Abstract. Cooperative tree replacement programs between a public utility holding company and its subsidiary and Ohio State University are described. The goals of the cooperative program are to reduce energy demand, reduce line clearance cost, develop production methods for new species, document survival and establishment in urban planting sites and increase the species diversity of urban plantings. Over a five year period, 5000 trees will be grown and transplanted. Presently, over 40 species are in production. The first plantings, established with one and two year old (1.5 to 9 m tall, 1.5 to 2.5 cm caliper) stock, were planted in 1992. Two and three year survival (averaged over all species and years) was high, 80%, but regrowth was slow, averaging 15 cm increase in height and 2.0 cm increase in diameter. Within a species, there was significant site-to-site variation in survival and growth. Successful tree replacement programs are dependent on three factors: high quality planting stock, site quality and aftercare.

This article describes two cooperative tree planting programs: the American Electric Power (AEP) SMART Tree project and the Columbus Southern Power/Ohio Power (CSP/OP) Tree Replacement Program. Columbus Southern Power/Ohio Power is a subsidiary of American Electric Power. The Ohio State University, Department of Horticulture and Crop Science, is a cooperator in both projects.

The AEP SMART Tree program has two objectives: 1) to reduce the demand for additional electric power generation capacity by planting trees in new home developments to give maximum summer shading, and 2) to remove trees that interfere with power service lines and replace them with large shrubs (trained into tree form) or small trees that have a mature height of under 8 m (25 ft). The goal is to produce and transplant 2800 trees between fall 1994 and spring 1997.

The CSP/OP project is a tree replacement program. The objectives are to remove improperly sited trees and replace them with trees that have a mature height less than 8 m (25 ft). A partial species list is given in Table 1. Many species under consideration are native to North America. The CSP/OP project will plant 2500 trees by spring 1999.

The university’s objectives are to develop production techniques and evaluate initial plant performance in the landscape for these species. Many of the species being grown are not readily available from nurseries because of biological limitations. These limitations include low root regeneration potential leading to low transplant survival and slow establishment, and complex seed dormancy mechanisms.

Wherever possible activities will be coordinated with municipal foresters and others responsible for tree planting programs. Tree planting programs coordinated through city foresters give the foresters first hand experience with, and allow them to assess the potential of, AEP SMART Tree species. Knowledge of species’ performance will develop a market for the best performers.

The production techniques developed will be transferred to interested nursery managers so that the species with the best performance can be produced on a commercial scale. By developing both the production techniques and the market, the cycle of “We don’t grow that tree because nobody orders it.”, and “We don’t request that tree because nobody grows it.” will be broken. A result will be increased species diversity in the urban landscape.
Economic Justification

The CSP/OP's Tree Replacement Program was justified on a cost savings basis. The time and cost of tree trimming and tree removal activities are given in Table 2. Tree trimming costs $29.47 per tree per trim cycle, or $76,875 per 2,500 trees per trimming cycle. Trees such as silver maple, Siberian elm and cottonwood need to be trimmed every two to three years, so trimming costs of $76,875 are recurring every two to three years. The cost of three trim cycles is $230,625 for 2,500 trees.

Table 1. Species in production for possible use in a tree replacement program. All species will be grown in tree form: a single central leader with minimum of 1.2 m (4 ft) clear trunk.

<table>
<thead>
<tr>
<th>Species</th>
<th>Other Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acer pensylvanicum</td>
<td>Striped Maple</td>
</tr>
<tr>
<td>Asimina triloba</td>
<td>Common Pawpaw</td>
</tr>
<tr>
<td>Caragana arborescens</td>
<td>Siberian Peashrub</td>
</tr>
<tr>
<td>Carpinus betulus</td>
<td>European Hornbeam</td>
</tr>
<tr>
<td>Celtis reticulata</td>
<td>Netleaf Hackberry</td>
</tr>
<tr>
<td>Cercis canadensis</td>
<td>Eastern Redbud</td>
</tr>
<tr>
<td>Corylus avellana</td>
<td>European Filbert</td>
</tr>
<tr>
<td>Diospyros virginiana</td>
<td>Common Persimmon</td>
</tr>
<tr>
<td>Eucommia ulmoides</td>
<td>Hardy Rubber Tree</td>
</tr>
<tr>
<td>Evodia danielli</td>
<td>Korean Evodia</td>
</tr>
<tr>
<td>Hovenia dulcis</td>
<td>Japanesees Raisintree</td>
</tr>
<tr>
<td>Koelreuteria paniculata</td>
<td>Goldenraintree</td>
</tr>
<tr>
<td>Laburnum anagyroides</td>
<td>Goldenchain tree</td>
</tr>
<tr>
<td>Maackia amurensis</td>
<td>Amur Maackia</td>
</tr>
<tr>
<td>Magnolia acuminata</td>
<td>Yellow Cumbertree</td>
</tr>
<tr>
<td>Magnolia kobus</td>
<td>Kobus Magnolia</td>
</tr>
<tr>
<td>Magnolia virginiana</td>
<td>Sweetbay Magnolia</td>
</tr>
<tr>
<td>Ostrya virginiana</td>
<td>American Hophombeam</td>
</tr>
<tr>
<td>Phellodendron amurense</td>
<td>Amur Corktree</td>
</tr>
<tr>
<td>Ptele trifoliata</td>
<td>Hoptree</td>
</tr>
<tr>
<td>Pterocarya fraxinifolia</td>
<td>Caucasian Wingnut</td>
</tr>
<tr>
<td>Pteroceltis tataronowii</td>
<td>Tatar Wingceltis</td>
</tr>
<tr>
<td>Quercus acutissima</td>
<td>Sawtooth Oak</td>
</tr>
<tr>
<td>Sassafras albidum</td>
<td>Common Sassafras</td>
</tr>
</tbody>
</table>

Table 2. Tree trimming and tree removal times, rates of pay and total per tree cost for each activity based on 1994 estimates for the Columbus, OH region.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Worker hours (per tree)</th>
<th>Rate (per hour)</th>
<th>Cost ($ per tree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trim</td>
<td>1.52</td>
<td>19.39</td>
<td>29.47</td>
</tr>
<tr>
<td>Removal</td>
<td>1.93</td>
<td>19.39</td>
<td>37.42</td>
</tr>
</tbody>
</table>

Fig. 1. Two year old tree form Magnolia virginiana. The vigorous growth obtained under Ohio Production System conditions allows large shrub species to be grown in tree form. Jim Venn is 1.8 m (5 ft 10 in) tall.

Trees.

The costs for a tree replacement program are: tree removal ($37.42/tree [Table 2], or $93,550 for 2,500 trees), replacement tree cost ($50/tree, or $125,000 for 2,500 trees) and tree distribution cost ($5.00 per tree, or $12,500 for 2,500 trees). Planting costs would be incurred by the home owner. A tree replacement program would cost $92.42 per tree ($231,050 for 2,500 trees). Tree replacement program costs are non-recurring so, a tree replacement would begin to "pay for itself" after three trimming cycles, as early as six years.

Production Techniques

All plant material used in the studies was produced under the Ohio Production System (OPS) conditions (3). Under OPS conditions, seeds are...
germinated in February, transplanted to copper-treated (SPINOUT, Griffin Corp., Valdosta, GA) containers and grown in a greenhouse for 10 weeks. Copper-treated containers are used to prevent root malformation. When roots contact the copper-treated interior container surfaces, root elongation is inhibited, which reduces circling and girdling root formation (1).

Plants are transferred outdoors after the spring frost date (May 15 for Columbus, OH) and potted into copper-treated #3 nursery containers. It is possible to produce 2 m tall whips by October, 8 months after seed germination.

The plants are then fall transplanted into copper-treated #10 nursery containers and grown for two additional years in a Pot-in-Pot system (2). After three growing seasons, 4 to 5 cm (1.5 to 2 in) caliper material is ready for planting in the AEP SMART Tree and the CSP/OP Tree Replacement programs. An advantage of OPS-produced AEP SMART Trees is reduced production time. Under traditional production techniques used in USDA Plant Hardiness Zones 5 and 6, 4 to 5 cm caliper trees may require five to eight years to produce. An additional advantage of OPS conditions is that some large shrub species can be grown in tree-
Fig. 3. Five year old *Quercus shumardii* at a Cleveland (left) and Columbus (right) site. The plants were produced under similar conditions and fall transplanted in 1991. The photos demonstrate how site quality and after care can modify growth potential. The Cleveland tree received no after care. The Columbus tree had a 1 m mulch ring placed around it at planting and was irrigated bi-weekly during the first growing season. The measuring stick near the Cleveland oak is held at 1.5 m (5 ft) height. Philip, in the left picture, is 1.2 m (4 ft) tall.

Survival and Regrowth Potential

Survival, averaged over two or three years after planting for all species, was 80% (Table 3). Most of the mortality occurred after the severe winter of 1992-1993.

Regrowth in “typical” city sites has been less than reported for OPS-produced plants transplanted into a site with more favorable soil conditions (a former agricultural field) (4). The first plantings used one- and two-year old planting stock 1.5 to 3 m tall and less than 2.5 cm in caliper; this is smaller than that typically used for curb lawn planting sites.

An observation (based on the early results and a small sample size) is that the high survival and regrowth potential of AEP SMART Trees can be modified by site conditions and post-transplanting management practices. This is illustrated by data from baldcypress (*Taxodium disticum*). All trees were produced under OPS conditions and fall transplanted into four sites in 1992. Survival ranged from 100% (in Upper Arlington) to 25% (at Worthington). At the Upper Arlington site (Fig. 2), the plants received the following post-transplanting care: a 1 m diameter mulch ring, once per year Round-up application within the mulch ring, two irrigations during the first year after transplanting and no fertilizer. After three growing seasons, plant height increased by an average of 50 cm (20 in). Trunk caliper averaged 5.3 cm (in). In contrast,
<table>
<thead>
<tr>
<th>Species</th>
<th>Location</th>
<th>Number planted</th>
<th>Year transplanted</th>
<th>Survival (%)</th>
<th>Initial ht (cm)</th>
<th>Initial cal. (cm)</th>
<th>Survival 1995 ht (cm)</th>
<th>Survival 1995 cal. (cm)</th>
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</thead>
<tbody>
<tr>
<td>Black Oak (Quercus velutina)</td>
<td>Pickerington 3</td>
<td>1992 66</td>
<td>150 NA</td>
<td>155 2.8</td>
<td>260 4.0</td>
<td>250 NA</td>
<td>270 3.1</td>
<td>215 2.8</td>
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<tr>
<td>Bur Oak (Q. macrocarpa)</td>
<td>Cleveland 6</td>
<td>1993 83</td>
<td>175 2.1</td>
<td>245 3.5</td>
<td>250 4.0</td>
<td>250 3.1</td>
<td>235 2.9</td>
<td>270 3.1</td>
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<tr>
<td>Chestnut Oak (Q. prinus)</td>
<td>Upper Arlington 1</td>
<td>1992 100</td>
<td>225 NA</td>
<td>320 5.1</td>
<td>260 3.9</td>
<td>320 5.1</td>
<td>270 3.1</td>
<td>280 4.0</td>
</tr>
<tr>
<td>English Oak (Q. robur)</td>
<td>Upper Arlington 2</td>
<td>1992 50</td>
<td>250 NA</td>
<td>280 4.0</td>
<td>260 3.9</td>
<td>280 4.0</td>
<td>270 3.1</td>
<td>280 4.0</td>
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<tr>
<td>Red Oak (Q. rubra)</td>
<td>Cleveland 5</td>
<td>1993 100</td>
<td>242 2.3</td>
<td>278 3.1</td>
<td>260 3.9</td>
<td>278 3.1</td>
<td>280 4.0</td>
<td>290 4.0</td>
</tr>
<tr>
<td>Sawtooth (Quercus velutina)</td>
<td>Upper Arlington 2</td>
<td>1992 100</td>
<td>228 NA</td>
<td>295 5.2</td>
<td>260 3.9</td>
<td>295 5.2</td>
<td>280 4.0</td>
<td>295 5.2</td>
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<tr>
<td>Scarlet Oak (Q. coccinea)</td>
<td>Upper Arlington 2</td>
<td>1992 100</td>
<td>233 NA</td>
<td>262 3.1</td>
<td>260 3.9</td>
<td>262 3.1</td>
<td>270 3.1</td>
<td>280 4.0</td>
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<tr>
<td>Shingle Oak (Q. imbricaria)</td>
<td>Worthington 1</td>
<td>1992 100</td>
<td>195 NA</td>
<td>120 2.5</td>
<td>260 3.9</td>
<td>120 2.5</td>
<td>120 2.5</td>
<td>120 2.5</td>
</tr>
<tr>
<td>Swamp Chestnut Oak (Q. michauxii)</td>
<td>Powell 8</td>
<td>1992 38</td>
<td>241 NA</td>
<td>311 3.8</td>
<td>240 4.1</td>
<td>240 4.1</td>
<td>240 4.1</td>
<td>240 4.1</td>
</tr>
<tr>
<td>Swamp White Oak (Q. bicolor)</td>
<td>Cleveland 9</td>
<td>1992 100</td>
<td>226 NA</td>
<td>251 3.8</td>
<td>260 3.9</td>
<td>251 3.8</td>
<td>260 3.9</td>
<td>270 3.1</td>
</tr>
<tr>
<td>White Oak (Q. alba)</td>
<td>Cleveland 8</td>
<td>1993 50</td>
<td>176 2.5</td>
<td>233 3.6</td>
<td>260 3.9</td>
<td>233 3.6</td>
<td>240 4.0</td>
<td>250 4.0</td>
</tr>
<tr>
<td>Kentucky Coffee Tree (Gymnocladus dioicus)</td>
<td>Pickerington 4</td>
<td>1992 100</td>
<td>203 NA</td>
<td>233 4.3</td>
<td>260 4.0</td>
<td>233 4.3</td>
<td>270 4.3</td>
<td>270 4.3</td>
</tr>
<tr>
<td>Blackgum (Nyssa sylvatica)</td>
<td>Cleveland 4</td>
<td>1992 100</td>
<td>205 NA</td>
<td>236 3.3</td>
<td>260 4.0</td>
<td>236 3.3</td>
<td>290 4.0</td>
<td>290 4.0</td>
</tr>
<tr>
<td>Baldcypress (Taxodium distichum)</td>
<td>Cleveland 6</td>
<td>1992 83</td>
<td>155 NA</td>
<td>264 5.5</td>
<td>264 5.5</td>
<td>264 5.5</td>
<td>264 5.5</td>
<td>264 5.5</td>
</tr>
<tr>
<td>Goldenrain Tree (Koelreuteria paniculata)</td>
<td>Pickerington 4</td>
<td>1992 100</td>
<td>155 NA</td>
<td>115 2.0</td>
<td>260 4.0</td>
<td>115 2.0</td>
<td>115 2.0</td>
<td>115 2.0</td>
</tr>
</tbody>
</table>

NA: Data not available.
-: Plant dead when measured June, 1995.
one baldcypress was transplanted into a residential site (Fig. 2). This tree received six irrigation treatments during the first two seasons after transplanting, an annual 450 g (1#) fall application of nitrogen and a 1 m diameter mulch ring. This tree is 4.75 m (15.6 ft) tall and 12.5 cm (5 in) in caliper. The contributions to the growth potential of the various post-transplanting practices are unknown.

Another example of site modified regrowth potential are six Shumard oak planted at one Cleveland site (Fig. 3) and one Columbus site (Fig. 3). Survival at Cleveland was 100%, but height increase only 5 cm (2 in) in three years. Caliper averaged 2.6 cm (1 in). In contrast, one 1.3 m (5 ft) tall Shumard oak was transplanted in 1991. This tree is now 7.3 m (24 ft) tall and 13 cm (5 in) in caliper. The homeowners watered and fertilized the plant for the first two growing seasons after transplanting. Research is needed to determine the effects of irrigation, mineral nutrition and site quality on transplant survival and regrowth so that city foresters can allocate scarce resources to the practices that most affect survival and growth. It is possible that the quality of the urban forest can be improved at minimal cost.

Literature Cited

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Columbus, OH 43210

Résumé. Cet article contient une description des programmes coopératifs de remplacement d'arbres entre une compagnie de service électrique et l'Université de l'état de l'Ohio. Les buts du programme sont de réduire la demande en énergie, de diminuer le coût de dégagement des lignes électriques, de développer des méthodes de production pour de nouvelles espèces, de documenter le taux de survie et la facilité d'implantation en milieu urbain et enfin d'accroître la diversité des espèces plantées en milieu urbain. Sur une période de cinq ans, plus de 5000 arbres seront produits et transplantés. A l'heure actuelle, plus de 40 espèces sont en production. Les premières plantations, effectuées à partir de vieux lots de une et deux années d'âge, ont été réalisées en 1992. Le taux de survie après la seconde et la troisième année était faible avec une moyenne de 15 cm en hauteur pour 2 cm en diamètre. Il existait des différences significatives entre les divers sites en ce qui touche le pourcentage de survie et le taux de croissance.