Root injury was observed more than 15 cm (6 in) beyond the zone in which the pH was altered. Damage to woody roots can be much more serious than loss of fine roots. Cambium injury that girdles a small section of root will result in death of the entire root beyond the point of injury, potentially causing extreme tree stress if a substantial portion of the root system is lost.

The requirements for separation of treatment holes in this experiment precluded the use of numerous, closely spaced (2 or more concentric rings of holes 60 cm {24 in} or less apart) treatment holes around each tree, as is commonly used in the landscape (Messenger, personal communication), and thus no changes of any kind were observed in the crown. It is not possible to predict how seriously an individual tree may be stressed by the loss of a portion of the root system as a result of the acid treatment, but it is conceivable that substantial root damage followed by a period of water stress could result in visible injury to the crown. Comparison with transplanted trees would indicate that trees with immature foliage would be the most vulnerable. In the landscape, crown damage seems to most often follow spring acid treatments.

Although the extent of root injury may vary with different soil types, the practice of reducing soil pH with sulfuric acid or other strong chemicals near existing trees must be approached with caution. This study shows that the pH reduction is confined to a small area and may be short-lived, while root injury can occur well beyond the zone of pH reduction and long-term damage may occur. Repeated acid treatments may be necessary to maintain low soil pH, compounding the root injury and chances for crown damage.

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Economic Feasibility of a Shade Tree Container Production System[1]

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Abstract

An economic model was developed to estimate the feasibility of producing red oak (*Quercus rubra*) whips in an established container nursery. Cost per plant was compared for a simulated container nursery of 6.88 and 13.76 ha (17 and 34 acres) at different levels of production. Variable cost per plant ranged from $3.48 when producing 100 plants to $3.16 when producing 4,160 or more. Fixed cost per plant was $.42 to $.55 higher in the small nursery, depending upon level of production. Total cost per plant varied from $3.86 to $4.59, depending upon nursery size and level of production. Sensitivity analysis indicated that total cost per plant is less responsive to changes in wage rate than changes in interest rates on operating capital. Reducing losses during the rapid-growth and overwintering phases of production is necessary in order to minimize total cost per plant.

Index words: Economics, container nurser, *Quercus rubra*

Significance to the Nursery Industry

This study has examined the expected costs of producing red oak whips in $CuCO_3$ treated containers. Depending upon the level of production, total cost per plant ranged between $4.28 and $4.59 for the 6.88 ha (17 acre) container nursery and $3.86 to $4.18 for the 13.76 ha (34 acre) nursery. Compared to the current alternatives, a five foot bare-root whip costing approximately $7.05 in 1990 or a five foot branched whip costing $10.40, there is an economic incentive for existing container nurseries to examine this new production system and begin supplying container-produced whips to field nurseries. Additionally, because the plants produced in the new system possess a vigorous root system and have been shown to reach saleable size quicker and with fewer losses (Chinery and Struve, unpublished data,

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7, 8), suppliers of the new whips would be justified charging a higher price than the traditional bare-root whip because the new product has been found to be a superior plant for shade tree production and/or landscape use.

Introduction

A new container growing system involving root system alteration through the use of cupric carbonate has increased transplant success of deciduous tree species such as red oak (*Quercus rubra*). Treating the container's inner surface with 100 g/l $CuCO_3$ produced trees with root systems which appeared more evenly distributed within the container and finely branched than trees grown in untreated containers. Trees in treated containers had overall greater shoot length, total root dry weights, and larger shoot-to-shoot ratios than untreated controls (1). After field planting, signs of visual stress (marginal leaf necrosis) and dieback were delayed or lessened in trees from treated containers. Treated trees also produced more shoot growth the season following transplanting (1). The advantage of high root regeneration potential of plants grown in $CuCO_3$ treated containers combined with an extended growing season led to the development of a new production system (3).

The purpose of this study is to examine the economic feasibility of incorporating the new production system, entitled the Ohio Production System (OPS) into an established container nursery operation. After determining the estimated fixed and variable costs associated with the system and the impact on production cost due to changing key production parameters: including nursery size, production level, labor cost and efficiency, and interest rate, conclusions regarding the profitability of OPS are presented. This information will assist nursery owners as they evaluate the feasibility of producing whips using the new system.

Materials and Methods

Building upon previous nursery cost studies (5, 6), an economic model was developed using the Lotus® 123® spreadsheet program to estimate the production cost for a shade tree whip using the OPS. Data from previous studies was updated to reflect the impact of inflation. Other data used in the model were collected from grower interviews and supplier catalogs. Descriptions of the facilities, equipment, assumptions concerning the site, expansion potential, scale of the nursery, and cost coefficients were based on the work of the S-103 committee (5). To accommodate the OPS, additional propagation facilities (greenhouse, mist bench, etc.) were included in the model nursery.

Variable costs were determined separately for each of the five production phases: Germination (February 1 to March 15), Establishment (March 15 to May 15), Acclimation (May 15 to June 1), Rapid-Growth (June 1 to October 15), and Overwintering (October 15 to March 15). Variable costs include: containers, soil, liners, chemicals, labor, and equipment expenses. Fixed costs for the entire nursery (including the OPS facilities) included: land, land improvements, buildings, equipment, irrigation equipment, and general overhead. Total fixed costs were then allocated to the OPS crop based on the amount of time and space required to produce the crop. It was assumed that fixed costs not allocated to the OPS crop would be allocated to other crops in the nursery. Details concerning the OPS, such as crop scheduling, and production activities within each phase are described in Struve and Rhodus (4).

Once the model was created, cost of production was estimated for two different nursery sizes, 6.88 and 13.76 ha (17 and 34 acres) and several production levels. Production level (desired number of saleable whips per crop) ranged from 100 to 95,850 for the small nursery and from 100 to 191,700 plants for the large nursery. It was assumed that both nursery sizes used 48% of their total area for growing crops. Sensitivity analysis was conducted to identify the relative impact on total cost per unit of changing the following production parameters: wage rate, labor efficiency, loss rates, and interest rates.

Results and Discussion

Fixed, variable, and total cost per plant were affected by level of whip production. Variable cost per plant was $3.48 when producing 100 plants and dropped steadily to $3.16 per plant for 4,160 plants, after which it remained constant, (Fig. 1). Nursery size did not affect variable cost per plant. Fixed cost per plant for the small nursery ranged from $1.12 at 100 plants to $1.25 at maximum capacity, while fixed cost per plant in the large nursery was generally $.40 to $.50 less than the small nursery, (Fig. 1). Total cost per plant was $0.35 (7.5%) higher in the small versus the large nursery when producing 100 plants but increased to $0.40 (10.0%) higher at 95,850 plants. For the small nursery, total cost per plant was minimized at an annual production of 4,126 plants. For the large nursery, total cost per plant was minimized and fairly constant at levels between 4,126 and 12,480 plants per year.

Total fixed cost per year increased within the large and small nursery for each increase of 4,160 plants. At that point, an additional greenhouse was constructed to house the OPS plants during the *germination* and *establishment* phases, thereby increasing the overall level of capital investment for the nursery. Although the addition of a greenhouse decreased polyhouse space and costs, the cost of a new greenhouse was higher than a polyhouse and therefore increased total fixed costs for the entire nursery. For each additional greenhouse, total fixed costs increased by $550

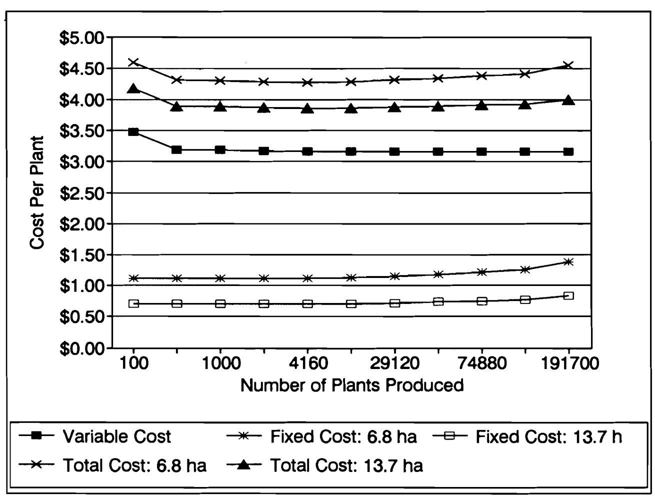

Fig. 1. Variable, fixed, and total cost per plant at different production levels and two nursery sizes.

Table 1. Percentage of variable, fixed, and total cost per plant for 2 nursery sizes and 5 phases of production.[z]

Production phases	Costs		Total costs	
	Variable	Fixed	Small[y]	Large[x]
Germination	2.4%	0.1%	1.8%	2.0%
Establishment	17.1%	4.2%	13.7%	14.6%
Acclimation	2.5%	7.0%	3.7%	3.4%
Rapid-Growth	66.6%	70.3%	67.5%	67.3%
Overwintering	2.0%	18.4%	6.3%	5.2%
Interest	9.4%		7.0%	7.6%
Total	100.0%	100.0%	100.0%	100.0%

[z]Production level of 4,160 plants.
[y]Small nursery is 6.88 ha (17 acres)
[x]Large nursery is 13.76 ha (34 acres)

because of increases in depreciation, insurance, taxes, and interest. However, the large nursery was able to spread the costs of the budgeted equipment and facilities over a larger number of plants, and thereby reduce the fixed cost component per saleable plant, relative to the small nursery.

Percentage of estimated variable, fixed, and total costs incurred during each of the five production phases are presented in Table 1. Total expenses incurred during the initial five week *germination* phase were the least of all phases. This phase begins on approximately February 1 when seed is sown in flats and placed on a mist bench in a heated greenhouse. The nine week *establishment* phase occurs next and incurs approximately 14% of total costs. Plants are removed from the mist bench, potted into 2833 cc (6″ × 6″, .1 cu/ft, #1) $CuCO_3$ containers, and grown in a warm greenhouse. The *acclimation* phase incurs only 3.4% of total variable costs. Here plants are moved outside and are placed under shadecloth for two weeks. Beginning approximately June 1, the *rapid-growth* phase lasts for the next 20 weeks and incurs 66% of total costs. During this phase, plants are shifted into 17,000 cc (11″ × 9″, 6 cu/ft, #3) $CuCO_3$ treated containers, staked and pruned to develop a central leader, irrigated, and fertilized through the summer and into the fall. The 18 weeks *overwintering* phase begins November 1 and ends March 7 when all plants are sold but incurs only 5% of total costs. The remaining 7% of total costs are due to interest charges on operating capital.

The percentage of total fixed costs per year incurred in each of the six cost categories was determined for both small and large nurseries. In both cases, the highest amount of fixed costs were attributed to general overhead, approximately 50%. This category includes expenses incurred for utilities, repairs, maintenance, advertising, personnel benefits, travel, and office expenses. Of the remaining fixed costs, buildings accounted for approximately 18%, machinery, equipment, and irrigation accounted for 18%, while the remaining 14% was split between land, land improvements, interest, insurance, and taxes. (statistics not presented)

Impact of Changing Production Parameters

Hourly wage rate and labor efficiency are factors generally under the control of the nursery manager. However, other factors such as availability of workers, their degree of experience, location of the nursery, and prevailing minimum hourly wage rate impact the manager's ability to effectively control total labor expenses. The impact on total cost per plant of increasing and decreasing the ***wage rate*** from an initial level of $5.00/hour was examined. For both nursery sizes and various production goals, total cost per plant was not significantly affected by changes in the wage rate. Even with a 50% increase in the wage rate ($7.50 per hour), total cost per plant increased by only 7%. Alternatively, lowering the wage below $5.00 did not result in significant savings. A wage of $3.50, 30% lower, only saved $.18 or 4.2% of total cost. (statistics not presented)

The ***number of workerhours*** needed to produce the OPS crop and the impact of changing worker efficiency on total cost per plant were also examined. As would be expected, there is a one for one correspondence between the impact on total cost due to changing labor efficiency and wage rate. In other words, increasing the labor wage rate by 50% and expecting labor to be 50% more productive results in a zero impact on total labor expense and consequently no change in total cost per plant. Results indicate that increasing labor efficiency by 30% returned a cost savings of 4.2%.

Varying ***loss rates*** (the number of plants estimated to be discarded during each phase due to poor health, grading, or death) in each production phase and the impact on total cost per plant was examined, Table 2. Loss rates might be influenced by seed quality, cultural practices, grower experience, and grading requirements. Initial germination rate was set at 90%, while loss percentages were 2% during *establishment*, 0% during *acclimation*, 8% during *rapid-growth*, and 0.5% during *overwintering*.

Table 2. Total cost per plant at various percentages of germination and loss rate.[z]

% Germination		Loss %	Production phases			
			Establishment	Acclimation	Rapid-growth	Overwintering
	Cost/Plant		Total cost per plant			
100	$4.274	0	$4.27	$4.28	$4.04	$4.26
95	4.276	3	4.28	4.30	4.13	4.36
90	4.279	5	4.29	4.31	4.19	4.44
85	4.281	8	4.31	4.33	4.28	4.54
80	4.284	10	4.32	4.34	4.34	4.60
70	4.289	20	4.38	4.39	4.64	4.94
60	4.294	30	4.43	4.46	4.94	5.28

[z]Nursery size of 6.88 ha (17 acres) producing 4,160 whips.

Table 3. Total cost per plant at different interest rates on long and short term assets and operating capital.[z]

Interest rate (%)	Long term	Change[y] %	Operating capital	Change[y] %	Short term	Change[y] %
8	$4.25	−0.60	$4.22	−1.39	$4.27	−0.15
9	4.27	−0.30	4.25	−0.69	4.28	−0.07
10	4.28	0.00	4.28	0.00	4.28	0.00
11	4.29	0.30	4.31	0.69	4.28	0.07
12	4.30	0.60	4.34	1.39	4.29	0.15
13	4.32	0.90	4.37	2.08	4.29	0.22
14	4.33	1.20	4.40	2.78	4.29	0.30
15	4.34	1.50	4.43	3.47	4.29	0.37
16	4.36	1.80	4.46	4.17	4.30	0.44
17	4.37	2.10	4.49	4.86	4.30	0.52
18	4.38	2.40	4.52	5.56	4.30	0.59

[z]Nursery size of 6.88 ha (17 acres) producing 4,160 whips.

[y]Percentage change from initial cost of $4.28 per whip.

Generally, increasing the loss rate had a greater effect on total cost per plant as the time in production increased. Losses in the *germination* phase had the smallest effects, with a decrease in germination from 100% to 70% increasing total cost per plant by only 0.35%. The effect of increasing loss in the *establishment* and *acclimation* phases was also relatively small, with larger changes in total cost per plant seen in the *rapid-growth* and *overwintering* phases. Increasing losses during the *overwintering* phase from 0% to 30% increased total cost per plant by $1.02 or 24%.

The impact of changing **interest rates** on total cost per plant is presented in Table 3. Total cost per plant was most affected by changes in interest rate on operating capital. Operating capital includes all expenses incurred during the year, excluding the purchase of assets which last longer than one year. Increasing the interest rate on operating capital from 10% to 18% increased total cost per plant to $4.52, a 5.6% increase.

Increasing the interest rates on long or short term loans also increased total cost per plant but not as much as above. Long term interest rate was applied to purchases of land improvements, buildings, and irrigation equipment. Increasing the interest rate to 16% resulted in an increase in cost per plant of $.10. The short term interest rate was applied to purchases of machinery and equipment. When short term interest rate increased to 18%, total cost per plant increased to $4.30.

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