CHERRYBARK OAKS FROM PERFORATED CONTAINERS PLANTED AS BAREROOTS WITH OPEN-GROWN OAK BAREROOTS

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Abstract-Large Cherrybark oak (Q. pagoda Raf.) grown for two years (1997 and 1998) were hoedad planted in bottomlands near Columbia, South Carolina. Successful oak plantations exist from planted bareroot cherrybark oak seedlings with heights below 50 centimeters, but costly efforts were often employed to ensure success. To overcome competing vegetation, seedlings greater than 1 meter are essential, but the roots of large oak seedlings present obstacles to planting. The one-liter, perforated container was designed to promote fine, feeder roots to penetrate outside of the container, and to restrict woody root formation at the soil-container interface. After two nursery growing seasons, there were no significant differences in survival, but yield favored conventional bareroot seedlings of 100 per square meter. Field survival of containerized seedlings after two years were significantly greater than bareroot seedlings, compensating for the higher cost of containerized seedlings. Seedlings from containerized stock of 100 per square meter also showed the greatest significant yield by year two.

INTRODUCTION

With increased demand for high quality oak products and potential legislation to restrict clearing of natural forests (Kellison 1993), it may not be enough to simply mimic nature = s processes in artificial oak regeneration, but to improve on them. Producing higher yield on less land with fewer starting costs is a prudent goal for the land manager, regardless of whether the land is publicly or privately owned.

Much research has been conducted to show the importance of oak seedlings having a bulky root system, and hence several first-order lateral roots (FOLR) (Ruehle and Kormanik 1986), which give rise to second-order laterals roots, and to fine, fibrous roots. For greatest stem size potential, it is preferable to have greater than 8 FOLR along the distal tap (Kormanik et al. 1994), with FOLR diameters above Imm (Thompson and Schultz 1994). Otherwise, seedlings are labeled by some researchers as Agenetic trash@. Unfortunately, after the planting process, root pruning (i.e., tailoring the seedling's root system to fit the planting hole) compromises many of these gains realized in the nursery.

Oak plantation success (i.e., an efficient operation) hinges on 1) high yield and 2) low initial costs. Poor cost efficiency involves one or both factors being deficient. In a study established in 1994 (Howell and Harrington 2002), undersized cherrybark oak (Q. pagoda Raf.) seedlings, grown three months in a greenhouse, survived and grew quite well, but not without the aid of high-priced fencing to protect them from browse. Moving away from protective shelters, a preferable option might be found with larger seedlings planted in open-field conditions.

The optimum size that would ensure plantation success at the lowest possible cost is debatable. Ground-line diameter may be the single most useful morphological measure of seedling quality (Johnson and Cline 1991) — ensuring field survival and promoting rapid growth (Mexal and South 1991); moreover, diameter is a good indicator of root mass (Coutts 1987). A competitive oak seedling should have a ground-line diameter above 10 millimeters (Pope 1993). Moreover, stem height above 1.5 meters is considered adequate to overcome competing vegetation and deer browse (Hannah 1987).

The perforated container (U.S. #6,173.531), patented in January 2001, is designed to restrict and train root growth. The patented hole perforations are to be substantially 1.5 millimeters, the midpoint between woody and feeder-root range, > 2 and < 1 millimeters, respectively (Lyford 1980). Upon inserting these containers into the ground, fine and fibrous root growth is encouraged, and the taproot should extend to the bottom of the container, where it follows the water pathway out of the container into the surrounding seedbed. With these large containers, the soil can be removed at the nursery for economic reasons, and thus bareroot seedling transport and planting are facilitated, hence the term Acontainerized-bareroot@. Therefore, the objectives of plantability and ease of transport should be satisfied, but what is more important is that this method may offer a more positive yield forecast.

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MATERIALS AND METHODS

Cherrybark oak seeds were sown (February 1997) as conventional bareroot or inside perforated containers in a partially shaded nursery in Auburn, GA. Two densities of 64 and 100 seeds per square meter were also tested. A third factor of perforation size (1 versus 1.5 millimeter holes) was tested for containers, and for conventional bareroot, the factor of trimming versus nontrimming was tested at planting. Thus, a randomized block design was employed with eight treatments across three blocks in the nursery, and 20 seeds sown per treatment per block. A completely randomized design was installed where nine stems were selected from each treatment, and replications were planted in designated positions in the field.

Due to the shaded conditions, portable greenhouses and lighting were used to provide a 2-month head start on the 1997 season. Seedlings emerged by early March, and by April 1, 1997, all growth devices were removed. Another aid to promote high-density growth was with lateral branch pruning. This operation was performed for six months (late April-late September) for two years. Seedlings were fertilized with (20N-20P-20K) daily during the active growing season. Seedlings were not undercut, and after lifting, were immediately transported to the planting site. At planting, trimming was performed on designated bareroot seedlings and all seedlings were planted at a 3.66 by 3.66-meter spacing.

Diameter, height, and survival are yield factors expressed in the equation: $Y_t = Avg(B*r_t^2*h_t)/2*S_t$; where at year t: Y_t = yield (cubic decimeters), r_t = radius (decimeters), h_t = height (decimeters), and S_t = percent survival. Nursery yield, two years from sowing (November 1998), was expressed in terms of stems per 1000. Plantation yield, two years from planting (December 2000), was expressed in terms of 750 stems per hectare.

Our research was not empirical, so cost information was adopted from a firm of undisclosed identity. The nursery involved 20 hectare with a workable area of 7,500 square meters per hectare (25 percent non-workable roads and buffer areas). With about 67 percent germination in our study, there was an effective production of 6.4 and 10 million stems from densities of 64 and 100 stems per square meter, respectively. All costs were influenced by capacity, and were thus included in pricing, whether fixed or variable. Salaries, land, dues, insurance, etc. are some items to be included which did not vary with treatment. Other costs included were the purchase and handling of containers, portable greenhouses, and labor required to package, store, and transport seedlings. When pricing, 30 percent profit was added. Thus, the price from the nursery became the seedling cost for each treatment in the field. Seedling price and planting costs were also variable in this study. Land and site preparation costs were not included in this paper. Costs were compounded with time (t) as follows: $C_t = EC * (1+i)^t$; where: C_t = total cost ($); EC = the sum of all costs ($); i = interest (8 percent).

Yield to cost ratios (E_c) provide cost efficiency indices. The equation is given as: $E_c = C_t/Y_t$; where: E_c = cost efficiency ($ per cubic decimeters), C_t = total cost ($ per 1000 or $ per hectare), and Y_t = yield in terms of yield (cubic decimeters per 1000 or per hectare).

RESULTS AND DISCUSSION

In the nursery, we realized near 65 percent representation (emergence and survival), due to poor germination, and there with no significant differences ("0.05) among treatments. Thus, effective density was less than that which was sown. After two years in the field (table 1), containerized bareroot had significant survival (about 78 percent) over conventional bareroot (about 49 percent). Nursery diameter, height, and yield favored conventional bareroot of density 100, and year-2 field diameter, height, and yield favored containerized-bareroot of density 100. As to why density 100 seedlings were larger than those of density 64 may be partly explained by the effective lower density after germination. However, since both treatment densities were reduced equally, the lowest density (64 seedlings per square meter) should have remained low and should have still supported the larger stems. Lateral branch pruning, which encourages mutual training, may have also had some impact on these results. Root alteration (Alt) showed no significant impact on yield or cost with containerized bareroot. However, the conventional bareroot, trimmed, 64 treatment was significantly greater than the rest in yield by year two.

Fixed costs (FC) ranged from 50 to 55 percent of the total costs of producing conventional bareroots. However, with containerization fixed costs ranged from 39 to 45 percent of the total, because about $30 per 1000 was needed to purchase containers (C), and an additional $55 per 1000 to embed and hand-sow the containers (SC). Mechanization of sowing conventional bareroot with two workers ($20 per hour) and a tractor drove sowing costs (SC) down to about 48 cents per 1000, plus or minus 5 percent for differences in density. Laborers involved in hand sowing, and other fieldwork, earn $10 per hour. If embedding containers could be mechanized, the higher wage and initial investments in machinery would over the long run lower the cost of the container-sowing operation. On the other hand, a $7,000 savings from not using the tractor when hand-sowing containers resulted in a minimal adjustment of $1 to $2 per 1000 (shown with FC). Some could argue that this justifies hand sowing using cheap labor.

Lateral branch pruning (table 2) was a cost factor unaffected by density ($62 per 1000), but the greatest cost benefit was realized by the fostering of increased basal diameter growth at the higher density. Lateral branch pruning (BP) also affected transport and packaging (TPK). Weight of a load to equal 13,620 grams (30 pounds) was utilized to determine the cost of transport and packaging. Since soil was removed from the containers at the nursery, and transport and packaging dealt with bareroot only, then the costs involved in transport was virtually the same for each treatment ($3.8 to $4.5 per 1000).

Table l-Percent survival (Srv), diameter (Dia: mm), height (Hgt: cm), yield (Yld: cubic decimeters per 1000 for the nursery or per hectare in the field), and cost efficiency (Eff: dollars per cubic decimeter) at year-2 nursery (N), year-2 field (2), transport and planting costs (TP(0): dollars per hectare), and year-2 field cost (Cst(2): dollars per hectare) for each treatment of root form (containerized bareroot (container) and conventional bareroot (bareroot)), density (64 or 100 stems per square meter), and root alteration (Alt: 1.5 versus 1.0 millimeter holes in containers, or trimmed (Trim) versus not trimmed (Xtrm) applied to bareroots in the field). Reported significance (S) at ? = 0.05 level. Notation: no difference (N); Forms differ (F); Densities differ (D); and the form-density interaction (FD).

Form:	Container				Bareroot				
Dens:	64		100		64		100		
Alt:	1.0	1.5	1.0	1.5	Trim	Xtrm	Trim	Xtrm	-S-
Srv(N):	63	77	72	58	63	63	65	65	N
Srv(2):	73	92	73	73	51	40	48	55	F
Dia(N):	8.9	9.9	9.1	8.6	8.8	8.8	10.2	10.2	FD
Dia(2):	14.7	13.9	16.8	18.1	14.3	12.9	13.2	11.3	FD
Hgt(N):	101	116	112	112	105	105	124	124	FD
Hgt(2):	131	140	180	171	148	124	125	124	FD
Yld(N):	39	48	37	41	39	39	57	57	FD
Yld(2):	81	94	127	149	81	34	43	30	FD
Eff(N):	11.5	9.4	9.5	8.6	9.4	9.4	4.6	4.6	FD
Eff(2):	7.4	6.1	4.0	3.3	6.2	15.8	8.8	13.5	FD
TP(N):	115	89	122	108	98	139	89	123	
Cst(2):	599	576	506	493	502	538	377	406	

The variable costs were responsible for adding an approximate $100 to containerized treatment over the conventional bareroot treatment. All costs (variable and fixed) were affected by density, since recompense involves seedling quantities rather than seedling qualities. If products were priced according to aspects of quality, pricing would be in terms of dollars per weight or volume. The cost of nursery land ($6.4 and $4.2 per 1000 for densities of 64 and 100, respectively) was spread over 30 years, and was an insignificant charge as compared to the total cost of operations.

Table 2— An itemized cost list (dollars per 1000) involving fixed costs (FC) in the nursery (wages and salaries, operations, utilities, and anything which is not specified separately). Other variables include costs of: land (LC), sowing (SC), lifting (Lft), loading and packaging (TPK), containers (C), fertilization and supplies (F), small portable greenhouses and lighting (GL) and branch pruning (BP). Year-2 total cost is also listed (Cst).

Form:	Container		Bareroot		Form:	Container		Bareroot	
Dens:	64	100	64	100	Dens:	64	100	64	100
FC:	202	129	204	130	LC	6.4	4.2	6.4	4.2
SC:	53	58	.46	.50	Lft:	12.3	11.5	7.6	9.3
TPK:	3.8	4.5	4.2	3.8	C:	30	30	0	0
GL:	78	50	78	50	F:	3	2	3	2
Cst:	450	351	366	262	BP:	62	62	62	62

In the field (table 2), nursery cost with 30 percent profit made up the price of seedlings. Some states may require tax, but our state did not. Transport and planting (TP) involved an average charge of $150 per 1000 for large seedlings, as compared to a charge of $35 per 1000 for planting small, bareroot seedlings in the 1995 study (Howell and Harrington 2002). It is intuitive that larger seedlings will demand higher seedling prices and will require greater costs to plant them. Nevertheless, one worker planting 100 saplings per hour is well within the realm of a large-scale planting production rate. The cost of trimming bareroot seedlings was offset by the cost of carrying and planting untrimmed seedlings.

Cost efficient nursery benchmarks (table 1) were set by the conventional bareroot of density 100, because it possessed the lowest costs and also had the highest yield. The $4.6 per cubic decimeter of this study was about 47 times as low as the best treatment of the 1995 study ($215 per cubic decimeters). After two years in the field, the containerized bareroot of density 100 was optimum, where high yield overcame the relatively higher costs of production, and it was the low field survival that hurt the conventional bareroot. The $3.8 per cubic decimeter value of this study was about three times below that of the best treatment ($12.4 per cubic decimeters) of the 1995 study. There were some protection mechanisms utilized in the 1995 study, which were not needed in this study. The only other costs that could be realistically added to this study are the cost of land and site preparation. These marginal costs are minimal compared to the other costs, and would not greatly dilute the cost efficiency results of this study.

CONCLUSION

Containerization effectively restricts the root system to parameters conducive to high-volume planting, while preserving the fibrous root important for nutrient uptake in the field. The perforated container, used in this study, brought into one operation the benefits of both containerized and bareroot seedling culture, where perforated holes permitted only fine roots, those less than 2 millimeters in diameter (Hendrick and Pregitzer 1993), to penetrate the container interface into an extended rooting environment. While the general rule holds true for all forest species, this fine-woody root transition range between 1 and 2 millimeters (Lyford 1980) is subject to vary somewhat among species.

Neither cost inputs nor the yield output should be under emphasized in nursery or plantation levels. The long-term payoff (i.e., the return on the invested dollar) will depend upon: 1) stand yield, highlighting representation (emergence and survival); 2) individual stem yield, promoting high volume growth; and 3) the cost to produce, establish, and sustain the crop. Benchmarks in cost, yield, and their combined efficiency should be set, and will thus encourage the comparisons of operations over space (from region to region) and time (from generation to generation).

The cost benchmark at the nursery level was set in this study by the conventional bareroot treatment, of density 100, but the small, unfertilized treatment from the 1995 study held the best mark between the two studies (Howell and Harrington 2002). When looking at variable costs only, the same treatment from the 1995 study would logically remain lowest in seedling cost, and the cost of transport and planting. However, the cost of spending several thousand dollars per hectare to fence and protect undersized seedlings actually negates any perceived advantage in an applicable sense. The field cost efficiency benchmarks of this study were manifested; even though higher priced saplings were utilized, which involved greater storage, transport and establishment costs. However, the bonus is that they were planted in a clearcut area with a high-volume planting tool, and without the aid of expensive shelters or fences for protection.

While nursery yield was best for the conventional bareroot, density 100 treatment, after two years in the field, the containerized, density 100 treatment set a second-year benchmark in this study. Second-year nursery yield in our study was 20 times that of the best treatment from the 1995 study, because our seedlings had a morphological age perhaps closer to what would be classified as fifth-year growth under natural conditions. Five-year morphological sizes are required for saplings to have a fighting chance to survive in indigenous sites where pioneer conifers and hardwoods possess faster growth rates (Clatterbuck 1987), especially for upland oaks on upland sites (McGee 1975; Loftis 1983). The oak paradox seems to be epitomized more with northern red oak than it is with cherrybark oak.

The container, 100 treatment showed the best cost efficiency in our study, and now offers a milestone with which to engage future findings. Undoubtedly, the cost efficiency benchmark set in this study will soon be superceded by innovative measures, which reduce costs or increase performance. Some of these measures may be found in: 1) growing larger seedlings at higher densities; 2) increasing seedling representation through improvements in germination and survival methods; and 3) facilitating branch pruning and/or root initiation by way of chemical or hormonal application. Once oak plantation success can be guaranteed on clearcuts of high site quality, morphologically superior oaks may be interplanted with low-cost, 1-O pines for training purposes. As of now, however, pines are viewed as major oak competitors.

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