ECONOMIES-OF-SCALE FOR NEWLY CONSTRUCTED SOUTHERN PINE NURSERIES

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Abstract.--Cost is an important consideration in constructing and operating new nurseries to grow bare-root and containerized southern pine seedlings for reforestation. Each type of nursery has different capital requirements. The cost of erecting a container seedling nursery is competitive with the cost of building a new bare-root nursery. By analysis it is shown that containerized seedlings can be grown economically and deserve a place in pine reforestation programs.

Additional keywords: Reforestation, regeneration.

The South's Third Forest report by the Southern Forest Resource Analysis Committee (1969) called for regenerating 30 million unproductive acres to pine by 1985. This need was seen as an addition to the reforestation of currently productive land from which the timber will be harvested. The report also called for an additional 60 million acres forested with genetically improved stock by the year 2000. However, the annual rate of regeneration by both direct seeding and planting in the entire South--including idle farmland, forest land understocked with pine, unproductive upland sites converted to pine, and recently harvested acreage promptly regenerated--has not exceeded 1.6 million acres since this report was issued 13 years ago. Present reforestation rates are barely achieving half the goal. A major constraint precluding attainment of the reforestation goal is the lack of seedlings. Twice as many are needed as are available; preferably these would all be from genetically improved seed.

An inadequate amount of seedling production capacity is the major bottleneck to growing sufficient seedlings. Finding suitable nursery sites is difficult, and building new nurseries is expensive. Just the construction costs for two new forest industry bare-root nurseries that began in 1980 were $1 million and $2 million for annual outputs of 18 and 35 million seedlings respectively. A third nursery that is under construction at a cost of $2 million will produce 25-30 million seedlings annually beginning in 1983 or 1984. These costs equate to between $56 and $67 per 1000 seedlings annual production capacity, excluding land cost. Yet these three nurseries add only 7 percent to the total southern pine nursery capacity. Applying these costs, it would require an additional $72 million to double existing pine seedling output, assuming that suitable nursery sites are already owned.

Building new container seedling nurseries could help meet the seedling need. But are they economical? This paper updates the estimated costs of building four types of new container seedling nurseries reported in Guldin (1982a, 1982b) and compares them to the cost of building new bare-root nurseries.

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NURSERY ALTERNATIVES

Bare-root nurseries have been the principal supplier of pine seedlings for artificial regeneration in the South since F.O. Bateman pioneered successful planting practices in the 1920s. Because of the bare-root capacity presently available, amounting to 1.2 billion seedlings last year, bare-root seedlings will remain dominant. They will continue as the benchmark against which the costs of new technologies, such as growing seedlings in containers, are compared.

The costs determined for each type of nursery are influenced by a number of assumptions. Biological assumptions vary among the five alternatives and will be addressed separately for each. Several cost assumptions, however, are common to all five. These are capital, labor, and overhead costs as well as costs of goods and services.

Capital costs were based entirely on price quotations from nursery equipment manufacturers and wholesalers or on actual bids for recently constructed facilities across the South.[2] Locally available construction materials were priced at retail outlets in the New Orleans, Louisiana area. A factor equal to 10 percent of total costs was added to cover miscellaneous items and contingencies. All costs are on a July 1, 1982, basis. An interest rate of 10 percent was used to amortize investments in facility components.

Labor costs were based on man-hours of labor required to perfrom tasks at existing nurseries, multiplied by standard wage rates of $6, $8, and $10 per hour for unskilled, skilled, and supervisory labor categories. An additional 15 percent of total wages was added for the cost to the employer of social security tax, workmen's compensation insurance and unemployment insurance. The last two were based upon Louisiana rates for new nursery businesses.

The quantities and costs of goods and services used to produce seedlings were based upon amounts required by facilities currently in operation and on prices quoted by their suppliers.

Direct overhead costs of the nursery operation itself were included in the total cost estimates. However, nothing was added for general administrative expenses related to higher echelons of the firm or agency.

BARE-ROOT NURSERY

Bare-root seedling total costs have both a capital component and a production component.

2/ The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such does not constitute an official endorsement or approval of the product by the U.S. Department of Agriculture to the exclusion of others which may also be suitable.

Capital Costs

Capital costs for a new bare-root nursery fall into three categories: land acquisition and site preparation, construction of nursery buildings, and purchase of equipment.

Wakeley (1954) outlined the quality and quantity of land required for new bare-root nurseries. He recognized that the best nursery soils are often also the best agricultural sites. A high price is required to bid such acreage from crop production. Land acquisition expenditures include not only the purchase price paid, but also search and closing costs. If a nursery site is already owned by the firm or agency, its cost comprises the net benefits foregone from the prior land use. In addition, if the location selected is not optimal, but is the best owned by the firm or agency, there is an opportunity cost involved in settling for a sub-optimal site. Using Wakeley's guidelines, it has been assumed that 3.5 acres are needed for beds, paths, roads, and administrative areas for each 1 million seedlings grown annually.

Once acquired, acreage must be cleared and leveled, beds laid out, and an irrigation system installed. Organic amendents, or other soil management practices, may be needed to build up the soil prior to producing the first crop of seedlings.

While all site improvements, such as the irrigation system, have an assumed 20 year lifetime, the inherent land value is presumed constant in perpetuity. Therefore, land acquisition costs must be converted to an annual value using the formula for a perpetual annual series rather than for a terminable annual series. Costs for land acquisition and site improvements were thus converted to an average annual cost basis per one million seedlings annual capacity. When this figure ($3,614 per million seedlings) is multiplied by nursery output the result is the annual land capital cost.

The required buildings are a nursery office, equipment storage and repair garage, a packing building, and a refrigerated seedling storage warehouse. The sizes of the first two do not vary with seedling production, but the sizes of the other two will. All buildings are assumed to have a 20-year life.

Equipment needs include pickup trucks, tractors, seed sowers, sprayers, seedling lifters, forklift trucks, and wagons. Nurseries that produce less than 6 million seedlings annually have at least one of each type of equipment. As nursery output exceeds 6 million seedlings, equipment needs rise rapidly, because seedling production becomes more heavily mechanized. In addition to more pieces of equipment, equipment size and horsepower also increase. Both factors contribute to higher costs. Equipment purchase prices were depreciated over assumed lifetimes, generally five years. Annual operating costs were then added and the sum divided by annual output to obtain the annual equipment cost per million seedlings.

The combined capital costs associated with land acquisition and development, construction of all needed buildings, and purchase and operation of equipment were converted to an annual cost per 1,000 seedlings for nurseries ranging in size from 5 to 30 million seedlings annually (fig. 1). The capital cost per 1,000 seedlings declines rapidly as nursery size increases to 12 million seedlings. Beyond 15 million seedlings, capital costs continue to decline as output increases, but at a much lower rate. The minimum output of a new bare-root nursery should be 15 million seedlings to obtain the most benefit from economies of scale.

Seedling Production Costs

Records for several public and private nurseries were examined, principally to determine staffing requirements and other costs by broad production categories. A composite budget was estimated, based on these costs, for a nursery producing 30 million seedlings annually (table 1). The total production cost of $27.16 per 1,000 seedlings includes all salaries, wages, employer-paid fringes (except pension plans), office expenses, seed, fertilizer, pesticides, packing supplies, and other miscellaneous items and materials essential for nursery operations. This cost is unaffected by nursery size, provided production rate remains constant.

The estimated cost is heavily dependent upon the amount of temporary labor used and the temporary employee wage rate. The assumed wage of $6.00 per hour, plus 15% in employer-paid fringe benefits, is higher than the minimum wage ($3.35 per hour plus 15%) typically paid by state nurseries. The daily rate for temporary employees at the Forest Service's W.W. Ashe Nursery in Brooklyn, MS, is currently $60.90. In a 1980 check of nursery hand-weeding costs, 7 of 22 industrial nurseries paid higher hourly rates than Ashe (Guldin 1982a). For temporary daily labor rates above or below the $55.20 used for our comparisons, production costs should be adjusted accordingly.

CONTAINER NURSERY ALTERNATIVES

Three major factors must be determined before cost estimates can be developed for a container seedling nursery: location of the nursery, type of germination house, and type of container. Location and type of germination house jointly determine the number of seedling rotations that can be germinated annually in each house. Type of container and size of germination house jointly determine the number of seedlings grown per rotation. Thus, all three elements together not only determine annual seedling output, but also influence costs.

Nursery Location

Contrary to the bare-root dictum that a site should be chosen which is as far north as possible to lengthen the seedlings' dormant period, container seedling nurseries should be located as far south as possible to maximize the frost-free growing period and minimize wintertime utility consumption. Both the number of rotations grown annually and output increase as the length of the growing season increases. Higher outputs spread annual capital costs over a larger number of seedlings.

Table 1.--Production costs for sowing, growing, lifting, and packing 30 million bare-root seedlings.

Seedling Production		Cost
Labor		
Permanent Employees	900 man-days @ $73.60	$ 66,240
Temporary Employees		
Seeding	1200 man-days @ $55.20	66,240
Hand Weeding	1200 man-days @ $55.20	66,240
Supplies and Materials		
Fertilizers		20,000
Pesticides		70,000
Miscellaneous		10,000
Seed	4100 lbs. @ $15.00/lb.	61,500
Maintenance	67% of annual equipment cost	41,930
Subtotal		$402,150
Lifting and Packing		
Labor		
Permanent Employees	400 man-days @ $73.60	$ 29,440
Temporary Employees	3700 man-days @ $55.20	204,240
Supplies and Materials		55,000
Maintenance	33% of annual equipment cost plus 10% of annual building cost	26,810
Subtotal		$315,490
Local Overhead		
Labor		
Supervisors	520 man-days @ $92.00	$ 47,840
Secretary	260 man-days @ $55.20	14,352
Supplies, Materials, and Utilities		35,000
Subtotal		$ 97,192
	Total Production Cost	$814,832
Total Production Cost per 1,000 Seedlings		$ 27.16

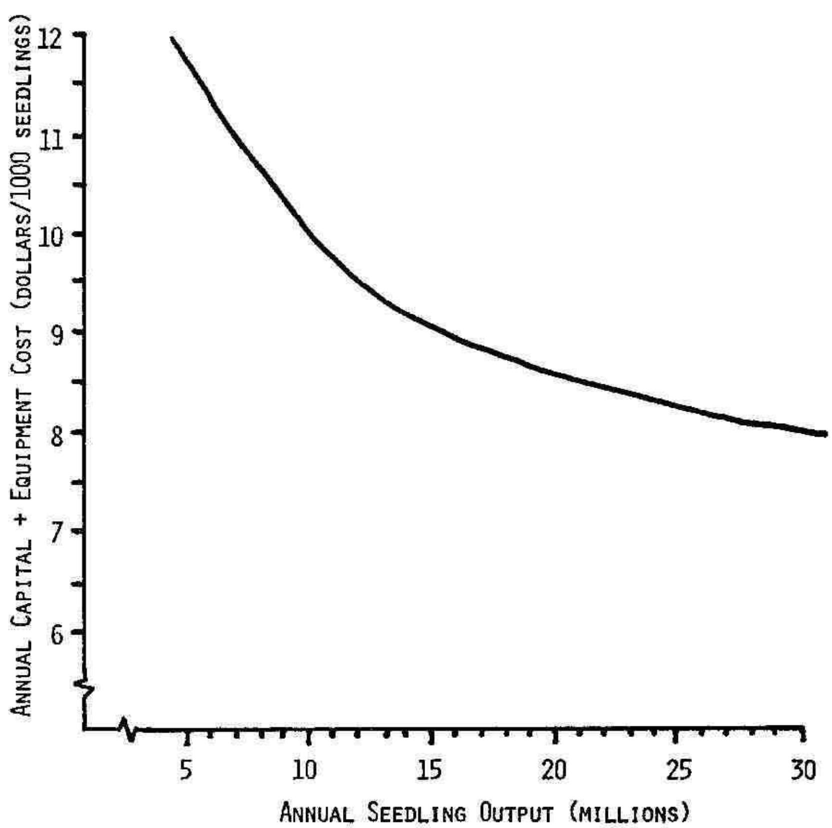

Figure 1.--Annual capital and equipment costs per 1,000 bare-root seedlings.

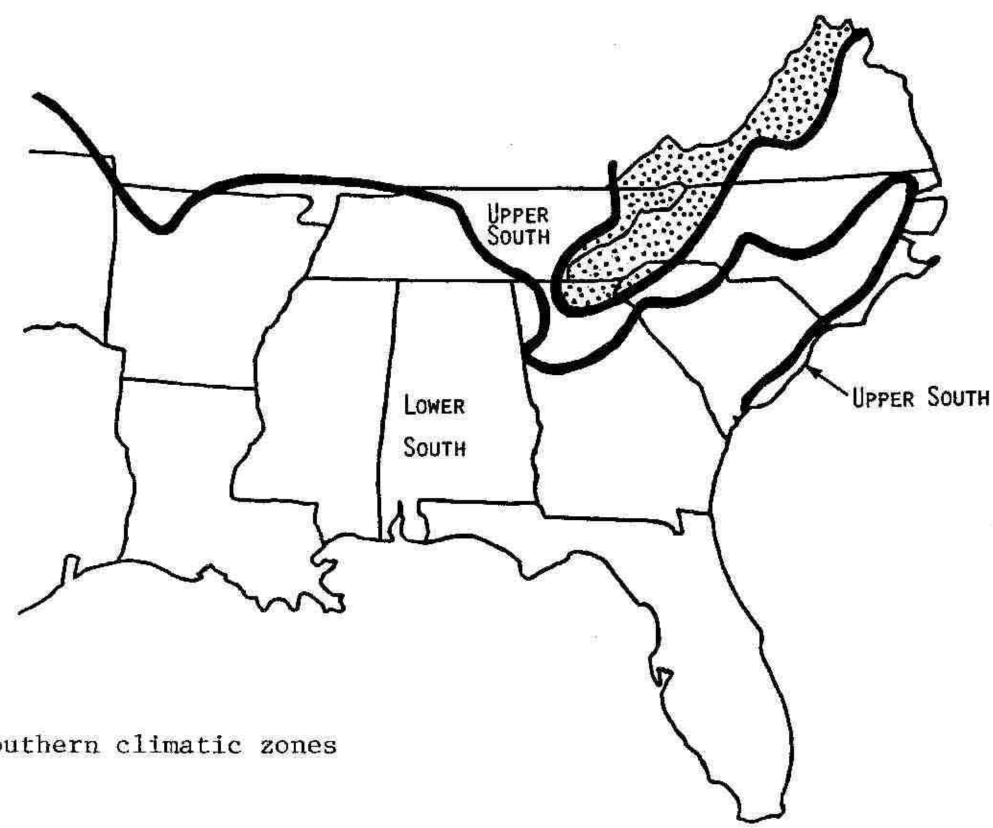

Figure 2.--Southern climatic zones

The South was divided into two climatic zones based on the length of the frost-free growing season and incidence of daily air temperatures exceeding 90°F (fig. 2). Seedling production schedules used in this study assumed that properly hardened seedlings would not be outplanted before the mean date of last frost in the spring nor later than one week before the mean date of first frost in the fall. Production schedules also assumed that seedlings could not be consistently outplanted during midsummer because of soil moisture and surface temperature limitations. The climatic criteria used to define the zones were:

	Frost-free Length of Growing Season	Days When Daily Maximum Air Temperature Exceeds 90°F
	(No. of days)	(No. of days)
Upper South	185-215	30-60
Lower South	215-310	60-120

Mircroclimatic conditions may alter actual production schedules and potential seedling outputs in either zone.

Germination Houses

A container seedling nursery requires buildings for three basic functions: filling containers with media and sowing seed, seed germination and initial seedling growth, and hardening seedlings off prior to outplanting. Although one building could be used for all three functions, production efficiency increases if separate buildings are available that specialize in each activity. A headhouse provides container filling and seed sowing space. Germination and initial seedling growth can occur in either a greenhouse or a shadehouse. Hardening off is most efficiently performed in a shadehouse. Because similar headhouses and shadehouses are used with different germination houses, specifying the type of germination house will identify the type of nursery.

The four types of container seedling nurseries (and germination houses) share several common features. Some of these relate to biological conditions, whereas others induce commonality for cost comparison purposes. The common features are:

--Each nursery "replicate" (smallest efficient production unit) has one headhouse, five greenhouses for germination, and five shadehouses for hardening off. An exception is the pole shadehouse nursery, which has one headhouse, no greenhouses, and six pole shadehouses for both germination and hardening off.

--A sufficient number of CCA type C treated southern pine pallets to fill each greenhouse and shadehouse, included in building construction costs.

--Loblolly (*Pinus taeda* L.) or slash pine (*P. elliottii* Engelm. var. *elliottii*) seedlings grown in 12 to 16 week rotations.

--One "greenhouse rotation" is equivalent to 3,420 square feet, ± 2 percent, of usable growing space. Greenhouse sizes were selected to provide this much net growing space per house, assuming that 67 percent of the gross floor space was usable. Widths of greenhouses currently manufactured were assumed, and greenhouse length was adjusted to provide the needed space. Multiplying container cell densities per square foot by the net growing space per rotation yields the total number of cells per rotation.

--Ninety-five percent of the cells produce plantable seedlings. Sowing two seeds per cell, plus thinning and transplanting excess seedlings to vacant cells, has attained this percentage of plantable seedlings in existing southern container seedlings nurseries. Labor costs include these activities.

--One "greenhouse rotation" per week is the maximum headhouse capacity.

--Only one-half acre of land is needed for each building. Suitable land with an adequate water supply should cost no more than $500 per acre.

Glass Greenhouse Nursery.--A glass greenhouse nursery has a wood-frame headhouse measuring 40 x 60 feet, which contains the nursery office; media-mixing, container-filling, and seed-sowing equipment; storage; lavatories; and main utility service station. A forklift truck for pallet handling is included. Each of the five gable-roofed, aluminum-framed, glass-glazed greenhouses measures 42 x 120 feet. The greenhouses contain complete and fully automated heating, cooling, carbon dioxide enrichment, and lighting systems; an overhead crawling waterer with fertilizer and chemical injector; and all utilities and connections, including a telephone alarm system. Each of the five pole shadehouses is 44 x 240 feet. They are constructed of shadecloth stretched over a nylon rope grid supported by three rows of CCA type C treated poles. Irrigation is the environmental control provided in the shadehouses. Each shadehouse provides sufficient space for two greenhouse rotations while hardening off seedlings prior to outplanting.

Shadehouses function as a "surge bin" between greenhouse production and field planting. The total construction cost of this nursery replicate is $713,135, which is equivalent to an annual fixed cost of $94,993 (table 2).

Fiberglass Greenhouse Nursery.--The same type of headhouse is used as for the glass greenhouse. Each of the five fiberglass-sided greenhouses has a double bowed and trussed roof covered with two layers of ultraviolet resistant polyethylene sheeting, held apart by air pressure form a small blower. The structures measure 34 x 150 feet. They contain the same climate control equipment as the glass greenhouse, except for the irrigation system. The fiberglass-sided greenhouse has a solid-set plastic pipe irrigation system buried in the floor, with threaded removable risers. A fertilizer and chemical injector is provided. The five pole shadehouses used for hardening off are of the same construction as those used in the glass greenhouse nursery, but each measures 36 x 300 feet. The total construction cost of this facility is $350,116, which is equivalent to an annual fixed cost of $51,144.

Table 2.--Capital costs of nursery construction, including land acquisition.

Number of Germination Houses	Type of Cost	Type of Germination House: Glass Greenhouse	Fiberglass Greenhouse	Timber Truss Greenhouse	Pole Shadehouse
One					
	Total	$208,751	$142,921	$85,644	$71,103
	Annual	28,653	20,904	13,911	10,695
Two					
	Total	334,847	203,187	115,091	86,009
	Annual	45,223	29,725	20,045	13,613
Three					
	Total	460,943	263,453	144,538	100,915
	Annual	61,793	38,546	26,179	16,531
Four					
	Total	587,039	296,624	169,378	115,821
	Annual	78,363	43,331	31,050	19,449
Five					
	Total	713,135	350,116	197,671	130,727
	Annual	94,993	51,144	36,868	22,367
Six					
	Total				145,633
	Annual				25,285

Timber Truss Greenhouse Nursery.--Annual seedling production levels are lower for this type of greenhouse than for the glass and fiberglass structures. Thus less expensive partially-mechanized media-mixing, container-filling, and seed-sowing equipment is used in the headhouse. A forlkift truck is still included. Timber truss greenhouses measure 34 x 150 feet. They are built onsite from standard softwood dimension lumber and poles. Timber trusses are constructed from 2 x 6 lumber to a 4 over 12 pitch using half inch plywood gussets. The trusses are set on 4-foot centers atop two pole walls 34 feet apart. The pole walls are constructed of 4-inch diameter CCA type C treated poles with a double 2 x 4 top plate. The trusses are tied together with sufficient 1 x 4 lumber to make the structure wind-firm for the locality and are covered with a layer of 2-inch galvanized poultry mesh and a single layer of 6 mil ultraviolet resistant polyethylene sheeting. Only irrigation and photoperiod control equipment are provided in the timber truss greenhouse. The pole shadehouses used for hardening are identical in size and construction to those used for the fiberglass greenhouse nursery. The total construction cost of a timber truss greenhouse nursery is $197,671 and the annual fixed cost is $36,868.

Pole Shadehouse Nursery.--The same type of headhouse used for the timber truss nursery is used for the pole shadehouse nursery. The construction and size of the shadehouses used for germination are identical to those used for hardening in the glass greenhouse nursery. This type of nursery is the least expensive to construct, but provides the least climatological control. Only irrigation is provided in this nursery. The total construction cost is $145,633, or an annual fixed cost of $25,285.

Types of Containers

Four types of containers, each in two sizes, were considered in the study: Styroblocks, Multipots, Rootrainers, and Todd Planter Flats (table 3). The purchase price of the containers, container reusability, container cell density per square foot, and labor requirements for container assembly, filling, and sowing are the 4 factors that affect the cost of growing seedlings.

Styroblocks, Multipots, and the Rootrainer trays can be used for six rotations. The Rootrainer cells, however, last only two rotations. Todd Planter Flats can be used for three rotations. These lifetimes, based on actual use in southern nurseries, were used to adjust the prices of the containers to a container purchase cost per 1,000 seedlings produced.

The Rootrainer "books" must be folded to form strips of cells which are then inserted into the Rootrainer tray. Seventeen Ferdinand books fill the tray with 102 cells, compared to 13 Fives books that provide only 65 cells. In addition, the trays themselves must be assembled. None of the other containers need assembly.

Analysis of the cost and operations records of existing container seedling nurseries in the South reveals that labor and material costs are determined primarily by the type of container selected. The labor cost for tending a single rotation once seed is sown is fixed, independent of the type of germination house. However, the labor cost per 1,000 seedlings is greatly influenced by container cell density.

Table 3.--Production costs for growing loblolly pine seedlings in containers of various cell densities and volume.

	Styroblocks		Multipots		Rootrainers		Todd Planter Flat	
	Quarter blocks Number 2	Number 4	V-50	V-93	Ferdinand	Fives	100A	150-5
1. Container Purchase 1/	$ 5.20	$ 6.88	$ 5.27	$ 8.83	$10.56	$15.62	$ 4.18	$12.19
2. Media @ $27/20 cubic feet	2.10	3.36	2.85	4.70	2.10	2.94	1.26	3.15
3. Seed @ $15/pound	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63
4. Seed Treatment	.08	.08	.08	.08	.08	.08	.08	.08
5. Fertilizer & Pesticides	.15	.15	.15	.15	.15	.15	.15	.15
6. Utilities 2/	1.51	1.93	1.88	3.14	1.31	1.89	1.92	3.06
7. Labor								
a. Filling and Seeding	1.77	1.77	1.27	1.40	3.73	3.73	2.71	2.71
b. Daily Greenhouse 3/ Management	7.10	8.52	8.31	13.88	5.78	8.33	8.07	13.53
c. Supervision 4/	3.55	5.96	5.82	9.90	3.55	4.17	5.76	9.65
Total Cost per 1000 cells	$23.09	$30.28	$27.26	$43.17	$28.89	$38.54	$25.76	$46.15
Total Cost per 1000 seedlings 5/	$24.31	$31.87	$28.69	$46.01	$30.41	$40.57	$27.11	$48.58
Container Cell Density Per Square Foot	96	75	82	49	118	82	80	50
Container Cell Volume in Cubic Inches	2.5	4.0	3.4	5.7	2.5	3.5	1.5	3.8

1/ Assembly costs are included, if needed. All costs include freight from the distributor to the mid-South (Monroe, LA; Vicksburg, MS; Natchez, MS).
2/ No active winter time growth in greenhouses is assumed, only extended hardening off (temperatures 35°-40° F overnight).
3/ Fixed cost of $2208 per greenhouse rotation (3420 square feet of growing space).
4/ Fixed cost of $1575 per greenhouse rotation.
5/ Assumes 95 percent of cells contain plantable seedlings.

CALCULATING CONTAINER SEEDLING TOTAL COSTS

Determining the total cost per 1,000 containerized seedlings involves several choices. Two facts must be known before cost calculations begin: the desired annual nursery output and the probable location of the nursery, whether in the upper or lower South (fig. 1).

The initial choice is the type of container to be used. The container establishes the cell density per square foot, which, with the assumed stocking level (95 percent plantable seedlings in this study), determines the number of germination houses needed to produce a given annual output. The three major variables affecting the choice of container are the container's cost contribution to seedling production, cell density, and cell volume. Low cost is generally traded off against low density or large volume. Barnett and McGilvray (1982) concluded that 100 cells per square foot is the optimal cell density for loblolly and slash pine. Lower densities are preferred for longleaf pine (P. palustris Mill). Containers with lower densities and larger volumes require a growing period longer than 12 to 16 weeks for the seedling roots to fully develop and bind the media together for easy extraction from the container. To illustrate the cost calculation method, Number 2 Styroblocks were selected because they have the lowest production cost per 1,000 seedlings and are the closest to the optimal cell density for loblolly pine.

The second choice is the type of germination house to be used. The timber truss greenhouse has the lowest capital cost per 1,000 seedlings in the lower South, while the pole shadehouse results in the lowest capital cost per 1,000 seedlings in the upper South (table 4). The fiberglass and glass greenhouse options offer greater control of seedling growth environment. However, the annual production per germination house from these two options is not sufficiently greater to reduce average capital cost per 1,000 seedlings to the timber truss greenhouse or pole shadehouse levels. If a controlled environment is required, the fiberglass greenhouse is clearly less expensive. However, the cost disparity between it and the two lower capital cost options suggests that multipurpose nurseries (combining progeny testing or other research with mass production of seedlings for reforestation) are cost efficient. If a highly-controlled environment is desired a greenhouse could be built separately from the houses used for mass production of regeneration seedlings. The fiberglass option should not be chosen for the entire reforestation nursery when only limited research space is needed.

High-capital greenhouses are not essential to produce quality reforestation seedlings in the South. To illustrate the cost calculation method, suppose that a nursery in the lower South is planned, using timber truss greenhouses for germination. Cost calculation proceeds as follows. From Table 4, find the annual output per timber truss greenhouse in the lower South when using Number 2 Styroblocks, 1,252 thousand seedlings. Then, divide the desired output of 25 million seedlings by the output per germination house. The quotient of 19.97, rounded to the next higher whole number, is the number of germination houses needed. Divide the rounded result by five, the number of germination houses per timber truss greenhouses replicate, to obtain the number of replicates needed. In the case of our example, 4.0 replicates are needed.

Table 4.--Annual Output Per Germination House

	Type of Germination House			
	Glass Greenhouse	Fiberglass Greenhouse	Timber Truss Greenhouse	Pole Shadehouse
	----Thousand Seedlings----			
Lower South				
#2 Styroblock	1246	1252	1252	633
#4 Styroblock	973	978	978	495
V-50 Multipot	1064	1036	1036	802
V-93 Multipot	636	639	639	323
Ferdinand	1531	1539	1539	778
Fives	1064	1036	1036	802
Todd 100A	1038	1044	1044	528
Todd 150-5	649	652	652	330
Upper South				
#2 Styroblock	934	939	939	633
#4 Styroblock	730	734	734	495
V-50 Multipot	798	802	802	802
V-93 Multipot	477	479	479	323
Ferdinand	1148	1155	1155	778
Fives	798	802	802	802
Todd 100A	779	783	783	528
Todd 150-5	487	489	489	330

Because the replicate quotient is a whole number, use the lowest capital cost of the range presented (table 5). In the example, the capital cost per 1,000 seedlings grown in Number 2 Styroblocks in timber truss greenhouses in the lower South is \$5.89. The total cost for these container grown seedlings is the sum of the capital cost per 1,000 seedlings and the production cost per 1,000 seedlings (table 3), \$5.89 + \$24.31 = \$30.20 per 1,000 seedlings.

If the replicate quotient ends in a decimal and not a whole number, some interpolation is needed. Suppose that only 20 million seedlings are needed. This translates into 16 timber truss germination houses and 3.2 replicates. For the three complete replicates, the lowest average capital cost can be used, \$5.89. However, the 0.2 replicate left is comprised of a headhouse and all its equipment, one germination house and one shadehouse. This last partial replicate has a much higher capital cost per 1,000 seedlings produced because 80 percent of the headhouse capacity is unused (four more germination houses could be served). A decimal replicate remainder of 0.2 requires using the highest capital cost of the range presented (table 5), \$11.11 per 1,000 seedlings. The average capital cost for all the seedlings produced is the arithmetic average:

$$\frac{(3.0 \times \$5.89) + (0.2 \times \$11.11)}{3.2} = \$6.22 \text{ per 1,000 seedlings}$$

Where decimal remainders are 0.4, 0.6, or 0.8, the capital cost range must be interpolated to find the upper quartile of the range, the midpoint of the range, or the lower quartile of the range respectively. As the decimal increases, the amount of unused headhouse capacity decreases, and the capital cost approaches the lower end of the range presented (table 5).

Most container seedlings nurseries presently operating in the South produce between 400,000 and 1.5 million seedlings annually. This is less than the full first replicate for all containers and germination houses investigated. These existing nurseries will find their marginal cost per 1,000 seedlings drop, due to increasing returns-to-scale, as outputs are increased to the point where the headhouse investment is heavily utilized in the 3 to 4 million seedlings annual output range. New container seedling nurseries should have annual outputs greater than 3 million seedlings and strive to size their operations in full replicates to benefit from economies-of-scale and efficient capital investment.

BARE-ROOT AND CONTAINER NURSERY COST COMPARISONS

A comparison of seedling production costs between the two types of nurseries reveals that three types of containers are competitive (within ± 10 percent) with bare-root seedlings (\$22.16): Number 2 Styroblocks (\$24.31), Todd 100A Planter Flats (\$27.11) and V-50 Multipots (\$28.69). Labor comprises 60 to 65 percent of bare-root seedling production cost, but only 50 to 60 of container production costs. Thus, bare-root costs would drop faster if a lower temporary wage rate than the assumed \$6.00 per hour were paid. But even at the minimum wage, use of the three competitive containers would still range from 2 percent cheaper to only 12 percent higher than bare-root seedlings (\$22.00).

Table 5.--Capital Cost per 1,000 Seedlings

	Type of Germination House			
	Glass Greenhouse	Fiberglass Greenhouse	Timber Truss Greenhouse	Pole Shadehouse
Lower South				
#2 Styroblock	$23.00-15.25	$16.69-8.17	$11.11-5.89	$16.89-6.65
#4 Styroblock	29.44-19.52	21.37-10.45	14.22-7.54	21.62-8.52
V-50 Multipot	26.93-17.85	19.54-9.56	13.00-6.89	19.77-7.79
V-93 Multipot	45.06-29.88	32.70-16.00	21.76-11.54	33.09-13.04
Ferdinand	16.89-11.20	12.26-6.00	8.16-4.32	12.40-4.89
Fives	26.93-17.85	19.54-9.56	13.00-6.89	19.77-7.79
Todd 100A	27.60-18.30	20.03-9.80	13.33-7.07	20.27-7.99
Todd 150-5	44.16-29.28	32.05-15.68	21.32-11.31	32.43-12.78
Upper South				
#2 Styroblock	$30.67-20.33	$22.26-18.15	$14.81-13.08	$16.89-6.65
#4 Styroblock	39.25-26.03	28.49-23.23	18.96-16.75	21.62-8.52
V-50 Multipot	35.90-23.80	26.06-21.25	17.34-15.32	19.77-7.79
V-93 Multipot	60.08-39.84	43.60-35.56	29.02-25.63	33.09-13.04
Ferdinand	22.52-14.93	16.34-13.33	10.87-9.61	12.40-4.89
Fives	35.90-23.80	26.06-21.25	17.34-15.32	19.77-7.79
Todd 100A	36.80-24.40	26.71-21.78	17.77-15.70	20.27-7.99
Todd 150-5	58.88-39.04	42.73-34.85	28.44-25.12	32.43-12.78

Consequently, changes in temporary wage rates will affect absolute production costs levels, but not the relative ranking of container versus bare-root technologies.

Production costs are essentially equivalent once a new nursery is constructed. Therefore, the key discriminator between container and bare-root seedling technology is relative capital cost. Past comparisons have been between bare-root seedling nurseries in their most efficient output range (15 to 30 million seedlings annually) and container nurseries one-tenth the size. Equitable comparison requires that both types of nursery have equivalent outputs.

A comparison of bare-root nursery capital costs per 1,000 seedlings (fig. 1) and the cost ranges for the four types of container nurseries (table 5) reveals that certain combinations of container and germination houses are quite competitive when headhouse capacity is fully utilized. The only two containers not competitive in either a timber truss greenhouse or pole shadehouse nursery are the V-93 Multipots and Todd 150-5 Planter Flats. The low capital cost of Ferdinand Rootrainers, by virtue of their high cell density, is sufficient to offset the production cost differential that favors bare-root seedlings. This makes the Ferdinand Rootrainer a fourth competitive container on a total cost basis.

The final comparison to be made concerns the initial capital investment required for a new nursery. In an era of high interest rates for private firms and of tightening public agency budgets, the level of initial construction costs could be a important consideration.

Construction expenditures for a 25 million seedling container nursery using Number 2 Styroblocks in the lower South are:

4 headhouses @ $55,697	$222,788
20 timber truss germination houses @ $13,271	265,420
20 pole shadehouses @ $14,096	281,920
22 acres of land @ $500	11,000
	$781,128

The total construction cost (including land costs) per 1,000 seedlings annual capacity is $31.25 -- half the $56 to $67 range (excluding land costs) of the three recently constructed bare-root nurseries. A public agency forced to purchase land for a new bare-root nursery could add another $10 to $15 per 1,000 seedlings annual capacity in cost.

If all the Number 2 Styroblocks needed to simultaneously fill all the germination and hardening houses are purchased as an initial construction expenditure ($617,760), their cost raises the construction expense to $55.95 per 1,000 seedlings annual capacity. Buying the blocks up front would lower production costs for the first 2 years to $18.84 per 1,000 seedlings -- 30 percent less ($208,000 annually) than at the bare-root level. After 2 years, when block replacement begins, the costs would rise from 30 percent less to 10 percent less than bare-root production.

CONCLUSIONS

Seedlings for reforestation can be produced as inexpensively in containers as in a new bare-root nursery. Four containers -- Number 2 Styroblocks, V-50 Multipots, Todd 100A Planter Flats, and Ferdinand Rootrainers -- all are cost competitive with bare-root seedlings grown in a new nursery.

The most cost-efficient procedures in the South is to grow seedlings in low-capital germination houses. High-capital germination houses do not boost output enough to pay for themselves.

Container seedling nurseries become cost-efficient at much lower output levels than do bare-root nurseries. The minimum container nursery capacity that captures the majority of economies-of-scale is a 3 to 4 million seedling annual output. Anything below this level results in under utilization of the headhouse investments. Full employment of headhouse machinery dictates the efficient production range of the nursery. Consequently, container seedling nurseries provide much greater flexibility in sizing the nursery to fit output needs and in locating the nursery to better serve planting areas.

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