The Container Tree Nursery Manual • Volume One

Nursery Planning, Development, and Management

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The Container Tree Nursery Manual

Volume One
Nursery Planning, Development, and Management

Introduction

In this first volume of the Container Tree Nursery Manual, we provide information and guidance on how to start it all. How do you build a nursery from scratch and equip it? What are the processes involved in growing container seedlings? How do you manage the process and the people?

So you want to build a nursery. Do you really need to grow your own seedlings? Would you be better off buying from someone else? In **chapter 1,** we discuss some of the basic concepts and terminology of forest and conservation nurseries and planting stock.

Okay, you've decided that you are going to start a nursery. Now, where are you going to put it? In **chapter 2,** we discuss the considerations and site selection factors.

Now, you've found a good nursery site and are ready to plan your container nursery. In **chapter 3,** we present some of the terminology of structure design so that nursery developers can talk intelligently with greenhouse contractors and suppliers. We also show rough cost estimates for types of structures, refer developers to other good sources of technical information, and discuss considerations in laying out the nursery site.

You've got the basic nursery laid out and need to select the equipment and supplies to get your first crop started. In **chapter 4,** we present some of the basic concepts and terminology of environmental control and seedling production equipment so that you can communicate with suppliers. Then we present cost estimates for these type of equipment as well as referring developers to other good sources of technical information.

Now you've got the nursery infrastructure built and the equipment installed. How do you manage your people and the workflow? In **chapter** 5, we present some of the basic concepts of managing a container nursery, especially what makes them different from other businesses. We also discuss some of the problems that might arise the first couple of years and provide troubleshooting tips.

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Volume One
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Chapter 1
Initial Planning and Feasibility Assessment

Contents

1.1.1 Introduction

This chapter is written primarily for those who are thinking of starting a forest or conservation nursery. This introductory material will also be useful to foresters and other natural resource specialists who use plant materials. Both prospective nursery developers and seedling users need a basic understanding of nursery terminology and concepts. Nursery developers must carefully analyze whether it would be most advantageous to start a nursery or merely to purchase seedlings from someone else. If the decision is to develop a new nursery, then it is necessary to evaluate the present market, make some estimates of production costs, and perform a systematic analysis.

1.1.1.1 Terminology

Prospective nursery developers and seedling users should be familiar with nursery terminology. Many of these terms have been borrowed from horticulture, but others have developed within the forest nursery industry.

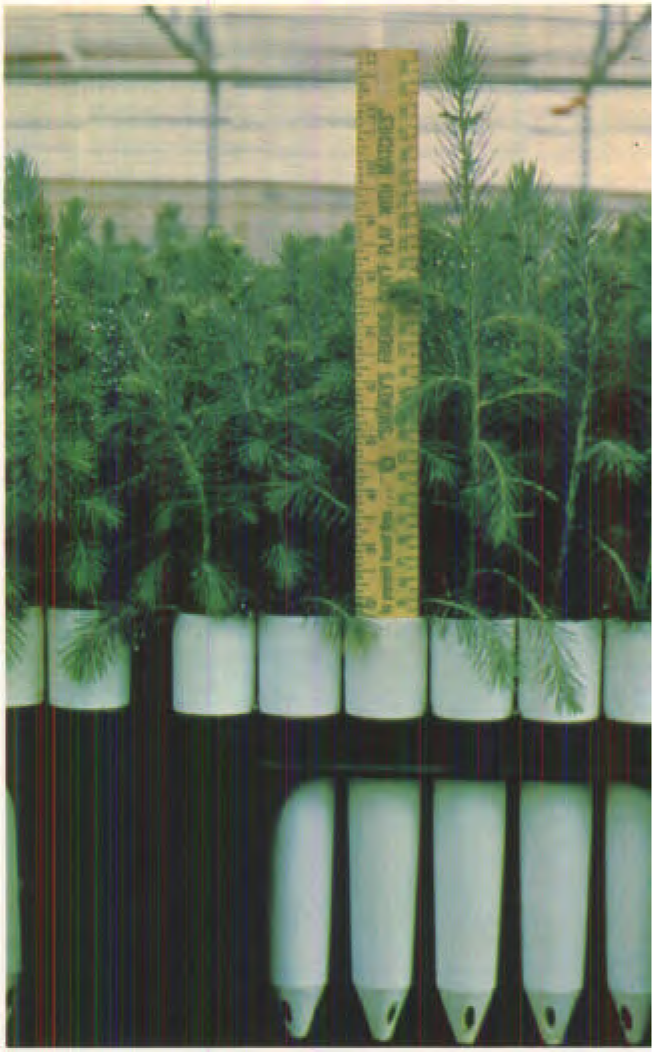
Seedlings. A ***seedling*** *is* a plant that has been grown from a seed. However, the term is often used loosely to refer to many types of nursery stock including transplants, rooted cuttings, and emblings (which are produced through micropropagation).

Stock type. Forest and conservation seedlings are traditionally divided into two basic stock types--bareroot seedlings and container seedlings--that describe how they were grown. **Bareroot stock** is typically grown in native soil in open fields (fig. 1.1.1A) and the seedling is removed from the soil during harvesting (fig. 1.1.1 B). **Container seedlings** are grown in artificial growing media (fig. 1.1.2A) in a controlled environment, such as a greenhouse, where growth-limiting factors can be manipulated (fig. 1.1.2B). Because the volume of growing medium is relatively small, the roots bind the medium into a cohesive **plug** by the time they are harvested (fig. 1.1.2C). Although the seedlings are also called "containerized," "container-grown," or "plug" seedlings, we prefer the term **container seedling** because it is simple and definitive.

Another stock type is the **transplant,** which is a seedling that has been physically removed from its seedbed or container and is replanted in another location for additional growth. Traditionally, most transplants have been bareroot seedlings that are grown for 1 or 2 years

B

Figure *1.1.1-*-*Bareroot seedlings are grown in outdoor nursery beds in native soil and are subject to local weather conditions* ***(A)****. After harvesting, they are stored and shipped for outplanting without soil around the root system* **(B)**.


A


B


C


D

Figure *1.1.2*---*Container seedlings are grown in a relatively small volume of artificial growing media **(A)** in a propagation environment designed to minimize factors that are potentially limiting to seedling growth **(B)**. At the end of the growing season, container seedlings are harvested with the root system and growing media forming a "plug" **(C)**. Plug + 1 seedlings are started as small-volume container stock and are then transplanted to bareroot nursery beds and grown for another season **(D)**.*

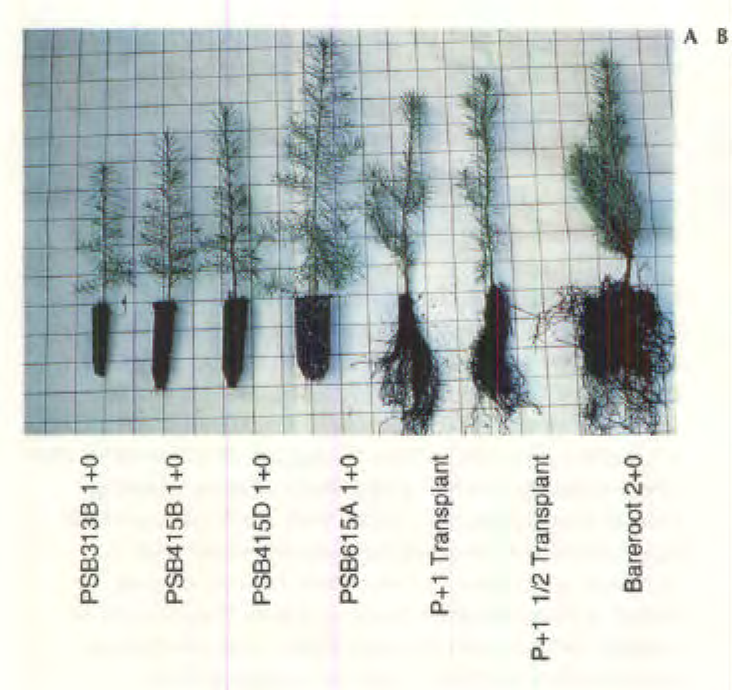
and are replanted into a transplant bed and allowed to grow for another year or two. Transplanting produces more caliper and root growth compared to seedlings and, although they are more expensive, transplants are used on tough outplanting sites, especially where vegetative competition is a problem. **Container transplants** (fig. 1.1.2D) are a rather recent innovation in which container seedlings are replanted in bareroot beds for an additional period of growth (Hahn 1984). **Miniplugs** are grown in very small volume containers and are grown specifically for transplanting (Hahn 1990). Although they are typically transplanted into bareroot beds, miniplugs can easily be transplanted into a larger volume container.

A stock type name is a shorthand method of describing seedling morphology (Scagel and others 1993). Historically, a numerical designation has been used to describe both seedlings and transplants. The first number corresponds to the number of years in the seedbed or seed container, and the second number refers to the number of years in the transplant bed or container. Bareroot seedlings are generally produced in from 1 to 3 years (1 +0 to 3+0), and transplants (for example, 1 +1 or 2+1) can vary considerably depending on the species, climate, and nursery system. The sum of the two numbers gives the total number of years needed to produce that stock type.

There is no standard nomenclature for describing container seedlings. Because most container seedlings are grown in one season or less, they are generally defined by the type and volume of the growth container. For example, a "Styro 4" refers to a seedling that has been produced in a Styrofoam© block container with cells that are approximately 65 cm3 (4 in') in volume. Other regions use different terminology. In British Columbia, some container stock types are grown for more than 1 year and so their names include container type, size, and length of growing period. For example, a PSB 313B 1+0 seedling was grown for 1 year in a Styrofoam block container that has cells that are 3 cm (1 .2 inches) wide and 13 cm (5.1 inches) deep (Scagel and others 1993). Container transplants are described by the number of years in the bareroot nursery, for example a plug-plus-one (P+1) transplant.

Container seedling customers should realize that, when ordering seedlings, stock type must be considered along with species and seed source. With the number of container sizes and cultural options, there is a wide variety of stock types from which to choose (fig. 1.1.3A). Each stock type has unique biological characteristics that affect seedling survival and growth after outplanting. Cost of production also varies with stock type, and the best choice will be a balance between cost and outplanting success. Several publications discuss different bareroot stock types and how they should be used in reforestation (Iverson 1984), and others have treated container stock types on a regional basis (Brissette and others 1991). Scagel and others (1993) provide an excellent discussion of the factors that should be considered in selecting stock types for outplanting sites in British Columbia. For example, because larger seedlings are needed to compete with brush competition and animal browsing on better outplanting sites, larger volume containers are specified in growing contracts (fig. 1.1.3B). A comprehensive treatment of container seedling stock types will be presented in volume six of this series, and their suitability for various outplanting sites will be treated in volume seven.

Seed source. One of the most important aspects of forest and conservation seedlings is that they are always identified by seed origin, with both geographical location (township-range-section or longitude-latitude) and elevation specified. A **seed zone** is a geographic area that is relatively similar in climate and soil and is described by a numerical code. For example, the forested areas of Arizona and New Mexico have been divided into 10 physiographic-climatic regions that are then subdivided into collection zones that are about 80 km (50 miles) wide (fig. 1.1.4A). These seed zones are also stratified vertically by increments of 150 m (500 feet) in elevation. A geographically diverse state like California can have over 80 different seed zones, with numerous elevation bands within each zone. All the seeds and cuttings that are collected in a particular area are labeled with that seed zone's code (fig. 1.1.4B).



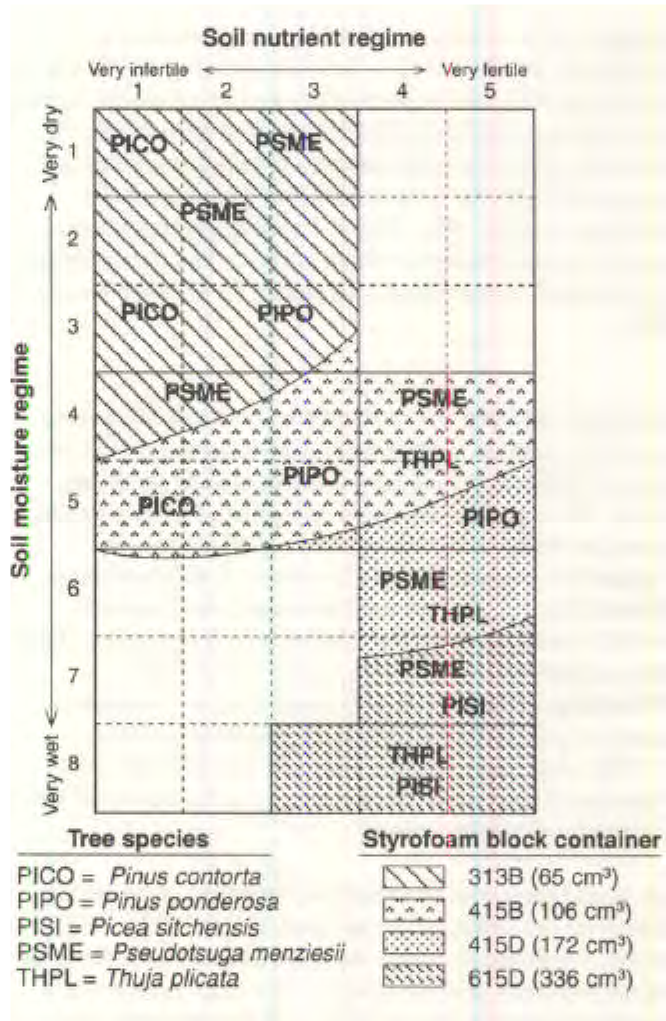
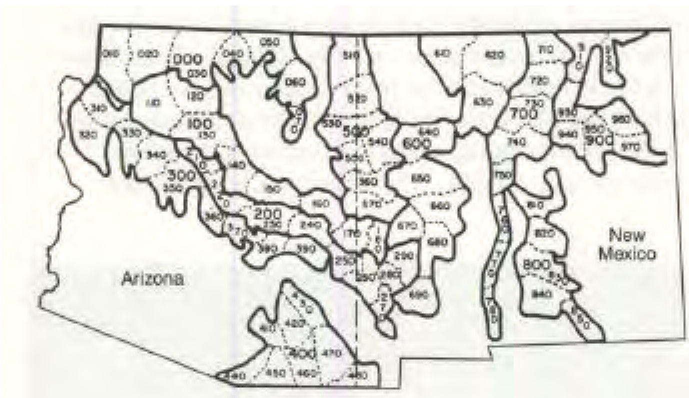


Figure ***1.1.3***---*Seedling quality is determined by conditions on the outplanting site, and a wide variety of container stock types are available (A). As site quality increases (higher soil moisture and fertility) on this British Columbia site, larger volume containers are specified that will produce larger seedlings (B) (modified from Scagel and others 7 993).*

Unless progeny tests have shown otherwise, it is best to plant seedlings back into their zone of origin. Thus, most seedlings grown for forest and conservation purposes are ordered by species, stock type, and seed zone. For example, Douglas-fir *(Pseudotsuga menziesii (Mirb.) Franco.)* seedlings from the Cascade Mountains to the east of Portland, Oregon, could be ordered for a site at 600 m (2,000 feet) elevation in seed zone 452. When this seedling order is sown in the nursery, this information on species, seed zone, and elevation is included into a **seed lot identification number** (fig. 1.1.4C). The seed lot number remains with this group of seedlings throughout their entire nursery tenure and is marked on the storage container when the seedlings are harvested for outplanting (fig. 1.1.4D). The process is completed when the seedlings are planted back into the same general climatic region in which the seed was collected. The importance of proper source identification cannot be overstated. Seedlings perform best within their seed zone, and many plantings have failed because the stock was poorly adapted to the outplanting environment. If a lot of seedlings loses its source code, nurseries often destroy the seedlings rather than have them outplanted in the wrong environment.

Nurseries. It is also important to define technical terms that describe nursery organization and layout.

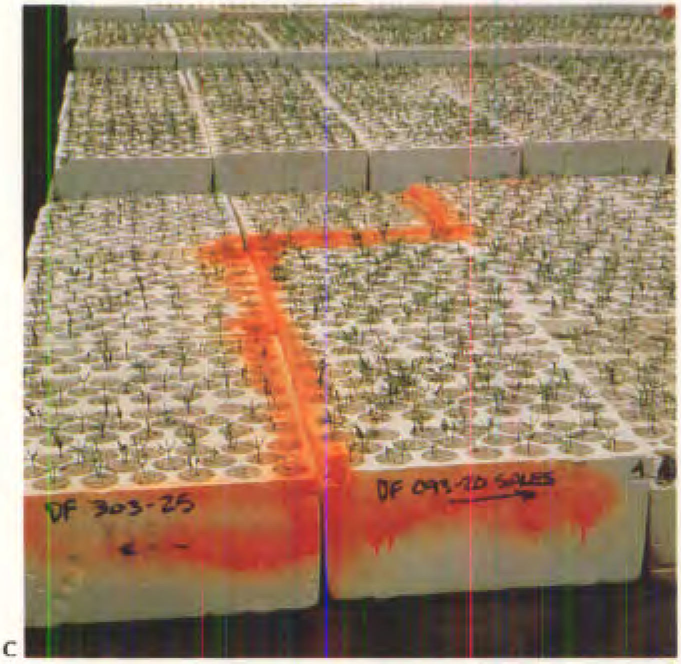
For our purposes, the term **container nursery** will refer to any operation that grows plants in containers in some sorb of modified propagation environment. The container itself generates a unique edaphic environment and most forest nurseries use some type of artificial growing medium (see volume two of this series). The degree of modification of the ambient environment varies considerably from open growing compounds with no environmental controls except for irrigation and liquid fertilizer injection to a variety of different propagation structures



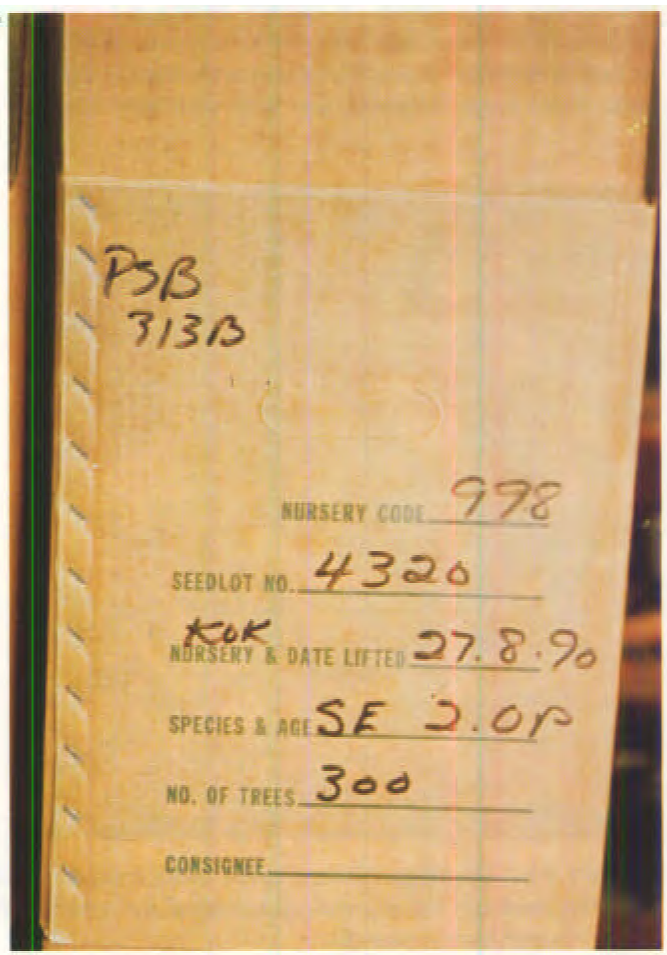
A

Figure ***1.1.4***-*The origin of seed of forest and conservation species is recorded by numerical seed zones, as illustrated in this seed zone map of Arizona and New Mexico. Blank areas are agricultural, grassland, or desert and contain no native forest **(A)**. "Source identified" seed **(B)** is a guarantee of seed orig=in and ensures that seedlings will be adapted to their outplanting site. The identity of different seed lots must be maintained at all times in the nursery **(C)** and when packed for shipment to the field **(D)**.*

B



C



D

(McDonald 1982). Fully enclosed greenhouses with the latest environmental control equipment can maximize seedling growth rates by creating an ideal environment with few limiting factors. There is no ideal type of container nursery; instead, nurseries reflect the local environment as well as the owner's experience and financial status. (A complete discussion of propagation environments and propagation structures is provided in chapter 3 of this volume.)

A **container tree nursery** specializes in producing native and introduced plants for forestry or conservation purposes. Traditionally, these have been seedlings of commercial forest trees, but in recent years, a wide variety of different plant species are being produced including shrubs, grasses, and sedges (Landis and others 1993). A well-designed container tree nursery consists of seedling production areas and service buildings, such as a headhouse, seedling storage areas, and administrative buildings. These are all interconnected by an internal transportation system, consisting of roads and conveyors, that has been laid out to facilitate movement of seedlings and supplies. A **nursery facility** is a comprehensive term that describes the total nursery site including seedling production areas and support buildings. Some forest nurseries have both container facilities and fields for producing bareroot seedlings and transplants. (Nursery propagation environments are discussed in chapter 3 and seedling production and environmental control equipment is discussed in chapter 4 of this volume.)

1.1.1.2 Seedling quality is determined by outplanting performance

One of the principal characteristics of forest and conservation nurseries is that their seedlings are typically planted in relatively harsh environments without irrigation or other subsequent care (fig. 1.1.5A). This differs markedly from seedlings from ornamental nurseries, which are planted in more favorable landscapes where they receive irrigation and fertilization at frequent intervals (fig. 1.1.5B). This difference is significant

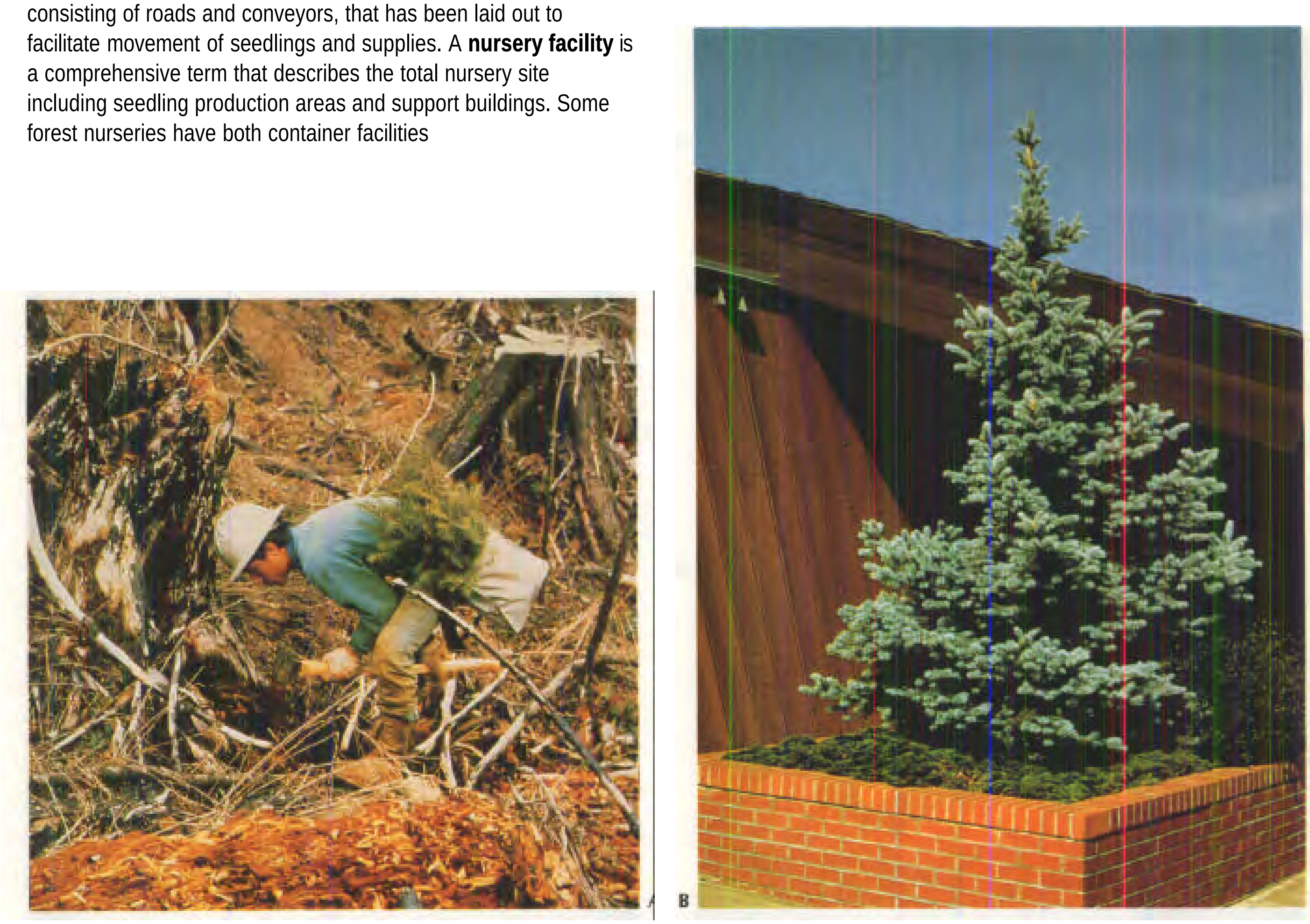


Figure *1.1.5*---*Seedlings planted in the forest must be capable of surviving and growing well without subsequent care **(A)**. This contrasts sharply with ornamental and landscape stock, which receive postplanting care, including regular irrigation and fertilization **(B)**.*

because the measure of seedling quality depends on the how the seedlings will be used-"fitness for purpose" (Ritchie 1984). This means that, although seedling quality is described at the nursery, it can only be proven on the outplanting site. There is no such thing as an "all-purpose" tree seedling. A "nice looking seedling" at the nursery will not survive and grow well on all sites.

Morphological specifications. Forest and conservation seedlings are described by traditional morphological dimensions (fig. 1.1.6A), and these terms are used by nursery personnel and seedling users. The most common dimensions are shoot height and stem diameter. **Shoot height** is the vertical distance from the growing medium to the tip of the terminal meristem or bud. **Stem diameter,** often called "caliper" or "root collar diameter," is the diameter of the main stem at the base of the shoot.

Because it is measured in millimeters, stem diameter can vary significantly with the exact location of the measurement. Therefore, most nurseries measure caliper at a standard location, such as 1 cm (0.4 inch) above the growing medium. All aspects of seedling morphology vary considerably between different sizes of containers, particularly with regards to container volume and growing density (fig. 1.1.6B).

Other seedling morphological specifications include root length, ovendry (OD) weight, and shoot-to-root (S:R) ratio (fig. 1.1.6A). Although they require destructive sampling, seedling dry weights are useful indices of crop development. The S:R ratio is a relative comparison of the size of the shoot to the root system and is sometimes specified by seedling users to match the stock type to conditions on the outplanting site.

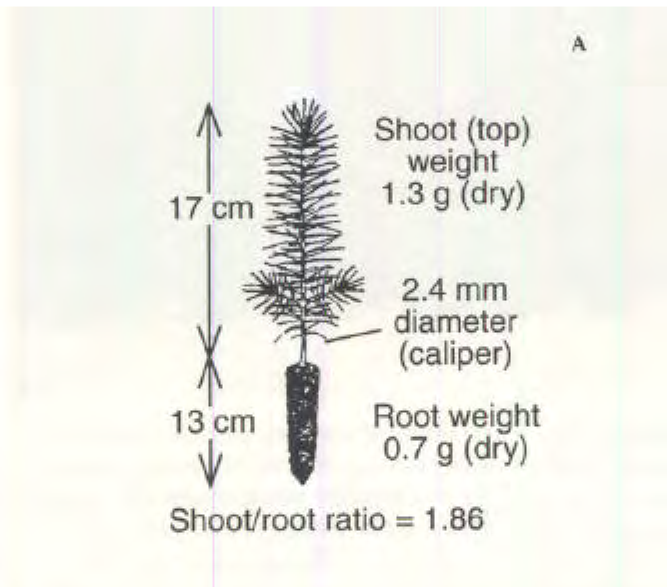


Figure *1.1.6*---*Specifications for container seedlings include morphological measurements, traditionally shoot height and stem diameter **(A)**. Seedling size and quality are greatly affected by nursery environment and cultural practices; for example, containers with larger volumes and lower growing density produce ponderosa pine seedlings with much larger stem diameter **(B)**. (Modified from Scagel and others 1993.)*

***The nursery effect*.** The physical appearance of any organism (its **phenotype)** is the result of its genetic makeup (its **genotype),** tempered by the environment in which it was raised:

$$\text{Phenotype} = \text{genotype} \times \text{environment}$$

In forest and conservation nurseries, the phenotype of a seedling is a function of its genotype (seed source, origin of cutting, or cultivar) and the environment of the nursery in which it was grown. Actually, the nursery environment is a composite of its geographic location, the type of propagation facility, and the cultural practices used to raise the seedling (fig. 1.1.7A). When the same seed lot is grown at different nurseries, even in the same geographic area, seedling morphology can be visibly different (fig. 1.1.7B).

Container seedlings grown at different nurseries may also be physiologically different. This response has been called the **nursery effect** and is an example of environmental imprinting, by which seedlings are influenced by nursery site conditions or cultural practices. Nursery imprinting is evident in day-to-day nursery and reforestation activities. Foresters who have planted seedlings from the same seed source that were grown at different nurseries have noticed differences in survival and growth. One study in Alaska compared container Sitka spruce *(Picea sitchensis* (Bong.) Carr.) seedlings from a local nursery to others grown from the same seed source in an Idaho nursery (Zasada and others 1990). The Idaho seedlings suffered significantly more animal browsing and frost damage the first several growing seasons compared to the local nursery stock. In another study with lodgepole pine *(Pinus contorta* Dougl. ex Loud.), Ying and others (1989) noted significant differences in outplanting performance from different nurseries but concluded that the effect is relatively short term (~15 years). Regardless, these differences may be enough to affect initial seedling establishment.

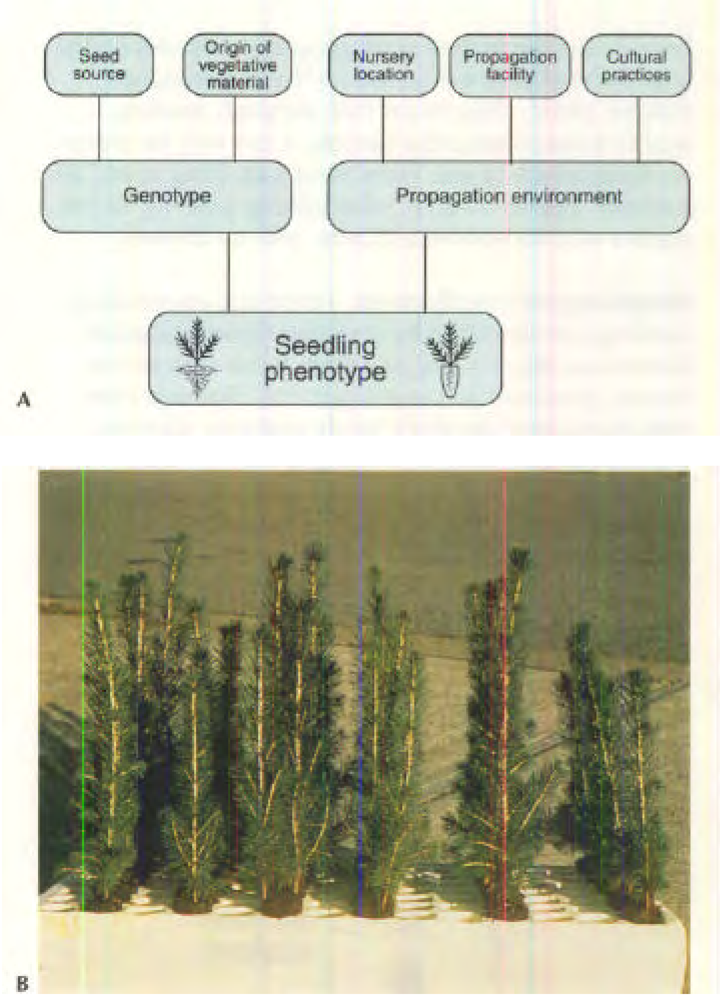


Figure 1.1.7---The *physical appearance of a container seedling (phenotype) is a function of its genetic makeup (genotype) and the propagation environment **(A)**. When the same seed lot of interior spruce (* Picea glauca x P. Engelmannii) *was sown at 6 different nurseries, the seedlings exhibited obvious variation in height, foliage color, and degree of lateral branching **(B)**. (B, from Scagel and others 7 993.)*

Prospective nursery developers and seedling users must take all these facts into consideration when planning a nursery or deciding which kind of seedlings to buy (table 1.1.1). The best seedling for a particular project will depend on many factors: seed origin, nursery culture, seedling handling and storage facilities, planting implement, and environmental conditions on the outplanting site. Research and actual experience have shown, however, that certain sizes and stock types perform better on some sites than others. Seedling quality will be discussed in more detail in volume six of this series.

Table 1.1.1—*Persons needing a steady supply of seedlings should consider both biological and economic factors*

Biological factors • Is the appropriate species available? • Can a local seed source of that species be found? • What about stock type? • Are seedlings available during the outplanting window? • Is seedling quality consistently high? • Others?
Economic factors • Are seedlings available at a reasonable cost? • How close is the nursery to the outplanting site? • Are local nurseries reliable? • What about political considerations? • Others?

1.1.2 Sources of Planting Stock

When confronted with a regular demand for tree seedlings, many people think about starting their own nursery. Growing tree seedlings requires a concerted and sustained effort, however, and so all the pros and cons of starting a nursery should be considered (table 1.1.2). The principal benefit of having a nursery is that the quantity, quality, and availability of planting stock can be controlled. Much time must be devoted to developing a new nursery, however, and considerable capital investment will be required. The projected need for seedlings must be long enough to amortize the investment. Therefore, individuals or organizations that need a steady supply of seedlings should first consider purchasing stock from an established nursery.

1.1.2.1 Purchasing seedlings

There are a number of advantages to purchasing seedlings instead of starting a nursery. First and foremost, time and capital are available for other uses (table 1.1.2). Producing tree seedlings can be a risky business venture, and buying planting stock from other nurseries means that many of the risks and day-to-day hassles associated with growing seedlings can be avoided. Potential tree nursery developers should carefully observe other operations already in the business and decide if the advantages of starting a nursery outweigh the disadvantages.

There are two basic ways to purchase seedlings from nurseries: speculation stock and seedling contracts.

Buying speculation stock. Some nurseries sow a certain percentage of their annual production specifically for the speculation market. Usually, these are species and seed sources that are adaptable to a wide geographical area or have proven to be marketable in the past. Surplus seedlings are also sold as speculation stock. Because of anticipated losses, most forest nurseries oversow their seedling orders and therefore have some seedlings available each year for sale on the open market. The quantity and seed source of this surplus stock varies from year to year, however, and so seedling users must contact different nurseries each season to learn what species and seed sources will be available. Speculation crops seldom match the proper seed and elevation zones and thus are often planted on less-than-optimum sites.

Contracting for seedlings. Because tree seedlings are a perishable product and the market is notoriously change-

Table 1.1.2—*The decision to purchase seedlings or start a new nursery requires careful analysis*

Purchase seedlings	
Pros	**Cons**
• Time and capital free for other uses • No nursery staff needed • More long-term flexibility • Others?	• No control over growing process • Often required to accept low bid • Less control over seedling quality and availability • Seedlings may not be adapted to your environment • Others?
Start Own Nursery	
Pros	**Cons**
• Most control over seedling quality and availability • Can develop local expertise on seedling growing and handling • Seedlings will be adapted to local environment • Don't have to rely on other individuals or organizations • Create job opportunities • Others?	• Large initial investment of capital and time • Long-term professional and economic committment • Must hire and maintain staff • Seedling markets are notoriously changeable from year to year • Could cause unwanted competition • Others?

able, economics dictate that most forest nurseries grow a large proportion of their seedlings on contract. As discussed earlier, forest nursery seedlings are different from ornamental stock in that most seed lots are biologically suitable for only a relatively few planting sites. Therefore, most foresters and other seedling users procure their stock by contract and specify the appropriate species and seed source.

An intermediate option is to purchase some trees from outside sources and grow the rest in a small-scale nursery (see section 1.1.5 for more discussion).

1.1.2.2 Starting your own nursery

Once the decision is made to start a nursery, the next question is whether it should be a bareroot or container facility.

***Bareroot nurseries**.* Bareroot seedlings are grown in open fields in native soil, and consequently, the soil, water supply, and climate of the nursery site must be suitable for tree growing. The rate of seedling growth and length of the growing season are largely controlled by the climate at the nursery site. Quality sites are often difficult to find in convenient locations, and good agricultural land is often expensive. A considerable capital investment is usually required to develop a bareroot nursery of any size. Bareroot nurseries are also sensitive to the economies of scale. Once a nursery is established and operations have begun, it is important to function at near-capacity levels to have reasonable unit production costs. Compared to container nurseries, energy requirements and associated expenses are relatively low. A more comprehensive discussion of site selection factors that should be evaluated when locating a bareroot nursery is presented by Morby (1984).

***Container nurseries**.* Container nurseries can be constructed on land with low agricultural value that would be unsuitable for bareroot seedling production. The amount of capital investment varies with the type of facility. Fully controlled greenhouses require expensive structures and environmental controls, but open growing compounds are much less costly. Because container seedlings are grown at high densities, less land is required compared to a bareroot nursery. Container nurseries are less sensitive to economies of scale and, in extreme situations, part or all of the nursery can be shut down to reduce operating costs. Container seedlings have high growth rates, especially in fully controlled environments, and so crops can be produced in one growing season. From a business standpoint, this means that container nursery managers can respond quickly to changes in the market. Greenhouse crops are more reliable than those grown in open compounds, but this comes at the expense of large amounts of energy. (The biological and economic factors to consider when locating a container nursery are presented in chapter 2 of this volume.)

Selecting the best alternative. The decision of whether to start a bareroot or container nursery must be carefully thought out because there are many things to consider. It is helpful to list the various considerations side-by-side for ease of comparison (table 1.1.3).

Biological considerations are of paramount importance in choosing between a bareroot or container nursery, and often, the lack of a suitable bareroot nursery site is the deciding factor. The general climate is also critical because container nurseries are typically favored at high latitudes or elevations where extremely short growing seasons make bareroot production impractical. Customers' needs, seedling handling and transportation systems, and the outplanting environment must also be evaluated. Because they are generally more tolerant to stresses such as desiccation, container seedlings are often the best option for harsh planting sites or when planters are inexperienced.

Economics must also be carefully analyzed, and a market analysis should always be done (see section 1.1.3). Projection of production levels, coupled with capital investment and operating costs, will indicate the most economically effective type of nursery at different production volumes. Energy source and cost are key factors that will significantly influence the choice between a container and bareroot facility.

Finally, consider availability of technical expertise, because the availability of a skilled nursery manager may influence the choice of nursery type. Few formal training programs in forest nursery management are available. However, several good university programs in greenhouse management or ornamental horticultural exist, and a trained horticulturist could be hired to manage a container tree nursery.

Under some circumstances, a nursery facility with both bareroot and container nursery capability might be most appropriate. Container nurseries are often used to grow seedlings from high-value or genetically superior seed while normal operational stock is grown in outdoor

Table 1.1.3—*Factors that should be considered when evaluating whether to start a bareroot or a container nursery*

Considerations	Container nursery	Bareroot nursery
1. Latitude/elevation—length of growing season	1. Better for areas with short growing seasons: high elevation or high latitudes	1. Better for areas with longer growing seasons: low latitudes or low elevations
2. Initial capital investment	2. Lower land costs, but structures and equipment can be expensive; land preparation is minimal	2. Land costs can be substantial, and preparation may be extensive; equipment costs vary with degree of mechanization
3. Land requirement	3. Less land needed because higher growing densities and lower cull rates produce higher yields	3. More land required because lower growing densities and higher cull rates produce lower yields
4. Soil quality	4. Not important if artificial growing media are used	4. Critical—physical and chemical factors must be surveyed
5. Water quantity	5. Lesser amounts required	5. Greater amounts required
6. Water quality	6. Good water is desirable, but poor water can be chemically treated	6. Good water is mandatory
7. Labor force	7. Only a few highly trained workers needed except during sowing, lifting, and packing	7. Large work crews needed during lifting and packing season
8. Facilities and equipment	8. Variable, ranging from open growing areas to sophisticated structures	8. Variable, ranging from all hand labor to highly mechanized operations
9. Seed-use efficiency	9. Very high efficiencies possible; better for high-value seed	9. Poorer yield per quantity of seed
10. Length of crop rotation	10. Three to eighteen months	10. One to four years
11. Crop characteristics	11. Some species grow better in containers: those with small seeds, weak germinants, slow-growing species, and those with dominant tap roots	11. Some species grow better as bareroot seedlings, such as broad-leaved hardwoods that need more growing space
12. Pests	12. Fewer pests with sterile artificial media, and less risk from abiotic injury in enclosed structures	12. Soil-borne pathogens and abiotic damage are more common

Table 1.1.3 (continued)—*Factors that should be considered when evaluating whether to start a bareroot or a container nursery*

Considerations	Container nursery	Bareroot nursery
13. Mycorrhizal fungi and other beneficial microorganisms	13. Must be added to artificial growing media	13. Normally present in soil
14. Seedling storage	14. Greater storage volume. Shaded storage possible for seedlings shipped in containers; cold storage necessary for extracted stock	14. Less storage volume. Cold storage necessary unless seedlings can be planted immediately
15. Seedling handling	15. Container seedlings are more tolerant of physical abuse or exposure	15. Bareroot seedlings are less tolerant of abuse or exposure
16. Transport to outplanting site	16. Seedlings in containers are bulky and heavy, but need not be cold-stored for short periods	16. Seedlings are lighter, can be closely packed, but must be kept cold
17. Outplanting site conditions	17. Container seedlings suffer less transplant shock, and so are superior for harsh sites	17. Bareroot seedlings suffer more transplant shock, and so do better on moderate sites
18. Length of planting season	18. Wider planting windows	18. Narrower planting windows

seedbeds. In places where nursery soil is more suitable for growing broad-leaved seedlings, conifer stock could be grown in containers. In another scenario, the amount of arable land at a bareroot nursery might become insufficient to meet increasing demands for seedlings, and so a greenhouse could be added to supplement production. A combination container and bareroot nursery is also more flexible to market changes and can offer a full range of stock types including container transplants.

The rest of this manual assumes that the decision was made to develop a container nursery facility. Informa tion on development and operation of bareroot nurseries can be found in Duryea and Landis (1984).

1.1.3 Evaluating the Present Nursery Market

Potential nursery developers must be very realistic about the market they are planning to fill. A market analysis should be done to collect facts about demand, competition, and prices.

1.1.3.1 Demand

For nurseries that are being developed to meet in-house seedling needs, the demand is already known. But, for nurseries that plan to supply seedlings to other users, potential customers should be surveyed and detailed information collected to answer these questions:

- What species, number, and size of trees are needed?
- When and where will these trees be outplanted?
- How long will these needs persist, and will they change over time?

In particular, nursery developers planning on growing seedlings for government tree-planting projects should be aware that most contracts are awarded on a minimum bid basis and so profit margins are small. Seedling demand from government agencies can vary considerably from year to year. For example, large fire rehabilitation projects typically create a large seedling demand for 1 or 2 years, but then the demand can drop precipitously in subsequent years with few fires. Reforestation projects after timber harvest have traditionally provided a relatively steady seedling demand in the Pacific Northwest, but recent changes in land-use policies have reduced the demand significantly. Therefore, potential nursery developers should carefully analyze their potential market and make certain that a sustained demand exists before investing in a nursery.

1.1.3.2 Competition

In addition to surveying the market, potential nursery developers must carefully analyze their competition. Forest and conservation nurseries in the United States can be categorized as government, forest industry, or private. A large percentage of the forest and range lands in the United States is managed by either Federal, State, or local government agencies. Some agencies, such as the USDA Forest Service and the USDI Bureau of Indian Affairs, have their own nurseries to produce seedlings for their needs; others, such as the USDI Bureau of Land Management, procure most of their seedlings from other government or private nurseries. Most States and some local government entities have their own nurseries. Although State nurseries provide seedlings to small private landowners, they do not engage in open competition with private nurseries. Forest industry nurseries produce seedlings for their own lands, but often also grow seedlings on contract for other customers. Numerous private nurseries also grow tree seedlings on contract or for speculation.

Container nursery developers will be in competition with both bareroot and container facilities, and so should find out all they can about the location, capabilities, and efficiencies of their potential competitors. National (Okholm and Abriel 1994a) and regional (Okholm and Abriel 1994b) nursery directories are available to help potential developers survey the competition. Private nurseries have worked hard to develop their businesses, and so don't expect them to share all their secrets! Because of their noncompetitive stance, government nurseries can be a good source of information about the local market.

After you have completed gathering information about the existing nursery capacity and markets, compare it with your own projections, and you should be able to decide whether developing a new nursery can be economically justified.

1.1.3.3 Price

Potential nursery developers should survey tree seedling prices in the local market and try to determine recent price trends. Many economic, political, and biological factors affect the price of seedlings from year to year. Be aware that price generally increases with size (volume) of container because larger seedlings require more growing space (table 1.1.4). Forest tree seedlings are traditionally sold on a per thousand basis, but many nurseries make 50 or 100 trees the minimum order. Because container stock is sometimes sold in the growth containers, some nurseries price their seedlings accordingly. For comparison purposes, however, seedling prices are usually converted back to a per thousand basis.

Most growers will be willing to furnish seedling price quotes over the telephone. Some state forestry organizations survey seedling prices regularly and so can furnish detailed listings. Prices can vary significantly from year to year, however, reflecting market trends. Because of the associated risks, contract seedling prices will generally be different than those for speculation seedlings. Sometimes, contract prices are artificially low because growers "underbid" the market to make sure that their nurseries are at full capacity. On the other hand, speculation seedlings will often be sold at bargain prices because they are surplus and cannot be held over for another growing season.

The next step is to estimate how much it would cost your potential nursery to produce a seedling crop and then compare these costs to market prices.

Table 1.1.4—*Container seedling production costs are significantly influenced by container size and spacing*

Container type	Cell volume		Cell spacing		Cost/1,000
	cm^3	in^3	Cells/m^2	Cells/ft^2	
Ray Leach Fir Cells	49	3.0	1,076	100	$160
Ray Leach Pine Cells	65	4.0	1,076	100	164
Styroblock 7	121	7.4	764	71	240
Ray Leach Super Cells	164	10.0	527	49	307

Source: Myers (1992).

1.1.4 Estimating Product Costs

Nursery developers should calculate product cost estimates to see if their seedlings will be competitive in the local market. Good cost estimates can be very time consuming, however, because they require considerable information about structures, equipment, labor, fuel, land, maintenance, and transportation. After collecting and organizing this information, the developer then analyzes how these costs will affect price per unit output at different nursery locations, facility types, and production levels. A good example of this process was reported by Guldin (1983), who analyzed the costs of producing container seedlings in the southern United States using four different types of containers and four growing structures. This economic information was then analyzed against comparable data for a bareroot nursery.

1.1.4.1 Requirements of a container nursery system

The first step in cost analysis is to identify all the things that are required to operate a nursery. Novice developers often assume that there is a standard system for growing container seedlings but, in reality, no such thing exists. Each species of plant has its own optimum environmental requirements, and each potential nursery location has a unique climate. Individuals and organizations also have their own goals and constraints that will affect development decisions. Therefore, nursery developers must realize that a container nursery facility must be carefully designed to match specific objectives (Ekblad 1973).

To make sure that all factors are considered, a relatively simple systems analysis approach should be used. A container nursery **system** consists of a series of **processes** (Furuta 1978). A specific process, such as sowing seed, involves a series of sequential **operations,** such as filling the container with growing medium and placing a calculated number of seeds in each container. Each process and operation in the system has specific **requirements** including structures, equipment, supplies, and labor (table 1.1.5).

The objective during the nursery development phase is to understand the system and its processes well enough to identify the requirements and estimate their associated costs. Some requirements will be standard for all types of nurseries, but others will vary. For example, a nursery that is designed to propagate seedlings vegetatively will have slightly different process and operations, and therefore different requirements, than one designed to produce plants from seeds. Other nursery requirements--such as maintenance, reliability, and safety--are not so obvious to a prospective nursery developer, but they must also be considered (Ekblad 1973). Maintenance requirements are those associated with keeping the nursery system running efficiently, whereas reliability requirements are those that keep the nursery working without catastrophic failure through the use of environmental controls, backup power, and alarm systems. Safety requirements must also be considered because even the most mechanically efficient operation must not involve unacceptable risks to nursery workers.

To ensure that all of the various requirements are considered, it is often helpful to visualize the nursery system, processes, and operations with a flow chart (see figure 1.4.11). Such a visual representation is an excellent way to show how the various steps in successful container seedling production relate in both spatial and temporal contexts. Because it is unreasonable to expect a fledgling nursery developer to know all the elements of a successful container nursery operation, the authors recommend visiting an existing nursery. In addition, there are several good references that deal with nursery development. Matthews (1983) listed the factors that should be considered for developing a container tree nursery in British Columbia, and Hanan and others (1978) discussed the economic considerations associated with ornamental container nursery development.

Once the nursery system has been broken down into its requirements, the associated fixed and variable costs must be estimated. In addition to the initial development expenses, annual fixed costs for depreciation, rent, insurance, and taxes also must be considered. Obtaining realistic costs for starting a container nursery facility will be difficult, especially for the novice, but this exercise is absolutely necessary for the development of a successful nursery. Government nurseries can be helpful in this regard because their production costs are public information (see table 1.5.1 in chapter 5 of this volume for an example).

1.1.4.2 Influence of nursery size and space utilization

The production capability of the proposed nursery is obviously an important factor that will affect product cost estimates. Larger facilities are more efficient because of the economies of scale but are also inherently more expensive to develop. Van Eerden (1982) found that 30 to 40% of nursery production costs in British Columbia were due to interest charged on investment and working capital. Thus, it is prudent to keep growing facilities as small as possible at the

Table 1.1.5—*A container tree nursery can be described as a system consisting of a series of processes composed of sequential operations with specific requirements*

SYSTEM: Container tree seedling nursery
  PROCESS: Sowing seed
    OPERATION: Placing a specific number of seeds per container
      REQUIREMENTS:
        Structure—headhouse
        Equipment—seed-sowing machine
        Labor—skilled, experienced workers
        Supplies—seed & electrical power

beginning, and expand gradually as seedling demand develops and funds are available.

In addition to the size of the nursery, seedling production capability is a function of several factors:

1. **Space use efficiency**---the net useable production space that can be achieved in each growing area. Forest tree seedlings are typically grown on pallets or raised benches, and so their arrangement and the efficiency of space utilization control the maximum number of seedlings that can be grown per unit area. Typically, overall greenhouse efficiencies range from 65 to 70% but can be high as 85%.
2. **Container size and arrangement**---the lateral dimensions and density of cells per growth container, and the number of containers that can be placed in the growing area.
3. **Production efficiency**--the proportion of shippable seedlings that can be produced per crop, and the number of crops that can be raised per year.

(More information can be found in chapter 3 of this volume.)

Multiple cropping is another way to increase seedling production per unit of growing area. In some parts of the United States, especially the South, more than one crop is grown per year in a container nursery (Guldin 1983). For example, some growers use the greenhouse as a starting facility. Once the young seedlings are established they are moved to another growing site, such as outdoor growing areas or a shadehouse, to finish their growth. A second crop can then be sown and finish the growing season in the greenhouse. Obviously, this production system is dependent on the type of nursery facilities and climate. Crops produced during the winter are always more expensive than summer crops because of the increased cost of heating and the greater time needed to meet target seedling quality (see production cost comparison in table 1.5.1 in chapter 5 of this volume). In very cold climates, fuel costs may be so high that only summer operation of the greenhouse is economical. (Crop scheduling is discussed further in volume six of this series.)

1.1.4.3 Energy and transportation considerations

Since the energy crisis of the early 1970's, concern about energy use have greatly changed the economics of container nursery operation. Most container nurseries, especially fully controlled greenhouses, use large amounts of energy, and so potential energy use and associated costs must be carefully analyzed. In fact, energy considerations are one of the most important factors to be considered when evaluating potential nursery sites. The types and amounts of energy that would be used in container nursery operation will vary with nursery design and operation. Cameron (1982) discusses a computer model available to predict energy needs in a greenhouse given various alterations in greenhouse structure or seedling culture at a given site.

Because forest tree seedlings are typically outplanted in distant locations, transportation to the outplanting site can be a significant economic consideration. Originally, because of the problems associated with seedling storage and transportation, bareroot nurseries were located as close as possible to the outplanting site. With the advent of refrigerated trucks and storage facilities, however, it has become biologically and economically feasible to ship container seedlings for long distances. This has led to a trend to locate nurseries in milder climates where nursery operating costs will be less. For instance, British Columbia has a mild climate in the lower Fraser River Valley, but short growing seasons and very cold winters in the interior of the province. Thus, most reforestation seedlings for the province are grown near Vancouver and shipped inland for planting (Van Eerden 1982). The container nursery developer should put considerable weight on placing the operation in a mild climate, even if the seedlings are to be delivered a considerable distance away. This assumes, however, that the nursery facility will be designed so that the seedlings can be properly conditioned before shipping and storage. In areas without refrigerated storage, nurseries must be located closer to the outplanting site to reduce shipping time and handling costs.

1.1.4.4 Balancing labor and equipment

It is possible to do all container tree nursery operations by hand, and this is the best option where labor costs are very low, creating jobs is an objective, or technology is prohibitively expensive or unavailable. Most nurseries use specialized equipment to increase efficiency and reduce labor costs. However, nursery developers should not become preoccupied with the mechanical and engineering aspects of a task without also considering economic and biological factors. Labor costs can be high during key seasonal operations in a nursery such as container filling and sowing, and harvesting and shipping. In between these periods, however, the nursery can be run by only a few skilled workers.

When evaluating the need for a piece of nursery equipment, the developer should consider the following questions:

1. Is this piece of equipment necessary to meet the biological needs of the seedlings?
2. How much time will this piece of equipment save, relative to the savings in labor?
3. How amenable is the task to mechanization?
4. Is time to complete the task a major consideration?
5. Will the equipment only be used for a very short time each year?
6. Can the equipment be leased or borrowed from local nurseries or other businesses?

The primary consideration in deciding whether to mechanize should always be the effect on seedling quality, and so each nursery process should be evaluated according to this criterion first. The intense activity during peak work periods can easily make mechanization appear desirable, but the nursery developer must keep in mind that a task lasting a brief time may well be accomplished most efficiently by intensive application of hand labor. Some processes, such as grading seedlings, require a trained eye and experienced hands and so are more difficult to automate. Other tasks, such as filling and sowing containers, must be done in a very short time period and so are usually worth the financial investment in equipment to speed up the process (Van Eerden 1982).

Mechanization becomes more economically feasible with an increase in size and sophistication of the nursery, and as the costs of temporary labor rise. However, the purchase of a new piece of equipment requires capital and new equipment must be used often enough to justify its cost. Low cost and innovative "homemade" equipment can be very efficient and cost effective. Thus, each case must be judged separately.

1.1.5 Feasibility Assessment and Development Tactics

The final step is to do a feasibility assessment, which is simply an analysis of the pragmatics of the situation. Compare your project seedling prices with estimated production costs and weigh them against the risks and potential profits associated with the enterprise. The resulting analysis should incorporate a variety of facility designs, sizes, and locations, so that the developer will be able to identify the best nursery facility to meet the projected seedling needs. At this point, it would be wise to reconsider whether the best option might be to purchase stock from an existing nursery.

If the analysis dictates that starting a nursery is still the best option, then timing and degree of development must be considered. Nursery development tactics depend on the degree of risk to be assumed and the urgency of the need for the seedlings. It may be prudent to start with a small pilot nursery rather than a full-scale facility. Container nurseries are ideal for this purpose because you can focus on growing critical species that have unique environmental requirements while procuring the more traditional stock from other nurseries. Growing only part of your seedling needs affords some security of supply and establishes the technical capability to produce the entire demand if needed.

In spite of all this discussion about evaluation and analysis, the final decision on whether to start a container tree nursery often rests with the management philosophy of the organization or the individual developer. Many nurseries have been constructed to meet specific needs or desires in the face of evidence to the contrary.

1.1.6 Summary

A person who is considering starting a container tree nursery must be familiar with the terminology and unique characteristics of forestry and conservation plants. Unlike most other crops, seedlings from forest nurseries are typically outplanted on relatively harsh sites without subsequent care. This difference is significant because it means that seedling quality is defined by the environmental conditions on the outplanting site. There is no such thing as an "all-purpose" tree seedling. When confronted with a demand for tree seedlings, most people or organizations think that they need to start their own nursery, but they should first consider purchasing stock from an established nursery. If they decide to start their own nursery, the next decision is whether it should be a bareroot or container facility. There are many factors to consider in choosing the best type of facility. Potential nursery developers must be very realistic about the market they are planning to fill, and an analysis should be done to collect facts about demand, competition, and prices. They must also estimate product cost to determine if their seedlings will be competitive in the marketplace. The final step is to do a feasibility assessment in which estimated seedling prices and production costs are compared to the risks and potential profits. If the decision is made to build a new nursery, then a suitable site must be selected and developed. How to go about doing so is discussed in chapter 2 of this volume.

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