Sustainable Small-Scale Nursery Production

A Publication of ATTRA - National Sustainable Agriculture Information Service • 1-800-346-9140 • www.attra.ncat.org

By Steve Diver and Lane Greer
Updated June 2008
by Katherine L. Adam
Agriculture Specialist

Sustainable nursery practices can increase plant marketability and reduce a nursery's impact on the environment. This publication focuses on the sustainable production of woody and herbaceous nursery plants, both in containers and in the field. It is not a primer for inexperienced growers, but a complementary source of information that concentrates on sustainable production techniques. Topics covered include integrated pest management, weed control and alternative fertilizers. The publication also introduces business management practices.

Contents

ATTRA – National Sustainable Agriculture Information Service is managed by the National Center for Appropriate Technology (NCAT) and is funded under a grant from the U.S. Department of Agriculture's Rural Business-Cooperative Service. Visit the NCAT Web site (*www.ncat.org/sarc_current.php*) for more information on our sustainable agriculture projects.

Introduction

This publication is for small-scale nursery managers who want to use sustainable practices and large-scale nursery managers interested in converting from conventional to sustainable practices. In this publication, small-scale defines a nursery with fewer than five acres in container production and fewer than 15 acres in field production. This publication does not include everything a nursery manager needs to know before going into production.

A nursery can be part of a diversification strategy to make a farm more profitable or a nursery can be a sole enterprise. In either case, it is important to start small and expand later. For general information on standard nursery production, please refer to publications and bulletins published by the Cooperative Extension Service and common horticultural texts and trade magazines. See the **Resources: Publications** section at the end of this document for a listing of nursery literature.

Sustainable nursery practices aim to reduce levels of synthetic fertilizers and pesticides, use integrated pest management systems to deal with insects, diseases and weeds and focus on building the soil to promote plant health. This document discusses sustainable nursery production in general before moving to sustainable container and field production techniques.

The nursery industry appears to be holding its own through 2007. The latest U. S. Department of Agriculture National Agricultural Statistics Service figures show a slight increase over 2006 in wholesale value of U.S. floriculture crops, the largest segment of the nursery industry (1a). The most important things to consider before starting production are what crops to grow and how to market them. In today's economy, it is no longer possible to grow crops without first considering the crop's marketability. Here are some facts to keep in mind before starting out:

Rows of greenbean beanstalks. Photo by Jandre Venter

- Container-grown crops generate about 10 times more sales per acre than field crops (1).

- Lawn and garden centers draw approximately 80 percent of their customers from a 5- to 15-mile radius (2). More than 60 percent of an average wholesale nursery's sales are to customers from within the state. Small nurseries sell about 20 percent of their plants to out-of-state customers (1).
- Retail garden centers usually want small plants in 1- to 3-gallon containers. Landscaping firms and landscapers want larger container plants in 3- to 5-gallon containers and balled and burlapped woody plants.
- The nursery industry is dependent on the construction industry and on the rate of unemployment in the vicinity of the nursery (1).

Marketing

Before entering the nursery business, a market analysis is necessary to determine what opportunities exist to sell plant materials in the local area. Most new firms begin with only a few acres of production and market in a 50-mile radius, unless growing for mail order or on contract (1). A market analysis includes finding out what crops other nurseries grow successfully in the region. The analysis also evaluates competition potential from area nurserymen. When considering the market, bear in mind this advice from Lynn Byczynski, editor of *Growing for Market*, a newsletter for small-scale producers:

> "I feel quite strongly that it is a serious mistake to commit to growing for anyone before you have become extremely confident of your skill as a grower. My recommendation for marketing is a simple one: Start where no one is depending on you. If you have nothing to sell, no one will have to know"(3).

Marketing starts with a decision about what to produce and at what volume. Nursery managers need to:

1) Determine what kind of customer the nursery will attract and what size of plants those customers want.

- *Mass merchandisers* want large volumes of a few popular plant species. Mass merchandisers purchase smaller plants. These customers may not care about buying specific plants, but focus on obtaining a good mix of fast-moving materials. Demand from these customers is seasonal (1). Plants in fashion vary from year to year.

  There are several disadvantages to dealing with mass merchandisers. These customers want instant shipment, pay the lowest price for plants and often do not take care of plants after receiving them, which can reflect poorly on a nursery.

- *Landscapers* look for large, high-quality specimens carefully identified by cultivar. Landscapers generally want to buy plants from a limited number of producers but also want to choose among many plants and plant sizes. Landscaper purchases are spread out through the year, with an emphasis on spring planting (1). Horticulture degrees with specialization in landscape architecture were popular career choices in the 1980s and 1990s, creating a solid base for nursery customers.

- *Lawn and garden centers* fall somewhere between the mass merchandiser and the landscaper. Some centers want variety in plants and plant sizes, some do not.

Other retail outlets include *mail order, Web sites, farmers' markets* and *starting a landscaping business.* Sales at farmers' markets will be local, but local can mean weekly travel of 200 to 300 miles to a large metropolitan area. Potential customers all share a common need to get uniform, well-grown plants from a producer without having to inspect the crop before each purchase (1).

2) Keep up with trends in buyer preferences.

Constant monitoring of customer characteristics and purchases is crucial. Advertising and promotion never end. Chain stores now carry nursery items. Convenience and escalating gas prices promote one-stop shopping.

Related ATTRA Publications

Solar Greenhouse Resources (Web only)

Renewable Energy Opportunities on the Farm

Energy Saving Tips for Irrigators

Woody Ornamentals for Cut Flower Growers

Phenology Web Links: Sequence of Bloom, Floral Calendars, What's in Bloom (Web only)

Agricultural Business Planning Templates and Resources

Biointensive Integrated Pest Management

Nematodes: Alternative Controls

Use of Baking Soda as a Fungicide

Notes on Compost Teas

Integrated Pest Management for Greenhouse Crops

Table 1. Types of nurseries	
Type	**Description**
Grower/retail nursery	Grows and sells plants on-site
Wholesale nursery	Grows plants for sale to other nurseries, landscapers or retailers, may grow plants on a contract basis
Landscape nursery	Provides landscape services and retail sales
Farmers' market	Grows plants to sell locally at retail prices
Mail order/ Web site	Grows plants to sell at the national level*
**Note: Recent legislation made it easier for states to collect sales tax on Internet sales.*	

3) Know what combination of plants will maximize profits.

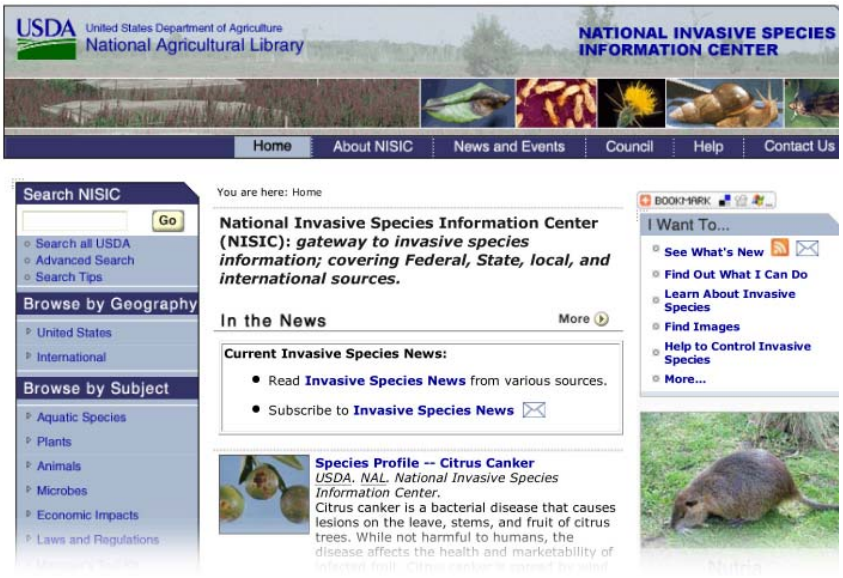
Ornamental plants fall into general categories of shade trees, conifers, perennials, vines, shrubs, bulbs and annuals. While most nurseries grow a range of plants, there is a trend toward specialization. Growing only native groundcovers or only daylilies are viable niche markets. The production of specialty crops, such as hardy bamboo and disease-free apple stock, and specialization in plants in short supply, like uncommon plants and very large trees, are niche markets even small growers can serve.

Keep abreast of recent developments in the industry. Subscribing to trade publications and attending trade shows or conferences are good ways to learn about grower issues like plant availability, new varieties for specific needs, popular sizes, specific growing conditions and enhanced services. Enhanced services can include providing photographs of plants and making presentations to landscape architects and other potential customers.

Invasive species

The USDA and other government agencies are increasingly concerned about invasive plant imports. Drug enforcement personnel are also concerned about the use of some plants. A concerted effort at the federal level to limit introductions of plant species to the United States raised concerns on the part of some plant explorers and nursery owners. However, it encouraged renewed interest in native species formerly put at a disadvantage by foreign imports, not only for in situ conservation, but also for increased use in landscaping. Several plants on invasive lists throughout the United States are important to the nursery trade. Plants such as Norway maple, butterfly bush, Japanese barberry and miscanthus have been lucrative sellers (4).

The USDA now maintains a Web site on invasive flora and fauna species at *www.invasivespeciesinfo.gov*. The National Park Service provides plant fact sheets and a helpful list of natural area invaders at *www.nps.gov/plants/alien*. Consulting such lists is advisable when making decisions on offering nursery stock to the public.



General production

There are two types of nursery production: *field* and *container*. Field stock is either direct-seeded or transplanted from seedlings and then lifted as bare-root stock for use as nursery liners, fruit trees, seedlings for Christmas trees, windbreaks and conservation plantings. Field stock is also grown for balled and burlapped landscape or shade trees. Container stock, which is propagated from seed, rooted cuttings and

Grower profile: Santa Ana Garden Center and Santa Ana Native Plant and Tree Nursery

The Santa Ana Pueblo, a small suburb of 497 residents, is located two miles north of Albuquerque, New Mexico. The town is home to a retail nursery and a wholesale nursery that supply plants and trees that thrive under arid local conditions. The Pueblo of Santa Ana Tribal Enterprises operates the retail Santa Ana Garden Center and the wholesale Santa Ana Native Plant and Tree Nursery.

Since tribal water rights to the adjacent Rio Grande take precedence, the garden center and nursery, along with a tribally operated golf course, greatly enhance landscaping and recreation options for Albuquerque and area residents.

The Santa Ana Garden Center and Santa Ana Native Plant and Tree Nursery maintain Web pages on the Pueblo of Santa Ana Tribal Enterprises Web site, *www.santaana.org*. The pages list more than 250 plant species, most grown from locally collected seed. The lists, organized alphabetically by scientific name, function only as a reference to what the venues stock. Plants must be picked up on-site since the stores are not mail-order businesses.

The Santa Ana Garden Center offers a large selection of drought-tolerant flowering native plants, shrubs and ground covers for xeriscaping and trees with low watering requirements. It also stocks native grasses for lawns or reclamation, herb and vegetable starts, wildflower seed, organic products, drip irrigation supplies, seasonal gift items and books. The store can also advise customers about plants for rock gardens, windbreaks, natural hedges, barriers, erosion control, wildlife habitat, food and medicinal uses.

Respect for tribal customs and the earth are strongly encouraged when visiting the nursery and garden center. Taking photographs at the sites is restricted, but images at the tribal Web site, *www.santaana.org/nursery.htm* and *www.santaana.org/garden.htm,* give an idea of how some plants are started in hoophouses with supplementary heating during the chilly north-central New Mexico winters (5).

field-grown seedlings, is common in both forestry and landscape nursery production.

Fifty years ago, nursery managers grew ornamental plants in the field and dug the plants up later for transplanting. Today, 80 percent of ornamental plants are container-grown. The switch occurred for several reasons. Container-grown trees have a greater chance for survival and establishment after transplanting. Containerized production does not require good soil and takes up less acreage. Containerized stock also enables the grower to extend the planting season.

Container and field production will be discussed separately, but there is commonality between the two forms of production. Most woody landscape plants, regardless of how they are grown, are propagated by cuttings. Both types of production require spending a high percentage of a nursery's budgets on farm-type mechanized implements and fertilizers (1).

Soil productivity is not as important when growing only containerized products, but relatively level land with good drainage is still necessary. Beginning nursery managers must learn the length of time required to produce marketable crops and how to schedule planting so the proper number of each species is available for the first year of sale and following years (1).

Irrigation

The two most widely used irrigation systems are overhead and drip or trickle systems. Overhead irrigation systems are designed to cover a large area and these systems are the least expensive to install. However, this method produces uneven water distribution, which can slow plant growth, encourage disease and contribute to runoff. A container nursery using overhead irrigation can use from 15,000 to 40,000 gallons of water per acre daily in the summer (6), a reminder that sufficient water is a prerequisite to nursery production.

Large containers are usually watered with a drip or trickle system, which uses 60 to 70 percent less water than an overhead system. Drip irrigation systems cost more to install but have superior application uniformity and efficiency. Drip irrigation systems are also affected less by wind and crop canopies and produce less runoff. Another advantage is that workers can continue working while the plants are being irrigated. The biggest disadvantage to a drip or trickle irrigation system, besides the initial cost, is keeping the pipes and emitters clean.

A third, less-used type of irrigation system is subirrigation using capillary sandbeds. In this system, water rises into containerized

Table 2. Comparison of water systems for container nursery stock (7)			
	Overhead sprinklers	**Drip or trickle irrigation tubes**	**Capillary beds**
Installation cost/acre	Moderate	Moderate to high	High
Maintenance	Low	High	High
Durability	Excellent	Low	Moderate
Labor	Low	Moderate to high	Low
Water distribution	Fair	Fair to good*	Good
Water use efficiency	Poor, very wasteful	Good	Good
Pump required	Large, high pressure	Small, low pressure	Small, low pressure
Water volume required	Large	Small	Small
Wind effect on distribution	Serious	None	None
**If ground is level and water quality is good*			

plants through capillary action. The sandbed is covered with at least 1 inch of fine sand and slopes very slightly. Water is released at the high end and slowly percolates to the low end. These systems cost the most to install, but have no runoff or leaching.

Sandbeds are normally built using wood sidewalls, a plastic bed liner, sand, a small tank, a drainpipe and a float valve. Sandbeds do not require the use of any electrical parts and provide a uniform and consistent supply of water without forming a saturated water table at the base of the soil column in the container. Sandbeds offer efficient and uniform crop growth while providing less water, less fertilizer and less pesticide. Sandbeds also require less labor since sprinkler heads, timers, pumps, valves and water-treatment systems don't need to be monitored (6).

The biggest disadvantage of sandbeds is that weeds and containerized plants grow into the structure. The Agroliner is a retail product designed to alleviate this problem. The Argoliner is a mat treated with Spin Out, a copper paint that prevents root growth and is registered by the Environmental Protection Agency. The mat is placed over the sand and under the containers.

Griffin LLC, a supplier of crop protection chemicals in Valdosta, Ga., sells Spin Out. For more information on ways to use Spin Out, see the **Container production** section. For distribution information, see the **Resources: Suppliers** section. For a list of articles related to sandbeds and subirrigation systems, see **Resources: Publications.**

Plants need to be watered often, especially during hot, sunny days. A typical nursery plant in a 1-gallon container can consume a pint of water a day, while the growing medium capacity may be only 1.5 pints. One important aspect of irrigation management is to group plants according to water requirements.

Irrigation runoff

The most important issue with irrigation in sustainable nursery production is water, fertilizer and pesticide runoff. Many states now have regulations limiting runoff and groundwater nitrate levels.

Subirrigation systems are designed to eliminate runoff, but overhead and drip or trickle systems may require special attention. Ditches planted with grass to slow down water flow or tile systems that direct water to a pond or other holding area can collect runoff water.

The water and some of the fertilizers present can be recycled by pumping water back out of the holding tank or pond after impurities like sand and silt settle out. Recycled water can improve plant growth. In experiments with more than 100 species

of ornamentals grown in 2.8-liter containers, the mean relative growth of plants irrigated with continuously recycled water was 103 percent of the control (8).

Pulse irrigation is another way to reduce runoff. In this system, a small amount of water is applied five or six times a day, instead of one heavy watering daily. Very little water escapes from the container or runs off from the field. Less fertilizer is applied because there is less leaching. Most nurseries that use this system use a computer to control water flow, since watering plants repeatedly by hand causes a huge increase in labor expenses.

There are several cultural practices that can reduce runoff:

- Avoid irrigating bare soil
- Have rough soil surfaces to provide surface storage of water
- Use less-porous media that retain moisture and nutrients
- Use slow-release fertilizers instead of liquid fertilizers

Researchers at The Ohio State University conducted experiments to reduce the amount of pesticides and growth regulators leached from nursery pots and trays. Researchers had excellent success mixing chemicals in ordinary latex paint and then painting the interior of the pots. The pots leached less and the growth regulator and pesticide researchers used, commercially available brands Bonzi and Marathon, provided more consistent control. This method also reduced worker re-entry intervals in the nursery area, since workers apply chemicals once at the beginning of the growth process (9).

Reducing moisture stress enhances growth more than increasing fertilizer concentration, a study conducted in the late 1990s found (10). This study, also conducted at The Ohio State University, used fertilizer concentrations between 50 and 200 milligrams per liter of nitrogen. The researchers showed that water stress might limit growth more frequently than limited nutrition under current container production practices. The researchers recommend using lower amounts of N fertilizer—about 50 milligrams per liter—and providing sufficient moisture.

Several Extension bulletins and other publications that deal with irrigation runoff issues are accessible on the Internet. See the **Resources: Web sites** section for more information.

Integrated pest management

Integrated pest management is an ecologically based pest control strategy that is part of the overall crop production system. It is called integrated because all appropriate methods from multiple scientific disciplines are combined into a systematic approach for optimizing pest control. Management implies acceptance of pests as inevitable components at some population level in the agricultural system (11).

An integrated pest management program involves using resistant cultivars, building up populations of beneficial organisms, monitoring numbers of pests, developing treatment thresholds and using spot treatments of pesticides that are the least harmful to beneficial organisms and the environment. It is important to identify pests early so nursery managers can take appropriate measures quickly.

There are numerous publications available from the USDA's Cooperative Extension Service that deal with integrated pest management for nurseries. See the **Resources** section for more information.

ATTRA publications on nursery-related pest management topics

Biointensive Integrated Pest Management

Nematodes: Alternative Controls

Use of Baking Soda as a Fungicide

Notes on Compost Teas

Integrated Pest Management for Greenhouse Crops

Container production

A wide selection of ornamentals is produced in containers. Homeowners usually prefer to buy containerized plants because the plants are easier to transport and transplant than balled and burlapped plants. The following section summarizes some important container production practices and addresses sustainable nursery management issues like recycling plastics, weed control and fertilization.

The advantages of containerized production include:

- Achieving high plant densities
- Using land unsuited for field production
- Planting at times independent of the weather
- Eliminating some operations, like root pruning
- Lowering transportation costs because of lightweight media
- Experiencing less root loss and a greater chance of survival than with field-grown trees

The disadvantages are also numerous:

- Small containers need frequent watering
- Nutrients deplete rapidly
- Plants require winter protection
- Plants easily become root-bound
- Wind can knock over trees
- Containers are costly
- Labor costs to pot up plants are high
- Temperature extremes stress roots

Growing certified organic nursery stock intended for sale to vineyards, berry farms and orchards raising organic produce is a niche market that requires special attention. Restricted products include common ingredients in conventional nursery production like chemical fertilizers, wetting agents, herbicides and synthetic insecticides and fungicides. For more information, refer to *NCAT's Organic Crops Workbook* and other ATTRA publications. For information about whether a commercial product is permitted, restricted or banned in organic production, consult the Organic Materials Review Institute Web site at *www.omri.org*.

Containers

There are several factors to keep in mind when deciding what containers to use. Factors include cost, design features that control root growth, durability, shipping capacity, availability, how the container affects growing medium moisture content and temperature and how the container suits the particular needs of the nursery.

Round, black plastic pots are the industry standard, but can cause root constriction that leads to plants with poorly developed root systems. There are other kinds of containers that promote better root systems. Copper-lined, white and light-colored containers all produce more root growth and square and stair-step pots help keep plants from becoming root-bound (1).

Pots and containers designed for enhanced root growth are an important feature in containerized nursery production.

Pots and containers designed for enhanced root growth are an important feature in containerized nursery production. Each pot and container offers its own advantages and disadvantages.

Copper

Foresters discovered that copper can control root growth. Copper kills root tips that come in contact with it, forcing roots to branch within the root ball instead of circling around it.

Plants grown in copper-treated containers are taller, less root-bound and have higher transplant survival rates. Plants grown in copper-treated containers also have increased nitrogen recovery and require fewer applications of nitrogenous fertilizer. More than 120 species perform better in copper-treated containers versus untreated containers. Copper-treated pots also do not leach or leach very little into groundwater or soil.

Copper-treated fiber pots, made from recycled paper, are biodegradable and can even be composted. The main problem with fiber pots is that the pots can degrade too quickly. Research at The Ohio State University showed that incorporating copper into fiber pots can increase their longevity (12). Dr. John Ruter at the University of Georgia found copper-treated fiber pots keep roots cooler in the summer, increase root dry weight and shoot dry weight of several species and can withstand shipping (13).

Griffin LLC, a supplier of crop protection chemicals in Valdosta, Ga., offers a product called Spin Out, a copper paint registered by the EPA. Root Right pots are round, black plastic pots manufactured with Spin Out as a component of the container walls. For more information on Spin Out and Root Right pots, contact the Lerio Corporation (14).

Growing tree seedlings in bottomless paper-based milk cartons is one way to use air root pruning.

Bottomless pots

Air root pruning is another way to prevent root circling. Air root pruning employs a similar mechanism to copper-treated pots. Root tips that come in contact with air are killed and the root system branches out within the root ball.

Growing tree seedlings in bottomless paper-based milk cartons is one way to use air root pruning. The milk carton, when folded open, creates a long, bottomless container. These containers are placed in a wooden flat with a wire-screen bottom and then filled with a soilless nursery mix. Another option is to place tree seedlings in plastic milk crates. The taproot grows downward and out through the bottom of the container. The root tip is exposed to the air, desiccates and dies back.

Repeated air-root pruning stimulates lateral branching and results in a fibrous root system as opposed to a strong taproot system. The benefit to the tree is rapid establishment in the field or landscape with increased scaffold branching and top growth. Nursery stock production by the milk carton method is especially useful for on-farm tree production and can be used in the propagation of a wide range of woody plants, including strong tap-rooted species such as black walnut, pecan and pines for Christmas trees.

There are other types of containers that promote excellent root branching and discourage root circling. RootMaker, developed by Dr. Carl Whitcomb at the horticulture research company Lacebark, Inc., is a pot that encourages root branching. RootMaker pots have staggered walls and a staggered bottom, which prevent root circling and direct roots toward holes in the walls and bottom of the pots. Whitcomb, formerly head of the nursery research program at Oklahoma State University, is well known for his numerous innovative approaches to unusual container systems.

Tubes

Long bottomless tubes are another production system that uses air root pruning. Tubes are generally made of plastic or Styrofoam. Nurserymen can use single tubes or several tubes imbedded in a flat. Tube plants range in size from large plugs sold as nursery liners to seedling trees grown in long, narrow pots and sold directly to consumers. Tubes are popular because they allow massive plant quantities to grow in a small area. Tubes are particularly adaptable to small-scale nursery production and to specialized stock like perennials and tree seedlings.

For more information on containers, see *The Container Tree Nursery Manual, Volume 2*, by Landis et al., listed in the **Resources: Publications** section. For suppliers of unusual pots, see the **Resource: Suppliers** section.

Pot-in-pot system

The pot-in-pot production method alleviates some of the problems associated with container production, such as blow-over and moisture loss (15). This system involves burying a holder pot, or moat pot, in the ground and placing a containerized plant inside this pot. The main drawback to this system is the high initial cost of the moat pot. The moat pot is a long-term investment since it will last 15 years or more. For more information on pot-in-pot systems, see the articles listed in the **Resources** section.

A container system that emphasizes hardy, fibrous roots

Cherry Lake Tree Farm in Groveland, Fla. developed a better way to grow containerized trees (16). Their patented Root-Enhancement System focuses on growing trees with a fibrous, lateral root system.

In the first stage, small liners grow in Deep Groove tube cell-pack trays of 38 or 51 cells. The cells are cone-shaped and lined with four vertical ridges that guide plant roots to a large hole at the bottom. These trays sit on benches in the greenhouse.

Deep Groove tube cell-pack trays are available from Growing Systems, Inc. (17). Larger liners are planted in Tree Bands, available from Anderson Die and Manufacturing (18). Before planting, all the trays are sprayed with Spin Out, a copper paint registered by the EPA.

The liners are inspected before potting. Workers cull liners with weak root systems and place the rest in 1- or 3-gallon containers. These pots contain grids that sit about 1 inch above the bottom of the pots and air-prune the roots. Container sleeves also hold the roots. The sleeves are made of a reusable geotextile pruning fabric developed by Cherry Lake and manufactured by Root Control, Inc. in Oklahoma City (19). The fabric lowers root zone temperatures and prunes roots.

When the trees reach an appropriate size, workers place them in pot-in-pot containers or transplant the trees into growbags. Finally, workers put the trees in a Spin Out-treated container in preparation for sale.

For a video of how this system works, visit the Cherry Lake Tree Farm at *www.cherrylake.com/Resources/Resources-Airpot.htm.*

Recycling plastic

Most nurseries use lots of plastic in the form of pots, flats, hanging baskets and greenhouse film. The nursery can reuse some of these products, but it's important to have a recycling system in place. Buying multi-year, ultraviolet-stabilized greenhouse film decreases the amount of sheet plastic used each year, but this kind of film is very expensive and not always readily available (20).

Fortunately, there are a number of recyclers around the country that accept nursery plastic. The Plastics Division of the American Chemistry Council Web site, *www.americanchemistry.com/s_plastics*, provides a wealth of helpful information on recycling of plastics. The plastics division also maintains the United States and Canada Recycled Plastic Markets Database with contact data for plastic recycling centers on a state-by-state basis. The Web site is *www.americanchemistry.com/s_plastics/sec_rpmd.asp?CID=1591&DID=6053*. Recyclers that accept agricultural plastics often have certain restrictions. Recyclers may require clean sheet plastic, which often means washing plastic before storage. Plastic must also be stored indoors properly. Most hard plastics like plug trays, flats, pots and hanging baskets are either No. 6 polystyrene or No. 2 high-density polyethylene. This distinction is important to some recyclers (20).

Many recyclers require nurseries to gather a certain amount of plastic before sending a truck to pick it up. Smaller nurseries may have trouble storing a large amount of plastic. Try combining plastic waste with other growers in the community. Some recyclers will not pay the grower for the plastic but do not charge for transportation costs, which are often high.

Weed control

Weed control is extremely important in container production. Weeds compete for water and nutrients and hinder sales of nursery stock. Weed control efforts should focus on two areas: in the pot and under the pot.

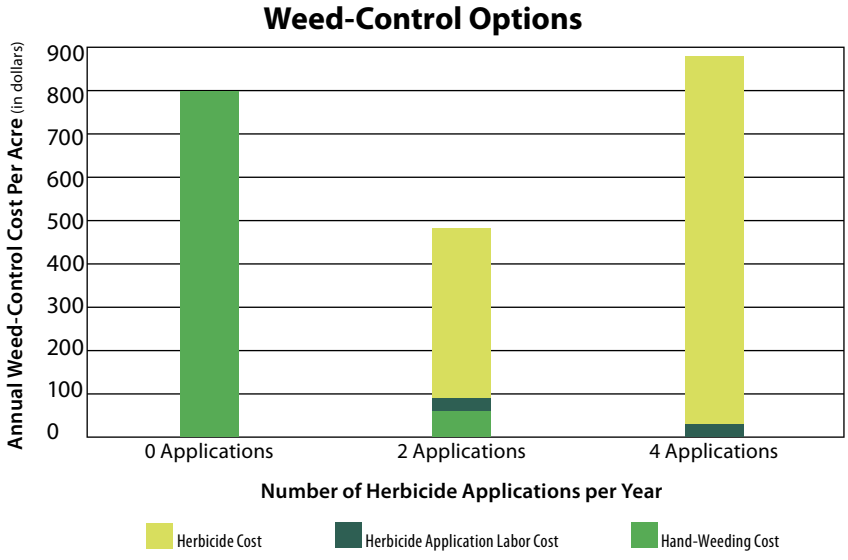
Sanitation is the least costly and most effective method for controlling weeds. To prevent weed seeds from blowing into pots, a vegetation-free zone on and surrounding the production bed is critical. To keep weeds from growing under the pot, place pots on geotextile weed barriers, often called fabric weed barrier or landscape cloth. Modern landscape cloths are durable and can last for 10 to 12 years in full sun. Landscape cloths do an excellent job of controlling weeds and are permeable to water from irrigation and rainfall, so drainage is not a problem. Although the initial cost is high, the expense can be prorated as an annual weed control investment.

Hand weeding is costly, but it may be appropriate in a small nursery setting. Weeds must be removed when they are small since large quantities of media are lost when pulling big weeds out of containers.

Herbicides are widely used in container nursery production. Growers use a weed-free medium to establish nursery plants, but wind, birds and surface irrigation water all deposit weed seeds onto the pot surface. Broadleaf and grassy weeds love to get a free ride into a container nursery because growing conditions in a media-rich pot are perfect. Pre- and post-emergent herbicides are commonly used in commercial nursery production to control these opportunists.

In 1991, Monrovia Nursery, with headquarters in Azusa, Calif., compared hand weeding to spraying herbicides and found that a combination of the two is the least-costly method (21). See *Figure 1* below. Monrovia found it took workers 10 hours of hand weeding per acre, performed 10 times a year, to keep the nursery weed-free without using pre-emergent herbicides. By using a pre-emergent once in the spring and once in the fall, the workers only needed to perform hand weeding seven times a year, spending one hour weeding each acre. Monrovia paid workers $8 an hour, the cost of herbicide was $200 per acre per application and it took two hours to apply. The **Field production** section below has more information on weed control.

Figure 1. Courtesy of American Nurseryman *(21). Used with permission.*



Alternatives to herbicides

Fabric weed barrier disks can control weeds in containers. The fabric disks are pre-slit and fit on top of the pot around the plant stem. Barrier disks prevent weeds from growing in containers by excluding sunlight and inhibiting weed germination. The disks are permeable to air and water but prevent germination of troublesome container nursery weeds like oxalis. The disks also reduce evaporation.

Tex-R Geodiscs are fabric disks treated with Spin Out. Geodiscs prevent weed growth by excluding light and pruning the roots of weed seeds that land on the fabric. Geodiscs provide effective weed control for up to three years and can be moved from pot to pot. For distributors, contact Texel USA (22).

Bonnie Appleton, director of the horticulture master's degree program at Virginia Tech, recently conducted research using Geodiscs on container-grown willow oaks (23). The Geodiscs suppressed all weeds completely. Trees grown in the pots with Geodiscs had higher top dry weights and root dry weights than trees grown without any form of weed control and trees sprayed with a conventional herbicide.

Bioherbicides

Corn gluten meal, a recently introduced weed control, is a by-product of corn syrup processing. Corn gluten meal is a pre-emergent herbicide applied in early spring. The meal works best when applied to the top one-quarter inch of soil and must be reapplied every year. Corn gluten meal is 10 percent nitrogen and acts as a slow-release fertilizer for the crop. Corn gluten meal is patented and sold as an herbicide. See the **Resources: Suppliers** section for corn gluten meal suppliers. Treating a large area can be quite expensive. Wheat gluten meal has many of the same effects as corn gluten meal, but it has not been patented and may be more affordable.

Recent research revealed that corn gluten hydrosylate, which is made from corn gluten meal, is more effective controlling

weeds than corn gluten meal (24) and can be applied at less than half the rate for effective weed control. Iowa State University, the patent holder of corn gluten meal as a natural herbicide, maintains a list of licensed suppliers for this product at *www.techtransfer.iastate.edu/en/for_industry/technology_search/cgm_licensees.cfm*. See the **Resources: Suppliers** section for information on purchasing corn gluten hydrosylate.

There are some new environmentally friendly contact herbicides that break down quickly and provide options for weed control in container nurseries around irrigation risers and perimeter areas and are also applicable for general use in field nursery production. One class of products is made from pelargonic acid, a fatty acid found in plants and animals. Available commercial products include Weed Eraser and Scythe. The products are sprayed on weeds and rapidly lower the weeds' pH level, weakening cell walls and killing the weeds within two hours. A second class of products contain acetic acid (vinegar), lemon juice, eugengol, thyme oil, orange oil and other natural ingredients. Commercially available products include Nature's Glory, Burnout and Bioganic. The products work as contact herbicides and control, with varying degrees of success, broadleaf and grassy weeds. Application to nursery plants should be avoided and several applications may be necessary to kill perennial weeds.

Fertilization

Large-scale container nursery production is a huge success largely due to advances in media and fertilizer combinations. Favorable media and fertilizer combinations are a result of several decades of research collaborations between land-grant universities, commercial nurseries and the fertilizer industry. Commercial synthetic fertilizers including slow-release and liquid fertilizers play a key role in this picture. Detailed information on commercial nursery mixes and fertilizer systems is available through the Cooperative Extension Service.

As organic production becomes standardized under the National Organic Program Final Rule, more nursery growers explore fertilizers acceptable in organic production. ATTRA also has several publications on the topic, including *Potting Mixes for Certified Organic Production*. Unlike synthetic greenhouse fertilizers, there is minimal research to support the use of organic fertilizers in a nursery mix recipe. Most of the following material will focus on organic fertilizers for container nursery production. In sustainable nursery production the emphasis is eliminating runoff, regardless of if the fertilizer source is synthetic or organic. Excessive nitrates and phosphorus are the most common problems in runoff water (25).

There are four basic ways to fertilize containerized plants: incorporate, topdress, liquid feed and foliar feed. In a nursery container, fertilizer incorporation in the nursery mix combined with liquid feeding should provide sufficient nutrition.

Several organic fertilizers provide nitrogen. Fertilizers include alfalfa meal, blood meal and cottonseed meal, among others. Materials that provide phosphorus include oak leaves, bone meal and shrimp wastes, among others. Greensand, granite meal and soybean meal all provide potassium. *Table 3* is not exhaustive, but it provides analyses of some popular organic and synthetic slow-release fertilizers.

Maintaining adequate levels of nutrients in the container medium is necessary for optimum growth of woody ornamentals. The levels of soluble nutrients in containers can be significantly reduced after three or four irrigations because of limited container volume and frequent application of water. Use slow-release and liquid fertilizing systems to overcome this problem.

Organic or synthetic slow-release fertilizers help cut down levels of nitrates in runoff water (1). Slow-release and controlled-release synthetic fertilizers, like commercially available Nitroform and Osmocote, are common in container production systems. Incorporate slow-release and controlled-release fertilizers into the growing media for best results. Do not topdress. Slow-release fertilizers are often used in combination with liquid fertilization.

Table 3. Analysis of organic and synthetic slow-release fertilizers				
Organic fertilizers	**%N**	**%P**	**%K**	**Other nutrients**
Bat guano (fresh)	10	3	1	Calcium
Bat guano (old)	2	8	0	Calcium
Blood meal	10	0	0	
Bone meal (steamed)	1	11	0	Calcium
Cottonseed meal	6	2	1	
Eggshells	1.2	0.4	0.1	Calcium and trace minerals
Fish emulsion	4	1	1	Sulfur
Fish meal	5	3	3	
Greensand	0.0	0.0	7.0	32 trace minerals
Hoof and horn meal	12	2	0	
Kelp meal	1.5	0.5	2.5	Trace minerals
Manure				
Cow	2	2.3	2.4	
Horse	1.7	0.7	1.8	
Pig	2	1.8	1.8	
Sheep	4	1.4	3.5	
Poultry	4	4	2	
Oak leaves	0.8	9.4	0.1	
Pine needles	0.1	0.0	0.5	
Sawdust, well rotted	0.0	0.2	0.2	
Soybean meal	7.0	0.5	2.3	
Worm castings	0.5	0.5	0.3	11 trace minerals
Slow-release synthetic fertilizers				**Effective period**
IBDU	31	0	0	
Lesco	20	6	12	4-6 months
MagAmp (also contains 25% magnesium)	8	40	0	100 days
Osmocote	13-19	6-14	12-14	3-4 or 8-9 months
Precise	12	6	6	3-4 months
Premix (also contains micronutrients)	24	7	8	6-8 weeks
ProKote	20	3	10	7-9 months
Sta-Green	12	6	6	6-8 weeks

Table 4. Materials for organic fertigation*		
Element	**Material**	**Benefits**
Nitrogen	Liquefied fish	Biostimulant, balanced NPK
	Liquid manures	Rapid uptake
	Phytamin 800	Rapid uptake, high solubility
	Sodium nitrate**	Rapid
	Spray-dried fish**	Rapid uptake, biostimulant
Phosphorus	Bat guano**	Rapid uptake
	Micronized rock phosphate**	Biostimulants, 16% P2O5
	Seabird guano**	Rapid uptake, 10% P2O5
Potassium	Soluble Sul-Po-Mag**	Supplies K, Mg, and S
	Soluble sulfate of potash**	50% K, 18% S
N-P-K combination	Fish products	
	Liquefied manures	
	Phytamin 3-2-3	Rapid uptake
	Seabird guano**	12-12-2.5
Calcium	Solution grade gypsum**	Calcium and sulfur
	Solution grade limestone**	98% CaCO3
Sulfur	Micronized sulfur**	Up to 90% S
	Solution grade gypsum**	
Trace mineral/ biostimulants	Compost teas	Biostimulant, humic acids
	Kelp extract powders**	Trace minerals, biostimulant
	Kelp extract liquids	Trace minerals, biostimulant
	Liquid humates	Humic acids, biostimulants
	Liquid trace minerals	Various formulations
	Micronized compost**	Biostimulant, humic acids
	Micronized humates**	Humic acids, biostimulant
	Rock dusts**	Trace minerals, biostimulant

**Reprinted with permission from Amigo Cantisano. 2000. Organic growers can fertigate! Growing for Market. March. p. 8-9.*

***Dry material: Must be premixed and thoroughly agitated in water prior to and during injection. May be less soluble than liquid formulations.*

Nitrogen is the main nutrient supplied through liquid feeding, or fertigation. Organic liquid fertilizers include fish emulsion, fish powder, blood meal, bat guano, seabird guano, worm castings and composted manure teas. Some forms of organic fertilizers are more adaptable to low-volume irrigation systems like drip or trickle systems. A 1992 study found that spray-dried fish protein and poultry protein fertilizers do not clog drip emitters and microsprinklers (26). Fish protein, blood protein, poultry protein and brewers yeast are all available as spray-dried materials. Amigo Cantisano, an organic agriculture consultant in California, compiled *Table 4* (27).

Foliar feeding can supplement soil and liquid fertilization, especially where certain

nutrients are deficient and must be incorporated into the plant quickly. Use filtered solutions of manure, seaweed, fish powder and fish emulsion. Seaweed is an excellent foliar material because it contains growth hormones, including auxins, gibberellins and cytokinins, as well as trace elements. Research suggests that foliar feeding programs enhance plant resistance to pest and disease attack. Compost teas are popular as a foliar feed primarily because of their disease-suppressive characteristics.

For more information on alternative fertilizers, request the ATTRA publication *Alternative Soil Amendments* and the Web-only database *Sources of Organic Fertilizers and Amendments.* Another useful resource is *Fertile Soil* by Robert Parnes (28), an in-depth publication on organic fertilizers. Parnes' publication provides detailed tables on the nutrient content of various manures and plant and animal by-products.

Potting media

Field soil is sometimes used in container mixes. Field soil makes up 10 to 30 percent of the mix by volume, but soil is heavy and requires the additional step of pasteurization to eliminate diseases and weed seeds. The standard replacement for soil is peat moss, but there is concern that peat is a non-renewable resource. Research is being conducted to determine what materials can be used to replace peat. Most of the products being tested are some form of waste.

Composted pine bark, a by-product of the lumber industry, is an excellent medium for containerized plants. Mixes containing more than 20 percent composted pine bark support a significant level of suppression of *Pythium* damping-off (30). Other alternatives are coir, spent mushroom compost, paper mill sludge, apple pomace, shredded newspaper, compost, processed alfalfa, processed kenaf, recycled cardboard and composted municipal yard waste. Most studies show that these alternative products should not compose more than 50 percent of the mix. For in-depth information on these topics, ask for the ATTRA publication *Potting Mixes for Certified Organic Production.*

Chris Starbuck, extension specialist at the University of Missouri, developed the Missouri Gravel Bed as an alternative growing system for nursery stock (29). The gravel bed uses a mixture of gravel and sand to get young plants established. The gravel bed is inexpensive because it uses neither containers nor potting mix, but produces healthy bare-root plants.

The gravel bed uses half-inch or smaller gravel mixed with 10 to 15 percent sand and is 14 to 18 inches deep to support 1.5-inch caliper trees. Starbuck places dormant, bare-root plants in the bed in early spring. He applies slow-release fertilizers on top of the gravel. Starbuck leaves plants in the bed for at least six weeks, but pulls the plants the year they are planted. He uses an automatic trickle irrigation system.

Starbuck helped growers in more than 40 states establish gravel beds for their operations. A grower in Iowa successfully overwintered plants in temperatures as low as minus 25 degrees Fahrenheit. The roots are as protected in gravel as they would be in soil and are more protected than they would be in containers.

Mycorrhizae are soil fungi that form beneficial associations with plant roots. Mycorrhizae enable plant roots to do a better job of gaining nutrients and water. The fungi can be used in field or container production. Growers achieve better stand establishment, use less fertilizer and inoculate bare-root seedlings when using mycorrhizae. Commercially available mycorrhizae stimulate the roots of almost all tree and shrub species. For a listing of suppliers of mycorrhizae, see ATTRA's *Sources of Organic Fertilizers and Amendments.*

Field production

Until the 1950s, virtually all nursery production occurred in the field. Field production is still widely used to produce bare-root seedlings for conservation plantings, fruit trees and nursery liners. The most profitable product of field nurseries is bagged and burlapped shade trees for the landscape industry. In-ground production is advantageous to tap-rooted tree species,

mass plantings, inexpensive establishment and large caliper (trunk diameter) size. Disadvantages of in-ground production include a higher percentage of plant loss and longer establishment periods after transplanting.

Field nursery production involves the use of unique soil management practices. Soil-building cover crops and crop rotations are important to maintain good soil structure, fertility and organic matter. Living mulches are cover crops planted in the aisles to hold the soil, provide traction, increase water infiltration and suppress weeds. Legume cover crops fix nitrogen and can be used to reduce the amount of nitrogen fertilizer applied each year. See ATTRA's *Overview of Cover Crops and Green Manures* for further information and resources.

Integrating living mulches, cover crops and the application of high-quality composts in field nursery operations are the fastest ways to improve nursery soil. To reduce pest problems, plant a diversity of species rather than a large block of single species followed by a large block of another species. Habitat management for beneficial insects is also an option in a field situation. For more information on this, see ATTRA's *Farmscaping to Enhance Biological Control.*

Nursery equipment and irrigation systems for field nursery production are unique. Suppliers are listed in the trade publication *Nursery Management and Production Buyer's Guide* and in the magazine *American Nurseryman.* See the **Resources: Publications** section for contact information.

A recent innovation in field nursery production is the use of in-ground fabric containers, sometimes called root control bags or field grow bags. Dr. Carl Whitcomb, formerly head of the nursery research program at Oklahoma State University, developed these containers in the early 1980s. The bags have a fabric or clear polyethylene bottom stitched or glued to walls made of non-woven fabric and come in several sizes (31). In theory, the bags combine the best qualities of container and field production.

The advantages of field grow bags are numerous. Bags enhance rooting, leave 80 percent of roots intact during transplanting, make harvesting easier, save labor and time, do not require special machinery at harvest and can be harvested year-round. Bagged and burlapped plants are normally harvested only during dormancy (31).

There are also disadvantages. The initial investment in grow bags is expensive, plants need more staking and water after transplanting, damaged bags cannot be used, mechanical cultivation and precise fertilizer application are difficult and bag removal can be difficult and time consuming (31).

The greatest disadvantage of growing in bags is marketing the plants. Few people know the advantages of growing in bags and find bagged trees less convenient to handle than containerized trees. One way around this is to grow the plant in a pot for the last year of production.

An important consideration in bagged and burlapped production is the loss of 200 to 250 tons of topsoil per acre at each harvest. The digging and removal of topsoil from bagged and burlapped nursery operations is a practice that can, over a long time, seriously deplete the farm's most important resource. There are two ways to fight topsoil depletion. Replace topsoil with something else or have a bare-root operation that does not require topsoil to leave the farm. Many growers use compost to replace some of the topsoil that is lost, but applying more than 40 tons of compost per acre is not recommended.

Integrating living mulches, cover crops and the application of high-quality composts in field nursery operations are the fastest ways to improve nursery soil.

Weed control

Weed control in modern field nursery production is based on the use of herbicides. There are many excellent non-chemical alternatives, however. These include mechanical cultivation, flame weeding, mulches, living mulches, steam and solarization.

Mechanical cultivation

Bärtschi-Fobro (32), a Swiss manufacturer of nursery equipment, offers small-scale

implements including a brush hoe for precision weeding in multiple-row seedling nursery beds. The company also makes brush heads that disturb the soil surface and dislodge weed seedlings as the drum turns. The company no longer has a U.S. distributor, but small-scale implements may still be available through used-equipment dealers.

Flame weeding

Flame torches, or flamers, may be an option in some nursery situations. Flaming works by searing and disrupting plant cells, not by burning plant tissue. Passing a flamer quickly over a weed is enough to kill the top of the weeds, but roots can re-sprout new growth. Broadleaf weeds are more susceptible to flaming than grassy weeds. Flaming needs to be repeated every two to three weeks to control grasses.

Flame weeders can be used to prepare a stale seedbed by flaming off the first and second flushes of weeds to emerge after seedbed preparation.

Flame weeders can be used to prepare a stale seedbed by flaming off the first and second flushes of weeds to emerge after seedbed preparation. Weed flamers can also control post-emergent weeds. To protect young seedlings from injury, use flaming shields. Taller seedlings and trees with well-developed bark can withstand directed flaming aimed at weeds growing in and between the rows. Although there is some criticism that flaming is not a sustainable practice because it uses fossil fuels, flame-killing a nursery bed or field of seedlings uses less fossil fuel than manufacturing, transporting and spraying an herbicide for the same job (33). For more information on flaming, contact ATTRA at 1-800-346-9140 or *www.attra.ncat.org*.

Mulches

Mulches are another way to exclude weeds. Mulches keep out weeds by limiting light and retaining moisture in the soil. Organic mulches should be 3 to 4 inches thick and need replenishing once or twice a year. Millcreek Manufacturing, based in Leola, Pa., offers a row mulching machine that can apply mulch and compost to field-grown stock (34). The machine costs about $5,000 and can mulch beds from 18 to 48 inches wide, from 1/2 inch to 10 inches deep.

Landscape fabric can also be used in field production. A fast way for growers to get into production is to lay cloth in the field, cut or burn holes in the cloth and then plant the liners or seedlings.

Researchers at Oregon State University found that mulches made of oyster shell, hazelnut shell and copper-treated geotextiles provide good suppression of liverwort, a prevalent weed in many nurseries. These three mulches outperformed mulches of rockwool, peat moss, coarse sand, perlite, pumice and the commercial herbicide Ronstarand Surflan. The mulches also outperformed iron oxide, copper sulfate and manganese sulfate fertilizers (35).

Living mulches

In a 1990s study conducted in Minnesota, researchers compared soil cultivation, herbicides and three living mulches for weed suppression in a field with six species of ornamental trees (36). The researchers used Norcen bird's-foot trefoil, Wheeler winter rye and a grass sod consisting of 80 percent Eton perennial ryegrass and 20 percent Ruby red fescue. The grass sod provided excellent weed control, but was overly competitive with the trees. The trefoil was infested with weeds. The winter rye, which was killed with herbicides and then acted as a mulch, provided good weed control and increased water infiltration and soil moisture. That evened out soil temperature fluctuations, reduced soil bulk density, improved nutrient cycling and reduced field maintenance costs. In general, the cover crops tended to reduce annual weeds and favor perennial species.

Steam

For years, conventional production systems used methyl bromide to sterilize soil before planting. One sustainable system that yields the same results uses steam to disinfest beds and greenhouses prior to planting. In a field planting, this system can treat planting beds. Steam is nontoxic, easy to apply,

Table 5. Organic mulches		
Type	**Source of weeds**	**Comments**
Grass clippings	Yes	Usually free, not very attractive
Newspaper	No	Inexpensive, very effective, not very attractive, can attract slugs
Cocoa hulls	No	Very expensive, decomposes in 2-3 years, adds high amounts of potassium
Cottonseed hulls	No	Expensive, not available everywhere
Pine bark nuggets	No	Decomposes in 2-6 years, chunks are bulky and can wash away
Shredded softwoods (cedar, cypress, etc.)	No	Price depends on local availability, attractive, decomposes in 2-5 years
Hardwood chips	No	Can be quite inexpensive if obtained from chipped shrubs or trees, decomposes in 1-3 years
Compost	No	Available, attractive
Corn stalks	No	Not available everywhere, unattractive
Wheat straw	Yes	Inexpensive, decomposes rapidly
Hay	Yes	Inexpensive, decomposes rapidly
Rice hulls	Yes	Not available everywhere
Pine straw	Yes	Inexpensive, attractive, decomposes in 1-2 years
Leaves	Yes	Usually free, compost first
Cardboard	No	Inexpensive, lasts a long time
Sawdust	No	Inexpensive, depletes nitrogen, can blow away, better to use aged material

controls the same soil pests as conventional methods and works in a wide variety of climates and conditions (37).

A small portable boiler is the best unit to use for a greenhouse. The Sioux Steam Flo, available from the Sioux Corporation, will work for greenhouse operations and costs about $5,700. For small beds in the field, larger units are available from Saskatoon Boiler Manufacturing in Canada. See **Resources: Suppliers** for contact information. The important differences in steam machines are how much heat the machines put out, how portable the machines are and how far into the soil the steam penetrates. Although most machines heat only the top 3 to 6 inches of soil, temperatures are high enough to kill most weed seeds. Machines that heat the soil to 140 degrees for at least 30 minutes kill pest fungi, bacteria, nematodes and weed seeds.

Solarization

Soil solarization is another option for killing pests before planting trees, shrubs or perennials. Treat only beds that will be planted. The basic principle of solarization involves stretching sheets of clear plastic across moist ground. Solar radiation heats the soil and kills pests, including weed seeds and harmful insects. Solarization can kill annual and perennial weeds if summer temperatures climb high enough. Solarization can also be used to disinfest reused or soil-based potting media. To do this, enclose the media in plastic bags and leave them in the sun for two to three weeks. Two layers of plastic kill more pests and work about four times faster than one layer (38). For more information on soil solarization, contact ATTRA at 1-800-346-9140 or *www.attra.ncat.org*.

Harvest and storage

At some point, nurseries must dig up field-grown trees and plants. See the **Resources: Suppliers** section for manufacturers of tree diggers. Plants are often stored after digging. Conventional production systems dig trees in late fall or early winter and store trees in warehouses until early spring. During this time, nurseries spray bare-root trees with fungicides and bacteriostats to keep problems from arising.

Researchers in Rhode Island experimented with Taxus bagged and burlapped stock to prevent the plants from rooting out, a condition where the roots grow into the burlap bags. They used Spin Out, an EPA-approved copper paint, in several different ways (39). Treatments included painting the bottom of the root ball with copper paint, setting the root ball on copper-treated burlap and rewrapping the root ball with copper-treated burlap before mulching. Although all these treatments provided good control of rooting out after 12 to 16 weeks, the most effective treatments were setting the root ball on copper-treated burlap and leaving it unmulched. The researchers also found that placing the root balls on TexR Agroliner, a Spin Out-treated non-woven fabric, stopped rooting out completely.

One way to cut production costs is to grow plants in smaller containers.

Costs

The costs of nursery production include overhead, direct and marketing costs. Overhead costs include all the general costs of operating the nursery, like taxes, depreciation, interest, rent, utilities, insurance, maintenance and repair, new construction, new equipment, supplies, managerial and administrative salaries and labor wages that cannot be assigned to a particular crop. Direct costs are tied to a crop, like purchasing seed, potting media and fertilizers. Keeping excellent records is the best way to accurately determine true costs.

Prices should reflect:

- Exact production costs that include a reasonable profit for each crop
- Prices and quantities offered by competitors
- Supply and demand for the crop, except prices for high-quality products and loyal customers (1)

The British Columbia Ministry of Agriculture, Fisheries and Food compiled a *Planning for Profit* series of online publications that details costs involved in establishing and growing several nursery species. These enterprise budgets provide information on expenses and income for perennial and tree crops grown in containers and in the field. The guides provide a rough idea of how much it costs to start production and how long it takes to make a profit. See the ministry's Web site at *www.agf.gov.bc.ca/busmgmt/budgets/index.htm* for more information.

For costs associated with establishing a small perennial nursery, see the handbook *Requirements and Costs of Establishing and Operating a Three-Acre Herbaceous Perennial Container Nursery* listed in the **Resources: Perennials** section. See Betrock Information System's Web site hortworld.com for a list of horticultural software that focuses on plant selection and nursery management.

Competitive prices can fall below the cost of production. In this circumstance, a nursery with a unique advantage, like proximity to its market or a superior product, may be able to maintain a higher price that covers costs without experiencing a serious drop in the number of plants sold.

Although it is desirable to make a profit on each kind of plant, sometimes it is good marketing strategy to grow some plants that may not be profitable in order to offer a well-rounded inventory. A small nursery might specialize in a few high-quality plants or produce some plants not carried by larger nurseries, which produce only plants with high sales volumes.

One way to cut production costs is to grow plants in smaller containers. Although the crop sells for less, the costs of media and containers are reduced, as well as the time needed to produce the crop. Selling plants at wholesale prices means less money received

for each plant, but also less money and time spent on marketing and advertising.

Summary

Nursery managers can alter their production systems to incorporate products and techniques that will help the nursery meet some of the goals of sustainable agriculture. Nurseries can reduce fertilizer and pesticide runoff, conserve soil, recycle plastics and use organic waste. Some nursery growers may find certified organic nursery stock or specialty nursery stock to be an economically profitable option. Healthy plants are a first line of defense against insects and diseases. Soil building practices and nursery media modifications play a central role in sustainable nursery management. The end result—a greener nursery—can build good relations with neighbors and help market nursery plants to the green industry.

References

1a) Newman, Julie. Tough times spell changes for greenhouse firms. GreanBeam Pro. Accessed July 31, 2008. *www.greenbeampro.com/content/view/1136/43*

1) Heuser, C.W. and R.F. Stinson (eds.). 1989. Nursery Production, 2nd ed. Pennsylvania State University, University Park, PA. 216 p.

2) Mathers, Hannah. 1996. An Overview of the BC Wholesale Nursery Industry: New Grower Information Package. Nursery Production Factsheet, Ministry of Agriculture, Fisheries and Food, British Columbia. p. 2.

3) Byczynski, Lynn. 1995. Going Commercial. Special Report for Growing for Market. Fairplain Publications, Lawrence, KS. 8 p.

4) Rodda, Kelli. The Real Green Industry: Native Plants. GreanBeam Pro. Accessed July 31, 2008. *www.greenbeampro.com/content/view/1438/44*

5) The nursery is located at 2 Dove Road, Bernalillo, NM 87004. 505-867-1323. The garden center is at 157 Jemez Dam Road, Bernalillo, NM 87004. 505-867-1322.

6) Svenson, Sven E., Dave G. Adams, and Robert L. Ticknor. 1997. Slow and steady. American Nurseryman. January 15. p. 50-52, 54-59.

7) Whitcomb, Carl E. 1988. Plant Production in Containers. Lacebark Publications, Stillwater, OK. p. 411.

8) Skimina, Conrad A. 1992. Recycling water, nutrients, and waste in the nursery industry. HortScience. September. p. 968-971.

9) Metzger, Jim. 1998. OSU research update: New production methods to reduce pesticide leaching and run-off. Ohio Florists' Association Bulletin. January. p. 13.

10) Rose, Mary Ann, Mark Rose, and Hao Wang. 1999. Fertilizer concentration and moisture tension affect growth and foliar N, P, and K contents of two woody ornamentals. HortScience. April. p. 246-250.

11) Zalom, F.G. et al. 1992. Integrated pest management: Addressing the economic and environmental issues of contemporary agriculture. In: F.G. Zalom and W.E. Fry (ed.). Food, Crop Pests, and the Environment: The Need and Potential for Biologically Intensive Integrated Pest Management. APS Press, St. Paul, MN. Also see *www.ipmnet.org*.

12) Biddinger, Eric, Dave Beattie, and Robert Berghage. 1999. The effects of copper-treated fiber containers on the growth of four commercial plant species. Greenhouse Product News. October. p. 22, 24-27.

13) Ruter, John M. 2000. Cross-country containers. American Nurseryman. February 1. p. 26-28, 30-31.

14) NSI. *www.nurserysupplies.com.* Plant locations in Pennsylvania, California, Oregon and Florida.

15) Haydu, John J. 1997. To bag or to pot? American Nurseryman. April 15. p. 40-42, 44-47.

16) Schlossberg, Matt. 2000. Getting back to the roots. American Nurseryman. February 1. p. 32-34, 36-37.

17) Growing Systems, Inc.
2950 N. Weil St.
Milwaukee, WI 53212
414-263-313
info@growingsystemsinc.com
www.growingsystemsinc.com

18) Anderson Die and Manufacturing
2425 SE Moores St.
Milwaukie, OR 97222
503-654-5629

19) Root Control, Inc.
1158 NW 44th
Oklahoma City, OK 73118
800-521-8089
info@treebag.com
www.treebag.com

20) Arent, Gale L. 1996. The greenhouse wastestream. HortTechnology. October-December p. 365-366.

21) Suttle, Walter. 1998. Weeding out costly controls. American Nurseryman. October 15. p. 24-29.

22) Texel USA
9987 Winston Dr.
Pinckney, MI 48169
734-878-1814

23) Appleton, Bonnie L. and Susan C. French. 2000. Weed suppression for container-grown willow using copper-treated fabric disks. HortTechnology. January-March. p. 204-206.

24) Williams, Greg and Pat Williams. 1997. More on corn gluten as a pre-emergence herbicide. HortIdeas. June. p. 62.

25) Developing a Management Plan for Irrigation Runoff. Texas A& M University. *http://aggie-horticulture.tamu.edu/greenhouse/nursery/environ/wmplan1.html*

26) Schwankl, L.J. and G. McCourty. 1992. Organic fertilizers can be injected through low-volume irrigation systems. California Agriculture. September-October. p. 21-23.

27) Amigo Bob Cantisano
P.O. Box 942
No. San Juan, CA 95960
530-292-3619
orgamigo@jps.net

28) Parnes, Robert. 1990. Fertile Soil: A Grower's Guide to Organic and Inorganic Fertilizers. agAccess, Davis, CA. 190 p.

29) Anon. 1998. Missouri gravel bed offers growing alternative for nursery stock. American Nurseryman. October 1. p. 20, 25.

30) Hoitink, H. A. J., Y. Inbar, and M. J. Boehm. 1991. Status of compost-amended potting mixes naturally suppressive to soil-borne diseases of floricultural crops. Plant Disease. September. p. 869-873.

31) Cole, Janet C., Roger Kjelgren, and David L. Hensley. 1998. In-ground fabric containers as an alternative nursery crop production system. HortTechnology. April-June. p. 159-163.

32) Bärtschi-Fobro
www.fobro.com

33) McCargo, Heather. 1997. Nursery crops can be grown organically. Maine Organic Farmer & Gardener. June-August. p. 29-30.

34) Millcreek Manufacturing Co.
www.millcreekmfg.com

35) Svenson, Sven E. 1998. Suppression of liverwort growth in containers using irrigation, mulches, fertilizers and herbicides. HortScience. June. p. 484. (Abstract)

36) Calkins, James B. and Bert T. Swanson. 1995. Comparison of conventional and alternative nursery weed management strategies. Weed Technology. October-December. p. 761-767.

37) Quarles, William. 1997. Steam—The hottest alternative to methyl bromide. American Nurseryman. August 15. p. 37-43.

38) Byczynski, Lynn. 1995. Use the sun to beat insects, weeds. Growing for Market. August. p. 14, 16.

39) Maynard, Brian K. and William A. Johnson. 1997. Using cupric hydroxide to reduce the rooting-out of B&B stock during storage. HortScience. June. p. 455-456. (Abstract)

Resources

Publications

For a complete list of propagation supplies, tree seed, nursery liners, plant materials, nursery supplies, equipment and services associated with the greenhouse and nursery industries, see *Nursery Management and Production—Buyer's Guide.* This information is now best accessed through the product directory at Green Beam Pro's Web site, *www.greenbeampro.com.*

The American Nursery and Landscape Association also carries a number of titles as well as nursery standards and booklets.

American Nursery and Landscape Association
12501 Street, NW, Ste. 500
Washington, DC 20005
202-789-2900
www.anla.org

General production

Barton, Susan et al. 2002. Establishing and Operating a Garden Center: Requirements and Costs. NRAES, S-161. Cornell University, Ithaca, NY.
This publication is widely available or contact National Resource, Agriculture and Engineering Service at www.nraes.org.

Dirr, Michael. 1998. Manual of Woody Landscape Plants. 5th ed. Stipes Publishing Co., Champaign, IL 1187 p.
This publication is widely available online or from the publisher.

Eaton, Gregory R., and Bonnie L. Appleton. 2002. Getting Started in the Nursery Business. Virginia Cooperative Extension. 430-050. 8 p. *www.ext.vt.edu/pubs/nursery430-050/430-050.pdf*

Harlan, Michael and Linda Harlan. 2000. Growing Profits: How to Start and Operate a Backyard Nursery. Moneta Publications, Citrus Heights, CA. 217 p.
This book has excellent practical information for starting a small-scale nursery. It includes information on starting a nursery and considers the business aspects and gives down-to-earth facts about production. The new edition widely available online or from the publisher.

Moorman, Gary, 1997. Scouting and Controlling Woody Ornamental Diseases in Landscapes and Nurseries. Pennsylvania State University, University Park, PA. 112 p. *http://pubs.cas.psu.edu/FreePubs/pdfs/uhi32.pdf*

North Carolina State University and North Carolina Association of Nurserymen. 2000. Nursery Short Course. Raleigh, NC. 31 p. *www.ces.ncsu.edu/depts/hort/nursery/pdf/short_course/2000/2000.pdf*

Perry, F. B., Jr., et al. 1990. Establishment and Operation of 20- and 40-acre Container Nurseries in Climatic Zone 9. Southern Cooperative Series Bulletin 341. Dept. of Research Information, Alabama Ag. Expt. Station, Auburn.
This publication is archived in land grant university libraries and can be accessed through Interlibrary loan.

Whitcomb, Carl E. 2003. Plant Production in Containers II. 2006. Lacebark Publications, Stillwater, OK. 460 p. *www.lacebarkinc.com*
This publication is widely available online as well as from publisher.

Whitcomb, Carl E. 2001. Production of Landscape Plants II (in the field). 2nd ed. Lacebark Publications, Stillwater, OK. *www.lacebarkinc.com*
This publication is widely available online as well as from publisher.

Propagation

Heuser, Chas. W., Jr., and Michael Dirr. 2006. The Reference Manual of Woody Plant Propagation. Varsity Press, Inc., Athens, GA.
This book contains complete propagation techniques for important woody plants. Material on plant tissue culture and other specialized techniques is included. The latest edition is widely available in paper and hardcover from online sources, as well as from the publisher.

Hartmann, H.T., et al. 2001. Plant Propagation: Principles and Practices. 7th ed. Prentice Hall, London. 880 p. and CD.
This is the standard reference on the science and practice of plant propagation. It contains detailed

information on propagation from seed or cuttings and describes and illustrates grafting and budding techniques. It covers reproduction by grafting or budding, which is practiced extensively for certain varieties of coniferous landscape trees, fruit trees and deciduous woody ornamentals. This reference is widely available from online booksellers.

Macdonald, Bruce. 2006. Practical Woody Plant Propagation for Nursery Growers. Timber Press, Portland, OR.

This book is widely available from online booksellers as well as the publisher.

Yerkes, Guy E. 1957. Propagation of Trees and Shrubs, USDA Farmers' Bulletin No. 1567. 54 p.

First published in 1945, this USDA bulletin is a good practical guide to the propagation of woody plants by seed and cuttings using on-farm resources. You should be able to obtain a photocopy of this Farmers' Bulletin through a land grant university library or through Interlibrary loan.

Young, James A., and Cheryl G. Young. 1992. Seeds of Woody Plants of North America. Dioscorides Press, Portland, OR. 407 p.

Seeds of Woody Plants of North America is a greatly revised edition of the legendary USDA This is Agriculture Handbook No. 450, Seeds of Woody Plants in the United States. This edition covers plants, including new material on native plants used in environmental plantings and Asian plant materials of importance. The focus is on propagation from seed; vegetative propagation is not covered. Presentation of material is condensed, however, and access to the USDA handbook may be helpful for literature citations, taxonomic information, tables and chapters on seed biology, genetics, pollen handling and harvesting and storage procedures. The handbook is available from online booksellers.

Perennials

Armitage, Allen. 1998. Herbaceous Perennial Plants. Varsity Press, Athens, GA. 1141 p.

This is a good book for general knowledge of perennials. It is widely available.

Nau, Jim. 1996. Ball Perennial Manual: Propagation and Production. Ball Publishing, Batavia, IL. 487 p.

This publication is an excellent resource for perennials. It gives a general description and information on hardiness, season of bloom, propagation, germination overview, growing techniques, varieties and cultivars, related materials and tips on how to use in the home garden.

The publication is widely available online or from:
Ball Publishing
P.O. Box 9
Batavia, IL 60510
888-888-0013
www.growertalks.com

Walker, Cathleen, and Leonard P. Perry. 1998. Herbaceous Perennials Production: A Guide from Propagation to Marketing. NRAES-93. Northeast Regional Agricultural Engineering Service, Ithaca, NY. 208 p.

This publication is widely available online and from:
NRAES Coop. Ext;.
P.O. Box 4557
Ithaca, NY 14852-4557
607-255-7654
607-254-8770 fax

Taylor, Reed D., et al. 1990. Requirements and Costs of Establishing and Operating a Three-Acre Herbaceous Perennial Container Nursery. Special Circular 136, Ohio

Agricultural Research and Development Center, The Ohio State University, Wooster, Ohio. 30 p.

This study identifies the resources and costs associated with an herbaceous 3-acre perennial nursery. Calculations are based on 1989 prices. The study calculates total costs per plant, based on how the plant was propagated, with calculations based on 1989 prices. Included in the cost estimates are land improvement, unheated polyhouse, heated polyhouse, cold frame, irrigation, fixed costs, labor, machinery, capital and variable costs. The study is archived in land grant university libraries and can be accessed through Interlibrary loan.

Pests and diseases

Dreistadt, Steve H. 2004. Pests of Landscape Trees and Shrubs: An Integrated Pest Management Guide. Publication 3359. University of California, Division of Agriculture and Natural Resources, Oakland, CA. 501 p.

Available at UC Coop. Extension offices and from:
ANR Publications
University of California
6701 San Pablo Ave., 2nd floor
Oakland, CA 94608-1239
800-004-8849
510-642-2431
http://anrcatalog.ucdavis.edu

Gill, Stanton, David L. Clement, and Ethel Dutky. 1999. Pests & Diseases of Herbaceous Perennials: The Biological Approach. Ball Publishing Co., Batavia, IL. 304 p.

Leslie, Anne R. 1994. Handbook of Integrated Pest Management for Turf and Ornamentals. Lewis Publishers/CRC Press, Boca Raton, FL. 672 p.

Lloyd, John et al. 1997. Plant Health Care for Woody Ornamentals. International Society of Arboriculture, Champaign, IL. 223 p.

This publication presents proactive approaches to woody plant health care in nurseries and landscapes. It focuses on diagnosing and treating diseases, pests and abiotic disorders. It is widely available online in paperback and from:
International Society of Arboriculture
P.O. Box 3129
Champaign, IL 61826
888.ISA.TREE
217-355-9411
isa@isa-arbor.com
isa-arbor.com

Texel USA
9987 Winston Dr.
Pinckney, MI 48169
734-878-1814

Soils

Amigo Bob Cantisano
P.O. Box 942
No. San Juan, CA 95960
530-292-3619
orgamigo@jps.net

Pot-in-pot system

Brand, Mark H. 1994. Pot-in-pot system—The best of field and container production. Yankee Nursery Quarterly. Spring. p. 1–4.

Haydu, John J. 1997. To bag or to pot? American Nurseryman. April 15. p. 40–42, 44–47.

Ruter, John M. 1997. The practicality of pot-in-pot. American Nurseryman. January 1. p. 32–37.

Ruter, John M. 1995. Effects of pot-in-pot production system on plant growth. American Nurseryman. February 15. p. 66–69.

Anderson Die and Manufacturing
2425 SE Moores St.
Milwaukie, OR 97222
503-654-5629

Growing Systems, Inc.
2950 N. Weil St.
Milwaukee, WI 53212
414-263-3131
info@growingsystemsinc.com
www.growingsystemsinc.com

Root Control, Inc.
1158 NW 44th
Oklahoma City, OK 73118
800-521-8089
info@treebag.com
www.treebag.com

Capillary sandbeds and subirrigation systems

Adams, Dave G., Sven E. Svenson, and Robert L. Ticknor. 1997. Making your bed. American Nurseryman. January 15. p. 60–62, 64–67.

This publication includes detailed plans for building a sandbed.

Svenson, Sven E., Dave G. Adams, and Robert L. Ticknor. 1997. Slow and steady. American Nurseryman. January 15. p. 50–52, 54–59.

Uva, Wen-Fei, Thomas C. Weiler, and Robert A. Milligan. 1999. Zero the hero. Greenhouse Grower. January. p. 158, 160. February. p. 68, 70. March. p. 44, 47–48.

This is a three-part series on subirrigation systems.

USDA publications

USDA publications—in the Agriculture Handbook, Miscellaneous Publication and Farmer Bulletin series—are a rich source of educational materials on field and container nursery production, seedling propagation and production, species selection and related topics. Publications such as the selected titles listed below may be found archived in university libraries designated as U.S. Government Document Repositories, or may be requested through Interlibrary loan. As noted, some are now online. Some publications may be for sale; order from:
U.S. Government Bookstore
U.S. Government Printing Office
710 No. Capital Street, NW
Washington, DC 20401
202-512-0132

202-512-1355 fax
http://bookstore.gpo.gov

Carlson, J.R. 1991. Conservation Tree and Shrub Cultivars in the Untied States. USDA Agriculture Handbook No. 692. 50 p.

Cordell, Charles E. 1989. Forest Nursery Pests. Agriculture Handbook No. 680. Forest Service, USDA. 184 p.
www.rngr.net/Publications/fnp

Engstrom, H.E., and J.H.Stoeckler. 1941. Nursery Practices for Trees and Shrubs Suitable for Planting on the Prairie-Plains. USDA. Miscellaneous Publication No. 434. 159 p.

Hardenburg, R.E. et al. 1986. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. USDA Agriculture Handbook No. 66. 130 p.

Landis, T.D. et al. 1990. The Container Tree Nursery Manual. Vols. 1–7: Agriculture Handbook No. 674-1 through 674-7. USDA Forest Service, Washington, DC.
www.rngr.net/Publications/fnp

This is a thorough treatise on the production of containerized trees and includes seven volumes. Volume 1 covers, planning, development and management; Volume 2 deals with containers and growing media; Volume 3 is about container nursery environment; Volume 4 covers seedling nutrition and irrigation; Volume 5 deals with pests and mycorrhizae; Volume 6 is about propagation; and Volume 7 covers processing, storage and outplanting of seedlings.

Peterson, G.W., and R. Smith. 1975. Forest Nursery Diseases in the United States. Agriculture Handbook No. 470. Forest Service, USDA. 125 p.

Stoeckler, J.H., and P.E. Slabaugh. 1965. Conifer Nursery Practice in the Prairie-Plains. Agriculture Handbook No. 279. Forest Service, USDA. 96 p.

Stoeckler, J.H., and G.W. Jones. 1957. Forest Nursery Practices in the Lake States. Agriculture Handbook No. 110. Forest Service, USDA. 96 p.

Williams, Robert D., and Sidney H. Hanks. Hardwood Nurseryman's Guide. Agriculture Handbook No. 473. Forest Service, USDA. 78 p.

University publications

Hamm, P.B., S.J. Campbell, E.M. Hansen. 1990. Growing Healthy Seedlings: Identification and Management of Pests in Northwest Forest Nurseries. Forest Research Laboratory, Oregon State University, Corvallis. 110 p.

Forest experiment station reports

Liegel, L.H., and C.R. Venator. 1987. A Technical Guide for Forest Nursery Management in the Caribbean and Latin America. General Technical Report SO-67. *www.srs.fs.usda.gov/pubs/1409*

Numerous bulletins and fact sheets on nursery production are available through the Extension Service, Agricultural Experiment Station, and U.S. Forest Service offices in each state. For materials available in each region, contact horticulture and forestry extension specialists.

Web sites

Nursery references and information

Sources of Information: Nursery Production

Ministry of Agriculture, Food and Industries—British Columbia
www.agf.gov.bc.ca/ornamentals/nursery/nursourc.pdf

Landscape, Nursery & Urban Forestry

UMass Extension
www.umassgreeninfo.org

Nursery Web
www.nursery.umd.edu/nursery.cfm

University of Maryland Web site on nursery production, IPM, and nutrient management. Includes a large collection of horticultural and nursery Web links, organized by type.

PLANT—Purdue Landscape and Nursery Thesaurus
http://bluestem.hort.purdue.edu/plant
Purdue University collection of Web links on landscape and nursery resources, with over 7,000 sites organized by topic.

Nursery-Related Internet Resources

Stuewe and Sons
www.stuewe.com/about/othersites.html

Useful Web Pages for Nursery Operators

Environmental Horticulture, University of Florida
http://hort.ifas.ufl.edu/people/yeagernurseopera.htm

Nursery production: General, nutrition, irrigation and water quality topics

Commercial Nursery Production Factsheet
Ministry of Agriculture, Food and Industries—British Columbia. *www.agf.gov.bc.ca/ornamentals/nursery/nursourc.pdf*

Green Beam Pro
www.greenbeampro.com
This site is maintained by Branch-Smith Publishing (NMPro, GMPro, Garden Center, Nursery Management & Production, Garden Center Products and Supplies, and Selling Elegance). The site offers articles, industry news and source lists for products and suppliers, as well as blogs and Project: Green Industry Open Registry.

Texas: Nursery, Floral and Landscape Network.
http://aggie-horticulture.tamu.edu/greenhouse
This Texas A&M site has nursery, greenhouse and integrated pest management resources.

Environmental Publications (2000)
Texas A&M University, Nursery/Floral Crops.
http://aggie-horticulture.tamu.edu/greenhouse/nursery/environ/index.html
This Web site covers developing a management plan for irrigation runoff, principles of irrigation management, monitoring the quality of irrigation water, integrated pest management for greenhouse crops and treating and recycling irrigation runoff.

Something to Grow On/Nutrient Management: The Key to Growing Healthy Nursery Crops in Containers (1997). *www.hort.cornell.edu/department/faculty/good/growon/index.html*
This is a Cornell University Web site on nutrient management for field crops, container crops and container media.

Irrigation Management Practices:
Checklist for Oregon. 48 p. Oregon State University, Bioresource Engineering
http://extension.oregonstate.edu/catalog

Using Compost in Landscape Beds and Nursery Substrates. North Carolina State University. *www.bae.ncsu.edu/bae/programs/extension/publicat/wqwm/ag473_14.html*

Nursery Crop Science. North Carolina State University. *www.ces.ncsu.edu/depts/hort/nursery*
This Web site includes cultural practices, research publications, upcoming nursery events and a knowledge center with learning modules for the nursery and greenhouse industry.

Ergonomics Papers: Prevention of Worker Injury in Nursery Production. Agricultural Ergonomics Research Center, University of California

Establishment and economics of nursery production

Ornamentals: Enterprise Budgets—Planning for Profit. British Columbia Ministry of Agriculture, Food & Fisheries. *www.agf.gov/bc.ca/busmgmt/budgets/index.htm*
This Web site provides enterprise budgets for commercial nursery production in British Columbia.

Starting in the Nursery Business (Revised 1994). Purdue University, HO-212
www.agcom.purdue.edu/AgCom/Pubs/HO/HO-212.pdf

Starting a Wholesale Nursery—Part I (Revised 2004). University of Arkansas.
www.uaex.edu/Other_Areas/publications/PDF/FSA-6055.pdf

Extension Nursery Publications. Missouri Alternatives Center. *http://agebb.missouri.edu/mac/links/linkview2.asp?catnum=160&alpha=N*

Integrated pest management

Beneficial Nematodes
www.nematodeinformation.com

Nursery IPM at University of Connecticut
www.hort.uconn.edu/IPM/index

Forest Insect and Disease Leaflets
USDA Forest Service
www.na.fs.fed.us/spfo/pubs/fidl.htm

Nursery Diseases of Western Conifers (1979). Forest Insect & Disease leaflet 157, USDA Forest Service
www.na.fs.fed.us/spfo/pubs/fidls/disease_west/nut_diseases.htm

Corn Gluten Meal Research Page
Dr. Nick Christians. Iowa State University
www.hort.iastate.edu/gluten

Biological Control of Pests in Forest Nurseries. Don Elliott, p. 145–147. In: National

Proceedings: Forest and Conservation Nursery Associations—1998. *www.srs.fs.usda.gov/pubs/863*

Biointensive Integrated Pest Management (2002). ATTRA. *www.attra.ncat.org/attra-pub/ipm.html*

Nursery associations and technology cooperatives

Canadian Nursery Landscape Association
www.canadanursery.com
This Web site provides links to regional associations in Alberta, British Columbia, Saskatchewan, Manitoba and other Canadian provinces.

Nursery Technology Cooperative
Oregon State University
http://ntc.forestry.oregonstate.edu

Southern Forest Nursery Management Cooperative
www.nurserycoop.auburn.edu

Southern Nursery Association
www.sna.org
This is a large site with newsletter archives, publications, conference proceedings, research, news and events.

Forest Conservation Nurseries Associations
http://westernforestry.org
This Web site provides nursery manuals and some past event information.

Directory of Nursery Supplies

GreenBeam Pro
www.greenbeampro.com
The Green Beam Pro site, maintained by Branch-Smith Publishing, offers extensive lists of products and supplies.

Pacific Coast Nurseryman: Structures & Equipment Suppliers List. *www.pacificcoastnurseryman.com/structures.htm*

Forest Nursery Resources

Forest Nursery Notes (FNN)
www.rngr.net/Publications/fnn
This publication now includes archives of Forest Nursery Notes.

Forest Nursery Northeastern Area Publications & ProductsReforestation, Nurseries and Genetic Resources at USDA Forest Service.
www.na.fs.fed.us/pubs

Native plants, specialty plants and perennials

Native Plants Journal online
http://nativeplants.for.uidaho.edu

Bamboo: A Multipurpose Agroforestry Crop (2001). ATTRA. *http://attra.ncat.org/attra-pub/summaries/bamboo.html*

Perry's Perennial Pages
Leonard Perry, University of Vermont
www.uvm.edu/~pass/perry

University of Georgia Trial Gardens
http://ugatrial.hort.uga.edu

Organizations

American Nursery & Landscape Association (ANLA)
1000 Vermont Ave., NW, Ste. 300
Washington, DC 20005-4914
202-789-2900
202-789-2893 fax
www.anla.org
ANLA, a membership organization, publishes key resources for the nursery industry, such as American Standard for Nursery Stock. The Horticultural Research Institute (HRI), a research division of ANLA, sponsors research and publishes Journal of Environmental Horticulture.

International Plant Propagators' Society, Inc.
615 Williams Grove Road
Mechanicsburg, PA 17055-7512
717-691-8898
717-691-5440 fax
www.isa-arbor.com
This group publishes Arborist News and Journal of Arboriculture, as well as a catalog of books, educational materials and software.

Perennial Plant Association
3383 Schirtzinger Road
Hilliard, OH 43026
614-771-8431
614-876-5238 fax
ppa@perennialplant.org
www.perennialplant.org
This group sponsors an annual symposium with accompanying proceedings and provides educational materials.

Horticultural associations and societies

Betrock's hortworld.com Information Systems. *www.plantfinder.com/Services/Associations.asp*

This Web site provides an extensive list of regional and statewide nursery associations.

Trade magazines

American Nurseryman
American Nurseryman Publishing Co.
77 W. Washington St., Ste. 2100
Chicago, IL 60602-2904
800-621-5727
312-782-3232 fax
www.amerinursery.com

This Web site requires a biweekly, print or online subscription. It provides a wide selection of books, videos and software.

Branch-Smith Publishing
P.O. Box 1868
Ft. Worth, TX 76101
800-433-5612
www.greenbeampro.com

See the Web site for details of publications.

Pacific Coast Nurseryman and Garden Supply Dealer.
Cox Publishing Co.
P.O. Box 1477
Glendora, CA 91740-1477
800-577-5225
626-914-3751 fax
www.pacificcoastnurseryman.com

Nursery Retailer
Brantwood Publications
2310 Northside Drive
Clearwater, FL 33761-2236
727-724-0020
727-724-0021 fax
thinkgreen@nurseryretailer.com

Nursery Retailer
www.nurseryretailer.com

This Web site provides an extensive list of horticultural trade magazines.

Suppliers

Suppliers for a few general nursery supplies are mentioned in the text, including root control pots, nursery equipment and steam distillation.

American Horticultural Supply, Inc.
4045 Via Pescador
Camarillo, CA 93012
800-247-1184
www.americanhort.com

This company supplies unusual pots including square, stairstep and bottomless.

Anderson Die and Manufacturing
2425 SE Moores St.
Portland, OR 97222
503-754-5629

This company sells to wholesalers such as American Horticultural Supply (above).

E-Z Implements, Inc.
16700 Pueblo Blvd.
Jordan, MN 55352
800-278-2531
952-492-2867 fax

This company sells tree diggers, tree shears and graders.

Growing Systems, Inc.
2950 N. Weil St.
Milwaukee, WI 53212
414-263-3131

This company sells Deep Groove tube cell-pack trays.

Lacebark, Inc.
P.O. Box 2383
Stillwater, OK 74075
405-377-3539
405-377-0131 fax
sales@lacebarkinc.com
www.lacebarkinc.com

Lacebark sells root control bags and RootMaker pots.

TreeBag, Inc.
115 NW 44th St.
Oklahoma City, OK 73118
800-521-8089
405-848-2302 fax
info@treebag.com
www.treebag.com/html

RootMaker Products, Inc.
P.O. Box 14553
Huntsville, AL 35815
800-824-3941
256-882-3199
www.rootmaker.com

This company is affiliated with Lacebark, Inc. and sells RootMaker pots.

Saskatoon Boiler Mfg. Co, Ltd.
2011 Quebec Ave.
Saskatoon, Saskatchewan
Canada S7K 1W5
306-652-7022
www.saskatoonboiler.com
This company sells Saskatoon Model 30HP-15 nursery steamer.

Sioux Corp. [formerly Sioux Steam Cleaner Corp.]
One Sioux Plaza
Beresford, SD 57004
605-763-3333
www.sioux.com

So You Want to Start a Nursery...
StartaNursery.com/containers.php

Stuewe & Sons, Inc.
2290 SE Kiger Island Drive
Corvallis, OR 97333-9461
800-553-5331
www.stuewe.com
This company sells unusual pots like square, stairstep and bottomless and nursery containers for tree seedlings.

Corn gluten

Corn Gluten Meal Licensees
Iowa State University
www.techtransfer.iastate.edu/en/for_industry/technology_search/cgm_licensees.cfm

Resource directories

Green Beam Pro
www.greenbeampro.com
The Green Beam Pro site, maintained by Branch-Smith Publishing, offers extensive lists of products and suppliers.

Pacific Coast Nurseryman: Structures & Equipment Suppliers List
www.pacificcoastnurseryman.com/structures.htm

Sustainable Small-Scale Nursery Production

By Steve Diver and Lane Greer
Updated June 2008 by Katherine L. Adam
Agriculture Specialist

Holly Michels, Editor
Amy Smith, Production

This publication is available on the Web at:
www.attra.ncat.org/attra-pub/nursery.html
or
www.attra.ncat.org/attra-pub/PDF/nursery.pdf

IP104
Slot 76
Version 113008