F <sup>S</sup>							P <sup>S, R</sup>	F <sup>S</sup>	G <sup>S</sup>					Do not tank mix with Aliette. Avoid contact with metal surfaces.	
Kocide <sup>d</sup>	Copper hydroxide	M1	G, N, L										G <sup>S</sup>					Do not tank mix with Aliette. Avoid contact with metal surfaces.	
Phyton 27	Copper sulphate pentahydrate	M1	G, N, L	F <sup>S</sup>							P <sup>S, R</sup>	F <sup>S</sup>						May damage tender open blooms. Do not tank mix with B-NINE or use within 7 days of a B-NINE application.	
Phyton 35	Copper sulphate pentahydrate	M1	G, N, L	F <sup>S</sup>							P <sup>S, R</sup>	P <sup>S, R</sup>	F <sup>S</sup>					Do not apply within 7 days of B-NINE or within 14 days of acidic compounds or Aliette/phosphite applications.	
Junction	Copper hydroxide + Mancozeb	M1 + M3	G, N, L	F <sup>S</sup>							F <sup>S, R</sup>	G <sup>S</sup>						Injury may occur from late season application; no post-bloom applications on some plants, check label.	
Protect T/O, Fore, Dithane	Mancozeb	M3	G, N, L	F-G <sup>S</sup>	P-F <sup>Dr</sup>	F <sup>S</sup>		F <sup>S</sup>		F-G <sup>S</sup>	G <sup>S</sup>		G <sup>S</sup>				P <sup>S</sup>	P-F <sup>Dr</sup>	Not for use on marigold.
Daconil Ultrex/Weatherstik, Mainsail	Chlorothalonil	M5	G <sup>e</sup> , N, L <sup>a</sup>					F <sup>S</sup>											Do not combine in the spray tank with other pesticides or fertilizers unless tested first. Avoid applications during bloom period on some plants: check label. Do not apply on poinsettia during or after bract formation.
Milstop	Potassium bicarbonate	NC	G, N, L																Do not mix with other pesticides or fertilizers not compatible with mild alkaline solutions. Does not require the addition of a surfactant. Do not use on young pansies.
Regalia	Extract of Giant Knotweed ( <i>Reynou</i>	P	G, N, L								F to P <sup>S</sup>								Concentrations at 1% or higher applied on young tissue may cause phytotoxicity.
Cease	<i>Bacillus subtilis</i>	44	G, N, L	P-F <sup>S</sup>															

Relative control rating: G= Good (100-80%); F=Fair (79-50%); P=Poor (49-0%).

<sup>1</sup> Key to Fungicide Groups: 1: methyl benzimidazole carbamates; 2: dicarboxamides; 3: demethylation inhibitors; 4: phenylamides; 5: amines; 7: carboxamides, 9: anilino-pyrimidines; 11: quinone outside inhibitors; 12: phenylpyrroles; 14: aromatic hydrocarbons and heteroaromatics; 17: hydroxylanilides; 19: polyoxins; 21: quinone inside inhibitors; 33: phosphonates; 40: carboxylic acid amines; 43: benzimidazoles; 44: microbial; 45: quinone x-inhibitors. M: multi-site activity; NA: not classified; P: plant extract.

<sup>2</sup> Product labeled for use in G = greenhouse; N = nursery; L = landscape

Dr = Product should be applied as a drench

Di = Product can be applied as a plant- or cutting- dip

S = Product should be applied as a foliar spray

R = Resistance to this pesticide has been detected in the pathogen population

i = Incompatible with Rootshield

a = Do not apply to landscapes associated with apartment buildings, daycare centers, playgrounds, schools, athletic fields, etc...

b = Only Truban 5G can be used in outdoor beds; Terrazole is for commercial use ONLY; label restricts the use of Terrazole in residential greenhouses or indoor plant sites.

c = Orvego can be used in GH, lathhouses, shadehouses, hardwood and conifer plantations, interiorscapes, and outdoor / field nurseries.

d = Kocide is only labeled for use on conifers in Christmas tree plantings and silviculture nurseries.

e = Do NOT apply with mist blowers or high pressure spray equipment in greenhouses.

Note: Recommendations for the use of agricultural chemicals are included here as a convenience to the reader. The use of brand names and mention or listing of commercial products does not imply endorsement nor discrimination against similar products or services not mentioned. Individuals who use agricultural chemicals are responsible for ensuring that the intended use complies with current STATE regulations and conforms to the product label. Examine a current product label before applying any chemical. For assistance, contact your county Cooperative Extension agent.

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# Key Pest Profiles and Critical Issues: *Weedy Plants, Liverworts, and Algae*

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## *Weed Management Overview*

In container and field production operations, weeds (including liverworts and algae) compete with ornamentals for water, light and nutrients. Ornamental crop growth is often reduced as a consequence of this direct competition, particularly in container-grown crops. Indirectly, weeds can serve as refuge for plant pathogens (including viruses), nematodes, and arthropod pests (including white fly, two-spotted spider mites and broad mites) that inflict substantial damage to nursery crops. Furthermore, weeds can reduce marketability of the crop. Certain key weeds are ubiquitous throughout the southeastern United States (*see key weed profiles, below*) occurring in both container and field nursery environments. Typically, these weeds persist as management problems via:

- Multiple annual generations (with seeds that have limited to no dormancy)
- Rapid growth
- Early flowering
- Prolific or high-viability seed set
- Highly mobile seeds that can drift on wind or be dispersed in irrigation water or are thrown
- Production of durable regenerative structures, which allow re-growth
- Persistent and spreading perennial vegetative structures

There is no simple, one-step solution that will successfully control problem weeds in ornamental plant production operations in the southeastern United States. Growers and managers must begin by developing and practicing a sound sanitation plan for the entire nursery area. To efficiently control weed populations, attention and management of weeds in non-production and nursery border areas is also necessary. As weed problems develop, managers must accurately identify the weeds and have a clear understanding of the weed's life cycle before an environmentally and economically sound decision can be made regarding a Best Management Practice for weed control.

It is difficult to fit weed management into a traditional IPM framework focused on scouting, population thresholds and reduced pesticide inputs because *optimized* weed management strategies include the use of preemergence herbicides, a *preventive* control approach. Best Management Practices for “weed control” are confounded by presence of a spectrum of winter annual, summer annual, biennial, and perennial weed species, with sedges, grasses and broadleaf weeds all within a single production environment.

### ***Pre-Meeting Survey and Focus Group Results***

Growers participating in the PMSP focus group meeting were asked to complete a pre-survey about weed pests to determine their prevalence, difficulty to control, damage potential, and severity of injury (Table 1). These preliminary results were used to focus discussion during the meeting. New or emerging weeds discussed at the focus group meeting were included below in the Plant Profiles for Select Weeds for Container and Field Nurseries.

Table 9. Pre-meeting survey of weeds by a focus group of nursery crop growers from FL, GA, NC, TN, and VA.

Weeds	Focus Group Pre-Ranking <sup>1</sup>	Prevalence <sup>2</sup>	Difficulty to Control <sup>3</sup>	Damage Potential <sup>4</sup>	Severity of Injury <sup>5</sup>
Spurge	1	6.0	5.0	5.5	1.7
Oxalis/woodsorrel	2	5.8	4.8	4.7	1.7
Liverwort	3	5.3	5.0	3.8	2.4
Eclipta	4	5.2	4.8	4.5	1.5
Bittercress	5	5.7	4.3	5.7	1.7
Groundsel	6	4.4	4.2	4.2	1.6
Crabgrass	7	4.0	4.0	3.2	1.6
Nutsedge	8	5.0	4.4	3.9	1.4
Bermudagrass	9	4.4	3.8	4.3	1.8
Horseweed (marestail)	10	4.0	4.3	4.0	1.4
Chickweed	11	4.5	3.6	3.7	1.6
Glyphosate resistant horseweed (marestail)	12	4.1	6.0	5.0	1.2
Henbit	13	3.7	3.0	3.2	1.4
Glyphosate resistant pigweed	14	3.6	4.7	4.3	1.3
Morningglory	15	3.9	3.3	2.5	1.4
Pigweed	16	3.9	3.7	3.0	1.4
Annual bluegrass	17	3.6	2.8	3.8	1.4
Mulberryweed	18	3.0	4.5	3.0	1.4
Ragweed	19	3.3	3.3	2.5	1.4
Chamberbitter	20	2.8	3.0	2.5	1.5
Bindweed	21	3.0	3.0	2.5	1.5
Johnsongrass	22	2.7	3.0	2.5	1.3
Horsenettle	23	3.6	2.5	3.0	1.3
Glyphosate resistant johnsongrass	24	2.7	3.0	3.0	1.3
Mugwort (wild chrysanthemum)	26	3.5	3.0	3.5	1.5

<sup>1</sup>Focus group pre-ranking = Focus group attendees completed a pre-meeting survey and ranked weeds based on highest priority. Weed species are listed from highest importance to lowest importance.

<sup>2</sup>Prevalence; 1=Don't know this weed; 2=Not found at site; 3=Rare (can hand pull); 4=Occasional (spot treat only if found); 5=Common (part of regular monitoring effort); 6=Actively managed every year. Means of the likert-type scale are presented without the response for "1=Don't know this weed" included.

<sup>3</sup>How easy or difficult to control is this weed. 1=Not applicable; 2=Easy; 3=Somewhat easy; 4=Moderate; 5=Somewhat difficult; 6=Difficult. Means of the likert-type scale are presented without the response for "1-Not Applicable" included.

<sup>4</sup>Estimated proportion of grower's most susceptible crop that is infested by this weed. 1=Not applicable; 2=0%; 3=1-5%; 4=6-15%; 5=16-25%; 6=>25%. Means of the likert-type scale are presented without the response for "1-Not Applicable" included.

<sup>5</sup>Please indicate the influence of weed injury on affected ornamental crops you grow. 1=Salable crop (easily hand-weeded or weeds acceptable); 2=Seasonal sale delayed until hand-weeded & new PRE applied; 3=Seasonal sale unlikely, hand-weed, transplant, & new growth & PRE application applied; 4=Quality of sale lost (grade reduced); 5=Total crop loss. Means are presented.

## *Plant Profiles for Select Weeds<sup>1</sup> for Container and Field Nurseries*

Named weeds may be problematic to ornamental plant production in field (**F**), container (**C**), or both systems (**B**). If both, the predominant system challenged by the weed may be indicated by an asterisk (\*).

<sup>1</sup>The following descriptions highlight many of the common and problematic weeds of nursery crops within the region but are not a comprehensive list of all problematic species. Each nursery will have many other species present at varying population densities, which must be considered when developing an integrated weed management plan. For example, morningglory, hedge bindweed, horsenettle, cudweed, lambsquarters, ragweed, and fall panicum are all common production challenges, but were not specifically identified during the two-day workshop. A systematic survey of weeds in southeastern United States nurseries is needed.

### *Select Broadleaf Weeds*

#### **Perennial Broadleaf Weeds:**

- Capable of living more than two years
- Primarily spread by seed produced in spring/early summer
- Some are capable of vegetative reproduction
- Controlled primarily by nonselective postemergence herbicides

#### **Summer Annual Broadleaf Weeds:**

- Mature in one season, seeds germinate in the spring or summer, flower in summer, sets seeds, then die in the fall.
- Die in fall or are killed by frost
- Controlled with well-timed preemergence herbicides (PRE) or kept in check with postemergence herbicides (POST)

#### **Winter Annual Broadleaf Weeds:**

- Mature in one season
- Seeds germinate in fall (some may germinate in early spring), overwinter as seedlings, flower in spring
- Die with warm weather (spring or early summer) as temperatures exceed 80°F
- Controlled with well-timed, selective preemergence herbicides or nonselective postemergence herbicides

## Select Broadleaf Weed Profiles

### Chickweed Species

(Common chickweed = *Stellaria media* [STEME]); mouseear chickweed = *Cerastium fontanum* spp.vulgare) [CERVU] (B)

#### Distribution, Damage and Importance, Origin:

- Both species are widespread and introduced

#### Life Cycle:

- Both chickweed species produce copious amounts of seeds.
- STEME is a winter annual
- CERVU may function as a short-lived perennial weed but generally displays a winter annual life cycle in the South.

#### Control Measures:

##### Cultural/Mechanical Control:

- Hand weeding or cultivation provides temporary control.
- Mulches are somewhat effective.

##### Biological Control:

- None noted.

##### Chemical Control:

- Both chickweed species can be controlled with PRE herbicides or non-selective POST.
- No selective POST control is available.

#### Field Diagnostic:

- Flowers – 5-white petals are each split nearly to the base.
- CERVU has vigorous growth that forms a denser mat of growth with stems and leaves that are covered with fine setae or hairs.
- STEME leaves are nearly hairless.

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

**Critical Issues and Needs:**

- Increased knowledge of PRE efficacy and longevity of PRE residual activity

*Common Groundsel*

(*Senecio vulgaris* L.) [SENVU] (B, C\*)

**Distribution, Damage and Importance:**

- Is widespread in the southeastern United States.
- Introduced

**Life Cycle:**

- Annual
- More common in cool weather but can persist year round in southeastern U.S.
- Wind-dispersed seed has no dormancy requirements, which produces multiple generations per year.

**Control Measures:****Cultural/Mechanical Control:**

- Sanitation – prevent infestations by preventing plants from going to seed.
- Seedlings removed relatively easily by hand, but re-establishment from seed is rapid.

**Biological Control:**

- A European rust-causing organism is present in the southeastern U.S., but is not significantly affecting common groundsel populations.

**Chemical Control:**

Few PRE herbicides are effective.

**Field Diagnostic:** yellow flowers, Seedhead resembles a dandelion, though smaller.

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted

**Critical Issues and Needs:**

- Resistance to triazine and some dinitroaniline herbicides has been noted.
- Efficacy data are needed to expand current PRE and POST herbicide labels.

*Doveweed*

(*Murdannia nudiflora*) [MURNU] C\*

**Distribution, Damage and Importance, Origin:**

- Widespread in the southeastern United States.
- Dense, fibrous root system.
- Prefers shady, moist sites
- Not well controlled by most PRE or POST herbicides.

**Life Cycle:**

- Summer annual, reproduces by seed.
- Germinates in late spring or early summer, much later than many other summer annual weeds.

**Control Measures:****Cultural/Mechanical Control:**

- Hand weeding is difficult as seedlings are very small and mature plants are mat-forming. Pieces left on the ground re-establish.

**Biological Control:**

- None noted.

**Chemical Control:**

- Few effective control options are available.
- Few PRE herbicides are effective.

- Most common POST herbicides are ineffective.
- No POST options available for containers.

**Field Diagnostic:** leaves grass-like, stem succulent, small purplish flowers

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted

**Critical Issues and Needs:**

- Often worse in conjunction with heavy irrigation and/or poor drainage
- Research needed on environmental conditions for reproduction and spread, as well as selectivity/efficacy of PRE and POST herbicides.

*Eclipta*

(*Eclipta prostrata*; syn. *E. alba*) [ECLAL] (**B, C\***)

**Distribution, Damage and Importance, Origin:**

- Widespread in the southeastern United States
- Dense fibrous root system
- Rapid growth in warm weather resulting in competition for water and nutrients
- Can grow in drain holes of pots

**Life Cycle:**

- Summer annual that may persist through the winter in warmer regions of the southeastern U.S.
- Reproduces by seed

**Control Measures:**

**Cultural/Mechanical Control:**

- Hand weeding is difficult as plants establish extensive root systems in containers.

**Biological Control:**

- None noted

**Chemical Control:**

- Few effective control options are available
- Few PRE herbicides are effective
- No POST options available for containers

**Field Diagnostic:**

- An aster (composite flowers) with reduced white petals and fleshy stems

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

**Critical Issues and Needs:**

- Often worse in conjunction with heavy irrigation
- Research needed on environmental conditions for reproduction and spread
- Selectivity/efficacy of PRE and POST herbicides

*Evening Primrose Species*

(*Oenothera* spp.) (cutleaf evening primrose [OEOLA]; common evening primrose [OEObI]; showy evening primrose [OEOSP]) (F)

**Distribution, Damage and Importance, Origin:**

- Widespread
- Native

**Life Cycle:**

- Winter annual or biennial
- Flowers May – Oct
- Tap rooting
- Reproduction by seed

## **Control Measures:**

### **Cultural/Mechanical Control:**

- Hand removal of taproot is difficult.

### **Biological Control:**

- None noted.

### **Chemical Control:**

- Few effective herbicides
- PRE herbicides are effective when timed appropriately
- Limited efficacy with POST herbicides. Some tolerance (not resistance) to glyphosate has been observed

**Field Diagnostic:** most species have yellow flowers, leaves have a prominent mid-vein.

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### **Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

### **Critical Issues and Needs:**

- Efficacy data needed to expand current PRE and POST herbicide labels.

### *Flexuous Bittercress*

(*Cardamine flexuosa*) [CARFL] (pepperweed, shotweed, snapweed) (**B, C\***)

### **Distribution, Damage and Importance, Origin:**

- The most common cool-season broadleaf weed in container nurseries.
- Introduced from Europe
- Currently distributed throughout North America
- Multiple bittercress species are present in container nurseries
- Dominant species differ between container nurseries and field/landscape plantings.

**Life Cycle:**

- Winter annual that can persist season-long in moist, cool environments.
- Seedpods (siliques) are explosively dehiscent.
- 5,000+ seeds per plant
- Seed viability is about 90%
- Seeds of *C. flexuosa* appear to have no dormancy requirements, leading to multiple generations per season. Other species produce seeds that are dormant.

**Control Measures:****Cultural/Mechanical Control:**

- Hand weeding will miss many seedlings.
- Mulches are only partially effective.
- Considered to be the most expensive weed to control in container nurseries due to rapid dissemination, resulting in a high cost for hand removal.

**Biological Control:**

- None noted.

**Chemical Control:**

- Most commonly managed using PRE herbicides.
- Resistance to isoxaben has been reported for this species.
- No selective POST herbicides are available besides isoxaben which controls very small seedlings.

**Field Diagnostic:** small white flowers, cigar-shaped seedpod

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

**Critical Issues and Needs:**

- Timing is key and often is missed with regard to seed germination and PRE use.
- Multiple generations and continuous germination result in re-establishment between control events (herbicide treatments, hand weeding, cultivation etc).
- Research is needed on the germination requirements, seed biology and fecundity of *C. flexuosa*.

## Henbit

(*Lamium amplexicaule*) [LAMAM] (dead nettle) (F)

### **Distribution, Damage and Importance, Origin:**

- Widespread
- Fibrous root system

### **Life Cycle:**

- Winter annual
- By seed (some produced via cleistogamy)

### **Control Measures:**

#### **Cultural/Mechanical Control:**

- Cultivation and mulches are effective.
- In shady, moist areas, mulches are less effective.

#### **Biological Control:**

- None noted.

#### **Chemical Control:**

- Several PRE herbicides are effective when timed appropriately.
- Careful selection of PRE herbicides is important due to variable responses between similar herbicides.
- Non-selective POST herbicides are effective.

**Field Diagnostic:** square stem, purple flowers

### **Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted

### **Critical Issues and Needs:**

- Grower education is needed. Low growing winter annuals such as henbit are generally not competitive with field-grown woody nursery crops.
- Selective POST options are needed

## Horseweed

(*Conzya canadensis*) [ERICA] (marestalk; fleabane) (B)

### **Distribution, Damage and Importance, Origin:**

- Wide-spread
- Erect growth habit can compete with crops for light. Erect stems may interfere with shearing operations.
- Glyphosate-resistant populations of horseweed are common
- Native

### **Life Cycles:**

- Winter or summer annual; historically horseweed is considered a winter annual that germinates in fall with limited germination in spring. Research, however, suggests the species has adapted to cropping systems and greater numbers of seeds now germinate in the spring, resulting in a summer annual life cycle.
- Flowers and seeds in late summer
- Copious seed sets are wind dispersed

### **Control Measures:**

#### **Cultural/Mechanical Control:**

- Cultivation is effective.
- Hand-weed to remove broken stems.

#### **Biological Control:**

- None noted.

#### **Chemical Control:**

- Several effective PRE herbicides are available, but application timing is critical.
- Glyphosate resistance is widespread.
- Other nonselective POST herbicides are effective on young seedlings but less effective on established plants.

**Field Diagnostic:**

- Forms a rosette of hairy leaves before bolting 3' to 9' tall in summer.

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

**Critical Issues and Needs:**

- Glyphosate resistance is widespread in portions of the southeastern US.
- Selective POST control options are needed.

*Liverwort*

(*Marchantia polymorpha* and similar species.) (C)

**Distribution, Damage and Importance, Origin:**

- Widespread
- Liverwort is not competitive for water or nutrients, but the vegetative growth can cover the tops of pots and exclude irrigation, thus resulting in crop loss.
- One of the most difficult to control weeds in covered houses, propagation nurseries and liner production.
- Introduced, unknown origin

**Life Cycle:**

- A primitive, non-vascular plant
- Reproducing by windborne spores, by small vegetative propagules called gemmae moved in slashed water droplets, and by fragmentation on contaminated substrate, containers, and propagation (liner) stock
- Vegetative mats go dormant in winter and dry out in summer but will re-grow when temperatures and moisture are conducive.

**Control Measures:****Cultural/Mechanical Control:**

- Increase solar (UV) exposure, decrease humidity, and limit irrigation

- Hand removal is a temporary control measure
- Sanitation
- Some mulches have shown promise in reducing liverwort

**Biological Control:**

- None.

**Chemical Control:**

- Few herbicides are labeled for *Marchantia* control
- Research with PRE herbicides has demonstrated variable results with excellent control in some trials and poor control in others.
- Few herbicides are labeled for use in covered structures where liverwort is most common.
- No selective POST herbicides are available
- Non-selective treatments such as acetic acid, long-chain fatty acids, natural oils, and diquat are effective for contact burn down, but regrowth can be rapid.

**Field Diagnostic:**

- Broad, flat, leaf-like structures
- No true roots or stems
- Small cups on “leaf” surfaces containing vegetative propagules (gemmae)

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted

**Critical Issues and Needs:**

- No effective treatments are available that are safe to ornamental crops at greatest risk of infestation.
- No selective POST herbicides are available
- Non-selective treatments such as acetic acid, long-chain fatty acids, natural oils, and diquat are effective for contact burn down, but regrowth can be rapid.
- Growers are unfamiliar with this plant and would benefit from better understanding its life cycle and control options
- Efficacy data are needed to expand current PRE and POST herbicide labels.

## *Morningglory*

(*Ipomoea spp.* ) several species are of importance in the Southeastern US. (F)

### **Distribution, Damage and Importance, Origin:**

- Widespread in southeastern U.S.
- Vining growth habit will disfigure crops, and, if left un-controlled can result in complete crop losses.

### **Life Cycle:**

- Summer annual vine
- Reproduction is by seed

### **Control Measures:**

#### **Cultural/Mechanical Control:**

- Seedlings are controlled by cultivation
- Not controlled by mulches
- Difficult to hand weed

#### **Biological Control:**

- None available.

#### **Chemical Control:**

- Not well controlled by most PRE herbicides
- POST herbicides are effective on young seedlings.

**Field Diagnostic:** vining growth form, white, blue or purple flowers in a funnel shape

### **Federal/State/Local Regulation and Pesticide Restrictions:**

- Noxious or prohibited in two states.

### **Critical Issues and Needs:**

- Very competitive weed with few effective control options
- Research is needed to identify effective PRE and POST herbicides.

## Mugwort

(*Artemisia vulgaris*) [ARTVU] (wild chrysanthemum; wormwood) **(B, F\*)**

### **Distribution, Damage and Importance, Origin:**

- Common in northeastern U.S.
- Becoming widespread in the southeastern U.S. via contaminated soil on equipment as well as balled and burlapped and liner stock.
- Introduced from Europe
- Very difficult to control in nursery crops and spreads rapidly once introduced into a field.

### **Life Cycle:**

- Perennial
- Reproduction is by rhizome pieces as short as 0.5 cm.
- Mugwort rarely reproduces via seeds but is known to do so in nurseries.

### **Control Measures:**

#### **Cultural/Mechanical Control:**

- Mowing is ineffective.
- Cultivation increases stand density, vigor and spread.

#### **Biological Control:**

- None noted.

#### **Chemical Control:**

- Broadcast, multiple applications of nonselective POST herbicides for multiple years is typical. Dichlobenil may be used in certain woody species.

### **Field Diagnostic:**

- Leaves of mugwort are similar in appearance to those of ornamental chrysanthemum, but mugwort does not have showy flowers.
- Leaf undersurfaces are white, covered with dense, fine hairs
- White, fleshy, creeping rhizomes

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

**Critical Issues and Needs:**

- Efficacy data are needed to expand current PRE and POST herbicide labels

*Musk Thistle*

(*Carduus nutans*) [CRUNU] (nodding plumeless thistle) **(B, F\*)**

**Distribution, Damage and Importance, Origin:**

- Important only in certain locations
- Non-native

**Life Cycle:**

- Biennial or winter annual
- Flowers June – Oct.
- Produces windborne seed

**Control Measures:**

**Cultural/Mechanical Control:**

- Cultivation controls seedlings

**Biological Control:**

- Two seed-feeding beetles provide population reductions.

**Chemical Control:**

- Few PRE and POST herbicides are labeled for control.

**Field Diagnostic:** leaf margins have spines, pink, purple, or white flowers

**Federal/State/Local Regulation and Pesticide Restrictions:**

- Federal and State noxious weed.

**Critical Issues and Needs:**

- Efficacy data is needed to expand current PRE and POST herbicide labels.
- Emergence timing is not well defined.

Pigweed

(*Amarathus* spp.) (slender amaranth [AMAVI]; smooth pigweed [AMACH]; redroot pigweed [AMARE], palmer amaranth [AMAPA], prostrate pigweed [AMALI], and others) (**B, F\***)

**Distribution, Damage and Importance, Origin:**

- Widespread
- Dense, competitive root system.
- Rapid growth rate
- Competitive for light and water
- Herbicide resistance is common
- Native

**Life Cycle:**

- Summer annual
- By seed

**Control Measures:**

**Cultural/Mechanical Control:**

- Controlled by mulches
- Cultivation controls seedlings but stimulates new germination.
- Young seedlings easily removed by hand but established plants have extensive root systems.

**Biological Control:**

- None available.

**Chemical Control:**

- PRE herbicides are effective.
- Resistance to some POST chemistry is known. Specifically, Palmer amaranth populations resistant to glyphosate and ALS-inhibiting herbicides are widespread.

**Field Diagnostic:** typically a reddish taproot, upright growth habit, small shiny black seeds

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

**Critical Issues and Needs:**

- Resistance to glyphosate and ALS -inhibiting herbicides is now widespread in agronomic and horticultural cropping systems.
- Prostrate pigweed incidence is increasing in container nurseries and landscape plantings. This species appears to differ from other members of this genus in several ways that leads to multiple populations per year. Yet, little is known of its biology or management.

*Sicklepod*

(*Senna obtusifolia*; syn. *Cassia obtusifolia* ) [CASOB] (coffeeweed; Java bean) (F)

**Distribution, Damage and Importance, Origin:**

- Widespread in southeastern U.S
- Native to North American tropics (between 23.5 degrees latitude north and south)

**Life Cycle:**

- Summer annual
- Reproduction is by seed
- Plant tissues are toxic to livestock

**Control Measures:****Cultural/Mechanical Control:**

- Seedlings are controlled by cultivation

**Biological Control:**

- Several biocontrol agents have been reported, but none are commercially available

**Chemical Control:**

- Not well controlled by most nursery herbicides
- Glyphosate or clopyralid are effective POST

**Field Diagnostic: yellow flowers, bean-shaped fruit, compound leaves**

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted

**Critical Issues and Needs:**

- Not well controlled by many PRE and POST herbicides.
- Research is needed to identify effective PRE and POST herbicides.

*Smartweed*

(*Polygonum caespitosum*) [POLBL], *P. persicaria* [POLPE], & *P. pensylvanicum* [POLPY]  
(tufted smartweed; ladysthumb, Pennsylvania smartweed; ) (**B, F\***)

**Distribution, Damage and Importance, Origin:**

- Widespread
- Prefers moist soil

- Very competitive
- Used as a trap crop for Japanese beetles
- Introduced from Asia

**Life Cycle:**

- Summer annual
- Dense fibrous root system
- Reproduction is by seed

**Control Measures:**

**Cultural/Mechanical Control:**

- Seedlings controlled by cultivation.

**Biological Control:**

- No biological controls are noted.

**Chemical Control:**

- Few PRE herbicides are labeled for controlling smartweed, but those that are available are effective when properly timed.

**Field Diagnostic:** pinkish-white flowers, presence of an ocrea

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

**Critical Issues and Needs**

- Efficacy data are needed to expand current PRE and POST herbicide labels.
- Germination requirements and emergence timing are not well defined.

## Spotted Spurge

(*Chamaesyce maculata*; syn. *Euphorbia maculata*) [EPHMA] (B, C\*)

### Distribution, Damage and Importance, Origin:

- Widespread in southeastern U.S.
- The most common summer annual broadleaf weed in container nursery crop production.
- Tolerates traffic and soil compaction
- Native
- Several closely-related species are important in nurseries including *C. prostrata* [EPHPT], *C. serpents* [EPHSN], *C. hysoppifolia* [EPHHS], and *C. hirta* [EPHHI]

### Life Cycle:

- Mat-forming summer annual
- Prolific seed set
- Multiple generations per year

### Control Measures:

#### Cultural/Mechanical Control:

- Cultivation and hand weeding will miss seedlings.
- Mulches are often ineffective

#### Biological Control:

- None noted.

#### Chemical Control:

- PRE, or non-selective POST when spurge is actively growing.
- No selective POST options are available

### Field Diagnostic:

- Milky sap exuded from broken stems helps differentiate prostrate spurge from purslane or knotweed.

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted

**Critical Issues and Needs:**

- Aggressive weed
- Difficult to control in containers and challenging to remove via handweeding
- May display some herbicide resistance
- Some differential herbicide tolerance between species has been reported
- No selective POST control options

*Wild Carrot*

(*Daucus carota*) [DAUCA] (Queen Anne's Lace) (F)

**Distribution, Damage and Importance, Origin:**

- Widespread
- Introduced

**Life Cycle:**

- Biennial (rosette in year 1)
- Reproduces by seeds

**Control Measures:****Cultural/Mechanical Control:**

- Long taproot makes hand removal difficult.
- Cultivation less effective on established plants.

**Biological Control:**

- Host plant resource for natural enemies of arthropod pests
- No biological controls

**Chemical Control:**

- Few herbicides labeled.

**Field Diagnostic:** leaves resemble carrot leaves but plant has a small taproot

**Federal/State/Local Regulation and Pesticide Restrictions:**

- Class B or secondary noxious weed in some midwestern states.

**Critical Issues and Needs:**

- Few PRE or POST herbicides are labeled for control. Efficacy data are lacking.

*Wild Mustard*

(*Brassica kaber*; syn. *Sinapis arvensis*) [SINAR] (common mustard, field kale) (**B, F\***)

**Distribution, Damage and Importance, Origin:**

- Widespread
- Introduced

**Life Cycle:**

- Winter annual
- Reproduction by copious production of seeds
- Seeds persist for years in the soil bank.

**Control Measures:****Cultural/Mechanical Control:**

- Controlled by cultivation and living mulches

**Biological Control:**

- None noted

**Chemical Control:**

- Several PRE herbicides are available

**Field Diagnostic:** yellow flowers, thin cigar-shaped seed pods

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

**Critical Issues and Needs:**

- Related species may differ in emergence patterns.
- Timing of control procedures influences control achieved.

*Woodsorrel Species*

(*Oxalis* spp.) (oxalis) (**B, C\***)

**Distribution, Damage and Importance, Origin:**

- Widespread
- Origin is unclear

**Life Cycle:**

- Prolific seeds produced from explosively dehiscent seedpods.
- Seeds have no dormancy requirements.
- Yellow woodsorrel (*O. stricta*) is a herbaceous annual (occasionally perennial) that reproduces by seeds and may spread by rhizomes.
- Creeping woodsorrel (*O. corniculata*) is similar but with a strongly prostrate growth habit, which spreads by seeds, stolons, or rhizomes.

**Control Measures:**

**Cultural/Mechanical Control:**

- Sanitation is critical to prevent weed spread.
- Hand weeding is inefficient because young seedlings are very small, and older plants produce stolons or rhizomes that are difficult to remove.

**Biological Control:**

- None noted.

**Chemical Control:**

- Controlled by well-timed PRE applications.
- No selective POST herbicides are available.

**Field Diagnostic:**

- Looks similar to clover but produces a 5-petaled yellow flower and heart-shaped leaflets.

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

**Critical Issues and Needs:**

- Acts as a host plant refuge for whiteflies and spider mites
- Forms stolons and rhizomes, making it challenging to remove via hand-weeding
- Control options in propagation or liner production are needed.

## *Select Grasses and Sedges*

### **Perennial Grass Weeds:**

- Controlled using a limited number of selective herbicides

### **Annual Grass Weeds:**

- Produces abundant seed.
- Displays vigorous growth.
- Dense root systems are highly competitive.
- Stimulated by frequent irrigation, poor drainage, excessive fertilization, and compaction.
- Controlled using timed PRE herbicides.

### **Sedges & Rushes:**

- Thrive in wet or poorly drained soils and survive in dry areas.
- Proper identification and an understanding of the biology of sedges is essential for effective management.
- Annual and perennial species: perennial species are the most difficult to control.
  - PRE herbicides are typically not effective.
  - POST herbicide options are limited and require repeat applications to achieve adequate control.
  - Lack of labels for the use of effective herbicides in nurseries.
  - Ornamental phytotoxicity data for POST applications are lacking.
- As a general rule, sedges are more of a problem in warmer climates.

## Select Weedy Grasses and Sedges

### Annual Bluegrass

(*Poa annua*) [POANN] (B)

#### Distribution, Damage and Importance, Origin:

- Widespread
- Introduced

#### Life Cycle:

- Winter annual grass
- Prolific seed set
- Germination occurs from early fall through spring.

#### Control Measures:

##### Cultural/Mechanical Control:

- Reduce irrigation during seasons of peak germination
- Mulches can be effective, but cultivation generally is not.

##### Biological Control:

- None noted.

##### Chemical Control:

- PRE herbicides are effective when timed appropriately
- One selective POST option
- Nonselective POST control with glyphosate

#### Field Diagnostic:

- Clump forming grass
- Light “apple” green in color
- Prow-shaped leaf tips.
- Whitish seedhead in spring

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

**Critical Issues and Needs:**

- Appropriate timing for PRE herbicide is the key challenge for effective control.
- Difficult to control in containers and challenging to remove via hand-weeding.
- Resistance to dinitroaniline herbicides has been reported in other crops.

*Bermudagrass*

(*Cynodon dactylon*) [CYNDA] (B, F\*)

**Distribution, Damage and Importance, Origin:**

- Widespread in southeastern U.S.
- Vigorous and aggressive root system
- Drought tolerant
- Introduced

**Life Cycle:**

- Perennial, warm-season grass
- Tolerant of a broad range of soil and climatic conditions
- Reproduction is by seeds, rhizomes and stolons

**Control Measures:****Cultural/Mechanical Control:**

- Hand-weeding is futile
- Cultivation and mulching are ineffective and may encourage growth and spread.

**Biological Control:**

- None noted.

**Chemical Control:**

- PRE control of plants is possible, but most infestations arise from vegetative propagules

- POST treatments require multiple applications throughout the season and over multiple years.

**Field Diagnostic:** aggressive rhizome and stolon production, narrow leaves, seedhead resembles crabgrass seedhead.

**Federal/State/Local Regulation and Pesticide Restrictions:**

- State noxious weed in CA, UT and AR

**Critical Issues and Needs:**

- PRE and POST herbicide efficacy data are needed. In particular, little data is available on controlling bermudagrass from seed.
- Particularly problematic when infesting ornamental grass production and plantings.
- Research is needed to determine effective products that can be used against bermudagrass without nearby ornamental plants experiencing phytotoxicity.

*Goosegrass*

(*Eleusine indica*) [ELEIN] (B, F\*)

**Distribution, Damage and Importance, Origin:**

- Widespread
- Forms a competitive and dense root system
- Tolerates compact soils and traffic
- Introduced

**Life Cycle:**

- Summer annual
- Reproduction is by seed
- Germinates later than crabgrass

**Control Measures:****Cultural/Mechanical Control:**

- Hand-weeding is difficult due to the plant's dense root system and prostrate growth habit.

**Biological Control:**

- None noted

**Chemical Control:**

- Several PRE and POST options are available, but herbicides are often less effective against goosegrass than crabgrass.

**Field Diagnostic:**

- Does not root at the nodes like crabgrass. Plant has a whitish base.

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

**Critical Issues and Needs:**

- At warm soil temperatures (> 65°F), seeds germinate about 2-3 weeks later than crabgrass.
- Seed germination may be tracked via climatic modeling

*Johnsongrass*

(*Sorghum halpense*) [SORHA] (F)

**Distribution, Damage and Importance, Origin:**

- Widespread
- Dense, competitive root system
- Tall, rapid growth competes with crops for light, water and nutrients.
- Introduced from Eurasia

**Life Cycle:**

- Perennial
- Flowers June-July
- Reproduces by seed and aggressive rhizomes

**Control Measures:****Cultural/Mechanical Control:**

- Cultivation can increase the density of stands, and contaminated soil on equipment can infest new areas.
- May be managed by close, frequent mowing, or by frequent cultivation.

**Biological Control:**

- None noted.

**Chemical Control:**

- Controlled from seed by several PRE herbicides
- Selective and non-selective POST herbicides are available but require multiple applications over several years to achieve adequate control.

**Field Diagnostic:** whitish midrib, corn-like plant, aggressive rhizome production, upright growth form. Reaches 5 feet tall or more.

**Federal/State/Local Regulation and Pesticide Restrictions:**

- A noxious or prohibited weed in several states

**Critical Issues and Needs:**

- Herbicide efficacy and timing data are needed for both PRE and POST herbicide chemistries.
- Reliance on glyphosate for johnsongrass control is common. Although it is not widespread at this point in time, resistance to glyphosate has been reported. Resistant populations are likely to spread, thus alternative management strategies are needed.

## *Large Crabgrass*

(*Digitaria sanguinalis* L.) [DIGSA] (B)

### **Distribution, Damage and Importance, Origin:**

- Widespread except in FL where other species of crabgrass are dominant.

### **Life Cycle:**

- Summer annual grass
- Prolific seed set
- Roots easily at nodes
- Several similar species are present in the southeastern U.S. with similar life cycles and control.

### **Control Measures:**

#### **Cultural/Mechanical Control:**

- Cover crops suppress large crabgrass emergence
- Mulches, cultivation or hand weeding of young seedlings are effective options
- Older plants are not well controlled mechanically

#### **Biological Control:**

- None noted.

#### **Chemical Control:**

- PRE herbicides are effective when properly timed and generally need to be reapplied to extend season-long control.
- Selective and non-selective POST herbicides require repeated applications.

**Field Diagnostic:** roots at the nodes, seedhead resembles fingers on a hand

### **Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted

### **Critical Issues and Needs:**

- In containers, crabgrass is challenging to remove via hand-weeding.

- Seeds germinate at cool soil temperatures (53-58°F).
- Germination may be tracked via climatic modeling.

### *Wild Garlic*

(*Allium vineale* [ALLVI]) & **WILD ONION** (*A.canadense* [ALLCA]) (F)

#### **Distribution, Damage and Importance, Origin:**

- Widespread
- Introduced

#### **Life Cycle:**

- Seed, aerial bulbils and underground bulblets

#### **Control Measures:**

##### **Cultural/Mechanical Control:**

- Infrequent cultivation can spread infestations.
- Frequent cultivation can provide control.
- Mulches are ineffective.
- Cover crops can suppress wild garlic.

##### **Biological Control:**

- None noted

##### **Chemical Control:**

- Very few herbicides are effective.

#### **Field Diagnostic:**

- Has a garlic odor when crushed
- Wild onion has a fibrous coat on the central bulb and does not produce bulblet offsets

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted

**Critical Issues and Needs:**

- PRE and POST herbicide efficacy evaluations are needed
- Herbicide efficacy testing should include assessments of surfactants

*Yellow Nutsedge*

(*Cyperus esculentus*) [CYPES] (B, F\*)

**Distribution, Damage and Importance, Origin:**

- Yellow nutsedge is widespread throughout the southeastern U.S.
- A similar species, purple nutsedge (*Cyperus rotundus* [CYPRO]), is less common and more difficult to control.
- Its densely-fibrous root system is a strong competitor with ornamental plants.

**Life Cycle:**

- Cold-tolerant perennial sedge
- Reproduction is by rhizomes and tubers, rarely by seed.

**Control Measures:****Cultural/Mechanical Control:**

- Hand-weeding fails to remove rhizomes and tubers.

**Biological Control:**

- Several have been investigated, but none have been sufficiently efficacious to be marketed.

**Chemical Control:**

- Few PRE herbicides provide suppression.
- Few selective POST options provide adequate control.
- Nonselective herbicides are effective but require multiple applications.

**Field Diagnostic:**

- *C. esculentus* has triangular stems and leaf tips that gradually extend to a point and a yellow seedhead.
- *C. rotundus* has a similar appearance, but with a blunt point at the leaf tip and brownish-purple seed heads.
- *C. rotundus* tubers are produced in chains (versus singly for *C. esculentus*).
- *C. rotundus* is less susceptible to herbicides and is less cold tolerant.
- Several annual sedges are common in container nurseries; these species lack rhizomes or tubers.
- *Kyllinga* spp., while still rare in nurseries, are becoming more common, and are more difficult to control than *Cyperus* spp.

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted

**Critical Issues and Needs:**

- Limited herbicide options
- Inconsistent control
- Herbicide efficacy and timing data are needed for both PRE and POST herbicide chemistries.

## *Emerging Weed Species of Concern*

### *American Burnweed*

*(Erechtites hieraciifolia)* [EREHI] (B)

#### **Distribution, Damage and Importance, Origin:**

- Becoming widespread
- Native

#### **Life Cycle:**

- Summer annual
- Seedlings emerge over an extended period of time
- Wind-dispersed seeds from flowers held erect on stems exceeding 4' height
- Dense and competitive root system



#### **Control Measures:**

##### **Cultural/Mechanical Control:**

- Hand weeding may result in removal of large volumes of container substrate.
- Do not let plants mature to flowering.
- Prevent plants on the perimeter of the property from going to seed.

##### **Biological Control:**

- None noted.

##### **Chemical Control:**

- Some PRE herbicides are effective when appropriately timed.

**Field Diagnostic:**

- Stems of burnweed produce abundant adventitious roots near soilless substrates or in contact with ground fabric due to high humidity.
- Nonnative *Crassocephalum crepidiodes* has reddish flowers that droop and is shorter than American burnweed, which can reach 4 feet in height.

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

**Critical Issues and Needs:**

- Efficacy data is needed to expand current PRE and POST herbicide labels.
- Conditions for germination are not well understood.

*Asiatic Hawksbeard*

(*Youngia japonica*) [UOUJA] (C)

**Distribution, Damage and Importance, Origin:**

- Throughout the southeastern U.S.
- Introduced from Asia
- Anecdotal reports suggest that this species may adversely affect people with asthma

**Life Cycle:**

- Winter or summer annual
- Reproduces by wind dispersed seeds
- More common in cool, moist climates and areas

**Control Measures:****Cultural/Mechanical Control:**

- Hand weeding is difficult because seedlings are small and larger plants produce a thick taproot.

**Biological Control:**

- None noted.

**Chemical Control:**

- No herbicides are currently labeled.
- Limited information is available on this pest's biology, ecology or control.

**Field Diagnostic:**

- Dandelion-like rosettes of hairy leaves
- Produces small yellow composite flowers on a branched, hairy stalk.

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

**Critical Issues and Needs:**

- Data is needed to identify effective PRE and POST herbicides.
- Ecology and biology information is needed, especially environmental modeling of seed germination and emergence.
- Reported to induce severe asthma in susceptible individuals.

*Benghal Dayflower*

(*Commelina benghalensis*) [COMBE] (tropical spiderwort)

(B)

**Distribution, Damage and Importance, Origin:**

- Portions of NC, FL, GA
- Competitive dense root systems
- Host of root-knot nematode (*Meloidogyne incognita*).
- Introduced from Asia



**Life Cycle:**

- Summer annual that may persist year-round in southern FL
- Reproduces by seed produced by above-ground and underground flowers
- Spreads by rhizomes and aboveground stems that root at the nodes
- Rhizomes do not overwinter except in the southern most extent of its range

**Control Measures:****Cultural/Mechanical Control:**

- Sanitation is critical to avoid moving seed in contaminated soil.
- Do not let plants mature to seed.

**Biological Control:**

- None noted.

**Chemical Control:**

- Limited PRE and POST herbicide efficacy data are available.
- Benghal dayflower is tolerant of glyphosate.
- Limited control recommendations are available via Dr. Robert Stamps, UF-IFAS:  
<http://edis.ifas.ufl.edu/EP350>.

**Field Diagnostics:**

- Broad, egg-shaped leaves
- Violet flowers
- Rooting at nodes, white, fleshy underground stem

**Federal/State/Local Regulation and Pesticide Restrictions:**

- Federal noxious weed.

**Critical Issues and Needs:**

- Federal Noxious Weed
- Infestations in a nursery require quarantine and eradication.
- Early detection and eradication educational resources are needed.

## Cogongrass

(*Imperata cylindrica*) [IMPCY] (kunai grass) (B, F\*)

### Distribution, Damage and Importance, Origin:

- Widespread in Gulf Coast states
- Isolated populations in WV and OR
- Forms dense, monotypic stands
- Introduced from Asia



### Life Cycle:

- Perennial
- Dense stands with deep roots
- Reproduction is by copious production of windborne seeds and rhizomes.

### Control Measures:

#### Cultural/Mechanical Control:

- Sanitation is critical to avoid moving seeds or rhizomes in contaminated soil or crops.
- Do not let plants mature to seed.
- Burning is ineffective (highly flammable, but re-establishes rapidly).

#### Biological Control:

- None noted

#### Chemical Control:

- Close mowing followed by disking and POST applications

### Field Diagnostic:

- Fluffy, white seed heads
- Finely toothed (serrate) leaf margins
- Prominent white midrib on leaf blade that is often off-center

### **Federal/State/Local Regulation and Pesticide Restrictions:**

- Federal noxious weed

### **Critical Issues and Needs:**

- Early detection mechanisms and education
- Efficacy data needed to expand current PRE and POST herbicide labels for field and container nursery production.

*Photo credit: Charles T. Bryson, USDA-ARS, UGA1299003 courtesy of [www.bugwood.org](http://www.bugwood.org).*

### *Dogfennel*

(*Eupatorium capillifolium* [EUPCP]) (B)

### **Distribution, Damage and Importance, Origin:**

- Widespread throughout the region
- Native

### **Life Cycle:**

- Reproduces by wind dispersed seeds
- Perennial plants have a woody base and crown that survives several years.



### **Control Measures:**

#### **Cultural/Mechanical Control:**

- Seedlings are controlled by cultivation or hand-weeding.
- Older plants are not well controlled.
- Mulches are partially effective for controlling dogfennel grown from seed.
- Mowing will reduce seed production.

#### **Biological Control:**

- None noted.

**Chemical Control:**

- Data available on PRE herbicide efficacy is limited.
- Glyphosate is effective for POST control but may require multiple applications.

**Field Diagnostic:**

- Clump forming
- Stems are woody and hairy at the base.
- Finely dissected leaves with a distinctive aroma when crushed.

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted.

**Critical Issues and Needs:**

- Increased knowledge of PRE and POST herbicide efficacy.
- Understanding of its dispersal and establishment.

*Marsh Parsley*

*Cyclospermum leptophyllum* (= *Apium leptophyllum*)  
[APULE] (C)

**Distribution, Damage and Importance, Origin:**

- Widely distributed in the South and increasingly common in container nurseries and landscape plantings.
- Tolerant of most PRE herbicides labeled for nursery crops



**Life Cycle:**

- Annual

- Reproduction is by seeds
- Conditions for germination are not well studied. Appears to germinate over an extended period of time from fall through early summer.

**Control Measures:**

**Cultural/Mechanical Control:**

- Not well controlled by mulches
- Can be difficult to hand weed because seedlings produce a rosette; mature plants have a stout tap root that is difficult to remove.

**Biological Control:**

- None

**Chemical Control:**

- Only one PRE herbicide labeled for use in container nurseries is effective.
- No data are available on POST herbicide efficacy.

**Field Diagnostic:**

- Finely dissected leaves
- Small white flowers that are tinged pink

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted

**Critical Issues and Needs:**

- Efficacy data are needed to expand current PRE and POST herbicide labels.
- Research is needed on germination and reproductive biology.

## *Mulberry weed*

(*Fatoua villosa*) [no Bayer code available] (hairy crabweed)  
(B, C\*)



### **Distribution, Damage and Importance, Origin:**

- Summer annual capable of having multiple generations per season.
- Seeds mature on very young plants
- Introduced

### **Life Cycle:**

- Abundant seed production
- Explosively dehiscent seedpods that can project seeds up to 4' from parent plants

### **Control Measures:**

#### **Cultural/Mechanical Control:**

- Sanitation is essential
- Hand-weeding will provide a control but is often ineffective as young plants may seed when less than 2 inches tall.

#### **Biological Control:**

- None noted

#### **Chemical Control:**

- PRE herbicides are effective if well timed.
- Non-selective POST herbicides are effective but must be applied to very young plants to prevent seed production.

### **Field Diagnostic:**

- Leaves resemble those of mulberry but are more triangular.
- Stems and leaves are hairy.

### **Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted

### **Critical Issues and Needs:**

- Efficacy data are needed to expand current PRE and POST herbicide labels.

### *Parthenium*

(*Parthenium hysterophorus*) [PTNHY] (Santa Maria feverfew) (**B, C\***)

### **Distribution, Damage and Importance, Origin:**

- Localized populations throughout eastern and central U.S.
- Introduced from the Caribbean
- Produces allelopathic compounds
- All plant portions are toxic to humans and livestock.



### **Life Cycle:**

- Annual.
- Prolific seed set.
- Deep taproot

### **Control Measures:**

#### **Cultural/Mechanical Control:**

- Sanitation is critical to avoid moving seed in contaminated soil.
- Do not let plants mature to seed.

#### **Biological Control:**

- None noted

**Chemical Control:**

- Few data are available.
- PRE herbicides can be effective if properly timed.
- Limited POST options (glufosinate & glyphosate).

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted

**Field Diagnostic:**

- Finely lobed (dissected) leaves
- Pubescent stems and leaves
- Small white flower heads

**Critical Issues and Needs:**

- Efficacy and application timing data is needed to expand current PRE and POST herbicide labels for nursery and container crops.
- Research concerning plant biology and ecology is needed to understand this weed's potential risk and spread.

*Photo credit: Charles T. Bryson, USDA-ARS, UGA2100032 courtesy of [www.bugwood.org](http://www.bugwood.org).*

## *Phyllanthus Species*

(*Phyllanthus tenellus*, longstalked phyllanthus [*below, left*]; *P. urinaria*, chamberbitter, gripweed [*below, right*]) (B, C\*)



### **Distribution, Damage and Importance, Origin:**

- Common in southern container nurseries and landscapes, and spreading.
- Spreads rapidly in nurseries over-topping small crop plants
- Not well controlled by many nursery and landscape PRE herbicides
- Introduced

### **Life Cycle:**

- Prolific seed set from explosively dehiscent seedpods
- Summer annuals
- Emergence in warm soil/substrate
- Multiple generations per season
- May persist year-round in some southern states

### **Control Measures:**

#### **Cultural/Mechanical Control:**

- Hand-weeding does not provide sufficient control.
- Do not let plants mature to seed.

**Biological Control:**

- None noted

**Chemical Control:**

- Most PRE herbicides provide incomplete control

**Field Diagnostic:**

- Flowers of *P. tenellus* are borne on stalked petioles on the undersides of leaves.
- Those of *P. urinaria* attach directly to leaves without petioles (sessile).

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted

**Critical Issues and Needs:**

- Difficult to control in containers.
- Densely fibrous root system is challenging to remove via hand-weeding.
- Efficacy data is needed to expand current PRE and POST herbicide labels.
- Environmental modeling to understand emergence patterns.

## Select Emerging Weedy Non-Vascular Plants

### Algae

(*Nostoc* spp.) (C)



#### Distribution, Damage and Importance, Origin:

- Introduced, becoming widespread.
- In nursery settings, *Nostoc* can form dark greenish-brown, jelly-like masses on soil, gravel, fabric weed barrier, cement, etc.
- *Nostoc* is slippery and can cause worker safety issues.
- When dry, algal sheets form a tough black crust that impedes water and nutrient access to soil.
- Introduced

#### Life Cycle:

- Little is known of the biology of this species in nurseries.
- Appears to be spread by water dispersal and on contaminated pots, substrates, clothing, footwear, propagation stock, etc.

#### Control Measures:

##### Cultural/Mechanical Control:

- Hand and mechanical removal of algae is temporary
- Reduce shading and irrigation and improve drainage to enable the ground to dry between watering.

##### Biological Control:

- None available

**Chemical Control:**

- Limited treatments are available and few labels specify algal control.
- Copper sulfate and lime may be beneficial, but phytotoxicity may occur.

**Field Diagnostic:**

- Gelatinous, olive-green masses turn black when dried

**Federal/State/Local Regulation and Pesticide Restrictions:**

- None noted

**Critical Issues and Needs:**

- *Nostoc* and similar algae form slippery mats on ground cloth and gravel creating safety hazards in nurseries.
- Growers are unfamiliar with this plant and would benefit from better understanding the *Nostoc* life cycle and control options.
- Herbicidal efficacy data are needed for nursery crops.

## *Chemical Control of Weeds in Container and Field Production*

### *Chemical Overview*

Control of weeds in container and field nurseries is unlike control of pathogens and insects because weeds and weed seeds are endemic and no cultural or environmental control is available to achieve adequate suppression of weeds in a nursery operation. Chemical controls, in the form of preemergence and postemergence herbicides, are the primary options for growers. While proper sanitation, cultural practices, media storage, etc. can reduce weed pressure (discussed later in this section), a near-zero tolerance policy on weeds by consumers forces growers to utilize either chemical control or labor to hand pull weeds. Due to the high cost of labor expended on hand weeding, combined with the loss of top dressed fertilizer and lost substrate when weeds are hand pulled, growers utilize herbicides to control weeds wherever possible.

Chemical control of weeds in container nurseries is principally accomplished through the use of preemergence herbicides whereas field nursery weed control typically combines preemergence and postemergent control methods. Predominant formulations of preemergence herbicides differ based on the type of growing operation, with container growers primarily utilizing granular products and field growers utilizing spray-applied products (e.g. liquids, water dispersible granules, wettable powders and emulsifiable concentrates). Postemergence herbicides are spray-applied products, with some products including surfactants to maximize adhesion of product to the weed leaf surface. Regardless of herbicide type, specific herbicide products are selected by growers with four considerations in mind:

- a. Efficacy of product on the targeted weed species
- b. Tolerance of nursery stock in treated areas to the herbicide choices available.
- c. Cost of product in comparison to cultural control or other chemical controls
- d. Compatibility with other treatments such as the ability to tank mix or combine 2 or more products to achieve improved weed control

### *Preemergence Overview*

In recent years, the number of preemergence herbicides labeled for use in container and field nurseries has increased dramatically. This increase in product options is due to the introduction of several new active ingredients as well as the release of combination products having 2 or more pre-emergent chemicals in a single product. The aim of chemical companies is to eliminate the need for growers to tank-mix chemicals.

Whether applied as granules or as spray treatments, most herbicide applications contain at least two active ingredients, chosen to broaden the spectrum of weed control while keeping individual herbicide doses low enough to be safe on a wide range of nursery crop species. The herbicides are often broadly categorized as having efficacy primarily on “broadleaf weeds” or “grass weeds”, although there is significant overlap in efficacy. A typical herbicide application will include a “broadleaf” herbicide with a “grass” herbicide (Table 11).

*Table 10. Common broadleaf and grass herbicides used in nursery production in the southeastern United States.*

<b><u>Common “Broadleaf” Herbicides</u></b>	<b><u>Common “Grass” Herbicides</u></b>
Isoxaben (Gallery)	Dinitroanilines: oryzalin (Surflan), pendimethalin (Pendulum & Corral), proflam (Barricade & RegalKade), trifluralin (Treflan)
Simazine (Princep)	Dimethenamid-p (Tower)
Oxyfluorfen (Goal)	Dithiopyr (Dimension Ultra)
Flumioxazin (Broadstar or Sureguard)	Napropamide (Devrinol)
	Oxadiazon (Ronstar)
	s-Metolachlor (Pennant Magnum)

*Postemergence Overview*

Use of postemergence herbicide is not widely practiced in container nurseries due to issues with nontarget applications. However, outside of the pad/bed areas, postemergence herbicides are more frequently used to control weeds in drainage ditches, roadways, surrounding substrate storage areas, around the periphery of the nursery, and around surface water supplies used for irrigation.

In field nurseries, postemergence herbicide use is far greater than container nurseries, with applications occurring in all parts of the nursery, including growing areas. Because application of postemergence herbicides sometimes leads to plant damage, growers minimize the exposure of plants to

these herbicides by utilizing specialized spray equipment, spraying only when environmental conditions are ideal, managing the timing of sucker removal, and not directly spraying foliage.

Some of the more popular postemergence herbicides in container and field nurseries include:

- Glyphosate (Roundup), a non-selective postemergence herbicide that is the most commonly-used herbicide in container and field nurseries.
- Glufosinate ammonium (Finale) and diquat (Reward), two nonselective postemergence herbicides.
- Clethodim (Envoy Plus), Fluazifop-P-butyl (Fusilade II and Ornamec) and sethoxydim (Segment), which are postemergence herbicides for selective grass control (Not labeled in all states).

# Listing of Preemergence and Postemergence Chemicals

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The following is a list of available preemergence and postemergent herbicides, product names, REIs, and general descriptions (Note: combination chemicals not listed; refer to tables later in section for combination products).

Chemicals included in this list are denoted as preemergence (**PRE**), postemergence (**POST**), or both (**B**). If both, the predominant use may be indicated by an asterisk (\*).

## **ASULAM** **(POST)**

(Asulox) – (REI of 12 hours). Asulox is a postemergence herbicide for the control of select weeds including several summer annual grasses, bracken fern, horseweed, and has been reported to suppress field horsetail. For use over a limited number of nursery crop and Christmas tree species.

## **BENTAZON** **(POST)**

(Basagran TO and Lescogran) – (REI of 12 hours). Basagran TO and Lescogran are postemergence herbicides for selective control of some seedling broadleaf weeds and yellow nutsedge. Avoid applying when rainfall is expected or irrigation is applied within 8 hours.

## **CLETHODIM** **(PRE)**

(Envoy) – (REI of 24 hours). Envoy is a postemergence herbicide used to control annual grasses and some perennial grasses. Perennial grasses are best controlled when the plants are small.

## **CLOPYRALID** **(POST)**

(Lontrel) -- (REI of 12 hours). Lontrel is a selective herbicide for control of certain broadleaf weeds. Susceptible weed species include many in the bean (Fabaceae) family (e.g. clover, sicklepod, vetch) and aster (Asteraceae) family (e.g.: aster, cocklebur, sowthistle, thistle). Labeled for use in field nurseries, not container nurseries. Nursery crops in susceptible families (such as redbud and honey locust) have been injured through root uptake following directed applications.

## **DICHLORBENIL** **(B)**

(Casoron) – (REI of 12). Casoron is a pre and postemergence herbicide that controls a broad spectrum of weeds, including difficult to control perennial weeds such as Florida betony and mugwort. Do not apply until 4 weeks after transplanting.

**DIMETHENAMID-P (PRE)**

(Tower) – (REI of 12 hours). Tower is a preemergence that provides broad spectrum control of many broadleaf and grass species. In most cases, needs a tank mix partner (e.g. proflam or pendimethalin). Newly transplanted material should be established prior to application. Also available in a granular formulation, Freehand, which is a combination of dimethenamid-P + pendimethalin.

**DIQUAT (POST)**

(Reward) – (REI of 24 hours). Reward is a nonselective, contact-action, postemergence herbicide. Do not apply to foliage or green stems of desirable ornamentals.

**DITHIOPYR (B, PRE\*)**

(Dimension Ultra, Dimension 2EW) – (REI of 12 hours) Dimension is primarily used for preemergence annual grass control in turf but is also labeled for use in container- and field-grown ornamentals. May be tank mixed with a “broadleaf” herbicide to expand the spectrum of weeds controlled.

**FENOXAPROP (POST)**

(Acclaim Extra) – (REI of 24 hours). Acclaim Extra is a selective postemergence herbicide that offers good control of annual grasses. Do not apply to ornamental grasses and do not apply to targeted weedy grasses when under drought stress.

**FLUAZIFOP-P-BUTYL (POST)**

(Fusilade and Ornamec) – (REI of 12 hours). Fusilade and Ornamec are selective postemergence herbicides used to control annual grasses and some perennial grasses. Perennial grasses are best controlled when the plants are small. Do not apply to ornamental grasses and do not apply to targeted grasses when under drought stress.

**FLUMIOXAZIN (B, PRE\*)**

(Sureguard and BroadStar) – (REI of 12 hours). Sureguard (sprayable formulation) and Broadstar (granular formulation) are low rate preemergence herbicides used to control many common broadleaf weeds such as common chickweed, spurge, bittercress, common groundsel, common lambsquarters,

morning glory, common purslane and other species. There is some control of annual grasses such as annual bluegrass, giant foxtail, goosegrass, and crabgrass. With the addition of a crop oil or surfactant, Sureguard provides postemergence control of many small, seedling broadleaf weeds. Sureguard is from a different class of chemistry than other herbicides currently available to growers but has the same mode of action as oxyfluorfen.

### **GLUFOSINATE**

**(POST)**

(Finale) – (REI of 12 hours). Finale is a postemergence, nonselective herbicide that kills grasses, broadleaf weeds and sedges. It is used for eliminating weeds around container beds and in field nurseries, as well as a directed spray at the base of trees. Two or more applications may be necessary for complete control of larger or perennial weeds. Contact herbicide with a limited amount of translocation in plants.

### **GLYPHOSATE**

**(POST)**

(Roundup Pro, and many others) - (REI of 4 to 12 hours depending on formulation). Glyphosate is a postemergence, nonselective, systemic herbicide that kills grasses, broadleaf weeds and sedges. It is used for controlling emerged weeds around container beds and in field nurseries, as well as a directed spray at the base of trees.

### **INDAZIFLAM**

**(PRE)**

(Marengo) - (REI of 12 hours). Marengo is a preemergence herbicide for the control of annual grasses and broadleaf weeds in woody nursery crops. Marengo is broad-spectrum and generally not combined with other preemergence herbicides. The GR formulation is used in container crops; the SC formulation is used in field-grown crops and as sanitation treatments in roadways and non-crop areas of nurseries. It is the only preemergence herbicide labeled for use inside covered structures such as plastic hoop houses and greenhouses. In such structures, it is only labeled for application to the floors, not for application to the crop inside a covered structure. The SC formulation has limited postemergence effects that can preclude use on certain ornamental crops, but may provide early postemergence control of crabgrass species and annual bluegrass, and will control or significantly stunt the growth of many seedling winter annual broadleaf weeds.

### **ISOXABEN**

**(PRE)**

(Gallery) - (REI of 12 hours). Gallery is a preemergence herbicide for the control of broadleaf weeds. Gallery is generally applied in combination with a “grass” herbicide to expand the spectrum of weeds

controlled. Also available in a granular combination with trifluralin for use in container nurseries under the trade names Snapshot and Showcase.

**S-METOLACHLOR**

**(PRE)**

(Pennant Magnum) – (REI of 24 hours). Pennant Magnum is a preemergence herbicide used primarily for the control of yellow nutsedge and annual grasses. Primarily used in field nurseries in combination with a “broadleaf” herbicide to expand the spectrum of weeds controlled.

**NAPROPAMIDE**

**(PRE)**

(Devrinol) – (REI of 24 hours). Devrinol is a preemergence herbicide labeled for use in field and container grown nursery crops for the control of annual grasses and some broadleaf weeds. Some suppression of yellow nutsedge may be obtained. Generally used in combination with a “broadleaf” herbicide for an expanded spectrum of weeds controlled.

**ORYZALIN**

**(PRE)**

(Surflan) - (REI of 12 hours). Oryzalin is a preemergence herbicide used for the control of most annual grasses, including crabgrasses, goosegrass, lovegrass and some small-seeded broadleaf weeds, including bittercress, common chickweed, spotted spurge, and yellow woodsorrel.

**OXADIAZON**

**(PRE)**

(Ronstar) - (REI of 12 hours). Oxadiazon is a preemergence herbicide effective on most nursery weeds, but provides poor control of sparges and common chickweed.

**OXYFLUORFEN**

**(PRE, POST)**

(Goal, Goal Tender,) – (REI of 24 hours). Goal is a pre- and early postemergence herbicide that controls a wide spectrum of grasses and broadleaf weeds. Apply prior to bud break or after full leaf expansion. . Oxyfluorfen is a common component in combination granular herbicides used in container nurseries including: Biathlon (with prodiamine), OH2 (with pendimethalin), Rout (with oryzalin), Regal OO (with oxadiazon), HGH 75 (with trifluralin). The granular formulations lack postemergence weed control associated with spray applications. The granular formulation should be applied when foliage is dry.

**PARAQUAT**

**(POST)**

(Gramoxone Inteon) – (REI of 24 hours). Gramoxone Inteon is a restricted use, nonselective, contact, postemergence herbicide that controls most seedling broadleaf weeds and some grass weeds. Do not allow product to contact foliage or green stems of desirable plants.

**PELARGONIC ACID**

**(POST)**

(Scythe) – (REI of 12 hours). Scythe is a nonselective, broad spectrum, contact, postemergence herbicide. It controls small annual weeds, while perennial weeds will out-grow foliar injury..

**PENDIMETHALIN**

**(PRE)**

(Pendulum and Corral) - (REI of 24 hours). Pendimethalin is a preemergence herbicide used in the control of most annual grasses, including crabgrass and goosegrass, as well as some broadleaf weeds, including spurge, common chickweed and woodsorrel from seed.

**PRODIAMINE**

**(PRE)**

(Barricade and RegalKade) - (REI of 12 hours). Prodiamine is a preemergence herbicide used in the control of most annual grasses, including crabgrass and goosegrass, as well as some broadleaf weeds, including spurge, common chickweed and woodsorrel from seed.

**SETHOXYDIM**

**(POST)**

(Segment) – (REI of 12 hours). Segment is a selective, systemic postemergence herbicide used to control annual grasses and some perennial grasses. Perennial grasses are best controlled when the plants are small. Do not apply to ornamental grasses and do not apply to targeted grasses when under drought stress.

**SIMAZINE**

**(PRE)**

(Princep and other trade names) – (REI of 12 hours). Simazine is a preemergence herbicide used for control of many broadleaf weeds in field grown nursery crops. It is generally used in combination with a “grass” herbicide to broaden the spectrum of weeds controlled.

Herbicide Trade Name	Active Ingredient	Ai/Acre	Product/Acre	REI (hrs)	Chemical Class	HRAC	WSSA	Company
Barricade 4L	Prodiamine	0.65 - 1.50 lbs.	21 - 48 fl. oz.	12	Dinitroaniline	K1	3	Syngenta
Barricade 65DG	Prodiamine	0.65 - 1.50 lbs.	1.0 - 2.3 lbs.	12	Dinitroaniline	K1	3	Syngenta
Biathlon 2.75 G	oxyfluorfen + prodiamine	2 lbs. + 0.75 lbs.	100 lbs	24	Diphenyl ether plus Dinitroaniline	E, K1	14, 3	OHP
BroadStar	Flumioxazin	0.375 lbs.	150 lbs.	12	Phenylphthalimide	E	14	Nufarm
Casoron 4 GR	Dichlobenil	4.0 - 6.0 lbs.	100 - 150 lbs.	12	Substituted Benzene	L	20	Crompton
Corral 2.68G	Pendimethalin	2 - 3 lbs.	76 - 114 lbs.	12	Dinitroaniline	K1	3	Everris
Devrinol 50DF	Napropamide	4 - 6 lbs.	8 - 12 lbs.	12	Alkanamide	K3	15	United Phos.
Devrinol 2G	Napropamide	2 - 3 lbs.	100 - 150 lbs.	12	Alkanamide	K3	15	United Phos.
Dimension Ultra 40WP, 2EW	Dithiopyr	0.25 - 0.5 lbs	0.48 - 0.95 lbs.  1-2 pints	12	Pyridazinone	K1	3	Dow Agro
Freehand 1.75G	Dimethenamid-P + Pendimethalin	1.75 - 3.5 lbs.	100 - 200 lbs.	24	Amide plus Dinitroaniline	K3, K1	15, 3	BASF
Gallery 75 DF	Isoxaben	0.5 - 1.0 lbs.	0.66 - 1.33 lbs.	12	Amide	L	21	Dow Agro

Jewel 3.25GR	Oxadiazon + Pendimethalin	3.25 lbs.	100 lbs	12	Oxadiazole plus Dinitroaniline	E, K1	14, 3	Everris
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Table 11. Preemergence herbicides labeled for container nursery stock.

Table 11 (cont'd). Preemergence herbicides labeled for container nursery stock.

Herbicide Trade Name	Active Ingredient	Ai/Acre	Product/Acre	REI (hrs)	Chemical Class	HRAC	WSSA	Company
OH-2 2GR	Oxyfluorfen + Pendimethalin	2 lbs. + 1 lbs.	100 lbs	24	Diphenyl ether plus Dinitroaniline	E, K1	14, 3	Everris
Marengo 0.0224 GR  Marengo 0.622 SC	indaziflam	0.0224 – 0.048 lbs.  0.036 – 0.075 lbs (SC)	100 – 200 lbs.  7.5 to 15.5 fl oz	12	Alkylazines	L	29	OHP
Pendulum 2GR	Pendimethalin	2.0 – 4.0lbs.	75 - 100 lbs.	12	Dinitroaniline	K1	3	BASF
Pendulum 3.3 EC	Pendimethalin	2.0 - 4.0 lbs.	2.4 - 4.8 qts.	24	Dinitroaniline	K1	3	BASF
Pendulum Aqua Cap 3.8ACS	Pendimethalin	2-4 lb	2.1 - 4.2 qts.	24	Dinitroaniline	K1	3	BASF
Pennant Magnum 7.62	s-Metolachlor	1.3 - 2.5	1.3 - 2.6 pints	24	Choroacetanilide	K3	15	Syngenta
Princep Liquid	Simazine	1 -3 lbs.	1 - 3qts.	12	Triazine	C1	5	Syngenta
Regal Kade 0.5G	Prodiamine	1.5 lbs.	300 lbs.	12	Dinitroaniline	K1	3	Regal

Regal O-O, 3GR	Oxyfluorfen + oxadiazon	2 lbs. + 1 lbs.	100 lbs	24	Diphenyl ether plus Oxadiazole	E	14, 3	Regal
Regalstar 1.2GR	Oxadiazon + prodiamine	2 lbs + 0.4 lbs.	200 lbs.	12	Oxadiazole plus Dinitroaniline	E, K1	14, 3	Regal

Table 11 (cont'd). Preemergence herbicides labeled for containernursery stock.

Herbicide Trade Name	Active Ingredient	Ai/Acre	Product/Acre	REI (hrs)	Chemical Class	HRAC	WSSA	Company
Ronstar 50 WSP	Oxadiazon	2 - 4 lbs.	4 - 8 WSP	12	Oxadiazole	E	14	Bayer
Ronstar G	Oxadiazon	2 - 4 lbs.	100 - 200 lbs	12	Oxadiazole	E	14	Bayer
Rout 3G	Oxyfluorfen + oryzalin	2 lbs. + 1 lbs.	100 lbs.	24	Diphenyl ether plus Dinitroaniline	E, K1	14, 3	Everris
Showcase 2.5G	Isoxaben + Trifluralin + Oxyfluorfen	0.25 - 0.5 lbs. + 2.0 - 4.0 lbs. + 0.25 - 0.5 lbs.	100 - 200 lbs.	24	Benzamide plus Dinitroaniline plus Diphenyl ether	L, K1	21, 3	Dow Agro
Simazine 4L	Simazine	2.0 - 3.0 lbs.	2.0 - 3.0 qts.	12	Triazine	C1	5	Agrisolutions
Simazine 90 DF	Simazine	2.0 - 3.0 lbs.	2.2 - 4.4 lbs.	12	Triazine	C1	5	Agrisolutions
Snapshot 2.5TG	Isoxaben + Trifluralin	0.5 - 1.0 lbs. + 2 - 4 lbs.	100 - 200 lbs.	12	Benzamide plus Dinitroaniline	L, K1	21, 3	Dow Agro
SureGuard 51WDG	Flumioxazin	0.25 - 0.38 lbs	8 - 12 oz.	12	Phenylphthalimide	E	14	Nufarm
Surflan 4AS	Oryzalin	2 - 4 lbs.	2 - 4 qts.	12	Dinitroaniline	K1	3	United Phos.
Tower 6L	Dimethenamid-P	0.98 - 1.5 lbs.	21 - 32 fl. oz.	12	Amide	K3	15	BASF

Table 11 (cont'd). Preemergence herbicides labeled for container nursery stock.

Herbicide Trade Name	Active Ingredient	Ai/Acre	Product/Acre	REI (hrs)	Chemical Class	HRAC	WSSA	Company
Weedfree 75, 5GR	Oxyfluorfen + Trifluralin	5 lbs.	100 lbs.	24	Diphenyl ether plus Dinitroaniline	E, K1	14, 3	Harrell's
XL 2 GR	Benefin (benfluralin) + Oryzalin	2 - 3 lbs. + 2 - 3 lbs.	200 - 300 lbs.	12	Dinitroaniline	K1	3	Helena

Table 12. Postemergence herbicides labeled for container nursery stock.

Herbicide Trade Name	Active Ingredient	ai/ Acre	Product/ Acre	REI (hrs)	Rainfast	Chemical Class	HRAC	WSSA	Company
Acclaim Extra	Fenoxaprop	0.09 - 0.17 lbs.	1.2 - 2.4 pt.	24	1 hour	Aryloxyphenoxypropionate	A	1	Bayer
Asulox	Asulam	3.34 lbs.	1.0 gal.	12	unknown	Carbamate	I	18	United Phoshorus
Basagran TO	Bentazon	0.75 - 1.0 lb.	1.5 - 2.0 pt.	12	4 hours	Benzothiazinone	C3	6	BASF
Casoron 4G	Dichlobenil	4 – 8 lbs.	100 – 200 lb.	24	NA	Benzonitrile	L	20	Chemtura
Envoy Plus	Clethodim	0.11 - 0.24 lbs.	13 - 32 fl. oz.	24	1 hour	Cyclohexanedione	A	1	Valent
Finale 1L	Glufosinate-ammonium	0.75 - 1.5 lbs	3.0 - 6.0 qt.	12	4 hours	Phosphinic acid	H	10	Bayer
Fusilade II	Fluazifop-P-butyl	0.25 - 0.38 lbs.	1.5 - 1.5 pt.	12	1 hour	Aryloxyphenoxypropionate	A/1	1	Syngenta

Table 12 (cont'd). Preemergence herbicides labeled for container nursery stock.

Herbicide Trade Name	Active Ingredient	ai/ Acre	Product/ Acre	REI (hrs)	Rainfast	Chemical Class	HRAC	WSSA	Company
Goal 2XL	Oxyflurofen	0.5 - 1.5 lbs.	2.0 - 6.0 pt.	144	unknown	Diphenyl ether	E	14	Dow Agro
Goal Tender	Oxyflurofen	0.5 - 1.5 lbs.	1.0 - 3.0 pt.	144	unknown	Diphenyl ether	E	14	Dow Agro
Gramoxone Inteon	Paraquat	0.25 - 1 lb.	1.3 - 4.0 pt.	24	30 minutes	Bipyridylum	D	22	Syngenta
Lontrel	Clopyralid	0.09 - 0.5 lb.	0.25 - 1.33 pt.	12	unknown	Pyridine compound	O	4	Dow Agro
Reward 2L	Diquat	0.5 - 1.0	1.0 - 2.0 qt.	24	1 hour	Bipyridylum	B	22	Syngenta
Roundup (various products)	Glyphosate	0.5 - 4 lbs ai	0.5 - 4 quarts (varies among formulations )	4 - 12	30 minutes to 6 hours	Phosphonoglycine	G	9	Monsanto
Segment	Sethoxydim	0.28 - 0.47 lbs.	1.1 - 1.9 qt.	12	1 hour	Cyclohexadione	A	1	BASF
Scythe	Pelargonic Acid	9.4 - 84 lbs.	2.2 - 20 gal.	12	1 hour	Biopesticide	Z	27	Dow Agro

Table 13. Efficacy of preemergence herbicides.

	Barricade/Regalkade	Biathlon	Broadstar/Sureguard	Casoron*	Dacthal	Devrinol	Dimension	Freehand	Eptam	Gallery	Goal	HGH 75	Image	Kerb	Marengo	OH2	Pendulum*	Pennant Magnum	Princep*	Regal OO	Ronstar G	Rout	Showcase	Snapshot TG	Surflan	Tower	XL
American Burnweed	p	g	g				G								g	p	f									f	
Bindweed, hedge (from roots)	p	p	p	f	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Bittercress	p	g	G	g			G	F		G	g	F	G		G	G	g	P	f	G	G	G		G	G	F	
Chamberbitter	p	f	g	p			p	F		p	f-g				G	f-g	p	p		g	g	f-g	f	G	f	f	
Chickweed, common	G	G	G	G	G	G	G	G	G	G	g	G	G	G	G	G	G	f	G	G	p	G		G	G		G
Chickweed, mouseear		G	G	G		p	G	G		G			G	G	G		G		p					G	p		
Cudweed				G		G		G		G			F		G	G	G		g	G				G	p		
Dandelion (seedling)			G	G		p				G			F		G	G	p	p	f	G		G		G	g		f
Deadnettle, purple				G	F								G						G	g							
Dogfennel	p	g	G	G				G		F					G	g	p		g		f	g		G	p		
Doveweed		p	G					G							G	p	p	f				p-f		p	p	G	
Evening primrose	p			G		p		F		f	G		G		G	g	G	f	g		F	G		G	g		
Eclipta	p	f	f	p				F		p	p		G		F	p	p	p		p	p	f	p	p	p-f	F	
Groundsel, common	f	G	G	G		G		f		f	G		G		G	G	p	F	G	G	G		G	G	F	F	
Henbit	G		G	G	F	g	G	f	G	G	G	G	G	G	G		G		G					G	G		G

Table 13 (cont'd). Efficacy of preemergence herbicides.

	Based on label: G = good control (80-100%) F = fair control (50-80%) P = poor control (0-50%)		Based on other research: g = good control (80-100%) f = fair control (50-80%) p = poor control (0-50%)																								
	Barricade/Regalkade	Biathlon	Broadstar/Sureguard	Casoron*	Dacthal	Devrinol	Dimension	Freehand	Eptam	Gallery	Goal	HGH 75	Image	Kerb	Marengo	OH2	Pendulum*	Pennant Magnum	Princep*	Regal OO	Ronstar G	Rout	Showcase	Snapshot TG	Surflan	Tower	XL
<b>Broadleaf Weeds</b>																											
Horseweed (marestail)	f	f	G	G		f	F			G	F				G	G	p	f	gg	G	f	G		G	F		
Knotweed, prostrate	f			G	F	G	p	G		F	G	G	f	G	G		G	g	f		g	g		G	G		G
Ladysthumb			G							G	G	G						gg						G			
Lambsquarters	G		G	G	G	G	f	G	F	F	G	G		G	G		G	f	G		G	G		G	G	F	
Lettuce, prickly		g		g		G				G	G					g			G					G	F		
Liverwort			g	p		p		F		p	p					g			p		f	g				F	
Morningglory, annual			G	f		p			F	F	G	f		G			f	f	G		f			F	F		
Mugwort (from rhizome)	p	p	p	G	p	p	p	p	F	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Mulberry weed		g	G				G	G							G									G			
Mustard, wild				G	P	f	G			G	G	G		G	G			p	G		g	g		G	F		
Phyllanthus, long stalked	p	f-g	G				p	F		p	f-g				G	f-g	p	p		f-g	f	f-g	f	G	f	f	
Pigweed spp.	G	g	G	G	F	G	F	G	F	G	G	G			G	G	G	G	G	G	G	G		G	G	G	
Smartweed			G	G	P	g		G		G	G	G		G			G	f	G		G			G	F		
Sowthistle, annual	p	g	G	g	F	G		G		G	G	G			G	G	g		f		G	G		G	F		
Spurge, prostrate	G		g	G	F	p	g			G	G	G			g	G	G	f	f	G	p-f	G		G	G		F
Spurge, spotted	g	g	G	G	F	p	g	G		G	G	G			G	G	G		f	G	p-f	G		G	F	G	

Table 13 (cont'd). Efficacy of preemergence herbicides.

Based on label: G = good control (80-100%) F = fair control (50-80%) P = poor control (0-50%)  Based on other research: g = good control (80-100%) f = fair control (50-80%) p = poor control (0-50%)	Barricade/Regalkade	Biathlon	Broadstar/Sureguard	Casoron*	Dacthal	Devrinol	Dimension	Freehand	Eptam	Gallery	Goal	HGH 75	Image	Kerb	Marengo	OH2	Pendulum*	Pennant Magnum	Princep*	Regal OO	Ronstar G	Rout	Showcase	Snapshot TG	Surflan	Tower	XL
	<b>Broadleaf Weeds</b>																										
Thistle, Bull				G						G	G																
Thistle, Musk										F															G		
Yellow Woodsorrel (Oxalis) from seed	G	G	G	G		p	g	G		G	G	G	g		F	G	G	p	p	G	G	G		G	G	g	F
Willowherb			f					G		F																G	
<b>Grasses (or grasslike)</b>																											
Barnyardgrass	G	g	F		F	G	G	G	G	p	F	G			g	G	G	G	G	G	G	G		G	G	G	G
Bermudagrass (rhizome)	p	p	p	f	p	p	p	p	p	p	p	p	p	p	P	p	p	p	p	p	p	p	p	p	p	p	p
Bermudagrass (from seed)	f					f			G	p	p			p	g	p	p	p	p		p	p		p	p		
Bluegrass, annual	G	G	F	G	F	G	G	G	G	p	F	G	F	G	G	G	G	G	G	G	G	G		G	G	G	G
Brome, downy						G	G			p				G					G					G	g	G	
Crabgrass, large	G	G	F	G	G	G		G	G	p	F	f			G	G	G	G	G	G	G	G		G	G	G	G
Crabgrass, smooth	G	G	F	G	G	G	G	G	G	p	f				G		G	G	G	G	G			G	G	G	G
Goosegrass	G	G	F		F	G	G	G	G	p	F	f		G	G	g	G	G	G	G	G	G		G	G	G	G
Johnsongrass (rhizome)	p	p	p	f	P	p	p	p	p	p	p		p	p		p	p	p	p	p	p	p	p	p	p	p	p
Johnsongrass (seedling)	G				F	F		G	F	p	f	G			g	g	G	f	p		f	g		F	G	G	G

Table 13 (cont'd). Efficacy of preemergence herbicides.

Based on label: G = good control (80-100%) F = fair control (50-80%) P = poor control (0-50%)  Based on other research: g = good control (80-100%) f = fair control (50-80%) p = poor control (0-50%)	Barricade/Regalkade	Biathlon	Broadstar/Sureguard	Casoron*	Dacthal	Devrinol	Dimension	Freehand	Eptam	Gallery	Goal	HGH 75	Image	Kerb	Marengo	OH2	Pendulum*	Pennant Magnum	Princep*	Regal OO	Ronstar G	Rout	Showcase	Snapshot TG	Surflan	Tower	XL
	<b>Grasses (or grasslike)</b>																										
Nutsedge, purple	p	p	p	f	P	p	p	p	F	p	p		F	p	P	p	p	p	p	p	p	p		p	p	p	p
Nutsedge, yellow	p	p	p	G	P	f	p	F	F	p	p		F	p	P	p	p	F	p	p	p	p			p	F	
Onion / garlic, wild					p								G		p				p	p					p		P

“G” - Good control: label states full control is to be expected. This does not guarantee that all products receiving a ranking of ‘G’ are equal in performance on a given weed.

“F” - Fair control: denotes that the herbicide may provide only partial control, suppression, limited longevity of control, or may require higher doses to achieve desired levels of control.

“P” - Poor control: denotes that the herbicide provides negligible to no control or suppression on a given weed.

Table 14. Efficacy of postemergence herbicides.

	<b>Acclaim Extra</b>	<b>Envoy</b>	<b>Fusilade II</b>	<b>Segment</b>	<b>Asulox</b>	<b>Basagran TO</b>	<b>Casoron</b>	<b>Goal**</b>	<b>Image</b>	<b>Kerb</b>	<b>Lontrel</b>	<b>Sureguard**</b>	<b>Finale</b>	<b>Gramoxone**</b>	<b>Reward**</b>	<b>Roundup Pro</b>	<b>Seythe**</b>
Based on the label: G = Good control (80-100%) F = Fair control (50-80%) P = Poor control (0-50%)																	
Based on other research: g = good control (80-100%) f = fair control (50-80%) p = poor control (0-50%)																	
<b>Broadleaf weeds</b>																	
American Burnweed	p	p	p	p							G						
Bindweed, hedge	p	p	p	p									G				P
Bittercress, hairy	p	p	p	p					G			G	gg	gg	gg	G	F
Chamberbitter	p	p	p	p									gg	gg	gg	gg	f
Chickweed, common	p	p	p	p		f	G	f	G	G		G	G	gg	gg	G	G
Chickweed, mousear	p	p	p	p			G		G	G		G	G	gg	gg	G	F
Cudweed	p	p	p	p			G		F		G			gg	gg		F
Dandelion (seedling)	p	p	p	p			G	f	F		G		G	gg	gg	G	F
Deadnettle, purple	p	p	p	p			G		G								G
Dogfennel	p	p	p	p			G					G		f	f		P
Doveweed	p	p	p	p								F	f	f		f	
Eclipta	p	p	p	p		f			G		g	F				G	F
Groundsel, common	p	p	p	p		p	F	F			G	F		gg	gg	G	F
Henbit	p	p	p	p		p	G	G	G	P		G	g	gg	gg	G	G
Horseweed (maretail)	p	p	p	p	G						G		G	f	f	G	F
Knotweed, prostrate	p	p	p	p			G	F		P				gg	gg	G	F
Ladysthumb	p	p	p	p		F		F			F	F					F
Lambsquarters	p	p	p	p		G	G	G		P		F	G	f	f	G	P
Lettuce, prickly	p	p	p	p				F			G		G	g	g	G	G

Table 14 (cont'd). Efficacy of postemergence herbicides.

Based on the label: G = Good control (80-100%) F = Fair control (50-80%) P = Poor control (0-50%)  Based on other research: g = good control (80-100%) f = fair control (50-80%) p = poor control (0-50%)	Acclaim Extra	Envoy	Fusilade II	Segment	Asulox	Basagran TO	Casoron	Goal**	Image	Kerb	Lontrel	Sureguard**	Finale	Gramoxone**	Reward**	Roundup Pro	Seythe**
	<b>Broadleaf Weeds</b>																
Liverwort	p	p	p	p				p				F		gg	gg	P	F
Morningglory, annual	p	p	p	p				F				G		gg	gg	G	F
Mugwort	p	p	p	p			G	p			f	p	G	f	gg	f	P
Mulberryweed						p		p			p		f	f	f	gg	f
Mustard, wild	p	p	p	p		G		G		P		G	G	gg	gg	G	F
Phyllanthus, long-stalked	p	p	p	p								G	gg	gg	gg	gg	f
Pigweed spp.	p	p	p	p		p	G	F	G			G	G	gg	gg	G	G
Smartweed	p	p	p	p		G	G	F		P	F	G	G	f	f	G	F
Sowthistle	p	p	p	p				F			G						
Spurge, prostrate	p	p	p	p		p	G	P	p			G		gg	gg	G	F
Spurge, spotted	p	p	p	p			G	P				G		gg	gg	G	F
Spurry, corn	p	p	p	p				F			G			gg	gg		G
Thistle, bull	p	p	p	p				P			G		f	p	p	f	F
Thistle, musk	p	p	p	p		G					G		F				
Yellow woodsorrel	p	p	p	p		p	G	P			p	p	G	gg	gg	gg	F
Willowherb	p	p	p	p													

Table 14 (cont'd). Efficacy of postemergence herbicides.

	<b>Acclaim Extra</b>	<b>Envoy</b>	<b>Fusilade II</b>	<b>Segment</b>	<b>Asulox</b>	<b>Basagran TO</b>	<b>Casoron</b>	<b>Goal**</b>	<b>Image</b>	<b>Kerb</b>	<b>Lontrel</b>	<b>Sureguard**</b>	<b>Finale</b>	<b>Gramoxone**</b>	<b>Reward**</b>	<b>Roundup Pro</b>	<b>Scythe**</b>
Based on the label: G = Good control (80-100%) F = Fair control (50-80%) P = Poor control (0-50%)																	
Based on other research: g = good control (80-100%) f = fair control (50-80%) p = poor control (0-50%)																	
<b>Grasses</b>																	
Bermudagrass	F	G	G	G		p				p	p	p	F-p	p	p	G	P
Bluegrass, annual	P	G	p	p		p		F	F	G	p	p	F	f	f	G	p
Brome, downy			G							G	p		G	F		G	
Crabgrass, large	G	G	G	G	G	p		F	F	P	p	p	G	g	g	G	f
Crabgrass, smooth	G	G	G	G	G	p			F	P	p	p	G	g	g	G	f
Goosegrass	G	G	G	G	F			F			p	p	G	g	g	G	
Johnsongrass (rhizome)	F	F	G	G	F	p					p	p	G	f	f	G	P
<b>Grass-like</b>																	
Nutsedge, purple	p	p	p	p		p	f	p	F	p	p	p	f	f	f	g	p
Nutsedge, yellow	p	p	p	p		G	G	p	F	p	p	p	G	f	f	F	P
Onion or garlic, wild	p	p	p	p					F		p	p	F			f	P

\*\*Effective on seedling weeds only

“G” - Good control: label states full control is to be expected. This does not guarantee that all products receiving a ranking of ‘G’ are equal in performance on a given weed.

“F” - Fair control: denotes that the herbicide may provide only partial control, suppression, limited longevity of control, or may require higher doses to achieve desired levels of control.

“P” - Poor control: denotes that the herbicide provides negligible to no control or suppression on a given weed.

## *Cultural Control of Weeds*

Weed management in ornamental production is most effectively achieved by preventative practices, primarily with the use of PRE herbicides (Gilliam et al., 1990; Gallitano and Skroch, 1993). However, correct sanitation is vitally important, as it reduces the number of weed seeds that have the potential to escape chemical control measures. Removal of established weeds in containers is limited mainly to hand weeding, so prevention is important.

Seeds are the primary source of weeds in production environments. Considering the majority of weed seeds are not distributed a great distance from the seed source, the elimination of seed-bearing weeds within and adjacent to production areas can greatly reduce weed incidence and severity in production. Surface irrigation supplies also may be a source of weed seed if surface water is not sufficiently filtered before application as irrigation water. To reduce weed introduction via irrigation water, weeds from the periphery of surface water supplies should be controlled prior to seed set and intake pipes should be properly placed below the water surface to avoid suction from the surface of the water while high enough to avoid suction of sediment from the bottom of the pond/lake.

A critical step in reducing weed infestations is to follow adequate sanitation measures during propagation and liner production. Liners are often the source for new weed species introduction into production areas. Few if any herbicides may be used in this phase of production, necessitating reliance on sanitation and hand weeding. When receiving liners from an outside source it is critical to monitor plants for weed introductions and to manage these weeds before they reproduce and spread.

Another essential part of weed management is to guarantee the production of a healthy crop that is able to out-compete the weeds. Monitoring soil fertility, pH levels, shade levels, plant spacing and pest populations can aid in preventing damaging levels of weeds, as can the use of mulches or ground covers in field nurseries.

Several studies have shown that both water (Bruns and Rasmussen, 1953; Jordan et al., 1963; Stickler et al., 1969) and fertilizer (Meadows and Fuller, 1983; Everaarts, 1992; Broschat and Moore, 2003; Altland et al., 2004) practices effect weed control effectiveness. For example, fertilizer, when top-dressed, tends to increase weed seed germination and establishment when compared to media-

incorporated fertilizer. Also, overwatering has been shown to reduce the longevity of herbicide. Overwatering in general will lead to an increase in weed problems as well as potential crop problems.

### *Non-Chemical Control*

Non-chemical control of weeds is done on a very limited basis in the industry. The primary method of non-chemical weed control in container nurseries is hand weeding. In field nurseries, mechanical cultivation is practiced, but typically as a supplement to a herbicide regime. Hand weeding is an extremely labor intensive and thus expensive task, yet it is an integral part of any successful weed control program. No herbicide is 100% effective in eliminating weeds; therefore, regular scouting and hand weeding to prevent emerging weeds from setting and dispersing seed is important. Living mulches and cover crops are used with success by many field nursery crop producers. These cover crops may be used as a seasonal ground cover within or between crops to manage erosion, or as a component of a full-season weed management program. Such systems must be customized to local conditions to find the right combination of cover crop species and other compatible weed management practices.

Physical barriers to weed emergence such as plastic mulches and geotextile fabrics are rarely used. Discs of geotextile materials may be used in nursery containers as a surface barrier to prevent weed establishment. Mulches applied as a top-dressing to the container substrate have been used occasionally with products like pine bark and organic byproducts such as Woolpak (a byproduct of the sheep industry in England). Other available barriers are; coco discs, plastic lids, crumb rubber, sawdust, and a bark mulch layer. However, there are challenges associated with these non-chemical options. Geotextile disks must be secured to the surface or wind will displace them. Also, holes must be punched to allow for irrigation emitter placement. Organic mulches are often a haven for weed seedling development. Additionally, most of these barriers are more costly than an effective preemergence herbicide program, but a full economic comparison of such systems has not been reported.

Although there have been advances in biological control of arthropod pests and plant pathogens in nursery crops, no such strategies are currently available for weed control in nurseries.

In pot-in-pot production system, geotextile sheeting or landscape fabric is used as a groundcover to prevent weeds from establishing around the socket and growing container. Holes are cut at the socket pots and secured when the growing container is recessed. This method works well for weed control around the recessed growing container. But the control of weeds in the growing container is a challenge.

It is difficult to apply liquid herbicides to the trees and the geotextile cover because herbicide is wasted when sprayed between pots. It is also difficult to maintain calibration and proper coverage with granular herbicides because of similar challenges.

## Weed Priorities: Extension

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Extension and research priorities below are a combination of pre-survey prioritizations by focus group attendees, as well as an in-focus-group-meeting sticker caucus, where attendees had 24 votes to place on all the initiatives listed below. Respondents could vote more than once for each initiative. Priorities were organized into themes.

- Training for avoiding herbicide injury to nursery crops.
- Improved decision-aids for selecting the most appropriate weed management options (e.g., economic thresholds, efficacy tables, resistance management protocols).
- Training leading to development of an overall integrated weed management plan, tailored to each specific production operation, for controlling weeds.

## Weed Priorities: Research

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- Phytotoxicity of both PRE- and POST emergence chemistries on diverse ornamental crops, with emphasis on new and expanding crop categories (e.g., perennials, ornamental grasses, tropical plants) being grown in the southeastern United States.
- Greater understanding of herbicide persistence and longevity of control relative to the need for reapplications or other supplemental management (e.g., pairing environmental/climatic models with knowledge of herbicide persistence and efficacy to better time both deployment and reapplication of PRE herbicides).

*Weed management strategies that reduce weed emergence, incidence, and overall costs of control including (but not limited to):*

- Understanding longevity of weed control provided by residual herbicides.
- Opportunities to achieve efficient weed control with reduced PRE and POST emergence herbicide use, particularly in crops nearing sale date.

- Accurate cost accounting of weed management systems including labor for hand-weeding and strategies for efficient resource utilization through use of IPM to decrease weed management costs.
- Weed management strategies for crops or sites in which broad-spectrum herbicides may not be available (such as propagation, greenhouses, edible crops, ornamental grasses, covered structures, etc).
- Investigating lower cost alternatives – including spray-applied treatments, generic products, or other strategies.

*Strategies for environmentally sound weed management:*

- Understanding and minimizing environmental impacts of residual long term pesticide and herbicide applications (production runoff, accumulation in irrigation water, etc.).
- Alternative strategies for weed management including mulches, barriers, biological, or biorational approaches for PRE and POST weed control.
- Understanding and avoiding crop injury from herbicide use in nurseries (e.g.: long-term consequences of POST emergence herbicide use such as glyphosate applications via “Enviromist” sprayer technology, or environmental persistence such as herbicide residue effects on seedling germination and liner growth).
- Biology and ecology of weeds in these unique nursery ecosystems (e.g., environmental and climatic modeling for predicting certain weed seed germination; development and reproduction of common and newly introduced species).

*Development of new weed control technologies and herbicide formulations, including:*

- Effectiveness and utility of cultural, physical and mechanical controls such as cover crops and living mulches.
- Selective weed management options for over the top spray application in containers.
- Testing, labeling and economics of organic weed control options, oxidizers and novel chemistries for weed control efficacy (e.g., ZeroTol [hydrogen peroxide] or Terracide on liverwort and algae)
- Improved spray-applied herbicide options for container nurseries that take into consideration legal limits, phytotoxicity, and efficacy.

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