Woody Ornamental and Landscape Plant Production and Pest Management Innovation Strategic Plan

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Acknowledgments

This document is a result of efforts and collaborations of a large group of people and is the amalgamation of two previous documents along with some original prose. The two documents that serve as the basis of this work are a pest management strategic plan developed through a grant to P. Knight (Mississippi State) and Charles Gilliam (Auburn) and a crop profile on the production of evergreen trees produced by R. Mizell and G. Knox for EPA. We have elected to alphabetize the contributors following the first four authors of the two main documents. Other contributions consisted of reviewing and editing of the document for which S. Arthers, E. Buss, D. Held, J. C. Horng and W. Klingemen deserve special thanks. The rest of the authors in the alphabetized list contributed by attending and participating in the planning meetings held in November of 2009. This effort was partially funded by a competitive grant from the USDA-SCRI program to Mizell, Knox, Funderburk, Hale, Klingemen, Mannion and Norcini.

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Project Summary: The woody landscape "green" industry is perhaps the most important agricultural commodity in the U.S., and consists of myriad organizational components involving plant production and landscape design, establishment, and maintenance. The production of thousands of plant species in containers, in-ground, under shade and in protected culture requires myriad culture and management practices. The plants are attacked by pests of all types. Due to consumer purchasing traits, tolerance is very low for imperfect plant products. As a result, there are high use rates of water, fertilizer, and pesticides that are neither worker nor environmentally friendly. Currently, in comparison to other commodities, the industry is unorganized and poorly funds research. Furthermore, the number of plant species, variation in growing methods and habitat types across the entire U.S. are problematic to any attempt to develop general production and IPM strategies and tactics. Nevertheless, the time is ripe for innovation in the green industry in all sectors to make production more sustainable and consumption more environmentally efficient. We propose to conduct a regional planning meeting to bring together the major stakeholders in the green industry to develop a document that will lay out a path for future change to holistic systems research and extension and lead to a SCRI CAPS proposal that will in turn lead in the future to a more sustainable and profitable industry.

Introduction: The total production of foliage, greenhouse, field and container-grown ornamental plants arguably ranks nursery production as one of the largest agricultural commodities in the U.S. California, Texas and Florida represent the three largest production states. A 2005 economic impact study conducted by the University of Florida estimated total Florida environmental horticulture industry sales in 2005 at $15.24 billion (Bn) (Hodges and Haydu, 2006; **http://www.fngla.org/fngla-action/doc/EconomicImpacts2005.pdf**). The total industry output amounted to $10.39 Bn, with $3.01 Bn for wholesale nurseries, $5.25 Bn for landscape services, and $2.13 Bn for horticultural retailers, which reflects the average gross margin on retail sales. Direct employment in the industry was 190,000 fulltime jobs, plus nearly 104,000 temporary, part-time or seasonal jobs.

Comparable increases are also occurring in other states. The breakdown of total sales for 2000 shows Florida nursery growers generated $1.74 billion in plant sales, retailers sold $3.64 billion in plants and related horticultural goods, and landscape businesses provided services valued at $3.11 billion. CA and TX statistics are similar and proportionately higher.

Nursery and landscape industries are interdependent (Fig. 1). The nursery industry is production agriculture; landscaping and landscape maintenance are agribusiness service industries which consume nursery products through sales and maintenance to homeowners and businesses. Household consumers are an important market for the nursery and landscape industries. An estimated 22 million U.S. households spent $14.6 billion on professional landscape, lawn-care and tree-care services in 1997. This was an increase of 1 million in the number of households using the services and a $600 million rise in spending over 1996 (Anonymous 1998). Many southeastern states are experiencing population growth and approximately 1000 people per week move to Florida along with thousands of tourists. New residents and visitors require new and better home, municipal, institutional and commercial landscapes. Urban landscape design will in large part determine the quality of the environment of the urban dweller, worker and visitor. Most new landscapes will be supported by local nursery production. Florida alone has 175,000 acres of golf courses, 75,000 acres of sodfarms, 1.5 mil. acres of lawns and 25,000 acres of cemeteries, along with thousands of acres of parks, recreational and miscellaneous areas related to the landscape and nursery industries.

Properly planned and maintained landscape adds beauty and value to any building. Ideally, landscapes should enhance the environment without negative economic and environmental impact and be energy efficient. Too often landscapes are intense consumers of pesticides, water, fertilizer and other energy inputs which lead to waste, pollution and health hazards. Industry dependency on unskilled labor increases the risks for accidents from pesticide exposure in both nurseries and landscapes. Industry and consumers are concerned about the environment and pesticide use (Mott 1999). Clearly, consumers recognize the importance of their immediate environment and wish to use resources in a responsible manner. Producers see the need to meet consumer expectations. According to the Organic Gardening's Gardening in America II survey, gardening is one of the most frequent and fastest growing activities of homeowners in the U.S. Flower and ornamental gardening are the most popular activities and "master" gardeners spend about 10 hours per week gardening during the growing season. Somewhere around 30-50% of gardeners have household incomes above $50,000.

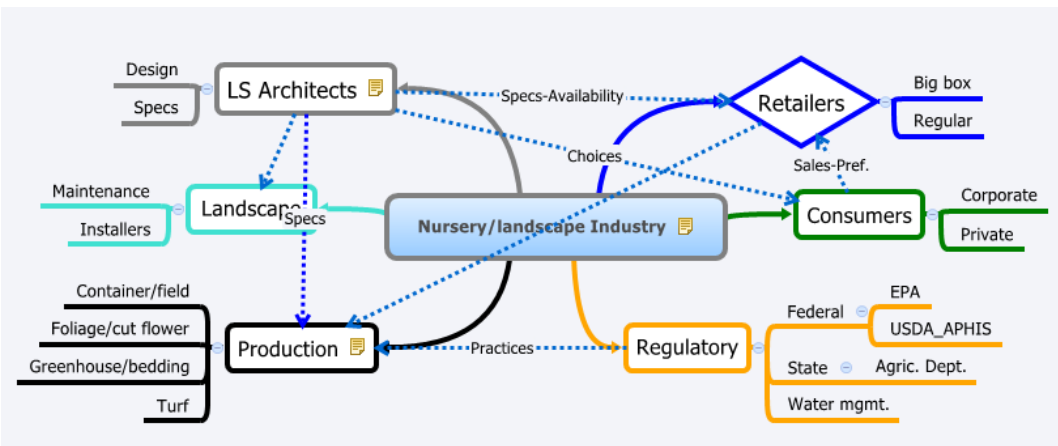

Figure 1: A conceptualization of the woody landscape plant industry depicting the major components involved.

As a result of the implementation of Worker Protection Standards (WPS), nursery producers and landscape maintenance personnel were forced to become more aware of and manage more judiciously their use of pesticides towards increasing worker safety. WPS together with the elimination or restriction of use of more toxic pesticides as a result of the Food Quality Protection ACT (FQPA) have forced changes in the industry toward using "softer" pesticides with shorter reentry intervals. Despite the notable progress that has been made in reduction of the quantity and quality of herbicide, insecticide and fungicide use, the Green Industry as a whole, still relies primarily on chemical pesticides for pest management. Basic pest management technology such as simple monitoring methods and resistant cultivars are available but are not fully utilized. Many reasons hinder the adoption of integrated pest management (IPM). One of the most frequently cited reasons is that a nursery plant is valued for its appearance and subsequently the low threshold for damage favors the intensive use of chemical pesticides. Pesticides are cheap relative to the total cost of production/maintenance, effective, easy to use and manage logistically (less knowledge intensive), and the margin of error for mistakes, e.g., risks, in pest suppression that relies on chemicals is low. It is also true that there is little incentive for nursery growers and landscapers to adopt other practices in the absence of market demand for different products or products grown using more benign culture and management practices.

Nevertheless, the approach taken by research and extension has been piecemeal and has not effectively explored and exploited the interactions between the ecological components of the production systems from a holistic perspective. A fundamental change to the conventional approach is needed to provide new breakthroughs to enable growers and landscapers to progress toward higher sustainability while exploiting the ecological services available.

The American Nursery and Landscape Association (2003) discussed the landscape and nursery industry as follows.

According to the Economic Research Service of the U.S. Department of Agriculture, the nursery and greenhouse industry comprises the fastest growing segment of U.S. agriculture. For example, while the number of U.S. farms of all types has declined over the last two decades, the number of nursery and greenhouse farms has increased. Grower cash receipts from nursery and greenhouse sales (on sales of plants to retail and distribution businesses) have grown steadily over the last two decades and are increasing at approximately $500 million per year. Of 18,860 nursery-crop farms, 650 (3.5 percent) had sales over $1 million.

The U.S. is the world's largest producer and market for nursery and greenhouse crops and these crops represent an important and unique segment of agriculture whose impact is felt on the national, state, and community level. In terms of economic output, nursery and greenhouse crops represent the second most important sector in U.S. agriculture, ranking seventh among all commodities in cash receipts, and among the highest in net farm income. Nursery and greenhouse crops are the top five commodities in 27 states, and the top 10 commodities in 42 states. Ten states account for more than two-thirds of all nursery-crop output in the U.S.: California (20%), Florida (11%), North Carolina (8%), Texas (8%), Ohio (5%), Oregon (5%), Michigan (2-4%), Pennsylvania (2-4%), Oklahoma (2-4%), and New York (2-4%). [Plant species and production practices in Texas are very similar to Florida. We estimate that at least 50% of the plants grown in California are commonly grown in Florida with similar production practices. Several of the larger nurseries (e.g., Monrovia) have operations in two or more of the three largest states.]

The nursery and landscape industry employs over 600,000 workers during peak seasons. Growers employ at least 45,000 workers year-round and 105,000 during peak seasons. Net farm income is the highest of any production specialty in U.S. agriculture. At an annual average of $53,589, nursery and greenhouse income is four times higher than the U.S. average ($13,458). Landscape and retail firms employ nearly 500,000 full-time, part-time, and seasonal workers.

Sixty-nine million U.S. households spent $30.1 billion at retail lawn and garden outlets in 1998, according to The National Gardening Association and The Gallup Organization, while over 21 million households spent $16.8 billion on professional landscape, lawn and tree care services. In total, Americans spent $46.9 billion improving their homes in 1998.

Production- Nursery and Landscape. Nursery plants may be produced in the field, in containers, by modified field production, or by any combination of these methods. Production typically starts with seeds or cuttings being used to produce a “liner” or young transplant. Nursery production is not as closely tied to seasonal activities as is typical with production of field crops, vegetable crops, row crops, and forages. Many nursery activities can be done at any time of year and may vary with the species being grown, geographic location, nursery practices, environment, and market. Figure 1A-C shows in graphic form several components of horticultural sales in the United States for the year 1998.

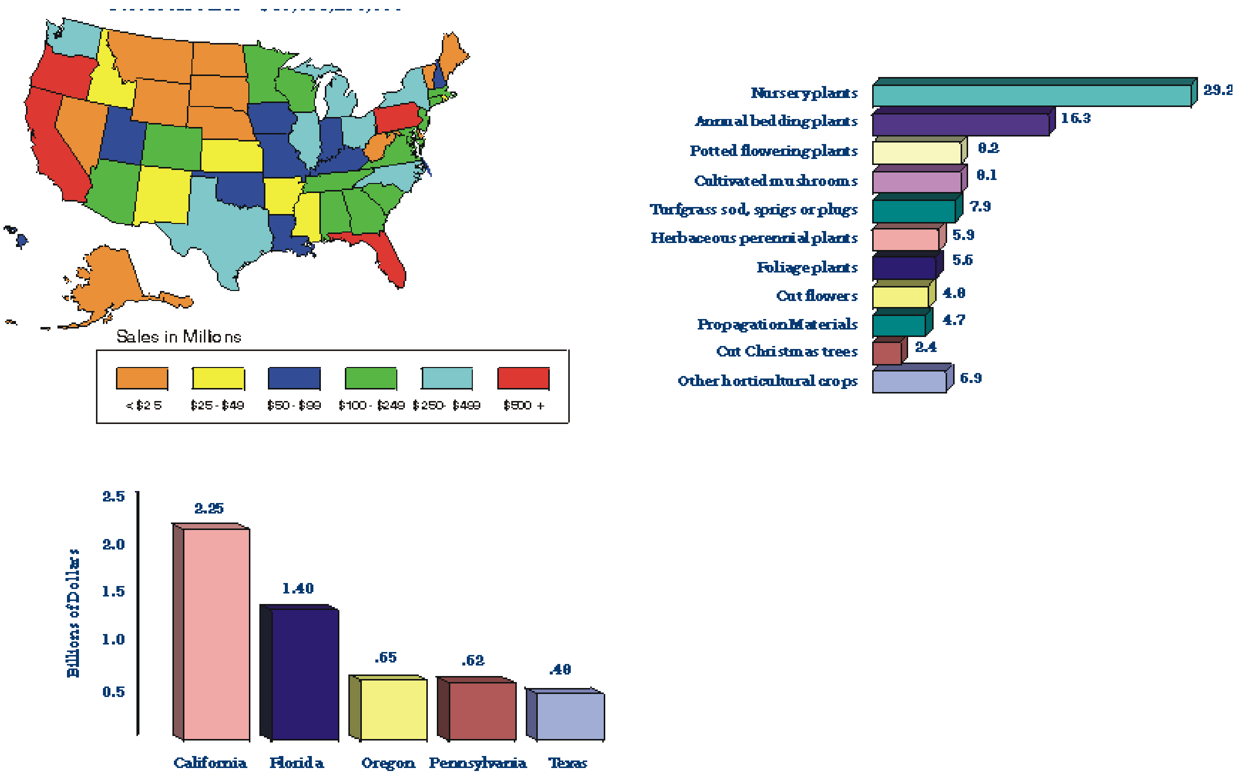

Figure 2A-C.—Horticultural sales in U.S.

A (upper left). Total horticultural sales by state ($ million).

B (upper right). Horticultural sales by commodity group (% of U.S. sales).

C (lower left). Sales of five leading states ($ billion). (After National Agricultural Statistics Service 2001.)

FIGURES 3–5 illustrate general plant production practices for the southeast U.S. TABLE 1 shows worker activities and potential pesticide exposure in relation to nursery activities.

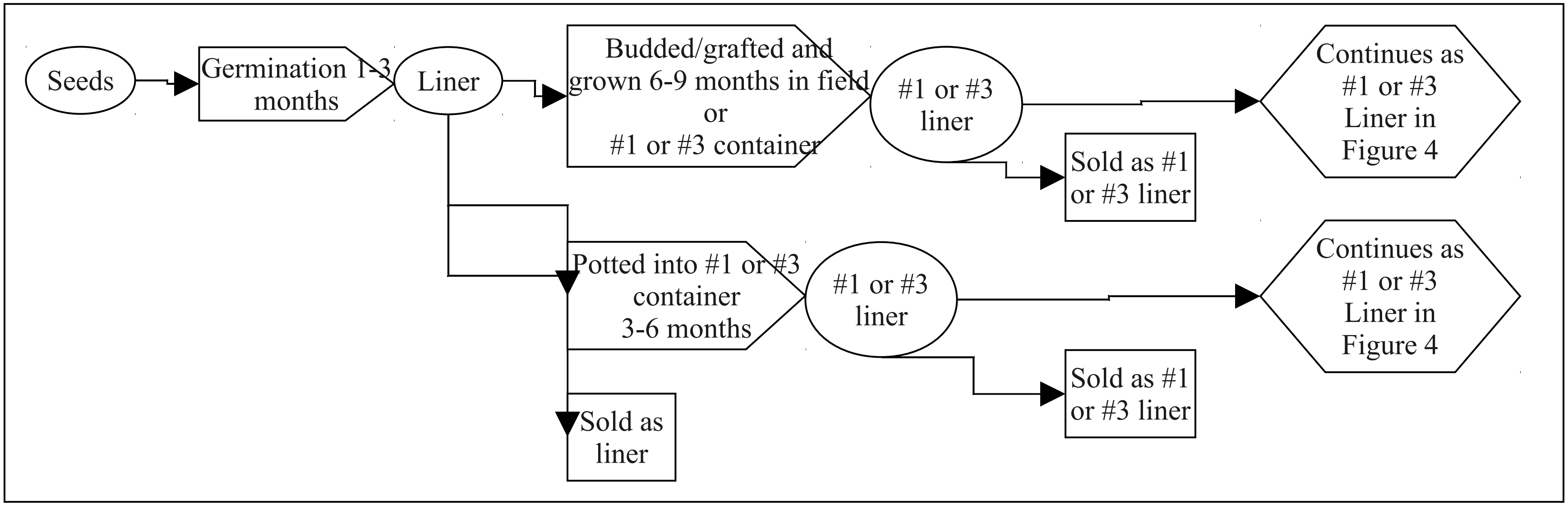

FIGURE 3: Flowchart (above) of liner production starting from seeds. Most seeds are planted during the winter. Germination time and growing time vary with species, nursery cultural practices, and environment.

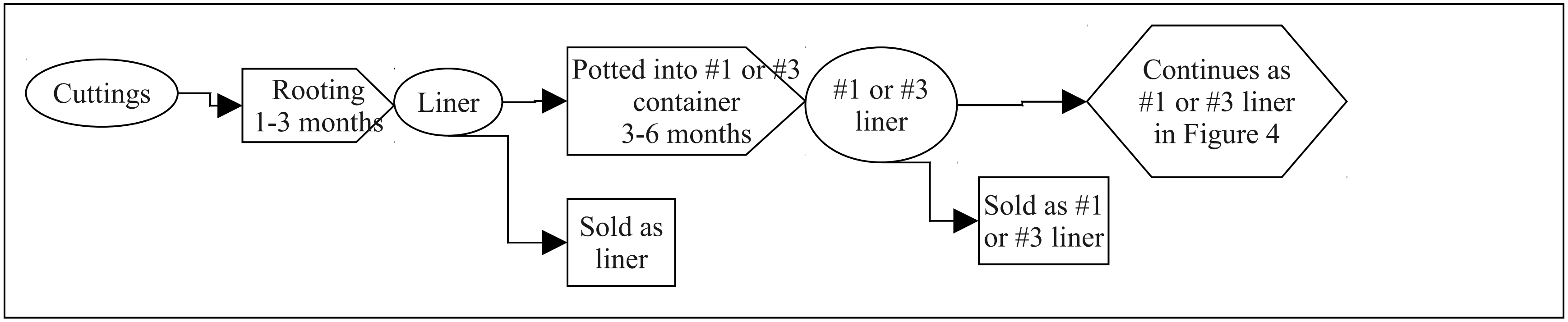

Figure 4: Flowchart of liner production starting from cuttings. Cuttings are most often taken during the spring and summer but may be taken at any time of the year depending upon the species, geographic location, and nursery practices. Rooting time varies with species, nursery cultural practices, and environment.

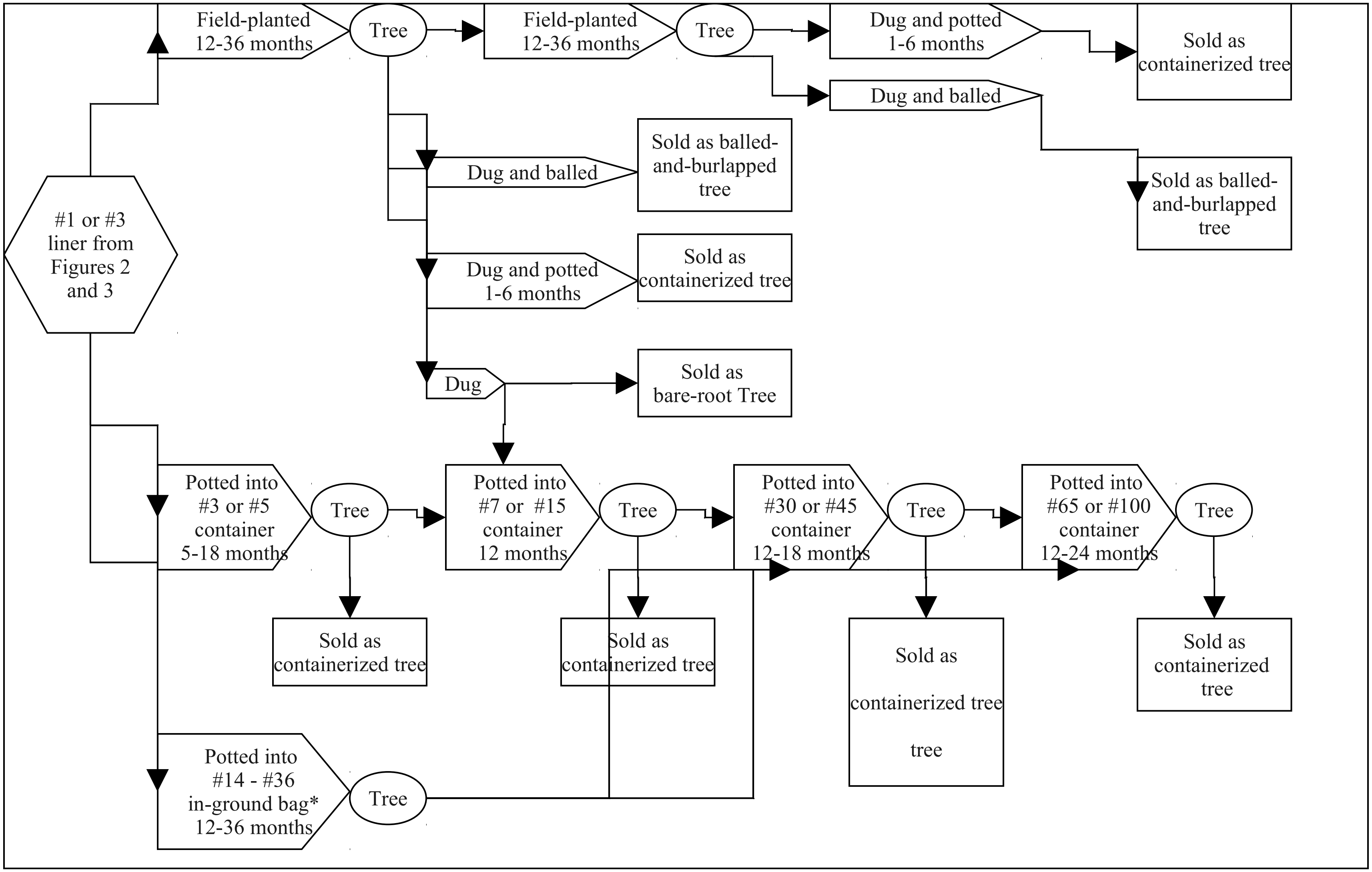

FIGURE 5: Flowchart of plant production starting from seed- or cutting-produced liner (from Figures 2 and 3). Growing time varies with species, geographic location, nursery cultural practices, and environment. Digging most often takes place in late fall and winter, but container potting can take place anytime. Time of harvest and sale depends on species, geographic location, nursery cultural practices, environment, and market. (* In-ground bags are a modified form of field production. An

in-ground bag is a cylinder made of a porous fabric with a plastic bottom. The porous fabric sides confine the roots within the bag yet allow for movement of moisture in and out of the bag. The impermeable plastic bottom prevents formation of tap roots that otherwise make digging difficult. An in-ground bag allows up to 80% or more of the roots to be harvested, far greater than that harvested when digging conventional field-grown trees. Because more of the root system is present at the time of digging, there should be less transplant shock and increased survival. Some species of in-ground bag trees may be harvested during the summer because of the greater proportion of roots harvested.)

Table 1: Plant nursery and worker activities associated with workers potential pesticide exposure. A crop may require 1-6 years of growth before harvest and sale.

Nursery activity	Time of year	Frequency	Worker activity	Potential pesticide exposure
Seed propagation	Usually winter	Once per crop (if seed propagated)	Manually planting seeds in containers or in the field or assisting a mechanical planter	Seeds may have been treated with a fungicide
Cutting propagation	Year-round, but mostly in spring and summer	Once per crop (if cutting propagated)	Pruning shears used to clip cuttings from plants; cuttings dipped in rooting hormone; drenching, dipping, or spraying cuttings with fungicide	Plants may contain pesticide residue; rooting hormone is applied to cuttings; fungicide drench, dip or spray may be applied to cuttings
Liner production	Year-round	0-4 applications per crop of fungicides and insecticides	Applied with handheld sprayer or granular applicator	Mixing and applying pesticides
Field planting (field nurseries)	Usually fall and winter	Once per crop	Use of mechanical planter or manually planting by hand, trowel, or shovel; fertilizer or herbicide applied by tractor or handheld sprayer or granular applicator	Application by tractor or handheld sprayer or granular applicator; walking through treated nursery beds and drift
Field preparation (field nurseries)	Usually fall and winter	Once per crop	Plowing, harrowing, grading, or rototilling; incorporation of organic matter or soil amendments with rototiller; fumigation	Use of fumigants
Potting (container nurseries)	Year-round	Once per crop	Potting machine or potting by hand	If plant will be sold within 1 year, potting substrate may contain insecticide (for fire ant control), fertilizer, herbicide
Spacing and consolidation (container	Year-round	0–3 times per year	Relocating containers to separate them, to provide more space for plant canopies, and to group	Plants, containers or potting substrate may contain pesticide residue; walking through the

Nursery activity	Time of year	Frequency	Worker activity	Potential pesticide exposure
nurseries)			containers by size and species	nursery beds
Staking	Year-round but usually associated with planting, potting or repotting	Usually annually	Manual insertion of stake into soil or container; manual or mechanical tying of plant stems to the stake	Plants may contain pesticide residue; walking through the nursery beds
Pruning	Year-round	Usually performed 1-3 times per year	Manual or mechanical shearing or pruning	Walking through the nursery beds; plants may contain pesticide residue
Insect and mite management	Year-round	Varies with species, weather, nursery cultural, pest management practices; 0-12 applications of pesticide per year	Application with tractor or hand-held sprayer or granular applicator	Mixing, loading, and applying pesticides
Disease management	Year-round	Varies with species, weather, nursery cultural, pest management practices; 0-4 applications of fungicides per year	Application with a tractor or hand-held sprayer or granular applicator	Mixing, loading and applying pesticides
Preemergence Weed Management	Year-round	Varies with species, weather, nursery cultural and pest management practices; up to 5 - 6 applications per year of preemergence herbicides	Application with a tractor or hand-held sprayer or granular applicator	Mixing, loading, applying pesticides
Postemergence Weed management (field nurseries)	Year-round	Varies with species, weather, nursery cultural and pest management practices; 0–6 applications per year of postemergence herbicides; cultivation or	Application with tractor or hand-held sprayer; cultivation by tractor or manually; mowing by tractor	Mixing, loading, applying pesticides; if cultivation is manual, walking through the nursery beds

Nursery activity	Time of year	Frequency	Worker activity	Potential pesticide exposure
		mowing also may occur		
Postemergence weed management (container nurseries)	Year-round	Varies with species, weather, nursery cultural and pest management practices; 0–4 applications per year of postemergence herbicides	Application with tractor or hand-held sprayer	Mixing, loading, applying pesticides
Root pruning (field nurseries)	Usually fall or winter	May never occur on some nurseries; annually or biennially otherwise	Use of tractor	Pesticide and fertilizer residue in soil medium; walking through nursery beds
Irrigation	Year-round	Several times per day (container) to several times per year (field)	Usually by automatic irrigation system (remotely operated); occasionally irrigated by handheld hose or bucket	If done by hand, walking through the nursery beds
Irrigation system maintenance	Year-round	As needed (perhaps several times per year)	Manual inspection, cleaning, and repair of irrigation system	Walking through the nursery beds; use of pesticide to remove microbial growth in irrigation pipe
Fertilization	Year-round	1–12 times per year or with irrigation	Tractor or handheld applicator; may be incorporated into potting substrate and thus occur at potting; May be applied as a liquid fertilizer injected into the irrigation system and thus occur with irrigation	If manual, walking through the nursery beds
Container re-set (container nurseries)	Year-round, often after windstorms or disturbance of plants by animals,	As needed (perhaps several times per year but usually only a small portion of the crop)	Manual	Plants, containers or potting substrate may contain pesticide residue; walking through the nursery beds

Nursery activity	Time of year	Frequency	Worker activity	Potential pesticide exposure
	erosion, etc.			
Digging (field nurseries)	Usually fall and winter	Once per crop	Use of mechanical tree-spade, tractor, or by hand	If by hand, plants and soil may contain pesticide residue
Grading	Year-round, usually winter and spring	Once per crop	Manual	Plants may contain pesticide residue
Loading and shipping	Year-round, usually winter and spring	Once per crop	Manual	Plants, root balls, soil, containers, or potting substrate may contain pesticide residue; walking through the nursery beds

Chemical Applications and Worker Activities

Plants are grouped in the nursery based on the size of containers, irrigation requirements, plant species, shipping date, or other category. Typically, container beds of black plastic, ground cloth or gravel are 40 feet (12 m) in width with bed length related to land topography or logistical needs. Roads of dirt or gravel and ditches to convey water runoff occur parallel to the beds. In-ground plants are grown in rows with row spacing matched to equipment needs and plant spacing matched to tree requirements for root space. Regardless of the growing or harvest method used, nurseries grow individual species in small contiguous blocks that make up the management units of the nursery and also serve as the treatment units for pesticide applications. Thus, applications are usually targeted to one or more blocks of plants with similar characteristics. Posting of applications to meet Worker Protection Standard (WPS) requirements are done on a block-by-block basis.

Pesticides in the nursery are applied most often to evergreens and shade trees with large air blast sprayers using 100-300 gallons of water per acre. Some nurseries treat smaller plants by overhead boom sprayers (0.5-.0.75 m above the canopy) including electrostatic sprayers that direct spray down into the plants to reduce drift. Smaller nurseries often employ small sprayers (boom or air blast) mounted on 4 x 4 All-Terrain Vehicles (ATV) that enable greater maneuverability and allow for spot treatments. Larger trees, small plants that are compact and present a challenge to obtain good coverage, and those infested with spider mites or other difficult-to-control pests, may be treated with a hand-held sprayer application. Insecticides, acaricides, and fungicides may be applied at 3- to 7-day intervals during the peak growth periods depending on the plant species, pest, shipping date, and other logistical factors. Applications directed at both disease agents and arthropod pests are very often tank mixes of two or more chemicals. The cost of applications and the time to cover large acreages containing many different species of plants makes tank mixes the primary choice.

Herbicides used by container nurseries are mostly granular formulations. They are applied by hand to each pot using portable applicators by laborers or by airplane. Application by airplane of granular herbicides is completed in the evening or weekends when a minimum number of laborers are present in the nursery. Field nurseries may use granular or liquid herbicides. Therefore, the table data that indicate the phenology and occurrence of pests represent the times when chemical applications and resulting worker exposure are possible.

Larger nurseries use one or more pesticide applicator crews of 1 or 2 workers each who continuously apply chemicals somewhere in the nursery during much of the year. Concurrently, other nursery activities proceed independently with coordination by the management and guided by posting of WPS signs to avoid treated areas and to follow Restricted Entry Interval (REI) requirements. Laborers in nurseries use small tractors and wagons for most of the transportation within the nursery. Supervisors and managers use pickup trucks or other utility vehicles. Based on a sample of 37 nurseries, woody and field nurseries in Florida averaged 0.59 Full-Time Equivalent (FTE) workers per acre (Hodges et al. 1998). Container nurseries in Florida averaged 0.54 FTE workers per acre.

Despite continued progress and increase in Integrated Pest Management (IPM) implementation in nursery crops, chemical pesticides remain the primary management tool. The combination of large numbers of pests attacking large numbers of plant species, the value of which is based on appearance, makes it very difficult for nursery growers to reduce pesticide use. Worker protection standards have forced nurseries to use least toxic alternatives or to make pesticide applications at times when labor is not present. The Southeast has a long growing season and specific pests occur during all months of the year. Therefore, although more pesticides are used in the spring, summer, and fall months, the potential for worker exposure may occur at any time during the year.

Preharvest Intervals and Restricted Entry Intervals

Preharvest intervals (PHI) do not often apply to these crops. However, because of quarantine regulations, limited pesticide applications may be applied to plants immediately prior to harvest or to loading and transport. Due to the intense labor requirements of nursery production, restricted entry intervals (REI) following pesticide application are critical to labor and production management. Most chemical pesticides used have relatively shorter REIs of 12-24 hours. When it is necessary to use pesticides with longer REIs, applications are often made on the weekends or evenings to avoid or minimize disruption of routinely-scheduled culture and management practices.

Regulatory and Quarantine Issues

Because the interstate shipment of plants and soil has the potential of containing and transporting dangerous pests, the nursery industry is heavily regulated by state and federal governments. Nurseries are subjected to periodic inspection and are provided with phytosanitary certification for interstate shipments by nursery inspectors. All international shipments of plants from the U.S. require inspection and certification immediately prior to loading of the shipment. Several quarantines in effect in the Southeast require periodic chemical pesticide treatments. The most extensive quarantine is that of the red imported fire ant *Solenopsis invicta* Buren. It requires treatment of the soil media and monthly inspections and mound treatments on the nursery grounds.

Alternative Management Tools

Evergreens and shade trees, as with other nursery products, are valued on size and appearance. The diversity of plant species grown by nurseries is very high, and subsequently, pest diversity is also high. In response to the logistics of dealing with a large diversity of plants and pests and the premium on appearance, preventative pesticides applications are often exclusively relied on. Much of the new chemicals registered for nursery production are less toxic than the older chemicals to humans, to nontarget organisms, such as beneficial organisms, and to the environment. However, broad spectrum and systemic pesticides are still preferred. Few systemic pesticides are still registered. Imidacloprid is one of these, and it is widely used against piercing-sucking insect pests. Very few alternative tools are available for nurserymen to substitute for conventional pesticides. Table 9 contains the few alternative insecticides that are available. Predatory mites and products containing *Bacillus thuringiensis* or its exotoxins are the alternative tools used most often by nurserymen. Predatory nematodes are receiving much research attention; however, they remain costly and have limited efficacy unless applied under the right set of conditions. There are also a wide range of beneficial arthropods (predaceous insects/mites and parasitic wasps) available supported by a multi-million dollar industry. However the limited understanding of how and where such biological agents can be effectively used to control major nursery pests continues to limit their widespread commercial adoption. Research and outreach activities are desperately needed to address this imbalance. Because most of the production of beneficials occurs in Europe, the shipping cost which increases the total pest management cost to US producers. We anticipate this situation will change as the domestic production and demand for biological control agents increases.

Pest Management

The most important factors considered by nursery growers in deciding whether to treat for the myriad pests affecting them (Fig. 6) are (in no order) weather, pest population level, degree of pest damage, changes in pest populations, pest life stage present, projected marketing date, treatment cost, plant disease inoculum level, presence of predators and parasites, and labor availability (scheduling). Most growers of ornamental plants recognize the importance of regular scouting within an IPM program. A survey of ornamental nursery growers revealed that 42% of growers regularly scheduled activities to scout for pests, and 12% used systematic sampling techniques to quantify pest populations. Most firms (90%) reported some kind of scouting (including general observations during other tasks), and only 3% did not scout at all. More than two-thirds of nursery firms (68%) indicated that they scouted more than once a week, 19% scouted weekly, 6% scouted once every 2 weeks, 1% scouted once every three weeks, and 2% scouted once every 4 weeks.

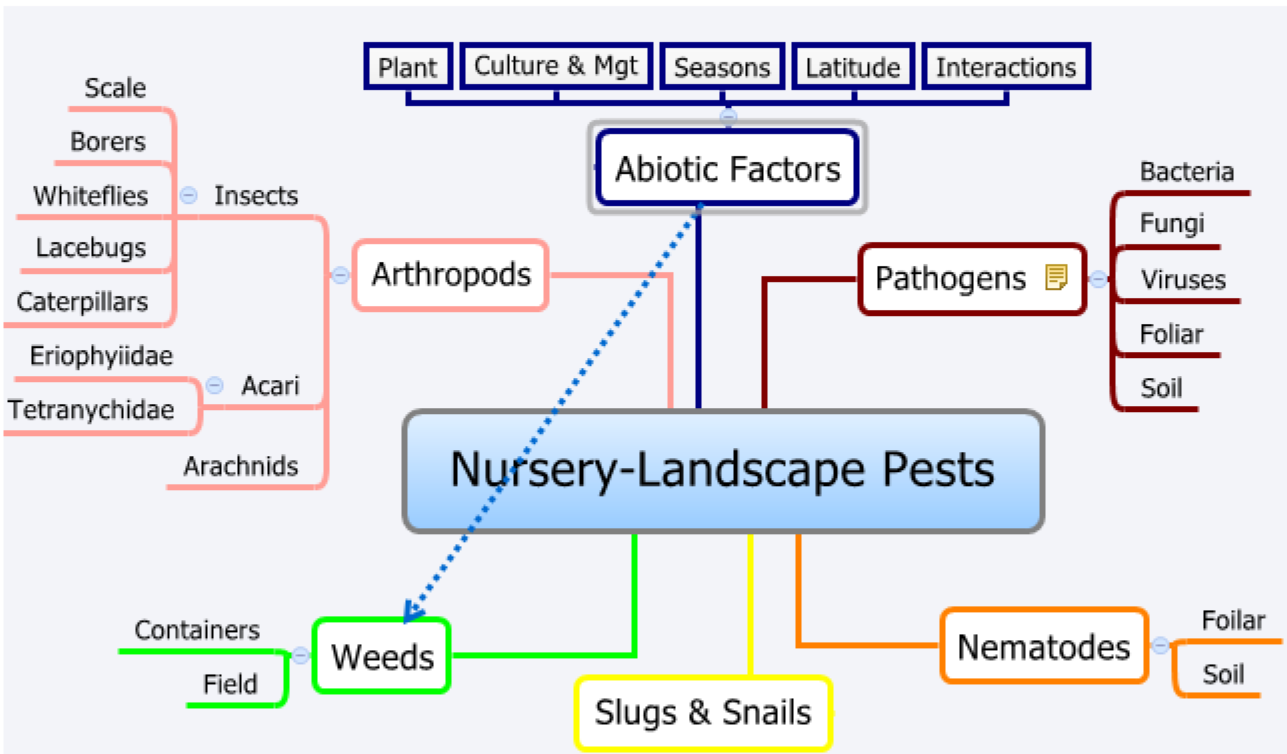

Figure 6: Outline of major pests groups of woody landscape plants

General Disease Control Practices

Prevention is the key to reducing disease-related plant and income losses during the production, marketing, and maintenance of trees and shrubs. Practices that prevent disease outbreaks include the use of disease-resistant cultivars or selections, cultural practices, landscape or nursery design features, and chemical control. Often, no single control practice will insure complete protection from a damaging disease, particularly to destructive root rots and selected foliar diseases. Rather, several practices maybe combined into a single management program to prevent costly disease outbreaks in production nurseries or in the landscape.

Disease Resistance

Establishment of disease resistant cultivars or species is an inexpensive, effective, environmentally- friendly means of preventing outbreaks of damaging foliar and soilborne diseases of trees and shrubs in both the nursery as well as commercial and residential landscapes. Prior to the establishment of a new or renovation of an existing landscape, the plant material specified for installation must not only be adapted to the climate, site, and proposed level of management but also be resistant to destructive diseases and nematode pests common on that species in that site or region. Use of resistant cultivars will greatly reduce if not eliminate the need for costly preventative fungicide sprays without any adverse affects on plant health or appearance. Specification of adapted, disease resistant trees and shrubs permits the establishment of attractive low maintenance, easy care landscapes that are often desired by commercial and residential customers.

Cultural Practices

Cultural practices employed to reduce the occurrence of damaging diseases include production bed or display area design, soil drainage and site preparation, potting medium components, fertility, and sanitation practices. Production bed and garden center display area layout has a profound impact on the development of root rot diseases of field-and container-grown trees and shrubs. Production beds and display areas should be crowned or sloped to speed the run-off of water and prevent “ponding” around the flats or containers. A drainage system should be designed to quickly move water around or away from production beds. Also, beds should be covered with plastic or weed barrier and topped with a layer of gravel, oyster shell, or a similar coarse material.

In landscapes, trees and shrubs such as azaleas, camellia, juniper, and rhododendron, which are susceptible to root rot diseases, should be planted on raised beds amended with aged bark, organic compost; or a similar material incorporated to a depth of 2 to 4 inches. Do not establish shallow-rooted trees and shrubs in areas that flood following a heavy rain.

Water management is a critical factor in the development of both foliar and root-rot diseases in both the nursery and landscape. In landscapes, severe summer droughts may predispose trees and shrubs to dieback and canker diseases. In the nursery, container stock should be grouped according to pot size and water needs to avoid over or under watering. In commercial and residential landscapes, surface (soaker hose) or drip irrigation is recommended, particularly for leaf spot-sensitive trees and shrubs such as roses and photinia. Slow, deep watering has also been shown to improve tree vigor and suppress stress-related root rot and dieback diseases on a variety of trees and shrubs.

In both the nursery and landscape, schedule overhead irrigation for mid-day or between midnight and dawn to minimize the length of time the foliage remains wet. Avoid watering with overhead sprinklers in the early evening or during the mid-morning hours. To avoid over watering, daily rainfall must be accounted for when scheduling irrigation. Root rot diseases are much more common on some shallow rooted plants such as azalea and rhododendron grown in saturated or flooded soils and potting media. In order to reduce reintroduction of water-borne spores or disease agents, avoid using water from ponds fed by nursery run-off for irrigation unless a chlorination or similar filtration system has been installed.

Media and soil drainage often have a significant impact on the occurrence and severity of root and crown rot diseases on trees and shrubs. Potting medium should drain rapidly and have about 20 to

30 percent pore space. Avoid using fine materials in potting media, such as peat moss or clay, which may settle and slow percolation of water. In the landscape, root rots and some stress-related dieback diseases of trees and shrubs have been linked with poorly-drained, compacted clay or silty fill soils. To reduce the risk of flooding or standing water, soils high in clay or silt should be amended with sand and organic material, such as leaf compost or aged bark. If necessary, install dry stream beds or dry wells in areas where water tends to stand. Composted red oak or aged pine bark amendments have been shown to suppress several damaging root rot diseases, such as *Phytophthora* root rot, of shallow-rooted trees and shrubs. The addition of soil to potting media is not recommended unless it has been sterilized, fumigated, or solarized. Pre-plant fumigation or solarization may suppress but will not eradicate root rot fungi and root-feeding nematodes.

Soil Fertility may influence the development of some diseases. Prior to establishment of new landscape plantings or transplanting container stock, fertility and pH of the soil or potting medium must be adjusted according to the recommendations of a soil fertility assay and the needs of the trees and shrubs grown. Excessive nitrogen fertilization increases the salinity of soil or potting media. Often, roots exposed to high salt levels are damaged and may be predisposed to attack by root rot fungi. In a nursery, a salt meter or similar device should be used to adjust nitrogen fertility levels and avoid salt injury. High nitrogen fertility levels may also increase the severity of several damaging leaf spot and blight diseases of trees and shrubs. The soft, succulent tissues produced as a result of over-fertilization are more easily attacked by some fungi and bacteria than hardened, mature leaves, shoots, and roots. Excessive top growth may be avoided by applying a slow release or an organic fertilizer. Routine use of compost as a fertilizer source may also suppress the development of some root rot and nematode-incited diseases.

Sanitation plays an important role in the development and control of foliar and soilborne diseases in the nursery and landscape. Removal of all plant debris as well as dead or unsalable container stock from nursery propagation, production, and display areas is recommended. Take cuttings for propagation from healthy stock plants. Discard diseased liners. In landscapes, collect and discard fallen leaves from around the base of trees and shrubs, such as roses and photinia, previously damaged by leaf spot diseases. Also, prune out cankered limbs from trees and shrubs. Cutting knives and pruning shears must be cleaned after each cut with a surface disinfectant (alcohol, for example) in order to prevent the spread of certain diseases, such as fireblight.

Potting media components should be stored on raised and, if possible, covered concrete or asphalt pads. Pots and other containers should not be reused unless they are carefully cleaned and disinfected. Hoses and tools should be secured above the ground and routinely cleaned. Propagation benches should be cleaned with a surface disinfectant.

Chemical Control

Chemical control is an effective method of protecting valuable shrubs and trees from foliar and soilborne diseases. In the nursery, fungicides and bactericides are often used to insure crop quality, but can increase production and maintenance costs. In landscapes, the diseases of the majority of trees and shrubs are so sporadic and damage so inconspicuous that routine treatments are unnecessary. Environmental concerns may eventually limit the commercial and residential use of some fungicides and other pesticides. Generally, minor diseases should be controlled using the maintenance practices listed above while the use of fungicides and bactericides should be reserved for the control of diseases that adversely affect the esthetics, marketability, and/or health of specimen trees and shrubs.

Effective use of preventative fungicides and bactericides demands that nursery and landscape managers be familiar with the damaging diseases and the factors that influence (temperature and moisture) that influence their development. Also, identification of target diseases is also critical when choosing an effective fungicide or bactericide due to the specificity of these products against plant pathogens. Typically, preventative fungicide or bactericide treatments are most effective when combined with recommended management programs.

The majority of fungicides and bactericides kill plant pathogenic fungi and bacteria, respectively, on leaf or shoot surfaces before infection occurs; most are ineffective once host tissues are infected. Systemic fungicides, however, will penetrate host tissues and stop further growth of fungi; thereby suppressing further symptom development. Once such treatments have stopped, these fungi, given the right conditions, will initiate disease and typical symptoms may reappear. To control root rot diseases on container-grown nursery stock, fungicide applications must be scheduled from the time cuttings are rooted until finished plant material is shipped. In container nurseries, routine treatment of trees and shrubs, susceptible to *Phytophthora* root rot, such as azalea, camellia, juniper, and rhododendron, is strongly recommended. Distribution of the fungicide throughout the potting medium is critical for effective control of root rot diseases. Preferably, a root rot fungicide should be incorporated into the potting media prior to stepping up liners or container stock. Depending on which soil fungicide is used, follow-up soil drenches or foliar sprays should start 1 to 4 months later. If a root rot fungicide was not added to the potting media, begin soil drenches or foliar sprays immediately after liners or container stock have been transplanted. Formulations of all root rot fungicides are also cleared for use on field-grown nursery stock and in landscape plantings. Fungicides may be incorporated into the soil prior to planting or applied as a side-dress, broadcast, soil drench and foliar treatment to established plants. To get optimum distribution of the fungicide throughout the soil or media profile, apply drenches or granular products when the plants need to be watered.

Application timing is crucial for effective control of foliar diseases. Unfortunately, timely identification of the causal pathogen is difficult and often requires an extended period of time that precludes immediate decision making. The overlap between host vulnerability, weather patterns favorable for infection, and availability of pathogen inoculum for many diseases, such as petal blight of azalea, fireblight on crabapple, and spot anthracnose on flowering dogwood, is often fairly narrow. For other diseases including blackspot of roses and *Entomosporium* leaf spot of photinia, that overlap may extend over much of the growing season. For best results, preventative applications must be started just as the window for disease development opens and treatments continued at the interval specified on the product label until conditions are no longer favorable for infection by that pathogen. Uniform coverage of the target area is also a critical factor in obtaining effective disease control with foliar-applied fungicides and bactericides. Typically, foliar sprays must be applied until the leaves are wet or until run-off of the spray solution.

Plant material in production beds, display areas, and landscapes should be routinely inspected for symptoms of common diseases. If a disease is found, then take appropriate measures to prevent further disease spread. For effective curative disease control, apply the highest specified rate of a product at the shortest treatment interval. Once healthy new growth appears and conditions are unfavorable for further disease spread, curative treatments may be stopped. When a foliar disease becomes an annual problem, a preventative spray should be started at the appropriate time the next year. Finally, producers and managers should purchase reference books, and other materials as well as search the web for descriptions of damaging disease and nematode pests for the plants they maintain as well as additional information concerning recommended control practices.

Common Diseases and Their Management

Crown Gall: Crown gall, caused by the bacterium, *Agrobacterium tumefaciens*, is a common bacterial disease of many species of dicotyledonous plants. The disease can be quite severe on deciduous trees and woody ornamentals. Crown galls are formed on roots, crowns, stems, trunks, and lower branches of plants. Biological control of this disease by nonpathogenic strain of *Agrobacterium radiobacter* K84 is possible.

Other Bacterial Diseases: Other bacterial diseases, such as fire blight, *Pseudomonas* blight, shot hole, and soft rots, occur on several ornamental plant species. Copper compounds, used in conjunction with cultural practices and host resistance, manage the control of these bacterial diseases. *Botryosphaeria* spp. canker: Canker diseases are observed in periods of environmental stress (extreme cold or heat) when leaves wither and branch dieback is apparent. Cankers develop slowly over months or years when fungi invade the plant following injury (hail, mowers, insect feeding, etc.) or stress (exposure to chemicals, or pathogens). A canker is a dead area on the stem or trunk of a tree or shrub typically occurring on older branches, or injured plant areas on smaller twigs. Vascular tissue under 'the canker is dead. The term "canker" is a general one referring to a symptom on the plant but does not indicate cause. One common canker disease is *Botryosphaeria* spp. seen on a wide range of ornamental plants. If the canker itself goes unnoticed, the newest leaves are usually the first clue to a problem. As the canker girdles the stem, leaves begin to wilt, turn yellow, and then brown. Look for these on drought-stressed trees. Some young twigs may curl downward. Bark on younger twigs may lose color or blacken. When a canker girdles the stem, the twig dies from that point to the tip. If the stem is not girdled, it may show one-sided death, or some leaves are affected and others are green. *Botryosphaeria* cankers are usually cracked, dry, and discolored. Fruiting bodies of the fungus appear as pinhead-sized black specks embedded in the bark. Often, these fruiting bodies appear as small bumps covering the canker. *Botryosphaeria* and other canker fungi infect only stressed trees; therefore, canker fungi are known as stress pathogens. Because stress is the predisposing factor, the first step toward disease management is identifying the source of stress. Correct or modify the site, soil, or surrounding plants to make the conditions less conducive to cankers. This might involve diverting drainage away from the plant, pruning surrounding plants to allow better air flow, fertilizing the tree, providing water during drought conditions, etc.

Once a canker problem is noticed, you have the option of leaving the canker alone or trying to remove the affected area. If it is on the trunk, you may opt to leave it alone or remove as much of the decayed wood as possible so the tree can more readily callous over the injury. Prune out stem cankers where possible to avoid entry of wood rot fungi into the trunk.

Practices to control the canker problem.

- Buy healthy-looking vigorous plants adapted to your area
- Plant at proper depth, spacing plants on mature size
- Transplant to larger containers before stock is badly pot-bound
- Grow plants in well-drained, fertile soils with needed pH
- Water as appropriate to prevent plant stress
- Reduce heat buildup in containers
- Syringe foliage at mid-day to reduce foliage temperatures and minimize heat stress
- Discard poor quality plant material
- Employ proper pruning practices and clean shears after each cut

There are no fungicides specifically labeled for the control of 'Bot Canker'. It has been suggested that applications of thiophanate-methyl as 3336, Domain, OHP 6672 (REI 12 hr) at high rate as a heavy trunk/foliar spray at 2 to 4 week intervals in combination with recommended maintenance practices. Few chemical tools are available to manage viruses and bacteria and post harvest handling of diseases in general is often problematic.

Damping-Off: Damping-off is the rotting of seeds, and the same pathogens that cause damping-off may cause cutting rots. The fungi that are most often associated with these diseases belong to the genera *Pythium, Fusarium*, and *Rhizoctonia*. These fungi can cause damage of a wide range of plants in seedbeds, seedlings, and cuttings. *Fusarium* is an increasing problem on liropes. Fungicides can be applied to damping-off of seeds until seedlings grow and gain some resistance to the pathogens. On cuttings, the use of pasteurized rooting and growing media and pathogen-free containers may avoid the use of fungicides. Commercial formulations of *Trichoderma* sp. (an antagonist fungus) are available for biological control.

Phytophthora Root Rot and Dieback: Phytophthora root rot and dieback caused by *Phytophthora* spp., is a damaging disease of many evergreen and deciduous trees including birch, black gum, boxwood, buckeye, cherry, Chinese chestnut, cotoneaster, dogwood, eleagnus, elm, Frazier fir, holly, honeylocust, magnolia, maple, mountain laurel, oak, pine, sweet gum, sycamore, taxus, and willow. Disease outbreaks may occur at almost any time during the production cycle as well as in landscape plantings. Phytophthora root rot greatly reduces the volume of the roots. The roots on diseased plants are brittle and brown to reddish-brown. A network of fine, discolored feeder roots may be confined to one area or include the entire root system. Then, the causal fungi usually colonize the crown of the diseased plants, often girdling the stem at or just above the soil line. A brown to reddish-brown discoloration of the tissues occurs just below the bark and may extend up the stem above the soil line. On some trees brown, water-soaked cankers oozing a dark-colored fluid or gum may develop at the soil line.

Symptoms first appear on one plant and later on surrounding plants. Some yellowing of the foliage, particularly at the shoot tips, leaf shed, slowed plant growth, and possibly limb dieback may occur in early stages of the disease. However, it is not uncommon for liners or container-grown stock to remain almost symptom-less until after transplanting into larger containers or landscape beds. These symptoms can be confused with those of a nutritional disorder, over-watering, drought stress, and a number of other factors. Established landscape plants may show symptoms of general decline for one or more years before succumbing to root rot.

Phytophthora root rot is caused by several species of fungi in the genus *Phytophthora*: *P. cinnamomi, P. parasitica, P. citricola, P. cactorum,* and *P. cryptogea*. They are easily introduced into a nursery on anything from rooted cuttings to container stock, infested soil or potting media, diseased roots, crowns, and other crop debris. The resting structures are readily spread from pot to pot throughout propagation and container production areas by soil and water. The rate of disease development is closely tied to favorable soil moisture and temperature conditions for fungus activity. Changes in growing medias that affect soil water and fertilizer holding capacities can strongly impact disease incidence.

Heaviest losses to root rot in most container production nurseries usually occur on flat, poorly drained beds where water is allowed to stand around container bases. Container stock grown in compacted, poorly drained potting media with little pore space is most likely to suffer from root rot. Over-watering will also contribute to losses from the disease. Container production areas should be crowned to speed water runoff and to prevent ponding around the base of the containers. Covering the crowned beds with black plastic or similar material along with a thick layer of gravel or oyster shells will greatly reduce the spread of *Phytophthora*. The drainage system should be designed to prevent runoff water from flooding container areas.

Stress caused by over-watering or lack of water can lead to increased root rot disease. Block plants by container size and water needs to prevent over- or under-watering. Be careful not to over-water container-grown deciduous trees and shrubs during the winter and early spring, particularly in areas likely to get heavy winter rains. Also, take daily rainfall into account when scheduling irrigation. Since root-rot resistance may be broken by drought stress, container-, field-, and landscape-grown plants should be watered as needed during periods of dry weather. Phytophthora root rot fungi have been found in ponds receiving runoff from production beds. To reduce the chances of contamination of liner or container stock with root rot fungi, use either chlorinated, deep well, or quality surface water from a clean pond or stream. Ponds fed by runoff water from the nursery should not be used to irrigate liners or container plant material unless a chlorination-filtration or other sterilization system is installed.

Low soil pH (3.5 to 4.5) will suppress spore release, thereby reducing disease. However, *Phytophthora* spp. activity is not slowed at soil pH's most conducive to plant growth. Over-fertilization with nitrogen can greatly increase susceptibility. Soft, succulent tissues produced in response to excess nitrogen are readily colonized by root rot fungi. Prevention is the key to controlling Phytophthora root rot. Once symptoms start to appear, much of the damage has already been done. No single control measure will ensure protection; several approaches (proper establishment and production practices, disease resistance, and chemical control) must be directed at preventing the introduction and spread of these fungi and at preventing conditions favorable for disease development.

Outbreaks of Phytophthora root rot in many nurseries can often be traced to contaminated potting media or diseased liners. Remove all debris from propagation and production areas before setting out the next liner or container crop. Annually treat or paint benches, flats, and other wooden items in propagation areas with 2-percent copper naphthenate or similar surface disinfectant. Components for container potting media should be stored on concrete pads to reduce contamination, and virgin, non-sterile soil must not be added to "soil-less" potting medium. Sterilization or pasteurization of soil or potting media in permanent propagation beds between each cutting crop is strongly recommended. Avoid reusing cell packs or containers unless they are first rinsed with water and then soaked in a disinfectant such as bleach or formaldehyde to kill any disease-causing fungi.

Cuttings for propagation should be taken from only disease-free stock plants. Pruning shears or knives should be cleaned with rubbing alcohol or a similar surface disinfectant after finishing with each stock plant. Wash off all soil and plant debris with a stream of water before lining out any cuttings. Stick cuttings in well-drained, soil-less media, preferably in new pots or cell packs. Place trays containing the cuttings on raised benches, a porous concrete pad, a thick layer of gravel, or similar coarse material. Do not put cutting trays on bare ground or soil covered just with black plastic.

Chemical control is successful only when combined with good nursery management practices. Fungicides act as a protective barrier around the root systems of healthy plants but will not kill the root rot fungi in root tissues. Best results have been obtained by scheduling fungicide applications from the time cuttings have rooted until the finished plants are shipped. A few scattered applications of fungicides during the production cycle are likely to have little impact on the disease. Fungicide drenches or foliar sprays for root rot control on woody cuttings should be delayed until the new roots start to appear.

Downy Mildew: These diseases are caused by fungi such as *Peronospora, Bremia, Plasmopara* and *Basidiophora* and appear as white to purplish-gray "down" on leaf undersides when they sporulate. The list of plants affected by downy mildew includes rose, salvia, and *Buddleia.*

Powdery Mildew: The most common powdery mildew fungi infecting ornamentals and trees are members of the genera *Erysiphe*, *Microsphaera*, *Podosphaera,* and *Uncinula*. In most hosts, young tender tissues and water sprouts are most susceptible to infection. Fungicides are very effective in controlling this disease. Cultural practices can be used in an integrated manner against this disease. Downy mildews appear to either be increasing their host ranges or new strains may have been introduced. *Buddleia* spp. and roses appear to be impacted.

Botrytis Blight: Often called gray mold in ornamentals, the fungus *Botrytis cinerea* has the capacity to grow as a saprophyte on dead and dying plant tissues as well as a pathogen attacking flowers, leaves, stems, bulbs and seedlings (damping-off diseases). A fuzzy gray appearance occurs when the fungus forms conidia (spores) in the damaged tissue giving. Most flowering plants are susceptible to *Botrytis.*

Leaf Spots: Many ornamental plants are susceptible to one or more species of fungi that cause leaf spots or blight. Common fungi that cause leaf spots include *Alternaria*, *Septoria*, *Colletotrichum* (causal agent of anthracnose), *Cercospora*, *Entomosporium*, *Gloesporium*, *and Phomopsis* species. These fungi cause circular to irregular brown, yellow, reddish, or black spots or blights on leaves and sometime on stems and blossoms. Fungicides are available for the management of leaf spot, but cultural practices must be integrated for control.

Needle Blights and Needle Casts: Needle blights and needle casts are caused by a diverse group of ascomycetous fungi (and their conidial stages) that occur on conifer foliage, buds, and shoots. In nurseries, some of these diseases can be controlled with fungicides.

Rusts: Rusts are named for the dry, brown, reddish or yellowish spore masses or pustules that many basidiomycetes fungi (*Puccinia, Uromyces*) form, commonly on lower leaf surfaces. Host resistance needs to be used if available. Fungicides can prevent severe infections from most rust fungi.

*Viruses***:** Numerous virus and viruslike pathogens have been described affecting ornamental plants and many are spread by insects such as aphids, whiteflies and psyllids. Viruses are difficult to diagnose and cause a range of symptoms similar to many other pathogens.

Chemical Control of Diseases

Fungicides are widely used for the management of plant diseases on woody ornamentals in the Southeast. Scouting of fields for the presence of disease is generally undertaken. The diagnosis of disease by professionals or plant disease diagnostic clinics or both is used very often. Commonly used fungicides and bactericides are listed in Table 2. General timelines of disease occurrences are summarized in Table 3. Fungicides and bactericides are applied most commonly from March to November. The introduction of new plant species to the portfolio such as grasses present a management challenge to the industry until their disease and other pest profiles are manifested under a range of growing conditions.

Table 2.—Fungicide and bactericide active ingredients, formulations, reentry intervals, and diseases targeted.

Active ingredient	Formulation[a]	Reentry interval (hours)[a]	Disease targeted
Chlorothalonil	DF, EC, F, L, WDG, WSP	12-48	Needle cast, blight[b]
Chlorothalonil + fenarimol	F	NA	
Chlorothalonil + thiophanate-methyl	WDG	12	Powdery mildews[c], rusts (*Melampsora*)[b,c]
Copper sulfate pentahydrate	L	24	Crown gall[c]
Fosetyl-aluminum	WDG	12	Damping-off[b], *Phytophthora* root rots[b,c]
Mancoseb	DF, F, WP, WSB	24	Rust, pine gall[b]

Mefenoxam	G, MC, WSP	0	*Phytophthora* root rots[b,c]
Propamocarb hydrochloride	MC	12	Damping-off[b,c], *Phytophthora* root rots[b,c]
Propamocarb hydrochloride + chlorothalonil	L	48	*Phytophthora* root rots[b,c]
Propiconazole	EC	24	Leaf spots and flower blights[c,d], powdery mildews[c], rusts (*Melampsora*)[c]
Thiophanate-methyl	F, G, LF, WDG, WP, WSB	12	Leaf spots and blights[c,d]

[a]DF = dry flowable, EC = emulsifiable concentrate, F = flowable, G = granular, L = liquid, LF = liquid flowable, MC = miscible concentrate, NA = not applicable, WDG = water-dispersible granules, WP = wettable powder, WSP = water-soluble bag, WSP = water-soluble pack.

[b]Affecting conifers.

[c]Affecting ornamental and shade trees.

[d]Caused by species of *Ascochyta, Botrytis, Cercospora, Corynespora, Entomosporium, Phomopsis, Ramularia,* or *Septoria.*

TABLE 3.—Time of expected peak occurrence of diseases of woody ornamental and shade trees and ornamental conifers.

DISEASE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Crown gall[a]												
Damping-off and cutting rot												
Phytophthera root rot and dieback[a]												
Powdery mildew[b]												
Bacterial diseases												
Leaf spots[b] and anthracnose												
Needle cast and blight[a]												
Rusts[a]												

[a] May be present year round.
[b] Will peak with the weather.

Nematodes (Crow and Dunn 2009)

Nematodes are microscopic worms which require specialized laboratory procedures to separate them from soil or plant samples and to identify them. Important nematodes of nurseries include foliar (*Aphelenchoides* spp.) and soilborne such as root-knot (*Meloidogyne* spp.), lesion (*Pratylenchus* spp.), and stunt (*Tylenchorynchus* spp.) nematodes. Burrowing (*Radopholus* spp.) and reniform (*Rotylenchulus* spp.) nematodes can injure nursery crops and are subject to quarantine. Nematodes are spread easily in any manner by which infested soil or plant materials are moved within growing areas. Equipment, water, hands, shoes, clothing, transplants and seeds can help spread them. Even wind-borne dust sometimes carries nematodes. Nematodes often may be prevented by careful cultural practices and strict sanitation procedures. However, nematicides are often needed to control established infestations. Typical root symptoms of nematode attack are: root knots or root galls, root lesions, excessive root branching, injured root tips, stunted or abbreviated root systems, and rotting of roots, bulbs, and rhizomes.

Integrated Nematode Management. Plant injury and losses to nematodes are most effectively reduced by an integrated program of preventive measures, sanitation, and chemical nematicides. For greatest energy and financial efficiency, consider all practical management techniques to select the combination that best fits each growing situation. Sanitation and prevention of stock plant infestation are the best defenses against nematodes in nursery crops. Knowledge of visual symptoms and nematode testing services offer the means to monitor these situations during the life of a crop. If a nematode infestation develops despite preventive measures, appropriate nematicides often may be applied with a good prospect of success if the infestation is detected early.

Sanitation and Preventive Maintenance. Plant only in pest- and pathogen-free soils or planting mixtures; heat-treat or fumigate if necessary to assure that planting mix is clean. Disinfest all plant containers, bins, benches and other equipment with a surface disinfestant such as sodium hypochlorite (bleach). Keep plant containers, flats, and planting soil clean by proper storage and preparation (Table 3). Store clean containers, sand, peat, and other potting medium components or completed media on concrete slabs, in concrete bins, or in other surfaces or containers that prevent contamination by run-off water, casual soil contact, etc. Do not move soil, plant material, pots, flats or any other materials from areas known to be infested to uninfested areas. A color code can be used as an aid to restrict movement. Wash hands and disinfect tools frequently when working in planting stock. Do this especially when moving from one area to another. Clean heavy machinery before it is used to move clean medium or medium components. Use nematode-free propagating stock; this may often be obtained from unrooted cuttings that have never been in contact with soil or other source of infestation. Source plants of some species which have been infested may be treated with hot water (Table 4), thus enabling production of more propagating material above ground, but nematode eradication is never assured. Use raised benches if possible; do not allow hose nozzles or tools to touch the ground. Quarantine regulations of some markets, such as California, may specify the height of raised benches. Where maximum greenhouse sanitation is desired, reduce the level of wind-blown soil that enters the structure, especially in windy weather, by maintaining continuous vegetative cover such as mowed turf around them. Paved roadways running near the structures also help. The value of some crops, particularly plugs from tissue culture, may merit such precautions.

Biological Control: Although biological control of some pests, particularly insects and mites, is being advocated commercially for a few specific situations, practical biological control of plant parasitic nematodes has not yet been achieved. Extensive research on nematode biological control agents is under way in many places around the world.

Chemicals: Chlorfenapyr is the active ingredient in Pylon® (Olympic Horticultural Products), a miticide/nematicide labeled for use on greenhouse ornamentals. Chlorfenapyr is a foliar treatment that can be used to manage foliar (*Aphelenchoides* spp.) nematodes. This product is not for use on root-feeding nematodes.

Pre-Plant Fumigation. Soil Fumigation: There are several broad-spectrum soil fumigants that may be used to disinfest potting media and/or soil in field nurseries before planting. Of these methyl bromide is most effective. There are several broad-spectrum soil fumigants that may be used to disinfest potting media and/or soil in field nurseries before planting. Of these methyl bromide is most effective. Existing supplies of methyl bromide may still be used by nurseries in Florida if it can be obtained. Metam sodium (Vapam®, Busan®, Nemasol®, and several other trade names) is injected into soil as a liquid and turn into a gas following application. It is fairly effective against weeds and moderately effective against fungi and nematodes. Different formulations are labeled for use on both potting media and field soil. Dazonet (Basamid®) is incorporated with soil as a granular material, but releases gases as it breaks down in soil. It is fairly effective against weeds and moderately effective against fungi and nematodes. Basamid is labeled for use on both potting media (Table 1) and field soil. 1,3-Dichloropropene is mixed with chloropicrin in Telone® C-17 to get a broad-spectrum of activity. 1,3-Dichloropropene is fairly effective against nematodes and chloropicrin is fairly effective against fungi. Neither chemical has much activity against weeds. Telone® C-17 is labeled only for use on field soil.

Common Weeds and Their Management

Weeds are aesthetically objectionable or undesirable plants growing in the nursery or landscape that may compete with the ornamental plants for water, nutrients and sunlight. Some weeds can also produce allelopathic chemicals that stunt crop growth. Competition and allelopathic interactions can cause direct or indirect reductions in crop growth or quality. Weeds indirectly affect crops or landscapes by harboring arthropod pests and by serving as reservoir for plant pathogens. Many nursery practices, such as pruning and chemical application, are often hindered by the presence of weeds. Air movement may be slowed by a thick stand of weeds, subsequently leading to a higher incidence of foliar diseases or frost damage. Weed management is therefore important at the direct production site (within containers or in field sites) and in the landscape as well as in surrounding.

The first step in weed management is accurate identification of weeds. Weeds can generally be divided into two groups: broadleaf plants (dicotyledons) and grasses and sedges (monocotyledons). Within each group, the weeds can be further classified by when they germinate (winter vs summer) and grow (annuals vs perennials). The predominant weed species vary with the site (lawn, landscape, field or container nurseries) and also with differences of season, environment, or geographic location. Some common weeds are given in Table 4.

Table 4: Common weeds of ornamentals by site and season of primary occurrence.

Common name	Scientific name	Lawn	Landscape	Field	Container
Perennial weeds: Monocots					
Bermuda grass	*Cynodon dactylon*	X	X	X	
Bluegrass, annual	*Poa annua*	X	X		
Cogongrass	*Imperata cylindrica*	X			
Dayflower, Benghal	*Commelina benghalensis*		X	X	X
Johnsongrass	*Sorghum halepense*		X	X	
Kyllinga	*Kyllinga brevifolia*	X	X		
Nutsedge, purple	*Cyperus rotundus*	X	X	X	
Nutsedge, yellow	*Cyperus esculentus*	X	X	X	X
Torpedograss	*Panicum repens*	X	X	X	
Perennial weeds: Dicots and others					
Betony, Florida	*Stachys floridana*		X	X	
Bindweed, field	*Convolvulus arvensis*		X	X	
Brazilian pepper	*Schinus terebinthifolius*		X	X	
Buttonweed, Virginia	*Diodia virginiana*	X			
Chickweed, mouseear	*Cerastium vulgatum*	X	X	X	X
Dichondra	*Dichondra repens*	X			
Dogfennel	*Eupatorium capillifolium*		X	X	X
Greenbriar	*Smilax* spp.		X	X	
Groundsel, common	*Senecio vulgaris*		X	X	X
Groundsel tree	*Baccharis halimifolia*				X
Kudzu	*Pueraria montana* var. *lobata*			X	
Liverwort	*Marchantia polymorpha*				X
Mimosa	*Albizzia julibrissin*		X	X	
Morning-glory	*Ipomoea* spp.		X	X	
Poison ivy	*Toxicodendron aradicans*		X	X	
Rose, multiflora	*Rosa multiflora*			X	
Trumpetcreeper	*Campsis radicans*			X	
Warm season (summer) weeds: Monocots					
Crabgrass	*Digitaria* sp.	X	X	X	X
Dayflower, spreading	*Commelina diffusa*		X	X	X
Goosegrass	*Elusine indica*	X	X	X	X

COMMON NAME	SCIENTIFIC NAME	LAWN	LANDSCAPE	FIELD	CONTAINER
Sandspur	*Cenchrus* spp.	X	X		
Sedge, annual	*Cyperus compressus*	X	X	X	X
Sedge, globe	*Cyperus globulosus*	X	X	X	
Warm season (summer) weeds: Dicots					
Artillery weed	*Pilea microphylla*				X
Carpetweed	*Molluga verticillata*	X	X	X	
Dollarweed or pennywort	*Hydrocotyle* spp.	X	X	X	
Eclipta	*Eclipta* sp.				X
Eveningprimrose	*Oenothera* spp.		X	X	
Feverfew, Santa Maria	*Parthenium hysterophorus*		X	X	
Lambsquarters	*Chenopodium* spp.		X	X	
Lespedeza, common, or Japanese clover	*Lespedeza striata*	X	X		
Morning-glory	*Ipomoea* spp.		X	X	
Mulberry weed, hairy crabweed	*Fatoua villosa*		X		X
Nightshade, black	*Solanum nigrum*		X	X	
Phyllanthus, chamberbitter	*Phllanthus urinaria*		X	X	X
Phyllanthus, longstalked	*Phyllanthus tenellus*		X	X	X
Pigweed	*Amaranthus* spp.		X	X	
Purslane, common	*Portulaca oleracea*		X	X	X
Pusley, Florida	*Richardia scabra*	X			
Ragweed, common	*Ambrosia artemisiifolia*	X	X	X	
Spanish needles	*Bidens bipinnata*		X	X	
Spurge, garden	*Chamaesyce hirta,* syn. *Euphorbia hirta*		X	X	X
Spurge, hairy	*Chamaesyce hirta,* syn. *Euphorbia vermiculata*		X	X	X
Spurge, prostrate	*Chamaesyce hirta,* syn. *Euphorbia humistrata*	X	X	X	X
Spurge, spotted	*C. maculata,* syn. *E. maculata, E. supine*	X	X	X	X
Woodsorrel, yellow	*Oxalis stricta*	X	X	X	X

COMMON NAME	SCIENTIFIC NAME	LAWN	LANDSCAPE	FIELD	CONTAINER
Cool season (winter) weeds: Monocots					
Bluegrass, annual	*Poa annua*	X	X		X
Ryegrass, annual	*Lotium multiflorum*	X	X	X	X
Cool season (winter) weeds: Dicots					
Bittercress	*Cardamine* spp.		X		X
Burweed, lawn	*Soliva pterosperma*	X	X		
Carrot, wild	*Daucus carota*			X	
Chamberbitter	*Phyllanthus urinaria*		X		X
Chickweed, common	*Stellaria media*	X	X	X	X
Clover, white	*Trifolium repens*	X	X	X	
Cudweed	*Gnaphalium* spp.		X	X	X
Geranium, Carolina	*Geranium carolinianum*	X	X	X	
Mayweed chamomile	*Anthemis cotula*		X	X	
Henbit	*Lamium amplexicaule*	X	X		
Medic, black	*Medicago lapulina*	X	X		
Mustard	*Brassica* spp.				X
Pepperweed	*Lepidium* spp.		X		
Shepherdspurse	*Capsella bursa-pastoris*		X		X
Sowthistle	*Sonchus* spp.		X	X	X
Vetch, common	*Vicia sativa*		X	X	

Preventative measures are the most effective means of controlling weeds. Eliminating weeds or reducing weed populations in and around the nursery and landscape can be accomplished by using cultural, mechanical, or chemical means, or any combination of these. Biological control of weeds has not been used in nurseries because of the diversity of the weeds found in nurseries and landscapes and the specificity of biological weed controls.

Cultural Methods of Weed Control: Weed infestations can be effectively prevented or controlled using an integrated program of cultural and chemical methods. When properly used, cultural methods of weed control can sharply reduce the need for herbicides.

Mulches: Mulches provide an excellent means of keeping weed growth in check, primarily that of annual weeds. However, new mulch materials are direly needed by the industry for range of functions they may provide. The most widely used mulches are composed of organic substances or synthetic materials. Pine straw, wood chips or nuggets, straw, and leaves are examples of organic mulches. Organic mulches should be 2-4 in. deep (after settling) and may need to be replenished yearly. Organic mulches are selected on the basis of esthetics, longevity, availability, cost, susceptibility to being washed away during heavy rains, and texture. Pine straw, for example, is a widely available, inexpensive mulch that is not susceptible to being washed away. However, it needs to be replenished annually. Compost should not be used as mulch because its fine texture and moisture-holding capacity provide an excellent medium for the germination of weed seeds. Mulches are not generally used on the substrate surface of containers.

No herbicides are labeled for use under containers of container-grown ornamentals. Therefore, mulches, such as crushed rock, black plastic, or landscape fabric (also known as geotextiles or weed barriers), are commonly used under containers to control weeds in the area around containers. However, the roots of weeds and plants can root into landscape fabric.

Irrigation Management: Some weeds thrive in wet or consistently moist soils. Dollarweed and some nutsedges are examples of weeds that can thrive in moist soil, and liverworts grow well when the surfaces of container media are kept moist. Reducing the rate or changing the timing of supplemental irrigation facilitates the eradication or prevention of the appearance of these weeds. Use of recycled water often contributes to weed and disease problems in production.

Dense Plantings: Crop plants can keep weed growth in check when the planting is dense or containers are spaced closely together. The plants will out compete the weeds for light, water, and nutrients.

Weed-Free Liners, Transplants and Plants: Seeds, rhizomes, and root pieces of weeds can be introduced into nurseries and landscapes by infested liners, transplants and plants. Weeds should be removed from the root ball or liner substrate.

Mechanical Methods of Weed Control: Hoeing, mowing, and mechanical cultivation are options for weed control. Cultivation works well on small and annual weeds, but it is usually not effective on perennial weeds because they will often regrow from the roots even if the tops are removed. Also, cultivation brings new weed seeds to the soil surface, and these can germinate and produce successive flushes of weeds. Routine cultivation requires checking for emerging weeds every two to three weeks for control by cultivation. If preemergence herbicides have been applied and activated, they form a herbicide barrier that must be left undisturbed to be effective. Cultivation disrupts this barrier and lessens the effectiveness of the herbicide. Therefore, cultivation should be avoided if preemergence herbicides are used. Other drawbacks of cultivation are root pruning of plants' surface roots, increased soil erosion, and potenial for soil buildup around the collar of plants.

Regardless of the preventative measures utilized to control weeds, hand-weeding is sometimes necessary. Weeds should be removed before they flower and set seed and further aggravate the weed problem. Discarded weeds can be composted because properly prepared compost will kill the weeds as well as their seeds.

Chemical Methods of Weed Control: Most growers and landscape maintenance personnel use herbicides for weed control. In a 1991 survey of Florida nurseries, found 71% used postemergence herbicides, 56% used premergence herbicides, and almost half used both (Porcini et al. 1996). Another report showed that herbicides represented 18% of the chemicals used for pest control in U.S. nurseries and greenhouses (SRI International 1992). It is likely that herbicide use has increased over the intervening years. However, most growers continue to incorporate cultural and mechanical practices to minimize herbicide use and reduce herbicide costs. The criteria for selecting an herbicide are the weeds that are present or will be present, the crop plant, the site (outdoors, greenhouse, field, container, etc.), and environmental conditions. Weeds found in the vicinity of the growing area and those that have been a problem in the past, must be properly identified in order to select an appropriate herbicide. Weed seeds can remain viable for three to five years or more in the soil or even in an improperly maintained compost pile.

All label directions must be followed when applying an herbicide, including the wearing of protective clothing and the observance of precautionary statements. Herbicides should be applied when winds are calm to avoid drift onto desirable plants. Likewise, applications should be timed to avoid major rainfall or excess irrigation to minimize runoff and potential pollution.

Postemergence Herbicides for Use on Ornamentals: Postemergence herbicides are applied directly to weeds. Postemergence herbicides can be classified as systemic or contact. Systemic herbicides are absorbed and move through the plant system. These are useful for controlling perennial weeds. Contact herbicides kill only the portion of the plant that is actually contacted by the herbicide. Contact-type herbicides control small annual weeds but only burn-back perennial or large annual weeds. Postemergence herbicides may be selective or nonselective. Selective herbicides kill specific plants. For example, there are several selective, systemic, postemergence herbicides that kill grasses but leave broadleaf weeds (and nursery plants) unharmed. Nonselective postemergence herbicides have the potential to kill or injure any plant that it contacts. These herbicides are most effective when the weeds are small and actively growing. Good spray coverage is important. Effectiveness of these herbicides generally is reduced if the weeds are under stress. If perennial weeds are large, efficacy is improved with spot applications of a translocated herbicide in late summer or early fall. The herbicide should remain on the plant several hours to be effective. Therefore, applications should be timed to avoid rain or irrigation within the specified period that might wash off the herbicide. Although postemergence herbicides labeled for landscape or field production remain in the soil for a short time after application, they have no residual and little or no soil activity; therefore, multiple applications are needed for perennial weeds. Some postemergence herbicides can be applied over-the-top of ornamental plants.

Table 5: Postemergence herbicides recommended for over-the-top application of tolerant ornamental species (Norcini 1999).

Weed	Herbicide	For use in--			
		Nursery		Land-scape	Green-house
		Container	Field		
Annual grasses, some perennial grasses	Fenoxaprop-P-ethyl	X	X	X	
Annual grasses, horse-weed (marestail)	Asulam	X	X		
Many broadleaf weeds	Bentazone	X	X	X	
Many annual, some perennial grasses	Clethodim Fluazipop-P-butyl	X	X	X	X
Several broadleaf and grassy weeds	Oxyfluorfen	X	X		
Several sedges	Imazaquin			X	
Many annual, some perennial grasses	Sethoxydim	X	X	X	

Table 6.—Postemergence herbicides recommended for directed spray application (Norcini 1999).

Weed	Herbicide	For use in--			
		Nursery		Land-scape	Green-house
		Con-tainer	Field		
Many broadleaf weeds	Bentazon	X	X	X	
Young, actively growing annual weeds	Diquat	X	X	X	X
Many broadleaf weeds and grasses	Glufosinate-ammonium Glyphosate	X	X	X	X
Annual broadleaf and grass weeds less than 6 in. tall	Fatty acids	X	X	X	X

Preemergence Herbicides for Use in Ornamentals: Stamps et al. (2002) discussed preemergence herbicides for use in ornamentals as follows.

Preemergence herbicides, by definition, are herbicides that are applied prior to weed seed germination. Control of weeds using preemergence herbicides is most successful when the correct herbicide is applied in the correct manner to a weed-free growing medium prior to weed seed germination. In field…situations, the soil should be freshly tilled, with large clods of soil broken up. The growing medium, whether soil or soilless, should be settled and firm at the time of herbicide application.

Herbicides should be applied uniformly to the treated area and then immediately incorporated into the growing medium and activated. Incorporation can be done either manually or by using overhead irrigation. Mechanical incorporation involves mixing the herbicide into the top layer of the growing medium, generally to a depth of 1-3 inches [2.5-7.5 cm]. Incorporation is generally employed to reduce herbicide losses from volatility and photodecomposition, but it also serves to activate some herbicides. More commonly, incorporation/activation is done by applying water using overhead irrigation, often about 0.5 inch [1.2 cm], after the herbicide has been applied. Recommendations regarding the depth of mechanical incorporation and/or the amount of irrigation water to apply to activate/incorporate the herbicides should be followed carefully in order to minimize the possibility of crop injury. Uniform herbicide coverage is dependent on good application technique and, for mechanized application, on well-maintained and calibrated equipment.

Many of the preemergence herbicides used in ornamentals are formulated as granular [boldface omitted] materials and should be applied evenly over the treated area. Avoid applications to moist foliage or to whorled or other foliage types that will accumulate and trap granules on the foliage. Application equipment used to broadcast these formulations should not grind the granules or increase the amount of dust; as this may generate potentially dangerous conditions to nearby plants and people. Use of materials that have been screened of fine particles, if available, is recommended.

For liquid applications, spray pressure should be constant and adequate to maintain uniformity and ensure droplet penetration through the plant canopy, but not excessive, leading to drift and non-target damage. Spray volume should be sufficient for thorough coverage. Herbicides should be thoroughly mixed (agitated) in spray tanks to obtain uniform results, and spray nozzle openings (orifices) should be checked regularly and replaced when wear becomes evident. Spray adjuvants that enhance coverage, penetration and/or persistence of herbicides can be added to some spray mixtures, especially if the mixtures are applied so that the crop foliage is not treated. Spray solutions that contain any new adjuvant for phytotoxicity should be tested on a small part of the crop.

Irrigation applications [boldface omitted] (chemigation) are the least labor-intensive method to apply herbicides; however, few herbicides are labeled for application in this manner. [See TABLE 7] In addition, some types of irrigation systems (e.g., drip) do not apply water to all areas that need to be treated and/or do not have adequate uniformity for this use. Herbicide formulations applied through irrigation systems must not clog nozzle openings. Florida and other states have laws that require that safety equipment must be provided if chemicals are to be injected into irrigation systems. Check valves, vacuum breakers, low-pressure drains, shutoff valves, remote chemical storage tanks, and interconnected power supplies to injector and irrigation pumps are some of the precautions necessary to prevent contamination of the water supply.

Liquid herbicides should be measured volumetrically, i.e., using measuring cups, graduated cylinders, etc. Since dry pesticides vary in density, it is not possible to give accurate volumetric conversions across brands and formulations so those formulations should be weighed.

It is a good practice to keep records of all pesticide applications, even of nonrestricted use pesticide including EPA registration and product lot numbers. These records can be useful for planning future weed control measures. In addition, they can be invaluable if crop damage occurs.

Regardless of the herbicide or application method used, it is strongly recommended that the effects be evaluated against untreated controls under your particular conditions before treating large areas. This is especially important when there is a statement on the label permitting use of the product on an ornamental not specifically listed on the label. A limited area or number of plants should be treated followed by a waiting period of 2 to 3 weeks, or longer if the label recommends, for any phytotoxic effects to appear. The larger the area treated, the more likely that phytotoxicity may occur, especially due to volatilization. Also, damage may not occur the first time a herbicide is applied, but may show up with repeated applications. Several formulations of a herbicide may be available with varying concentrations; consequently, recommendations on the manufacturer's label should be followed explicitly. These herbicide formulations are labeled for application in certain environments (outdoors, in shadehouses and/or in greenhouses) and specific locations (containers, field and/or landscape) and can only be applied in those specified environments and locations.

Although most preemergence herbicides labeled for use in ornamentals have relatively low acute mammalian toxicities, they are potentially dangerous if handled improperly and, therefore, the safety precautions on the label(s) must be followed. Growers should read the entire label, including the small print, before buying or using the herbicide. Applicators must wear personal protective equipment (PPE) and comply with restricted entry intervals (REI) (see TABLE 7). The telephone number and address of the nearest County Poison Control Center should be listed in a convenient location in case of an accidental poisoning. Have clean copies of herbicide labels and material safety data sheets should be available to be taken to the Poison Control Center or hospital in the event of an emergency. If a herbicide is labeled for use specifically in a particular state for example, 24(c) Special Local Need labeling in Florida, the grower should obtain a copy of the supplemental label from your supplier when the product is purchased; otherwise, it will be used illegally.

Many of the herbicides listed in the following tables have low solubilities in water and are quite strongly held to binding sites in growing media and, therefore, are not readily leachable. However, the relatively long persistence (long degradation half-lives, $T_{½}$) of some of these products creates the potential for leaching losses to still occur with potential effects on ground water.

Herbicides should be stored in their original labeled containers, out of reach of children. All pesticides should be kept under lock and key. Empty containers [should be] rinsed with water at least three times with the rinsate poured into the spray tank. Empty containers [should be disposed of] promptly and safely according to local, state and federal disposal laws.

TABLE 7: Active ingredients and formulations of some preemergence herbicides labeled for ornamental crops (Stamps et al. 2002).

ACTIVE INGREDIENT	FORMULATION[a]	ACTIVE INGREDIENT	FORMULATION[a]
Alachlor	EC	Oxadiazon	G, WSP
Benefin + oryzalin	G	Oxadiazon + prodiamine	G
Bensulide	EC, G	Oxyfluorfen	EC

Dacthal	DF	Oxyfluorfen + oxydiazon	G
Dichlobenil	G	Oxyfluorfen + oryzalin	G
Dithiopyr	EC, WSP	Oxyfluorfen + pendamethalin	G
Imazaquin	DF, LC	Pendimethalin	EC, G, WDG
Isoxaben	DF	Prodiamine	FL, G, WDG
Metalochlor	EC	Pronamide	WP
Napropamide	DF, G	Simazine	DF, L, WDG
Napromamide + oxadiazon	G	Trifluralin	G
Norflurazon	WDG	Trifluralin + isoxaben	G
Oryzalin	AS		

[a] AS = aqueous suspension, DF = dry flowable, EC = emulsifiable concentrate, FL = flowable, G = granular, L = liquid , LC = liquid concentrate, WDG = WG = water-dispersible granules, WP = wettable powder, WSP = water-soluble pak.

Arthropod Pests

Woody landscape plants in the region are attacked by numerous arthropod pests, including spider mites, broad mites, scales, mealybugs, whiteflies, aphids, lace bugs, grasshoppers, sawflies, leafminers, gall makers, leaf feeding beetles, boring beetles and caterpillars, slugs, and snails (TABLE 8). Although destruction of plants by arthropod pests has been estimated at no more than 10-15%, any amount of pest damage on an ornamental plant can reduce Trees grown in larger containers or held for longer than usual periods of time due to economic conditions result in increased numbers of stressed plants. Moreover a number of exotic woodboring insects have become established in the U.S. As a result, attacks by woodboring pests that perform a natural role of decomposers or recyclers such as bark beetles and lepidopteran caterpillars increase. These insects are particularly difficult to control and few efficacious chemical agents are available (TABLE 9).

Mites: Three types of mites attack container and landscape plants: spider mites, false spider mites, and eriophyid mites. Spider mites are among the most common pests of ornamental nursery plants in the region. Spider mites are tiny, eight-legged pests that feed on plant cells by piercing the cells on the underside of leaves with two small chelicerae (needle-like mouthparts) and sucking up the cell contents. The damage appears as stippling on the upper surface of the leaves. Many species of spider mites produce webbing. Eriaphyid mites are microscopic, worm-like mites that have only four legs. They are often referred to as rust mites or gall mites because they cause the plants to form galls or russeting of the leaves. Many species of mites feed on ornamental trees.

The twospotted spider mite *Tetranychus urticae* Koch is considered the number one pest of ornamentals. Two other mite species the southern red mite *Oligonychus ilicis* (McGregor) and the spruce spider mite *O. ununguis* (Jacobi) are important pests of conifers. Other mite pests include the Lewis spider mite, *Eotetranychus lewisi* (McGregor), on poinsettia, broad mites, cyclamen and European red mites. Spider mites are often found on azalea, camellia, chrysanthemum, holly, ligustrum, pyracantha, and viburnum. The mites are found on the lower leaf surface where they puncture the plant tissue with their piercing mouthparts and suck the plant juices. Severe infestations cause leaves to abort and can result in the covering of leaves and even the entire plant by the silken webbing spun by this pest. The life cycle of mites under ideal conditions (at about 80°F or 27°C) requires between 7 and 10 days from egg to adult but can vary even more at other temperatures. Many overlapping generations of mites occur each year, and adult females can lay several hundred eggs during their lifetime. Damage from twospotted spider and spruce spider mites tends to be more severe during hot, dry weather, and the highest population levels are usually seen between April and May and between September and October. However, they may occur in high populations anytime during the year. Populations of southern red mites occur during the cool, wet conditions in fall-winter-spring with highest infestations occurring from January to April.

Monitoring for mites is essential for proper control. To detect spider mites and false spider mites, one must use a 10X (or higher) hand lens. Mites or evidence of mites (cast skins and webbing) can be found by looking on the underside of leaves. A white sheet of paper or enamel pan can be placed under branches and the branch struck with a blunt object to dislodge the mites. If mites are present they will appear to be little specks running around on the white paper or pan. Eriophyid mites are difficult to detect. When symptoms of eriophyid mites appear, they should be sent to a specialist for determination. Beneficial (predatory) mites can be found in association with spider mites, but their use in nursery production has not been adequately studied. Insecticidal soaps and horticultural oils are highly recommended because they have short reentry periods (e.g., 4 hr) and are relatively safe for the workers and environment. Many miticides are labeled for mites on ornamental trees. Most miticides do not kill the egg stage, so multiple applications are necessary (usually at 5 day intervals) to effectively control spider mites.

Armored and Soft Scales: Armored scales, soft scales, and mealybugs are the major types of scale insects, all of which secrete a protective waxy covering over their bodies. The waxy covering is directly attached to the body of soft scales. Other differences are: armored scales live and feed beneath the protected covering but are not attached to it. Soft scales excrete honeydew but armored scales do not. Susceptibility to insecticides varies by grouping. The only mobile stage for immature scales is the newly hatched crawler stage which settles after finding an appropriate feeding spot. Armored scales may complete their life cycle in 30-40 days, but some require a year. The most common scale insects include the armored scales - white peach scale, *Pseudaulacaspis pentagona* (Targioni Tozzetti); the false oleander scale (= magnolia white scale), *Pseudaulacaspis cockerelli* Sclater, the tea scale, *Fiorinia theae* Green, the gloomy scale, *Melanaspis tenebricosa* (Comstock) and cycad aulacaspis scale, *Aulacaspis yasumatsui* Takagi; and the soft scales - the brown soft scale, *Coccus hersperidium* L., the Florida wax scale, *Ceroplastes floridensis* Comstock; cottony cushion scale, *Icerya purchasi* Maskell; the European fruit lecanium, *Parthenolecanium corni* Bouche, the Fletcher scale, *P. fletcheri* (Cockerell); and the oak leucanium, *P. quercifex* (Fitch). Because control of scale insects becomes more difficult as they mature, the unprotected crawler stage should be targeted for control. Treatments during the dormant season with dormant oils are often used to manage persistent scale populations.

Mealybugs: Mealybugs are also small, soft-bodied insects covered with a thick layer of waxy dusts or threads. They complete their life cycle in about 30 days at 80°F (27°C), but it may take up to 8 or 10 weeks under cooler conditions. Most infestations occur during the spring and summer months. Host plants include ornamental grasses, sago palms, fruit trees, azalea and hollies. Unlike the armored and soft scale insects to which they are related, mealybugs are able to move around on the plant throughout their lives. Adults and immatures usually congregate together, and the waxy deposits that cover them protect them from insecticide applications. In addition to feeding on plant juices with their piercing-sucking mouthparts, soft scales and mealybugs damage the plants by excreting honeydew upon which the black sooty mold fungus grows. The most common nursery mealybug pest in the region is the striped mealybug, *Ferrisia virgata* (Cockerell).

In greenhouse production, the citrus mealybug, *Planococcus citri* (Risso), the longtailed mealybug, *Pseudococcus longispinus* (Targioni-Tozzetti), and the Madeira mealybug, *Phenacoccus madeiresis* Green, are important pests. The pink hibiscus mealybug, *Maconellicoccus hirsutus*, is an exotic pest now well established in the landscapes of Florida (2002), Louisiana (2006), and Texas (2007). A new infestation was detected in Georgia (2008) and the threat for the pink hibiscus mealybug to spread to other parts of the country remains high. The miscanthus mealybug, *Miscanthiococcus miscanthi* has become an important pest of Miscanthus ornamental grass varieties.

Aphids: Aphids infest most ornamental nursery plants and are commonly found on camellia, crape myrtle, gardenia, pittosporum, podocarpus, roses, milkweed, daylilies and oleander. Common aphid pests in ornamental nurseries and landscapes include the crape myrtle aphid, *Sarucallis kahawaluokalani* (Kirkaldy); the green peach aphid, *Myzus persicae* (Sulzer)*;* the cotton or melon aphid*, Aphis gossypi* (Glover)*;* and the spirea aphid, *Aphis spiraecola* Patch. These soft-bodied insects are frequently found in groups on stems or lower leaf surfaces, especially on young plant tissue. Most species usually either feed solely on meristomatic tissue or on leaves. Aphid feeding causes leaves to curl, flower distortion, and defoliation. In addition to direct feeding damage, aphids along with thrips, leafhoppers, membracids and whiteflies can vector plant diseases including phytoplasma, bacteria and viruses, and the sooty mold that grows on their excreted honeydew can reduce product quality. Aphids reproduce continuously through parthenogenesis and the highest aphid numbers are generally observed in spring and throughout the summer. However, the yellow rose aphid, *Acythrosiphon porosum* reaches its highest populations on roses during the winter and early spring in North Florida and South Georgia. Aphids and the sugar-laden honeydew they excrete are widely used as food by generalist beneficial insects and arguably should be tolerated and conserved whenever possible to help sustain natural enemies.

Whiteflies: Whiteflies frequently infest crape myrtle, gardenia, ligustrum, and viburnum. The citrus whitefly, *Dialeurodes citri*, and the sweetpotato whitefly, *Bemisia tabaci* (Gennadius), are the most common pests. Several new biotypes of the sweetpotato whitefly B (more commonly) known as the silverleaf whitefly, *Bemisia argentifolia* Bellows & Perring and Q have appeared apparently in response to insecticide use (imidacloprid) and have become problematic in protected as well as outdoor culture. *Trialeurodes vaporariorum* (Westwood) or the greenhouse whitefly is a major pest in protected culture. Many alternative host plants, such as privet, grow wild in the field adjacent to nurseries serve as reservoir hosts that produce extremely high adult populations of citrus whiteflies in spring and summer. The adult whiteflies then move into the nursery and can be found on any plant species as they search for their host plants. Growers are often unaware of this colonization phenomenon. Chemical control of sweetpotato whitefly is complicated by the pest's ability to develop resistance to many insecticides. While adult whiteflies have wings and are covered with a powdery wax, the immatures (nymphs) are flat, oval, and somewhat transparent, remaining on the underside of leaves. The whitefly life cycle lasts between 3 and 6 weeks, depending on the temperature. Eggs are deposited on the underside of leaves, and after 4 to 12 days, hatch into active nymphs called crawlers. The crawlers choose a feeding site, settle on the leaf, insert their mouthparts, and remain sedentary throughout the nymphal stage. During severe infestations, nymphs may cover the lower surfaces of leaves. After molting three times, the whitefly enters the pupal stage and matures to an adult in about 30 days. The life cycle for the silverleaf whitefly is as short as 21 days at 80°F, and there are overlapping generations of whiteflies in the region. While immature whiteflies are confined to the underside of leaves, the small, white adults can be found anywhere on the plant, scattering in short flights when disturbed. Like other plant-feeding insects with piercing-sucking mouthparts, whiteflies remove plant juices.

Leaves therefore become pale or spotted as a result of whitefly damage. Like aphids and soft scales, whiteflies excrete honeydew upon which black sooty mold grows.

Caterpillars: Some of the caterpillars that feed on ornamental plants in the region include armyworms, the azalea caterpillar, the fall webworm, the whitemarked tussock moth, the tent caterpillars, oak canaker worm, and the bagworms. Armyworms, *Spodoptera* spp., are active from summer until the fall with populations peaking from June through September. They prefer to feed on foliage and can chew large holes in the leaves of host plants. The host specific azalea caterpillar *Datana major* Grote & Robinson skeletonizes leaves when the caterpillars are young and completely destroys them when they are older. The larvae of the fall webworm *Hyphantria cunea* (Drury) feed on the leaf surface for 4 to 6 weeks after hatching from the egg. They construct webs between branches within which many caterpillars may be found feeding. Caterpillars of the whitemarked tussock moth *Orgyia leucostigma* (J.E. Smith) hatch in late spring and feed on shade trees. A second generation develops from late August to early September. Bagworms *Thyridopteryx ephemeraeformis* Haworth are general feeders. They use small pieces of twigs and leaf material to construct a bag, within which the caterpillar remains, and it protrudes its head out to feed on foliage. In some years the bagworms can completely skeletonize Leyland cypress trees. Larvae of the forest tent caterpillar *Malacosoma disstria* Hübner feed on many hardwood species in early spring and often cause severe damage at budbreak by destroying the newly developing buds. Several other miscellaneous lepidopteran species such as *Epismus tyrius;* the oriental fruit moth *Grapholita molesta* (Busck)*;* and the pyracantha leaf crumpler feed on the leaves of the terminals of maples, oaks, and pyracantha.

Leaf feeding beetles: Leaf beetles usually from the arthropod families Chrysomelidae. Curculionidae or Scarabaeidae and damage the foliage of many nursery and landscape plants. *Altica* spp. infests crape myrtle in June and July. Chrysomelidae. The redheaded flea beetle, *Systena frontalis* (F.), through adult feeding, damages *Ilex* spp., *Wiegelia* spp. and *Althea* spp. The strawberry root worm, *Paria fragariae* Wilcox, is becoming a major pest of azalea, Virginia sweetspire and Indian hawthorne in the Southeast. Little information on the biology of these species is available. Curculionidae. The Fuller rose beetle *Pantomorus cervinus* (Boheman), and whitefringed beetles *Graphognatha* spp. are general feeders during the summer months. Scarabaeidae. Japanese beetle, *Popillio japonica* Newman, and several species May (*Phyllophaga* spp.) and green June beetles, *Cotinis nitida* (L.) and miscellaneous “chafers” feed on the foliage of a wide range of ornamental plant species. Japanese beetle is restricted in range to the upper southeast at present. *Myllocerus undecimpustulatus undatus* Marshall is an exotic weevil introduced to Florida from India that is polyphagous and damages a number of landscape plants.

Borers: Many species of borers, both beetles (Cerambycidae, Buprestidae, Curculionidae) and moths (caterpillars) (Sesiidae), either burrow deep into the wood, enter just under the bark, feed in the plant's root crown, or remain on smaller twigs and shoot tips to feed. Most borers attack wounded or stressed trees. The black twig borer, *Xylosandrus compactus* (Eichhoff), is one example of a borer that attacks several tree species, particularly dogwood, redbud, and magnolia even when trees appear healthy. Dogwoods are also susceptible to the dogwood twig borer *Oberea tripunctata* Mulsant and flatheaded borers. Other Oberea spp. are also important pests. The introduced granulate ambrosia beetle, *Xylosandrus crassiusculus* (Motschulsky) attacks hardwoods such as oaks, Bradford pear, golden raintree, *Carya* spp., and *Prunus* spp. The red oak borer *Enaphalodes rufulus* (Haldeman) can infest weakened or damaged oaks, especially laurel and water oaks. Other borers seen occasionally include the flatheaded appletree borer *Chrysobothris femorata* (Olivier), the peachtree borer and related *Synanthedon* spp. Borer attack is more likely to occur when trees and plants are already weakened, such as by drought, soil compaction, mechanical wounds, or stress from transplanting. Borer management relies mainly on preventative, because once the insects are under the bark, they are difficult to control. However, these insects in aggregate manifest a continuum of behaviors relative to the quality of the host plants they may attack. Many are highly aggressicve and attack ostensibly “healthy” trees whereas other species are only able to establish successfully in weakened, dying or dead plant material. Systemic insecticides have been shown to have efficacy against some borers such as the Emerald Ash and the Asian longhorned borers in trees that are actively growing and whose tissue is intact enough to conduct the active ingredient throughout the tree bole. In addition, entomophagous nematodes have demonstrated efficacy against wood boring insects and have potential as biological controls.

Bark beetles usually attack trees in spring and early summer and may complete a generation in 35-40 days. Most of the borers require 6-12 months to complete a generation, and adult emergence occurs usually in spring or early summer. Few if any efficacious insecticides are available to suppress this group of pests.

The metallic woodboring beetles (Coleoptera: Buprestidae) and roundheaded borers (Cerambycidae) are unpredictable and often significant pests of woody plants. Adult beetles in the buprestid family often have bright metallic coloration on the wings and abdomen. Larvae are commonly called flatheaded borers, because one or several thoracic segments are generally enlarged giving the appearance of a flattened 'head' region. In contrast, larvae of roundheaded borers have a cylindrical profile. Therefore, the emergence holes of adult buprestids tend to be flattened (D-shaped), while the emergence holes of cerambycids are round (hence the name flatheaded and roundheaded borers).

Among the 15,000 species of buprestids worldwide (750 in North America), several are common problems in nursery and landscape plantings like the flat-headed appletree borer *Chrysobothris femorata* (Olivier), the Pacific flatheaded borer *Chrysobothris mati* (Hom), the two-lined chestnut borer *Agrilus bilineatus* (Weber), and the bronze birch borer *Agrilus anxius* (Gory). The cerambycids have an estimated 1000 species in the United States with several species that are problematic to ornamentals, like the red oak borer *Enaphalodes rufulus* (Haldeman), the white oak borer *Goes tigrinrus* (De Geer), the southern pine sawyer *Monochamus titillator* (Fabricius), and locust borer *Megacyllene robiniae* (Forster). The larval stage is generally the most damaging stage for buprestids and cerambycids due to tunneling and feeding activity beneath the bark of trunks, branches, roots, and occasionally within leaf tissue. However, it is the adult stage of species like the cerambycid twig girdler *Oncideres cingulata* (Say), and the cerambycid twig pruner *Elaphidionoides villosus* (F.) that damage plants.

Larval damage may be cryptic until the larva becomes large enough produce visible trunk injury. Both families have species capable of attacking healthy plants, but like other borer groups, many are opportunistic in taking advantage of weakened or dying trees. Plants undergoing transplanting stress can be particularly vulnerable to borers. A recent field survey determined that about 8.4% of production red maples had signs of buprestid damage within 2 years of transplanting. Containerized trees are equally vulnerable to buprestid attacks. Red maple is one of the top trees produced in the southeastern U.S. Larval damage from both borer families generally involves girdling of the vascular systems within the trunk with the cerambycids often tunneling deeper into the xylem. The frass of buprestids tends to be flattened and cake-like, while cerambycid larvae produce frass that is more fibrous or granular.

Several families in the order Lepidoptera have species with the wood-boring habit. Clearwing borers (Lepidoptera: Sesiidae) include a number of nursery-attacking species. Important examples include the dogwood borer *Synanthedon scitula* (Harris), peachtree and lesser peachtree borers, *Synanthedon exitiosa* (Say), *Synanthedon pictipes* (Grote & Robinson), the rhododendron borer *S.rhododendri* (Beutenmuller), the lilac borer *Podosesia syringae* (Harris), oak borer *Paranthrene* spp., and banded ash borer, *Podosesia aureocincta* (Purrington & Nielsen). In addition to the family Sesiidae, several other Lepidoptera families have species with wood-boring caterpillars that regularly attack commercial nursery plants. Examples in the family Tortricidae include maple tip moth *Proteotera aesculana* (Riley), the Nantucket pine tip moth *Rhyacionia frustrana* (Comstock), and other species in the genus *Rhyacionia*. Examples in the family Pyralidae include the root collar borer, *Euzophera ostricolorella* (Hulst), the American plum borer *Euzophera semifuneralis* (Walker), the magnolia borer, *E. magnolialis Capps* and *Dioryctria* spp. The c1earwing and pyralid borers tend to attack the main trunk of trees, while the tip moths bore shoots on the tips of trees. *E. magnolialis* is primarily a pest of magnolias in container nurseries.

Integrated Pest Management for Borers

1. Entomophagous nematodes sprayed on the trunk (clearwing borers).
2. Pruning / burning infested materials.
3. Larval borer removal (knife or wire hook).
4. Trunk wraps to reduce mechanical injury or cover potential oviposition sites. This method may-also predispose trees to trunk injury, which could make trees more susceptible to borers.
5. Reduce plant stress (proper watering, fertilization, not planting too deep, etc.).
6. Monitor activity with traps to improve pesticide application timing, reduce unnecessary treatments, and conserve beneficial insects.
7. Biological control of wood-borers is questionable. Most biological agents attack larval borers after trunk damage has already been initiated. Biological agents may reduce overall populations of borers, but will generally not prevent trunk damage already initiated by borers.

Lace Bug: Occasionally, lace bugs attack lantana - *Teleonemia scrupulosa* Stål, azalea - *Stephanitis pyriodes* (Scott), pyracantha - *Corythucha cydoniae* (Fitch), sycamore - *Corythucha ciliate* (Say), hawthorn - *C. cydoniae* (Fitch), oaks - *C. arcuata* (Say) and other plant species. Newly introduced species of ornamental grasses have reported lace bug pests. The lace bug, Leptodictya plana Heidemann, has been found in Georgia on Pennisetum ornamental grasses. Most lace bugs are specific to one or a few plant species. The insect feeds from the underside of the leaf and produces a whitish speckling on the upper leaf surface. Severe infestations on shrubs may result in leaf abortion, reduced growth, and death of the plant. Even during light infestations, feeding damage can produce unsightly marks on leaves. Lace bug eggs are deposited on the lower leaf surface. The life cycle from egg to adult is completed in about 30 days, and there are 3 to 5 generations each year. Lace bugs are attacked by egg parasitoids, are readily susceptible to insecticides and easily controlled.

Red Imported Fire Ant: *Solenopsis invicta* (Buren) is a direct pest in nurseries due to the impact of bites and stings on laborers, and nesting in equipment and outdoor electrical boxes, but it is more important as a quarantine pest. There is also a black imported fireant*, Solenopsis richteri* Forel, in north Mississippi and Alabama and a hybrid of the two species also occurs. A strict management protocol must be followed by any nursery that ships plants to destinations outside the fire ant quarantine area. The protocol requires scheduled inspections and treatment of all nursery property plus an insecticide treatment that is applied as an amendment to the growing media. Caribbean crazy ant, *Paratrechina pubens* Forel, an introduced ant species from the West Indies has become an important nuisance pest in Florida landscapes from the Keys to Jacksonville.

Thrips. Thrips in general are found commonly or flowers and besides their impact as a nuisance in cut flowers when taken indoors they are well known as important vectors of plant diseases such as tomato spotted wilt virus in greenhouses and in other crops. However, several invasive species have become important pests of ornamental plants and cause direct damage to leaves and other plant parts through feeding. Chilli thrips, *Scirtothrips dorsalis* Hood, is a polyphagous species feeding on plants from ~40 different families including roses, rhododendrons, camellia and pyracantha. The Cuban laurel thrips, Gynaikothrips ficorum (Marchal), is an important new pest of *Ficus* spp.

TABLE 8: The seasonal occurrence of arthropod pests of nursery-grown evergreen and shade trees in Horticultural Zone 8. (Light gray box = pest may be present; dark gray box = time when high populations may occur.)

PEST	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Twospotted spider mite												
Southern red mite												
Spruce spider mite												
Lace bugs												
Epismus tyrius												
Pyracantha leaf crumpler												
Bagworm												
Forest tent caterpillar												
Fall webworm												
Altica foliacea												
Whiteflies												
Whitefringed beetles												
Aphids												
Crape myrtle aphid												
Scales												
Striped mealybug												
Azalea leafminer												
Azalea lace bug												
Azalea caterpillar												
Red imported fire ant												
Peachtree borer												
Lesser peachtree borer												
Elm borer												
Magnolia borer												

Flatheaded appletree borer	
Maple callus borer	
Ash borer	
Dogwood borer	
Dogwood twig borer	

Table 9: Arthropod pests of landscape, nursery, and field-grown ornamentals, the registered insecticides and acaricides used to control them, and the reentry intervals (REI) in hours for these pesticides.

TARGET PEST	PESTICIDE (REI[a])
Aphids	Acetamiprid, azadirachtin (4), befenthrin, cyfluthrin (24), cypermethrin, fenpropathrin (24), imidacloprid, kinoprene (4), permethrin, pymetrozine, petroleum oil, *Beauveria bassiana*, *Paecilomyces flumosoroseus*, rotenone, insecticidal soaps (4)
Beetles	Rotenone, carbaryl, pyrethroids
Borers	Chlorpyrifos, permethrin, bifenthrin (Onyx, Onyx Pro)
Broad spectrum	Acephate (24), bendiocarb, carbaryl, chlorpyrifos, deltamethrin (24), diazinon, naled (24), dimethoate (48), disulfoton (24), lambda-cyhalothrin, malathion, trichlorfon (24), nicotine, pyrethrin + rotenone (4), pyrethrin + piperonyl butoxide (4)
Caterpillars	Cyfluthrin (24), cypermethrin, phosmet (24), cryolite, spinosad, tebufenozide (4), *Bacillus thuringiensis*, rotenone
Fire ants	Abamectin, bifenthrin, fenoxycarb, fipronil (24), hydramethylnon, pyriproxyfen, tefluthrin, indoxacarb (48)
Grubs	Chlorpyrifos, neonicotinoids, trichlorfon
Katydids	Cryolite
Leafminers	Cyromazine, pyriproxyfen
Lepidoptera	Tebufenozide, spinosad, dimilin (4)
Mealybugs	Acetamiprid, azadirachtin (4), fenpropathrin (24), pyridaben
Mites	Abamectin, azadirachtin (4), bifenthrin, bifenazate, dicofol, etoxazole, fenpropathrin (24), fenbutatin-oxide (48), fenproproxifen, hexythiazox, pyridaben, quioxaline (24), petroleum oil, *Paecilomyces, fumosoroseus*, insecticidal soaps (4)
Scales	Azadirachtin (4), fenoxycarb, kinoprene (4), permethrin, pyriproxyfen, imidacloprid, thiamethoxam, dinotefuran, acephate, malathion, dimethoate, insecticidal soaps, petroleum oil, *Paecilomyces fumosoroseus* (4)
Slugs, snails	Methiocarb (24)

Thrips	Abamectin, acephate (24), bifenthrin, carbaryl, cyfluthrin (24), imidacloprid, lambda-cyhalothrin, novaluron, permethrin, spinosad
Weevils	Phosmet (24)
Whiteflies	Acetamiprid, azadirachtin (4), bifenthrin, cyfluthrin (24), fenoxycarb, fenpropathrin (24), imidacloprid, kinoprene (4), pymetrozine, pyridaben, pyriproxyfen, quinoxaline (24), tebufenozide (4), *Beauveria bassiana, Paecilomyces fumosoroseus*

[a] REI is 12 hours unless otherwise noted.

Table 10: Insecticides and acaricides registered for use in landscape, nursery, greenhouse or field-grown ornamentals.

Common Name	Trade Names	Target Pests	Reentry Intervals (hrs)
Abamectin	Avid, Affirm, Abacide	Mites, fire ants	12
Acephate	Address, Ascend, Orthene	Broad spectrum	24
Acetamiprid	TriStar	Aphids, whiteflies, mealybugs	12
Acequinocyl	Shuttle O, Kanemite	Mites, insects	12
Azidiractin	NeemGuard, Ornazin, Bioneem, Azatin	Mites, scales, whiteflies, aphids, mealybugs	4
Bendiocarb	Dycarb, Turcam	Broad spectrum	12
Bifenazate	Floramite	Mites	12
Bifenthrin	Attain, Talstar, Onyx	Mites, aphids, whiteflies, fire ants	12
Bufprofezin	Talus	IGR, whiteflies, scale, mealbugs	12
Carbaryl	Sevin, Carbaryl	Broad spectrum	12
Chinomethionate	Joust	Mites (all stages) and whiteflies	24
Chlorfenapyr	Pylon	Mites, fungus gnats, foliar nematodes	12
Chlorpyrifos	Dursban, Duraguard	Borers, grubs, broad spectrum	12
Clofentezine	Ovation	Mites	12
Clothianidin	Celero 16WSG, Arena	Aphids, whiteflies, mealybugs	12
Clothianidin + bifenthrin	Aloft	Broad spectrum	12
Cryolite Clothianidin	Kryocide	Caterpillars, katydids	12
Cyfluthrin	Tempo, Decathalon	Aphids, caterpillars, whiteflies, beetles	24
Cyfluthrin + Imidacloprid	Discus	Broad spectrum	12
Cypermethrin	Ammo	Caterpillars, aphids	12
Cyromazine	Citation	Leafminers, fungus gnats	12
Deltamethrin	DeltaGard T&O	Broad spectrum	24
Diazinon	Diazinon, Knoxout	Broad spectrum	12
Dibrom	Naled	Broad spectrum	24
Dicofol	Kelthane	Mites	12
Dicrotofos	Bidren, Inject-A-Cide	Broad spectrum	48
Diflubenzuron	Adept, Dimilin	Whiteflies, fungus gnats, caterpillars	12
Dimethoate	Cygon, Dimethoate 400	Broad spectrum	48
Dinotefuran	Safari, Starkle	Whitefly, aphids, scales, leafminers	12
Disulfoton (thiodemeton)*	Di-Syston 15G (canceled 13 June 05)*	Broad spectrum	24*
Endosulfan	Thiodan, Phaser	Broad spectrum	48
Esfenvalerate	Asana XL	Broad spectrum (Xmas trees)	48
Etoxazole	Tetrasan	Mites	12
Fenbutatin oxide	Vendex, ProMite	Mites	48
Fenoxycarb	Award, Preclude, Logic, Precision	Fire ant bait, scales, whiteflies	12
Fipronil	TopChoice	Fire ants	24
Fenpropathrin	Tame	Mites, aphids, whiteflies	24
Fenproximate	Akari	Mites	12
Flonicamid 50 WG	Aria	Piercing-sucking insects	12
Fluvalinate	Mavrik, Aquaflow	Broad spectrum	12
Hydramethylnon	Amdro	Fire ant bait	12
Hexythiazox	Hexygon	Mite eggs only	12
Imidacloprid	Marathon, Merit, Provado, Imicide	Whiteflies, aphids	12
Imidacloprid + Bifenthrin	Allectus	Broad spectrum	12
Indoxacarb	Advion	Fire ants	
Iron phosphate	Sluggo	Slugs, snails	12
Kinoprene	Enstar II	Whiteflies, aphids, scales	4
Lambda-cyhalothrin	Scimitar	Broad spectrum	12
Malathion	Malathion	Broad spectrum	12
Milbemectin	Ultiflora	Mites	12
Metaldehyde	Deadline	Slugs, snails	12
Methidathion	Supracide	Broad spectrum	48
Methiocarb	Mesurol	Slugs, snails, thrips	24
Neem oil	Triact	Broad spectrum	12

Novaluron	Pedestal	Whiteflies, thrips, mealy bugs	12
Oxydemoton-methyl	Metasystox-R2	Broad spectrum	48
Permethrin	Astro, Ambush	Aphids, scales, borers	12
Phosmet	Imidan	Caterpillars, weevils	24
Pyridahl	Overture	Thrips, Lepidoptera	12
S-methoprene	Extinguish	Fireants	4
Tebufenpyrad	Pyranica	Mites	
Thiomethoxam	Flagship, Meridian	Broad spectrum	12
Trichlorfon	Dylox	Broad spectrum	24
Propylineglycol monolaurate	Acaritouch	Mites	12
Pymetrozine	Endeavor	Aphids, whiteflies	12
Pyridaben	Sanmite	Mites, whiteflies, mealybugs	12
Pyriproxyfen	Distance, Knack, Pyrigo	Whiteflies, leafminers, scales, fireants	12
Spinosad	SpinTor, Conserve, Justice, Entrust	Caterpillars, thrips, fireant	12
Spiromesifen	Judo, Forbid	Mites, whiteflies	12
Spirotetramat	Kontos	Mites, sucking insects, Xyl/Phl systemic	12
Tebufenozide	Confirm T&O	Whiteflies, caterpillars	4
Tefluthrin	Fireban	Fire ants	48
Alternative/biorationals			
Bacillus thuringiensis	Able, Dipel, Javelin, Steward, Ketch Xentari, M-Press, Agree, Attack	Caterpillars	12
B. israeli	Gnatrol	Fungus gnats	4
Crop Oil	Omni, Volck, Target	Scales, aphids, mites	12
Horticultural oil	SunSpray oil	Scales, aphids, mites, thrips	4
Beauveria bassiana fungus	Botanigard, Naturalis-O	Whiteflies, aphids	12
Nicotine	Tobacco dust, Nicotine .sulfate	Broad spectrum	12
PFR 97	*Paeciliomyces* sp. Fungus	Whiteflies, aphids, mites, scales	12
Pyrethrin + rotenone	Pyrellin	Broad spectrum	4
Pyrethrin + pipronyl butoxide	Pyrenone	Broad spectrum	4
Rotenone	Rotenone	Aphids, beetles, caterpillars	12
Soap, insecticidal	M-pede, Ringer, Murphy ,Safer	Mites, aphids, scales	4
Mustard oil+chili extract	Valorum	Repels sucking insects	4
Predacious Nematodes			
H. megidis	Nemacyst H	Grubs	4
S. carpocapsae	Millenium	Grubs	4
S. feltiae	Nemacyst	Grubs	4
H. riobravo	Biovector	Grubs	4
H. indica	Grubstake	Fungus gnats	4
S. feltiae	Nemacide	Grubs	4
Future Planned Registrations:			
Pyridalyl		Lepidoptera, Thrips	
Spiromesifen	Forbid, Oberon	Insects and mites	

Slugs and Snails

Snails **(**Dekle, G. W. and T. R. Fasulo. 2009): Snails belong to the class Gastropoda, and are related to the clams and oysters. They prefer an undisturbed habitat with adequate moisture and good food supply. The snail body is protected by a hard shell, usually marked with spirals. Most land snails are nocturnal, but following a rain may come out of their hiding places during the day. They move with a gliding motion by means of a long flat muscular organ called a foot. Mucus, constantly secreted by glands in the foot, facilitates movement and leaves a silverlike slimy trail. The brown garden snail (European brown snail) *Helix (Cyptoomphalus)aspersa* Müller was described by O.F. Müller in 1774 from specimens collected in Italy. This plant feeder has been disseminated into many parts of the world intentionally as a food delicacy, accidentally by the movement of plants, and by hobbyists who collect snails.

Hosts: *Buxus microphylla* 'Japonica' (California boxwood), *Crinum* sp., *Cupressus sempervirens* L. (Italian cypress), *Grevillea* sp., *Hibiscus* spp., and *Juniperus* spp., *Rosa* sp., and other unidentified plants and shrubs. Flowers: alyssum, antirrhinum, aster, balsam, carnation, candytuft, chrysanthemum, dianthus, dahlia, delphinium, hollyhock, larkspur, lilies, marguerite, mignonette, nasturtium, pansy, pentstemon, petunia, phlox, stock, sweet-pea, verbena, and zinnia. Trees: apple, apricot, citrus, peach, and plum. Shrubs: hibiscus, magnolia, and rose.

Economic Importance: Snails feeding on cultivated plants may become serious pests. In California, enormous populations sometimes become established in citrus groves and cause serious damage to leaves and fruit (Basinger 1931). They also cause economic damage to truck crops and ornamental plants. Large numbers of snails are a nuisance around a residence. Due to the brown garden snail, various states in the United States have quarantine restrictions concerning plant materials brought in from other states.

Management of the brown garden snail is a four-step process that involves pruning tree skirts; banding tree trunks with copper foil or a basic copper sulfate slurry; putting out poison bait to reduce their populations; and making releases of the predatory decollate snail *Rumina decollata* (UC/IPM 2000). Habitat reduction will aid in control. Remove anything snails may hide under: boards, bags, brush and debris. During the night, place a board on the ground near damaged plants. Elevate the board with four stones placed under the corners. The snails will take shelter under the board in the morning and can be removed and then destroyed then by dropping into a jar filled with water and a little rubbing alcohol. Some birds, especially ducks, will feed on these snails (Garofalo 2001). Barriers of diatomaceous earth, sand or ashes provide only temporary control. With a beer trap the goal is to trap and drown snails and slugs in a shallow dish with beer placed slightly below grade so that the lip of the dish is even with the soil. However, this does not provide reliable control (Bradley 1999).

Slugs (from Stange, L.A and J. E. Deisler. 2009) are not commonly seen or collected because they are active mostly at night and inconspicuous during the day. Notes on the color of the mucus secreted by the living slug are helpful in identification. Slugs are easily recognized by their soft, unsegmented bodies, dorsally covered completely or in part by a tough leathery skin, the mantle. The head has a pair of upper tentacles bearing eyes, and a pair of shorter, olfactory ones. Positive identification of species often depends on internal anatomy. Color is often used, but considerable variation can occur. Little slug damage has been reported in Florida, but elsewhere some of the introduced European slugs have caused great damage on many vegetable plants in urban and suburban gardens and in cellars where they may attack potatoes. They are also fond of mushrooms. They also cause concern for the unsightly slime trails on ornamentals. They may transmit plant pathogens. Little is known of their significance as intermediate hosts of disease parasites of animals. As a precaution, slugs should not be picked with bare hands. Introduced slugs may disturb the natural ecological balance in some areas, leading to the disappearance of native species.

Biology: Slugs are hermaphroditic, but often the sperm and ova in the gonads mature at different times (leading to male and female phases). Slugs commonly cross fertilize and may have elaborate courtship dances. They lay gelatinous eggs in clusters that usually average 20 to 30 on the soil in concealed and moist locations. As soon as they hatch, young slugs (often lighter in color than adults) are active, crawl and feed if the temperature and humidity conditions are right. It is often several days before any plant injury becomes apparent, because they merely rasp away surface tissues. Slugs, especially young and hungry ones, can lower themselves from plants by mucus threads that may extend several feet.

Management: Natural enemies are relatively few. Some birds, especially ducks, feed on slugs. Predator snails such as *Euglandina rosea* (Férussac) attack slugs. Few predaceous insects attack slugs, but the larvae of Lampyridae and adult Carabidae (Coleoptera) do so occasionally. There are some dipterous parasites (especially Sciomyzidae). A few fungous diseases are known. Adverse climatic conditions (e.g., dry, hot weather or excessive rains) serve to lessen depredations but do not appear to be of great significance. The rather poor slug fauna of Florida may be due to historic factors or perhaps to some natural factor as soil types. Clean surroundings will aid in controlling slug populations, and removal of boards, sacks, piles of brush, and other debris will limit slug numbers. When chemical control is indicated, the use of baits is recommended in commercial greenhouses. Methiocarb and Metaldehyde are the only effective labeled molluscacides.

Needs: There are a number of destructive exotic mollusk species that are potential invaders to the U.S. that should be prevented from entry and establishment. Preparation such as identification and survey methods for their management when and if they become established should be conducted.

Vertebrates

There are a few basic principles to consider when dealing with vertebrate pests. The first is to recognize the difference between an animal's habitat and its habits. The area that provides an animal with all of its basic survival needs (such as food, water, shelter, and space) is known as habitat. Habit refers to the behavior of an individual animal or species. The second principle to consider is that there are many management options which fall into two basic categories: lethal and non-lethal.

Lethal methods: Toxic baits were once based on pure grains such as wheat, bran, and oats which are preferred foods of common animal pests. Modem baits are often a mixture of grains formed into pellets. Because these baits are less attractive than pure grain baits, they must be presented in their freshest form. Do not use baits that are old, moldy, wet, or in any other state of decay. Before purchasing toxic baits, it is important to read the label as they often carry restrictions on use, placement, and intended species. Toxic baits can cause accidental or secondary poisoning. Accidental poisonings result when small children, family pets, or other non-target animals consume the bait and become ill. Secondary poisoning may result when a predator eats a pest that has been poisoned.

Trapping may be the best alternative for moles, pocket gophers, mice and rats (lethal method). Trapping confirms the identity of the damage-causing pest and helps pinpoint the source of future problems. The biggest benefit is that there is no chance of accidental or secondary poisoning. However, non-target species can sometimes be trapped. The key to effective trapping is sufficient practice.

Though shooting an animal pest may provide emotional satisfaction, it is generally a poor choice. In many residential areas, shooting is illegal and dangerous. Even in rural areas, the amount of time it takes to hunt down the pest may make it impractical.

Non-lethal methods: Non-lethal methods include exclusion, repellents, frightening devices, live trapping, and aversive measures. One of the most effective and long-lasting non-lethal methods is exclusion--putting up fencing, screening, netting, or any other material that acts as a physical barrier. The goal is not only to deny the pest admittance to the production area, but to redirect the animal and change its behavior. Technology has produced a number of new materials for exclusion protection including high tensile material for permanent fences and portable electric fences for pests on the move. Some growers have had success with underground materials for fossorial species such as moles, pocket gophers, and ground squirrels. For some pests, particularly birds, exclusion is the only legal option. Other forms of exclusion include low-powered electrical shock and ultrasonic devices. Probably one of the most popular non-lethal forms of pest management is repellent use. Repellents discourage animals by taste, smell, or visibility. Repellents are often short lived, especially in wet weather and can be easily washed away by rain or irrigation. They often require multiple applications, and may not work for your particular pest. However, repellents are easy to use, and can be an important aspect of a non-lethal pest management strategy.

There is a wide variety of scare devices available from nurseries, garden centers, catalogs, and the internet. Animals can become accustomed to the loud sounds, flashing lights, fake snakes, and most other devices. Rotating the devices to different parts of the garden may increase the effectiveness. Scare devices generally do not work alone, but may be used in combination with other methods.

Pest identification: The first step in a pest animal control strategy is to determine what type of pest you have. Is its habit below ground, above ground, above and below ground, or is it a flyer? Below ground pests include moles and pocket gophers. Above and below ground pests include woodchucks, ground squirrels, chipmunks, rabbits, and voles.

Rabbit damage can be easily confused with deer damage. Rabbits feed near ground level on small shrubs, small woody trees, turf, vegetables, and some flowers. There is a variety of methods available to control rabbit feeding. Since they are not good climbers, a short fence of about 3 feet made of a 2 or 3 inch woven mesh is adequate. There are also commercially available repellents on the market. The most common active ingredient is thiram, which is intended to reduce gnawing of trunks and limbs. To use a live trap, first identify the route that the rabbit uses most often. Bait the trap with lettuce, carrots, or beet tops. If the trap is based at the rabbit's entrance to the garden, bait may be unnecessary. Growers have tried many scare devices: metallic flashing, rattles, noisemakers, and scarecrows. It is possible to make rabbits voluntarily relocate. Because rabbits need protective cover for escape routes, consider the removal of brambles and other dense, woody vegetation. In combination with fencing this is effective and non-lethal.

Birds and bats make up the flyer category of vertebrate pests. Sapsuckers are important emerging pests of large trees in both the nursery and landscape in Texas. A few strategies for controlling birds include the use of bird netting, landing inhibitors such as steel spikes, ultrasonic bird repellent devices, or scare devices such as Irri-Tape. Bats are really not problem animals. Most of them feed on insects during nightly flights. Some gardeners use bat houses to attract bats. However, wasps are fond of nesting in bat houses. Netting the plants will provide protection from bats.

Above ground pests include tree squirrels, rats, mice, raccoons, skunks, opossums, feral hogs and deer. The best deterrent to skunks in the garden is exclusion and prevention. Remove pet food from outside areas at night. Do not add food scraps to the compost pile. Surround your production area with a 2 foot high wire mesh or picket fence, and screen all openings beneath your house and outbuildings. Trapping skunks can be dangerous as they are a primary source of rabies. If pets are sprayed, neutralize the smell with a wash of diluted vinegar or tomato juice.

Opossums are the only marsupial native to North America. To deter them keep trash picked up and garbage cans sealed. A short four foot fence of chicken wire with the top foot to foot and a halfbent outward should keep opossums out. Use live traps baited with bread and jelly.

Deer are adaptable animals, often found in areas that would be considered unlikely for such a large species. As urban communities move further into rural landscapes, deer damage becomes an increasing occurrence. Deer are ruminants with four-chambered stomachs. One deer eats six to eight pounds of plant material each day. Because of their complex digestive system, deer can and will eat anything including pebbles and twigs!

Control strategies for deer are more complicated than those of smaller animals. Large scale exclusion, repellents, and scare devices are all viable control options. Deer have a volmolfactory gland which allows them to not only smell and taste, but actually perform a combination of the two. Therefore, repellent products must deter based on taste and scent. Control strategies for feral hogs include baited traps and humane disposal through hunting.

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Identified Overarching Priorities For
Nursery-Landscape Production Developed In the Planning Meeting, 4-6 Nov. 2009

Production Priorities
Research:
- Quality and quantity of water
- Recycling water, nutrient management, EC tolerance of various crops, herbicides and pesticides in runoff
- Pest management, impact of agriculture chemicals;
- Water application technology, (i.e., overhead, drip, etc.), use rate, leaching
- Cultural management practices relative to plant production and pest management
- Sustainable production practices, container design and substrate decisions
- Substrate selection and recycling
- Plant stress
- Crop selection and implication of pest management and sustainability
- Consumer preference, landscape architects
- Economic impact of BMPs

Extension:
- BMPs
- Landscape architects training
- Dissemination of information , content and media
- Recycling of nursery materials, pots and other plastic planting materials
- Training programs for pest management
- Consumer education regarding sustainability
- Product efficacy and safety trials
- Chemical issues
- Training on production nutrient issues and impacts

Regulatory:
- Research based water use legislation/BMP
- Runoff standards
- Economic impact of regulatory issues
- A real-time mechanism for producer feedbacks to regulatory agencies
- Regulatory conflicts with BMPs

Disease Priorities
Research:
- Host plant resistance
- Detection, prediction, and identification
- Biorational nematicides
- Compatibility of bio-rational products with other chemicals
- Alternative suppression practices
- Soil and water borne diseases
- Biological controls

- Management of viruses
- Emerging pathogens detection and management, i.e., *Colletrichium* spp., *Xylella fastidiosa, Nectria* spp.

Extension:

- Real-time dissemination of information
- Nematode control for liners
- Resistance management
- Application technology and tools

Regulatory:

- New registrations for new disease
- New diagnostic technologies
- Shipping and quarantine issues

Weed Science Priorities

Research:

- Alternative management tools
- MSMA replacement
- Postemergence management options after preemergence failure
- Species with data gaps, i.e., liver wort, Cogongrass
- Sustainable mulches
- Economic analyses of technology used throughout the crop production, retail, and landscape
- Weed control in liner production and greenhouse crops
- Survey and risk assessment of area-wide emerging weeds
- Herbicide resistance management
- BMP related issues
- Ecological analyses
- Prediction tools
- Essential oils as alternative controls

Extension:

- BMPs in weed management
- Worker safety
- "Green" as a marketing tool
- Bilingual training materials
- Regional web site for weed identification, efficacy, and compatibility with crop
- Demonstration of herbicide efficacy

Regulatory:

- Data-based products and regulations
- Invasive species strategies and territory

Arthropod Priorities

Research:

- Prediction tools
- Ecological interactions and exploitation

- Alternative controls, e.g. trap crops, banker plants
- Biological controls, natural enemies
- Emerging pests biology and suppression technologies, ex. Strawberry rootworm
- Plant stress –pest interactions
- Host plant resistance
- Insect-vectored diseases
- Non-target impacts and compatibilities of chemical tools

Extension:

- Landscape architect training
- Dissemination of old and new information
- Targeted audience outreach
- Sustainable landscaping and nursery design
- Application techniques, e.g, calibration, mixing, pH…..
- “Green” labeling

Regulatory:

- Shipping and quarantine issues
- BMPs
- Water quality and pesticide related issues
- Conflicts of IPM with regulations
- Streamline biological products registration

List of issues that were raised and discussed in the individual sessions of the planning meeting. Overarching priorities were extracted from this list in a separate discussion session.

Production

Research

- Variety of production practices makes generalizations difficult
- Overreliance on pesticides – non-chemical alternatives need to be cheap
- Sustainable technologies are attractive but must be cost effective
- Reduce pesticide use through calibration
- Use biological control early in production cycles, e.g. trees??
- Physiological effects of tissue culture post-transplant.
- Salinity requirements are needed for a broad range of ornamental crops, especially in pot in pot systems, *Kousa* dogwood is an example.
- Need for a prediction models for forecasting consumer demand was brought up.
- Regarding plant specs, is there a way to influence what landscapers want. All trees and shrubs typically grown in a landscape nursery are very homogenous.
- Niche plants that have more character and not dictated by the market and landscape
- What do growers want in plant selection? Looks and easy to grow
- Lower production costs, anything to do with labor saving – mechanization (easy for greenhouse production).
- Better nutrient management. What is the actual rate of fertilizer needed for a given plant? Improving nutrient uptake efficiency, Effects of climate on fertilizer regimes, Relationship with fertilizer use and pest incidence, e.g. aphids like high N
- Work needs to be done on mycorrhizal fungi (or microfauna) and how they impact plant physiology in containerized and field grown plants. May also prove to be beneficial in alternative substrates where nutrient availability may be limiting factor. Mycorrizal/growing media and other approaches to increasing N uptake efficiency.
- Water quantity and quality, ex. using BMPs; Water quantity and quality, efficient irrigation systems .Underground water quality – P content/concentration – Use of reclaimed water for landscape and nursery irrigation, high salts in recycled water, Group planting blocks according to water need, Overhead vs drip (what effect on insects and diseases?)
- Containers – fiber pots/ biodegradable pots, These pots are more feasible for smaller plants such as bedding plants, Large pots break down too soon, Recycle pots, Pot-in-pot system – more efficient system – conserve water and nutrients What about field container production? In order to get things done easier and fast. Squat pots- why does the industry use pots that are taller than wide. Plant roots want to grow outward much of the bottom is 'wasted space'. Squat pots may provide a better situation for root development and are less prone to wind-throw.
- Pest issues that cannot be controlled adequately with pesticides, Scale on magnolia? Enhanced by mosquito control killing parasitic wasps.
- Exposure to pesticides
- IPM/scouting
- Biological control.
- Consumer education about non-zero pest tolerance
- Public education good 'Green' bugs versus bad bugs

- Cultural controls
- Pesticides, adjuvants (stickers/spreaders)
- Sanitation, start clean
- Demand for 'over the top' herbicides. Timing of herbicides with rainfall (improved formulation to extend residual activity under wet conditions)
- Carbon credits/carbon utilization/carbon footprint?
- What about pruning? Use of PGR to save pruning?
- Algae, worker safety

Extension

- Containers – recycle pots at county level
- BMPS

Regulatory

- Better process for plant certification for interstate shipping
- BMPS
- Cost to growers of water regulations
- Lack of recycle options for current potting materials – new materials
- Water management: municipalities and water boards need to communicate with green industry, decide how much water is needed and what the actual cost of irrigation water.

Diseases Priorities

Research

- Viruses in *Canna*, *Hosta* viruses?
- *Thelaviopsis* in TN. Difficult to control, susceptibility information is critical for control/ reduction.
- Many diseases are undetected
- Common theme in pathology is water *management (P. ramorum* used as example.)
- *Rhizoctonia, Pythium, Phomopsis* are all common.
- Stress cankers are important, often caused by drought
- Rusts can be a problem on hawthorn berries
- No field diagnostics
- Post-harvest issues
- Disease without enough tools (virus, bacteria; *Fusarium*)
- Downy mildew spreading to new hosts
- Leaf spot on *Itea*
- Media types and root rots
- Resolving issues related to environmental conditions that cannot be controlled
- Overcycling plants have issues related to media
- Dieback and canker are major problems
- Pot design or additive (bottom layer) and media that improve drainage
- Water management with regard to disease management
- Holes in tools for disease management a more holistic program integrating chemical and biological control
- Tank mixes? What combinations and rotations are best, addressing resistance issues
- Emerging pests- *Exobasidium* on native plants, azaleas, blueberries
- As more natives are being produced what will need to be addressed

- Root stock superior forms and for resistance in ornamentals, example of gardenias root stock for nematode control
- Lethal yellowing – regulations regarding transport
- Disease issues related to water recycling, recycled pond water treatment or filtration research to prevent disease-
- Computer models to predict disease- Time release stickers so when have heavy rainfall event
- Early warnings or environmental cues that predict disease
- Weather stations that send out alerts for preventive controls
- Plant signals that indicate disease pheromones
- Ecological indicators that predict disease, example of stinkhorns indicating disease
- ET controllers
- Multifunction slow release materials
- Testing plants as "cleaning" regarding carbon capture
- Continued plant breeding for resistance with pest-prone groups
- Container-grown plants, different ways to change the container to minimize diseases
- Water recycling treatment and filtering for disease management
- Phenological indicators by zone and plant stressors that induce diseases
- Developing holistic programs that combine traditional chemistry and biological
- Tools to provide a scan of existing soil and identify pathogens present
- If charts could be organized for timing of activity by zone it would be helpful across disciplines
- *Fusarium* management major problem, example was on *Liriope* spread by division
- Disease control practices
- Lack of bactericides and viruscide; fire blight in production and landscape;
- Root rots from use recycle water; *Phytophthora rumorum* (sudden oak death; regulatory);
- Substrate using less leaching fraction/fertilization; a complete list of plants host or susceptible of SOD; disease transmission from insect damage;
- Daylily rust---screening susceptible cultivars; rust affecting grass species, which is shipped around as biofuel stocks
- Propagation is the place of sanitation, critical for the rest of production
- Powdery mildew on oaks and holly
- Identification of (anthracnose?) on *Itea virginica; Colletotrichum*
- *Cercospora/Cornespora* (worse than *Cercospora*); associated with wet period/root saturation;
- Search for "soft" chemicals (essential oil, etc.), compost tea
- Summer/late June—August (maybe September): heat and humidity, fast release of slow release fertilizers, *Phytophthora* and so forth; weather association with disease pressure; looking for alternative fertilizers with different release curve to deal with the summer heat
- Downy mildew -larger host range (coleus, buddleia, etc.)
- Knockout rose problems
- Postharvest issue -PGR research for compact plants for shipping; reduce stem breakage due to excessive growth
- *Fusarium* - few fungicide tools
- Disease control -limited or delayed identification and thus treatment

- New substrates -how that impact root diseases
- *Disease resistance in Cercospora*

Extension:

- Dissemination of information on diseases to increase familiarity
- Current production practices
- On-line source for multi-institutional disease information (keep it simple)
- Possibly link to SPDN website.
- Regional information for diseases for growers, might be good to disseminate through social media (twitter, blogs, email, etc.) Confidentiality would be important.
- Provide growers websites and useful on-line tools.
- IPM pipeline for tying together all aspects of pest management.
- Prediction models for disease development
- Pest alerts
- Expand existing framework already in place, Syngenta has program set up for turf that might be modified for ornamentals.
- How irrigation affects disease incidence (match irrigation with plant water requirements);
- Links between cultural and preventive practices predisposing plants to disease
- Chemical resistance
- Black spot on roses
- Resistant dogwood
- Powdery mildew chemical resistance
- Developing resistant varieties is not terribly difficult, but consumer acceptance of them poses a greater challenge.
- What crops could benefit from resistance
- Photinia
- Indian hawthorn (*Entomosporium*)
- What can be done in a residential landscape.
- There are very few nematicides labeled by landscape. there are several biological compounds being evaluated (Nemacur) evaluation of these biocides in the nursery and landscape would be useful.
- Hot water bath treatment for foliar nematodes.
- *Xylella fastidiosa* biological control available?
- eXtension - national posting board for asking questions related to ornamentals.
- Would phrenology gardens benefit disease prediction
- Irrigation as a source of infection? Fertilizer reclamation to reduce nutrient availability
- Chlorinating irrigation equipment. Treatment of recycled water should be a priority
- Identifying asymptomatic plants.
- Regulatory issues
- *P. ramorum* issues
- *Nectria* on maples

Weeds Priorities

Research

- Lower sales leads to less labor, less pesticide expenses which results in more weeds
- Weed species distribution and ultimate range

- Source of weeds: pine bark, media, delimiting survey
- Resistance to rotation, economy leads to cost cutting in weed control which leads to unclean stock being shipped, growers avoid restricted use pesticides to avoid government hassles
- Cost/benefit analysis goes on constantly
- Hand weeding "just in time" can cause problems if it sits at retailer any period, incomplete hand weeding results in multiple labor efforts as plant goes through producer to end user
- Pre-emergence herbicides (REI) reapplication vs. major rainfall events
- Post-emergence for individual species in site specific situations
- Alternative controls: geodisks, 3 inches pine bark nuggets, sweet gum mulch in landscapes, using perennial peanuts as organic ground cover crop
- Exploit allelopathy
- Organic producers, nothing organic for tree grower in TX
- Pollinators and crops, herbicide timing of application, efficacy
- Irrigation Water Issues: weed seeds in irrigation water, herbicide contamination of irrigation water, weeds around and in irrigation ponds (this issue affects production, other pest issues)
- Noxious weed management: developing a model system for managing noxious weeds
- Non-crop vegetation management: cover crops, living mulches, trap crops, banker plants, pollinator crops, etc.
- Pot barriers (mulches, gels, sleeves, stockings, no-move slow release fertilizer/herbicides)
- Suggestion- Mulches currently are not used on substrate surface of containers.. could research use of mulches as a sustainable strategy; would need to look at production issues, i.e. rooting depth, pathogens, insects
- Other "additives" to containers to deter weeds Organic compounds that act as herbicides
- Covers, biodegradable, "lids" burlap, sleeves, stockings physical barriers
- Broadening labels, definite need for preemergent herbicides
- Weed control in liners
- Noxious weed issues, i.e. tropical spiderwort,
- Model for dealing with noxious weeds in all production areas
- Irrigation ponds as a source of weed seeds, pathogens and herbicide residues
- How does managing non-crop vegetation impact biocontrol, pollination- drainage (cover crops and filtration issue, mitigation of contaminants
- In addition to source consider timing and environmental events (conditions) affecting weed control in general, geographical area affects on persistence
- "Quick" test "litmus" to determine activity in container?
- Scouting as an overarching issue across disciplines as it influences timing
- Products that are applied to the surface that provide a barrier to weed germination example cited was osmocote that provides almost a gel-like barrier that covers the pot
- Slow release technology for herbicides that would extend weed control
- Extension- dissemination of information
- Research on barriers
- Snapshot and other pesticide efficacy/resistance
- Consumerism what will the consumer tolerate?

- Sustainability- will it pay. Will the client accept practices that may reduce "quality" or are there alternatives that provide similar quality
- Control for weeds coming out of drain holes- create something within a container that will be flexible
- Polywastes, manufacturing issues
- Branding or identifying sustainable production via a certification as a component of consumer attitudes/ cost-benefit analysis
- How much product can be used under varying environmental conditions?
- Mulches -lawn and landscape, field and container nursery, searching for alternative mulches. What's available: matted mulch, geotextiles, coco-mulch, rubber, cypress mulch (sustainability), recycled glass, sustainable mulch—unsustainable mulch; termite issue in mulch; mulch adding problems in landscape (adding weeds; Japanese climbing ferns from pine straws), over mulching; weeds growing from area uncovered by mat in container, wind blowing; peanut hulls---nematode; pecan hull---no slug/snail problems; from recycled materials, local source; live mulch (multi-functional: landscape; erosion control)---shade tolerant ground covers (perennial peanut); cover crop (shading?); eco-turf;
- Alternative substrate: transferability
- Irrigation management: retention ponds, Clemson research on plant species; NRCS pilot plants; use of recycled water, aquatic weed, disease problems; biofilm (algae) accumulation (slime) even with chlorine injection; herbicides for pond weed control
- Recycle soil/culls, minimal bacteria/fungi problem
- Hybrid between herbicide and barrier method,
- Kaolin, salts, non-salts, reflective mulch, not so well in frost protection,
- Slug prevention
- Essential oils as herbicides;
- Greenhouse liverwort, no good tools available
- Freehand/Tower some efficacy in field container;
- Bermuda grass control, ban on MSMA, alternatives needed
- Herbicide residual longevity
- Rodeo (aquatic glyphosate); greenhouse herbicide in general, fatty acid, etc
- Policy/regulatory: license issues?
- Odors - urban landscape; ban on fertilizer use in urban area;

Extension

- Consumer/market acceptance of sustainable alternatives (certification programs, pot labels, branding; encompassing sustainable production, pest control, perhaps even fair labor standards)
- Odors - urban landscape
- Improved outreach/communication (getting the right info to the right recipient in formats that are easy to understand/use/etc.
- Application techniques
- Urban encroachment on nursery production
- Education/publication in different languages
- Public education on herbicide safety
- Through different media; right plants at right places
- Lower inputs
- Town hall meeting with public

Regulatory

- Weigh costs of government forcing new expenses
- Interactions with state pesticide regulators is a beneficial outreach effort
- Better communication between industry and federal/state issues

Arthropod Priorities

- Network of Southern phenology gardens (tying pest activity with obvious plant characteristics like flowering). Gardens should be strategically placed to cover all climatic gradients.
- Basic biology and life cycle, ecology behavior of new, emerging and invasive pests, scales, borers, ambrosia beetles, galls, mites, Red headed flea beetles and other emergent pests information on new pests
- Scale IPM Research across several states.
- Ground cover with Bt gene and other transformations that will reduce pest problems-transgenic solutions
- IPM and biological controls should be an emphasis
- Conservation of beneficial- management of beneficials, effect on beneficial is one component, how other management of the nursery cultural factors impact beneficial
- Traps, colors
- Lists of where beneficial are available
- Use of banker plants and their potential in management
- Potential use of trap crops or plants for insects
- Use of indicator plants to identify first invaders
- Non crop vegetation as a reservoir of pathogens and other pests
- Organization of nursery to provide resources at appropriate time for natural enemies, example hollies blooming providing nectar for scale parasites
- Diversifying the nursery and its side effects??
- Management of beneficial- can tie to weed management
- Demonstration of biological control programs needed (risk adverse)
- Phenological indicators (gardens) to assist in better timing scouting/control efforts
- Pest prediction- phenological modeling.
- Economics and cost benefit analyses need to be done
- Pest development models with pesticide application, e.g. scale (e.g. temperature/seasonal/crop/regional related)
- Sentinel plants for pests
- Different EIL for conventional versus biorational programs.
- Plant stress interactions
- Production practice/pest interaction research needed
- HPR Pest Resistant plants and interactions with other pests, beneficials, functionality of the plant in the landscape
- Pest resistance (labeling whitefly example)

Priority groups *

Pest	Production	Landscape
Scale	*	*

Thrips	*	*
Aphids	*	*
Borers	*	
Lacebug		*
Mites	*	*
Whitefly	*	
Flea Beetle	*	

Extension

- Find reduced input programs involving biorationals and biologicals that work with research to back them up, then sell the program with backup from researchers
- Difficulty in raising industry taxes for R&D maybe employ tax credits for producers?
- Green labeling – economic incentive
- Nursery example. Develop concise IPM program that reduces cost of production,lowers pesticide usage, for specific crops, concise outputs
- Point of sale information for homeowners
- Cost comparison between different biological and chemical programs. Bottom line.
- IPM training – statewide training needed
- consumer education/acceptance of bio control (good versus bad bugs – Mike's grass example)
- transfer technology from Europe and Canada. understanding of how biological actually work
- organic controls
- Spectrum of activity of insecticides is not well understood by growers- better system for dissemination of information important to practitioners
- Regular communication with stakeholders transmitting environmental and pest info (technology: twitter notification; twitter network; blog).
- Extension- easier access to available information

Regulatory

- Education of regulatory people so that pests on plants not scheduled for movement don't need to be controlled