Shoots From Roots: A Horticultural Review

Peter Del Tredici

Many successful plant propagation techniques were inspired by observations of plants in nature. What plant propagator has not seen suckers arising at some distance from the main stem of a tree or shrub and concluded that this is a plant that could be propagated from root cuttings.

Such observations can be traced back at least to the days of the ancient Greek philosopher Theophrastus (371–287 BC). As he was in most botanical matters, Theophrastus was the first to describe the process of root-sucker formation and to attempt to elucidate the causes:

> Now most trees produce these suckers next to the trunk, the roots being here most shallow; and the olive produces them from the base of the trunk as well. But the pear, pomegranate and all trees that produce suckers not only close to the trunk but at a distance from it, have long roots, and send up the shoot wherever the long root comes near the surface, for it is here that the conflux is formed with the resulting concoction as it is warmed. This is why there is nothing fixed about the place of the sucker, for there is nothing fixed about the approach of the root to the surface and the site of the conflux (Book 1: 3.5).

The earliest description that I could find of actual propagation of trees from roots is by John Evelyn, who in 1706 (and perhaps as early as 1664) noted that species of *Ulmus*, *Prunus*, and *Populus* produced root suckers that could be

A stand of root sprouts from a single forty-year-old sweetgum tree, Liquidambar styraciflua. *The sprouts range in age from one to fifteen years, and some are over five inches in diameter at breast height. The grids are one meter on each side. Photograph by P. P. Kormanik, U.S. Forest Service, Athens, Georgia, from Kormanik and Brown, 1967.*

dug up and planted. Evelyn went so far as to include detailed instructions for how to propagate trees from roots: "To produce succers, 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 HMS *Bounty* was charged with transporting from the South Pacific to the West Indies. It was during the breadfruit's five-month propagation period in Tahiti that the Bounty's crew developed the taste for liberty that ultimately led to their infamous mutiny in 1789.

The Ecology of Root Suckering

In addition to its importance to propagation, root suckering in trees and shrubs also has significant ecological implications, as documented in the new edition of *Silvics of North America,* edited by Russell Burns and Barbara Honkala and published in 1990. Of the 108 nontropical, native trees listed in *Silvics,* 22 of them (21%) are reported to reproduce from root sprouts. Whether this ratio of root-sprouting to nonroot-sprouting species would hold true for a wider sample of trees remains to be determined.

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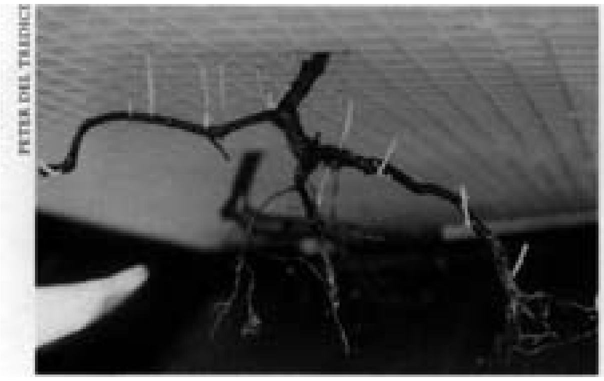
An old specimen of the American beech growing at the Arnold Arboretum. It has produced abundant root suckers.

The most well-known root-suckering tree is the quaking aspen, *Populus tremuloides.* This species plays a particularly important ecological role in the Rocky Mountain region, where "clones" of a single tree have been found covering more than 107 acres and totalling an estimated 47,000 distinct stems. In the East, *Sassafras albidum* spreads primarily from root suckers, as does the ubiquitous black locust, *Robinia pseudoacacia,* and the understory-dwelling pawpaw, *Asimina triloba.* Another root-suckering species that has been extensively studied is the American beech, *Fagus grandifolia,* which grows over much of eastern North America. In the northern and eastern parts of its range, the species grows at moderate elevations on cool, rocky slopes and root suckers profusely following logging or disease-induced injury. In the southern and western parts of its range, however, beech is a bottomland species and shows little or no tendency to root sucker. Because this trait is difficult to put onto a herbarium sheet, however, few taxonomists have recognized it as a legitimate character for distinguishing the southern and northern ecotypes as distinct subspecies.

Propagation From Root Cuttings

Since the mid-1800's, an extensive literature on the propagation of plants from root cuttings has appeared. Especially noteworthy is an article by the German author, Wobst (1868), that provides an extensive list of species—including many not referred to 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). Interestingly, references to root-cutting propagation are more numerous in the older literature than in the modern. This is probably because modern advances in softwood stem-cutting technology—



This specimen of sweet fern (Comptonia peregrina) *was dug up from the wild and placed in a closed "mist box." Buds developed along the roots within a month.*

including the use of polyethylene film, rooting hormones, and intermittent mist—have rendered the slower and more cumbersome process of propagating by root cutting obsolete. Nevertheless, a number of difficult-to-root woody plants—primarily in the families Anacardiaceae, Araliaceae, Leguminoseae, Myricaceae, and Rosaceae—are still most effectively propagated from root cuttings. In particular, there are many native shrubs that, because of their root-suckering habit, are ideal candidates for stabilizing roadside banks and other difficult habitats. Species in the genera *Rhus, Comptonia, Myrica, Robinia, Aralia,* and *Clethra* do well under such conditions and can all be propagated from root cuttings.

Unfortunately, much of the literature on root-cutting propagation is difficult to interpret because of 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 literature on root cuttings by identifying those species that have been reported by more than one author to reproduce from root cuttings (see Tables 1 and 2). I have made an exception to this requirement of independent confirmation if an author provides documentary evidence of successful root-cutting propagation with a given species. Of necessity, this article is limited to hardy woody plants. 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 author's experience or expertise.

It is worth noting that all of the species listed in this article as being propagated from root cuttings are angiosperms. The only two gymnosperms ever documented as producing root suckers in nature are tropical conifers, *Araucaria cunninghamii* (Burrows 1990) and *Dacrydium xanthandrum* (Wong 1994). Interestingly, *A. cunninghamii* was also listed by Wobst in 1868 as propagated from root cuttings. Despite reports that *Ginkgo biloba* and *Sequoia*

Root suckers produced by Crataegus punctata *(AA#5608) growing at the Arnold Arboretum.*

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 well beyond the scope of this paper. For information on this topic, one should consult the excellent review by Peterson (1975). For a detailed ecological study of root sprouting by a tree in its native habitat, consult Kormanik and Brown (1967) on *Liquidambar styraciflua.*

What follows is a summary of the information available on the techniques for propagating woody plants from root cuttings, as described in the English-language horticultural literature. After the section on techniques are lists of species that have been successfully propagated from root cuttings.

Types of Root Cuttings

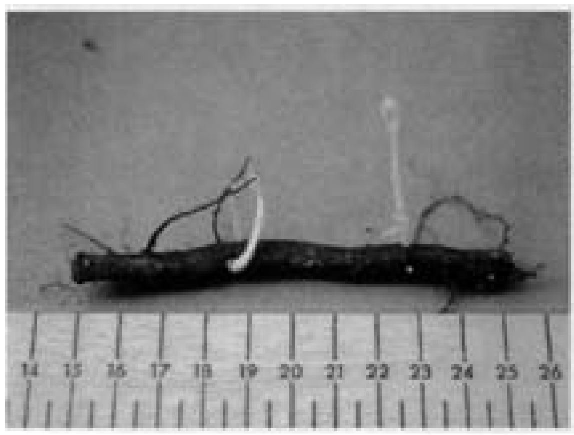
When discussing the propagation of plants from root cuttings, precise terminology is needed to describe the so-called polarity of the root. *Proximal* describes the end of the root nearest to the stem from which the root grew; *distal* describes the end furthest from the parent stem. This is important to remember because when a root cutting develops a 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:

1) *Natural suckering without division.* This category includes species that produce root suckers naturally near the parent trunk, forming a densely packed cluster of stems.

2) *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 fragments of the parent plant that can be readily transplanted.

3) *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 also occurs 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.

4) In situ *whole root cuttings.* This category includes plants that form 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 numerous severed roots behind. Provided they are not disturbed, these roots will give rise to new shoots.



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Successfully propagated root cuttings of the English hawthorn, Crataegus laevigata.

5) Ex situ *detached root cuttings.* This category includes plants that form suckers from root cuttings 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 number of plants produced.

Source of Root Cuttings

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

1) There is a clear distinction between roots spouting in nature and induced sprouting from root cuttings. Some species that do not appear to sucker in nature can be induced to produce sprouts from root cuttings propagated under nursery conditions.

2) Unfortunately, many horticultural selections in which the desired mutation consists of a periclinal chimera, including many desirable 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 different types of meristems in root versus shoot buds, a difference that is most strikingly seen in blackberries (*Rubus* spp.), in which plants propagated from stem cuttings are covered with thorns while those from root cuttings are thornless (Creech 1954; Peterson 1975).

3) While it may seem obvious, it is important to remember that horticultural selections grafted onto seedling understock cannot be propagated from root cuttings.

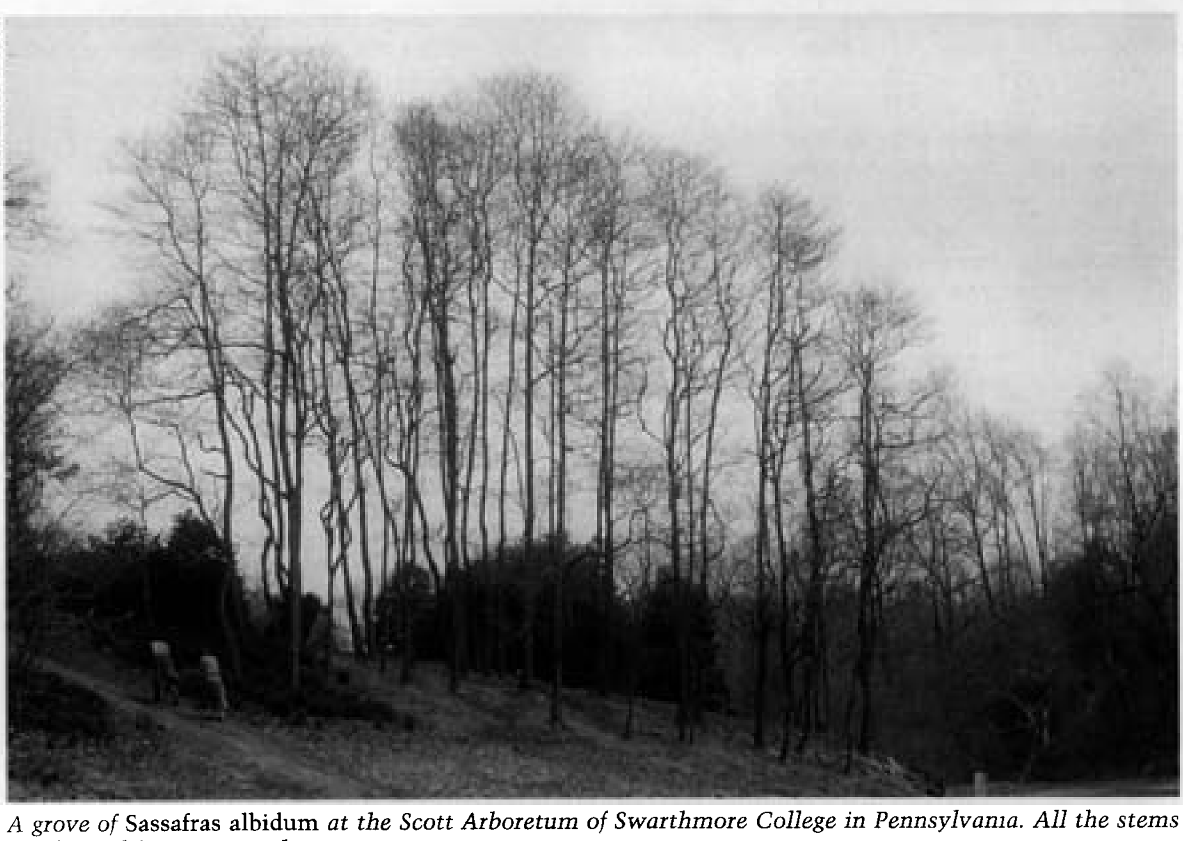
4) Younger plants reproduce more reliably from root cuttings than older plants.

5) 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).

6) Some species can readily be propagated from *ex situ* detached root cuttings, while others will only produce shoots from *in situ* whole root cuttings. Experience is the only way to determine the most effective type of propagation method for any given species.

Timing for Root-Cutting Collection

Most authors agree that late fall or early winter—from October through December, when roots possess their maximum carbohy-



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A grove of Sassafras albidum *at the Scott Arboretum of Swarthmore College in Pennsylvania. All the stems are derived from root suckers* drate concentrations—is the best time to collect root cuttings (Browse 1980b; Macdonald 1987; Hartman et al. 1990). In areas with cold climates, root cuttings are also collected in late winter to early spring (Saul 1847; Flemmer 1961). Because root buds must develop *de novo* from the inner tissues of the root, they can sometimes be quite slow to develop. In contrast, dormant buds on the trunk are preformed and sprout out rapidly following injury. 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 three to six centimeters long, while those planted directly out-of-doors should be ten to fifteen centimeters long (Flemmer 1961; Dirr and Heuser 1983). As Browse (1980b) points out, however, such generalizations can sometimes 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 must 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 (Flemmer 1961; Macdonald 1987). This makes it easier to establish proper orientation when sticking the cuttings into the propagation bed. Cuttings can be stuck either vertically or diagonally, 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

The use of fungicide greatly improves the success rates of root cuttings (Browse 1980b; Macdonald 1987). Once cuttings have been made, they can either be put in a plastic bag with a powdered fungicide and shaken so that the entire root piece is covered or dipped briefly in a liquid formulation. Treating root cuttings with superficially applied cytokinin does not appear to significantly enhance shoot production above that of 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 minimally heated storage structure until early spring. During this storage period, the cuttings will callus over and begin the bud formation process. (Browse 1980b; Macdonald 1987).

Propagation Environment

1) *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 shrubs that naturally form root buds (Flemmer 1961).

2) *Cold frames.* These have reportedly been 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.

3) *Cool greenhouse.* Fall-collected root cuttings that have been kept in cold storage can be propagated very well in a cool greenhouse when "direct stuck" in individual containers in late winter. Root cuttings collected in late winter or early spring should be immediately planted in a cool greenhouse with bottom heat (Dirr and Heuser 1987).

Additional information on the relationship between the propagation environment and root cutting performance, as well as the optimum environment for propagating selected species, can be found in Browse (1980b) and Macdonald (1987).

Propagation Medium

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

Root Cuttings as a Source of Shoots for Stem-Cutting Propagation

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 from the base of the new shoot rather than from the original root piece. Because of this phenomenon, a modified technique has been developed that involves removing shoots propagated from root cuttings in the greenhouse and using them 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; Flemmer 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, such as the pawpaw, *Asimina triloba,* that have not been successfully propagated from *ex situ* root cuttings. These species must be pro-

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, 28	*Laurus nobilis:* 2, 12
Albizia julibrissin: 2, 4, 8, 10, 14, 15, 17, 23, 26	*Liquidambar styraciflua:* 3
Amelanchier spp.: 4, 10, 14, 23, 28	*Maackia amurensis:* 4, 8, 10
Asimina triloba: 1, 2	*Maclura pomifera:* 4, 5, 22, 26
Broussonettia papyrifera: 2, 10, 17, 23, 26	*Malus* spp.: 4, 10, 14, 17, 24
Carya spp.: 2	*Morus* spp.: 2, 14, 28
Catalpa spp.: 2, 4, 23, 26, 28	*Paulownia tomentosa:* 6, 23, 26, 28
Cedrela sinensis: 1, 2, 4, 23	*Phellodendron amurense:* 2, 4,10, 23
Cladrastis spp.: 2, 4, 10, 23	*Picrasma quassioides:* 15, 23
Crataegus spp.: 1, 28	*Populus* spp.: 1, 10, 14, 17, 23, 25, 26
Cydonia oblonga: 2, 12, 26, 28	*Prunus* spp.: 1, 2, 4, 8, 14, 17, 24, 28
Elliottia racemosa: 15	*Pterocarya* spp.: 1, 10
Euonymus spp.: 1, 12, 24	*Pyrus calleryana:* 10, 17, 24
Evodia spp.: 2, 4	*Robinia pseudoacacia:* 2, 14, 17, 23, 25, 28
Ficus carica: 17, 28	*Sassafras albidum:* 2, 4, 14, 17, 23, 26
Gleditsia triacanthos: 10, 24	*Sophora japonica:* 17, 28
Gymnocladus dioicus: 4, 10, 22, 23, 26	*Staphylea* spp.: 2, 10, 28
Halesia spp.: 2, 26	*Ulmus* spp.: 10, 14, 17, 28
Kalopanax pictus: 10, 23	*Xanthoceras sorbifolium:* 1, 2, 4, 8, 10, 21, 23
Koelreuteria paniculata: 1, 2, 4, 8, 10, 17, 23, 26	*Zizyphus jujuba:* 2, 17, 28

pagated using *in situ* techniques applied to plants in the late fall. The method involves cutting around the stem(s) of a plant with a sharp spade, then moving out fifteen to twenty-five centimeters and cutting a second, concentric, circle around the first. All 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 and potted up in the fall or the following spring. This technique is particularly effective for propagating shrubs that sucker naturally.

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

Acanthopanax spp.: 2, 17
Actinidia deliciosa: 10, 17
Aesculus parviflora: 4, 10, 14, 17, 23
Amorpha spp.: 4, 28
Aralia spp.: 1, 2, 4, 10, 14, 17, 23, 28
Aristolochia spp.: 1, 22
Aronia spp.: 4, 24, 28
Berberis spp.: 12, 28
Bignonia capreolata: 4, 23, 26, 28
Camellia spp.: 8, 19
Campsis radicans: 4, 14, 17, 23
Caragana spp.: 2, 28
Celastrus spp.: 1, 2, 4, 14, 17, 28
Chaenomeles spp.: 2, 4, 8, 10, 14, 17, 23, 24, 26, 28
Clematis: 21, 28
Clerodendrum spp.: 1, 4, 10, 14, 17, 23, 22
Clethra alnifolia: 1, 8, 10
Comptonia peregrina: 1, 4, 10, 14, 17, 23, 28
Corylus maxima: 12, 17
Cotinus spp.: 11, 24
Cyrilla racemiflora: 8, 10, 17
Daphne spp.: 4, 8, 10, 17, 23, 28
Decaisnea fargesii: 23
Elaeagnus spp.: 2, 26
Fatsia spp.: 2, 4
Forsythia spp.: 12, 17, 24, 28
Fothergilla spp.: 10, 28
Gardenia spp.: 19, 28
Hippophae rhamnoides. 2, 26, 28
Hydrangea quercifolia: 10, 14
Hypericum calycinum: 17, 12
Ilex spp.: 8, 11, 24
Illicium floridanum: 10, 11
Indigofera spp.: 4, 10, 23
Lagerstroemia indica: 4, 8, 10, 23
Leitneria floridana: 1, 4
Lonicera spp.: 12, 28
Meliosma spp.: 4, 23
Myrica spp.:10, 14, 17
Nandina: 26, 28
Orixa japonica: 4, 23
Paliurus spp.: 2, 26
Pyracantha coccinea· 10, 24
Rhododendron spp. (azaleas): 8, 16, 28
Rhodotypos scandens: 10, 24
Rhus spp.: 4, 10, 14, 17, 23, 26, 28
Ribes spp.: 10, 28
Robinia hispida: 4,10, 14, 17, 23
Rosa spp.: 2, 10, 14, 17, 21, 23, 28
Rubus spp.: 1, 2, 4, 10, 14, 17, 18, 23, 28
Sambucus spp.: 2, 23
Sorbaria sorbifolia· 2, 10
Spirea spp.: 11, 24
Symphoricarpos spp.: 17, 24
Syringa vulgaris: 2, 8, 10, 14, 17, 23, 24, 28
Vaccinium spp.: 1, 2
Viburnum spp.: 24, 28
Wisteria spp.: 4, 8, 14, 28
Xanthorhiza simplicissima: 14, 28
Zanthoxylum spp.: 2, 4, 10, 23, 28

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