IPM for Shrub Production

Edited by Amy Fulcher

UT Extension

UK Ag Horticulture

• Preface •

This manual is dedicated to Mr. Mark Halcomb, retired University of Tennessee Area Nursery Extension Specialist, who worked tirelessly to assist nursery producers large and small. His endless devotion to the Tennessee nursery industry was the rising tide that lifted all ships.

This manual is funded by USDA Extension IPM Grant in partnership with University of Kentucky Integrated Pest Management Program. The Nursery Crops project team, lead by Amy Fulcher and Win Dunwell, expresses appreciation to Dr. Ric Bessin, Ms. Patty Lucas, and Dr. Douglas Johnson for their support, Dr. Frank Hale and Dr. Alan Windham for their careful review of this document, and Ms. Andrea Menendez for early phases of document preparation and copy editing.

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Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the University of Tennessee Institute of Agriculture. This publication contains pesticide recommendations that are subject to change at any time. The recommendations in this publication are provided only as a guide. It is always the pesticide applicator's responsibility, by law, to read and follow all current label directions for the specific pesticide being used. The label always takes precedence over the recommendations found in this publication. Always refer to the product label for specific information on proper product use, tank-mix compatibility, and crop tolerance.

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Please remove page & return to Amy Fulcher, UT Extension Specialist & Assistant Professor for Sustainable Ornamental Plant Production.
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• CHAPTER 1 •

FIELD PRODUCTION OF DECIDUOUS FLOWERING SHRUBS

by Mark Halcomb
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and

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Highlights

1. Shrub sales have enjoyed popularity due to recent introductions of flowering shrubs with a long bloom time and/or showy floral presence, such as rose and hydrangea.
2. Many flowering shrubs are quick and easy to propagate.
3. Many shrubs are quite adaptable, making them easy to produce.

Introduction

This chapter describes production of deciduous flowering shrubs commonly produced in Tennessee and Kentucky nurseries. Information is appropriate for species such as crapemyrtle, forsythia, spirea, and weigela. Much of the information can be applied to red and yellow twig dogwood, some euonymus, hibiscus, and flowering almond. Flowering shrubs are a staple of the Green Industry. Annual US sales of flowering shrubs are estimated at $647,155,000 (USDA, 2009). In recent years, two flowering shrubs have dominated sales and have seemingly been recession-proof: Knock Out® roses and hydrangeas. Many flowering shrubs are easy to propagate and produce, making them a good choice for new growers.

Highlights

1. Deciduous shrubs are propagated by rooting cuttings in fields or mist beds.
2. Softwood cuttings are collected and stuck in the summer.
3. Hardwood cuttings are collected and stuck in the dormant season.
4. Rooting hormones are not used in field stuck cuttings but are used on softwood and hardwood cuttings placed in flats filled with rooting medium.
5. A useful conversion for working with rooting hormone is 10,000 ppm = 1%.

Stock block of magnolia and quince.

Propagation

Deciduous shrubs can be propagated by one of two cutting techniques: hardwood cuttings placed in beds or rows (direct sticking) or softwood cuttings placed in mist beds. Direct sticking cuttings is the older of the two techniques. Stock block plants are pruned hard to force a proliferation of branching to be used for cuttings. Hardwood cuttings are collected in the winter from a stock block of plants. Branches are gathered into handfuls and tied with machines. The bundles are cut into 6-8 inch lengths with a band saw. It is important to mark the tip end from the basal end, as only the basal end should be placed in the soil to form roots. The bundles are stored in damp sand until late winter/early spring (often March in Tennessee).

Direct Sticking - Field

The following is the process for lining out hardwood cuttings for rooting in the field:

1. The tractor marks the future rows to provide uniform spacing between the rows.
2. Cuttings are stuck by hand in rows. Workers usually sit on the ground, scooting backwards down the row, sticking as they go. Some will tie a box of cuttings to their foot, dragging a supply with them.
3. Cuttings are stuck about a half-inch apart into long rows, row after row. The close spacing and tractor speed will not allow mechanical sticking.
4. Rooting hormones are not used. If there is adequate, even moisture throughout the spring and summer, there may be 80 percent rooting; if not, 20-40 percent.
5. Irrigation is desirable and would lead to a greater percentage of rooting and larger sized rooted cuttings.

Crapemyrtle, forsythia, spirea, and weigela are commonly rooted this way. After one season, bareroot liners are harvested, graded, and sold. The rooted cuttings are either lined out at a wider spacing for balled and burlapped production, potted for a quick 1-year crop, or sold packaged. To sell packaged, the roots and damp sawdust are placed in a small poly bag. See Propagation Bed Construction — for Seed or Cuttings (Halcomb, 2012), for specific information on building beds for direct sticking or seed propagation.

Mist Bed Propagation

The second technique is rooting softwood cuttings in mist beds. The process for sticking softwood cuttings is as follows:

1. Softwood cuttings are collected early in the morning and placed in coolers.
2. Sticks are cut into sections, lower leaves are removed, and large leaves are cut back to reduce the leaf area that will lose moisture.
3. Rooting hormone may be applied as a quick dip or talc.
4. Cuttings are stuck in trays of propagation substrate and placed under mist.

While mist beds are fairly simple to construct, they are an added expense, must be maintained, and require a reliable source of water. Any disruption in mist, even for a short period in the summer, can lead to total crop loss.

Rooting Hormone

Rooting hormones (often the auxin IBA) are generally used on softwood cuttings rooted in mist beds. The potassium salt of IBA (K-IBA) has traditionally been used by growers to prepare rooting solutions. Very recently, technical grade K-IBA previously available to growers from scientific supply companies became

unavailable due to lack of Environmental Protection Agency (EPA) registration. Water-soluble salts of IBA, dilutable concentrates (containing IBA+NAA), powder (talc) formulations of IBA, and gel formulations of IBA are acceptable alternatives. See the Root-Promoting Products for Commercial Cutting Propagation of Nursery Crops Including Alternatives to K-IBA (Boyer and Blythe, 2013) for a more detailed description.

Rooting powders are easy to use. Simply wet the stem, dip in powder of the desired concentration, and tap to remove the excess powder. Many propagators prefer to use a small wood dowel to make an opening in the rooting medium for the stem so the powder is not displaced when the stem is pushed into the medium.

Mixing rooting hormone to the desired concentrations can be much more affordable than buying a prepared concentration. However, it can be difficult to accurately change the concentration of rooting hormones in the powder form. It is challenging to adequately mix the talc and uniformly distribute the rooting hormone, and talc without fragrance can be difficult to procure. Liquid rooting hormone can be easily diluted to a desired concentration. See Table 1.1. for a general table on diluting rooting hormone adapted from several textbooks.

See Table 1.2 for general cutting propagation information for common deciduous shrubs. Detailed propagation techniques for numerous plant species are available (Hartmann et al., 2010). Growers who are interested in propagation may want to consider joining the Eastern or Southern chapter of the International Plant Propagators' Society.

Mist beds in an unheated quonset hut.

Table 1.1. Diluting concentrated IBA to 0.1%, 0.3%, and 0.8% ppm.

EASE OF ROOTING	DESIRED IBA CONCENTRATION (PPM)	ETHANOL (ML)	IBA (GRAMS)	WATER (ML)	FINAL VOLUME (ML)
Easy	1000	500	1	500	1000
Moderate	3000	500	3	500	1000
Difficult	8000	500	8	500	1000

Table 1.2. Cutting type and hormone type and concentration for several deciduous shrubs†.

SCIENTIFIC NAME	COMMON NAME	TYPE OF CUTTING	ROOTING HORMONE	CONCENTRATION (PPM)
Abelia xgrandiflora	Glossy Abelia	semihardwood	IBA talc or quick-dip or IBA-NAA	1000-2000
Aronia arbutifolia	Red Chokecherry	softwood-semihardwood[1]	IBA quick-dip	4000
Buddleia davidii	Butterfly-bush	softwood or semihardwood	IBA	8000
Caryopteris xclandonensis	Bluebeard	softwood-semihardwood[1]	K-IBA[3]	3000 [3]
Chaenomeles speciosa	Quince	softwood	IBA	1000-5000
Clethra alnifolia	Summersweet Clethra	softwood	K-IBA	1000
Cornus sericea (C. stolonifera)	Redosier Dogwood	softwood-semihardwood May-September[1] hardwood November-March[1]	N/A	N/A
Deutzia gracilis	Slender Deutzia	softwood or hardwood	IBA talc	1000-3000
Forsythia xintermedia	Border Forsythia	softwood	none needed but K-IBA quick-dip can be used[2]	1000-3000 [3]
Fothergilla major	Large Fothergilla	softwood[1]	none needed but up to 10,000 IBA quick-dip can be used[2]	
Fothergilla gardenii	Dwarf Fothergilla	softwood[1]	IBA	4000

SCIENTIFIC NAME	COMMON NAME	TYPE OF CUTTING	ROOTING HORMONE	CONCENTRATION (PPM)
Lagerstroemia	Common Crapemyrtle	softwood hardwood	IBA no treatment	1000-1250 NA
Spirea x*bulmalda*	Bumald Spirea	softwood	auxin	1000
Syringa vulgaris	Lilac	softwood	IBA talc	3000
Viburnum carlesii	Koreanspice Viburnum	softwood[1]	IBA talc[2]	8000 [2]
Viburnum dentatum	Arrowwood Viburnum	softwood[2]	IBA[2]	1000-8000 [2]
Viburnum nudum	Smooth Witherod	softwood-semihardwood[1]	N/A	N/A
Viburnum plicatum var. *tomentosum*	Doublefile Viburnum	softwood-semihardwood[1]	IBA[2]	1000 [2]
Viburnum xburkwoodii	Burkwood Viburnum	softwood-semihardwood[1]	IBA/50% alcohol[2]	1000 [2]
Viburnum x*carcephalum*	Fragrant Viburnum	softwood-semihardwood[1]	N/A	N/A
Vitex negundo	Chastetree	softwood	IBA[3]	N/A
Weigela florida	Old Fashioned Wiegela	softwood softwood	IBA quick-dip IBA talc	1000-3000 8000

All propagation information from Hartmann and Kester's plant propagation: Principles and practices, 8th edition, Prentice Hall, unless otherwise noted.

[1]Raulston, J.C. 1995. Propagation guide for woody plants in the NCSU Arboretum. NCSU Arboretum, Raleigh, NC.

[2]Dirr, M. 2009. Manual of woody landscape plants. Stipes, Champaign, IL

[3]The International Plant Propagators' Society combined proceedings, various years

[†]Note: K-IBA became unavailable just prior to printing this document. Propagators should experiment with substitutes to identify the type and concentration that best replaces K-IBA in their propagation system.

Highlights

1. Soil test before planting and fertilizing.
2. Phosphorus mines are estimated to be depleted in 50-100 years.
3. Plant in well-drained soil.
4. Planning to harvest every other plant is not the most efficient use of land and resources.
5. Do not plant too deeply. The first order lateral roots should be near ground level.
6. Mechanical spades can reduce worker injuries and increase number of plants harvested in

Production

Site Selection

No special requirements are needed other than well-drained soil in full sun. It is not common to allocate the best available soil for deciduous shrubs. They generally grow fast and are sold for a low price.

Fertilization

Check the optimum pH ranges in the fertility section of UT Extension Handout Nursery Field Production (Halcomb, 2009). A medium level of phosphorus and potassium is desirable for all of these crops but base applications on soil test results. Soil test early enough so that any lime,

phosphate, or potash can be broadcast prior to planting. Fertilize only with needed nutrients.

Sidedress lightly with a half rate after most cuttings have 2-3 roots at least an inch long and again in late June with no more than 50 pounds of actual nitrogen per acre.

Table 1.3. Fertilizer weight corresponding to 50 pounds of actual nitrogen per acre of root zone.

POUNDS OF FERTILIZER	FERTILIZER ANALYSIS
250	20-10-10[1]
333	15-15-15
385	13-13-13

Field Spacing

To harvest a 3-6 foot plant, plant a minimum of 4.5 feet apart within the row. Middles should be wide enough to work, control weeds, and not damage the crop. Middles should be at least the width of the widest tractor or implement used in middles plus 2 feet per side. For example, a 3' implement + 4' = 7' middle.

Table 1.4. Plant populations on a solid acre, no roads.

3 x 4 = 3,630	4.5 x 6 = 1,613	5 x 8 = 1,089
3 x 4.5 = 3,227	4.5 x 7 = 1,383	5 x 9 = 966
3.5 x 4 = 3,112	4.5 x 8 = 1,210	6 x 5 = 1,452
3.5 x 4.5 = 2,766	4.5 x 9 = 1,076	6 x 6 = 1,210
4 x 4 = 2,723	5 x 5 = 1,742	6 x 7 = 1,037
4 x 4.5 = 2,420	5 x 6 = 1,452	6 x 8 = 908
4.5 x 5 = 1,936	5 x 7 = 1,245	6 x 9 = 807

Remember to leave a 10-12 foot roadway from which to load and spray. An air-assisted sprayer is convenient for pest control. Use water sensitive paper to determine how well your air-assisted sprayer is penetrating the foliage in multi-row blocks. Recent demonstrations have shown that multi-row blocks can exceed the ability of an air-assisted sprayer to thoroughly cover the foliage, especially for heavily pruned plants that develop a dense branch structure. Shrubs will likely be hand dug so accommodating a digging implement is not essential; however, small mechanical spades are becoming more prevalent.

Planning to dig and sell every other plant, thus allowing more room for the remaining plants is a logical strategy, but it often doesn't work. Sales may decline, every other plant may be too small, or somebody may forget; besides, every other plant is half of the crop.

[1]Nursery crops generally use a 3-1-2 ratio of nitrogen, phosphorus and potassium. Using a “high” middle number almost always over-applies phosphorus. This wastes phosphorus and the loss of phosphorus in runoff leads to eutrophication. Currently, phosphorus mines are expected to be depleted in as little as 50 years.

Planting

Exercise caution to avoid planting too deep. While not as heavily scrutinized as tree planting depth, shrubs should have the upper roots within an inch or two of the soil line. It is also critical to prevent cultivation from throwing additional soil over the roots. Some producers replace the disc blade that throws the soil with a smaller diameter blade.

Irrigation

Irrigation, or a settling rain of about 1 inch, is necessary within a few days after planting, depending on temperature, humidity, and sun intensity for optimum survival and establishment. During extended dry periods or drought, supplemental irrigation can be essential to plant survival and optimum growth. Irrigation during dry periods is an important preventative measure to reduce pest issues as many water stressed plants are more likely to succumb to pests such as canker diseases, borers, and mites. Many shrubs will benefit from consistent moisture throughout production. Irrigation can be provided by drip tape, shown in the lower left image or a traveling gun.

Pruning

Deciduous shrubs must be pruned regularly in order to develop dense branching structure that includes branches and foliage at the base of the plant, as is desired by consumers. Some shrubs may need to be pruned several times a season during production which can become expensive. Mechanized systems for pruning can make

Field grown shrubs can be irrigated with a traveling gun or drip tape (shown above).

Regular pruning is often necessary to grow high quality plants. Pruning often starts during propagation.

this a more time-efficient task. Plant growth regulators are another option for controlling growth of shrubs.

Harvesting

Deciduous flowering shrubs are commonly sold when 3-6 feet tall, which equates to a 3-4 year crop, depending on species, size of liner, soil type, fertility, moisture, growth rate, pruning, etc. Harvesting occurs the last 1-2 years. Traditionally, shrubs were hand dug even as tree spades became common, but it is becoming more typical to dig shrubs with a small mechanical spade. The use of a mechanical spade reduces physical strain on workers, potentially increasing the number of plants that can be dug and loaded and reducing injuries.

Digging the Correct Size Ball

The American Standard for Nursery Stock was written by the American Nursery & Landscape Association (ANLA). It establishes techniques for measuring plants and minimum rootball sizes for particular plant sizes and different plant types. A copy of the standards may be viewed and printed from this link for free: http://www.anla.org/docs/About%20ANLA/Industry%20Resources/ANLAStandard2004.pdf.

Root ball sizes should always be of a diameter and depth to encompass enough of the fibrous root system as is necessary for the rapid establishment of the plant and enough of the structural roots as are necessary to support the plant remaining upright.

Deciduous shrubs are divided into four different types regarding plant size, number of canes/stems, and the minimum rootball diameter. This is explained in the standards. Producers are not legally bound to follow the ANLA standards, but it is a good business practice and helps ensure clear communication with customers and that customer expectations are met.

Table 1.5. American Nursery and Landscape Association standards for deciduous shrubs.

DIGGING GUIDE FOR DECIDUOUS SHRUBS	
HEIGHT (FEET)	**MINIMUM BALL DIAMETER (INCHES)**
2.5	12-13
3	14-16
4	18-20
5	24
6	30

Highlights

1. The IPM principle of prevention is critical during propagation.
2. Significant insect pests include Japanese beetle and redheaded flea beetle.
3. Significant diseases include southern blight, powdery mildew, and various leaf spot diseases.
4. Timely weed management is necessary to produce high quality shrubs with full foliage at the base of the plant.

Phytophthora root rot infecting forsythia (L), Japanese beetles attacking rose (R).

Integrated Pest Management (IPM)

IPM during Propagation

During propagation, critical steps can be taken to prevent the spread of insects, mites, and diseases. Begin by scouting stock plants routinely and controlling pests of significance. Do not take cuttings from pest-infested plants. Regularly sanitize pruning shears when collecting cuttings so that disease is not spread within stock blocks. Likewise, if rooted cuttings are purchased, inspect them closely before accepting the shipment. Look carefully for pests and keep the cuttings separate from other plants for as long as is feasible so that if a pest is identified it will not spread throughout the nursery. Sanitize trays before sticking cuttings and use new

propagation substrate. Do not reuse propagation substrate without first steam sterilizing it. Minimize foot traffic in your propagation houses and place a footbath with sanitizer at the entrances to limit the opportunity to introduce pests. Sanitize surfaces, bench tops, etc. before working with cuttings (See Table 1.6). Remove organic matter and debris from containers and other surfaces before sanitizing as they can reduce effectiveness of sanitizers. Change out rooting hormone periodically throughout each day and never allow plants or debris to come into contact and contaminant the stock solution or supply of rooting hormone. Insect screening over openings such as vents can also help prevent infestations.

Sanitizer and a bundle of cuttings ready to be stuck.

Select Foliar Insects

Japanese Beetle

This pest ranges from Georgia to as far north as Nova Scotia and Ontario. In Kentucky and Tennessee, Japanese beetle recently expanded its range into the far western regions, and light infestations have become common in eastern and central regions. Japanese beetle is a concern because the Japanese beetle harmonization plan must be followed during harvesting and shipping even in locations where populations are low enough so as not to cause extensive foliar damage. It overwinters as a partially grown grub, resumes feeding in spring, pupates near the soil surface, and emerges as an adult between late May and early July. Japanese beetle females lay eggs about 2.5-10 cm into the ground and hatch in about two weeks. Grubs feed primarily on the roots of grasses and some woody ornamentals. Adults feed on leaves and flowers. Because Japanese beetles avoid leaf veins, their feeding can cause foliage to appear lacelike or skeletonized. They are most active during the warmest part of the day and tend to congregate on foliage and flowers in the outer canopy and tips of branches. In areas in the far western portions of Tennessee and Kentucky, controls for foliar feeding may be warranted due to the extreme defoliation that Japanese beetles can cause when their numbers are high. Reducing smartweed and other preferred host plants from the nursery may be a good strategy to avoid attracting Japanese beetles; however, the number of host plants that are commonly grown in nurseries is so great that this may not be feasible. Pheromone traps attract more beetles to an area than traps can generally hold and are considered to exacerbate a Japanese beetle

infestation. Select resistant plants when possible.

Redheaded Flea Beetle

The redheaded flea beetle is a relatively new pest of significance. It is only about 3.5-5 mm long and is shiny and black with a reddish tint on its head. Like other flea beetles, this pest has large back legs to aid it when jumping. These insects feed on the outer layers of leaves, avoiding veins. Their feeding damage can negatively affect bud development and sometimes severely reduces the appearance of plants. The redheaded flea beetle overwinters as an egg and hatches around May. There is one generation per year. Because this pest is relatively new, there is little known about effective IPM strategies.

Select Diseases of Shrubs

Southern Blight

Southern blight can attack barberry, buddleia, dogwood, forsythia, hydrangea, rose-of-Sharon, and quince. Southern blight strikes quickly once the weather is hot. Several plants can be killed before it is recognized and identified. Southern blight outbreaks are usually not widespread. Southern blight can be identified in the field with reasonable accuracy due to rapid plant death, white web-like mycelia, and round mustard seed-sized storage structures on the base of the plants and just under the soil line. Removal of soil from the base of an infected plant can help prevent a new infection after replanting. Till in organic matter and ensure that it is fully decomposed before planting.

Powdery mildew resistant magnolia (L), and powdery mildew susceptible magnolia (R).

Powdery Mildew

Several commonly produced shrubs are susceptible to powdery mildew. Fungal growth on the surface of the leaf gives infected leaves a white, powdery appearance. This disease can cause plants and their fruit to become dwarfed or blemished. Leaves can also develop chlorosis and die. The new, tender growth that is developing is most susceptible. Therefore, practices that stimulate new growth such as pruning and heavy nitrogen fertilization can encourage powdery mildew. Also, densely pruned plants and closely spaced plants will have reduced air and light penetration into the canopy, which creates a humid microclimate within the plant. A humid environment will favor powdery mildew development. Overwintering houses are very humid. Overhead irrigation can also create a humid environment but it can have

advantages too. Powdery mildew spores (conidia) will not germinate on wet leaves. Free water on the leaf surface can cause the spores to burst. Frequent overhead irrigation or rainfall can also wash spores from the leaf surface and actually help prevent infection. Look for powdery mildew resistance when selecting shrubs.

Leaf Spot

There is a large variety of both fungal leaf spots as well as some bacterial leaf spots that can affect shrubs. Symptoms range from brown to purple to tan spots and blotches. Spots may be solid or have a border of another color. Spots may be angular or round and can be delineated by veins or span veins. Leaf spots often do not negatively affect a plant's health, but they can be unsightly. Leaf spots are more common when there is a humid microclimate (See Powdery Mildew above). Ensure plants have proper sunlight and air circulation and try to select shrubs based on resistance to leaf spot. Chemical controls are not generally necessary during field production but may be the year of sale for container grown shrubs.

Pesticide Recommendations

For chemical controls for insects, mites, and disease-causing pathogens, refer to the UT Insect and Plant Disease Control Manual (Redbook) https://ag.tennessee.edu/EPP/Pages/TFS.aspx or download the app developed by UT in collaboration with other southern universities: IPM*Pro* at http://wiki.bugwood.org/IPMPro_app. Refer to Tables A and B: Preemergence and Postemergence-Nursery Crops under the Weed Control heading at http://www.utextension.utk.edu/mtnpi/handouts.html for a complete list of labeled pre and postemergence herbicides for most common woody ornamentals. For pest identification contact your county extension office or the UT Soil, Plant, and Pest Center http://soilplantandpest.utk.edu. For cultural information on these and more pests, consult http://utuknurseryipm.utk.edu.

Table 1.6. Sanitization practices for treating tools, equipment, pots, flats, surfaces, and other related items[1].

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

[1]Table prepared by Kelly Ivors and Mike Munster, NCSU; originally published in Adkins et al. 2010. Pest Management Strategic Plan for Container and Field-Produced Nursery Crops in GA, KY, NC, SC, TN.

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