Pest Management Strategic Plan
for Container and Field-Produced Nursery Crops

Based on a workshop held July 30-31, 2009
at the North Carolina Research and Education Center,
Mills River, NC

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a grant from the Southern Region IPM Center
and coordinated by the
Southern Nursery Integrated Pest Management Working Group (SNIPM)

PMSP Authors:
Craig Adkins, Greg Armel, Matthew Chappell, J.C. Chong,
Steven Frank, Amy Fulcher, Frank Hale,
William Klingeman III, Kelly Ivors, Anthony LeBude,
Joe Neal, Andrew Senesac, Sarah White, Jean Williams-Woodward, Alan Windham

Editor and contact:

Amy Fulcher
University of Kentucky
Department of Horticulture
N318 Ag Science North
Lexington, KY 40546-0091
859-257-1273
afulcher@uky.edu
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Workshop Participants

Craig Adkins  
NCSU Agricultural Resource Center  
120 Hospital Avenue NE/Suite 1  
Lenoir, NC 28645  
Phone (828) 757-1290  
craig_adkins@ncsu.edu

Greg Ammon  
Ammon Wholesale Nursery  
6089 Camp Ernst Road  
Burlington, KY 41005  
Phone (859) 586-6246  
gammon@fuse.net

Jerry and Beth Blankenship  
Blankenship Farms and Little Creek Nursery  
1229 John Oliver Road  
McMinnville, TN 37110  
Phone (931) 668-9482, (931) 273-9007  
nsyliners@blomand.net

Pat Carey  
Riverfarm Nursery  
2901 N Buckeye Lane  
Goshen, KY 40026-9721  
Phone (502) 228-5408  
Fax (502) 228-7360  
PatC@riverfarm.com

Matthew Chappell  
The University of Georgia  
Horticulture Department  
211 Hoke Smith Building  
Athens, GA 30602  
Phone (706) 542-9044  
hortprod@uga.edu

Steven Frank  
Entomology  
North Carolina State University  
Department of Entomology  
Campus Box 7613  
2301 Gardner Hall  
Raleigh, NC 27695-7613  
Phone (919) 515-8880  
steven_frank@ncsu.edu
Amy Fulcher
University of Kentucky
Horticulture Department
N318 Ag Science North
1100 Nicholasville Road
Lexington, KY 40546-0091
Phone (859) 257-1273
afulcher@uky.edu

Mark Gantt
Hefner's Nursery
4135 Springs Road
Conover, NC 28613
Phone (828) 256-5271
mganttt@charter.net

Stanton Gill
Central Maryland UME
11975 Homewood Road
Ellicott City, MD 21042
Phone (301) 596-9413
sgill@umd.edu

Frank Hale
The University of Tennessee
Soil, Plant and Pest Center
5201 Marchant Drive
Nashville, TN 37211-5112
Phone (615) 835-4571
fahale@utk.edu

Elliot Hallum
Mountain Creek Nursery
941 Scenic Hills Drive
McMinnville, TN 37110
Phone (931) 934-2192
ehallum@gmail.com

Juang-Horng (J.C.) Chong
Pee Dee Research and Education Center
2200 Pocket Road
Florence, SC 29506-9727
Phone (843) 662-3526 ext. 224
juanghc@clemson.edu

Kelly L. Ivors
Plant Pathology
Mountain Horticultural Crops Research and Extension
Center (MHCREC)
455 Research Drive
Mills River, NC 28759
Phone (828) 684-3562 ext. 143
kelly_ivors@ncsu.edu

William Klingeman, III
Plant Sciences Department
2431 Joe Johnson Drive
252 Ellington PSB
The University of Tennessee
Knoxville, TN 37996-4500
Phone (865) 974-7324
wklingem@utk.edu

Anthony LeBude
Horticultural Science
Mountain Horticultural Crops Research and Extension Center (MHCREC)
455 Research Drive
Mills River, NC 28759
Phone (828) 684.3562
anthony_lebude@ncsu.edu

Patty Lucas
University of Kentucky Research and Education Center
P.O. Box 469
Princeton, KY 42445-0469
Phone (270) 365-7541 ext. 218
plucas@uky.edu

Phillip Porter
Ray Bracken Nursery
460 Woodville Road
Pelzer, SC 29669
Phone (864) 277-1990
dougg@raybracken.com

Cliff Ruth
740 Glover Street
Henderson County Center
Hendersonville, NC 28792
Phone (828) 697-4891
cliff_ruth@ncsu.edu

Ben Sanders
Griffith Propagation Nursery, Inc.
2580 Antioch Church Road
Watkinsville, GA 30677
Phone (888) 830-3236 or (706) 310-0027
bts352@hotmail.com

Andrew Senesac
Cornell University Cooperative Extension
Long Island Horticultural Research and Extension Center
3059 Sound Avenue
Riverhead, NY 11901
Phone (631) 727-3595
afs2@cornell.edu

Steve Toth
Southern Region Integrated Pest Management Center
1730 Varsity Drive, Suite 110
Raleigh, NC 27606-2194
Phone (919) 513-8189
Steve_Toth@ncsu.edu

Tiffany Wells
Adcock's Nursery
6141 Sunset Lake Road
Fuquay-Varina, NC 27526
Phone (919) 552-8286
Tiffany@adcocksnursery.com

Sarah White
Clemson University Department of Horticulture
150 Poole Agricultural Center
Box 340319
Clemson, SC 29634-0319
Phone (864) 656-7433
swhite4@clemson.edu

Alan Windham
The University of Tennessee
Soil, Plant and Pest Center
5201 Marchant Drive
Nashville, TN 37211-5201
Phone (615) 835-4572
awindha1@utk.edu
Executive Summary

About the Workshop

Nursery crop producers from five states (GA, KY, NC, SC, and TN) 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.

Workshop Agenda

Southern Region Nursery Crop Pest Management Meeting
July 30-31, 2009
Mountain Horticultural Crops Research and Extension Center
Mills River, NC

Facilitator: Steve Toth
Moderator: Amy Fulcher
Recorder: Patty Lucas

Thursday, July 30, 2009

8:00-8:10 Load presentations
8:10-8:30 Welcome—Kelly and Anthony
Introductions—Amy Fulcher
Overview of meeting, objectives, and goals – Steve Toth

8:30-11:00 Overview of production by an Extension horticulture representative from each state (production regions, major nursery crops, major pests, worker activities at different crop stages and during various pest occurrences, and pest management for top 10 crops)

8:30-9:00 GA—Matthew Chappell
9:00-9:30 KY—Amy Fulcher
9:30-9:40 Break
9:40-10:10 NC—Anthony LeBude
10:10-10:40 SC—Sarah White
10:40-11:10  TN—Frank Hale and Alan Windham
11:10-12:00  Growers present overview of their production and pest management practices
11:10-11:22  Break
11:2-11:34   GA—Ben Sanders
11:34-11:46  KY—Greg Ammon
11:46-11:58  KY—Pat Carey
11:58-12:10  NC—Mark Gantt
12:10-1:00   Catered lunch and presentation, “Success with IPM in Maryland Nurseries”, Stanton Gill, University of Maryland
1:00-1:12    NC—Tiffany Wells
1:12-1:24    Break
1:24-1:36    SC—Phillip Porter
1:36-1:48    TN—Jerry Blankenship
1:48-2:00    TN—Elliot Hallum
2:00-2:30    Break
2:30-4:30    Prioritize top 10 pests submitted by growers in advance of the meeting. Generate four lists per pest group: top 10 pests, emerging pests, research needs, and Extension needs
   2:30-3:10  Grower Comments on Diseases—Kelly Ivors
   3:10-3:50  Grower Comments on Insects—Steven Frank
   3:50-4:30  Grower Comments on Weeds—Andrew Senesac
4:30-4:55    Grower perspectives/concerns on environmental issues—Steve Toth
4:55-5:00    Wrap up and announcements for Friday
6:00 pm      Supper provided at Lake Julian

**Friday, July 31, 2009**

8:00-9:30    Small group discussion
             Why IPM is adopted or not?, Top 10 Pests, Research Needs, and Extension Needs
9:30-11:30  Survey update—Anthony LeBude
            Final priority setting—Steve Toth

11:30–Noon Travel reimbursement instructions and concluding remarks—Amy Fulcher

Noon     Meeting adjourned for growers

Box lunches provided for growers and university representatives

Noon-3:00pm

University representatives compile meeting data from growers, make preliminary
assessments, and assemble information for draft executive summary. Meeting time is
allotted for representatives to meet by discipline.
Overall Priorities

**Research Priorities**

- Make IPM profitable and viable for nursery crop production.
- Identify effective treatments for foliar nematodes
- Identify plant phenological indicators of arthropod pest activity
- Investigate how to manage arthropod pest complexes rather than individual species
- Whole systems approaches to pest management
- Determine cause and treatment of *Cryptomeria* tip disorder
- Develop more cost effective management of fire ants
- Understand glyphosate damage in nursery crops, symptoms, application technology
- Determine physiological differences between container and field grown plants with regard to pest susceptibility and pesticide treatments
- Develop systemic controls of borer and scale insects
- Identify surfactant and penetrate use for insect control in trees
- Conduct efficacy and cost analysis of generic pesticides
- Develop a controlled release preemergence herbicide
- Determine appropriate timing of pest monitoring, scouting, and pesticide applications for weeds, arthropods, and diseases
- Test efficacy of chemigation techniques- test efficacy of chemicals
- Investigate biology of black root rot

**Extension Priorities**

- Encourage the support and use of county Extension personnel (serving the green industry) in the dissemination of information
- Utilize multi state collaboration of university/industry personnel to develop a regional web site/clearing house for compiling and disseminating pest/pest management information
- Emphasize use of digital diagnosis through county offices
- Develop training and certification for scouting (expand to on-line and through distance education)
- Develop and make available efficacy tables to include REI and mode of action group
• Create awareness regarding timing of pesticide application to increase worker protection and effectiveness of chemicals

**Regulatory Priorities**

• 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
Background

**Pre-Meeting Survey Results**

Growers participating in the PMSP Meeting were asked to list and rank the most problematic pests at their nursery (Table 1). These preliminary rankings were used to focus discussion during the meeting.

*Table 1. Pre-meeting ranking of insects by a focus group of ten nursery crop growers (two growers per state, GA, KY, NC, SC, TN).*

<table>
<thead>
<tr>
<th>Insect Pests</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borers: dogwood, magnolia, FHAB, and others</td>
<td>9(^1)</td>
</tr>
<tr>
<td>Scale: white peach, calico, lecanium, tea, wax, and others</td>
<td>9</td>
</tr>
<tr>
<td>Spider mites incl. red spider mite</td>
<td>8</td>
</tr>
<tr>
<td>Granulate ambrosia beetle</td>
<td>5</td>
</tr>
<tr>
<td>Japanese beetle</td>
<td>5</td>
</tr>
<tr>
<td>Aphids</td>
<td>5</td>
</tr>
<tr>
<td>Leafhoppers</td>
<td>4</td>
</tr>
<tr>
<td>Fire ants</td>
<td>3</td>
</tr>
<tr>
<td>Bagworm</td>
<td>3</td>
</tr>
<tr>
<td>Maple tip borer</td>
<td>2</td>
</tr>
<tr>
<td>Flea beetles</td>
<td>2</td>
</tr>
<tr>
<td>Emerald ash borer</td>
<td>1</td>
</tr>
<tr>
<td>Twig girdler</td>
<td>1</td>
</tr>
<tr>
<td>Strawberry root weevil</td>
<td>1</td>
</tr>
<tr>
<td>Lacebug</td>
<td>1</td>
</tr>
<tr>
<td>Eastern tent caterpillar</td>
<td>1</td>
</tr>
<tr>
<td>Thrips</td>
<td>1</td>
</tr>
<tr>
<td>Broad mites</td>
<td>1</td>
</tr>
<tr>
<td>Midge larvae clogging filters</td>
<td>1</td>
</tr>
<tr>
<td>Snail</td>
<td>1</td>
</tr>
<tr>
<td>Whiteflies</td>
<td>1</td>
</tr>
<tr>
<td>Leafminers</td>
<td>1</td>
</tr>
</tbody>
</table>
Rank = number of votes, greater number of votes indicates more participants found this to be a problem weed.

Table 2. Pre-meeting ranking of diseases by a focus group of ten nursery crop growers (two growers per state, GA, KY, NC, SC, TN).

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powdery mildew</td>
<td>7(^1)</td>
</tr>
<tr>
<td>Rust</td>
<td>6</td>
</tr>
<tr>
<td>Leaf spot, incl. black spot</td>
<td>7</td>
</tr>
<tr>
<td><em>Phytophthora, Rhizoctonia</em> Root Rot</td>
<td>9</td>
</tr>
<tr>
<td>Cankers, incl. <em>Seridium, Fusarium</em> /cold injury, and others</td>
<td>4</td>
</tr>
<tr>
<td>Fireblight</td>
<td>4</td>
</tr>
<tr>
<td>Anthracnose</td>
<td>3</td>
</tr>
<tr>
<td><em>Pythium</em></td>
<td>2</td>
</tr>
<tr>
<td><em>Botrytis</em></td>
<td>2</td>
</tr>
<tr>
<td><em>Verticillium</em> wilt</td>
<td>1</td>
</tr>
<tr>
<td>Bacterial scorch</td>
<td>1</td>
</tr>
<tr>
<td>Foliar nematodes</td>
<td>1</td>
</tr>
<tr>
<td><em>Bryozoa</em> control on ponds</td>
<td>1</td>
</tr>
<tr>
<td>Tip blight juniper</td>
<td>1</td>
</tr>
<tr>
<td>Tip blight on <em>Cryptomeria</em></td>
<td>1</td>
</tr>
<tr>
<td><em>Phomopsis</em></td>
<td>1</td>
</tr>
<tr>
<td>Southern blight</td>
<td>1</td>
</tr>
</tbody>
</table>

\(^1\)Rank = number of votes, greater number of votes indicates more participants found this to be a problem weed.
Table 3. Pre-meeting ranking of field and container weeds by a focus group of ten nursery crop growers (two growers per state, GA, KY, NC, SC, TN).

<table>
<thead>
<tr>
<th>Weeds</th>
<th>Ranking¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutsedge</td>
<td>6</td>
</tr>
<tr>
<td>Spurge</td>
<td>5</td>
</tr>
<tr>
<td>Horseweed (marestail)</td>
<td>4</td>
</tr>
<tr>
<td>Bittercress</td>
<td>3</td>
</tr>
<tr>
<td>Crabgrass</td>
<td>3</td>
</tr>
<tr>
<td>Annual bluegrass</td>
<td>2</td>
</tr>
<tr>
<td>Eclipta</td>
<td>2</td>
</tr>
<tr>
<td>Oxalis</td>
<td>2</td>
</tr>
<tr>
<td>Thistle</td>
<td>2</td>
</tr>
<tr>
<td>Algae</td>
<td>1</td>
</tr>
<tr>
<td>Bermuda grass</td>
<td>1</td>
</tr>
<tr>
<td>Chickweed</td>
<td>1</td>
</tr>
<tr>
<td>Coffeeweed</td>
<td>1</td>
</tr>
<tr>
<td>Evening primrose</td>
<td>1</td>
</tr>
<tr>
<td>Grasses</td>
<td>1</td>
</tr>
<tr>
<td>Groundsel</td>
<td>1</td>
</tr>
<tr>
<td>Henbit</td>
<td>1</td>
</tr>
<tr>
<td>Johnson grass</td>
<td>1</td>
</tr>
<tr>
<td>Knotweed</td>
<td>1</td>
</tr>
<tr>
<td>Liverwort</td>
<td>1</td>
</tr>
<tr>
<td>Wild mustard</td>
<td>1</td>
</tr>
<tr>
<td>Perennial rye cheat</td>
<td>1</td>
</tr>
<tr>
<td>Pigweed</td>
<td>1</td>
</tr>
<tr>
<td>Smart weed</td>
<td>1</td>
</tr>
<tr>
<td>Wild carrot</td>
<td>1</td>
</tr>
<tr>
<td>Wild chrysanthemum</td>
<td>1</td>
</tr>
<tr>
<td>Wild onion/ Wild garlic</td>
<td>1</td>
</tr>
</tbody>
</table>

¹Rank = number of votes, greater number of votes indicates more participants found this to be a problem weed.
Nursery Crop Production

Introduction to Nursery Crop Production

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, and the 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 20th 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 gallon. 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 five states (GA, KY, NC, SC, and TN) represented by this PMSP, nursery producers are only 24-48 hours away from half the population of the United States. These same five states collectively produced 10% of the value in nursery crops in 2007 in the United States (Table 4) (USDA, 2009).
Table 4. Number of producers, total acreage and value of nursery crops for five southern states.

<table>
<thead>
<tr>
<th>State</th>
<th>Number of producers</th>
<th>Total acreage</th>
<th>Value in million $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Georgia</td>
<td>501</td>
<td>8,074</td>
<td>125.2</td>
</tr>
<tr>
<td>Kentucky</td>
<td>332</td>
<td>3,976</td>
<td>23.6</td>
</tr>
<tr>
<td>North Carolina</td>
<td>1250</td>
<td>23,443</td>
<td>251.9</td>
</tr>
<tr>
<td>South Carolina</td>
<td>314</td>
<td>7,375</td>
<td>91.4</td>
</tr>
<tr>
<td>Tennessee</td>
<td>793</td>
<td>33,591</td>
<td>177.2</td>
</tr>
<tr>
<td>Totals</td>
<td>3190</td>
<td>76,459</td>
<td>669.3</td>
</tr>
</tbody>
</table>

Percent of U.S. total: 14% 17% 10%

1 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 $91,000,000 due to insects and diseases (NCDA, 2005). Losses due to plant disease in Georgia in 2007 were estimated to be $43,410,000 for nurseries (Martinez, 2008).

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 Crop Production**

Many pests and diseases are difficult to eradicate once established in a nursery. Thus, sanitation/hygiene management practices should be introduced before infection and followed assiduously in nurseries to reduce pressure from diseases enhanced by poor sanitation. Once a disease is 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 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). Nurseries that follow 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, drainage, profile and slope. 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, non-flooding river bottoms. 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 movement. Bottomland sites may be more susceptible to cold pockets resulting in damage to sensitive crops from less air movement or less air drainage. Cold sensitive species should be sited on upland soils with better air drainage.

Access to both high quality and a large quantity of irrigation water are 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, grassed waterways and field edge buffer strips.

A field nursery site should first be soil tested to determine the soil’s fertility. The number of soil tests 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 litter. Traditional methods to increase organic matter in fields include green manure crop rotation utilizing a double cropping system of grasses and small grains. Small grains may be sown in the fall, killed with an herbicide, and then plowed under prior to producing seeds in the spring. Sorghum-Sudan hybrids are commonly used as summer cover crops sown in April or May. Most are mowed at least twice to prevent seed formation, and then plowed under in the fall.

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. 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 size of plant needed or the market for the crop. Plants sold to professional landscapers or as municipal trees 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. To increase the moisture in the plants and to 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 during winters. 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.

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 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, nitrogen can be incorporated at 50 lbs. per acre and all other nutrients at appropriate rates according to soil tests to a depth of 6 to 8 inches.

In subsequent years, nitrogen application rates should be based on the amount of nitrogen per plant rather than pounds of nitrogen per acre. Fertilizer should be placed within the root zone as a side dress at the rate of 0.25 to 0.5 oz. nitrogen per plant rather than previous recommendations of 100 to 200 lbs. nitrogen 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. nitrogen before bud break.

During the second year, each plant should receive 0.5 to 1.0 oz. 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. 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 and impact 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 topdress. 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 times of plant rest (mid-summer/late fall-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 extremely inefficient to use because of large plant spacing, but they are the method of choice for most field nurseries. In fields irrigated with this system, water is lost when applied between rows and run-off may occur. An acre of nursery stock may need an inch of irrigation (acre-inch) applied 1 to 2 times per week. An acre-inch of water is 27,000 gallons. A large water supply is required if this amount of water is applied to large acreages.

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 installed 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. 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 the 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 structural pruning, such as removing crossing branches, branches with poor angles, and closely spaced branches. 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, 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 chances of a co-dominant leader.

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” on the trunk, or higher if final use is for street trees. Ornamental trees and smaller caliper trees may have substantially lower permanent branches. 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 ½” 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 suckers. 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. 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. At this time, trees are straightened, excess soil is removed from the base of the trunk, and stakes are installed. 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, creating challenges for spraying during the spring and during other times of precipitation, 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 erosion, but will not fix nitrogen like crimson clover.

Floor Management: Clippings

Nursery workers should collect and dispose of pruning 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 preemergence herbicides to have better contact with soil. 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 season (spring or fall). 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 plants is standard (has 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 the 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**

The growing medium used in container production is typically a soilless substrate. 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.
The pH and electrical conductivity of every pine bark load needs to be tested each time a new load is delivered to the nursery.

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 will 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 percent 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. Drainage from nursery crops should not be allowed to penetrate and saturate the substrate inventory or disease causing organisms may spread from production the stored substrate. The inventory supply should, however, be moistened if it will be stored for a long period and turned periodically, 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.

*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, dissolving mineral nutrients each time and carrying 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 monitor irrigation uniformity 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 the similarly sized pot and plastic bag. Thirty minutes after the irrigation cycle has been completed for the day, collect and measure the amount of water in each container. The water in C1 is the total volume applied and the water in C2 is the amount 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 test efficiency of irrigation distribution 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. If there are major differences between pots within the same irrigation zone, then distribution of water might be uneven. 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 (Na and Cl), pH, electrical conductivity, alkalinity, and turbidity are all factors that influence irrigation water quality. Whether of municipal, well, surface, or retention pond origin, irrigation water needs to be frequently tested and monitored to promote efficient use of fertilizer, chemical, and water resources.

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), many pesticides (organophosphates, synthetic pyrethroids, carbamates, chlorinated hydrocarbons, ethephon – a growth regulator, and others) undergo hydrolysis, a reaction with water that causes chemical breakdown. The higher the pH (more alkaline) the quicker the breakdown, and for every unit increase in pH, the hydrolysis rate 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 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 or growth regulator mixture/dilution will begin to degrade, effectively reducing the chemical application rate. Because poor water quality is not easily identifiable (i.e. no colors, no smells, no tastes), this problem can persist for years without recognition. As a result, excessive spray applications with harsh chemicals might occur as compensation, even without grower intention. This scenario can create pesticide resistance in some insects and pathogens. Long-term, the use of buffering agents will enhance pesticide and growth regulator effectiveness and residual control.
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 at a pH of 8.0 compared with water at a pH of 5.0 (Copes et al., 2004). 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. However, if irrigation water is recycled and high pH, alkalinity, plant growth issues, and pest infestations are recurring problems, additional treatment options such as acid injection or mixing with an alternative water source (make-up water) should be considered to reduce plant stress from both abiotic and biotic factors.

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 (Yeager et al., 2007). 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 water from over 75% of the nursery (Garber et al., 2002). Since the early part of the 21st 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), only 30% of respondents treated irrigation water with chlorine (LeBude et al., unpublished data). 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 with changing personnel, water sources, weather, and development/urbanization. There are many options for treating water, but all depend upon a basic knowledge of various water quality factors. Various physical, chemical, and biological contaminants need to be removed from irrigation water. Water source (municipal, well, surface, and/or recycled) influences the treatment(s) necessary before water can be used for irrigation.

**Filtration** or removal of unwanted particles is the most common and necessary treatment technology used to cleanse irrigation water. 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 disinfect 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 µmol/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 *Rhzoctonia 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, silver, copper, and zinc) 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 Cu$^{2+}$ toxicity thresholds for three ornamental crops, *Dendranthema x grandiflora* ‘Fina’, *Rosa x hybrida* ‘Lavlinger’, and *Pelargonium x hortorum* ‘Evening Glow’, and found that Cu$^{2+}$ concentrations > 2.4 µmolar resulted in
visible plant injury. Care should be taken that 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 ppm), manganese, calcium, and suspended solids inhibiting proper UV function (Roberts, 1999). Some nurseries are altering drainage (runoff) flow routes to maximize exposure to natural UV light to improve UV aided disinfestation 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.

**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 g/0.18=50 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 grower/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).

**Calendar of Worker Activities in Field Nursery**

**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.

**Nursery Crop Production Literature Cited**


Key Pest Profiles and Critical Issues:  
*Insect Pests*

**Aphids**

*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, *Paraprociphilus 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, *Adelges 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 that has a high sugar content but is nutrient poor.
• Honeydew forms a sticky layer on leaves and objects below trees.
• Honeydew is a substrate for black sooty mold which is unattractive and reduces plant photosynthesis but is not pathogenic.
• 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:**

**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.
o Fertilizer, particularly nitrogen, makes plants more nutritious for aphids and can substantially increase aphid population growth by reducing development time and increasing fecundity.

o 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:**

o Aphid populations in field production are constantly subject to predation and parasitism. Many existing populations of parasitoids and predators attack aphids.

o In many cases aphids are fully controlled by natural enemies. Populations tend to cycle as aphid abundance increases predators, and parasitoids quickly extinguish the infestation.

o 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.

o 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.

o The effectiveness of biological control (conservation or augmentative) in field productions is unknown.

o Existing biological control can be disrupted by the use of broad-spectrum insecticides.

**Chemical:**

o Aphids are relatively unprotected from insecticides and thus susceptible to a number of products.

o Many species feed on the undersides of leaves, so coverage of these areas is important.

o 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:

<table>
<thead>
<tr>
<th>Chemical Class</th>
<th>Common Name</th>
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<tbody>
<tr>
<td>Carbamates</td>
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<td>Organophosphates</td>
<td>acephate</td>
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<td>Pyrethroids</td>
<td>bifenthrin, permethrin</td>
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<td>Neonicotinoids</td>
<td>acetamiprid, clothianidin, dinotefuran, imidacloprid, thiamethoxam</td>
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<td>Feeding blockers</td>
<td>pymetrozine, flonicamid</td>
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<td>Azadirachtin</td>
<td>azadirachtin, neem oil</td>
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<tr>
<td>Horticultural oil</td>
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<tr>
<td>Insecticidal soap</td>
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**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:**

**Flat headed 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.

**Round headed borers** (Coleoptera: Cerambycidae): 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, *Eudociminus mannerheimii* (Boheman)

**Lepidopteran borers** (Lepidoptera: Sessiidae): 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.
• All borers have chewing mouthparts that are used by adults or larvae to bore into woody plants.
• 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 appearance as larvae produce galleries below.
- Boring below the bark results in blisters and gnarled scars as the tree produces bark in the wounded area.
- 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 much of the Upper Midwest south to Virginia, West Virginia, and Kentucky (USDA, 2009a).
- 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 apple tree 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 round headed apple tree 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:**

**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 borers.

**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:

<table>
<thead>
<tr>
<th>Chemical Class</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organophosphates</td>
<td>chlorpyrifos</td>
</tr>
<tr>
<td>Pyrethroids</td>
<td>bifenthrin, permethrin</td>
</tr>
<tr>
<td>Neonicotinoids</td>
<td>dinotefuran, imidaclorpid</td>
</tr>
</tbody>
</table>

**Federal Restrictions:** Areas infested with emerald ash borer or Asian longhorn borer are subject to quarantine (UDSA APHIS 2009a).
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 neonicitinoids 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.

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)

Host Name:

Bagworm feeds on a total of 128 plant species. Preferred hosts of bagworm include *Acer, Aesculus, Juniper, Platanus, Robinia, Thuja, 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, leaftiers, 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:

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.
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.

Cultural:

- 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.

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:

<table>
<thead>
<tr>
<th>Chemical Class</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Organophosphate</td>
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<td>Microbial</td>
<td>Bt</td>
</tr>
<tr>
<td>Spinosyn</td>
<td>spinosad</td>
</tr>
<tr>
<td>IGR (benzoic acid hydrazide)</td>
<td>tebufenozide</td>
</tr>
<tr>
<td>Pyrethroid</td>
<td>cyfluthrin, bifenthin, lambda-cyhalothrin</td>
</tr>
</tbody>
</table>

**Federal/State/Local Regulations:**
- None noted.

**Critical Needs:**
- Evaluate resistant plant species or cultivars.

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

**Common Species:**
- Apple flea beetle, *Altica foliacea* (LeConte 1858); 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, *Monocesma coryli* (Say); Imported willow leaf beetle, *Plagiodera versicolora* (Laicharting); Cottonwood leaf beetle, *Chrysomela scripta* Fabricius; and *Chrysomela interrupta* Fabricius.

**Host Plants:**
- 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.
- 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.

- An example of a leaf beetle life cycle follows:
  - 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:**

**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.

**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 setboldi*, 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:**

- 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.

**Federal/State/Local Regulations:**

- None noted.

**Critical Needs:**

- Evaluate resistant plant species or cultivars.

**Granulate Ambrosia Beetle**

**Species:**

*Xylosandrus crassiusculus* (Motschulsky); occasionally *Xylosandrus germanus* (Blandford)

**Host Plants:**

124 plant species are known to be attacked by granulate ambrosia beetle (Schedl, 1962). 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.

**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-bait 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 by ethanol traps.
- Because of rapid degradation of the insecticides in the field, reapplication every 10-14 days may be needed until the trees break dormancy/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:

<table>
<thead>
<tr>
<th>Chemical Class</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrethroids</td>
<td>bifenthrin, permethrin</td>
</tr>
</tbody>
</table>

**Federal/State/Local Regulations:**

- None.

**Critical Issues & Needs:**

- Improve prediction of adult flight across the South
• 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

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:

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:

- 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:

<table>
<thead>
<tr>
<th>Chemical Class</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organophosphate</td>
<td>chlorpyrifos, diazinon</td>
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<td>Carbamate</td>
<td>carbaryl</td>
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<tr>
<td>Neonicotinoid</td>
<td>thiamethoxam</td>
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<tr>
<td>Neonicotinoid plus pyrethroid</td>
<td>imidacloprid plus cyfluthrin</td>
</tr>
<tr>
<td>Pyrethroid</td>
<td>cyfluthrin, bifenthrin, lambda-cyhalothrin</td>
</tr>
</tbody>
</table>

**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. Some specific examples of Eriophyid mites include 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.

Host Plants:

- Many species of trees and woody ornamentals are attacked by spider mites 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.

Distribution, Damage and Importance:

- Most of the common species have a cosmopolitan distribution in the Southeast.
- Mites have piercing mouth parts 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.
- 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.

Control Measures:

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.
- Chemicals used in nurseries include:

<table>
<thead>
<tr>
<th>Chemicals Class</th>
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<tr>
<td>Organophosphates</td>
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<td>soap</td>
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</table>

**Federal/State/Local Regulations and Pesticide Restrictions:**
- None.

**Critical Issues and Needs:**
- 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* Bure

**Distribution, Damage & Importance:**

• Introduced into the United States in the 1930s 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, 2009a).

• 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.
- Chemicals based on USDA-APHIS guidelines on RIFA quarantine treatments in the nursery (USDA, 2007, USDA-APHIS, 2009b):

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Brand Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bifenthrin</td>
<td>Talstar, Bifenthrin Pro</td>
</tr>
<tr>
<td>Chlorpyrifos</td>
<td>Dursban, Chlorpyrifos</td>
</tr>
<tr>
<td>Diazinon</td>
<td>Diazinon</td>
</tr>
<tr>
<td>--------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Fenoxycarb</td>
<td>Award (bait)</td>
</tr>
<tr>
<td>Fipronil</td>
<td>Chipco Choice, Chipco TopChoice</td>
</tr>
<tr>
<td>Hydramethylnon</td>
<td>AmdroPro, SiegePro (baits)</td>
</tr>
<tr>
<td>Methoprene</td>
<td>Extinguish (bait)</td>
</tr>
<tr>
<td>Pyriproxyfen</td>
<td>Distance (bait)</td>
</tr>
<tr>
<td>Tefluthrin</td>
<td>Fireban</td>
</tr>
</tbody>
</table>

**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

**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 hesperidium* Linnaeus); cottony maple scale *Pulvinaria innumerabilis* (Rathvon), etc.
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,* and *Quercus.*

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.

Life Cycle:
- Life cycle of scale insects vary by species.
- Armored scales have 4 female life stages (egg, crawler, 2\textsuperscript{nd}-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, 2nd-instar nymph, adult, with some species having an additional nympha! 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 2nd-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:

Cultural/Mechanical:

  o The most important cultural control tactic is to maintain and promote the health of nursery crops through proper planting, irrigation and fertilization practices.
  o Healthy shrubs and trees can better withstand and recover from scale infestations.
  o Removal and immediate disposal of infested plant materials and alternative host plants in the production areas are important in preventing the introduction and spread.
  o Little information is available on resistant plant taxa. Some Acer taxa resistant to calico scale have been reported (Seagraves, 2006).

Biological:

  o 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.
  o The effectiveness of biological control (conservation or augmentative) in field productions is unknown.
  o Existing biological control can be disrupted by the use of broad-spectrum insecticides.

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.

Chemicals used in the nurseries include the following:
<table>
<thead>
<tr>
<th>Chemical Class</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbamates</td>
<td>carbaryl</td>
</tr>
<tr>
<td>Organophosphates</td>
<td>acephate, chlorpyrifos, dimethoate, disulfoton, malathion</td>
</tr>
<tr>
<td>Pyrethroids</td>
<td>bifenthrin, cyfluthrin, cyhalothrin, deltamethrin, fenpropathrin, permethrin</td>
</tr>
<tr>
<td>Neonicotinoids</td>
<td>acetamiprid, clothianidin, dinotefuran, imidacloprid, thiamethoxam</td>
</tr>
<tr>
<td>Juvenile hormone mimics</td>
<td>kinoprene, pyriproxyfen</td>
</tr>
<tr>
<td>Feeding blockers</td>
<td>pymetrozine, flonicamid</td>
</tr>
<tr>
<td>Buprofezin</td>
<td>buprofezin</td>
</tr>
<tr>
<td>Tetramic acid derivatives</td>
<td>spirotetramat</td>
</tr>
<tr>
<td>Azadirachtin</td>
<td>Azadirachtin, neem oil</td>
</tr>
<tr>
<td>Horticultural oil</td>
<td></td>
</tr>
<tr>
<td>Insecticidal soap</td>
<td></td>
</tr>
</tbody>
</table>

**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.
Correlations between scale insect taxonomy and phenology.

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.

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.

Some species previously not known to be pests of certain plant species, such as Melanaspis deklei on wax myrtles, have become a significant problem. A better understanding of what triggers an outbreak is needed.

**Scarab and Weevil Grubs**

**Common Species:**

**Scarab beetles (Scarabaeidae):**


**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):
<table>
<thead>
<tr>
<th>Chemical Class</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dip treatment for B&amp;B and container plants:</strong></td>
<td></td>
</tr>
<tr>
<td>Organophosphate</td>
<td>chlorpyrifos</td>
</tr>
<tr>
<td>Pyrethroid</td>
<td>bifenthrin</td>
</tr>
<tr>
<td><strong>Drench treatment for container plants:</strong></td>
<td></td>
</tr>
<tr>
<td>Pyrethroid</td>
<td>bifenthrin</td>
</tr>
<tr>
<td>Neonicotinoid</td>
<td>imidacloprid, thiamethoxam</td>
</tr>
<tr>
<td><strong>Media incorporation for container plants:</strong></td>
<td></td>
</tr>
<tr>
<td>Pyrethroid</td>
<td>bifenthrin, tefluthrin</td>
</tr>
<tr>
<td>Neonicotinoid</td>
<td>imidacloprid</td>
</tr>
<tr>
<td><strong>Methyl bromide fumigation:</strong></td>
<td></td>
</tr>
<tr>
<td>Methyl bromide</td>
<td></td>
</tr>
<tr>
<td><strong>Pre-harvest soil surface treatment:</strong></td>
<td></td>
</tr>
<tr>
<td>Neonicotinoid</td>
<td>imidacloprid, imidacloprid+cyfluthrin, thiamethoxam</td>
</tr>
</tbody>
</table>

**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:

<table>
<thead>
<tr>
<th>Soil applied in early spring:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Class</td>
</tr>
<tr>
<td>Neonicotinoid plus pyrethroid</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foliar application:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbamate</td>
</tr>
<tr>
<td>Pyrethroid</td>
</tr>
</tbody>
</table>

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.

Entomology Extension Priorities

- 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.
• Emphasize the importance of decreasing stress on plants and using appropriate production practices to do so.

Entomology Research Priorities

• Improve mite management.
• Develop thresholds and what products to use to avoid secondary pest outbreaks i.e., potato leafhopper applications increasing mite populations
• Use of water conditioner for pH
• Develop understanding of production practices relationship with pest outbreaks—focus on insect complexes, not on an individual but rather focus on a plant to allow the consolidation of sprays.
• Determine if improved nutrition in the fall will reduce attacks by the flatheaded apple tree 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.
• Timing in pruning.
• Increase chemical efficacy by determining correct surfactants and their rate.
• Improve borer identification technique, distinguish between various borers.
• Determine insect biology, host preference and overwintering host preference and how production practices might affect both.
• Products that control pests with minimal negative effects on natural enemies and pollinators.
• Determine possibilities for management of granulate ambrosia beetle after they enter trees.
• Investigate pesticide efficacy, life history, timing of sprays, trials to show using life history and timing of sprays for Japanese maple scale, white peach scale.
• Develop thresholds for Japanese beetles.
Arthropod Priorities

The arthropod pests were rated during the workshop on 1) how difficult they are to control and 2) how common they are (Table 5).

Table 5. Arthropods ranked by growers and university representatives on difficulty to control and prevalence.

<table>
<thead>
<tr>
<th>Arthropods</th>
<th>Difficulty to Control</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aphids</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Borrers</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Caterpillars</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Flea/leaf beetles</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Granulate ambrosia beetle</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Japanese Beetle</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Leafhoppers</td>
<td>1</td>
<td>7</td>
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<tr>
<td>Mites</td>
<td>14</td>
<td>16</td>
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<tr>
<td>Root grubs/weevils</td>
<td>5</td>
<td>3</td>
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<tr>
<td>Scales</td>
<td>26</td>
<td>20</td>
</tr>
</tbody>
</table>

¹Rank = number of votes, greater number of votes indicates more participants found this to be a problem weed.
<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Mode of Action Group</th>
<th>Aphids</th>
<th>Caterpillars</th>
<th>Soft scale</th>
<th>Armored scale</th>
<th>CW and FH borers</th>
<th>Granulate ambrosia beetle</th>
<th>Flea beetles</th>
<th>Adult Japanese beetles</th>
<th>Leafhoppers</th>
<th>Spider mites</th>
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<td>Akari™</td>
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</table>
Notes:

G = Good
F = Fair
P = Poor
Unk. = unknown mode of action

Blank spaces indicate either a product is not labeled for use on a particular pest or not enough information is available to assign an efficacy rating.

This chart is provided for convenience of the reader. Insecticide labels and laws change frequently. It is the responsibility of the applicator to follow the label instructions and determine a safe and legal product for a specific application. Common products were listed by their trade names only as a convenience. Mention of a product does not constitute endorsement, nor does omission of a product imply ineffectiveness.

^Effective on flatheaded borers only.

^Regional differences and/or application techniques may have affected efficacy.
Entomology Literature Cited


http://nationalplantboard.org/docs/jbcolumn.pdf


USDA APHIS. 2009b. Imported Fireant Quarantine Map. 

Entomology General References


Key Pest Profiles and Critical Issues: Diseases

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 that have 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 disinfect equipment and other tools (refer to Table 6).
- Maintain calendar records of disease problems. Scout for disease symptoms during specific times of the year based on previous history.
<table>
<thead>
<tr>
<th>Material or Treatment</th>
<th>Trade Name</th>
<th>Formulation</th>
<th>Remarks</th>
<th>Contact Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol, ethyl and isopropyl (grain, rubbing, wood) (70-100%)</td>
<td>Various commercial brands; Lysol Spray (also includes quaternary ammonium)</td>
<td>Full strength</td>
<td>Evaporates quickly, so adequate contact time may not be achieved; high concentrations of organic matter diminish effectiveness; flammable</td>
<td>10 min for equipment, pots, flats and surfaces. Tools can be dipped for 10 seconds and allowed to dry. Do not rinse.</td>
</tr>
<tr>
<td>Phenolics</td>
<td>Pheno-Cen Spray Disinfectant</td>
<td>Full strength</td>
<td>Phenol penetrates latex gloves; eye/skin irritant; remains active upon contact with organic soil; may leave residue</td>
<td>10 min for equipment, pots, flats and surfaces. Tools can be dipped for 10 seconds and allowed to dry. Do not rinse.</td>
</tr>
<tr>
<td>Peroxyacetic acid and hydrogen peroxide mixture</td>
<td>ZeroTol</td>
<td>2.5 oz per gallon of water</td>
<td>Corrosive; causes irreversible eye damage; eye/skin irritant. Low odor. Use according to label.</td>
<td>10-15 min</td>
</tr>
<tr>
<td>Quaternary ammonium</td>
<td>Consan Triple Action 20; Physan 20; GreenShield 20;</td>
<td>1 tablespoon per gallon of water</td>
<td>Effective for non-porous surface sanitation, e.g. floors, walls, benches, pots. Low odor, irritation. Use according to label.</td>
<td>10-15 min</td>
</tr>
<tr>
<td>Sodium hypochlorite (5.25%)</td>
<td>Clorox; Commercial bleach</td>
<td>10% or a 1:9 ratio of bleach : water</td>
<td>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.</td>
<td>10-15 min for equipment, pots, flats and surfaces. Tools can be dipped for 10 seconds and allowed to dry. Do not rinse.</td>
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<tr>
<td>Steam</td>
<td>NA</td>
<td>Cover or seal</td>
<td>For plastic pots/trays, heat center of steamer between 150°F and 160°F; For less heat-sensitive objects, heat to 180°F.</td>
<td>60 min; 15 min.</td>
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<tr>
<td>Solarization</td>
<td>NA</td>
<td>Place clean items on solid surface, cover tightly with CLEAR plastic.</td>
<td>Clear plastic works very well.</td>
<td>140°F, 4 to 8 hr/day for 7 days</td>
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</tbody>
</table>
**All items should be free of organic debris before exposing to the treatments.**
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 (\textit{Cornus florida} x \textit{Cornus 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.

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
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 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 grouped by similarities in chemical structure and mode of action. Highly effective compounds like the triazoles and QoI fungicides (e.g., strobilurins) with specific modes of action have been recently developed. 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.

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.
Black Root Rot

Pathogen:

*Thielaviopsis basicola* (syn. *Chalara elegans*).

Hosts:


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 chlorotic plants 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 foliage 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* are the best way to determine if a suspect plant is infected.

**Disease Cycle:**
- *Thielaviopsis* is a dematiaceous hyphomycete.
- *Thielaviopsis* produces two distinct spores: cylindrical, dark brown, multi-septate chlamydospores (aleuriospores) and unicellular, cylindrical, hyaline endoconidia.
- Endoconidia are extruded in chains endogenously from conidiophores.
- Chlamydospores may be observed in infected roots.
- *Thielaviopsis* 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 which could attract fungus gnats and shore flies
- Adjusting pH of mix to 5.5 and using certain nitrogen sources have only been 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.
- 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.

**Cedar Ruts**

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

**Hosts:**


**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. juniperi-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 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 twigs.
• 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, spermagonia form on the leaf, fruit or twig depending on the rust species.
• Spermagonia formation is followed by aecia in which aeciospores are produced.
• Aeciospores are wind-borne and infect juniper needles.
• Cedar rusts generally overwinter on the evergreen (juniper) 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 is time consuming.
- Removing junipers 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, sterol biosynthesis inhibitor and strobilurin groups are used to protect susceptible plants from rusts, including mancozeb, myclobutanil, propiconazole, triadimefon, trifloxystrobin and azoxystrobin.

Critical Issues and Needs:

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

Downy Mildew

Pathogens:

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

Hosts:


Distribution and Importance:

- Downy mildew has become a serious problem throughout the southeast 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 which infect new growth.
- Once conditions become warm (>85°F) and dry, the pathogen disappears 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.
o Pruning tools should be sterilized frequently to prevent spreading the bacterium.
o Trees should not be irrigated overhead during bloom.
o The disease is worse on succulent tissues.
o Avoid excess nitrogen fertilization and heavy pruning, which promotes succulent growth that is more susceptible to infection.
o Remove water sprouts that form on susceptible hosts, as they are especially susceptible to the pathogen.
o Space container plants to promote air movement and lateral branching.
o Remove severely infected plants.
o 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, Phyton 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.

**Fungal Canker Diseases**

**Pathogens:**
*Botryosphaeria dothidea, B. ribis, B. rhodora, Seiridium cardinal, S. unicorne, 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:**
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* is the most important. Other species associated with diseased ornamental plants include *P. cactorum*, *P. cambivora*, *P. citricola*, *P. citrophthora*, *P. cryptogea*, *P. dreschleri*, *P. hedraiandra*, *P. megasperma*, *P. nicotianae*, as well as several undescribed *Phytophthora* species.

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 6).
- 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:
  o None noted.

Chemical Control:
  o Chemical control of Phytophthora or Pythium root rot is successful only when integrated with best management practices.
  o Fungicides work better as prophylactic treatments.
  o Incorporated fungicides are usually more uniformly distributed throughout the substrate or soil and may provide better protection.
  o If a root rot fungicide was not incorporated into the substrate, begin drenches or foliar sprays immediately after plants have been transplanted.
  o Soil drenches usually provide better protection from root rot than foliar sprays.
  o Treatment schedules and rates will depend on the plant being grown, the level of disease pressure, and the fungicide used.
  o Fungicides recommended for Phytophthora and Pythium root rot control in container- and field-grown plants are listed (Table 7).

Table 8. Chemicals recommended for Phytophthora and Pythium root rot control.

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Trade name</th>
<th>FRAC code*</th>
<th>Sites**</th>
<th>REI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mefenoxam</td>
<td>Subdue</td>
<td>4</td>
<td>G, N, L</td>
<td>0 hr</td>
</tr>
<tr>
<td>Azoxystrobin;</td>
<td>Heritage;</td>
<td>11</td>
<td>G, N, L</td>
<td>4 hr</td>
</tr>
<tr>
<td>Pyraclostrobin;</td>
<td>Insignia;</td>
<td>11</td>
<td>G, N, L</td>
<td>12 hr</td>
</tr>
<tr>
<td>Fenamidine;</td>
<td>FenStop;</td>
<td>11</td>
<td>G</td>
<td>12 hr</td>
</tr>
<tr>
<td>Etridiazole</td>
<td>Terrazole; Truban</td>
<td>14</td>
<td>G, N, L</td>
<td>12 hr</td>
</tr>
<tr>
<td>Dimethomorph</td>
<td>Stature</td>
<td>40</td>
<td>G, N</td>
<td>12 hr</td>
</tr>
<tr>
<td>Cyazofamid</td>
<td>Segway</td>
<td>21</td>
<td>G, N, L</td>
<td>12 hr</td>
</tr>
<tr>
<td>Fosetyl aluminum;</td>
<td>Aliette;</td>
<td>33</td>
<td>G, N, L</td>
<td>12 hr</td>
</tr>
<tr>
<td>Phosphorous acid;</td>
<td>Alude;</td>
<td>33</td>
<td>G, N, L</td>
<td>4 hr</td>
</tr>
<tr>
<td>Potassium phosphate;</td>
<td>Agri-Fos;</td>
<td>33</td>
<td>G, N, L</td>
<td>4 hr</td>
</tr>
<tr>
<td>Dipotassium</td>
<td>Fosphite;</td>
<td>33</td>
<td>G, N, L</td>
<td>12 hr</td>
</tr>
<tr>
<td>phosphonate</td>
<td>Vital;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BioPhos</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 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. rosea*

**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 of the *Oidium sp.* 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 (cleistothecium).
- Inside the ascocarp are sac-like structures (asci) in which ascospores are produced. The fungi overwinter in the sexual stage primarily.
- When the sexual stage is present, species of powdery mildew fungi are separated morphologically by chasmothecial appendages, the number of asci within the chasmothecium, and the number and shape of ascospores.
- 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.

**Emerging 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 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. More education involving newly emerging plant diseases will be essential for their rapid detection, identification, and control.

**Plant Pathology Extension Priorities**

- Develop resources that provide information regarding cultural practices as well as chemical controls with efficacy tables that also include other details such as curative/preventative activity and certain state label restrictions.

**Plant Pathology Research Priorities**

- Evaluate the efficacy of products applied via chemigation.
Disease Priorities

The diseases were rated during the workshop on their importance to growers (Table 8).

Table 9. Diseases ranked by growers and university representatives by importance (10 being most important, 1 being least important).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Root rots (<em>Phytophthora</em> and <em>Pythium</em> spp.)</td>
</tr>
<tr>
<td>9</td>
<td>Fungal leaf spots</td>
</tr>
<tr>
<td>8</td>
<td>Powdery mildew</td>
</tr>
<tr>
<td>7</td>
<td>Downy mildew</td>
</tr>
<tr>
<td>6</td>
<td><em>Phomopsis</em></td>
</tr>
<tr>
<td>5</td>
<td>Black root rot</td>
</tr>
<tr>
<td>4</td>
<td><em>Botryosphaeria</em></td>
</tr>
<tr>
<td>3</td>
<td>Cedar rusts</td>
</tr>
<tr>
<td>2</td>
<td><em>Passalora</em> needle blight</td>
</tr>
<tr>
<td></td>
<td>(<em>Cercosporidium</em> needle blight or <em>Cercospora</em> blight)</td>
</tr>
<tr>
<td>1</td>
<td>Fire blight</td>
</tr>
</tbody>
</table>

1Rank = number of votes, greater number of votes indicates more participants found this to be a problem weed.
Table 10. Relative effectiveness of various chemicals for disease control in woody ornamentals.

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>FRAC*</th>
<th>Black root rot</th>
<th>Cedar rusts</th>
<th>Downy mildew</th>
<th>Fire blight</th>
<th>Fungal leaf spots</th>
<th>Passalora needle blight</th>
<th>Phytophthora root rot</th>
<th>Pythium root rot</th>
<th>Powdery mildew</th>
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</thead>
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<tr>
<td>Cleary 3336® / Fungo® Flo</td>
<td>1</td>
<td>G^DR, DR</td>
<td>F^S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F^S</td>
</tr>
<tr>
<td>Banrot®</td>
<td>1 + 14</td>
<td>F^DR</td>
<td>G^S</td>
<td></td>
<td>P^DR</td>
<td>G^DR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectro™</td>
<td>1 + M5</td>
<td>G^S</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>G^S</td>
</tr>
<tr>
<td>Banner® Maxx^4</td>
<td>3</td>
<td>F^S</td>
<td>G^S</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>G^S</td>
</tr>
<tr>
<td>Eagle® / Hoist™ / Systhane™</td>
<td>3</td>
<td>F^S</td>
<td>F^S</td>
<td>F^S</td>
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<tr>
<td>Rubigan® AS</td>
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<td>F^S</td>
<td>G^S</td>
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<td>F^S</td>
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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

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 regulations and conforms to the product label. Examine a current product label before applying any chemical. For assistance, contact your county Cooperative Extension agent.
Plant Pathology Literature Cited


General References


Key Pest Profiles and Critical Issues: 

Weedy Plants, Liverworts and Algae

Weed 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 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)
- Prolific or high-viability seed set
- Highly mobile seeds that can drift on wind or be dispersed in irrigation water
- 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, perennial, sedges, grasses and broadleaf weeds all within a single production environment.

Plant Profiles for Select Weeds\(^1\) 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 (*)

\(^1\)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.

**Summer Annual Broadleaf Weeds:**
- Mature in one season seeds germinate in the summer, flower in summer, set seed 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, 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 postemergence control.

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 seed.
• 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:

  o Hand weeding or cultivation provide temporary control.
  o Mulches are somewhat effective.

Biological Control:

  o 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:
- Becoming widespread in the southeastern United States.
- Introduced.

Life Cycle:
- Annual
- More common in cool weather but can persist year round southeastern United States
- Wind-dispersed seed has no dormancy requirements, producing 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 United States but is not significantly affecting weed populations.

Chemical Control:

- Few PRE herbicides are effective.

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 needed to expand current PRE and POST herbicide labels.

Eclipta

(*Eclipta prostrata; syn. *E. alba*) [ECLAL]

(B, C*)

Distribution, Damage and Importance, origin:

- Widespread across southeastern United States.
- Dense, fibrous root system.

Life Cycle:

- Summer annual that may be perennial in warmer regions of the southeastern US.
- 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 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.

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:**

- Introduced (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.
- 5000+ seeds per plant.
- Seed viability is about 90% with no dormancy requirements, leading to multiple generations per season.

**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 the high cost of hand removal.

**Biological Control:**

- None noted.

**Chemical Control:**
Most commonly managed using PRE herbicides.

Resistance to a common nursery herbicide has been reported for this species.

No selective POST herbicides are available.

**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).

**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.
- Non-selective POST herbicides are effective.

**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 the crops.
- Selective POST options are needed.

**Horseweed**

(*Conzyla canadensis*) [ERICA]

(marestail; fleabane)

(B)

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

- Wide-spread
- Erect growth habit can compete with crops for light.
- Native
Life Cycles:

- Winter annual, but often emerges in the spring.
- 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:

- A few PRE herbicides are available.
- Glyphosate resistance is widespread.

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.

**Knotweed Species**

*Polygonum aviculare and other similar species.*

(knot-grass; bird-grass; prostrate knotweed [POLAV])

(B, F*)

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

- Widespread
- Introduced

**Life Cycle:**

- Summer annual
- Seed emergence occurs in early spring (about one month before large crabgrass) and may be appropriate for climatic modeling to determine proper timing for PRE herbicide applications.
- Produces a thin taproot

**Control Measures:**

**Cultural/Mechanical Control:**

- Tolerates compaction and drought
- Controlled with cultivation and mulches

**Biological Control:**

- None noted.

**Chemical Control:**

- PRE herbicides are effective when applied early enough.
Data on POST herbicide efficacy is limited.

Field Diagnostic:

- Unlike spurge spurge, knotweeds do not produce milky latex when stems and leaves are broken.

Federal/State/Local Regulation and Pesticide Restrictions:

- None noted.

Critical Issues and Needs:

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

**Mugwort**

*Artemisia vulgaris* [ARTVU]

(wild chrysanthemum; wormwood)

(B, F*)

Distribution, Damage and Importance, Origin:

- Common in northeastern US
- Becoming widespread via contaminated soil on equipment as well as balled and burlapped and liner stock
- Introduced from Europe

Life Cycle:

- Perennial.
- Reproduction is by rhizome pieces as short as 0.5cm.
- 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 reapplication of non-selective POST herbicides for multiple years is typical.

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.

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.

Pigweed

(Amaranthus spp.)

(green amaranth; smooth pigweed [AMACH]; redroot pigweed [AMARE], palmer amaranth [AMAPA], livid amaranth [AMALI], and others)
(B, F*)

Distribution, Damage and Importance, Origin:

- Widespread.
- Dense competitive root system.
- Native.

Life Cycle:

- Summer annual.
- By seed.

Control Measures:

   Cultural/Mechanical Control:

     - Controlled by mulches.
     - Cultivation controls seedlings but stimulates new germination.

   Biological Control:

     - None noted.

   Chemical Control:

     - PRE herbicides are effective.
     - Resistance to some POST chemistry is known.

Federal/State/Local Regulation and Pesticide Restrictions:

- None noted.
Critical Issues and Needs:

- Resistance to glyphosate and ALS -inhibiting herbicides has occurred.
- Livid amaranth incidence is increasing in container nurseries.

**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.
- By 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.

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.

Sicklepod

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

Distribution, Damage and Importance, Origin:

- Widespread in southeastern United States.
- Native to North American tropics.

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

Federal/State/Local Regulation and Pesticide Restrictions:

- None noted.

Critical Issues and Needs:

- Research is needed to identify effective PRE and POST herbicide labels.

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
- 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.

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.

Spotted Spurge

(*Chamaesyce maculata; syn. Euphorbia maculata*) [EPHMA]

(B, C*)
Distribution, Damage and Importance, Origin:

- Widespread in southeastern United States.
- 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.

**Biological Control:**

- None noted.

**Chemical Control:**

- PRE, or non-selective POST when spurge is actively growing.

**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).
- By seed.

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.
- No biological controls.

Chemical Control:

- Few herbicides labeled.

Federal/State/Local Regulation and Pesticide Restrictions:

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

Critical Issues and Needs:

- A related weed, marsh parsley (*Cyclospermum leptophyllum*) [APULE], is an annual weed with a preference for cool weather, moist soil and standing water.
- Like wild carrot, marsh parsley has similarly dissected leaves, but plants are smaller and flowers in the umbel are smaller and less showy.
- Herbicidal efficacy data for marsh parsley control is lacking and no herbicides currently labeled for nursery use are effective.

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.

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 indeterminate

Life Cycle:

- Prolific seed set from explosively dehiscent seedpods.
- Seeds have no dormancy requirements.
- Yellow woodsorrel (*O. stricta*) is an herbaceous annual (occasionally perennial) that reproduces by seed, rhizome & stolons.
- Creeping speedwell (*O. corniculata*) is similar but with a strongly prostrate growth habit.

Control Measures:

Cultural/Mechanical Control:

- Sanitation is critical to prevent weed spread.
- Hand weeding is inefficient because weeds quickly reestablish.

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.

**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

*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.
- Non-selective POST control with glyphosate.

**Field Diagnostic:**

- Clump forming grass
- Light “apple” green in color
- Prow-shaped leaf tips.

**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 United States
• 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.

**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 seeds.
- 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.

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:**

- Dense, competitive root system.
- Tall, rapid growth competes with crops for light, water and nutrients.
-Introduced from Africa.
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.

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.

Federal/State/Local Regulation and Pesticide Restrictions:

- None noted.

Critical Issues and Needs:

- Herbicide efficacy and timing data is needed for both PRE and POST herbicide chemistries.
**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 US 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.
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.

**Perennial Cheatgrass**  
(*Bromus secalinus*) [BROSE]  
(brome grass; cheat; chess; rye brome)  
(F)

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

- Challenge in specific locations within the southeastern US.
- Dense root system competes with crops
- Introduced from Eurasia

**Life Cycle:**

- Winter annual
- Flowers June – Aug
- By seed

**Control Measures:**

**Cultural/Mechanical Control:**

- Sanitation is critical to avoid moving seed in contaminated soil.
o Do not let plants mature to seed.

**Biological Control:**

o None noted.

**Chemical Control:**

o Few herbicides labeled for nursery use give effective control.

**Field Diagnostic:**

- Similar to downy brome with awns of cheat seeds much shorter and with fewer hairs on the leaf collar.

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

- Noxious weed in AR

**Critical Issues and Needs:**

- PRE and POST herbicide efficacy data are lacking and few herbicides are labeled.
- Additional research is needed.

**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 United States.
• 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.
o Few selective POST options provide adequate control.

o Nonselective herbicides are effective but require multiple applications.

Field Diagnostic:

- *C. esculentus* has triangular stems and leaf tips that gradually extend to a point.
- *C. rotundus* has a similar appearance, but with a blunt point at the leaf tip and brownish-purple seed heads.
- Purple nutsedge tubers are produced in chains (versus singly for CYPES).
- Purple nutsedge 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 is 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 burnweed heights that commonly exceed four inches.

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 United States
- 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:

• Efficacy data is needed to identify effective PRE and POST herbicide.
• 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 (some reproduce via cleistogamy propagation by using non-opening, self-pollinating flowers).  
- Rhizomes.  
- Root at nodes.

**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.
- Benghol dayflower is tolerant of glyphosate.

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 cynlindrica) [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 weed re-establishes rapidly).

Biological Control:

- None noted.

Chemical Control:

- Close mowing followed by disking and POST applications

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.

**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 survive 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.
Gyphosate 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.

**Doveweed**

*(Murdannia nudiflora)* [MUDNU]

*(B, C*)

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

- Locally important in coastal states and spreading
- Introduced from Asia

**Life Cycle:**

- Summer annual
- Continuous emergence in warm months
• Most common in wet areas

Control Measures:

Cultural/Mechanical Control:

  o Hand-weeding often misses small, grass-like seedlings.

Biological Control:

  o None noted.

Chemical Control:

  o Few effective PRE herbicides are available.
  o Doveweed is tolerant of most POST herbicides including glyphosate.

Field Diagnostic:

• Grass-like seedlings
• Succulent stems that root at the nodes and form a mat.
• Distinctive small lavender to purple flowers in mid to late summer and into early fall.
• Distinguished from marsh dayflower (*Murdannia keisak*) by the length of the sepals.

Federal/State/Local Regulation and Pesticide Restrictions:

• None noted.

Critical Issues and Needs:

• Efficacy data is needed to identify effective PRE and POST herbicide labels.
• Ecological and biological information is needed, especially environmental modeling of seed germination and emergence.

**Mulberryweed**

*(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 is needed to expand current PRE and POST herbicide labels.

Phyllanthus Species

(*Phyllanthus tenellus*, longstalked phyllanthus [below, left]; *P. urinaria*, chamberbitter, gripeweed [below, right])

(B, C*)
Distribution, Damage and Importance, Origin:

- 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 most 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.

**Ragweed Parthenium**

(*Parthenium hysterophorus*) [PTNHY]

(Santa Maria feverfew)

(B, C*)

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

• Localized populations throughout eastern and central US.
• 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:**

- Little data is available.
- PRE herbicides can be effective if properly timed.
- Limited POST options (glufosinate & glyphosate).

Federal/State/Local Regulation and Pesticide Restrictions:

- None noted.

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).*

_Select Emerging Weedy Liverworts and Algae_
**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.
- Nostac 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.

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.

Liverwort

(*Marchantia polymorpha*)

(C)

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

- Introduced and becoming widespread.
- In nursery containers, liverworts form a dense, dark greenish-brown, leathery mass on the substrate surface.
- Both when wet and dry, liverwort sheets form a surface that impedes water and nutrient access to the substrate.
- Introduced.

**Life Cycle:**
• Dispersed by windborne spores, splashed gemmae, and via fragmentation on contaminated substrate, containers, and propagation (liner) stock.

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:**

- Limited PRE and POST herbicidal efficacy.
- Few herbicides are labeled for *Marchantia* control.

Federal/State/Local Regulation and Pesticide Restrictions:

• None noted.

Critical Issues and Needs:

• Growers are unfamiliar with this plant and would benefit from better understanding its life cycle and control options
• Efficacy data is needed to expand current PRE and POST herbicide labels.
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 11. Common broadleaf and grass herbicides used in nursery production in the southeastern United States.**

<table>
<thead>
<tr>
<th><strong>Common “Broadleaf” Herbicides</strong></th>
<th><strong>Common “Grass” Herbicides</strong></th>
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<tbody>
<tr>
<td>Isoxaben (Gallery)</td>
<td>Dinitroanalines: oryzalin (Surflan), pendimethalin (Pendulum &amp; Corral), prodiamine (Barricade &amp; RegalKade), trifluralin (Treflan)</td>
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<tr>
<td>Simazine (Princep)</td>
<td>Dimethenamid-p (Tower)</td>
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<td>Oxyfluorfen (Goal)</td>
<td>Dithiopyr (Dimension Ultra)</td>
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<tr>
<td>Flumioxazin (Broadstar or Sureguard)</td>
<td>Napropamide (Devrinol)</td>
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<tr>
<td></td>
<td>Oxadiazon (Ronstar)</td>
</tr>
<tr>
<td></td>
<td>s-Metolachlor (Pennant Magnum)</td>
</tr>
</tbody>
</table>

**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 (preemergence or postemergence) in container and field nurseries.
- Glufosinateammonium (Finale) and diquat (Reward), two non-selective post-emergence 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, labeled in GA).

Listing of Preemergence and Postemergence Chemicals

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). For a list and information about sites and modes of action for Common Commercial Pre-packaged Herbicide Mixtures, see UT Extension Publication PB1775:


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 post-emergence 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 red bud and honey locust) have been injured through root uptake following directed applications.

DICHLOBENIL (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. prodiamine 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 non-selective, contact-action, postemergence herbicide. Do not apply to foliage or green stems of desirable ornamentals.

DITHIOPYR (B, PRE*)
(Dimension Ultra) (REI of 12 hours) Dimension is primarily used for preemergence annual grass control in turf but is also labeled for use in 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 grasses. Do not apply to ornamental grasses and do not apply to targeted grasses when under water 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 water stress.

**FLUMIOXAZIN**  
(B, PRE*)  
(Sureguard and BroadStar) – (REI of 12 hours). Sureguard and Broadstar 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.

**GLYPHOSATE**  
(POST)  
(Roundup Pro, and many others) - (REI of 4 to 12 hours depending on formulation). RoundupPro 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.

**ISOXABEN**  
(POST)  
(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 combination with trifluralin for use in container nurseries, Snapshot TG.

**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.

**NORFLURAZON**
(PRE) (Predict) – (REI of 12 hours). Predict is a preemergence herbicide that provides excellent control of most annual grasses and certain broadleaf weeds. Also suppresses nutsedge in field grown nursery stock. Do not apply until the fall following the first season of growth after transplanting. Avoid contact with foliage. Not recommended for use on course textured soils.

**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, prostrate spurge, and yellow woodsonnel.

**OXADIAZON**
(PRE) (Ronstar) - (REI of 12 hours). Oxadiazon is a preemergence herbicide effective on most nursery weeds, but has poor control of spurges and common chickweed.

**OXYFLUORFEN**
(PRE, POST) (Goal, Goal Tender,) – (REI of 24 hours). Goal is a pre- and 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: Scotts 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, non-selective, 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 non-selective, broad spectrum, foliar applied postemergence herbicide. It provides burndown of both annual and perennial broadleaf and grass weeds.

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 woodssorrel.

PRODIAMINE (PRE)
(Barricade and RegalKade) - (REI of 12 hours). Prodiamine is a pre-emergent herbicide used in the control of most annual grasses, including crabgrass and goosegrass, as well as some broadleaf weeds, including spurge, common chickweed and woodssorrel.

SETHOXYDIM (POST)
(Segment) – (REI of 12 hours). Segment is a selective, 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 water 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.

TRIFLURALIN (PRE)
(Treflan) – (REI of 12 hours). Treflan is a preemergence herbicide for the control of annual grasses and broadleaf weeds in container or field conditions.
**Table 12. Preemergence herbicides labeled for container nursery stock**

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Active Ingredient</th>
<th>ai/ Acre</th>
<th>Product / Acre (hrs)</th>
<th>REI</th>
<th>Chemical Class</th>
<th>HRAC</th>
<th>WSSA</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barricade 4L</td>
<td>Prodiamine</td>
<td>0.65 - 1.50 lbs.</td>
<td>21 - 48 fl. oz.</td>
<td>12</td>
<td>Dinitroaniline</td>
<td>K1</td>
<td>3</td>
<td>Syngenta</td>
</tr>
<tr>
<td>Barricade 65DG</td>
<td>Prodiamine</td>
<td>0.65 - 1.50 lbs.</td>
<td>1.0 - 2.3 lbs.</td>
<td>12</td>
<td>Dinitroaniline</td>
<td>K1</td>
<td>3</td>
<td>Syngenta</td>
</tr>
<tr>
<td>BroadStar</td>
<td>Flumioxazin</td>
<td>0.375 lbs.</td>
<td>150 lbs.</td>
<td>12</td>
<td>Phenylphthalimide</td>
<td>E</td>
<td>14</td>
<td>Valent</td>
</tr>
<tr>
<td>Casoron 4 GR</td>
<td>Dichlobenil</td>
<td>4.0 - 6.0 lbs.</td>
<td>100 - 150 lbs.</td>
<td>12</td>
<td>Substituted Benzene</td>
<td>L</td>
<td>20</td>
<td>Crompton</td>
</tr>
<tr>
<td>Corral 2.68G</td>
<td>Pendimethalin</td>
<td>2 - 3 lbs.</td>
<td>76 - 114 lbs.</td>
<td>12</td>
<td>Dinitroaniline</td>
<td>K1</td>
<td>3</td>
<td>Scott's</td>
</tr>
<tr>
<td>Devrinol 50DF</td>
<td>Napropamide</td>
<td>4 - 6 lbs.</td>
<td>8 - 12 lbs.</td>
<td>12</td>
<td>Alkanamide</td>
<td>K3</td>
<td>15</td>
<td>United Phos.</td>
</tr>
<tr>
<td>Devrinol 2G</td>
<td>Napropamide</td>
<td>2 - 3 lbs.</td>
<td>100 - 150 lbs.</td>
<td>12</td>
<td>Alkanamide</td>
<td>K3</td>
<td>15</td>
<td>United Phos.</td>
</tr>
<tr>
<td>Dimension Ultra 40WP</td>
<td>Dithiopyr</td>
<td>0.31 - 0.38 lbs</td>
<td>0.78 - 0.95 lbs</td>
<td>12</td>
<td>Pyridazinone</td>
<td>K1</td>
<td>3</td>
<td>Dow Agro</td>
</tr>
<tr>
<td>Freehand 1.75G</td>
<td>Dimethenamid-P + Pendimethalin</td>
<td>1.75 - 3.5 lbs</td>
<td>100 - 200 lbs.</td>
<td>24</td>
<td>Amide plus Dinitroaniline</td>
<td>K3, K1</td>
<td>15, 3</td>
<td>BASF</td>
</tr>
<tr>
<td>Gallery 75 DF</td>
<td>Isoxaben</td>
<td>0.5 - 1.0 lbs.</td>
<td>0.66 - 1.33 lbs.</td>
<td>12</td>
<td>Amide</td>
<td>L</td>
<td>21</td>
<td>Dow Agro</td>
</tr>
<tr>
<td>Jewel 3.25GR</td>
<td>Oxadiazon + Pendimethalin</td>
<td>3.25 lbs.</td>
<td>100 lbs</td>
<td>12</td>
<td>Oxadiazole plus Dinitroaniline</td>
<td>E, K1</td>
<td>14, 3</td>
<td>Scott's</td>
</tr>
<tr>
<td>(OH-2) 2GR</td>
<td>Oxyfluorfen + Pendimethalin</td>
<td>2 lbs. + 1 lbs.</td>
<td>100 lbs</td>
<td>24</td>
<td>Diphenyl ether plus Dinitroaniline</td>
<td>E, K1</td>
<td>14, 3</td>
<td>Scott's</td>
</tr>
<tr>
<td>Product Name</td>
<td>Active Ingredient(s)</td>
<td>Application Rate</td>
<td>Coverage Area</td>
<td>Application Rate</td>
<td>Active Ingredient(s)</td>
<td>Coverage Area</td>
<td>Manufacturer</td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
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<td>------------------</td>
<td>----------------------</td>
<td>---------------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td>Pendulum 2GR</td>
<td>Pendimethalin</td>
<td>1.5 - 2.0 lbs.</td>
<td>75 - 100 lbs.</td>
<td>12 Dinitroaniline</td>
<td>K1</td>
<td>3</td>
<td>BASF</td>
<td></td>
</tr>
<tr>
<td>Pendulum 3.3 EC</td>
<td>Pendimethalin</td>
<td>2.0 - 4.0 lbs.</td>
<td>2.4 - 4.8 qts.</td>
<td>24 Dinitroaniline</td>
<td>K1</td>
<td>3</td>
<td>BASF</td>
<td></td>
</tr>
<tr>
<td>Pendulum Aqua Cap 3.8ACS</td>
<td>Pendimethalin</td>
<td>0.8 - 1.6 lbs.</td>
<td>2.1 - 4.2 qts.</td>
<td>24 Dinitroaniline</td>
<td>K1</td>
<td>3</td>
<td>BASF</td>
<td></td>
</tr>
<tr>
<td>Pennant Magnum 7.62</td>
<td>s-Metolachlor</td>
<td>1.3 - 2.5 lbs.</td>
<td>1.3 - 2.6 pints</td>
<td>24 Choroacetanilide</td>
<td>K3</td>
<td>15</td>
<td>Syngenta</td>
<td></td>
</tr>
<tr>
<td>Predict 78.6DF</td>
<td>Norflurazon</td>
<td>2.4 lbs.</td>
<td>3.0 lbs.</td>
<td>12 Pyridazinone</td>
<td>F1</td>
<td>12</td>
<td>Syngenta</td>
<td></td>
</tr>
<tr>
<td>Princep Liquid</td>
<td>Simazine</td>
<td>1.0 - 3.0 lbs.</td>
<td>1.0 - 3.0 qts.</td>
<td>12 Triazine</td>
<td>C1</td>
<td>5</td>
<td>Syngenta</td>
<td></td>
</tr>
<tr>
<td>Regal Kade 0.5G</td>
<td>Prodiamine</td>
<td>1.5 lbs.</td>
<td>300 lbs.</td>
<td>12 Dinitroaniline</td>
<td>K1</td>
<td>3</td>
<td>Regal</td>
<td></td>
</tr>
<tr>
<td>Regal O-O, 3GR</td>
<td>Oxyfluorfen + oxadiazon</td>
<td>2 lbs. + 1 lbs.</td>
<td>100 lbs.</td>
<td>24 Diphenyl ether plus Oxadiazole</td>
<td>E</td>
<td>14, 3</td>
<td>Regal</td>
<td></td>
</tr>
<tr>
<td>Regalstar 1.2GR</td>
<td>Oxadiazon + prodiamine</td>
<td>2 lbs. + 0.4 lbs.</td>
<td>200 lbs.</td>
<td>12 Oxadiazole plus Dinitroaniline</td>
<td>E, K1</td>
<td>14, 3</td>
<td>Regal</td>
<td></td>
</tr>
<tr>
<td>Ronstar 50 WSP</td>
<td>Oxadiazon</td>
<td>2.0 - 4.0 lbs.</td>
<td>4.0 - 8 WSP</td>
<td>12 Oxadiazole</td>
<td>E</td>
<td>14</td>
<td>Bayer</td>
<td></td>
</tr>
<tr>
<td>Ronstar G</td>
<td>Oxadiazon</td>
<td>2.0 - 4.0 lbs.</td>
<td>100 - 200 lbs.</td>
<td>12 Oxadiazole</td>
<td>E</td>
<td>14</td>
<td>Bayer</td>
<td></td>
</tr>
<tr>
<td>Rout 3G</td>
<td>Oxyfluorfen + oryzalin</td>
<td>2 lbs. + 1 lbs.</td>
<td>100 lbs.</td>
<td>24 Diphenyl ether plus Dinitroaniline</td>
<td>E, K1</td>
<td>14, 3</td>
<td>Scott's</td>
<td></td>
</tr>
<tr>
<td>Showcase 2.5G</td>
<td>Isoxaben + Trifluralin + Oxyfluorfen</td>
<td>0.25 - 0.5 lbs. + 2.0 - 4.0 lbs. + 0.25 - 0.5 lbs.</td>
<td>100 - 200 lbs.</td>
<td>24 Benzamide plus Dinitroaniline plus Diphenyl ether</td>
<td>L, K1</td>
<td>21, 3</td>
<td>Dow Agro</td>
<td></td>
</tr>
<tr>
<td>Simazine 4L</td>
<td>Simazine</td>
<td>2.0 - 3.0 lbs.</td>
<td>2.0 - 3.0 qts.</td>
<td>12 Triazine</td>
<td>C1</td>
<td>5</td>
<td>Agrisolutions</td>
<td></td>
</tr>
<tr>
<td>Simazine 90 DF</td>
<td>Simazine</td>
<td>2.0 - 3.0 lbs.</td>
<td>2.2 - 4.4 lbs.</td>
<td>12 Triazine</td>
<td>C1</td>
<td>5</td>
<td>Agrisolutions</td>
<td></td>
</tr>
<tr>
<td>Product Name</td>
<td>Active Ingredients</td>
<td>Rate</td>
<td>Mix Rate</td>
<td>Rate of Application</td>
<td>Use Code</td>
<td>Rating</td>
<td>Manufacturer</td>
<td></td>
</tr>
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<td>-------------------</td>
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<td></td>
</tr>
<tr>
<td>Snapshot 2.5TG</td>
<td>Isoxaben + Trifluralin</td>
<td>0.5 - 1.0 lbs. + 2 - 4 lbs.</td>
<td>100 - 200 lbs.</td>
<td>12</td>
<td>Benzamide plus Dinitroaniline</td>
<td>L, K1</td>
<td>21, 3</td>
<td>Dow Agro</td>
</tr>
<tr>
<td>SureGuard</td>
<td>Flumioxazine</td>
<td>0.25 - 0.38 lbs</td>
<td>8 - 12 oz.</td>
<td>12</td>
<td>Phenylphthalimide</td>
<td>E</td>
<td>14</td>
<td>Valent</td>
</tr>
<tr>
<td>Surflan 4AS</td>
<td>Oryzalin</td>
<td>2 - 4 lbs.</td>
<td>2 - 4 qts.</td>
<td>12</td>
<td>Dinitroaniline</td>
<td>K1</td>
<td>3</td>
<td>United Phos.</td>
</tr>
<tr>
<td>Surflan 85DF</td>
<td>Oryzalin</td>
<td>2.0 - 4.0 lbs.</td>
<td>2.4 - 7.1 lbs.</td>
<td>12</td>
<td>Dinitroaniline</td>
<td>K1</td>
<td>3</td>
<td>United Phos.</td>
</tr>
<tr>
<td>Tower 6L</td>
<td>Dimethenamid-P</td>
<td>0.98 - 1.5 lbs.</td>
<td>21 - 32 fl. oz.</td>
<td>12</td>
<td>Amide</td>
<td>K3</td>
<td>15</td>
<td>BASF</td>
</tr>
<tr>
<td>Treflan 5G</td>
<td>Trifluralin</td>
<td>4 lbs.</td>
<td>80 lbs.</td>
<td>12</td>
<td>Dinitroaniline</td>
<td>K1</td>
<td>3</td>
<td>Dow Agro</td>
</tr>
<tr>
<td>Weedfree 75, 5GR</td>
<td>Oxyfluorfen + Trifluralin</td>
<td>5 lbs.</td>
<td>100 lbs.</td>
<td>24</td>
<td>Diphenyl ether plus Dinitroaniline</td>
<td>E, K1</td>
<td>14, 3</td>
<td>Harrell's</td>
</tr>
<tr>
<td>XL 2 GR</td>
<td>Benefin (benfluralin) + Oryzalin</td>
<td>2 - 3 lbs. + 2 - 3 lbs.</td>
<td>200 - 300 lbs.</td>
<td>12</td>
<td>Dinitroaniline</td>
<td>K1</td>
<td>3</td>
<td>Helena</td>
</tr>
<tr>
<td>Herbicide Trade Name</td>
<td>Active Ingredient</td>
<td>ai/ Acre</td>
<td>Product/ Acre</td>
<td>REI (hrs)</td>
<td>Rainfast</td>
<td>Chemical Class</td>
<td>HRAC</td>
<td>WSSA</td>
</tr>
<tr>
<td>----------------------</td>
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<td>---------------</td>
<td>-----------</td>
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</tr>
<tr>
<td>Acclaim Extra</td>
<td>Fenoxaprop</td>
<td>0.09 - 0.17 lbs.</td>
<td>1.2 - 2.4 pt.</td>
<td>24</td>
<td>1 hour</td>
<td>Aryloxyphenoxypropionate</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>Asulox</td>
<td>Asulam</td>
<td>3.34 lbs.</td>
<td>1.0 gal.</td>
<td>12</td>
<td>unknown</td>
<td>Carbamate</td>
<td>I</td>
<td>18</td>
</tr>
<tr>
<td>Basagran TO</td>
<td>Bentazon</td>
<td>0.75 - 1.0 lb.</td>
<td>1.5 - 2.0 pt.</td>
<td>12</td>
<td>4 hours</td>
<td>Benzothiazinone</td>
<td>C3</td>
<td>6</td>
</tr>
<tr>
<td>Casoron 4G</td>
<td>Dichlobenil</td>
<td>4 – 8 lbs.</td>
<td>100 – 200 lb.</td>
<td>24</td>
<td>NA</td>
<td>Benzonitrile</td>
<td>L</td>
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<td>Casoron CS</td>
<td>Dichlobenil</td>
<td>1.96 - 6.02 lbs.</td>
<td>1.4 - 4.3 gals.</td>
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<td>Envoy Plus</td>
<td>Clethodim</td>
<td>0.11 - 0.24 lbs.</td>
<td>13 - 32 fl. oz.</td>
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<td>Glufosinate-ammonium</td>
<td>0.75 - 1.5 lbs</td>
<td>3.0 - 6.0 qt.</td>
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<td>Fusilade II</td>
<td>Fluazifop-P-butyl</td>
<td>0.25 - 0.38 lbs.</td>
<td>1.5 - 1.5 pt.</td>
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<td>Roundup (various products)</td>
<td>Glyphosate</td>
<td>0.25 - 1 lbs.</td>
<td>1 - 4 quarts</td>
<td>4 - 12</td>
<td>30 minutes to 6 hours</td>
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Table 14. Efficacy of preemergence herbicides

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<th>Snapshot TG</th>
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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%)
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**Grasses (or grasslike)**

| Barnyardgrass     | G | G | F | F | G | G | G | G | p | F | G | G | G | G | G | G | G | G | G |

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<th>Weed Type</th>
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<td>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.</td>
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<td>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.</td>
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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.

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.

Poor control: denotes that the herbicide provides negligible to no control or suppression on a given weed.
### Table 15. Efficacy of postemergence herbicides

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**Grasses**

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<tbody>
<tr>
<td>Nutsedge, purple</td>
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<tr>
<td>Nutsedge, yellow</td>
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<tr>
<td>Onion or garlic, wild</td>
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**Effective on seedling weeds only**
Cultural Control of Weeds

Weed management in ornamentals 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. Over watering 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 Extension Priorities

- Improved management guidelines for “hard to control” weeds such as; seasonal timing for postemergent (POST) weed control to manage perennial weed pests in nursery borders, field rows and new (e.g., container and pot-in-pot) production areas.
- Improved monitoring tools, protocols, and educational programs (e.g., improved guides for identifying “emerging weeds of concern”).
- 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.
- Education on avoiding crop damage from herbicides.

Weed Research Priorities

- 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).
- A systematic survey of the current state of weeds in nursery production systems across the southeastern United States.
- Greater understanding of herbicide persistence and longevity of control relative to the need for re-applications or other supplemental management (e.g., pairing environmental/climatic models with
knowledge of herbicide persistence and efficacy to better time both deployment and re-
application of PRE herbicides).

- Effectiveness and utility of cultural, physical and mechanical controls such as cover crops and
  living mulches, physical barriers (e.g., landscape fabric, geotextile, woolpack, hair and coir disks
  and large bark chip topdressings).
- 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.
- Opportunities to achieve efficient weed control with reduced PRE and POST emergence
  herbicide use, particularly in crops nearing sale date.
- 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.
- Phytotoxicity of both PRE- and POST emergence chemistries on the 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.
- Development of new weed control technologies and herbicide formulations, including:
  - chemical mowing / vegetation suppression
  - strategies and technologies to extend seasonal duration of weed control efficacy (such
    as: slow-release formulations for PRE herbicides)
  - integration of nutrients, PRE herbicides and/or insecticidal/miticidal chemistries in
    slow-release formulations
  - 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
  - Biological or biorational options for PRE and POST weed control
  - Selective weed management options.
Weed Priorities

Weed pests were rated during the workshop on their importance to growers (Tables 9 and 10).

Table 16. Weeds of container production ranked by growers and University representatives by importance.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Weed Species</th>
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<tbody>
<tr>
<td>9</td>
<td>Spurge</td>
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<tr>
<td>7</td>
<td>Oxalis/woodsorrel</td>
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<tr>
<td>6</td>
<td>Bittercress</td>
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<tr>
<td>5</td>
<td>Liverwort</td>
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<td>5</td>
<td>Groundsel</td>
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<tr>
<td>4</td>
<td>Eclipta</td>
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<tr>
<td>2</td>
<td>Annual Bluegrass</td>
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</tbody>
</table>

1Rank = number of votes, greater number of votes indicates more participants found this to be a problem weed.

Table 17. Weeds of field production ranked by growers and University representatives by importance.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Weed Species</th>
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<tbody>
<tr>
<td>12</td>
<td>Yellow Nutsedge</td>
</tr>
<tr>
<td>7</td>
<td>Crabgrass</td>
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<tr>
<td>7</td>
<td>Marestail/horseweed</td>
</tr>
</tbody>
</table>

1Rank = number of votes, greater number of votes indicates more participants found this to be a problem weed).
Weedy Plant Literature Cited and General References


University of Arkansas Publication MP44. http://www.uaex.edu/Other_Areas/publications/PDF/MP44/E_TradeNames.pdf


Acknowledgements

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