

**Crop Timeline for  
Nursery-Grown Evergreens and Shade Trees**

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## Introduction

This timeline provides a general overview of the crop production, worker activities, and key pests in nursery-grown evergreen and shade trees in Horticultural Zone 8 (Figure 1). Zone 8 contains a large percentage of the nursery industry in the southern United States. It includes four of the largest nurseries in the United States. Zone 8 comprises parts of North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas in the southern U.S as well as areas in California. This timeline also is applicable for the southern portion of Zone 7 and the northern portion of Zone 9 because similar culture and management practices are used to grow the same plant species that are affected by the same pests. The phenology of Zone 7 will be slightly slower and the growing season will be slightly shorter in comparison to Zone 8. The characteristics of Zone 9 will differ in the opposite extreme from Zone 7.

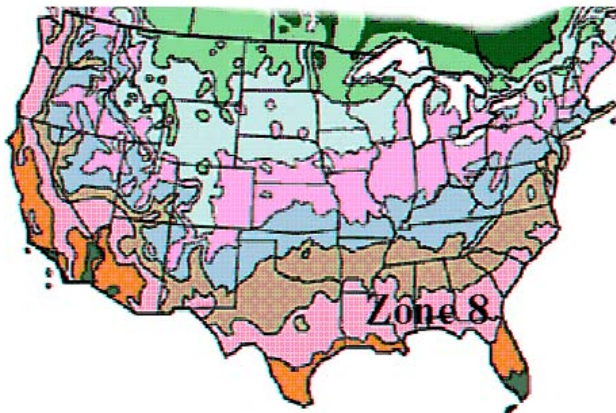


FIGURE 1.--Horticultural Zone 8 is the focus of this timeline.

### Value and Size of the Tree Nursery Industry

Nursery and greenhouse crops represent the sixth largest agricultural commodity group in the United States with farm receipts of \$12.12 billion (b) in 1998 (Economic Research Service 1999). This is the fastest growing major segment of U.S. agriculture. Between 1991 and 1998, sales of nursery and greenhouse crops increased by 30%, or 16% in inflation-adjusted terms. These sales represent an average annual growth of 2%. This strong growth was driven by the robust U.S. economy, i.e., the expansion in housing and the increase of per capita consumption of ornamental plants (Hodges and Haydu 2002).

California, Texas, and Florida represent the three largest production states. An economic

impact study of the year 2000 conducted by the University of Florida in 2001 shows that the nursery and landscape industry's total Florida sales were \$8.5 b, a 44% jump since 1997. Comparable increases are also occurring in other states. The Florida greenhouse and nursery industry had more than 5,000 commercial producers and a production area of 126,000 acres that included 223 million square feet under protective cover (National Agricultural Statistics Service 2001). Ornamental plant sales by Florida growers of \$1.45 b included \$843 million (M) for floriculture crops and \$528 M for nursery crops, sod, and other greenhouse and nursery crops. Sales increased by 24% during the period 1991-98. The increase was 10.7% in inflation-adjusted terms and represented an annual growth of 1.3%. In the year 2000, sales of floriculture and nursery crops by large Florida wholesale growers included \$393 M for tropical foliage plants, \$142 M for potted flowering plants, \$100 M for cut cultivated greens, \$95M for annual bedding plants, \$47 M for propagative materials, \$29 M for cut flowers, \$13 M for herbaceous perennials, \$216 M for deciduous shrubs and other ornamentals, \$71M for broadleaf evergreens, \$52 M for deciduous shade trees, and \$59 M for propagation materials (National Agricultural Statistics Service 2001) . Estimated total sales by Florida horticulture firms in 2000 were \$191 M for deciduous shade, flowering, and fruit trees and \$176 M for evergreen trees. About 31% of all firms sold trees in 2000, and the share of sales of deciduous trees was 9% while the share of sales of evergreen trees was 8%.

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. In 1997, nursery and greenhouse operations had sales of \$10.9 billion, up 43 percent from 1992. 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.

Figure 1A-C shows in graphic form several components of horticultural sales in the United States for the year 1998.

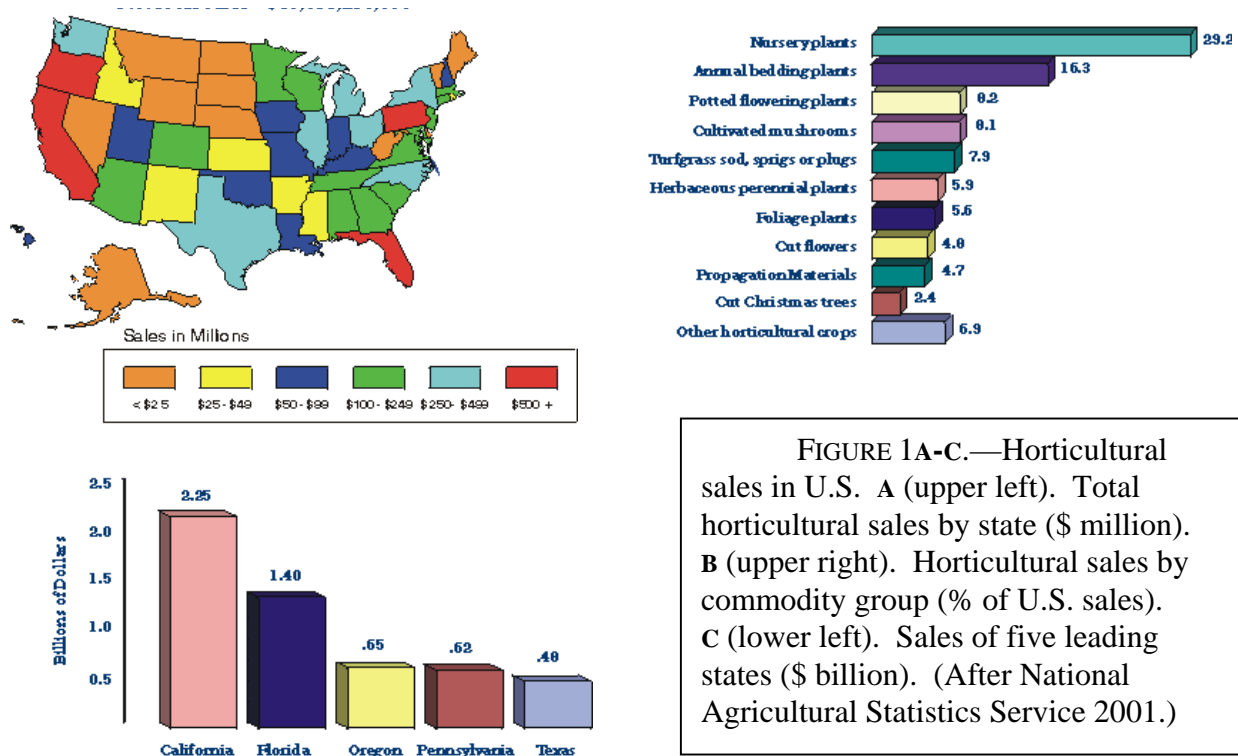


FIGURE 1A-C.—Horticultural sales in U.S. A (upper left). Total horticultural sales by state (\$ million). B (upper right). Horticultural sales by commodity group (% of U.S. sales). C (lower left). Sales of five leading states (\$ billion). (After National Agricultural Statistics Service 2001.)

### Tree Production

Trees 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.

FIGURES 2 –4 illustrate general tree production practices for the southeast U.S. TABLE 1 shows worker activities and potential pesticide exposure in relation to nursery activities.

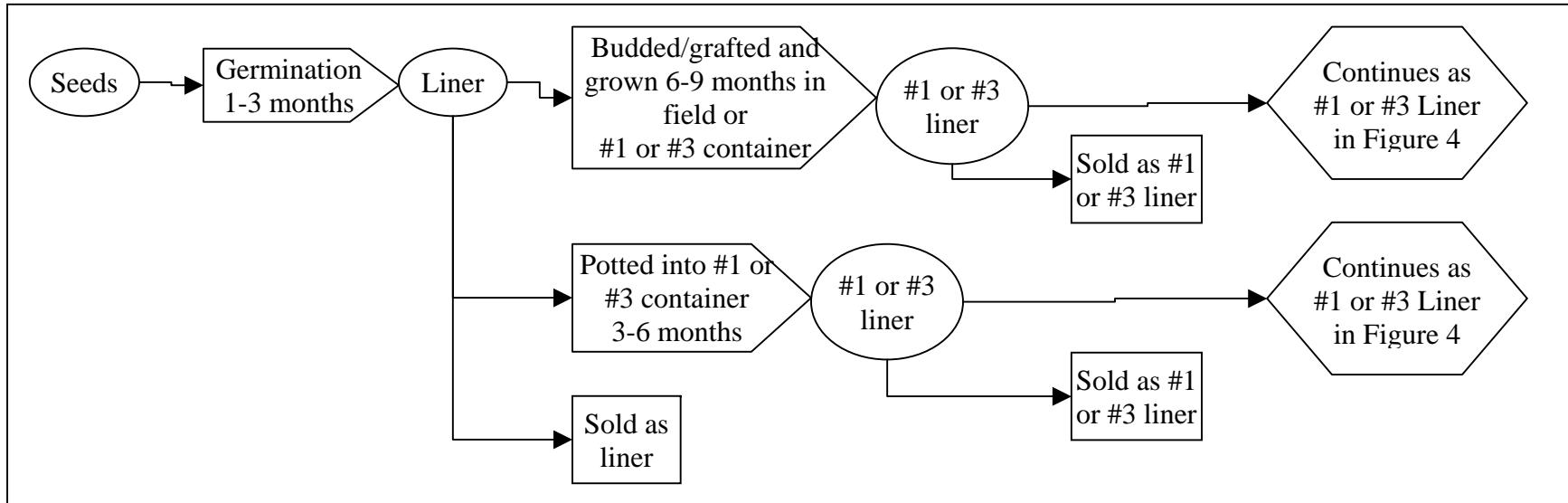


FIGURE 2.—Flowchart (above) of tree liner production starting from seeds. Most seeds are planted during the winter. Germination time and growing time vary with species, nursery cultural practices, and environment.

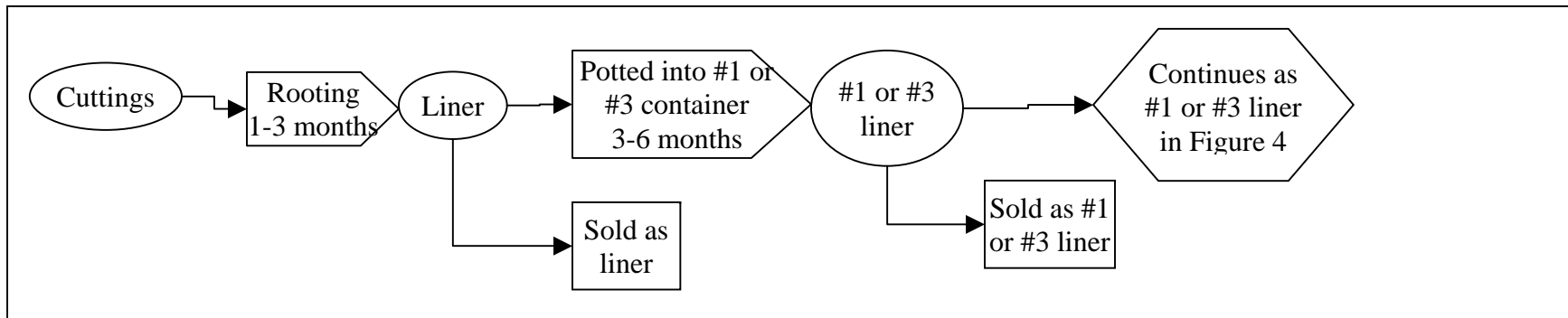


FIGURE 3.--Flowchart of tree liner production starting from cuttings. Cuttings are most often taken during the spring and summer but may be taken at any time of the year depending upon the species, geographic location, and nursery practices. Rooting time varies with species, nursery cultural practices, and environment.

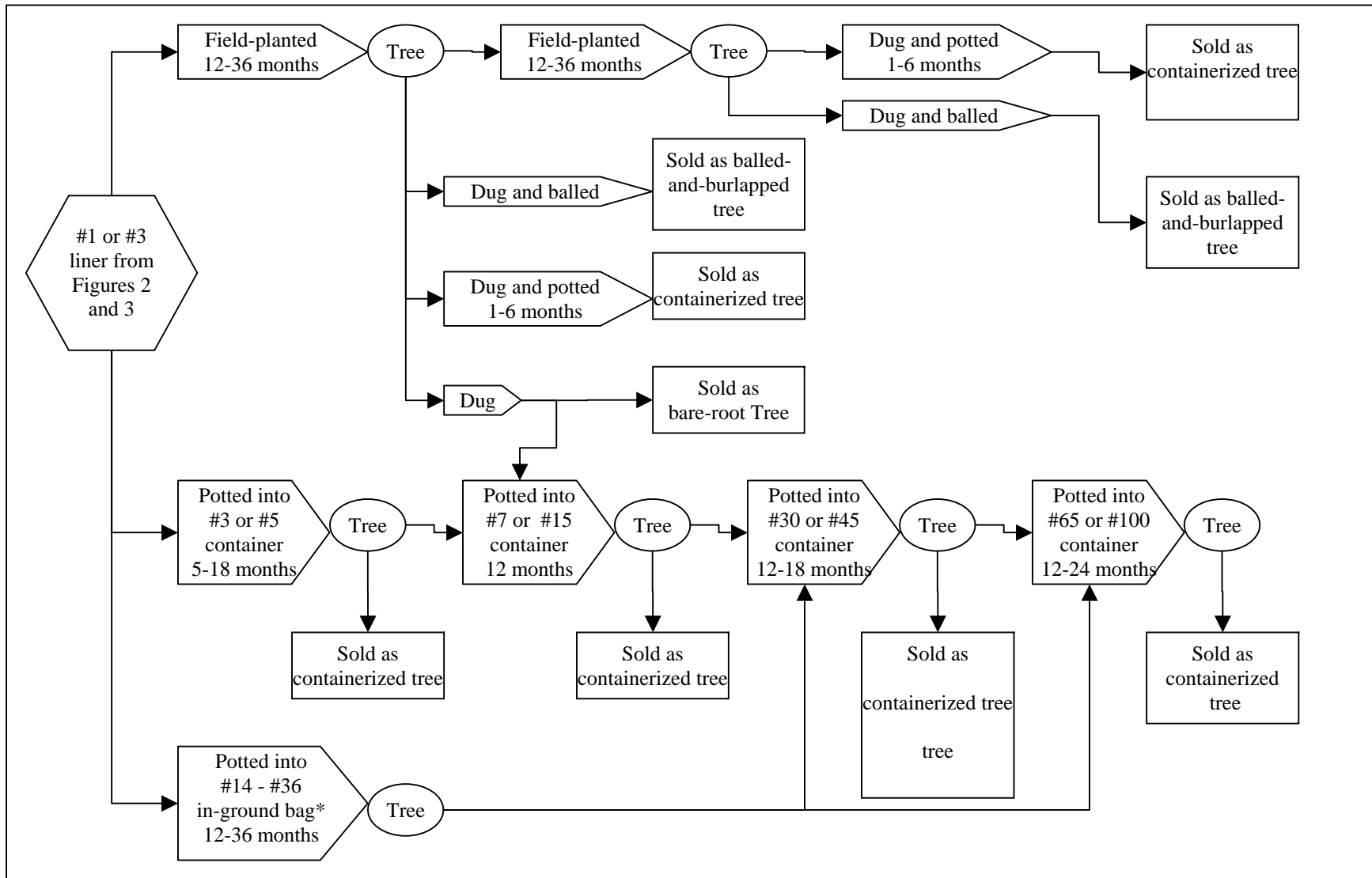


FIGURE 4.--Flowchart of tree production starting from seed- or cutting-produced liner (from Figures 2 and 3). Growing time varies with species, geographic location, nursery cultural practices, and environment. Digging most often takes place in late fall and winter, but container potting can take place 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.--Tree 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 of herbicide by tractor or handheld sprayer or granular applicator; walking through treated nursery beds
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	Assisting potting machine or potting by hand	If plant will be sold within 1 year, potting substrate may contain insecticide (for fire ant control)
Spacing and	Year-	0-3 times per year	Relocating containers to separate	Plants, containers or potting

NURSERY ACTIVITY	TIME OF YEAR	FREQUENCY	WORKER ACTIVITY	POTENTIAL PESTICIDE EXPOSURE
consolidation (container nurseries)	round		them, to provide more space for plant canopies, and to group containers by size and species	substrate may contain pesticide residue; walking through the 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	Year-round	Varies with species, weather, nursery cultural	Application with tractor or hand-held sprayer; cultivation by tractor	Mixing, loading, applying pesticides; if cultivation is

NURSERY ACTIVITY	TIME OF YEAR	FREQUENCY	WORKER ACTIVITY	POTENTIAL PESTICIDE EXPOSURE
management (field nurseries)		and pest management practices; 0–6 applications per year of postemergence herbicides; cultivation or mowing also may occur	or manually; mowing by tractor	manual, walking through the nursery beds
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	
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)	Year-round, often after	As needed (perhaps several times per year but usually only a small	Manual	Plants, containers or potting substrate may contain pesticide residue; walking through the

NURSERY ACTIVITY	TIME OF YEAR	FREQUENCY	WORKER ACTIVITY	POTENTIAL PESTICIDE EXPOSURE
nurseries)	windstorms or disturbance of plants by animals, erosion, etc.	portion of the crop)		nursery beds
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 handgun 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 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, not all woody, field nurseries in Florida averaged 0.59 Full-Time Equivalent (FTE) workers per acre of field nursery (Hodges et al. 1998). Container nurseries in Florida averaged 0.54 FTE workers per acre. These figures should be fairly representative of nurseries throughout Zone 8.

Despite continued progress and increase in Integrated Pest Management (IPM) implementation in nursery crops, chemical pesticides remain the primary management tool. The combination of a large

numbers of pests attacking a large number 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. Zone 8 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. 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 Zone 8 require periodic chemical pesticide treatments. The most extensive quarantine is that of the red imported fire ant (*Solenopsis wagneri*). 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 the basis of the quality of their appearance. Moreover, 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 pesticide applications are relied on heavily. Much of the new chemicals registered for nursery production are less toxic than the older established chemicals to humans, to nontarget organisms, such as beneficial organisms, and to the general environment. However, broad spectrum and systemic pesticides are 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.

## Pest Management

The most important factors considered by nursery growers in deciding whether to treat for pests are pest population level, weather, degree of pest damage, changes in pest populations, pest life stage, projected marketing date, treatment cost, presence of predators and parasites, plant disease inoculum level, and labor availability (scheduling). Most growers of ornamental plants recognize the importance of regular scouting within an Integrated Pest Management 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.

### 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.

#### *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. 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 common in a wide variety of crops and ornamentals. Root rot is the most common disease in nursery crops. An aerial form of this disease could occur on shoot tips and stem as dieback. Integrated disease management is needed for this disease. Overwatering must be avoided in order to manage root rots. Several fungicides are available for the management of this disease.

### *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.

### *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.

### *Chemical Control of Diseases*

Major diseases affecting the production of woody ornamental plants in Florida include crown gall, damping-off, cutting rots, *Phytophthora* root rot and dieback, powdery mildew, bacterial diseases, fungal leaf spots, anthracnose, needle-casts and blights, and rusts. Fungicides are widely used for the management of these plant diseases on woody ornamentals in Florida. 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 were summarized in Table 3. Fungicides and bactericides are applied most commonly from March to November.

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

ACTIVE INGREDIENT	FORMULATION <sup>a</sup>	REENTRY INTERVAL (HOURS) <sup>a</sup>	DISEASE TARGETED
Chlorothalonil	DF, EC, F, L, WDG, WSP	12-48	Needle cast, blight <sup>b</sup>
Chlorothalonil + fenarimol	F	NA	
Chlorothalonil + thiophanate-methyl	WDG	12	Powdery mildews <sup>c</sup> , rusts ( <i>Melampsora</i> ) <sup>b,c</sup>
Copper sulfate pentahydrate	L	24	Crown gall <sup>c</sup>
Fosetyl-aluminum	WDG	12	Damping-off <sup>b</sup> , <i>Phytophthora</i> root rots <sup>b,c</sup>
Mancozeb	DF, F, WP, WSB	24	Rust, pine gall <sup>b</sup>
Mefenoxam	G, MC, WSP	0	<i>Phytophthora</i> root rots <sup>b,c</sup>
Propamocarb hydrochloride	MC	12	Damping-off <sup>b,c</sup> , <i>Phytophthora</i> root rots <sup>b,c</sup>
Propamocarb hydrochloride + chlorothalonil	L	48	<i>Phytophthora</i> root rots <sup>b,c</sup>
Propiconazole	EC	24	Leaf spots and flower blights <sup>c,d</sup> , powdery mildews <sup>c</sup> , rusts ( <i>Melampsora</i> ) <sup>c</sup>
Thiophanate-methyl	F, G, LF, WDG, WP, WSB	12	Leaf spots and blights <sup>c,d</sup>

<sup>a</sup>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.

<sup>b</sup>Affecting conifers.

<sup>c</sup>Affecting ornamental and shade trees.

<sup>d</sup>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 <sup>a</sup>												
Damping-off and cutting rot												
<i>Phytophthora</i> root rot and dieback <sup>a</sup>												
Powdery mildew <sup>b</sup>												
Bacterial diseases												
Leaf spots <sup>b</sup> and anthracnose												
Needle cast and blight <sup>a</sup>												
Rusts <sup>a</sup>												

<sup>a</sup> May be present year round.

<sup>b</sup> Will peak with the weather.

### Weed Pests

The predominant weed species in nurseries vary with the type of nursery (field or container) and also with differences of season, environment, or geographic location. Some common weeds are given in Table 4.

TABLE 4.—Common weeds of nursery-grown evergreen and shade trees in the study area and season of primary occurrence.

COMMON NAME	SCIENTIFIC NAME	Nightshade, black	<i>Solanum nigrum</i>
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<b>Perennial weeds</b>		Phyllanthus, chamberbitter	<i>Phyllanthus urinaria</i>
Bermuda grass	<i>Cynodon dactyylon</i>	Phyllanthus, longstalked	<i>Phyllanthus tenellus</i>
Betony, Florida	<i>Stachys floridana</i>	Pigweed	<i>Amaranthus</i> spp.
Bindweed, field	<i>Convolvulus arvensis</i>	Purslane, common	<i>Portulaca oleracea</i>
Chickweed, mouseear	<i>Cerastium vulgatum</i>	Pusley, Florida	<i>Richardia scabra</i>
Dogfennel	<i>Eupatorium capillifolium</i>	Ragweed, common	<i>Ambrosia artemisiifolia</i>
Greenbriar	<i>Smilax</i> spp.	Sedge, annual	<i>Cyperus compressus</i>
Groundsel, common	<i>Senecio vulgaris</i>	Sedge, globe	<i>Cyperus globulosus</i>
Johnsongrass	<i>Sorghum halepense</i>	Spanish needles	<i>Bidens bipinnata</i>
Kudzu	<i>Pueraria montana</i> var. <i>lobata</i>	Spurge, garden	<i>Chamaesyce hirta</i> , syn. <i>Euphorbia hirta</i>
Liverwort	<i>Marchantia polymorpha</i>	Spurge, hairy	<i>Chamaesyce hirta</i> , syn. <i>Euphorbia vermiculata</i>
Morning-glory	<i>Ipomoea</i> spp.	Spurge, prostrate	<i>Chamaesyce hirta</i> , syn. <i>Euphorbia humistrata</i>
Nutsedge, purple	<i>Cyperus rotundus</i>	Spurge, spotted	<i>C. maculata</i> , syn. <i>E. maculata</i> , <i>E. supine</i>
Nutsedge, yellow	<i>Cyperus esculentus</i>	Woodsorrel, yellow	<i>Oxalis stricta</i>
Poison ivy	<i>Toxicodendron aradicans</i>	<b>Cool season (winter) weeds</b>	
Rose, multiflora	<i>Rosa multiflora</i>	Bittercress	<i>Cardamine</i> spp.
Torpedograss	<i>Panicum repens</i>	Carrot, wild	<i>Daucus carota</i>
Trumpetcreeper	<i>Campsis radicans</i>	Chamberbitter	<i>Phyllanthus urinaria</i>
<b>Warm season (summer) weeds</b>		Chickweed, common	<i>Stellaria media</i>
Artillery weed	<i>Pilea microphylla</i>	Clover, white	<i>Trifolium repens</i>
Carpetweed	<i>Molluga verticillata</i>	Cudweed	<i>Gnaphalium</i> spp.
Crabgrass	<i>Digitaria</i> sp.	Geranium, Carolina	<i>Geranium carolinianum</i>
Crabweed, hairy	<i>Fatoua villosa</i>	Mayweed chamomile	<i>Anthem cotula</i>
Dayflower, spreading	<i>Commelina diffusa</i>	Medic	<i>Medicago trunculata</i>
Dollarweed or pennywort	<i>Hydrocotyle</i> spp.	Medic, black	<i>Medicago lupulina</i>
Eclipta	<i>Eclipta</i> sp.	Mustard	<i>Brassica</i> spp.
Eveningprimrose	<i>Oenothera</i> spp.	Pepperweed	<i>Lepidium</i> spp.
Goosegrass	<i>Elusine indica</i>	Ryegrass, annual	<i>Lotium multiflorum</i>
Lambsquarters	<i>Chenopodium</i> spp.	Sheperdspurse	<i>Capsella bursa-pastoris</i>
Morning-glory	<i>Ipomoea</i> spp.	Sowthistle	<i>Sonchus</i> spp.
Mulberry weed	<i>Fatoua villosa</i>	Vetch, common	<i>Vicia sativa</i>

### Weed Management

Weeds compete with nursery plants for water, light, space, and nutrients. In addition, weeds

can be detrimental to the growth of ornamental plants by harboring populations of insects, mites, and other pests that can then move onto nursery plants. Weeds growing in and around the nursery can easily spread into adjacent nursery beds. Weed management is therefore important both at the direct production site (within containers or in field sites) as well as in surrounding areas (in aisles and around greenhouse and nursery entrances).

Preventative measures are the most effective means of controlling weeds. Eliminating weeds or reducing weed populations in and around the growing area 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 the specificity of biological weed controls.

### *Cultural Methods of Weed Control*

Weed infestations can be effectively 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. 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.

#### *Dense Plantings*

Plants themselves can keep weed growth in check when the planting is dense or containers are spaced closely together. The plants will outcompete the weeds for light, water, and nutrients.

### *Weed-Free Liners and Transplants*

Seeds, rhizomes, and root pieces of weeds can be introduced into nurseries by infested liners and transplants. 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 in nursery areas. 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 nursery plants' surface roots, increased soil erosion, and potential for soil buildup around the collar of nursery 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 use herbicides for weed control. In a 1991 survey of Florida nurseries, found 71% used postemergence herbicides, 56% used preemergence 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 a 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 a 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 Tran located 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 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 (maretail)	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 pesticides... 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. [italics omitted] ...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. [italics omitted] 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. [italics omitted] [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,  $T_{1/2}$ ) 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 <sup>a</sup>	ACTIVE INGREDIENT	FORMULATION <sup>a</sup>
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		

<sup>a</sup> 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

Evergreen and shade trees in the region are attacked by numerous arthropod pests, including spider mites, broad mites, scales, mealybugs, whiteflies, aphids, lace bugs, 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 its value. Production of larger container trees is a current industry trend and this trend will likely result in increased numbers of stressed plants. As a result, attacks by related boring pests, such as bark beetles and lepidopteran caterpillars, will likely increase. These insects are particularly difficult to control and few efficacious chemical agents are available (TABLE 9).

#### Mites

Spider mites are among the most common pests of ornamental nursery plants in the region, and the twospotted spider mite, *Tetranychus urticae*, is considered the number one pest of ornamentals. Two other mite species, the southern red mite, *Oligonychus ilicis*, and the spruce spider mite, *O. ununguis*, are also important. 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 mite occur during the cool, wet conditions in fall-winter-spring with highest infestations occurring from January to April.

### *Scales and Mealybugs*

Armored scales, soft scales, and mealybugs are 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, but armored scales live and feed beneath the protected covering but are not attached to it. 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 white peach scale, *Pseudaulacaspis pentagona*; the brown soft scale, *Coccus hesperidum*; the false oleander scale (= magnolia white scale), *Pseudaulacaspis cockerelli*; the Florida wax scale, *Ceroplastes floridensis*; the tea scale, *Fiorinia theae*; and the European fruit lecanium, *Parthenolecanium corni*. 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 are often used to manage persistent scale populations.

### *Mealybugs*

Mealybugs are also small, soft-bodied insects covered with waxy 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 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 mealybug pest in the region is the striped mealybug, *Ferrisia virgata*.

### *Aphids*

Aphids infest most ornamental nursery plants and are commonly found on camellia, crape myrtle, gardenia, and oleander. Common aphid pests in ornamental nurseries include the crape myrtle aphid, *Tinocallis kahawaluokalani*; the green peach aphid, *Myzus persicae*; the cotton aphid, *Aphis gossypii*; and the spirea aphid, *Aphis spiraecola*. These soft-bodied insects are frequently found in groups on stems or lower leaf surfaces, especially on young plant tissue. Aphid feeding causes leaves to curl, flower distortion, and defoliation. In addition to direct feeding damage, aphids can be vectors of plant 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.

### *Whiteflies*

Whiteflies frequently infest crape myrtle, gardenia, ligustrum, and viburnum. The citrus whitefly, *Dialeurodes citri*, and the silverleaf whitefly, *Bemisia argentifolia*, are the most common pests. Many alternative host plants, such as privet, grow wild in the field adjacent to nurseries and 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 silverleaf 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 scales, whiteflies excrete honeydew upon which black sooty mold grows.

### *Caterpillars and Leaf Beetles*

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 forest tent caterpillar, and the bagworm. 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 leaves of host plants. The azalea caterpillar, *Datana major*, skeletonizes leaves when the caterpillars are young and completely destroys them when they are older. The larvae of the fall webworm, *Hyphantria cunea*, 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*, hatch in late spring and feed on shade trees. A second generation develops from late August to early September. Bagworms, *Thyridopteryx ephemeraeformis*, are general feeders. They use small pieces of twigs and leaf material to construct a bag, within which the caterpillar remains, and it protrudes the front end of its body out to feed on foliage. Larvae of the forest tent caterpillar, *Malacosoma disstria*, 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*; and the pyracantha leaf crumpler feed on the leaves of the terminals of maples, oaks, and pyracantha.

Other leaf beetles damage the foliage of crape myrtle, oaks, and other nursery plants. *Altica* spp. infests crape myrtle in June and July, and whitefringed beetles, *Graphognatha* spp., are general feeders during the summer months.

### *Borers*

Many species of borers, both beetles and moths (caterpillars), 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. The black twig borer, *Xylosandrus compactus*, is one example of a borer that attacks several tree species, particularly dogwood, redbud, and magnolia. Dogwoods are also susceptible to the dogwood twig borer, *Oberea tripunctata*, and flatheaded borers. The introduced Asian ambrosia beetle, *Xylosandrus crassiusculus*, attacks hardwoods, such as oaks, Bradford pear, golden raintree, *Carya* spp., and *Prunus* spp. The red oak borer, *Enaphalodes rufulus* can infest weakened or damaged oaks, especially laurel and water oaks. Other borers seen occasionally include the flatheaded apple tree borer, *Chrysobothris femorata*, and the peach tree 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 must be preventative, because once the insects are under the bark, they are difficult to control. 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.

### *Lace Bugs*

Occasionally, lace bugs attack azalea, hawthorn, oak, pyracantha, sycamore, and others. 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.

### *Red Imported Fire Ant*

*Solenopsis wagnerie*, the red imported fire ant, is present throughout the Zone 8 target region. The fire ant is a direct pest in nurseries due to the impact of bites and stings on laborers, but it is more important as a quarantine pest. A strict management protocol must be followed by any nursery that ships plants to destinations outside the fire ant quarantine area. Whereas about 75% of the nursery production in Zone 8 is consumed within the region, most of the largest nurseries are affected by quarantine regulations and follow the quarantine protocol. 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.

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	J	FEB	MAR	APR	MAY	JUN	JUL	AUG	S	O	NOV	DEC
Twospotted spider mite												
Southern red mite												
Spruce spider mite												
Lace bugs												
<i>Epismus tyrius</i>												
Pyracantha leaf crumpler												
Bagworm												
Forest tent caterpillar												
Fall webworm												
<i>Altica foliacea</i>												
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 <sup>a</sup> )
Aphids	Acetamiprid, azadirachtin (4), bifenthrin, cyfluthrin (24), cypermethrin, fenpropathrin (24), imidacloprid, kinoprene (4), permethrin, pymetrozine, petroleum oil, <i>Beauveria bassiana</i> , <i>Paecilomyces fumosoroseus</i> , rotenone, insecticidal soaps (4)
Beetles	Rotenone
Borers	Chlorpyrifos, permethrin
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), <i>Bacillus thuringiensis</i> , rotenone
Fire ants	Abamectin, bifenthrin, fenoxycarb, fipronil (24), hydramethylnon, pyriproxyfen, tefluthrin (48)
Grubs	Chlorpyrifos
Katydid	Cryolite
Leafminers	Cyromazine, pyriproxyfen
Lepidoptera	Tebufenozide (4)
Mealybugs	Acetamiprid, azadirachtin (4), fenpropathrin (24), pyridaben
Mites	Abamectin, azadirachtin (4), bifenthrin, bifenazate, dicofol, etoxazole, fenpropathrin (24), fenbutatin-oxide (48), fenproproxifen, hexythiazox, pyridaben, quinoxaline (24), petroleum oil, <i>Paecilomyces fumosoroseus</i> , insecticidal soaps (4)
Scales	Azadirachtin (4), fenoxycarb, kinoprene (4), permethrin, pyriproxyfen, petroleum oil, <i>Paecilomyces fumosoroseus</i> , insecticidal soaps (4)
Slugs, snails	Methiobarb (24)
Weevils	Phosmet (24)
Whiteflies	Acetamiprid, azadirachtin (4), bifenthrin, cyfluthrin (24), fenoxycarb, fenpropathrin (24), imidacloprid, kinoprene (4), pymetrozine, pyridaben, pyriproxyfen, quinoxaline (24), tebufenozide (4), <i>Beauveria bassiana</i> , <i>Paecilomyces fumosoroseus</i>

<sup>a</sup> REI is 12 hours unless otherwise noted.

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