

# **Crop Profile Container and Field-Produced Nursery Crops in GA, KY, NC, SC, and TN**

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# Nursery Crop Production

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## *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 United States. 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.

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. Trees are mechanically harvested and sold as bareroot or are balled and burlapped. Since the mid 20<sup>th</sup> century, container production of ornamental plants in the southeastern United States has grown to meet demand. Inventory and availability of container grown trees, shrubs, perennials and annuals is unmatched by field-grown production. 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. 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 soil, topography, 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. These same five states collectively produced 10% of the value in nursery crops in 2007 in the United States (Table 4) (USDA, 2009).

*Table 1. Number of producers, total acreage and value of nursery crops for five southern states.*

State	Number of producers <sup>1</sup>	Total acreage	Value in million \$
Georgia	501	8,074	125.2
Kentucky	332	3,976	23.6
North Carolina	1250	23,443	251.9
South Carolina	314	7,375	91.4
Tennessee	793	33,591	177.2
Totals	3190	76,459	669.3
Percent of U.S. total	14%	17%	10%

<sup>1</sup> All values in table based on USDA 2007, 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). Integrated pest management (IPM) is emerging as the most effective and efficient tool growers use to limit crop and monetary losses attributed to pests (Bolin et al, 2007).

## *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.

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.

### *Land/Soil Preparation*

Nursery fields may be amended with bark, compost, municipal yard wastes or organic amendments like cattle manure or poultry liter. Traditional methods to increase organic matter in fields include green manure crop rotation utilizing a double cropping system of 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.

### *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. Plants are transplanted using mechanical transplanters or planted by hand. Field-ready transplants are often kept moist and shaded prior to being planted, with care given to ensure that roots do not dry out.

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 planting 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.

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

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. The third year 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 and have been shown to reduce growth and may contribute to nutrient runoff and impact water quality.

Controlled release fertilizers (CRF) fertilizers developed specifically for field-use have been introduced. While more expensive, one application of CRF will last the entire growing season.

### *Irrigation*

Field nurseries utilize either hose reel irrigation equipment or a low volume application method. An acre of nursery stock may need an inch of irrigation (acre-inch) applied 1 to 2 times per week.

Drip irrigation is a highly efficient system that uses low water volume and low pressure to deliver water directly to the root zone. 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). Drip irrigation results in less water lost to evaporation or run off. In addition, weed seeds are not irrigated by water distributed over large areas, which results in fewer weeds in the nursery.

### *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. 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. 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. Contaminated pruning tools can spread pests.

### *Flexing and Staking*

Flexing is a manual technique that is used to straighten tree trunks. Flexing is most commonly done in the spring (less commonly in the fall). If stakes are going to be 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. Trees are hand tied or stapled to stakes. Stakes are often removed after the first year. Both staking installation, as well as removal, and flexing put workers in contact with plant material during the growing season, coinciding with pesticide application.

### *Floor Management: Driveways and Middles*

Driveways and middles may be kept bare, planted with fescue, or planted with a non-fescue cover crop. Following spring planting, soil is tilled, fescue seed is sown and grass is mowed periodically. Crimson clover is one of the more common non-fescue cover crops (Halcomb 2009). 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. 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*

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. 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). 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. Branches are tied to facilitate digging and prevent breakage, which constitutes additional contact with plant surfaces that may contain pesticide residue.

## *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. Sampling 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).

### *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, excess irrigation 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.

### *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: 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 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 all should be monitored.

When 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, 2005; Kong et al., 2004; Maurer et al., 1995). 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 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. 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. Nutrients from controlled release fertilizers 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. The damaged tissue can be misdiagnosed for a biotic pest problem. Plants do not absorb excess nutrients, so over-application results in nutrient leaching and loss with nursery runoff.

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). 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). Over-fertilization can contribute to pest problems.

## *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.

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# Key Pest Profiles and Critical Issues:

## *Insect Pests*

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### **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, *Paraprociophilus tessellates* (Fitch); Woolly elm aphid, *Eriosoma americana* (Riley); Woolly apple aphid, *Eriosoma lanigerum* (Hausmann), etc.

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

#### **Host Plants:**

- Aphids can infest virtually all woody and herbaceous ornamental plants grown in nurseries.
- Some of the plants most commonly infested by aphids are *Rosa*, *Lagerstroemia*, *Liriodendron*, and *Prunus* spp.
- Adelgids infest many genera of conifers including *Abies*, *Picea*, *Pseudotsuga*, *Pinus*, and *Tsuga*.

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

- Most of the common species have a cosmopolitan distribution in the Southeast.
- All aphid species feed by sucking plant sap from vascular or other tissue with piercing mouthparts.
- Feeding results in deformed and/or small leaves, discoloration, defoliation, and in some cases plant death from reoccurring or large infestations.

- Aphids produce large amounts of honeydew as a by-product of feeding on phloem 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.
- Fertilizer, particularly nitrogen, makes plants more nutritious for aphids and can substantially increase aphid population growth by reducing development time and increasing fecundity.
- Some plant varieties are more resistant to aphids than others. For example, crapemyrtle varieties have a great range of resistance to crapemyrtle aphid, so resistant varieties can be selected.

### **Biological:**

- Aphid populations in field production are constantly subject to predation and parasitism. Many existing populations of parasitoids and predators attack aphids.
- 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.
- 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.
- Conservation biological control may be achieved by diversifying the plant species in a habitat and, in particular, providing floral resources and alternative hosts for predators and parasitoids.
- The effectiveness of biological control (conservation or augmentative) in field productions is unknown.
- Existing biological control can be disrupted by the use of broad-spectrum insecticides.

### **Chemical:**

- Aphids are relatively unprotected from insecticides and thus susceptible to a number of products.
- Many species feed on the undersides of leaves, so coverage of these areas is important.
- Systemic products can improve efficacy by killing aphids that feed on the plant even if they were not contacted by the insecticide.

- Chemicals used in nurseries include:

Chemical Class	Common Name
Carbamates	carbaryl
Organophosphates	acephate
Pyrethroids	bifenthrin, permethrin
Neonicotinoids	acetamiprid, clothianidin, dinotefuran, imidacloprid, thiamethoxam
Juvenile hormone mimics	pyriproxyfen
Feeding blockers	pymetrozine, flonicamid
Azadirachtin	azadirachtin, neem oil
Horticultural oil	
Insecticidal soap	

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

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

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

- A better understanding of the life history of aphids for effective management.
- Improvement in predicting important life history events using degree-day models or plant phenological indicators.
- Development of thresholds that include natural enemy abundance to help growers determine if pesticides are necessary or if the population is under natural control.
- Because of the variation in phenology and management strategies, Extension personnel and grower training is needed to improve monitoring and management efficiencies.
- Assessment of the efficacy and the cost-benefit ratio of augmentative biological control and development of improved implementation methods.

- Development of conservation biological control tactics, such as habitat manipulation with flowering plants, to increase the abundance, diversity, and efficacy of naturally occurring predators and parasitoids.
- Development of banker plant systems for use in outdoor nurseries to support natural enemies and suppress aphids.

## **Borers**

### **Common species:**

**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, *Eudocimus mannerheimii* (Boheman)

**Lepidopteran borers** (Lepidoptera: Sesiidae): Dogwood borer, *Synanthedon scitula* (Harris); Lilac borer, *Podotesia syringae* (Harris); Banded ash clearwing borer, *Podotesia 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:

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

**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 neonicotinoids and chlorantraniliprole that have lower vertebrate toxicity and impact on natural enemies.
- Research on how to make products more effective with surfactants, stickers, or other products.
- Research on curative applications to kill borers once they are inside trees.
- Impact of insecticide applications targeting borers on natural enemies and secondary pest outbreaks such as mites.

### **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:

Chemical Class	Common Name
Organophosphate	chlorpyrifos
Carbamate	carbaryl
Microbial	Bt
Spinosyn	spinosad
IGR (benzoic acid hydrazide)	tebufenozide
Pyrethroid	cyfluthrin, bifenthrin, lambda-cyhalothrin

**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, *Monocesta 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 seiboldi*, is a very effective parasitoid of imported willow leaf beetle pupae.
- The use of broad-spectrum insecticides can kill beneficial predators and parasitoids which can lead to pest resurgence.

**Cultural:**

- 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 and flush out.
- Once inside the wood, no insecticides (including the systemic neonicotinoids) are known to have any effect on the adults and larvae.
- Chemicals used in the nurseries:

Chemical Class	Common Name
Pyrethroids	bifenthrin, permethrin

**Federal/State/Local Regulations:**

- None.

**Critical Issues & Needs:**

- Improve prediction of adult flight across the South

- 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 *Craetagus*, *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:

Chemical Class	Common Name
Organophosphate	chlorpyrifos, diazinon
Carbamate	carbaryl
Neonicotinoid	thiamethoxam
Neonicotinoid plus pyrethroid	imidacloprid plus cyfluthrin
Pyrethroid	cyfluthrin, bifenthrin, lambda-cyhalothrin

#### **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:

Chemicals Class	Common Name
Organophosphates	acephate
Pyrethroids	bifenthrin, permethrin
Avermectins	abamectin
Mite growth regulators	hexythiazox
Tetronic acids	spiromesifen
Carbazate acaricides	bifenazate
Unclassified acaricides	etoxazole
	acequinocyl
	pyridaben
	oil, paraffinic
	oil, petroleum
	soap

#### **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* Buren

#### **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):

<b>Common Name</b>	<b>Brand Name</b>
Bifenthrin	Talstar, Bifenthrin Pro
Chlorpyrifos	Dursban, Chlorpyrifos

Diazinon	Diazinon
Fenoxycarb	Award (bait)
Fipronil	Chipco Choice, Chipco TopChoice
Hydramethylnon	AmdroPro, SiegePro (baits)
Methoprene	Extinguish (bait)
Pyriproxyfen	Distance (bait)
Tefluthrin	Fireban

### 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 hesperidum* 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<sup>nd</sup>-instar nymph, adult, sometimes with an additional nymphal instar) and 5 male life stages (an additional 'pupal' stage).
  - There can be 1 to 6 (or more) generations per year, depending on species and climate.
  - Overwintering of females can be accomplished by any life stage. Males generally do not overwinter as older instars.
  - Eggs generally hatch in the spring (first generation), and the crawlers disperse either passively by air movement or actively by crawling.
  - Armored scales can be either parthenogenic or obligately biparental.
  - Some species are host specific, but most pestiferous species are highly polyphagous.

- Soft scales generally have 4-5 female life stages (egg, crawler, 2<sup>nd</sup>-instar nymph, adult, with some species having an additional nymphal instar) and 6 male life stages (additional ‘pre-pupal’ and ‘pupal’ instars).
  - Most species have one annual generation.
  - Overwintering is often accomplished by late-instar nymphs on twigs or branches.
  - Eggs generally hatch in the spring. Crawlers feed on the leaves in spring and summer, molt into 2<sup>nd</sup>-instar nymphs, and move back onto the twigs to overwinter just before leaf drop. Bodies of adult females swell dramatically in early spring.
  - Many are known to be parthenogenic (although males are sometimes detected) but some are also known to be obligately biparental.

## **Control Measures:**

### **Cultural/Mechanical:**

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

### **Biological:**

- Scale insect populations in field production are constantly under predation and parasitism. Many existing populations of parasitoids and predators attack scale insects of all stages.
- The effectiveness of biological control (conservation or augmentative) in field productions is unknown.
- Existing biological control can be disrupted by the use of broad-spectrum insecticides.

### **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:

Chemical Class	Common Name
Carbamates	carbaryl
Organophosphates	acephate, chlorpyrifos, dimethoate, disulfoton, malathion
Pyrethroids	bifenthrin, cyfluthrin, cyhalothrin, deltamethrin, fenpropathrin, permethrin, pyrethrin
Neonicotinoids	acetamiprid, clothianidin, dinotefuran, imidacloprid, thiamethoxam
Juvenile hormone mimics	kinoprene, pyriproxyfen
Feeding blockers	pymetrozine, flonicamid
Buprofezin	buprofezin
Tetramic acid derivatives	spirotetramat
Azadirachtin	Azadirachtin, neem oil
Horticultural oil	
Insecticidal soap	

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

None noted.

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

- Better understanding of life histories of scale insects is important for effective management.
- Improvement in predicting important life history events, such as the emergence of crawlers, using degree-day models or plant phenological indicators.

- 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):**

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

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

Black vine weevil, *Otiorhynchus sulcatus* (Fabricius)

### **Host Plants:**

- White (scarab) grubs typically attack roots of grasses. A variety of containerized nursery plants are also being attacked, e.g. *Rhododendron*, *Rosa*, and *Thuja*.
- Black vine weevil attacks more than 100 species of plants, with *Euonymus*, *Ilex crenata*, *Kalmia*, *Pieris*, *Rhododendron*, *Taxus*, and *Tsuga* being the most common hosts.

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

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



- Oriental beetle was introduced from Japan and first detected in Connecticut in the 1920's. This species is currently distributed from New England to OH and SC.
- Black vine weevil was introduced from Europe in the early 1900s and is currently distributed from ME to the Carolinas and west to WA and OR.
- Scarab and weevil grubs are serious pests of the roots of turfgrass and field-grown or containerized shrubs. Feeding damage on the roots reduces uptake of water and nutrients, weaken the plants, reduces plant growth, and may open wounds for the invasion of pathogens.

### **Life Cycle:**

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

### **Control Measures:**

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

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

#### **Biological:**

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

**Chemical:**

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

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

**State/local Regulations:**

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

**Critical Needs:**

- Evaluate more effective insecticides for quarantine treatment.
- Improve biological control of white grubs in containerized nurseries.

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

Japanese beetle, *Popillia japonica* Newman

#### **Host Name:**

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

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

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

#### **Life Cycle:**

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

#### **Control:**

##### **Monitoring:**

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

#### **Biological:**

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

#### **Cultural:**

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

#### **Chemical:**

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

- Insecticides used in nurseries for Japanese beetle adult control:

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

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

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

#### **Critical Needs:**

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

# Key Pest Profiles and Critical Issues: *Diseases*

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## *General Disease Control Practices for Nursery Ornamentals*

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

## *Cultural Control Practices*

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

- Provide adequate spacing for plants. Air movement is limited when plants are grown too close together, which allows moisture to remain on leaves for longer periods of time. Decreased spacing fosters upright, succulent growth, which can be predisposed to disease. Wider spacing in beds and container areas promotes faster drying after wet periods and promotes lateral branching.
- Avoid excessive soil moisture. Overwatering enhances damping-off and root rot diseases. Do not plant in areas 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 disinfest 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 2. Products or treatments used for sanitizing tools, equipment, pots, flats, and surfaces.*

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

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

## Disease Resistance

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

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

Plant breeding is used to cross plants of the same species or of different species (interspecific crosses) with the intent of combining desirable traits or developing new or superior horticultural traits. On occasion, unintended outcomes occur and resistance is found to a troublesome disease such as powdery mildew along with dogwood anthracnose resistance. The Stellar series of dogwoods (*Cornus florida* x *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

development. Growers should consult disease guidebooks or take advantage of diagnostic services offered by state and/or private labs for accurate disease identification.

Fungicides are most effective at protecting plants from foliar and soilborne infections when used 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.

# Plant Profiles for Select Diseases for Container and Field Nurseries

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## **Black Root Rot**

### **Pathogen:**

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

### **Hosts:**

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

### **Distribution and Importance:**

- *Thielaviopsis* is wide-spread in native soils and has been associated with root rot diseases of over 100 genera, mostly herbaceous plants.
- In woody ornamentals, black root rot has been associated with 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 Rusts**

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

**Hosts:**

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

**Distribution and Importance:**

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

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

**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.

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

#### **Biological Controls:**

- None noted.

#### **Chemical Control:**

- Unfortunately, under high disease pressure, chemical applications will not be 100% effective.
- Chemical control consists of spraying the antibiotic streptomycin sulfate (e.g. Agri-Mycin), or copper (Nu-Cop, Cu-PRO, Champion, Camelot, 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. unicorn*, *S. cupressi*, *Phomopsis* spp.

#### **Host Name:**

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

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

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

#### **Life Cycle:**

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

#### **Control Measures:**

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

**Cultural/Mechanical Control:**

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

**Biological Control:**

- None noted.

**Chemical Control:**

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

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

None

**Critical Issues and Needs:**

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

**Fungal Leaf Spots**

**Pathogens:**

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

**Hosts:**

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

**Distribution and Importance:**

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

**Disease Cycle:**

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

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

- Spacing plants to speed the drying of foliage.
- Removing leaf litter.
- Placing a mulch barrier over leaf litter to act as a physical barrier.

- Pruning to remove diseased foliage and open the canopy.  
Resistant species and cultivars exist for some ornamental plant groups.
- Some rose cultivars have been identified with resistance to black spot and *Cercospora* leaf spot (Mynes et al.).
- There are differential reactions among *Aesculus* spp. to *Guignardia* species that cause leaf blotch.

#### **Biological Control:**

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

#### **Chemical Control:**

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

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

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

#### **Passalora Blight**

##### **Pathogens:**

*Passalora sequoiae* syn. *Cercosporidium sequoiae*

##### **Host Name:**

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



**Distribution, Damage and Importance:**

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

**Life Cycle:**

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

**Control Measures:**

Management depends primarily on preventative fungicide applications.

**Cultural/Mechanical Control:**

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

**Biological Control:**

- None noted.

**Chemical Control:**

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

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

None noted.

**Critical Issues and Needs:**

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

**Phytophthora Root Rot and Pythium Root Rot****Pathogens:**

*Phytophthora* spp.; Phytophthora root rot is caused by several species of *Phytophthora*, although in the southeast *P. cinnamomi* 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. hedraiaandra*, *P. megasperma*, *P. nicotianae*, as well as several undescribed *Phytophthora* species.

**Hosts:**

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

**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:**

- None noted.

**Chemical Control:**

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

*Table 3. Chemicals recommended for Phytophthora and Pythium root rot control.*

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

\* Always rotate chemicals with different modes of action.

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

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

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

### **Powdery Mildew**

#### **Pathogens:**

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

#### **Hosts:**

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

#### **Distribution and Importance:**

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

### **Disease Cycle:**

- Powdery mildew fungi are identified by morphological characteristics of the asexual and sexual states.
- On most woody hosts, the asexual stage of the fungus is the stage most commonly observed.
- Asexual spores (conidia) may be produced in chains on stalks (conidiophores).
- In flowering dogwood, the asexual spore 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 and are not well studied in their native habitat, which is often unknown. Nurseries and greenhouses are not isolated geographically, and the movement of both propagation and finished stock occurs across the globe. Due to the increased movement of plant material, ornamental production in the southeastern United States is faced with the constant threat of introduced exotic or regulated pathogens from infested plant material. As examples, *Phytophthora ramorum*, the causal agent of sudden oak death, was introduced into nurseries in several southeastern states in 2004 on



infected nursery stock originating from California. Daylily rust was first identified in the United States in Georgia in 2000 and was not known to occur in North Carolina until 2002, but it has appeared in nurseries each year since. Since the 1980's, dogwood anthracnose has spread rapidly in the Appalachians on *Cornus florida* and has been reported on over 12 million acres in 180 counties. It continues to threaten dogwoods in nurseries and throughout their native range. More education involving newly emerging plant diseases will be essential for their rapid detection, identification, and control.

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

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## *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 and/or; production of durable regenerative structures, which allow re-growth.
- Persistent and spreading perennial vegetative structures.

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 preemergent herbicides (PRE)...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. Integrated weed management strategies will need to focus on improved systems for managing multiple pest species while addressing critical issues of economics, crop safety, resistance management, and environmental stewardship. A full discussion of grower-identified needs and issues is presented in the Nursery Crops Pest Management Strategic Plan. Some of the critical needs identified by growers in that PMSP can be summarized in these broad categories:

- Methods for reducing the costs associated with weed control such as:

- improved options for postemergence removal of weeds from container production (such as POST herbicides, non-herbicide options),
- improved understanding of economics related to nursery weed management systems;
- Improved performance of preemergence herbicides through modeling weed biology / emergence, herbicide longevity,
- Improved technologies to enhance weed control and crop safety;
- Environmentally enhanced systems including scouting, ground cover conservation, integrated systems
- Improved management options for particularly difficult to control weeds such as liverwort and perennial species including nutsedge, johnsongrass, and others,
- Improved resources and training
  - Decision aids – traditional and electronic
  - Training to help growers, crop consultants, Cooperative Extension staff and nursery pest management specialists make informed weed management decisions.

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

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

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

### Select Broadleaf Weeds

**Perennial Broadleaf Weeds:**

- Capable of living more than two years.
- Primarily spread by seed produced in spring/early summer.
- Some are capable of vegetative reproduction.

**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:**

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

#### **Biological Control:**

- None noted.

#### **Chemical Control:**

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

### **Field Diagnostic:**

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

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

- None noted.

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

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

### **Common Groundsel**

(*Senecio vulgaris* L.) [SENVU]

(B, C\*)

**Distribution, Damage and Importance:**

- 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**

(*Conyza canadensis*) [ERICA]

(maretail; 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 spurges, 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; ladythumb, 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]

(bromegrass; 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.
- Do not let plants mature to seed.

**Biological Control:**

- None noted.

**Chemical Control:**

- 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.
- Few selective POST options provide adequate control.
- Nonselective herbicides are effective but require multiple applications.

**Field Diagnostic:**

- *C. esculentus* has triangular stems and leaf tips that gradually extend to a point.
- *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.
- Limited control recommendations are available via Dr. Robert Stamps, UF-IFAS:  
<http://edis.ifas.ufl.edu/EP350>.

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

- Federal noxious weed.

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

- Federal Noxious Weed
- Infestations in a nursery require quarantine and eradication.
- Early detection and eradication educational resources are needed.

### **Cogongrass**

(*Imperata cylindrica*) [IMPCY]

(kunai grass)

(B, F\*)

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

- Widespread in Gulf Coast states
- Isolated populations in WV and OR
- Forms dense, monotypic stands
- Introduced from Asia



**Life Cycle:**

- Perennial.
- Dense stands with deep roots.
- Reproduction is by copious production of windborne seeds and rhizomes.

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

- Sanitation is critical to avoid moving seeds or rhizomes in contaminated soil or crops.
- Do not let plants mature to seed.
- Burning is ineffective (highly flammable, but 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.

*Photo credit: Charles T. Bryson, USDA-ARS, UGA1299003 courtesy of [www.bugwood.org](http://www.bugwood.org).*

## **Dogfennel**

(*Eupatorium capillifolium* [EUPCP])

(B)

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

- Widespread throughout the region
- Native

### **Life Cycle:**

- Reproduces by wind dispersed seeds
- Perennial plants have a woody base and crown that 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.



- Glyphosate is effective for POST control but may require multiple applications.

**Field Diagnostic:**

- Clump forming
- Stems are woody and hairy at the base.
- Finely dissected leaves with a distinctive aroma when crushed.

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

- None noted.

**Critical Issues and Needs:**

- Increased knowledge of PRE and POST herbicide efficacy.
- Understanding of its dispersal and establishment.

**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:**

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

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

- None noted.

##### **Chemical Control:**

- Few effective PRE herbicides are available.
- 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, gripweed [*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 4. Common broadleaf and grass herbicides used in nursery production in the southeastern United States.*

<b><u>Common “Broadleaf” Herbicides</u></b>	<b><u>Common “Grass” Herbicides</u></b>
Isoxaben (Gallery)	Dinitroanilines: oryzalin (Surflan), pendimethalin (Pendulum & Corral), prodiamine (Barricade & RegalKade), trifluralin (Treflan)
Simazine (Princep)	Dimethenamid-p (Tower)
Oxyfluorfen (Goal)	Dithiopyr (Dimension Ultra)
Flumioxazin (Broadstar or Sureguard)	Napropamide (Devrinol)
	Oxadiazon (Ronstar)
	s-Metolachlor (Pennant Magnum)

#### *Postemergence Overview*

Use of postemergence herbicide is not widely practiced in container nurseries due to issues with nontarget applications. However, outside of the pad/bed areas, postemergence herbicides are more frequently used to control weeds in drainage ditches, roadways, surrounding substrate storage areas, around the periphery of the nursery, and around surface water supplies used for irrigation.

In field nurseries, postemergence herbicide use is far greater than container nurseries, with applications occurring in all parts of the nursery, including growing areas. Because application of postemergence herbicides sometimes leads to plant damage, growers minimize the exposure of plants to these herbicides by utilizing specialized spray equipment, spraying only when environmental conditions are ideal, managing the timing of sucker removal, and not directly spraying foliage.

Some of the more popular postemergence herbicides in container and field nurseries include:

- Glyphosate (Roundup), a non-selective postemergence herbicide that is the most commonly used herbicide (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:

<http://www.utextension.utk.edu/publications/pbfiles/PB1775.pdf>

*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.

**DICHLORBENIL****(B)**

(Casoron) – (REI of 12). Casoron is a pre and postemergence herbicide that controls a broad spectrum of weeds, including difficult to control perennial weeds such as Florida betony and mugwort. Do not apply until 4 weeks after transplanting.

**DIMETHENAMID-P****(PRE)**

(Tower) – (REI of 12 hours). Tower is a preemergence that provides broad spectrum control of many broadleaf and grass species. In most cases, needs a tank mix partner (e.g. 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 coarse 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 woodsorrel.

#### **OXADIAZON**

**(PRE)**

(Ronstar) - (REI of 12 hours). Oxadiazon is a preemergence herbicide effective on most nursery weeds, but has poor control of spurge 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 woodsorrel.

**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 woodsorrel.

**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 5. Preemergence Herbicides Labeled for Container Nursery Stock*

<b>Herbicide</b>	<b>Active</b>	<b>ai/</b>	<b>Product /</b>	<b>REI</b>	<b>Chemical</b>			
<b>Trade Name</b>	<b>Ingredient</b>	<b>Acre</b>	<b>Acre</b>	<b>(hrs)</b>	<b>Class</b>	<b>HRAC</b>	<b>WSSA</b>	<b>Company</b>
Barricade 4L	Prodiamine	0.65 - 1.50 lbs.	21 - 48 fl. oz.	12	Dinitroaniline	K1	3	Syngenta
Barricade 65DG	Prodiamine	0.65 - 1.50 lbs.	1.0 - 2.3 lbs.	12	Dinitroaniline	K1	3	Syngenta
BroadStar	Flumioxazin	0.375 lbs.	150 lbs.	12	Phenylphthalimide	E	14	Valent
Casoron 4 GR	Dichlobenil	4.0 - 6.0 lbs.	100 - 150 lbs.	12	Substituted Benzene	L	20	Crompton
Corral 2.68G	Pendimethalin	2 - 3 lbs.	76 - 114 lbs.	12	Dinitroaniline	K1	3	Scott's
Devrinol 50DF	Napropamide	4 - 6 lbs.	8 - 12 lbs.	12	Alkanamide	K3	15	United Phos.
Devrinol 2G	Napropamide	2 - 3 lbs.	100 - 150 lbs.	12	Alkanamide	K3	15	United Phos.
Dimension Ultra 40WP	Dithiopyr	0.31 - 0.38 lbs	0.78 - 0.95 lbs.	12	Pyridazinone	K1	3	Dow Agro
Freehand 1.75G	Dimethenamid-P + Pendimethalin	1.75 - 3.5 lbs.	100 - 200 lbs.	24	Amide plus Dinitroaniline	K3, K1	15, 3	BASF
Gallery 75 DF	Isoxaben	0.5 - 1.0 lbs.	0.66 - 1.33 lbs.	12	Amide	L	21	Dow Agro
Jewel 3.25GR	Oxadiazon + Pendimethalin	3.25 lbs.	100 lbs	12	Oxadiazole plus Dinitroaniline	E, K1	14, 3	Scott's
(OH-2) 2GR	Oxyfluorfen + Pendimethalin	2 lbs. + 1 lbs.	100 lbs	24	Diphenyl ether plus Dinitroaniline	E, K1	14, 3	Scott's
Pendulum 2GR	Pendimethalin	1.5 - 2.0 lbs.	75 - 100 lbs.	12	Dinitroaniline	K1	3	BASF



Pendulum 3.3 EC	Pendimethalin	2.0 - 4.0 lbs.	2.4 - 4.8 qts.	24	Dinitroaniline	K1	3	BASF
Pendulum Aqua Cap 3.8ACS	Pendimethalin	0.8 - 1.6 lbs.	2.1 - 4.2 qts.	24	Dinitroaniline	K1	3	BASF
Pennant Magnum 7.62	s-Metolachlor	1.3 - 2.5	1.3 - 2.6 pints	24	Choroacetanilide	K3	15	Syngenta
Predict 78.6DF	Norflurazon	2.4 lbs.	3.0 lbs.	12	Pyridazinone	F1	12	Syngenta
Princep Liquid	Simazine	1 -3 lbs.	1 - 3qts.	12	Triazine	C1	5	Syngenta
Regal Kade 0.5G	Prodiamine	1.5 lbs.	300 lbs.	12	Dinitroaniline	K1	3	Regal
Regal O-O, 3GR	Oxyfluorfen + oxadiazon	2 lbs. + 1 lbs.	100 lbs	24	Diphenyl ether plus Oxadiazole	E	14, 3	Regal
Regalstar 1.2GR	Oxadiazon + prodiamine	2 lbs + 0.4 lbs.	200 lbs.	12	Oxadiazole plus Dinitroaniline	E, K1	14, 3	Regal
Ronstar 50 WSP	Oxadiazon	2 - 4 lbs.	4 - 8 WSP	12	Oxadiazole	E	14	Bayer
Ronstar G	Oxadiazon	2 - 4 lbs.	100 - 200 lbs	12	Oxadiazole	E	14	Bayer
Rout 3G	Oxyfluorfen + oryzalin	2 lbs. + 1 lbs.	100 lbs.	24	Diphenyl ether plus Dinitroaniline	E, K1	14, 3	Scott's
Showcase 2.5G	Isoxaben + Trifluralin + Oxyfluorfen	0.25 - 0.5 lbs. + 2.0 - 4.0 lbs. + 0.25 - 0.5 lbs.	100 - 200 lbs.	24	Benzamide plus Dinitroaniline plus Diphenyl ether	L, K1	21, 3	Dow Agro
Simazine 4L	Simazine	2.0 - 3.0 lbs.	2.0 - 3.0 qts.	12	Triazine	C1	5	Agrisolutions
Simazine 90 DF	Simazine	2.0 - 3.0 lbs.	2.2 - 4.4 lbs.	12	Triazine	C1	5	Agrisolutions
Snapshot 2.5TG	Isoxaben + Trifluralin	0.5 - 1.0 lbs. + 2 - 4 lbs.	100 - 200 lbs.	12	Benzamide plus Dinitroaniline	L, K1	21, 3	Dow Agro
SureGuard	Flumioxazine	0.25 - 0.38 lbs	8 - 12 oz.	12	Phenylphthalimide	E	14	Valent

Surflan 4AS	Oryzalin	2 - 4 lbs.	2 - 4 qts.	12	Dinitroaniline	K1	3	United Phos.
Surflan 85DF	Oryzalin	2.0 - 4.0 lbs.	2.4 - 7.1 lbs.	12	Dinitroaniline	K1	3	United Phos.
Tower 6L	Dimethenamid-P	0.98 - 1.5 lbs.	21 - 32 fl. oz.	12	Amide	K3	15	BASF
Treflan 5G	Trifluralin	4 lbs.	80 lbs.	12	Dinitroaniline	K1	3	Dow Agro
Weedfree 75, 5GR	Oxyfluorfen + Trifluralin	5 lbs.	100 lbs.	24	Diphenyl ether plus Dinitroaniline	E, K1	14, 3	Harrell's
XL 2 GR	Benefin (benfluralin) + Oryzalin	2 - 3 lbs. + 2 - 3 lbs.	200 - 300 lbs.	12	Dinitroaniline	K1	3	Helena

*Table 6. Postemergence Herbicides Labeled for Container Nursery Stock*

<b>Herbicide Trade Name</b>	<b>Active Ingredient</b>	<b>ai/ Acre</b>	<b>Product/ Acre</b>	<b>REI (hrs)</b>	<b>Rainfast</b>	<b>Chemical Class</b>	<b>HRAC</b>	<b>WSSA</b>	<b>Company</b>
Acclaim Extra	Fenoxaprop	0.09 - 0.17 lbs.	1.2 - 2.4 pt.	24	1 hour	Aryloxyphenoxypropionate	A	1	Bayer
Asulox	Asulam	3.34 lbs.	1.0 gal.	12	unknown	Carbamate	I	18	United Phoshorus
Basagran TO	Bentazon	0.75 - 1.0 lb.	1.5 - 2.0 pt.	12	4 hours	Benzothiazinone	C3	6	BASF
Casoron 4G	Dichlobenil	4 – 8 lbs.	100 – 200 lb.	24	NA	Benzonitrile	L	20	Chemtura
Casoron CS	Dichlobenil	1.96 - 6.02 lbs.	1.4 - 4.3 gals.	24	NA	Benzonitrile	L	20	Chemtura
Envoy Plus	Clethodim	0.11 - 0.24 lbs.	13 - 32 fl. oz.	24	1 hour	Cyclohexanedione	A	1	Valent
Finale 1L	Glufosinate-ammonium	0.75 - 1.5 lbs	3.0 - 6.0 qt.	12	4 hours	Phosphinic acid	H	10	Bayer
Fusilade II	Fluazifop-P-butyl	0.25 - 0.38 lbs.	1.5 - 1.5 pt.	12	1 hour	Aryloxyphenoxypropionate	A/1	1	Syngenta
Goal 2XL	Oxyflurofen	0.5 - 1.5 lbs.	2.0 - 6.0 pt.	144	unknown	Diphenyl ether	E	14	Dow Agro
Goal Tender	Oxyflurofen	0.5 - 1.5 lbs.	1.0 - 3.0 pt.	144	unknown	Diphenyl ether	E	14	Dow Agro

Gramoxone Inteon	Paraquat	0.25 - 1 lb.	1.3 - 4.0 pt.	24	30 minutes	Bipyridylum	D	22	Syngenta
Lontrel	Clopyralid	0.09 - 0.5 lb.	0.25 - 1.33 pt.	12	unknown	Pyridine compound	O	4	Dow Agro
Reward 2L	Diquat	0.5 - 1.0	1.0 - 2.0 qt.	24	1 hour	Bipyridylum	B	22	Syngenta
Roundup (various products)	Glyphosate	0.25 - 1 lbs.	1 - 4 quarts	4 - 12	30 minutes to 6 hours	Phosphonoglycine	G	9	Monsanto
Segment	Sethoxydim	0.28 - 0.47 lbs.	1.1 - 1.9 qt.	12	1 hour	Cyclohexadione	A	1	BASF
Scythe	Pelargonic Acid	9.4 - 84 lbs.	2.2 - 20 gal.	12	1 hour	Biopesticide	Z	27	Dow Agro

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