CONTAINER SIZE AND FERTILIZATION AFFECT NURSERY COST AND FIFTH-YEAR FIELD PERFORMANCE OF CHERRYBARK OAK

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Abstract—Successful regeneration of bottomland hardwoods relies on the production of vigorous, plantable, and affordable stock by commercial nurseries. To quantify nursery cultural influences on subsequent field performance of cherrybark oak (*Quercus pagoda* Raf.), seedlings were grown in a greenhouse in small, medium, or large containers for three months with or without fertilization. In December 1994, seedlings were planted at a bottomland site near Milledgeville, GA with or without removal of the container soil as a method to reduce transport and planting costs. Estimated costs per thousand seedlings for these practices were about $1225, $560, and $185 for large, medium, and small containers, respectively. A 30 percent profit margin was added to each price. The incremental cost of fertilization per thousand seedlings was about $12, $6, and $2 for large, medium, and small treatments, respectively. Cost savings from container soil removal were substantial for the large containers, and savings decreased with decreasing container size. Five years after planting, survival of seedlings from large containers (97 percent) was significantly greater than that from small containers (85 percent). Soil removal was associated with reductions in seedling survival, but only in the absence of fertilization. Stem diameter and height of seedlings from small containers were less than those of seedlings from medium and large containers, and they were also significantly greater in the presence versus absence of fertilization. Fifth-year seedling size did not vary significantly between levels of soil removal. Nursery and fifth-year cost efficiencies were greatest for fertilized, soil removed, medium containers and for fertilized, small containers.

INTRODUCTION

Large seedlings are recommended for successful artificial regeneration of oak (Ruehle and Kormanik 1986), but high cost and difficulty of planting them can greatly limit cost effectiveness and applicability of this method of regeneration. Poor performance of planted oaks probably reflects the need for improvements in both nursery and planting technology. It is one thing to grow an ideal oak seedling to a sapling size in one or two years, but then to correctly plant the proportional root mass can impose quite the endurance test (Bowersox 1993). Planting speed and quality under these conditions can be compromised, especially when specifications require holes in difficult soils greater than 15 centimeters depth. Large seedlings with proportionately sized root systems cannot be correctly and efficiently planted unless they are undercut at lifting, root-pruned at the time of planting, or the planting hole is of sufficient size to accommodate the extensive root system. Unless root alteration is performed, planting seedlings with roots larger than the hole will result in either root deformation (Haase *et al.* 1993) or root desiccation because of shallow planting.

The field applicable alternative may best be found in root confinement, rather than in root alteration -, i.e., growing seedlings with root systems designed to fit the planting tool, instead of reducing the size of the root system to accommodate the planting tool. The former attempts to prevent rooting excess, while the latter attempts to correct the problem. Containerized seedlings have shown success in survival and growth, and a further incentive of root confinement should be to facilitate the planting of large stems. Another incentive for containerizing seedlings is to permit managers to plant late into the season, and to maintain more of a three-dimensional root configuration after planting.

It is not clear how containerized seedlings will fare when planted as bareroot stock, or how such procedures will affect cost of planting or nursery production. In an attempt to address these issues, a study on cherrybark oak was initiated to compare field performance, associated costs of nursery production and planting, and cost efficiency of among treatments that included differences in container size, nursery fertilization, and removal of container soil at the time of planting.

MATERIALS AND METHODS

In a greenhouse on the University of Georgia campus, Athens GA, seeds of cherrybark oak were sown July 1994 in small, medium, or large containers (3.5, 6.5, and 11.5 centimeter diameters, respectively) and grown for 3 months. A randomly selected half of the seedlings received a weekly fertilization treatment with a water solution of 20N 20P 20K. A total of 100 seedlings were

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cultured for each of the six treatments (three container sizes x two fertilization levels). In October 1994, seedlings were moved to an open-air enclosure to stimulate the onset of dormancy. The planting site, a 0.1-hectare area fenced to prevent deer browse, is located on an abandoned field in the lower flood plain of the Oconee River near Milledgeville Georgia. Competing vegetation was suppressed with a broadcast application of a 2 percent water solution of Accord® (glyphosate) herbicide in July 1994. Prior to planting, seedlings were randomly assigned to either removal or retention of container soil as a test to reduce transport and planting costs. In December 1994, seedlings were planted with a hoedad at a spacing of 0.5 x 1.8 meters. The experimental design is completely randomized with three replications of 13 seedlings for each of the twelve treatments, a total of 468 seedlings. Survival, basal stem diameter, and height of each seedling were measured one, two, three, and five years after planting. A per-hectare value of total stem volume (cubic decimeters) was calculated for each treatment replication assuming a planting density of 750 seedlings per hectare.

The retail price required to produce a thousand seedlings was estimated for each treatment using real cost information from an undisclosed nursery. The price equaled the seedling cost at planting plus the cost of planting. We assumed a nursery that contained 7500 square meters of production space (15 greenhouses). Container diameter determined capacity of container production. Fixed costs, including salaries, insurance, dues, research and development, land, buildings, and supplies, were assumed to be influenced by greenhouse capacity. Treatment-related costs included fertilizer and application costs, labor and materials for packaging, transport and storage of seedlings as affected by container size, and labor and materials associated with container soil removal. The price per thousand seedlings included 30 percent profit. Field costs, such as the purchase price of land and costs of site preparation, were not included in this analysis. Costs were compounded for five years assuming an eight percent interest rate. The ratio of nursery cost (dollars per hectare of planted seedlings) to stem volume yield (cubic decimeters per hectare) was calculated to provide an index of cost efficiency.

RESULTS AND DISCUSSION

In the nursery, we achieved almost 100 percent stocking of growing space. Five years after planting, survival of seedlings from large containers (97 percent) was significantly greater than that from small containers (85 percent). Unfertilized, soil intact seedlings were also significantly lower in numbers (83 percent) as compared to the other treatment combinations, which is to be expected from nutrient deficient seedlings, but these results seem counterintuitive since the soil was left intact. From the nursery, fertilized seedlings from large and medium containers were significantly greater in diameter (4 millimeters), height (32 centimeters), and yield (2.2 cubic decimeters per 1000). Seedlings from the large and medium container sizes remained significantly larger than those from small containers by year one, and as expected, fertilized seedlings remained significantly larger than those not fertilized. By year five, fertilized seedlings from large and medium containers remained significantly greater in diameter (43 millimeters), height (338 centimeters), and yield (1.84 cubic meters per hectare). Initial stem diameters (< 5 millimeters) and heights (< 50 centimeters) were smaller than those currently recommended for artificial regeneration (Ruehle and Kormanik 1986).

Full stocking of growing space in the nursery seedbed or in the field is critical if costs are to be minimized. Increasing seedbed density or maintaining survival favors the cost side of the equation. All fixed costs (wages, salaries, investments, etc.) were to be recovered in the pricing of the product. The fixed costs to grow 600,000 stems in large size containers carried a relative charge per thousand seedlings of $1003, $451 to grow 1,333,000 stems in medium size containers, and $142 to grow 4,267,000 stems in small size containers. Since there was near 100 percent stocking in the nursery, the quantity sown was the quantity harvested. If stocking had been less, nursery fixed costs would have increased to cover this shortfall.

Variable costs, also affected by the quantity supplied, were most influenced by fertilization and soil removal. Fertilization had little impact with values of $12, $6, and $2 per 1000 seedlings for large, medium, and small treatments, respectively, representing the combined supply and application costs of fertilization. Regardless of the capacity, the cost of fertilization is a small price to pay for the yield increase resulting from it. Soil removal, on the other hand, displayed the greatest cost impact on materials saved. Soil and amendment costs were calculated by determining the cost required to replace either 100 percent of the material (soil intact), or 10 percent of the material (soil removed) every year for each container size treatment. At $1 for every 50 pounds of material, the relative costs figured to be $28, $30, and $24 per 1000 seedlings for large, medium, and small soil intact treatments, respectively, but only 10 percent of these costs were charged when soil was removed. The assumption is that sterilized soil and amendments will be reused from year to year in the soil-removed situation, and only 10 percent of which needs to be replaced.

Seed sowing costs were affected by the time required to sow seed into containers. Relative times in seconds to prepare and fill 20 containers with soil and to sow seed were about 320, 200, and 120 seconds for large, medium, and small containers, respectively, which translates into a sowing cost of $45, $27, and $18 per thousand, respectively. The rate of pay to the laborer was determined to be $10 per hour, and this wage remained the same with all operations involving the use of time.

Nursery transport costs were calculated according to the amount of time required to move a load 100 feet in three minutes, and transporting in the nursery was performed in two trips (from the head house to the greenhouse position after sowing, and from the greenhouse to the packing house at harvest time). The cost per 1000 seedlings to move large containers was calculated to be about $56 with nine containers per trip, about $25 with 20 medium containers per trip, and about $10 with 50 small containers per trip.

Packing materials were affected by the relative size of seedlings and whether or not soil was left intact. The amount of seedlings to equal 30 pounds was the criteria utilized, and thus the heavier the seedling, the larger the quantity of bags required. The cost of bags ($1) includes the costs involved in the packaging operation. All soil removal treatments, regardless of container size, carried a similar bag charge (about $2 per 1000 seedlings), with an average of 500 seedlings per bag. However, packing costs with heavier, soil intact seedlings were about $80 per 1000 seedlings for the large, $39 for the medium, and $10 for the small container sizes.

The total nursery costs (fixed and variable) were figured to be about $1225, $560, and $185 per 1000 seedlings for large, medium, and small containers, respectively. With the additional 30 percent profit margin included for pricing each treatment, the values increased to about $1590, $730, and $240 per 1000 seedlings for large, medium, and small containers, respectively. Prices became the relative costs of the seedlings purchased for planting. Thus, to express seedling price per hectare, reduce the nursery seedling price by 25 percent (assuming 750 stems per hectare).

The planting operation involved the cost of carrying seedlings to their respective positions to be planted (determined by the weight of the load) and the time (seconds per seedling) it required to plant them. Each of these integrated tasks (involving weight and time) in the planting operation was equally allocated. The wage paid to the worker in the field was $15 per hour, as opposed to the $10 per hour nursery wage. Each soil removal treatment, regardless of container size, carried similar costs for planting, with a fifth year of compounded cost of $25 per hectare. Treatments with soil left intact, however, constrained the planting operation to differ greatly with container size, with fifth year costs of about $139, $85, and $34 per hectare for large, medium, and small container sizes, respectively. Removing soil from the seedlings of small container does not offer the same reduction in planting costs as it does from those seedlings of medium and large containers.

There were other plantation costs that could be assessed, e.g., site preparation and land costs, but these types of costs were not factors in our study because they had no influence on our treatments. Therefore, total fifth-year plantation costs, involving only the cost of seedlings and planting them, were about $1335, $630, and $220 per hectare for large, medium, and small container sizes, respectively.

The nursery treatments having the greatest cost efficiency were those of medium, fertilized, soil removed ($277 per cubic decimeter), and small, fertilized ($247 per cubic decimeter). Fifth-year results indicated similarly the lowest values of cost efficiency for fertilized, soil removed, medium containers ($285 per cubic meter), as for fertilized, small containers ($272 per cubic meter). It is interesting to note that the large, fertilized, soil removed treatment by year five was great enough in yield (2.47 cubic meters per hectare) to overcome a relatively large seedling and planting cost ($1261 per hectare), and displayed a cost efficiency ($510 per cubic meter) almost equal to that of the unfertilized, small containers ($468 per cubic meter). This illustrates how excellent seedling performance from expensive seedlings can, after five years, "catch up" with inexpensive seedlings that have lagged in growth.

CONCLUSION

Successful artificial oak regeneration involves many factors that carry both cost and yield implications. Representation, both in the nursery and in the field, is a critical factor which deals with the quantity supplied to the market, dictating the price to be attached to the product (Tomek and Robinson 1990). The productivity of an operation, which we have attempted to demonstrate here, can be increased by: 1) increasing seedling density in the allocated space; 2) improve percent emergence after sowing; and 3) maintain high survival percentages after germination or after planting in the field. However, It has been shown in this study, as in others (South 1993), that stem diameter is typically reduced when seedlings are grown at high densities, and this has an impact on long-term plantation success.

The quality of the product, other than the genetic properties, was expressed in terms of seedling size or stem yield (i.e., proportional allocations of mean diameter and height were described in the stem volume equation), but quality cannot be completely evaluated without attempting to evaluate the entire process of production. Stem yield is much easier to describe and evaluate statistically, than is the estimation of the costs associated with production, which may explain why cost accounting is often avoided. This is acceptable when the study is strictly biological. In this study of applied science, however, hypothetical cost estimation involved many cost assumptions (e.g., costs of labor, nursery space, supplies, etc.). Assumptions can be most credible when derived from empirical operations, and our estimates for each treatment utilized real cost information from an undisclosed nursery. It was where no operation or empirical data exists that values must be derived from factors of time, volume or weight. Valuation must be revised, therefore, from time to time, place to place, and according to current knowledge.

While the small and medium, fertilized treatments were optimum in cost efficiency, the large, fertilized, soil removed treatment showed great promise in overcoming the excessive costs. The cherrybark oak benchmarks established here have shown fifth-year yield results that could arguably be considered morphologically eight years old according to plantation standards (Kennedy 1993), or ten years old when grown under natural conditions. Moreover, this benchmark offers a challenge to future research to produce the same or better yield, and also to eliminate any extreme costs attached to production (Howell 2002). We have yet to accurately and completely test the limits of nursery and plantation cost efficiency.

When one wishes to compare studies from place to place or from time to time, other costs pertinent to production must be evaluated. Protecting the seedlings in our study was cost prohibitive in practice (several thousand dollars per hectare depending on the materials used), and the inclusion of costs like this can dilute the gains perceived. Nevertheless, one could argue that expensive, and perhaps non-applicable, methods must be eliminated to promote large-scale regeneration of cherrybark oak.

As natural oak stands are depleted and the demand for oak products rise, there will be an increased emphasis toward higher productivity on a given land base. If land owners or managers are to invest in the oak stand, confidence must be established that vigorous stems will be efficiently purchased and planted, that costly procedures will not be required to ensure survival, and that steady growth will secure high future stem yield and plantation success.

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