PROMOTION OF ROOT REGENERATION IN DIFFICULT-TO-TRANSPLANT SPECIES[1]

D. K. STRUVE[2], R. D. KELLY[3], AND B. C. MOSER[4]

Department of Horticulture
2001 Fyffe Ct.
Ohio State University
Columbus, Ohio 43210

Difficult-to-transplant species such as scarlet oak, *Quercus coccinea*, and black gum, *Nyssa sylvatica*, have considerable ornamental value, but are not widely offered in the nursery trade. Poor transplant survival has made these species uneconomical for nurserymen to produce and landscapers to install. If a means of increasing transplant survival can be found then these and other ornamentally valuable but difficult-to-transplant species could be added to the nursery catalog lists and increase the range of plants available to landscape architects.

It has been estimated that as little as 2% of the soil volume originally exploited by a plant's root system is retained in standard balling and burlapping operations (20). Root systems are further disturbed when a plant is dug bareroot. Without the protective soil ball the roots, especially the small feeder roots most responsible for water and nutrient absorption, are easily desiccated and broken. It is essential that a plant rapidly regenerate a root system to insure survival following transplanting.

Natural Pattern of Root Regeneration. Ease of transplanting is directly related to the density of the root system and the rate of root regeneration. Pirone (12) has listed plants based on their relative ease of transplanting. Those rated as difficult-to-transplant are typified by a coarse root system. Characterization of twice-transplanted 1.5-in. caliper scarlet oak (considered difficult-to-twice-transplant) root systems found that they were less fibrous than the more easily transplanted pin oak (17). Also, the rate of root regeneration was slower in scarlet oak seedlings than in pin oak. In spring, scarlet oak regenerated fewer roots, 6 vs. 16, and began root regeneration 4 weeks later than pin oak when grown under greenhouse conditions.

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[2] Assistant Professor, Department of Horticulture, Ohio State University, Columbus, Ohio 43210.

[3] Research Associate, Department of Biological Sciences, Wayne State University, Detroit, 48202.

[4] Head, Department of Horticulture, Purdue University, West Lafayette, Indiana 47907.

The dynamics of honeylocust root regeneration should be studied and contrasted with those of scarlet oak since the former is considered easy-to-transplant but coarse-rooted. The difference in transplant ability might be attributed to rate of root regeneration and/or rate of root elongation.

The potential for root regeneration varies with species, the physiological and developmental stage of the plant, and the environmental conditions during root regeneration. Generally, under field conditions there are two peaks in the natural pattern of root regeneration (16). The fall peak results almost exclusively from the elongation of existing roots, whereas the spring peak results from both the elongation of existing roots and the initiation and subsequent elongation of newly initiated roots. Tulip tree (4) and black walnut (19) seedlings exhibit the typical seasonal pattern of root regeneration. Indolebutyric acid (IBA) applications to the root systems at transplanting only enhanced spring root regeneration, having little effect in the fall. Root regeneration resulted exclusively from elongation of newly initiated roots, as the seedlings used in these studies had no intact roots. The root tips were either lost during digging or were pruned before auxin treatment.

When a coarse-rooted species is dug few intact roots are retained. Therefore, root regeneration usually results from new root initiation and subsequent elongation. Root initiation occurs primarily in the spring in the presence of nondormant buds and is often inhibited by dormant buds (1, 14). The natural bud dormancy developed in the fall is broken by exposure to chilling temperatures during winter and early spring. Because harvesting leaves coarse-rooted species with few intact roots, root regeneration (via new root initiation and elongation) would not occur until spring. Thus, the common practice of transplanting difficult-to-transplant species in spring has a physiological basis.

Increasing Root System Density and Improving Root Regeneration in Difficult-to-Transplant Species. Difficult-to-transplant species commonly have a well-developed taproot. Although the taproot is damaged by repeated digging and root pruning during production, the root system remains coarsly branched. Nurseries, in an effort to improve on the plant's root regeneration characteristics, have explored several means of increasing the density of the root system. Among these methods is container production. By growing seedlings in open bottom containers, the taproot is air-pruned as it grows beyond the bottom of the container. This method has increased the fibrousness of the root system but concentrates the actively growing roots at the container bottom. If a 9 in. deep container is used, all of the seedling's actively growing roots will be 9 in. below the soil surface when planted (5). Most nutrients are located in the upper 3 to 4 in. of soil. In reforestation work this concentrating of roots has caused stunting, presumedly due to poor nutrition. In nursery practice, stunting due to poor nutrition probably would not be a problem since adequate nutrition is usually provided by the grower. However, there is the problem of little or no root distribution in the top 9 in. of soil, necessitating a deeper soil ball when harvesting.

Treating root systems of difficult-to-transplant species with auxin to increase root regeneration is an alternative to container production and a proven method of increasing transplanting success (Table 1). However, as mentioned earlier, auxin application is most beneficial in stimulating root regeneration in the spring.

The root soak or dip method, simply soaking or dipping the root system in an auxin solution, would seem to be the commercially acceptable method due to ease of application. This method does require large volumes of auxin solution to adequately treat root systems of all but small seedlings.

Treating black walnut (19), tulip tree (4), and scarlet oak (18) with IBA root soaks increased root regeneration by increasing the number of roots regenerated. The optimum concentration for a 5 min. soak ranged from 1,000 to 3,000 ppm. Concentration above 3,000 ppm or soaks longer than 5 min. inhibited root regeneration and shoot development.

Table 1. Species, method of auxin application, and auxin concentration used to stimulate root regeneration in seedlings.

Species	Method of Application	Auxin	Concentration (ppm)	Reference
Acer saccharinum	Lanolin paste	IAA,IBA	1000, 3000	13
Cercis canadensis	Soak	IBA	3000	11
Crataegus phaenopyrum	Toothpick, soak	IBA	1000, 3000	z
Carya illinoinensis	Toothpick, soak & others	IBA	400, 1000	2, 15
Juglans nigra	Soak, toothpick	IBA	1000, 3000	11, 19
Liriodendron tulipifera	Soak	IBA	1000, 3000	4
Nyssa sylvatica	Soak	IBA	1000, 3000	11
Pyrus communis 'Bartlett'	Toothpick, talc	IBA	1000, 8000	8
Quercus alba	Soak	IBA	1000, 3000	11
Q. borealis	Soak, toothpick	IBA	100, 300, 1000, 3000	6,z
Q. coccinea	Soak, toothpick	IBA,NAA 2,4-D 2,4,5-TP	100, 300, 1000 3,000, 10, 100, 300	18
Q. palustris	Toothpick	IBA	1,000 10,000	9
Tilia × *euchlora*	Toothpick	IBA	1000	2

[z] Struve, unpublished data.

Other auxins have been tested; naphthaleneacetic acid, 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid, but the results were varied and require additional research.

Inserting auxin impregnated toothpicks transversely through a root is another means of stimulating root regeneration (2, 8, 9, 11, 15, 18). This method was first used by Romberg and Smith (15) on pecan and has been used subsequently on a number of species (Table 1). Auxin impregnation is accomplished by placing toothpicks in an auxin solution and drawing a vacuum or by allowing them to soak overnight.

The auxin-impregnated toothpick method has several advantages: First, it increases the number of roots regenerated. With one-year-old scarlet oak seedlings 19 times more roots were regenerated by toothpick-treated seedlings than by control seedlings and 3 times more roots than the best auxin root-soak treatment, 19, 1, and 5 roots, respectively (18). Second, the majority of the newly regenerated roots arise from the site of toothpick insertion. With natural root regeneration or auxin soaks the majority of the roots are regenerated near the cut surface. When roots are regenerated near the cut surface, most of the benefit of increased numbers of regenerated roots is lost in the subsequent harvest operations. Toothpicks, however, can be inserted near the crown of a seedling, resulting in less root loss during digging. The toothpick treatment allows nurserymen to engineer a plant's root system. The toothpick could be inserted into the root at the time plants are graded.

One criticism of the toothpick treatment could be the cost. Moser (10) has estimated the cost of auxin impregnation and toothpick insertion to be 1.3 cents each. A small study was begun in 1982 to determine if the benefits of toothpick treatment would justify the cost.

The field study was begun, with the cooperation of Manbeck's Nursery, New Knoxville, Ohio, by treating the root systems of ten 8-ft red oak liners with 5 auxin-impregnated toothpicks per plant in March, 1982. The trees were labeled and field-planted that spring with untreated control trees. One treated tree died following transplanting. Three trees were dug bare root in November, 1982, to examine root regeneration. Caliper and height of the remaining 6 treated and 10 adjacent untreated trees were measured in October, 1983. Toothpick-treated red oak liners averaged 4 ft. (1.3 meters) taller and 0.4 in. (1.1 cm) greater caliper than untreated liners (Table 2).

Table 2. Height and caliper of toothpick-treated and control red oak liners 19 months (two growing seasons) after treatment. -Eight-foot tall liners were treated March, 1982, and measured October, 1983.

Treatment	Height (m)	Caliper (cm)
Control[z]	4.0 (12 ft)	3 ± 0.76 (1.25 in)
Toothpick[y]	5.3 (16 ft)	4.1 ± 0.5 (≅ 1.75 in)

[z] Average of 10 trees.
[y] Average of 6 trees.

The 1983 Lake County Nursery Exchange catalog lists 1¼, 1½, and 1¾ in caliper bare-root red oaks at $21.00, $26.65 and $33.85, respectively. The toothpick-treatment trees average ¼ to ½ in larger caliper than untreated trees, returning between $5.65 and $12.85 (the difference in list price between 1¼ and 1½ and 1¾ in caliper trees) for the 6.5 cent treatment cost.

An additional benefit of any auxin treatment, especially the toothpick treatment, is increased survival following transplanting. The toothpick treatment decreased mortality of red oak seedlings from 25% to 4%, 43 vs. 5 of 125 seedlings, respectively (Struve, unpublished data).

Auxin treatments, via root soaks or impregnated toothpicks, in addition to promoting root regeneration, have consistently promoted shoot growth the first year following treatment (2,4,6,8,9,19). It is not known how long shoot growth is promoted.

Stimulation of Root Regeneration in Easy-to-Transplant Species. The toothpick method has been used to stimulate root regeneration in 3 to 7½ in caliper pin oaks transplanted bareroot (9 and Struve, unpublished data). In the first experiment, transplant survival and growth of pin oaks transplanted via tree spade, bareroot or bareroot but treated with auxin-impregnated toothpicks, were compared. Although shoot growth was not as great as tree spade dug trees, the toothpick-treated bareroot trees had greater shoot growth than untreated bareroot trees. Survival for all 3 treatments, a total of 41 trees, was 100%. The toothpick method is the best means of auxin treatment for large sized trees. The amount of auxin solution needed to treat the root system of a 3 in caliper or larger tree would be prohibitive.

Auxin treatments, via root soaks or impregnated toothpicks, are effective means of increasing transplant survival, increasing root system density, and increasing shoot growth. However, there are many unanswered questions pertaining to the number of roots regenerated, the longevity of the regenerated roots, and the relationship between root system density, increased shoot growth, and transplant survival. Additional research is needed to answer these and other practical questions in order to improve the survival of plants moved bare-root.

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RICK RAY: How do you put the toothpicks into the roots?

DAN STRUVE: It depends on if you have electricity or not. We have done such crass things as driving a nail into the root and pulling it out and then inserting the toothpick. Ideally you should have an electric drill.

RICK RAY: Could you use a system like they use in the army for injecting?

DAN STRUVE: It is possible.

CAMERON SMITH: Have you done any direct injection experiments?

DAN STRUVE: No.

CAMERON SMITH: With a little DMSO you might be able to mobilize the auxin.

HERBICIDES FOR CONIFER SEEDBEDS

LARRY J. KUHNS

Department of Horticulture
The Pennsylvania State University
103 Tyson Building
University Park, Pennsylvania 16802

Weeds are the most costly pest to control during the production of conifer seedlings. Competition from weeds causes losses in density and quality. Hand-pulling weeds is expensive and also causes a decrease in density when conifer seedlings are pulled along with the weeds. For these reasons, a safe and effective form of chemical weed control is needed.

Weed Control Program. When planning production schedules, growers should include a weed control program. In the past, weed control was often treated like firefighting — the problem was attacked after it was started. But you can have much safer and effective weed control by developing a weed control program. A program incudes three basic steps: