At the end of the 3rd growing season, trees are adequately branched with central leaders, will stand 6 to 7 ft in height, and will average 1 to 1½ inches in caliper.

Although these elements seem to be rudimentary, desired growth will not be achieved if the schedule is not strictly adhered to. In addition to the timing of certain activities, monitoring the trees and correcting any deficiencies is just as vital.

Successful Production of Difficult-to-Transplant Native Woody Trees

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For almost 10 years our nursery in southern Ohio has been working on developing a system to produce difficult-to-transplant or taprooted trees so they can be successfully moved to their final destination. The production system we are using today is allowing us to grow and successfully transplant many of the more beautiful natives in a short period of time which here-to-for were nearly impossible to field transplant successfully or at least at any successful ratio that made it a profitable venture. This system has allowed us to go from a seed, to a containerized liner, to a 2-inch caliper tree in 42 months and only 24 to 26 months are spent in the ground.

The demand for trees and shrubs and, in particular indigenous natives, has been extremely high the last couple of years. Our tiny nursery is receiving orders and request in the numbers of thousands. The last 50 to 75 years showed a marked decline in the use of native trees I suspect because of their notorious reputation for transplant difficulty or they may have been considered too "ordinary" for most people to seek them out.

The late Dr. Phillip Kozel of Ohio State University infected me in the early 1970s with a great appreciation and love for the native species. As a young landscape designer fresh out of school, I couldn't wait to start designing landscapes using beech (*Fagus*), nyssa (*Nyssa*), sassafras (*Sassafras*), white oak (*Quercus alba*), etc. Needless to say, I was extremely frustrated when I found that absolutely no one grew these plants. Now 25 years later, I realize what a lot of these reasons were, but we have come a long way to resolving many of these problems with transplant difficulty. There is great interest in the buying public, and I think we know now how to put a good root system on them.

Our nursery has developed a system of growing a containerized liner which when planted in a fertile nursery field in the fall, can produce a 2-inch caliper tree, with a multiple-branched root system that will transplant readily in 2 years. Growing trees in containers is nothing new but before the development of Spin-Out™ and Whitcomb's special 'Roomaker' pots most of the root system was wrapped around the sides and bottom of the container dictating an eventual death sentence for the plant.

Two of the most important factors in this system we developed that help to insure success is by starting with the right plant, (or liner) and fall planting. (Remember, we are talking about native species.) The right plant should be an indigenous native, which means you have to have an idea of the seed source of your liners. Buying seeds or seedlings from and unknown source or from outside your climatic zone is like a crapshoot. The seed of most of our natives is either collected by myself personally or

received from trusted friends and colleagues in or north of my region.

Once our seed has been collected, processed, and properly stored we begin the process of growing a seedling that contains a fibrous root system rather than a single taproot. This is a particular challenge specific to many of the natives that we consider desirable. Altering the root system at a very early age is one of the keys in this entire system. We have used a variety of methods over the years, but as new products have become available we are constantly testing for improvements. We are currently using containers primarily produced by the I.E.M. Corporation called Tray Masters which produces Spin-Out™-treated trays with quite a variety of cell numbers and cell depths to germinate the seed. What is allowing us to change the root system on these plants is the use of copper inside the cell walls and air pruning.

Except for the fall germinating species such as *Aesculus* and white oak groups, most of the seeds are brought out of the coolers in February or March and placed in the celled flats to germinate typically using bottom heat. Where deep kadon flats are used, the bottom of the flats are covered with landscape fabric coated with Spin-Out™. The celled trays are Spin-Out™-treated on the interior and have a fairly large opening at the bottom to prune the taproot. We feel that the air pruning is just as important as the copper treatment on the sides of each cell. This year the I.E.M. Company double treated our cell trays to help improve the root pruning. My initial reaction is that they need to up the percentage of copper in the paint. Additionally, all of our seedlings trays are inoculated with either endomycorrhizal or ectomycorrhizal preparations produced by Dr. Donald Mark's company Plant Health Care.

Germinating over 200 species of trees is not without its challenges, obviously the seeds need to have been properly stored, stratified, and scarified in order to germinate, but a person could grow old waiting for certain species to germinate. The most difficult problems we contend with germinating the seeds in greenhouses are the growth of algae on the flats, fungus gnats, over watering, and in general fungal diseases. We use a Davis Solar Twelve Mist Controller in our propagation houses for irrigation.

For many years we tried to duplicate Struve's work at Ohio State and tried to produce a usable field liner from seed in one growing season. We were able to do this but it was very inconsistent, as is often the case with seed. So we have settled on a 2-year process of growing a liner. The first being germination and initial growth phase of a seedling ranging from 6 to 30 inches in height and a root system contained in a pot approximately the size of a quart. The seeds are usually germinated in the smallest cell possible for the seed to fit and then transplant into 24-cell trays were they will remain until the following spring; they are then up canned to 1- or 2-gal containers for the 2nd years growth.

When the chance of frost has passed the seedling trays are moved outdoors and grown on raised benches which enhances the air pruning. During the summer growing season the seedlings are graded and culled as we look for genetic impurities or generally weak plants.

The seedlings are overwintered in inflated minimal heat quonset structures and in most cases we allow the winter temperatures to dip to the mid 20s by the dead of winter. In March we begin up canning last years seedlings to either 3-, 4-, or 6-qt containers depending on the species and its general vigor. Whenever possible the 3-qt container is used to save on space and shipping costs once the plants are sold. This

second growing season is extremely labor intensive as each tree needs to be trained to grow perfectly straight on bamboo stakes to the size of a nursery liner, generally 4½ to 7 ft tall, some lightly branched.

Our growing medium is custom blended for us by a neighboring nursery with a mixer and it contains pine bark and rice hulls, municipal sewage sludge and granite pebbles in addition to sulfur, fertilizer, and epsom salt. Our fertilizer is incorporated into the mix because of the labor savings and the problem with our plants blowing over in the wind. Top dressing is generally necessary mid-way through the growing season and keeping the pH of the soil medium low for most natives is very important for our region.

About half of our production is grown inside our 30 ft wide, high-walled greenhouses under 30% shade, the other half is grown on outdoor gravel beds with the wind and frost being major complications. Except for the plants grown in 5- and 7-gal containers, which are all on a drip system, all plants are watered with overhead irrigation from surface ponds.

Growing containerized trees is extremely labor intensive as each plant requires staking and multiple visits to that plant during that growing season to assure that the leaders are still intact and growing straight. In the Cincinnati area, finding labor for this task is usually more challenging than growing the plants.

By Labor Day or mid-September most of our 2nd-year seedlings have reached the salable height of a proper nursery liner and we begin cutting back on water hoping that the fertilizer in the pots is beginning to run low so the plants can harden off. Slowing these plants down and hardening them off before a hard freeze is one of the most difficult parts of this accelerated growth process.

The soil in our nursery fields is prepped around Labor Day and we are ready to begin fall planting of our containerized liners. Before the liners go to the field the root systems are drenched with a bio-stimulant such as "Grower" to aid in transplant shock reduction and all plants are sprayed with a deer repellent. We watch the weather closely and try to time the planting accordingly if rain is forecast, however, we do have drip irrigation and will plant by mid-September whether it rains or not.

The benefits of fall planting in a nursery can not be overstated. Everything works better in the fall than it does when you are planting in the spring. The soil conditions allow the equipment to work as it was designed, the warm temperatures help keep the planting crew in an up beat mood, and you are just plain not as rushed as you are in the spring. We feel that placing an undisturbed root system into warm moist soil in the fall gives us a full years advantage over spring-planted bare-root liners which are usually mudded in into wet cold soil. Usually by Thanksgiving it is very difficult to pull a fall-planted liner out of the soil because so much root growth has occurred by then. This growth of roots in the first fall is what allows us to harvest a 2-inch caliper tree in two growing seasons from transplanting. We feel our first growing season is similar to the second or third season of a bare-root liner in most cases.

First year growth on these liners is usually so extensive that it is necessary to stake the plant. The caliper of the trunk does not usually catch up to the top growth until the next fall and we never trim back lower branches and side growth during the first growing season because it adds so much structural stability. This initial staking is usually done in the winter following the planting of the liner. The second winter many of the branches are headed back closer to the trunk leaving about 3 buds so

that the next season's growth is very full. The second seasons growth is very vigorous as was the first and the development of the caliper continues and with proper pruning being done we have a salable plant by the end of the second season.

We feel that one of the main reasons for this phenomenal accelerated growth is the quantity of roots on the tree. When a tree is spring planted into cold wet soil it has to develop a root system from it's cut roots quickly, which it can not do because of the soil temperatures, while at the same time it is trying to put on top growth. Our fall-planted liners already have roots established.

My observations as a nurseryman for years has been that a tree seems to transplant better if I cut multiple small roots rather than several very large roots; this is exactly the type of root system that develops from a 'Spin-Out™-treated containerized tree. Another advantage of fall planting containerized tree liners is the total elimination of the root pruning process we all go through with bareroot liners. It now takes us less time to plant our entire crop then it used to take just to root prune our bareroot plants.

Genotypic and Environmental Effects on Root Cutting Propagation of *Pulmonaria* Species and Cultivars

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INTRODUCTION

Root cutting propagation is the technique in which plant roots are severed from the mother plant, cut into individual pieces, placed under moist, warm conditions, and allowed to develop into new plants after the formation of adventitious buds and roots. The propagation of ornamentals by root cuttings is an economical and efficient technique for some plant species. However, it is a method that is underutilized and should be given greater attention by plant propagators. The increasing costs of cutting production make it worthwhile for propagators to evaluate root cutting propagation as a possible means to increase plant production and decrease costs.

Root cutting propagation has several advantages: it can be carried out with unskilled labor, provides a fast way to multiply clonal material, requires limited propagation facilities, is useful for some plants where other methods have not been found satisfactory, is useful when only one sex of a dioecious plant is required, and can be carried out during the winter when weather is unsuitable for outdoor work. There are some disadvantages — these include limited information on the number of potential plants that can be obtained from stock plants, variability of results from year to year for some species, potential "weed" problems of severed roots that remain in a stock plant area, inconvenience of handling roots from outside stock plants if they are not sufficiently washed, variability in production as a result of the time of year cuttings are made, and the problem of propagating chimeral variegated plants.

Pulmonaria species, commonly called the lungworts, are one of the "hottest" groups of perennial plants for the shade garden. They are low-growing, clump-forming plants that grow best in full to part shade in moist soil. Some *Pulmonaria*