The Propagation of Hardy, Woody Plants from Root Cuttings: A Review

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INTRODUCTION

Many successful plant propagation techniques draw their original inspiration from observing the behavior of plants in nature. What plant propagator has not observed sprouts arising at some distance from the main stem of a tree or shrub and thought to themselves that this plant might be propagated from root cuttings. Such observations can be traced back at least to the propagation of hardy, woody plants from root cuttings in the days of John Evelyn, who, in 1706 (and perhaps as early as 1664) observed that species of *Ulmus, Prunus*, and *Populus* produced root sprouts that could be dug up and planted. Remarkably, Evelyn also gave detailed instructions for how to propagate trees from roots: "To produce suckers, lay the roots bare and slit some of them here and there discretely, and then cover them." The most famous case of plant propagation from root cuttings is, of course, that of the breadfruit, *Artocarpus altilis*. This was the plant that the notorious Captain Bligh of the *Bounty* was charged with of transporting from the South Pacific to the West Indies. It was during the breadfruit's 5-month propagation period, spent in Tahiti, that the crew developed the taste for freedom that ultimately led to their infamous mutiny in 1789.

Since the mid-1800s, an extensive literature on the propagation of plants from root cuttings has grown up. Interestingly, there are references to root cutting which seem to be more numerous in the older literature than in the modern. This is probably because advances in softwood stem cutting technology (rooting hormones and intermittent mist) have rendered the slower and more laborious process of root cutting propagation obsolete. Nevertheless, a number of difficult-to-root woody plants—primarily in the families Anacardiaceae, Leguminoseae, Myricaceae, and Rosaceae—are still most effectively propagated from root cuttings.

Unfortunately, much of the literature on root cutting propagation is difficult to interpret because of the imprecise use of terminology. In particular, many horticulturists consider any woody structure that occurs underground to be a root, regardless of its anatomical origin. This means that plants that produce shoots from underground stems—including rhizomes, stolons, or lignotubers—are often incorrectly classified as "root sprouters." Another problem is that many horticulturists have uncritically copied plant lists from earlier writers, without either evaluating the validity of the prior observation or citing a proper source (e.g., Donovan, 1976).

The primary purpose of this article is to cut through the confusion that has plagued the horticultural literature on root cuttings by identifying those species that have actually been reported to reproduce from root cutting by more than one author (Tables 1 and 2). I have made an exception to this requirement of independent confirmation if an author actually provides documentary evidence for a given species. Those genera that are not confirmed by a second author are listed at the end of this article as good candidates for future research (Table 3).

An especially interesting article is by Wobst (1868), a German author who provides an extensive list of species—including many not mentioned by other authors—that can be propagated from root cuttings. Other early articles on root cutting propagation are by an American (Saul, 1847), a German (Katzer, 1868), and an Englishman (Lindsay, 1877, 1882). A more modern reference that is extremely interesting, but has not been cited in the horticultural literature, is *Silvics of North America* (Burns and Honkala, 1990). This book, which covers the ecology of important timber species, has a special section for each entry on vegetative regeneration. In Table 4, I have included a list of those species that are reported in this book to reproduce from root sprouts following logging. Of the 108 nontropical, native angiosperms listed, 22 of them (21%) are reported as showing the ability to reproduce from root sprouts. Whether this figure is representative of the general proportion of root sprouting to non-root-sprouting species for a wider sample of trees remains to be determined.

It is worth noting that all of the species discussed in this article are angiosperms. The only two gymnosperms have ever been documented to produce root suckers in nature are tropical conifers, *Araucaria cunninghamii* (Burrows, 1990) and *Dacrydium xanthandrum* (Wong, 1994). Interestingly, *Araucaria cunninghamii* was also listed by Wobst (1868) as propagated from root cuttings. Despite reports that *Ginkgo biloba* and *Sequoia sempervirens* produce root sprouts (Donovan, 1976), recent research (Del Tredici, 1992) has shown that these gymnosperms produce shoots from underground stems (lignotubers) not from roots.

The anatomy and physiology of root sprouts is a very complex subject and outside the scope of this paper. For this information, one should consult the excellent review by Peterson (1975). For a detailed ecological study of root sprouting by a tree in its native habitat, one should consult the article by Kormanik and Brown (1967) on *Liquidambar styraciflua*.

What follows below is a summary of the general information on the techniques of propagation of hardy woody plants from root cuttings, as described in the English-language horticultural literature. To critically evaluate the extensive literature on tropical plants or herbaceous perennials propagated from root cuttings would be a massive task that is well beyond this authors' experience or expertise. Following the techniques section are the lists of species that have been successfully propagated from root cuttings.

TYPES OF ROOT CUTTINGS

When discussing the propagation of plants from root cuttings, precise terminology is essential to describe the so-called polarity of the root. Proximal describes the end of the root nearest to the stem from which the root grew, distal describes the end furthest from the parent stem. This is an important concept because when a root cutting develops a shoot bud, it typically forms at the proximal end. Following the classification system established by Hudson (1956), five distinct types of root propagation can be distinguished among woody plants, based on the relationship between parent plant and root sprouts, or suckers as they are also known:

- **Natural Suckering without Division.** This category includes species that produce root suckers naturally near the parent trunk, forming a densely packed cluster of stems.
- **Natural Suckering with Division.** This category includes plants—mainly shrubs—that sucker from uninjured roots at some

distance from the base of the parent plant. Under undisturbed conditions these plants form large, spreading colonies. The connecting roots have a tendency to wither away, thereby creating natural divisions of the parent.

- **Induced Suckering.** This category includes plants that form root suckers in response to superficial injury to the root, such as that caused by lawn mowers. Induced suckering can also be seen following traumatic injury to the trunk of a tree or shrub, provided its root system is left intact. Many of the tree species listed in *Silvics of North America* (Burns and Honkala, 1990), fall into this category, insofar as they only produce root sprouts following logging.
- **In Situ Whole Root Cuttings.** This category includes plants that form root suckers from a root that has been completely severed from the parent plant but left *in situ* until a sucker has grown from the proximal end. This phenomenon is often observed in nurseries after a tree or shrub has been dug, leaving the distal ends of severed roots behind. Provided the ground is not disturbed, these roots will eventually give rise to vegetative shoots.
- **Ex Situ Detached Root Cuttings.** This category includes plants that form root suckers from root cuttings that are dug up in the fall or winter, cut into short segments, and planted in the field or in containers. From the propagator's point of view, this is the most important category of root cutting propagation because it allows for rapid increase in the numbers of plants.

SOURCE OF ROOT CUTTINGS

When propagating plants from root cuttings, the source of the propagules is critical. The following generalizations apply:

- There is a distinction between roots spouting in nature and induced sprouting from root cuttings. Some species that do not normally sucker can be induced to produce sprouts from root cuttings under nursery conditions.
- Selections in which the desired mutation consists of a periclinal chimera, including many variegated plants, will not come true from root cuttings. This is because root buds typically arise endogenously from the interior of the root, while buds that are produced on shoots arise exogenously from more superficial tissue layers. This difference in the point of origin produces slightly different types of meristematic organization between root and shoot buds (Creech, 1954; Peterson, 1975).
- While it may seem obvious, it is important to remember that selections grafted onto seedling understock cannot be propagated from root cuttings.
- Younger plants reproduce more reliably from root cuttings than older plants.
- Thick pieces of the root proximal to the parent trunk seem to produce shoots more readily than thin root pieces distal to the parent trunk (Creech, 1954).

TIMING OF ROOT CUTTING COLLECTION

Most authors agree that late fall or early winter—from October through December—is the best time to collect root cuttings, when roots possess their maximum carbohydrate concentrations (Flemer, 1961; Browse, 1980b; Macdonald, 1987; Hartmann et al., 1990). In areas with cold climates, root cuttings are also collected in late winter to early spring (Saul, 1847; Flemer, 1961). Because root buds must develop *de novo* from the inner tissues of the root, they can often be quite slow to develop. In general, the later in the season the root cuttings are collected, the warmer the environment they require for successful propagation (Hudson, 1956; Browse, 1980b).

SIZE OF ROOT CUTTINGS

The optimal size of the cuttings is determined by the environment in which the cuttings will be placed. In general, cuttings stuck in a greenhouse can be 3 to 6 cm long, while those planted directly out-of-doors should be 10 to 15 cm long (Flemer, 1961; Dirr and Heuser, 1983). As Browse (1980b) points out, however, such generalizations can sometime oversimplify the situation: "Only experience can dictate the length of the root cutting of any particular plant and only then in relation to the environment to which it will be subjected—usually a prepared outdoor bed, a cold frame, or a glasshouse bench—the size of the cutting needed decreasing with the warmth of the environment. Size is, of course, a function of two parameters, length and thickness, and although it has been shown that thicker cuttings produce shoots more effectively, those produced from thinner roots establish better."

POLARITY OF ROOT CUTTINGS

All authors agree that the so-called polarity of the cuttings always be respected. Buds tend to form most readily at the proximal end of the cutting (that closest to the trunk). Most authors recommend that this end of the cutting be given a straight horizontal cut, while the distal end of the cuttings receives a sloping, diagonal cut (Flemer, 1961; Macdonald, 1987). This makes it easier to establish proper orientation when sticking the cuttings into the propagation bed. When the cuttings are being stuck, they can be either vertical or diagonal, with the proximal end of the cuttings just at or slightly above the soil surface. Cuttings can also be placed horizontally in flats and covered with a centimeter or two of soil (Creech, 1954; Macdonald, 1987).

TREATMENT OF ROOT CUTTINGS

Fungicide application greatly improves the success rates of root cuttings (Browse, 1980b; Macdonald, 1987). Once cuttings are prepared, they should be put in a plastic bag with a powdered fungicide or dipped briefly in a liquid formulation and shaken so that the entire root piece is covered. Treating root cuttings with superficially applied cytokinin does not appear to significantly enhance shoot production above that of the untreated controls (Brown and McAlpine, 1964; Macdonald, 1987).

WINTER STORAGE OF ROOT CUTTINGS

Root cuttings collected in the fall can be stored in boxes or flats, covered with a moist, well-aerated medium, and put in a frost-free storage structure until early spring. During this storage period, the cuttings will callus over and begin the bud formation process. In late winter or early spring the cuttings can be planted out in the nursery or planted in containers in the greenhouse (Flemer, 1961; Browse, 1980b; Macdonald, 1987).

PROPAGATION ENVIRONMENT

Good discussions of the relationship between the propagation environment and root cutting performance, as well as lists of what plants are best propagated under what environmental conditions can be found in Browse (1980b) and Macdonald (1987).

Out of Doors. In areas with mild winters, root cuttings can be planted directly in the field in late fall or early winter. In areas with severe winters, root cuttings can be collected in the fall and put in cold storage until spring, when they can be planted directly in the nursery. Direct field planting works best with suckering shrubs that naturally form root buds (Flemer, 1961).

Cold Frames. These have been reported to be used successfully in areas with relatively mild winters, such as Great Britain or the Pacific Northwest. They afford more protection to the cuttings than does field planting and therefore offer a greater chance of success.

Cool Greenhouse. For propagation in a cool greenhouse, fall-collected root cuttings that have been kept in cold storage work very well when direct stuck in individual containers in late winter. Root cuttings can also be collected in late winter or early spring, in which case they should be immediately planted in a cool greenhouse with bottom heat (Dirr and Heuser, 1987).

PROPAGATION MEDIUM

The rooting medium should be very well drained to provide maximum aeration. Successful mixes consist of various percentages of peat, bark, sand, grit or perlite. The well-drained medium inhibits the growth of pathogenic fungi and enhances root development (Flemer, 1961; Browse, 1980b; Macdonald, 1987).

ROOT CUTTINGS AS A SOURCE OF STEM CUTTINGS

Interestingly, many root cuttings will produce shoots relatively quickly, but soon collapse after failing to generate new roots (Creech, 1954; Macdonald, 1987). Typically, new roots do not form on a cutting until after the shoot is formed, and often they develop adventitiously from the base of the new shoot rather than from the original root piece. Because of this phenominom, a modified technique has been developed that involves forcing shoots on root cuttings in the greenhouse, which are then removed and used as softwood cuttings. Because these shoots are physiologically juvenile they tend to root more readily than cuttings taken from other parts of the tree (Creech, 1954; Flemer, 1961; Fordham, 1969).

IN SITU ROOT CUTTING TECHNIQUES

It is important to keep in mind that there are many species that sucker naturally in nature (e.g. *Asimina triboba*), that have not been successully propagated from ex situ root cuttings. The species must be propagated using in situ techniques applied in the late fall. This method involves cutting around the stem(s) of a plant with a sharp spade, then moving out the 15 to 25 cm and cutting a second concentric circle around the first. All servered roots are left in the ground and shoot buds will form at their distal ends come spring. Such "pre-cut" plants can easily be dug up and potted the following year.

Table 1. Hardy trees that have been successfully propagated from root cuttings, followed by their appropriate literature citations.

Ailanthus altissima: 2, 4, 6, 14, 17, 23, 26, 27
Albizia julibrissin: 1, 2, 4, 8, 10, 14, 15, 17, 23, 26
Amelanchier species: 4, 10, 14, 23, 27
Asimina triloba: 1, 2
Broussonetia papyrifera: 2, 10, 17, 23, 26
Carya species: 2
Catalpa species: 2, 4, 23, 26, 27
Toona sinensis (syn. *Cedrela sinensis*): 1, 2, 4, 23
Cladrastis species: 2, 4, 10, 23
Crataegus species: 1, 22, 27
Cydonia oblonga: 2, 12, 26, 27
Elliottia racemosa: 15
Euonymus species: 1, 12, 24
Tetradium (syn. *Euodia*) species: 2, 4
Ficus carica: 17, 27
Gleditsia triacanthos: 10, 24
Gymnocladus dioica: 4, 10, 22, 23, 26
Halesia species: 2, 26
Kalopanax septemlobus (syn. *K. pictus*): 10, 23
Koelreuteria paniculata: 1, 2, 4, 8, 10, 17, 23, 26
Laurus nobilis: 2, 12
Liquidambar styraciflua: 3
Maackia amurensis: 4, 8, 10
Maclura pomifera: 4, 5, 22, 26
Malus species: 4,10, 14, 17
Morus species: 2, 14, 27
Paulownia tomentosa: 6, 23, 26, 27
Phellodendron amurense: 2, 4, 10, 23
Picrasma quassioides: 1,4, 15, 23
Populus species: 1, 10, 14, 17, 23, 25, 26
Prunus species: 1, 2, 4, 8, 14, 17, 24, 27
Pterocarya species: 1, 10
Pyrus calleryana: 10, 17, 24
Robinia pseudoacacia: 2, 14, 17, 23, 25, 27
Sassafras albidum: 2, 4, 14, 17, 23, 26
Sophora japonica: 17, 27
Staphylea species: 2, 10, 27
Ulmus species: 10, 14, 17, 27
Xanthoceras sorbifolium: 1, 2, 4, 8, 10, 21, 23
Zizyphus jujuba: 2, 17, 27

Table 2. Hardy shrubs and vines that have been successfully propagated from root cuttings, followed by their appropriate literature citations.

Acanthopanax species: 2, 17
Actinidia deliciosa: 10, 17
Aesculus parviflora: 4, 10, 14, 17, 23
Amorpha species: 4, 27
Aralia species: 1, 2, 4, 10, 14, 17, 23, 27
Aristolochia species: 1, 22
Aronia species: 4, 24, 27
Berberis species: 12, 27
Bignonia capreolata: 4, 23, 26, 27
Camellia species: 8, 19
Campsis radicans: 4, 14, 17, 23
Caragana species: 2, 27
Celastrus species: 1, 2, 4, 14, 17, 27
Chaenomeles species: 2, 4, 8, 10, 14, 17, 23, 24, 26, 27
Clematis species: 21, 27
Clerodendrum species: 1, 4, 10, 14, 17, 23, 22
Clethra alnifolia: 1, 8, 10
Comptonia peregrina: 1, 4, 10, 14, 17, 23, 27
Corylus maxima: 12, 17
Cotinus species: 11, 24
Cyrilla racemiflora: 8, 10, 17
Daphne species: 4, 8, 10, 17, 23, 27
Decaisnea fargesii: 23
Elaeagnus species: 2, 26
Fatsia species: 2, 4
Forsythia species: 12, 17, 24, 27
Fothergilla species: 10, 27
Gardenia species: 19, 27
Hippophae rhamnoides: 2, 26, 27
Hydrangea quercifolia: 10, 14
Hypericum calycinum: 17, 12
Ilex species: 8, 24
Illicium floridanum: 10, 11
Indigofera species: 4, 10, 23
Lagerstroemia indica: 4, 8, 10, 23
Leitneria floridana: 1, 4
Lonicera species: 12, 27
Meliosma species: 4, 23
Myrica species:10, 14, 17
Nandina domestica: 26, 27
Orixa japonica: 4, 23
Paliurus species: 2, 26
Pyracantha coccinea: 10, 24
Rhododendron species (azaleas): 8, 16, 27
Rhodotypos scandens: 10, 24
Rhus species: 4, 10, 14, 17, 23, 26, 27
Ribes species: 10, 27
Robinia hispida: 4,10, 14, 17, 23
Rosa species: 2,10, 14, 17, 21, 23, 27
Rubus species: 1, 2, 4, 10, 14, 17, 18, 23, 27
Sambucus species: 2, 23
Sorbaria sorbifolia: 2, 10
Spiraea species: 11, 24
Symphoricapos species: 17, 24
Syringa vulgaris: 2, 8, 10, 14, 17, 23, 24, 27
Vaccinium species: 1, 2
Viburnum species: 24, 27
Wisteria species: 4, 8, 14, 27
Xanthorhiza simplicissima: 14, 27
Zanthoxylum species: 2, 4, 10, 23, 27

Table 3. Hardy, woody genera that are reported by only one authority to be propagated from root cuttings or to produce root suckers in nature. These *unconfirmed* genera are good candidates for future research.

Alnus: 27	*Mahonia*: 24
Buckleya: 1	*Menispermum*: 27
Buddleja: 11	*Mespilus*: 11
Calycanthus: 27	*Neillia*: 12
Cercis: 27	*Parthenocissus*: 11
Chimonanthus: 11	*Phoebe*: 11
Coriaria: 11	*Photinia*: 27
Cornus: 12	*Potentilla*: 11
Cotoneaster: 27	*Ptelea*: 27
Cytisus: 11	*Punica*: 11
Diervilla: 27	*Sapindus*: 11
Diospyros: 11	*Sarcococca*: 24
Dirca: 27	*Sorbus*: 27
Genista: 27	*Stephanandra*: 11
Hibiscus: 11	*Tamarix*: 27
Jasminum: 11	*Trachelospermum*: 11
Kerria: 27	*Vitex*: 11
Ligustrum: 27	*Vitis*: 11
Lindera: 26	*Weigela*: 27
Lycium: 11	*Zelkova*: 1

Table 4. Native North American timber trees listed in *Silvics of North America* (5) as reproducing from root sprouts following logging. Those genera marked with an * have not been reported in the horticultural literature as propagated from root cuttings.

*Acer negundo**	*P. deltoides*
Carya cordiformis	*P. grandidentata*
C. ovata	*P. tremuloides*
Diospyros virginiana	*P. balsamifera ssp. trichocarpa*
*Fagus grandifolia**	*Prunus pensylvanica*
Gleditsia triacanthos	*Quercus michauxii**
Liquidambar styraciflua	*Q. virginiana**
Maclura pomifera	*Robinia pseudoacacia*
Morus rubra	*Salix nigra**
*Nyssa sylvatica**	*Sassafras albidum*
Populus balsamifera	*Ulmus thomasii*

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