AN INNOVATIVE STEP IN PLANTATION MANAGEMENT:
PLANTING CONTAINER-GROWN SEEDLINGS

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Abstract

The South's Third Forest report called for regenerating 30 million unproductive acres to pine by 1985. Present artificial regeneration methods and levels are inadequate to attain this goal. Planting container-grown seedlings is a cost-effective and biologically advantageous technique to increase the acreage artificially regenerated. Increased outputs of container-grown seedlings would benefit NIPF landowners.

The fundamental problem of plantation management is that we do not have enough plantations. The South's Third Forest report (Southern Forest Resource Analysis Committee 1969) called for regenerating 30 million unproductive acres to pine between 1969 and 1985 (1.76 million acres annually) in addition to regenerating the pine stands harvested. This month marks the end of the twelfth planting season since the Third Forest report was issued. Only four planting seasons remain in which to achieve the 1985 goal.

Artificial regeneration is required on a substantial portion of the 30 million acres, as well as on much of the pine land harvested. Planting bare-root seedlings and direct seeding were the only two operational artificial regeneration techniques available in 1969. Both have been used to establish plantations

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successfully. During the 1978-1979 planting season, 917 million pine seedlings were planted on an estimated 1.53 million acres of public and private forest land across the South (Southern Forest Institute 1979). Another 52,000 acres were direct seeded to pine. The harvested areas are included in the 1.58 million acres planted and seeded: it therefore follows that pine plantations were established on only a small portion of the 1.76 million acres of unproductive land to be regenerated. Present regeneration efforts must be doubled to meet the annual goal targeted in The South's Third Forest. Even then the 1985 goal will not be attained before the year 2000.

Two problems that prevent the establishment of sufficient pine plantations to meet the 1985 goal, assuming landowners are willing to regenerate their forests, are insufficient bare-root seedling production capacity, and inadequate control over direct-seeding stocking density.

Present bare-root seedling nurseries, especially state-owned facilities, are operating at capacity, some even exceeding levels which can be sustained. Louisiana state nurseries are approaching a two-years-in-production-to-one-year-fallow management plan because of heavy seedling demand, although the one-year-in-production-to-one-year-fallow plan is preferred. The 2:1 plan cannot be used very long without damaging the nursery soil. The Texas Forest Service Nursery at Alto, Texas, reduced production 70 percent in 1980 and will almost phase out production in 1981 because the soil is "worn out," according to Kramer (1980). Large demands for seedlings led to over-production for the past seven years.
The summer drought of 1980 killed many seedlings. Louisiana statewide survival average of 45.5 percent—the lowest on record—was attributed to the drought. Estimates of mortality ranged up to 98 percent in some areas. Further, many states reduced seedling production in 1980 to get back to more desirable soil management conditions. Increased demand for seedlings to replant areas sustaining drought losses led to a seedling scarcity and heavy pressure to produce extra seedlings in 1981 to "catch up."

An alternative to the problem of insufficient bare-root planting stock is to establish plantations by direct seeding. Despite the availability of effective seed coatings to reduce animal depredation without hindering germination and improved seed dispersal techniques, direct seeding is not widely used. A primary reason is that stocking density cannot be reliably controlled. Regeneration becomes either "feast" (establishing several thousand seedlings per acre) or "famine" (establishing one to two hundred seedlings per acre). Offered this choice, most reforestation managers have opted for the "feast" that was followed by the "indigestion" of having to remove excess seedlings in a costly pre-commercial thinning. If the variation in stocking density could be diminished, direct seeding rates could be calibrated to reduce precommercial thinnings costs to a tolerable level. Until this is possible, planting will remain the preferred regeneration method.

Planting seedlings grown in containers is an artificial regeneration alternative. Container-grown seedlings have been proved biologically feasible in research conducted over the past decade by the Southern Forest Experiment Station, North Carolina Division
of Forestry, and a handful of southern forest industries. The following advantages have been documented (Barnett 1974a and 1974b, Goodwin 1974 and 1980, and Guldin 1981): higher outplanting survival rates; superior initial height growth; a longer planting season; rapid nursery development and initial seedling production; and more efficient use of costly, genetically improved seed. Despite these advantages, container-grown seedlings are not widely used. The primary reason is that their production cost is presumed to be much higher than the cost of bare-root stock.

This paper reports the results of a study that compared the cost of growing seedlings in containers with the cost of growing them in a bare-root nursery (Guldin 1981). The lowest cost container operation is described, followed by a discussion of the advantages of container seedling nurseries for NIPF landowners.

Improper Cost Comparisons

Previous estimates of the cost of growing seedlings in containers were based on small-scale pilot tests with containers and production methods now recognized as inferior to the present procedures. These cost estimates were compared to prices of bare-root seedlings purchased from a state nursery. While the state nursery was the logical seedling source for reforesting NIPF lands, the comparison was irrelevant for two reasons.

Output levels of the two types of nurseries differed by several orders of magnitude. Comparing the cost per thousand of growing seedlings in a 300,000-seedling-per-year container nursery
with the cost per thousand of growing seedlings in a 30-million-
seedling-per-year bare-root nursery overlooked economies-of-scale.
Comparisons of seedling costs should be made for nurseries with
equivalent outputs.

Ownership of the two kinds of nurseries may differ also. A
container facility is frequently conceived as a privately-owned
"in-house" facility while many bare-root facilities are publicly
owned. Different classes of owners employ different accounting
methods to calculate the total cost of seedling production. For
example, funds to purchase and develop public nursery sites are
commonly provided in a single fiscal year's budget, treated as an
expense, and excluded from all future production cost calculations.
Similar outlays for privately owned nurseries are treated as depre-
ciable capital, and enter production cost calculations. Second,
salaries of nursery supervisors are typically paid from an over-
head account not directly chargeable to nursery labor accounts,
while private nurseries include such salaries. As a result of
governmental accounting practices, the public "subsidizes" seedling
production. For a proper cost comparison between the two types of
seedlings, a common set of accounting practices must be used for
both types of nurseries.

When differences in the scale of production and accounting
practices are resolved, bare-root and container-grown seedling
production costs may be equitably compared. The minimum efficient
scale of production can then be examined and the impact of differ-
ext nursery cost accounting methods investigated.
Study Methods

Three major variables affect the cost of growing seedlings in containers: the type of container, the type of nursery germination house, and the nursery locations.

Containers

Seedling production cost differences between types of containers are affected by the container price, and by the labor inputs required. No. 2 Styrobloc,

1 unlike the Spencer-Lemaire Roottrainers, require no assembly prior to filling with media. Kys-Tree-Starts come ready to sow with seed, requiring neither assembly nor labor and media to fill them.

The four containers studied provided a range in cell density from 82 to 150 cells per square foot, Table 1. With proper seed handling, double sowing, thinning and transplanting, 95 percent of the cells can produce plantable seedlings. Varying cell densities will provide different outputs from the same greenhouse, resulting in different average variable costs per thousand seedlings, although daily greenhouse operation costs are independent of the container used.

Container reusability also affects production costs. The Kys-Tree-Start container is outplanted with the seedling and not reusable. Spencer-Lemaire cells are considered usable for 2 rotations. Styrobloc is usable for 6 rotations. Even if Styrobloc were only used twice instead of 6 times, the cost of loblolly pine seedlings would be $4 less per thousand than if raised in Spencer-Lemaire Ferdinand Roottrainers, Table 1.

1 Mention of trade or corporation names is solely to identify equipment and does not imply endorsement of any product by the U.S. Dep. Agric. to the exclusion of others which may be suitable.
Table 1.—Variable cost of growing seedlings in containers of differing cell density

<table>
<thead>
<tr>
<th>Type of Seedling</th>
<th>Cell Density (per sq. ft.)</th>
<th>Average Variable Cost of Growing Seedlings</th>
<th>Loblolly</th>
<th>Longleaf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare-root</td>
<td>25</td>
<td></td>
<td>20.73</td>
<td>20.73</td>
</tr>
<tr>
<td>Spencer-Lemaire Roottrainer &quot;Fives&quot;</td>
<td>82</td>
<td></td>
<td>36.17</td>
<td>38.32</td>
</tr>
<tr>
<td>Number 2 Styroblock</td>
<td>96</td>
<td></td>
<td>20.25</td>
<td>22.40</td>
</tr>
<tr>
<td>Spencer-Lemaire Roottrainer &quot;Ferdinand&quot;</td>
<td>118</td>
<td></td>
<td>29.09</td>
<td>( )²</td>
</tr>
<tr>
<td>Kys-Tree-Start</td>
<td>150</td>
<td></td>
<td>35.83</td>
<td>( )²</td>
</tr>
</tbody>
</table>

¹Slash pine costs are the same as loblolly pine costs.

²The cell density per sq. ft. of these containers is too dense for consistently good longleaf pine results.
Facilities

Three types of buildings are needed for a container seedling nursery. A headhouse furnished office space, container and media storage, and space for the media mixing, container filling, and seed sowing machinery. After filling and seeding, containers are placed in a germination house for 6 to 8 weeks. The four types of germination houses studied were: glass greenhouses, fiberglass greenhouses with a double-layered polyethylene roof, timber truss greenhouses, and pole shadehouses. Next, the containers are moved to a shadehouse where the seedlings harden off for 4 to 8 weeks prior to outplanting. Pole shadehouses were provided for each of the three greenhouse options. The shadehouses were twice the size of the greenhouses to provide "surge" capacity between greenhouse production and the field planting crews.

An efficient nursery has both sufficient greenhouses to utilize fully the headhouse media mixing, container filling, and seed sowing capacity and sufficient shadehouses to utilize greenhouse space efficiently. One headhouse can service 5 greenhouses or 6 shadehouses during seed germination. Because each greenhouse requires a shadehouse for hardening off, the smallest efficient greenhouse nursery would have 11 buildings. The smallest efficient pole shadehouse nursery would have 7 buildings.

All the greenhouses have about 3,425 square feet in gross floor space, 67 percent of which is utilizable for seedling production. After seeding in the headhouse, containers are placed on CCA type C treated southern pine pallets and moved by forklift truck to the germination house. All germination houses have
irrigation systems with fertilizer and chemical injectors. The shadehouses are also equipped with irrigation systems.

Costs were obtained from catalogs of nursery equipment suppliers, price quotations from pallet, forklift truck and greenhouse manufacturers, and bids on recently constructed public facilities across the South, all adjusted to January 1, 1980 basis. Prices for dimension lumber and other locally available materials were obtained from retail lumber yards. Summing all the construction costs for 11-house or 7-house replicates yields the total fixed cost of container nursery production. Total fixed costs were converted to annual fixed costs using a 10 percent interest rate over the variable lives of individual facility components.

**Location**

For this cost analysis, the South was divided in 4 climatic zones, based upon the frost-free length of the growing season and the incidence of daytime temperatures exceeding 90 degrees F, Figure 1. Because seedlings in shadehouses must already be hardened off before the first frost, the final rotation is moved from the greenhouse to the shadehouse at least 6 weeks prior to the expected first fall frost. Planting rates decline when daily maximum air temperatures exceed 90 degrees F because of possible heat injury and moisture stress. Adequate shadehouse storage must be provided to hold seedlings ready for outplanting during this period so that greenhouse production is not constrained.

These two climatic variables dictate nursery production schedules, annual outputs, and average fixed costs of production.
Adding average fixed cost per thousand seedlings to the variable cost of production yields total production cost per thousand. Total production costs were calculated for loblolly and slash pine grown in No. 2 Styroblocks, Figures 2 to 5.

Discussion

The sawtoothed discontinuities of the cost curves arise from adding a new headhouse, greenhouse, and shadehouse to the most efficient 11-house nursery. Thus, efficient levels of output jump in steps. It may be less expensive to increase outputs between steps by squeezing an extra rotation or two out of an existing facility than by adding another headhouse that would be underutilized.

The unsubsidized cost of developing a new bare-root nursery was calculated following Wakeley (1954). Development costs were obtained from bids for recently constructed facilities across the South, adjusted to a January 1, 1980 basis. Total fixed costs were amortized using a 10 percent interest rate. A perpetual life was assumed for the land itself. Other nursery components had fixed economic lives. Variable costs of bare-root nursery production were obtained from the U.S. Forest Service's W. W. Ashe Nursery for the 1978-1979 production season, Table 1. They are assumed representative of southern facilities. The total cost per thousand of bare-root seedling production does not differ significantly from container seedling production costs in Zones 1, 2, or 3, Figures 2, 3, and 4.

The following information is based on Zone 3 costs, Figure 4. Container seedlings are less expensive than bare-root seedlings at
output levels less than 7.3 million seedlings per year. Twenty-nine percent of all southern bare-root nurseries produce less than 7.3 million seedlings annually. Another 17 percent produce 7.3 to 11.5 million seedlings annually. In this output range, container seedlings cost from two cents to forty-five cents per thousand more than bare-root seedlings.

Substantial economies-of-scale are captured with an annual output as low as 2 million seedlings. This output level is the minimum efficient nursery size. Facility expansions requiring an additional headhouse should provide at least 2 million additional seedlings annual capacity to capture most of the possible economies-of-scale arising from the new headhouse. At this output level, container seedlings are $3.50 per thousand cheaper than bare-root seedlings grown in the same size nursery. Two million seedlings will reforest 2,750 acres at 6 x 10 spacing. This is small scale for many forest products firms, but may meet the needs of landowner cooperatives or tree farm families.

In addition to low minimum efficient size, there are two other advantages that NIFF landowners can obtain by using container-grown seedlings: low capital investment and an extended planting season.

Many public agencies face a perennial shortage of capital construction funds. Container nursery construction costs are half those for an equivalent size bare-root nursery. In other words, you can buy twice as much container seedling production capacity as bare-root production capacity for the same price. The capital investments required are low enough that landowner cooperatives and small forest products firms can benefit from containerization.
Losing a year's growth is the major cost landowners bear if land remains unplanted after seedling supplies are exhausted. Because firms have alternative seedling sources, it is the NIPF landowners who stand to suffer most from prolonged and habitual seedling shortages. New container nurseries can be developed quickly and inexpensively, to augment existing bare-root nursery production and help alleviate seedling shortages.

A final advantage to NIPF landowners is an extended planting season. Container-grown seedlings can be planted throughout the year, more than doubling the length of the planting season. Planting contractors prefer planting large acreages during the bare-root season to minimize moves to new sites and to maximize their seasonal income. Contractors are reluctant to move from one landowner client to another planting small parcels when industries guarantee large planting contracts in one vicinity. However, when work is harder to find at the end of the bare-root planting season, and containers can still be planted, most contractors are glad to plant anywhere.

NIPF landowners who use container-grown seedlings may also get planting done at bargain prices at this time. Labor problems arise when contractors are forced to hire a large, unskilled, temporary workforce to meet bare-root deadlines. Extending the planting season allows planting to be done by a smaller, permanent crew of skilled workers, reducing labor problems and costs.

Seedling production costs are only a part of the cost of establishing plantations. I also compared the costs of transporting, preparing the site and planting container-grown versus bare-root
seedlings. Shipping palletized seedlings in their containers, using simple angle-iron pallet racks bolted to truck frames or lightweight trailers, is as inexpensive as shipping bundled bare-root seedlings. Firms and agencies planting container-grown seedlings operationally report that site preparation and planting cost no more than for bare-root seedlings, whether the work is done by contract or in-house. In some cases, site preparation and planting are less expensive.

Summary

In public forest nurseries, less nursery bed space is devoted to growing seedlings to meet the needs of NIPF landowners because public nurseries have been expanding slower than seedling demand and are doing more and more contract growing for large firms as genetically improved seed becomes available. Unless this situation is remedied quickly, the 1985 regeneration goal of The South's Third Forest will not be met. It is the NIPF lands, the majority ownership class, that will not be planted. Container seedling nurseries appear to be a cost-effective method of meeting seedling production needs of this class of owners and can help solve the fundamental problem of plantation management—there are not enough plantations.
Figure 2.—Loblolly and slash pine seedling costs in zone 1: Bare-root vs. Number 2 Styroblocks.
Figure 3.—Loblolly and slash pine seedling costs in zone 2: Bare-root vs. Number 2 Styroblocks.
Figure 4.—Loblolly and slash pine seedling costs in zone 3: Bare-root vs. Number 2 Styroblock.
Figure 5.—Loblolly and slash pine seedling costs in zone 4: Bare-root vs. Number 2 Styroblock.
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Barnett, J. P.

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