

Crop Profile for Ornamental Plants in North Carolina

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General Production Information

The greenhouse and nursery industry is an important agricultural commodity in North Carolina, ranking ahead of tobacco and 38 other reported commodities and ranking third (\$841 million) behind only hogs and broilers (1). Ornamental plant production accounts for 12.7% of all farm receipts in North Carolina. The growth of ornamental plant production is up at least 6% in the past decade, and nursery production in North Carolina ranks sixth after California, Florida, Georgia, Michigan, and Texas. North Carolina ranks fourth in the nation for total greenhouse and nursery cash receipts (2). Today over 2000 different crops are grown commercially in the ornamental industry.

Nursery and Greenhouse Industry Statistics

In 2002, the North Carolina Department of Agriculture certified 1829 nurseries that grew over 500 different ornamental plant cultivars on 13,452 acres. This is an increase of 376 nurseries from 1998. Container production of nursery crops began in the mid-1950's in North Carolina, initially beginning with 1 gallon metal food cans or 5 gallon egg cans. Ornamental crops are now sold in sizes from one-half inch diameter plug cells to 300 gallon box-grown trees and trees up to 6 inch caliper dug with mechanical tree spades. Nursery plant products are propagated, potted, shipped, and sold every day of the year. In 1994, the Federal Crops Insurance Reform Act first included container grown nursery crops. As the Federal Crops Insurance Corporation began working with the nursery industry, 1600 container grown nursery crops were eligible for catastrophic insurance coverage. In an expanded program for 1999, 12,000 container grown ornamental crops will be eligible for insurance coverage and over 80,000 combinations of crops and container sizes will be eligible for coverage. This clearly provides evidence of the diversity of the nursery industry. Wholesale nursery businesses have diversified by targeting sales to landscape firms, retail garden centers, mass merchants and super stores and mail order marketing. Diverse markets demand many different plant products, sizes, forms and packages. However, all ornamental crop production still requires to various degrees the application of chemical pesticides to protect them from diseases and insects, and to prevent the shipping and spread of pests to consumers.

Ornamental plant production is a specialized and labor intensive segment of agriculture. The small producer may be owner as well as operator and has a basic knowledge of propagation, fertility, irrigation, potting substrates, structures, pest control, business management and marketing. In larger operations key individuals are usually assigned a single responsibility. Unlike row crops, where expenditures and profit are calculated on a per acre basis, nursery and greenhouse crop expenditures and profit are calculated on a per square foot of growing area or even on a per plant basis. Nursery and greenhouse managers deal with much smaller, but higher, value production units than other agricultural crops, and to make a profit, there is little room for error. Production of nursery crops involves a wide range of ornamental plants often with diverse cultural requirements. A nursery may grow trees, shrubs, vines, evergreens and deciduous plants. These plants may require different pest management programs, irrigation frequency, fertilizer rate, and light requirements. Species with similar requirements are usually grouped together in the nursery and grown using the same cultural practices.

Diversity of the Ornamental Plant Production Industry

Production Regions

Although total production area of these crops does not exceed 25,000 acres in North Carolina, average value of nursery and greenhouse crops exceeds \$50,000 per acre. Floriculture crops are produced in every county of North Carolina. The relatively mild winter temperatures combined with the cooler summer temperatures of the western part of the state make it ideal for greenhouse and nursery production. The primary production areas for woody ornamentals are in western North Carolina and in areas surrounding

large metropolitan centers.

Production Practices

Greenhouse operations vary from smaller seasonal firms which only grow spring bedding plants to year-round operations that grow crops on a continuous basis. The type of crop grown varies with the season. Growers produce bedding plants, geraniums, hanging baskets, and Easter lilies in the spring, produce garden chrysanthemums and perennials in the summer, and grow poinsettias, azaleas, and kalanchoes in the winter. Potted florist chrysanthemums and cut flowers are grown year-round. Potted orchids are also grown year-round with production taking 3 to 5 years until the plant is marketable.

Worker Activities

Workers are closely associated with most aspects of ornamental plant production, particularly in greenhouse floriculture where workers handle cuttings, plugs, potting mix, pots, and growing plants as well as fertilizer and pesticide application equipment. The use of automation is commonplace in the larger greenhouse operations in the state, and the sophistication of the technology increases each year. In turn, many processes in these large operations are now carried out by electronic eyes, computers, and automated machinery.

Worker Activities in Greenhouse Production — Workers typically put small plants (plugs, bare-root and rooted) into a soilless potting substrate at a potting bench. Such mixes usually contain sand, sphagnum moss or pine bark, perlite, vermiculite, lime, fertilizer, but rarely pesticides. The plants are usually put into pots or flats that are then incorporated into the growing area. Rooted cuttings of cut flowers are usually planted directly into beds of soil that has been amended with bark, peat moss or some other organic material. Depending on the crop and grower, plants are often drenched within 2 weeks after planting with a fungicide to inhibit root diseases and bare root cuttings are treated with a rooting hormone. Insecticides are often applied to the plants as needed based on insect populations to help manage insects and mite pests. Plants are irrigated once or twice a day, and cuttings are misted through much of the day. Workers sometimes apply a weak fertilizer solution at each watering cycle, depending on the crop and grower. With a typical 13-week crop, workers disbud, pinch or apply plant growth regulators to encourage branching and compact growth after plants have been in the production area for a few weeks. The generous use of water often encourages the growth of algae on benches and walkways that are controlled with algicides to discourage shore flies. Fungicides for leaf and flower diseases are often used when cloudy weather causes increased relative humidity within the greenhouse. Because environmental conditions may vary dramatically from hour to hour in greenhouses, workers often examine plants throughout the day to prevent over-heating or drying out. Ultimately the mature plants are loaded onto trays and transported to a shipping area to be sold.

Worker Activities in Nursery Production — Nursery operations include grading liners, planting, pruning, controlling weeds and other pests, irrigating, fertilizing and digging. Workers in nurseries usually spend part of their time in greenhouses or unheated protective structures and part of the time

outdoors. A crop cycle may be one year long or two, three or even more years. Workers plant rooted cuttings into a potting mix of sand, bark, peat moss or other organic material at a planting bench. The plants are loaded onto trailers and transported to outdoor plant production areas usually covered with black plastic film, mesh, or gravel (to discourage weeds from growing between the pots). Workers often drench plants with a fungicide as soon as they are potting up to help control root diseases. Plants are often repotted annually as they grow so workers and are sometime moved into shelters for the winter. Insecticides, fungicides, bactericides, herbicides, and plant growth regulators help control pests and plant growth. Adequate pest management is essential for successful nursery production.

Time Line for Pest Management on Ornamentals in Greenhouses and Nurseries

Pest management is a year-round process for greenhouses and nurseries. Although some seasonality occurs with greenhouse pests (flower thrips flights in May and September, for example), the sheltered growing conditions within a greenhouse allow for constant development of plant pests. Pests such as aphids, spider mites and whiteflies develop slowly in winter and rapidly in hot weather, so frequency of scouting is higher during the summer.

Nursery pests are more dramatically affected by weather. Even during the winter, plants should be scouted for armored scales, rodent damage, and weeds. Drenches for petal blight and oils for armored scales and spruce spider mites, southern red mites and other pests are made in January, and some crops are pruned to control unwanted growth.

In February, alcohol traps are used to detect the first flight of Asian ambrosia beetles, so a protective application of permethrin can be applied when these beetles appear in February or March.

In March, crops are scouted for insect, mite, disease, weed and vertebrate pests at least twice, and certain plants are drenched with fungicides to control root rots.

Plants are scouted weekly in April to detect spring pests such as cool-season mites (eriophyid, southern red, spruce spider, and boxwood mites), aphids, azalea lacebugs, leafminers on boxwood and holly, eastern tent caterpillars, forest tent caterpillars, boxwood psyllids, Nantucket pine tip moth, euonymus scale, and *Pityogenes* beetles on balled and burlapped white pines. Preemergence herbicides are applied in new fields, and in liner and seed beds. Pheromone traps are used for lilac/ash borer, banded ash clearwing borer and lesser peachtree borer and treatments made as needed. Plants at a high risk of severe anthracnose, leaf spots, or twig blights are sprayed. Scouts look for petal blight on azalea, leaf gall on rhododendron, fireblight on pyracantha and crabapple, cedar-apple rust on red cedar, anthracnose on river birch, and powdery mildew on many crops.

In May, plants are scouted at least twice for aphids, lacebugs (azalea and hawthorn), scales (cottony,

lecanium, terrapin, euonymus and wax), bagworms, caterpillars, mites, leafminers (boxwood and holly), black vine weevil, white grubs, boxwood psyllids, leafhoppers, borers (dogwood, rhododendron, azalea/dogwood twig and ash/lilac), spittlebugs, and maple petiole borer. Crabapples are treated for fire blight when blossoms are 20% open. When conditions are cool and wet, plants with aerial *Phytophthora* are sprayed, and new growth on junipers is protected from tip blight. Preemergence herbicides and postemergence herbicides are applied to field and container stock, weed liners and seed beds. Fields are scouted for emerging nutsedge Florida betony, mugwort, bindweed, and perennial grasses and postemergence herbicides are applied if needed.

June pests include aphids, lacebugs, bagworms, caterpillars, flower thrips, leafhoppers, June beetles, Japanese beetles, black vine weevil, mites, borers, boxwood psyllid, and spittlebugs. June is also the best time to treat the crawler stage of the cottony maple scale, cottony camellia scale, Indian wax scale, and lecanium scale, and other soft scale insects. Fungicide applications during periods of wet weather help prevent the spread of foliar, fungal pathogens such as *Botrytis*, *Alternaria*, *Colletotrichum*, and *Cercospora* leaf spot. Fungicides are applied to specimen trees as the buds begin to open. Hollies are drenched to protect them from black root rot. In field production, trees are pruned to establish single leaders and control excessive growth, and weeds are controlled with directed postemergence herbicides. Preemergence herbicides are reapplied in June as well.

In July plants should be scouted twice for aphids, caterpillars, Japanese beetle, June beetle, mites, scales (soft and gloomy), black vine weevil, and lacebugs as well as *Rhizoctonia* web blight and *Phytophthora* aerial blight. Preemergence and postemergence herbicides are applied to fields and containers, and the second of three yearly applications of preventative root rot fungicides are drenched on to provide *Phytophthora* protection of container crops that historically have root problems. Symptoms of *Botryosphaeria* dieback and bacterial scorch (*Xylella* sp.) show up in July, August, and September.

Plants are scouted in August for aphids, caterpillars, mites (two-spotted and false), gloomy scale, white grubs, and borers (peachtree and banded ash clearwing). Field nurseries are treated in late August to early September for white grubs. Pheromone traps are used for peachtree borer and banded ash clearwing borer. Ornamental cherries, peaches, plums and cherrylaurels are treated for peachtree borer. Fungicide sprays for foliar fungal pathogens are applied if the weather is wet. Plants are monitored for signs of powdery mildew, and fungicide applications are made at first sign of disease. Dead branches with *Botryosphaeria* and *Phomopsis* are pruned out and a fungicide application made after pruning may be warranted to protect fresh wounds from infection. In field production, scouting for weeds and application of preemergence herbicides for winter annual weed control are made. Perennial weeds are controlled by glyphosate in late August or September.

In September, crops are scouted twice for insect, mite, disease and weed pests including peachtree borer, white grubs, mites (two-spotted, false, southern red, and spruce spider), and scales (magnolia and tuliptree). Summer annual and perennial weeds that escaped summer control application are treated with touch up hand weeding. Preemergence and postemergence herbicides are applied for field and container stock at least 3 weeks prior to covering in winter protection structures. If white grubs were not treated in August, then a fall treatment is made now. Scouting for scab on crabapple, black spot and downy mildew

on rose, and powdery mildew on many woody ornamentals continues in September. New growth of junipers is sprayed to protect from twig blight infection. In field production, preemergence herbicides are applied within 48 hours after planting fall broadleaved and coniferous liners.

Crops are scouted at least once in October especially for white grubs and cool season mites (eriophyid, spruce spider and southern red), powdery mildew and *Botrytis*. Treatments with horticultural oil are made if necessary.

Crops are scouted at least once in November. Fungicides, preemergence herbicides or any ammonium or urea containing fertilizers are applied at least 3 weeks before crops are covered avoid volatilization damage to crops. Diseased, cankered, and galled (cedar-apple rust on juniper; white pine blister rust; black knot of plum and cherry, and insect or mite galls) branches are pruned out and destroyed. Severely infected trees are destroyed. Fallen leaves are removed and destroyed from around trees and shrubs that had any leaf spotting diseases earlier.

Crops are scouted at least once in December for mites on conifers and armored scales. Winter protection houses and winter protection fabrics are checked for rabbit, mouse or vole damage.

Relatively few pests of ornamentals have developed resistance to pesticides. These include some whiteflies, aphids, spider mites, leafminer flies, a few thrips, diseases and weeds. Pest management on ornamentals is complicated by the large number of host plants and the several distinct sites and categories of users. For example, to be used in a greenhouse, the pesticide must be labeled for use in a greenhouse. In addition, if the greenhouse is a commercial greenhouse, then the pesticide must have directions for "Agricultural Uses" on the label. Like-wise in nurseries, pesticides must have directions for "Agricultural Uses" and must be labeled for field-grown or container-grown nursery stock. Because of the large number of host plants, commercial plantmen must deal with a myriad of insect, mite, disease and weed pests. No single pesticide lists all host plants, all pests, and all sites on a label, so plantmen are forced to stock a number of chemicals to deal with various aspects of pest management on ornamental plants.

To avoid or minimize the impact of plant diseases, an integrated approach to pest management must be followed. In container nursery production, careful consideration must be given to the layout of the production beds in terms of surface coverings, drainage, plant spacing, and to the source and treatment of irrigation water. The source and treatment of irrigation water is also an important consideration in greenhouse production. Good sanitation practices are extremely important in either nursery or greenhouse production.

Nurseries and greenhouses are not isolated geographically, and the movement of both propagation and finished stock occurs across the globe. Due to this movement of plant material, ornamental production in North Carolina is faced with the constant threat of introduced exotic or regulated pathogens into our state on infested plant material. In 2003 and 2004, *Ralstonia solanacearum* race 3 biovar 2 was introduced into greenhouse facilities in North Carolina on infected geranium cuttings originating from Kenya and Central America. The introduction of this federally regulated pathogen resulted in the destruction of thousands of plants. In March 2004 it was discovered that *Phytophthora ramorum*, the causal agent of Sudden Oak

Death, was introduced into North Carolina nurseries on infected nursery stock originating in California. Daylily rust was not known to occur in North Carolina until 2002 and it has shown up in nurseries each year since. Daylily rust is a documented problem in Central America, and plants are commonly shipped from these locations to Florida for distribution throughout the United States. There has also been an increased interest in growing vegetative annuals. Many of these plants, like geraniums, originate from offshore facilities.

Insect, Mite, and Mollusk Pests of Ornamentals

Aphids — Because of their resistance to many pesticides, melon aphids and green peach aphids are the two most common aphid pests in greenhouses and nurseries. The melon aphid has two definite color forms, a yellowish green form and a dark green form that appears to be black until examined in strong light. Green peach aphids also have two color forms, a light green form and a reddish form. Adequate coverage is important for aphid management as thick foliage may shelter the aphids from the pesticide. Of pyrethroid, carbamate, and organophosphate insecticides, acephate works the best for aphid control. Alternatives include oils, insecticidal soaps, as well as imidacloprid and other newer systemic pesticides.

Beetles — Japanese beetles feed on over 275 different plants, including many shade and fruit trees, ornamental shrubs, small fruits, garden crops, and weeds. Asian ambrosia beetles attack some herbaceous flowering plants as well as trees and shrubs. Bark beetles such as the southern pine beetle sometimes kill pines over wide areas. Black vine weevils attack the leaves of various shrubs and their grubs feed on the roots of rhododendrons, taxus, and other plants in container-grown and field-grown stock. Twig girdlers infest the smooth-barked twigs of elms, oaks pecans, and zelkovias in late summer and cause undesirable dieback and multiple stems. Female twig girdlers chew through the bark from the outside. Twig pruners attack field grown hardwood trees and weaken twigs and branches to the point they dieback and break off. Leaf beetles in the genera *Paria*, *Altica*, and *Rhabdopterus* chew holes in the new leaves of hollies, camellias, azaleas, and crapemyrtles at night.

Bugs — Hemipterans such as plant bugs, stink bugs, and lace bugs are insects that insert slender mouthparts into plants (or animals) and inject saliva as they feed. Some bugs then suck out the predigested plant juice and leave behind plant empty cells that are conspicuously pale. Bugs have a portion on the wing tips that is noticeably more papery and translucent than the remaining parts (except lace bugs that have uniformly lacy wings). Bugs lay their eggs on their host plants, and immature bugs feed on the same plant as their parents. Lace bugs and plant bugs are two families of bugs that most commonly attack ornamental plants. The azalea lace bug is the most frequently reported insect pest in landscapes and nurseries. After a short time, a heavy infestation of lace bugs may cause the leaves to become bleached and bronzed in appearance. Azalea lace bugs are difficult to control with contact insecticides because the eggs are inserted into the leaf tissue and covered with a drop of varnish-like excrement and are thereby protected from insecticides. Plant bugs cause distorted growth and premature leaf drop.

Caterpillars — Armyworms, bagworms, borers, cutworms, tent caterpillars, handmaid moths and other prominents (azalea caterpillar, yellownecked caterpillar), and webworms attack ornamentals in greenhouses and nurseries in North Carolina. Most of the caterpillars that feed on ornamentals are immature stages of moths. Moths usually lay their tiny eggs on leaves or stems. A few days later, tiny caterpillars hatch and begin feeding. Damage from the first three or four instars is insignificant. However, the latter part of the fourth, the fifth, and the sixth instar caterpillars consume a considerable amount of foliage and petals. These last few stages cause much more damage than the earlier stages, and the damage accrues quickly. Fully grown caterpillars then pupate and in a few weeks or months, a new generation of moths emerges to mate and lay eggs for a new generation. In nature, caterpillars are plagued with numerous parasites, predators, and diseases. One disease, *Bacillus thuringiensis*, is available as a biological control agent. *Bacillus thuringiensis* (B. t.) is much more effective against young, small caterpillars than it is for older, larger ones. Other strains of B.t. are specific to different groups of insects including beetles and mosquitoes.

The beet armyworm is a typical caterpillar pest of flowers including mums, marigolds, carnations, and roses. Several generations occur each year. Grayish brown female moths lay up to 600 eggs in masses of 15 to 150 eggs mostly on the undersides of leaves usually near the soil. Females prefer young rather than old plants. When the tiny worms hatch, they feed in groups especially in the growing tips where they web several leaves together. Young larvae are very susceptible to pesticides but they reside inside the webbed foliage where it is difficult to treat them. Older larvae feed on the open leaves and are more accessible, but they are more tolerant of pesticides. Growers should consider screening greenhouses to keep beet armyworm and other moths out.

The lesser canna leafroller is a small caterpillar related to the European corn borer, pickleworm, coneworms, sod webworms and others. The lesser canna leafroller overwinters as larvae in the leaves of canna and the moths emerge to mate and lay eggs after the new growth emerges in spring. When the larvae hatch, they feed within the new, still rolled up leaves. The lesser canna leafroller is not cannibalistic; several caterpillars can be found feeding inside one rolled leaf. The lesser canna leafroller caterpillars only feed on the upper epidermis and mesophyll. If not managed, lesser canna leafrollers may completely destroy the aesthetic value of cannas. Canna seems to be the only host plant for this pest, so that if the plants are somewhat remote from other cannas, it may be possible to drastically reduce the lesser canna leafrollers just by carefully removing all dead leaves and stems in the fall after the frost has killed it back. It is possible to eradicate this pest by using acephate as a spray several times during the growing season. *Bacillus thuringiensis* insecticides are also effective when sprayed directly downward into the rolled leaves so that the pesticide can soak into the shelter around the worms.

Flies — Narcissus bulb flies attack flowering bulbs in field-grown flowers, landscapes, and gardens. The flies emerge in May and lay eggs for a new generation of maggots. Trichlorfon seems to be the only insecticide labeled for bulb fly control. Leafminer flies, especially *Liriomyza trifolii*, were serious pests before the development of abamectin, cyromazine, and imidacloprid. Given the history of the development of pesticide resistance in fly populations, complete reliance upon chemicals for fly control does not seem like a good idea. Darkwinged fungus gnat maggots feed on fungi and decaying plant roots. As the maggots tunnel from dead roots into live roots and stems, they sometimes cause serious damage to

the plant. Shore flies and their maggots do little harm to ornamentals, but the presence of shore flies is a nuisance to growers, workers, and customers. Limiting excessive irrigation and controlling algae on which the maggots feed are two non-chemical methods of shore fly management.

Red imported fire ants feed mostly on soft-bodied insects such as maggots, grubs, and caterpillars. Occasionally, they have been reported consuming fleshy seedlings, buds or soft tissue of plants. These ants build mounds in any type of soil, but seem to prefer open, sunny areas such as lawns and pastures. The above ground part of the mound is only a small portion of the nest which may penetrate 3 feet into the soil. Fire ants sting readily, and a few people are hypersensitive enough to stings that they may have life-threatening systemic reactions. Baits or insecticide drenches control single mounds. Nests may reappear periodically. Red imported fire ants are a hazard to the workers and public.

Scale insects and mealybugs — Armored scale insects such as euonymus scale, tea scale, and white peach scale, are usually more prevalent in nurseries than in greenhouses. Soft scale insects such as brown soft scale and hemispherical scale are usually found on foliage plants indoors. Mealybugs are very difficult to control with spray applications. Some of the systemic pesticides such as imidacloprid give good control of soft scales and mealybugs, but systemic pesticides seem to have no effect on armored scale insects. Timing of spray treatments for soft scales and armored scales is important as the crawlers are much more susceptible to pesticides than older scales. Wax scales and soft scales that lay their eggs in white, fluffy ovisacs are susceptible to sprays in late May and early June. Magnolia scales and tuliptree scales are susceptible to sprays in the fall and early winter.

Thrips — Flower thrips and western flower thrips are the two most prevalent thrips pests of ornamentals in North Carolina. Flower thrips has one enormous late spring flight and a smaller late summer flight. Although it is not resistant to pesticides, the huge number of flower thrips makes greenhouse screening or frequent pesticide applications during the flight necessary. On the other hand, the western flower thrips does not seem to migrate in enormous numbers, but it has tolerance to many pesticides and it is a vector of impatiens necrotic spot virus. Spinosad is the most effective of the currently labeled pesticides for western flower thrips management. The label recommends not using spinosad on consecutive generations of thrips to slow the acquisition of pesticide resistance. Spinosad is also labeled for caterpillars, leaf beetles, leaf miners, gall midges, and spider mites. Abamectin gives very good thrips suppression. Avid also controls spider mites, broad mites and leafminers. In addition, methiocarb is labeled for aphids, mites, slugs and snails in the greenhouse, and it has been reported that Mesurol works well for western flower thrips control. Growers should consider rotating among chemical groups of pesticides, and monitoring with blue or yellow sticky cards.

Whiteflies — Greenhouse whitefly, silverleaf whitefly, and citrus whitefly are the three most important whitefly pests of ornamentals. Whiteflies resemble tiny, snow-white moths usually found on the undersides of leaves. Immature whiteflies are scale-like insects also found on the lower surface of leaves. Whiteflies infest a wide variety of ornamentals — even trees! Heavily infested plants become chlorotic and unthrifty. Honeydew and sooty molds further detract from the appearance of the crop. Uncontrolled whiteflies usually destroy the commercial value of ornamental plants. Chemical control with contact sprays is difficult because the eggs and immature forms are resistant to many aerosol and insecticide

sprays (except oxythioquinox). With contact sprays, one must make regular applications of pesticides to control emerging adults until the last of a whole generation of immature whiteflies has emerged. Horticultural oils (e. g. Sunspray, Ultrafine) and insecticidal soaps are labeled and remarkably effective for killing adults and crawlers considering that their residue is not toxic to whiteflies — only the wet spray. Imidacloprid and other newer systemics give adequate suppression.

Mites — Spider mites, false spider mites, tarsonemid mites (broad mite, cyclamen mite), and eriophyid mites damage ornamentals in North Carolina. Spider mites cause tiny yellowish spots to form as they feed. Predaceous mites and small lady beetles feed on spider mites and parasitic fungi infect these mites, especially in humid weather. Hot, dry weather apparently inhibits the parasitic fungi and speeds up the life cycle of two spotted spider mites. Spruce spider mites and southern red mites often die out in hot weather in the Piedmont and Coastal Plain, leaving only their eggs to survive. Butterfly bush, roses, and some other shrubs are susceptible to spider mites. Daylilies and flowering bedding plants are often infested by spider mites during the summer. Horticultural oils and soaps are moderately toxic to spider mites. Soaps and oils have virtually no residual activity so both pesticides may have to be applied two or three times for complete control (about 5 days in between sprays). Seventeen active ingredients are now labeled for spider mite management on ornamentals (abamectin, bifenthrin, chlorfenapyr, clofentezine, fenpropathrin, fenpyroximate, fluvalinate, hexythiazox, horticultural oil, lambda-cyhalothrin, methiocarb, Neem oil, pyridaben, propargite, and soap).

Broad mites and cyclamen mites infest a variety of ornamental plants (African violets, ageratum, azaleas, begonias, gerberas, gloxinias, lantana, maples, marigolds, snapdragons, verbena, zinnia, etc.). Broad mites are so small that they are virtually invisible on the host plants even with a good hand lens. Also the mites tend to crowd into the crevices and buds and feed on the growing tips. Their toxic saliva causes the twisted, hardened and distorted growth in the terminal of the plant. The effects of their feeding may persist long after the mites have been eradicated. Bifenthrin, chlorfenapyr (may be phytotoxic), endosulfan lambda-cyhalothrin, pyridaben, and abamectin control cyclamen mites and broad mites. Of these pesticides, only abamectin is translaminar to any real degree.

Slugs — Slug damage resembles that done by caterpillars or wireworms. Limacid and arionid slugs deposit a slimy mucous as they move about and they rasp away leaves and flowers. Methiocarb and metaldehyde are useful for slug management. Slugs and snails may consume several times their own body weight each night. Slugs are often attracted to fragrant blossoms and succulent leaves. Birds (up to 6% of the diet of starlings), ducks, moles, toads, shrews and carnivorous ground beetles, rove beetles, and firefly beetles feed on slugs. Sciomyzid flies and nematodes also parasitize slugs. In addition, slugs are preyed upon by omnivorous slugs such as the spotted garden slug. Dry weather sometimes kills up to 90 percent of slug eggs and young per year.

Insecticides, Miticides, and Molluscicides Labeled for Ornamentals

1. abamectin (Avid) — macrocyclic lactone: Abamectin is extracted from the soil bacterium *Streptomyces avermitilis*. Avid is useful for spider mite and leafminer control. It also helps control western flower thrips. {REI of 12 hours}

2. acephate (Orthene, Pinpoint, PT 1300) — organophosphate: It is labeled for many insects in greenhouses and nurseries, including fire ants. Aphids resistant to diazinon and other traditional organophosphates are somewhat susceptible to acephate. It is also labeled as a tank mix with fenpropathrin which makes fenpropathrin much more useful in nurseries and greenhouses. {REI of 24 hours }
3. acetamiprid (TriStar) —neonicotinoid: This is a foliar applied, translaminar and systemic insecticide labeled for aphids, mealybugs, and whiteflies. {REI of 24 hours }
4. azadirachtin (Azatin XL) — tetran- or triterpenoid plant extract: An insect growth regulator, azadirachtin give moderate control of whiteflies, aphids, thrips, fungus gnats, caterpillars, beetles, mealybugs, and leafminers. {REI of 4 hours }
5. *Bacillus thuringiensis* (Bactospeine, Bactur, Biotrol, Javelin, DiPel, Thuricide, Victory) — bacterium: Specific to caterpillars, *B. t.* gives control of young worms without harming beneficial organisms. {REI of 12 hours }
6. *Bacillus thuringiensis* H-14 (Gnatrol) — bacterium: Primarily used for darkwinged fungus gnat management, it is compatible with other biological control organisms. {REI of 4 hours }
7. *Beauveria bassiana* (BotaniGard, Naturalis-O) — parasitic fungus: It is labeled for aphids, mealybugs, thrips, whiteflies. It is compatible with other biological control organisms. {REI of 12 hours }
8. bifenazate (Floramite) — carbazate: It gives quick knock down and three weeks of residual control. It is compatible with biological controls. The manufacturer recommends rotating this product with other miticides for pesticide resistance management. {REI of 4 hours }
9. bifenthrin (PT 1800 Attain, Talstar) — pyrethroid: This pyrethroid controls aphids, armyworms, cutworms, fire ants, loopers, mealybugs, mites, and whiteflies. {REI of 12 hours }
10. carbaryl (Sevin) — carbamate: This broad-spectrum insecticide kills as a contact and stomach poison. Carbaryl is used to manage armyworms, leaf-feeding beetles, caterpillars, centipedes, cutworms, loopers, millipedes, pillbugs and sowbugs. {REI of 12 hours }
11. chlorfenapyr (Pylon) — pyrrole: Originally labeled for broad mite, cyclamen mite, and spider mites, it is now labeled for use against foliar nematodes on greenhouse ornamentals. {REI of 12 hours }
12. clofentezine (Ovation) — tetrazine: This restricted use pesticide is labeled to control mites on commercial ornamental plants grown in greenhouses, saran and shade houses, outdoor containers and field grown nursery stock. {REI of 12 hours }

13. cryolite (Kryocide) — sodium aluminofluoride: It has limited labeling (codling moth and Fuller rose beetle on woody ornamentals). {REI of 12 hours}
14. cyfluthrin (Decathlon) — pyrethroid ester: This is broadly labeled for insects in greenhouses, nurseries, and landscapes (but not spider mites other than clover mites). {REI of 12 hours}
15. cyromazine (Citation) — insect growth regulator: This chitin synthesis inhibitor is labeled primarily for dipterous leafminers. {REI of 12 hours}
16. diflubenzuron (Adept) — insect growth regulator: It is labeled for armyworm, fungus gnat, shore fly, and whitefly in greenhouses. {REI of 12 hours}
17. endosulfan (Thiodan) — chlorinated hydrocarbon: It is a cyclodiene for aphid, whitefly, and mite management. {REI of 24 hours}
18. fenoxycarb (Award, Logic, Preclude, Precision) — carbamate and insect growth regulator: This juvenile hormone mimic acts on the immature stages of fire ants, fungus gnats, scale insects, shore flies, and whiteflies. Although alternative pesticides exist for these troublesome pests, it is always a good idea to maintain a mix of pesticides classes and modes of action for pest suppression so that growers can meaningfully rotate pesticides to minimize the acquisition of pesticide resistance by insects and mites. {REI of 12 hours}
19. fenpropathrin (Tame) — pyrethroid ester: It is used to manage aphids, whiteflies, and spider mites. {REI of 24 hours}
20. fenpyroximate (Akari) — phenoxy pyrazole miticide: It gives quick knockdown of mites and 3 to 4 weeks of residual control. Fenpyroximate shares a similar (METI) mode of action with pyridaben so it is not a good idea to rotate between these two chemicals. {REI of 12 hours}
21. fluvalinate (Mavrik) — pyrethroid ester: This pyrethroid is used to manage aphids, mites, thrips and mealybugs (except for resistant species). {REI of 12 hours}
22. hexythiazox (Hexygon) — carbamate: This miticide acts on eggs of twospotted spider mites on ornamentals (plants, trees and vines) growing in greenhouses and commercial nurseries. {REI of 12 hours}
23. horticultural oil (Ultra Fine, Sun Spray) — highly refined petroleum oil: Although labeled for numerous pests, oils excel at controlling armored scale insects and (at the dormant season rate) spider mite and aphid eggs. {REI of 4 hours}
24. hydromethylnon (Amdro Pro) — trifluoromethyl aminohydrazone metabolic inhibitor: This

product is labeled primarily for fire ant management in nurseries. {REI of 12 hours}

25. imidacloprid (Marathon, Merit) — chloronicotinyl: This works well against a number of otherwise pesticide-resistant aphids and whiteflies. Because it is labeled for numerous crops across the world, resistance will doubtlessly arise in aphids and whiteflies. {REI of 12 hours}
26. Kinoprene (Enstar II) — insect growth regulator: This juvenile hormone mimic is used for management of scales, whiteflies and mealybugs. {REI of 4 hours}
27. lambda-cyhalothrin (Scimitar, Topcide) — pyrethroid ester: This is labeled for several important greenhouse pests including aphids, caterpillars, mealybugs, soft scale insects, and spider mites. {REI of 24 hours}
28. malathion — organophosphate: This is one of the early organophosphate that still has usefulness primarily for mealybugs. It is relative safe to humans. {REI of 12 hours}
29. metaldehyde (Deadline) — aldehyde: Metaldehyde is extremely useful for slug management.
30. methiocarb (Mesurol, PT1700) — carbamate: Methiocarb is an extremely useful pesticide for control of slugs, snails, aphids, mites and western flower thrips. The 75% WP formulation is restricted for use in greenhouses and nurseries only. {REI of 24 hours}
31. naled (Dibrom) — organophosphate: This venerable organophosphate is labeled for aphids, caterpillars, leafrollers, and mealybugs in greenhouses. {REI of 24 hours}
32. neem oil (Triact, Trilogy) — highly refined oil extracted from neem seeds: It is labeled for armored scales, aphids, leafhoppers, and spider mites. {REI of 4 hours}
33. novaluron (Pedestal) — benzoylurea insect growth regulator: This product is labeled for armyworms, caterpillars and thrips in greenhouses. {REI of 12 hours}
34. permethrin (Astro, Permethrin Pro, Pounce, Pramex) — pyrethroid ester: This product is labeled for a variety of leaf-feeding and boring insects in greenhouses and nurseries. Although some aphids and whiteflies are resistant to it, permethrin is still useful for many other pests. {REI of 24 hours}
35. phosmet (Imidan) — organophosphate: This is only synthetic petrochemical used by organic farmers because they have no other alternative for plum curculio control. Phosmet even in its 70% WSB formulation is not a restricted use pesticide, and it has good labeling for caterpillar and beetle pests ornamental trees. {REI of 24 hours}
36. propargite (Ornamite) — sulfite ester acaricide: This product is labeled for spider mites in the

greenhouse. {REI of 7 days)}

37. pymetrozine (Endeavor) — pyridine azomethines: It apparently paralyzes the sucking mechanism of aphids and whiteflies. {REI of 12 hours }
38. pyrethrins (Pyrenone, PT 1100, PT 1600, PT 1700 X-clude) — plant extract: Although very susceptible to UV breakdown, these give excellent knockdown. {REI of 4 hours }
39. pyridaben (Sanmite) — pyridazinone: This product blocks cellular respiration, causing pests to lose mobile coordination and collapse. {REI of 12 hours }
40. pyriproxifen (Distance) — insect growth regulator: This product is labeled primarily for sucking pests, a few caterpillars, fire ants, shore flies and fungus gnats. {REI of 12 hours }
41. soap (M-Pede, Olympic Insecticidal) — salt of fatty acid: Soap gives moderate knock down of aphids, spider mites, and whiteflies. Soaps are compatible with biological control programs. Phytotoxicity may occur if insecticidal soaps are applied repeatedly. {REI of 12 hours }
42. spinosad (Conserve) — macrocyclic lactone: This has broad labeling for caterpillars, fire ants, and other pests of greenhouse and nursery-grown plants that spinosad controls adequately, but its excellent control of western flower thrips makes spinosad especially useful for greenhouse flower growers. {REI of 4 hours }
43. tefufenozide (Confirm) — insect growth regulator: This product accelerates the molting of caterpillars. {REI of 4 hours }
44. thiamethoxam (Flagship) — systemic neonicotinoid insecticide: This is a systemic pesticide for sucking insects, especially phloem feeders such as aphids and whiteflies. {REI of 12 hours }

Insecticide, Miticide, and Molluscicide Use Estimates — In North Carolina greenhouses, pesticides with reentry intervals longer than 12 hours are generally not preferred by growers, which greatly limits the use of acephate, acetamiprid, endosulfan, mesurool, naled, permethrin, and propargite. Abamectin (especially for thrips), fluvalinate, imidacloprid, kinoprene, and soap (often used as an adjuvant) are the most frequently used insecticides in greenhouses. Bifenazate, pymetrozine, pyridaben, and spinosad (especially for thrips) are used "some" of the time. Acetamiprid, bifenthrin, diflubenzuron, fenoxycarb, fenpropathrin, and oil are used "occasionally." Azadirachtin, *Beauveria bassiana*, endosulfan, methiocarb, and permethrin tend to be "rarely" used. Growers often maintain stocks of insecticides that are occasionally, rarely, or never used just in case a rare pest flairs up or because of the trouble of disposing of pesticides.

In North Carolina nurseries, 24 hour reentry intervals are less troublesome because workers are in less contact with plants and because the frequency of insecticide applications is lower than in greenhouses.

Acephate and hydromethylnon (for fire ants) are heavily used. Abamectin (for mites), bifenthrin, carbaryl, endosulfan, fluvalinate, imidacloprid, and oil are industry standards for pest management. Less commonly used are acetamiprid, cyfluthrin, hexythiazox, malathion, and soap. As in the case with greenhouse growers, nurserymen often maintain inventories of pesticides that are rarely used.

Weed Pests of Ornamentals

Many kinds of plants become weed pests in greenhouses, nurseries, and landscapes. Both weed plants and seeds can be transported in soil and root balls and introduced on equipment. Seeds can be blown into a site by the wind or carried by wildlife. Management of weeds should combine cultural as well as chemical control. Weeds compete for water, light, space, and nutrients and weeds can also harbor insect, mite, and disease pests of ornamentals. Predominant weeds change by season, but the following are usually fairly common. Thus far, the acquisition of resistance to herbicides has not been a major problem in field-grown nursery stock, and rotation among classes of herbicides does not seem to be necessary.

Bermudagrass is a creeping perennial that is dormant during the winter and buds out from underground roots called rhizomes the following spring. It blooms throughout the summer. Seeds form on four or five very narrow fingers on the tip of a slender, leafless stalk. In plant beds landscapers use ground cover fabrics to suppress Bermudagrass. Hand pulling is not effective because the underground rhizomes are hard to pull up completely. The rhizomes that escape from hand pulling soon shoot up more plants. Selective grass herbicides can be used to control Bermudagrass in plant beds.

Common chickweed is a fairly common winter and spring weed. Its flower petals vary from small, white, and star-shaped to inconspicuous or absent. The leaves are round, and the lower ones have petioles. The upper leaves sit against the stem. The stems are weak and the plants sprawl along the ground as they mature. Common chickweed reproduces by seed and sometimes becomes quite abundant, forming low, dense patches of bright green. The creeping stems root at the nodes where they form a fibrous root system. Common chickweed prefers cool, moist, shady areas, although it can survive in compacted soils.

Crabgrasses germinate from March through early May and live until frost in the fall. When large crabgrass and smooth crabgrass are young, the plants are prostrate, with pale stems branching from the center. Crabgrasses become branched and upright when crowded. Both large and smooth crabgrass are common and grow best with adequate light and moisture. The leaves of large crabgrass are hairy, pale blue green, and 2 to 6 inches long. Smooth crabgrass has smooth, dull green leaves 1 to 4 inches long with sharply pointed ends (leaves are slightly hairy near the stem). In August and September, the flowers and seeds of crabgrasses extend like fingers from the tip of a stalk.

Dallisgrass is a coarse, fast-growing, perennial grass that produces abundant seeds. Dallisgrass can rapidly invade landscapes. If un-mowed, the plant grows 1 to 4 feet high in clumps. The seed stalks are 1 foot or more tall, and the flower head has 3 to 5 terminal branches that open out and then droop. The leaf sheath is a little flat and hairy at the base, and it is usually tinged red. The leaf sheath appears slightly

bloated. Leaves are produced near the base of the plant on short shoots that form a knotty mass of very short rhizomes. Although the tillers do not root at the nodes as crabgrass does, dallisgrass grows faster than most desirable turfgrasses, which increases the need for frequent mowing.

Florida betony or rattlesnake weed grows in full sun to partial shade and tolerates both wet and dry soils. Some of the roots are tubers that resemble a rattlesnake's tail. In the fall, new plants sprout from seeds and tubers. Florida betony grows rapidly during the winter. Its narrow leaves grow in pairs on square stems. The pink to white flowers are shaped like those of other mints, and appear in late spring and early summer. The flowers occur in groups of three to nine at the base of the leaves. Hot weather and extremely cold weather force Florida betony to become dormant. Mulch and fabric weed barrier under the mulch will help manage Florida betony. Pull by hand when soil is moist to prevent tubers from breaking off and sprouting new plants. Spot treatments with non-selective herbicides can be used if the Florida betony is not intertwined with ornamental plants.

Henbit is a small, wild mint that branches at ground level and grows from 3 to 12+ inches high. When henbit is chopped into pieces, some pieces may root. The stems are square, and the opposite, dark green leaves are hairy on top with crinkled edges. The lowest leaves have petioles, but the upper leaves attach directly to the stem and may wrap around the stem. From April to June, henbit has 3/4 inch, purple, tube-shaped flowers in groups just above the upper leaves. The plants die down in summer, and seeds survive to sprout in the fall.

Prostrate spurge germinates at soil temperatures from about 60 ° F to over 90° F. Prostrate spurge grows right at the soil surface. It has a central taproot, and the branches form a mat up to 2 feet wide. The leaves are small (5/8 inch or less), oval, and close to the stem. They may be hairy or have small purple spots. Prostrate spurge blooms from June through October. The flowers are very small and occur in clusters at the bases of the leaves and at the tips of the branches. Landscapers pull this weed by hand in plant beds. Herbicides work when the situation allows their use.

Woodsorrel (sometimes called *Oxalis*) is a perennial most obvious during the cool season, but new seedlings also pop up during the summer. The small, bushy, yellow-green plant grows from a central taproot. Woodsorrel leaves are up to 3/4 inch across and have three heart-shaped leaflets. The stems are slender and sometimes root at the nodes. It blooms from May to September. The yellow flowers are about 1/2 inch across and have five petals. One to four flowers appear at the end of each stem. The seed pods are about 1 inch tall and are on slender stalks. When dry, the pods break open suddenly if touched and throw the seed as far as 6 feet. Woodsorrel reproduces from stem pieces as well as from seed and should be hoed or hand pulled from plant beds.

Yellow nutsedge is a most conspicuous during the warm growing season where it appears like a pale-green, upright, weedy grass. Yellow nutsedge spreads rapidly in moist soils from rhizomes that produce nutlets. The leaves are shiny and waxy on top and dull on the backside. The fibrous roots are mixed with rhizomes. The nutlets form at the end of each rhizome. These nutlets are actually tubers that can persist in the soil for months or years. Yellow nutsedge flowers are at the top of a triangular stem. The flowers form a branched, flat-topped, straw-colored burr. Yellow nutsedge blooms from July through September.

Herbicides Registered for Ornamentals

1. benefin + oryzalin (XL) — dinitroaniline: This product is labeled for annual grass weeds and broadleaf weeds. {REI of 24 hours}
2. bentazon (Basagran TO): — triazine: This photosynthesis inhibitor is labeled for sedges and other selected weeds in turf and some ornamentals. {REI of 12 hours}
3. clethodim (Envoy) — cyclohexanedione, chemically similar to sethoxydim: This product is a selective postemergence labeled for control of weedy grasses (but not sedges or broadleaf weeds). {REI of 24 hours}
4. clopyralid (Lontrel, Stinger) — dinitroaniline: This post-emergent herbicide controls certain broadleaf weeds in turf and ornamentals grasses in nurseries and landscapes. {REI of 12 hours}
4. dazomet (Basamid G) — other: This soil fumigant is useful for most annual and perennial weeds. {REI of 24 hours}
5. dichlobenil (Barrier, Casoron) — nitrile: This pre-emergent herbicide is labeled for annual grass, broadleaf weeds, and perennial weeds. {REI of 12 hours}
6. diquat bromide (Diquat, Reward): This is a post-emergent, quick-acting herbicide applied as a directed spray to kill most young annual weeds. It has no residual activity in the soil, and perennials are likely to resprout. {REI of 12 hours}
7. dithiopyr (Dimension) — pyridine: This is a pre-emergent herbicide for annual grass and broadleaf weeds in turf. {REI of 12 hours}
8. EPTC (Eptam): This is a thiocarbamate herbicide labeled for controlling annual and some perennial weeds, most notably purple nutsedge (*Cyperus esculentus*) and mugwort (*Artemisia vulgaris*) in ornamental plantings. However, this herbicide has a relatively short residual and consequently is not frequently used. Furthermore, there are effective alternatives in the marketplace.
9. fenoxaprop-P (Acclaim Extra) — aryloxyphenoxy propionate, chemically similar to fluazifop-P: This is a post-emergent herbicide for annual grass and perennial weed control. {REI of 12 hours}
10. fluazifop-P (Fusilade II, Ornamec) — aryloxyphenoxy propionate, chemically similar to fenoxaprop-P: This is a post-emergent herbicide for annual grass and perennial weed control.
11. glufosinate (Finale) — phosphinic acid: This is a post emergence herbicide labeled for most

annuals and perennials in the greenhouse. {REI of 12 hours}

12. glyphosate (Glyphos, Roundup Pro, Touchdown Pro) — glycine: This is a post-emergent, nonselective herbicide that kills grasses, broadleaf weeds and sedges around container beds and in field nurseries. Glyphosate is a systemic herbicide that requires between 3 and 10 days to kill most weeds, but may require a second application for nutsedge, bermudagrass and other weeds that have underground storage organs. {REI of 12 hours}
13. halosulfuron (Manage) — sulfonyleurea: This product is labeled as a post-emergent selective herbicide for sedge management. {REI of 12 hours}
14. imazaquin (Image) — imidazolinone: This product is a pre-emergent or post-emergent herbicide for annual grasses, broadleaf weeds, and sedges. {REI of 12 hours}
15. isoxaben (Gallery) — benzamide: This product is a preemergence herbicide labeled for annual grasses and broadleaf weeds. {REI of 12 hours}
16. isoxaben + trifluralin (Snapshot) — benzamide + dinitroaniline: This mixture is a pre-emergent herbicide for grasses and broadleaf weeds, including common chickweed, spurge, wood sorrel and annual grasses. {REI of 12 hours}
17. metolachlor (Pennant) — chloroacetamide: This is a pre-emergent herbicide labeled for annual and broadleaf weed management. {REI of 24 hours}
18. methylcarbamidithioic acid (Vapam) — other: This is a soil fumigant that is useful for most annual and perennial weeds. The green industry is concerned about the loss of this product. It is an important alternative to methyl bromide. It can be used for pre-plant soil fumigation in nursery seedbeds, liner beds and fields. It can also be used in landscape beds. Currently it does not have wide usage in ornamentals, but when methyl bromide is no longer available use of this product is likely to increase dramatically unless another, more effective alternative is identified. It also controls soil insects and provides some control of nematodes and fungal pathogens. {REI of 48 hours}
19. napropamide (Devrinol) — acetamide: This is a pre-emergent herbicide labeled for annual grasses and broadleaf weeds. {REI of 12 hours}
20. napropamide + oxadiazon (Pre Pair) — acetamide + oxadiazole: This mixture is a combination of two pre-emergent herbicides labeled for most nursery weeds. {REI of 12 hours}
21. norflurazon (Predict) — pyridazinone: This is a pre-emergent herbicide labeled for annual grasses and broadleaf weeds. {REI of 12 hours}

22. oryzalin (Surflan) — dinitroaniline: This is a selective, pre-emergent herbicide used for the control of annual grasses and many broadleaf weeds. {REI of 12 hours}
23. oxadiazon (Chipco Ronstar) — oxadiazole: This is a pre-emergent herbicide is effective on most nursery weeds, but not sparges and common chickweed. {REI of 12 hours}
24. oxyfluorfen (Goal) — diphenylether: This is a pre-emergent herbicide labeled for annual and broadleaf weeds. {REI of 24 hours}
25. oxyfluorfen + oryzalin (Rout) — diphenylether + dinitroaniline: This is a broad-spectrum, pre-emergent herbicide mixture used in the control of many weeds found in nurseries, including sparges. {REI of 24 hours}
26. oxyfluorfen + oxadiazon (RegalStar) — diphenylether + oxadiazole: This is a pre-emergent herbicide mixture labeled for annual grasses and broadleaf weeds. {REI of 12 hours}
27. oxyfluorfen + pendimethalin (Ornamental Herbicide 2) — diphenylether + dinitroaniline: This mixture is a pre-emergent herbicide used to control a variety of nursery weeds, particularly sparges. {REI of 24 hours}
28. paraquat (Gramoxone Extra) — bipyridylum: This is a post-emergent, quaternary nitrogen herbicide used for annual weed control. {REI of 12 to 24 hours}
29. pelargonic acid (Scythe) — other: This is a post-emergent herbicide labeled for most annual and perennial weeds including use in greenhouses. {REI of 24 hours}
30. pendimethalin (Hurdle, Pendulum/Turf and Ornamental Weedgrass Control) — dinitroaniline: This pre-emergent herbicide used in the control of some annual grasses and some broadleaf weeds, including prostrate spurge, common chickweed and woodsorrel. {REI of 12 hours}
31. prodiamine (Factor) — dinitroaniline: This is a broad-spectrum, pre-emergent herbicide used to control a range of weeds, including sparges. Prodiamine is the predominant pre-emergent herbicide used in the cut foliage industry. {REI of 12 hours}
32. propyzamide (Kerb) — benzamide: This product controls annual grasses and broadleaf weeds with pre-emergent or early post emergent application. {REI of 12 hours}
33. sethoxydim (Vantage) — cyclohexanedione, chemically similar to clethodim: This product is a selective postemergence labeled for control of weedy grasses (but not sedges or broadleaf weeds). {REI of 24 hours}
34. simazine (Princep) — triazine: This is a pre-emergent herbicide used for annual grass and

broadleaf weeds. {REI of 12 hours}

35. s-metolachlor (Pennant Magnum) — chloroacetamide: This is a pre-emergent herbicide used for annual grass and broadleaf weeds. {REI of 24 hours}
36. trifluralin (Preen, Treflan) — dinitroaniline: This is a pre-emergent herbicide labeled for annual and broadleaf weeds. {REI of 12 hours}

Herbicide Use Estimates — In North Carolina greenhouses, glufosinate is the most widely used herbicide. Glyphosate is the most used herbicide in North Carolina nurseries. Paraquat and sethoxydim are also frequently used for weed management in nurseries.

Nematode Pests of Ornamentals

Foliar nematodes are becoming increasingly common on a wide range of herbaceous and woody ornamental plants grown in greenhouses and nurseries. Abelia, ferns, hosta, lantana, salvia, and viburnum are just a few examples of the 250+ known plant species susceptible to foliar nematodes and that have been seen infested with foliar nematodes in North Carolina nurseries. A 400% increase in the number of ornamental plant samples diagnosed with foliar nematodes was recorded between 1990 and 2000 at the North Carolina State University Plant Disease and Insect Clinic. Foliar nematodes are expected to become an even larger problem due to extremely limited management options available for control. Foliar nematodes generally go undetected until physical plant damage is observed. There is no cure for foliar nematodes, and exclusion is currently the best option for control. To control foliar nematodes, managers need a more effective nematicide than chlorfenapyr for use on both greenhouse and nursery grown crops.

Nematicide Registered on Ornamentals

1. chlorfenapyr (Pylon) — pyrrole: Originally labeled for broad mite, cyclamen mite, and spider mites, it is now labeled for use against foliar nematodes on greenhouse ornamentals (the only nematicide labeled for foliar nematodes in the U.S.). However, experimental trials on naturally infested lantana and abelia have found this product to be ineffective in eradicating foliar nematodes, but success has been reported on other hosts grown under greenhouse conditions.

Disease Pests of Ornamentals

Fungal leaf spot diseases: Numerous fungi are capable of causing foliar leaf spots on both nursery and greenhouse grown ornamentals. Infection is typically favored by high humidity and leaf surfaces that remain wet for extended periods of time enabling fungal spores to germinate and infect. Because the

quality and marketability of ornamental crops is highly dependent upon appearance, there is a zero tolerance in production nurseries and greenhouses for most leaf spot diseases. Because of this, fungicide applications must be made preventatively or at the very first sign of disease, which is often before the fungal pathogen can be positively identified. Broad-spectrum fungicides, such as chlorothalonil, propamocarb, and mancozeb, are among the most commonly applied foliar fungicides by North Carolina nursery growers. Many of the newer, low-risk fungicides are systemic in nature, and present a greater risk of fungal pathogens developing resistance to the fungicide. The broad-spectrum fungicides when used in rotation with the systemic fungicides generally provide good efficacy and lower the risk of resistance.

Bacterial leaf spot diseases— Bacterial leaf spot diseases can be difficult to control in part due to the rapid rate of multiplication of the pathogen, but also by the limited effectiveness of bactericides. Copper-containing fungicides are typically used for bacterial leaf spot diseases, but resistance to copper among bacterial populations has been well documented in other parts of the country. The use of copper and mancozeb together has provided reasonable control of bacterial leaf spot diseases when trailed on several ornamental crops. Cultural management is equally if not more important in managing bacterial leaf spot diseases. English Ivy, cherry laurel, and chrysanthemum are commonly infected by bacterial leaf spot pathogens. And in the past two years, a bacterial leaf spot disease of holly has occurred in several nurseries.

Black root rot (*Thielaviopsis* sp.) — Development of black root rot is favored by high soil pH and low soil temperatures. This fungus can persist in the soil for many years, even in the absence of susceptible plants. When roots of a susceptible plant grow near persistent spores in the soil, the spores germinate infect the root tip and turn it black as infection progresses and more spores are formed on the root. The fungus is dispersed by spores carried by water, wind, equipment and infected transplants. Black root rot reduces plant vigor and causes stunting of terminal growth, shortening of internodes and interveinal chlorosis. Diseased plants usually decline over a period of months and frequently die during or following dry periods. Black root rot is an ongoing problem in bedding plant production, especially on pansy, annual vinca, petunia, and million bells. In nursery production, Japanese hollies are highly susceptible to black root rot.

Damping off — Damping-off is a common disease of seeds and seedlings caused primarily by *Pythium* and *Rhizoctonia*. Pre-emergence damping-off affects germinating seeds and prevents emergence and stand establishment. Post-emergence damping-off causes young seedlings to collapse and die. The fungi cause a stem lesion at the base of the seedlings that girdles the stem causing the seedling to collapse. Seedlings affected by post-emergence damping-off typically die in a concentric pattern radiating away from a central point of initial infection in a seedling tray. *Pythium* damping-off is usually favored by over watering. *Rhizoctonia* damping-off is favored by humid, warm conditions. Several other fungi such as *Fusarium*, *Thielaviopsis*, and *Botrytis* also cause damping-off under unfavorable growing conditions. Proper media preparation to provide good soil drainage, structure, aeration, water-holding capacity and plant nutrition helps prevent damping off. Proper seeding rates and good sanitation help manage damping off, too. Fungicides such as etridiazole, fludioxonil, mefenoxam, or etridiazole + thiophanate methyl should give adequate control providing an accurate diagnosis of the responsible pathogen is made..

Gray mold (*Botrytis*) — This fungus attacks senescing plant tissue such as the petals of flowering ornamentals such as African violet, begonia, chrysanthemum, exacum, geranium, impatiens, marigold, poinsettia, snapdragon, flowering ornamentals particularly during periods of high humidity and little air movement. Leaves often become infected where petals have fallen on the leaf tissue. It is the most common foliage disease on greenhouse grown crops and is difficult to control without careful monitoring and management of the environmental conditions in the greenhouse. Lesions on infected plants produce a multitude of spores giving the disease its common name ‘gray mold.’ The spores are liberated by air currents, watering, or any worker-associated activity such as disbudding, pruning, or spraying pesticides. Fenhexamid, chlorothalonil and strobilurin fungicides provide some prevention of disease but fungicide resistance is common to thiophanate-methyl and dicarboximide based fungicides.

***Phytophthora* root rot** — This is a common problem on flowering ornamentals such as azalea, camellia, interiorscape plants, rhododendron, snapdragon, as well as boxwood. *Phytophthora* infects over 900 other plant hosts. *Phytophthora* kills the roots and root crown of infected plants. All species of *Phytophthora* require extended periods of high soil moisture to cause disease, so avoid over watering and poor drainage. Infected plants are often stunted, have small leaves, and the roots are brown and rotted. At the base of stems near the soil line, infected wood under the bark is brown instead of a healthy white. Leaves may wilt and plants may appear to die suddenly when hot, dry weather begins. The roots of resistant cultivars that have been stressed by drought or flooding become susceptible.

Powdery mildews — Many ornamental plants are susceptible to one or more species of powdery mildew fungi. The first signs of powdery mildew are patches of white powdery-looking fungal colonies on the leaf surfaces and stems. Infection is favored by cool nights with high relative humidity (above 85%) followed by warm dry days with temperatures between 70° and 80° F. Unlike most other fungal leaf spot diseases, free water on the leaf surfaces suppresses spore germination. Azalea, begonia, calendula, chrysanthemum, crabapples, crapemyrtle, dogwood, euonymus, gerbera, grape ivy, hydrangea, phlox, poinsettia, rose, snapdragon, verbena, veronica, and zinnia are often infected with powdery mildew. Infected leaves may become puckered and distorted. New growth may become twisted and deformed, and infected flower buds do not open properly. Once powdery mildew growth is extensive, it is usually too late for fungicides to restore plant appearance.

***Pythium* root rot** — Greenhouse flowering crops such as flowering annuals, chrysanthemum, interiorscape plants, lily, poinsettia, snapdragon, verbena, and zinnia are all susceptible to *Pythium* root rot when grown in soil conditions that are wet and poorly-drained. Infected plants are stunted and grow poorly, and severely infected plants die. The fungus survives in the soil on dead plant material. Plants that are crowded and too succulent are particularly vulnerable. Using pathogen-free potting media and disease-free plants help control *Pythium* in growing areas. Fungicides for the control of *Pythium* on many ornamental plants include fosetyl-aluminum, propamocarb, mefenoxam, etridiazole, and thiophanate-methyl + etridiazole.

Rhizoctonia — This fungus causes root rot of greenhouse flowering crops (annuals, chrysanthemum, lily, and poinsettia) and stem rot of other flowers (begonia, celosia, impatiens, poinsettia, salvia, and zinnia). *Rhizoctonia* also causes web blight of azalea and other bunchy shrubs during hot, humid weather when

infected soil splashes onto the leaves. Aerial symptoms can develop rapidly. Fludioxonil and thiophanate-methyl are considered moderately effective in managing *Rhizoctonia* diseases, but pathogen-free potting media and other sanitation practices are probably more important.

Rust — Rust pathogens are typically quite host specific, and usually require two different hosts in which to complete their lifecycle. Snapdragons, asters, and hollyhocks are common hosts. Geranium rust shows up occasionally and primarily affects *Pelargonium x hortorum*, especially zonal geraniums, where it infects the leaves and sometime the petioles and stems during cool, moist conditions. On the bottom of infected leaves, tiny pale yellow spots appear and eventually turn into rusty brown spore pustules. Concentric rings of pustules may form around the original spot. Infected leaves turn yellow, dry up, and fall prematurely. Using culture-indexed cuttings in clean greenhouses helps control geranium rust. Removal of infected leaves and plants and discarding any leftovers also helps, and reducing relative humidity should help inhibit this rust.

Fungicides Registered for Ornamentals

1. *Agrobacterium radiobacter* (Galltrol) — bacterium: This product, based on a biological control, is used to control crown gall of euonymus as a preplant root dip in nurseries.
2. azoxystrobin (Heritage) — strobilurin: This product is labeled for greenhouse and nursery for downy mildew, fungal leaf spots, powdery mildew, root rots, and rust control on annual, perennial, bedding, and flowering potted plants as well as woody ornamentals. {REI of 4 hours}
3. chlorothalonil (Concorde, Daconil Ultrex, Echo 720, Termil, 2787) — chloronitrile: This product is one of the most widely used fungicides in this industry. It is used as foliar spray, a soil drench, and as a greenhouse fumigant/smoke in the greenhouse industry (Termil). The product is labeled on numerous crops and has long standing grower acceptance and is valuable in pesticide resistance management of fungal leaf spots, powdery mildew, rust and *Botrytis* diseases. {REI of 48 hours}
4. chlorothalonil + thiophanate methyl (Spectro 90) — chloronitrile + benzimidazole: This product is labeled for *Alternaria* leaf spot, *Botrytis* blight, powdery mildew, rust, and *Phytophthora* aerial shoot blight on foliar diseases annual, perennial, bedding, and flowering potted plants in greenhouses. {REI of 12 hours}
5. copper hydroxide (Kocide 2000 T/N/O, Nu-cop) — : This inorganic fungicide helps control *Alternaria* diseases, anthracnose, bacterial leaf spots, *Botrytis*, *Entomosporium*, and *Volutella*. {REI of 48 hours}
6. copper hydroxide + mancozeb (Junction) — dithiocarbamate: This product is labeled for bacterial leaf spots, *Botrytis* blight, and fungal leaf spots, on foliar diseases, annual, perennial, bedding, and flowering potted plants in greenhouses. {REI of 24 hours}

7. . copper sulfate (Camelot) — complex copper: This product is labeled for bacterial leaf spots on annual, perennial, bedding, and flowering potted plants in greenhouses. {REI of 12 hours}
8. copper sulfate pentahydrate (Phyton 27) — complex copper: This product is labeled for bacterial leaf spots, *Botrytis*, downy mildew, and scab control on annual, perennial, bedding, and flowering potted plants in greenhouses. {REI of 12 hours}
9. dimethomorph (Stature DM) — morpholide in the family cinnamic acid amide: This newly registered product is effective against *Phytophthora* root when applied as a preventative drench. This product is valuable as a rotational product with Subdue MAXX. {REI of 12 hours}
10. etridiazole (Terrazole, Truban, etc.) — thiadiazole: This product is very widely used in greenhouses and nurseries as a soil drench on bedding plants, container and foliage plants to control root rot caused by *Pythium* and *Phytophthora*. Subdue Maxx is the most widely used product for control of these two pathogens but there is concern about resistance to Subdue Maxx. {REI of 12 hours}
11. etridiazole + thiophanate methyl (Banrot) — thiadiazole + benzimidazole: This mixture is applied to the soil mix at seeding or transplanting or as a drench on bedding, foliage, and container plants to manage *Fusarium* root and crown rot, as well as root rots and damping-off in greenhouses and nurseries where *Pythium*, *Rhizoctonia* or *Thielaviopsis* is a problem. {REI of 12 hours}
12. fenarimol (Rubigan AS) — pyrimidine: This product is labeled for powdery mildew and rust on annual, perennial, bedding, and flowering potted plants in greenhouses and nurseries. {REI of 12 hours}
13. fenhexamide (Decree) — hydroxylanilide: This product is labeled for *Botrytis* blight on geranium and other flowering ornamentals in greenhouses and nurseries. {REI of 4 hours}
14. fludioxonil (Medallion) — phenylpyrrole: This product is labeled for *Alternaria* leaf spot, *Botrytis* blight, *Cylindrocladium* root rot , *Rhizoctonia* stem blight, *Rhizoctonia* damping off and root rot, and *Thielaviopsis* spp. root rot in greenhouses and nurseries. {REI of 12 hours}
15. flutolanil (Contrast) — anilide (oxathiin): This product is labeled for *Rhizoctonia* aerial blight, stem blight, and root rot as well as *Sclerotium* blight in greenhouses and nurseries. {REI of 12 hours}
16. fosetyl-aluminum (Aliette) — : This systemic organic phosphate fungicide is sprayed and drenched in greenhouses and nurseries to control downy mildew and fire blight, as well as diseases caused by *Phytophthora*, *Pythium*, and *Xanthomonas*. {REI of 12 hours}
17. iprodione (Chipco 26GT, Chipco 26019, Sextant) — dicarboximide: This contact fungicide is

- drenched or sprayed in greenhouses and nurseries to control diseases caused by *Alternaria*, *Bipolaris*, *Botrytis*, *Drecholera*, *Exserohilum*, *Fusarium*, *Monilinia* and *Rhizoctonia*. {REI of 12 hours}
18. kresoxim-methyl (Cygnus) — strobilurin: This product is labeled for powdery mildew, rust, and black spot in greenhouses and nurseries. {REI of 12 hours}
 19. mancozeb (Dithane T/O, Fore, Mancozeb DB, Protect T/O) — ethylene (bis) dithiocarbamate (EBDC): This product is widely used in the ornamental industry. It is labeled for use on numerous crops and pathogen species. This product is very old but is critical in fungicide resistance management. {REI of 24 hours}
 20. mancozeb + dimethomorph (Duosan, Stature WP, Zyban) — ethylene (bis) dithiocarbamate (EBDC)+ Cinnamic Acid Derivative: This mixture is a broad-spectrum, systemic protectant spray to control anthracnose, black spot, downy mildew, flower blight, powdery mildew, scab and rust in greenhouses and nurseries. {REI of 12 or 24 hours}
 21. mefenoxam (Mefenoxam 2, Subdue MAXX) — acylamine benzenoid: This product controls *Phytophthora* and *Pythium*, as a seed treatment to control damping-off, and as a foliar spray for bedding, foliage, flowering and woody ornamentals in greenhouses and nurseries. {REI of 12 hours}
 22. myclobutanil (Systhane, Eagle, Immunox) — triazole: This product is labeled for powdery mildew, rust, leaf spots, Scab, and petal blight in greenhouses and nurseries. {REI of 24 hours}
 23. neem oil (Triact 70) — Clarified hydrophobic extract of neem oil: This product is labeled for powdery mildew on annual, perennial, bedding, and flowering potted plants in greenhouses and nurseries. {REI of 4 hours}
 24. PCNB (Terraclor, Revere) — aromatic Hydrocarbon: This product is used in greenhouses and nurseries as a drench at seeding or transplanting or as a premix into the potting mix. It is useful on bedding plants, flowers, and woody ornamentals for *Botrytis*, *Ovulinia*, *Pellicularia*, *Rhizoctonia*, *Sclerotinia*, *Sclerotinium*, and *Stromatinia* control. {REI of 12 hours}
 25. piperalin (Pipron) — piperadine: This product is labeled for powdery mildew on flowering ornamentals in greenhouses and nurseries. {REI of 12 hours}
 26. propamocarb (Banol) — carbamate: This fungicide is registered for use on ornamentals to control *Pythium* and *Phytophthora* in greenhouses and nurseries, but is not widely used in North Carolina on ornamentals. {REI of 12 hours}
 27. propiconazole (Banner MAXX) — triazole: This is a systemic fungicide sprayed on bedding

plants, flowers and woody ornamentals only in nurseries to control anthracnose, *Entomosporium*, powdery mildew, rust, and scab. {REI of 24 hours }

28. *Streptomyces griseoviridis* (Mycostop): This product, based on a biological control, is labeled for *Fusarium* root and crown rot on annual, perennial, bedding, and flowering potted plants in the greenhouse.
29. sulfur dust — mineral: This product is labeled for powdery mildew on flowers. {REI – see label directions }
30. thiophanate methyl (Cleary's 3336, Fungo Flo, OPH 6672, Sys Tec 1998, T-Storm) — benzimidazole: This is one of the most widely sprayed and drenched fungicides in the landscape industry, the nursery industry and in the greenhouse floral industry. It is systemic and effective on a wide variety of fungal pathogens such as *Botrytis*, *Fusarium*, *Penicillium*, *Rhizoctonia*, *Sclerotinia* and *Thielaviopsis*. It seldom causes phytotoxicity. There is resistance in several fungal pathogens to this active ingredient. Many newer fungicides are as effective as or more effective than thiophanate methyl but many growers use this product because they have confidence in both its effectiveness and its non-phytotoxic nature. This product is widely labeled for ornamentals. {REI of 12 hours }
31. thiophanate methyl + mancozeb (Zyban) — benzimidazole + dithiocarbamate: This product is labeled for *Ascochyta* ray blight, anthracnose, *Botrytis*, powdery mildew, and *Volutella* blight in greenhouses and nurseries. {REI of 24 hours }
32. triadimefon (Bayleton, Strike 50) — triazole: This product is labeled for leaf gall of azalea, leaf spot, powdery mildew, *Sclerotinia* flower blight, twig rust, of annual, perennial, bedding, and flowering potted plants in greenhouses and nurseries. {REI of 12 hours }
33. trifloxystrobin (Compass O) — strobilurin: This product is labeled for powdery mildew, and *Rhizoctonia* web blight, of annual, perennial, bedding, and flowering potted plants in greenhouses and nurseries. {REI of 12 hours }
34. triflumizole (Terraguard) — imidazole: This product is labeled for powdery mildew, *Rhizoctonia* aerial blight, rust, and *Rhizoctonia* root and stem rot of annual, perennial, bedding, and flowering potted plants in greenhouses and nurseries. {REI of 12 hours }

Fungicide Use Estimates — In North Carolina greenhouses, mfenoxam is a favorite drench for damping-off, but etridiazole + thiophanate methyl is sometimes used. Thiophanate methyl is also a widely used as a spray and a drench. Azoxystrobin is the principal fungicide used for powdery mildew, downy mildew, and rusts. Copper sulfate pentahydrate is regularly used for bacterial leaf spots and other diseases. Fludioxonil and mancozeb are used "some" for various diseases. Chlorothalonil is effective but reluctantly used in greenhouses because of its long REI. Etridiazole, fenarimol, mancozeb +

dimethomorph, myclobutanil, and triadimefon are used much less frequently than the preceding fungicides.

In North Carolina nurseries, chlorothalonil (drenches, sprays, and smoke generators), etridiazole, fosetyl-aluminum, mefenoxam, and thiophanate methyl are the principal fungicides used for foliar and root diseases.

Plant Growth Regulators for Ornamentals

Plant growth regulators (PGRs) are pesticides that affect plant growth. Because growing conditions vary slightly from grower to grower, applying PGRs may take some experience to achieve desired plant growth. PGRs are production tools, like water and fertilizer and not as remedies for poor cultural practices. PGRs are most effective when applied at the correct time to regulate plant development (growth retardants cannot "shrink" an overgrown plant, they must be applied before plants stretch). Growth retardants such as daminozide, chlormequat chloride, paclobutrazol, or uniconazole-p improve color and general condition and to reduce the rate of growth rate of the plant. Chemical pinchers such as dikegulac sodium, ethephon, or methyl esters of fatty acids increase plant branching for bushy plants. Chlormequat chloride and gibberellic acid enhance flower initiation and synchronize flowering.

Plant growth regulators vary in their impacts on ornamental plants. Some inhibit plant growth and others encourage vegetative growth, flowering, or rooting. Plant growth regulators that have high activity require a higher degree of management to use as the slightest mis-measurement may have disastrous results. The higher the level of activity, the more care must be used in measuring and applying the plant growth regulator. When two plant growth regulators of low activity such as daminozide and chlormequat chloride are tank mixed, the combined impact moves from low to moderate.

The predominant PGR used in greenhouse production is daminozide. Its versatility and low degree of activity enable greenhouse growers to customize applications to a crop based on the prevailing weather and rate of growth of the plant. For vigorous plants or cultivars, growers may prefer to use paclobutrazol. Both chemicals have been utilized by the industry for a number of years and growers have developed the expertise to determine optimal application rates to control excessive plant growth.

Plant Growth Regulators Registered on Ornamentals

1. ancymidol (A-Rest) — substituted pyrimidine: This gibberellic acid synthesis inhibitor is labeled for greenhouses and nurseries. It has moderate activity. {REI of 12 hours}
2. chlormequat chloride (Cycocel) — quaternary ammonium: This gibberellic acid synthesis inhibitor is labeled for greenhouse use. It has low activity. {REI of 12 hours}

3. cytokinin/gibberellic acid (Fascination) — synthetic Cytokinin/gibberellin: This growth promoter is labeled for greenhouse use. It has high activity. {REI of 4 hours}
4. daminozide (B-Nine) — hydrazide: This gibberellic acid synthesis inhibitor is labeled for greenhouses and nurseries. It has low activity. {REI of 12 hours}
5. dikegulac sodium (Atrimmec) — unclassified: This DNA synthesis inhibitor is labeled for greenhouses and nurseries. It has high activity. {REI of 12 hours}
6. ethephon (Florel Brand Pistill) — acid: This ethylene generator promotes branching and is labeled for greenhouses and nurseries. It has medium activity. {REI of 48 to 72 hours}
7. gibberellic acid (GA3) (Florgib 4L, GibGro, ProGibb T&O) — gibberellin (GA): This growth promoter is labeled for greenhouses, nurseries, and turf. It has high activity. {REI of 4 or 12 hours}
8. IBA (Hormodin) — rooting hormone synthetic auxin: This rooting hormone is labeled for greenhouses and nurseries. {REI of 0 hours}
9. IBA+NAA (Dip N Grow) — rooting hormone synthetic auxin: This rooting hormone is labeled for greenhouses and nurseries. {REI of 0 to 24 hours}
10. methyl esters of fatty acids (Off-Shoot O) — fatty acid: This chemical pincher is labeled for greenhouses and nurseries. It has medium activity.
11. paclobutrazol (Bonzi, Piccolo) — triazole: This gibberellic acid synthesis inhibitor is labeled for greenhouses and nurseries. It has high activity. {REI of 12 hours}
12. uniconazole-p (Sumagic) — triazole: This gibberellic acid synthesis inhibitor is labeled for greenhouse use only. It has high activity. {REI of 12 hours}

Plant Growth Regulator Use Estimates — In North Carolina greenhouses and nurseries, chlormequat chloride, ethephon, and paclobutrazol are the most used PGRs. Daminozide is the fourth most frequently used PGR. Ancymidol, gibberellic acid, IBA, and uniconazole are least frequently used.

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