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Propagation of Several Native Ornamental Plants

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PROPAGATION OF SEVERAL NATIVE ORNAMENTAL PLANTS

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Interest in growing native plants has been increasing in recent years. In an effort to better understand some valuable native plants for use in the Northeast, the propagation and taxonomy of several plants with potential as landscape plants were explored. In an effort to make more propagation information available to nursery growers and plant propagators, commercially feasible propagation methods were researched.

Asarum canadense, Canadian wild ginger, seed is typically difficult to germinate; so warm stratification and gibberellic acid were tested to determine if this process would increase germination. Warm stratification mimics conditions to which the seed would typically be exposed in nature, and gibberellic acid is a plant hormone that can substitute for cold stratification and help increase germination of seeds. After one, two, or three months in warm stratification; seed was soaked in gibberellic acid for 24 hours and placed in petri dishes. None of the seeds germinated, this could be the result of a double dormancy in the seed.

Comptonia peregrina, sweet fern, is a native shrub often used in landscapes and erosion control. Because seed is difficult to germinate and stem cuttings are not successful, root cuttings are the commonly used propagation method. Root cuttings were

tested for their reaction to cold stratification length and temperature. The cuttings did respond to stratification length and temperature, with one month of cold stratification we achieved 100% rooting. In addition to rooting at higher percentages, cuttings treated with consistent temperatures of 3-4°C also rooted sooner, had more shoots per cell, and had longer shoots.

Two species of dogwood, *Cornus alternifolia* and *C. rugosa*, were tested for their reaction to different treatments of stem cuttings. *C. alternifolia* roots readily from softwood cuttings, but rooted cuttings have some difficulty overwintering. Extended photoperiods did not increase rooting percentages, suggesting that photoperiods do not effect rooting. *C. rugosa* is a relatively unknown in the nursery trade, so research was conducted to determine optimum propagation methods. Softwood cuttings were taken, but the leaves quickly turned brown and the cuttings died. Hardwood cuttings rooted at much higher percentages, with supplemental lighting actually being detrimental to rooting.

Gaultheria procumbens, wintergreen, is a native woody plant with many potential uses in the landscape. Seed is typically hard to germinate, so seed was soaked for 24 hours in gibberellic acid to determine if germination percentages could be increased. Light conditions (ambient, extended, and dark) were also tested. Gibberellic acid did significantly increase percentages and ambient light conditions were found to be best for germination.

Viburnum lantanoides and *V. nudum* var. *cassinoides* were tested for their reaction to treatments of softwood stem cuttings, rooting hormones, and extended photoperiods. *V. lantanoides* rooted readily with 1000 ppm K-IBA treatment and light

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Chapter 1

INTRODUCTION

Native plants are of incredible interest and importance to the horticulture industry. Not only do horticulture professionals value native plants for their countless landscape uses, we also recognize their value in preserving natural ecosystems around the world. Our native plants evolved in New England, adapting to our soil conditions, rainfall, and cold winters, making them ideal plants for managed landscapes. Not only are they adapted to our environment; they also provide much needed food and shelter for countless species of animals.

Ornamentally, native plants have many uses and attributes, from herbaceous perennials for summer flowering to trees and shrubs that provide year-round interest in the garden. Native plants are of great importance in the battle against invasive plants that threaten natural habitats around the country. By encouraging the use of native species horticulture professionals will not only select and grow superior plants for managed landscapes, we will also be taking an important step in preserving our natural environment.

Native plants need to be part of our modern managed landscapes. Expanding the availability of native plants will supplement the plant selection of both native and non-native species that horticulturalists have available. Promoting natives will not result in the replacement of all non-native species, as many non-native species are valuable ornamental plants. From herbaceous species that provide color and interest in perennial gardens to the trees and shrubs that are the backbone of landscape design, native species are ideal. Native species meet and exceed standards of drought, disease, and pest tolerance in their native habitats while at the same time help provide the colors, textures, and forms that make landscape designs successful (Dreyer, 1993).

In 1997, the Tennessee Exotic Pest Council outlined seven reasons for the use of native plants for landscaping:

- Natives are adapted to regional conditions, may require less maintenance, and are cost-effective.
- Natives are hardy, withstand extreme cold winter, and do not suffer from die back.
- Natives are environmentally friendly and require fewer pesticides and fertilizers because of natural adaptations.
- Use of natives promotes biodiversity and land stewardship.
- Use of native plants provides food and shelter for native wildlife.
- Native plants can be used to restore regional landscapes.
- Use of natives ensures there will be less chance for introduced ornamentals to become invasive.

By promoting the use of native plants in nurseries and garden centers, horticulturalists may be able to begin to lessen the demand for some popular plants that have escaped cultivation and pose threats to natural areas. Exotic plants, (plants introduced into this country from other areas of the world) for the most part, are important ornamental and agricultural crops that play important roles in the industry. Unfortunately, many have escaped cultivation and are crowding out and smothering native habitats. These are defined as invasive plants, and are costing federal and local governments millions of dollars to control. Some of these plants are commonly used in managed landscapes. The Garden Club of America's Horticulture Committee compiled a list of plants than can be used instead of invasives. For example, natives *Clethra alnifolia, Vaccinium corymbosum,* and *Ilex verticillata* are all recommended substitutions for the potentially invasive *Euonymus alatus*. They believe that by promoting plant alternatives, gardeners can help preserve and promote plant biodiversity.

Understanding native plant propagation will also help lessen another threat to native plants: the collection of plants from the wild. *Asarum canadense* and *Gaultheria procumbens* (Canadian wild ginger and wintergreen) are both commonly propagated by division. If stock plants of either of these (or any other native plant propagated by division) are not available, digging from the wild has become the option for providing these plants to consumers. This is not an acceptable practice, so providing plant propagators with the resources to grow their own stock plants (in the case of these two plants, via seed propagation) and to propagate from them will reduce the need to collect plant material from the wild.

The feasible propagation and production of native plants is important to plant growers. With easier propagation methods will come greater availability of these plants in the nursery trade. Ideally, with greater availability of a wider selection of native plants nursery owners will be able to give their customers alternatives to invasive plants. Of the plants in this research, several are currently used commercially, while others are just beginning to be discovered as landscape plants. By researching feasible commercial propagation methods, better propagation information will be available to the nursery industry.

Two species of *Cornus* will be researched to enhance understanding of their propagation. *C. alternifolia*, the Pagoda Dogwood, is currently available from some nurseries. Its attractive horizontal branching growth habit makes it an ideal candidate for the winter landscape. In addition, its creamy white flowers and clean, glossy green foliage (which turns an attractive scarlet red in the fall) make it a worthwhile specimen in any garden. Propagation is currently by softwood cuttings, with variable success getting the cuttings though their first dormant period (Dirr and Heuser, 1987). To improve propagation success, softwood cuttings will be taken and treated with rooting hormone and then placed under different light conditions (regular and 24-hour) to see if extended photoperiod will increase rooting and growth. *C. rugosa*, the Round-Leafed Dogwood, is less-known. Native in Eastern North America, its appeal lies in not only its white flowers, but also in the potential for selection of fall color, which ranges from deep oranges to reds. There is currently no literature available on vegetative propagation, so hardwood propagation will be explored because a close relative, *Cornus serecia*, roots readily from hardwood cuttings. Hardwood cuttings will be taken in late winter, treated with rooting hormones, and placed under different lighting conditions (regular and 24-hour) to determine if extended photoperiods increase rooting percentages.

Viburnum is a widely grown genus of garden shrubs. Their popularity is growing due to increased attention not only to their flowers, fruit, and foliage displays, but also their benefits to wildlife. The two plants in this research, *V. lantanoides* (syn. *V. alnifolium*), hobble-bush *and V. cassinoides*, withe-rod, will make ideal plants for the understory in woodland gardens and along the woodland edge. Both are native to Eastern North America and are currently used sparingly in the nursery industry. With increased information about their propagation, more nursery growers can make them available to their customers. For both of these plants, softwood cuttings will be taken and treated with rooting hormones. They will then be exposed to two different lighting conditions (regular day and 24-hour) to determine if extended light increases rooting percentages.

Sweet fern, *Comptonia peregrina*, is a shrub that thrives in sandy, sunny sites along roadsides, in disturbed or clear-cut areas, and in other difficult locations. It has the potential to be useful as a tall groundcover in gardens and an erosion control plant along roadsides. Its glossy green foliage is aromatic and turns a bright scarlet red in the fall. Seed of sweet fern is difficult to germinate, so root cuttings have long been the preferred method for propagation. Improving this method will be the goal of this research. Taking root cuttings in the fall and studying the effect of the length and temperature of cold stratification can establish a propagation method that is successful for nursery growers in the north.

Gaultheria procumbens, wintergreen, is the Maine state herb. It is a small woody plant used as a groundcover in a range of conditions. Its small white flowers followed by red berries make it attractive in the spring and summer, and its foliage creates an outstanding mat of purple in the fall. Seed propagation is relatively difficult. Cullina (2000) noted that wintergreen is slow from seed and the seed may benefit from a cold stratification. Gibberellic acid is a plant hormone that can substitute for the cold stratification and increase seed germination. By testing the effects of gibberellic acid and lighting conditions on *G. procumbens* seed, better propagation can be discovered.

Herbaceous species are also important to the native garden. *Asarum canadense*, Canadian wild ginger, is a small groundcover with matte green leaves that serves as a companion to many woodland plants. It grows readily in the garden and division is the most common method of propagation. Seed germination is difficult. Barton (1944) noted that the seeds need alternating periods of warm and cold stratification. This research will determine if the process can be sped up via the use of gibberellic acid and warm stratification to break dormancy.

The Sierra Club stated, "the key to wildlife and native plant conservation is the continued existence of diverse natural ecosystems and the preservation of native biodiversity" (2001). By promoting the nursery propagation and use of native plants in landscapes, gardens, and in restoration and erosion control projects, horticulturalists can contribute to this conservation effort.

Chapter 2

LITERATURE REVIEW

Why Native Plants?

Native plants represent a wide variety of ornamental plants that not only provide for our need for beauty in the landscape, but also fill the need for plants that are cold-hardy and more disease and pest resistant. They also support the stability of the natural landscape.

Definition of Native

C. Colston Burrell (1997) defined native plants as those that are growing and reproducing in a specific site, state, or region without introduction. William Cullina (2000), plant propagator and nursery manager at the New England Wildflower Society, stated that native plants are those which were growing in North America prior to European settlement. For many, the date of European settlement is important in determining what plants are native, and for others a native plant is defined in the strictest sense of the word and includes only those plants that are indigenous to the particular site in question. For the purposes of this research we will use Cullina's definition and consider a plant native if it was growing here prior to European settlement. The plants selected for this research are particularly suited for growth in the Northeastern United States, but can be grown anywhere in the country where the climate is suitable.

Reasons for Growing Native Plants

There are several reasons for growing native plants. They adapt to our environment, offer ornamental characteristics, help feed and shelter wildlife and lead to the preservation and promotion of natural habitats. They also can, in some cases, be offered as alternatives for some invasive species that are currently becoming a problem in our natural landscapes.

Adaptations to Our Environment. Native plants have evolved over years to adapt to the conditions of their specific ecosystem. Without fertilizer, irrigation, or pesticides, they have survived and thrived through our cold winters and the variable weather of our springs, summers, and falls. They adapt to our soil conditions (Dreyer, 1993) and have evolved with other species to form complex natural ecosystems.

In California, a drought some years ago devastated green lawns and lush gardens. After the drought, nurseries found it difficult to sell water-loving plants to homeowners. Instead, people wanted plants that would grow without costly inputs such as irrigation. As a result, the use of California native plants became more popular (McLaughlin, 1980).

Highway departments in many states are establishing programs to promote the reintroduction of wildflowers, grasses, and shrubs onto roadsides and median strips. In California, the highway department found that by using native plants, herbicide use is reduced and erosion control is improved because many native plants have deeper root systems. In Texas, roadsides in many locations are mowed only after the natives have gone to seed. There is a 600-plus page book produced by the Federal Highway Administration which highlights native plants for each state, and in states like Iowa and

Wisconsin, native plant use is increasing while mowing maintenance is decreasing (Line, 2000).

It is important to note, however, that native plants are not meant to replace all of the non-native, or introduced ornamental plants. Many non-native plants have become valuable assets to gardens and landscapes (Kendel and Rose, 2000). Also, not all native plants are meant for use in the managed landscape. Landscapes are disturbed habitats, and because a plant that will thrive in the wild does not mean it will do the same in the garden, where soil conditions, light, and other factors may be different from a plant's usual habitat (Birr, 1987).

Ornamental Attributes. Native plants offer attractive attributes from spring through winter. These attributes vary from flowers and fruit to texture and growth habit, all of which successfully contribute the landscape. In addition to how they look, many will grow in difficult situations, making them even more desirable plants.

Many professionals point out the virtues of native plants. Dreyer (1993) noted the striking horizontal branching pattern of pagoda dogwood (*Cornus alternifolia*) and the color and fragrance that the summer sweet clethra (*Clethra alnifolia*) both add interest to the landscape. Natural heritage also plays a role in some peoples decision to grow native plants. Many people choose to plant landscapes that echo a local native plant community (Burrell, 1997). Native plants fill a niche in gardens that satisfies our need for aesthetically pleasing, low maintenance, hardy plants (McTavish, 1986).

On a more practical level, many native plants are used as carefree ground covers. Bearberry (*Arctostaphyllous uva-ursi*) thrives in sandy, poor soils, forming a dense mat of foliage in otherwise problem areas (Dreyer, 1993). Sweet fern (*Comptonia peregrina*) has the ability to fix nitrogen via nodules in its roots (Ziegler and Heuser, 1963) and can be used as roadside erosion control as well as a groundcover in gardens (Zak and Bredakis, 1967). Many other native plants are used in erosion control or wetland mitigation, and all contribute greatly to the beauty of the landscape in which they were planted to restore.

On golf courses, native plant use is gaining popularity. On one coarse in Missouri, native plants not only increased the aesthetics of the course, but also reduces maintenance. Less water is used in their native plantings and only a very light fertilizer (1-1-1) application is needed. The superintendent at this course, however, points out that the best advantage to native plants is the beauty they bring to his course. (Weston, 1990).

Wildlife Benefits. Native plants also support and shelter wildlife. The fruits of native plants feed wildlife, and this wildlife is added bonus for many gardeners. Native plants provide excellent shelter for these animals as well.

Many of the animals that are currently managed for game are native to North America, and as a result, they are best adapted to feeding on the native plants they evolved with. Not only can native plants provide essential shelter for displaced wildlife, but many species provide the same nutritional value without the ecological threats that may be associated with nonnative forage plants (Virginia Department of Conservation, 2002). In other areas, native aquatic plants help shelter and support fish, which in turn support native bird populations. In Hawaii, land donated to the state was turned into a haven for native plants, fish, and birds by replacing many of the nonnative invaders with native plants friendly to fish and birds (United States Fish and Wildlife Service, 1995).

Preserving and Promoting Natural Habitats. Interest in native plants has increased for a variety of reasons beyond their ornamental characteristics. The need for native plants seed has increased as interest in native plants for use in habitat rehabilitation increases. Richards (1998) indicated that the production and storage of native plant seed is of particular interest to those who restore larger amounts of land, especially sites that have been destroyed by fire. Erlich (1990) noted that ecosystems are critical to the supply of fresh water and the fertility of the soil, among many other things. Native plants can also be used for erosion control in locations where other plants won't grow. *Comptonia peregrina* (sweet fern) can be used as erosion control, as it rapidly fills in embankments and disturbed areas (Hyde et al., 1972). In addition, native plants can be used to preserve the diversity of a site or a landscape, which is important for not only plants, but also wildlife.

Native plants are also of interest because of the problems that are being experienced as a result of invasive plants. Overly aggressive plants introduced for their ornamental or economic attributes have invaded natural areas around the country. In the Northeast, *Lythrum salicaria* (purple loosestrife) is choking out wetlands and *Acer platanoides* (Norway maple) is threatening the woodlands. Because of the seriousness of the problem, the federal government, by executive order in 1999, created the Invasive Species Council to design and implement an Invasive Species Management plant to evaluate the way in which plants are introduced into the country, and to make an effort to decrease the chances of introducing new species that pose a threat to the environment (Clinton 1999).

Federal, state, and local agencies spend millions of dollars on attempting to control invasive species. Once they have been established in the landscape eradication is extremely difficult. The estimate annual cost associated with controlling purple loosestrife (*Lythrum salicaria*) alone is $45 million dollars (Pimentel et al., 2000). This plant is spreading at an alarming rate and is changing the basic structure of our wetlands (Thompson et al., 1987). Overall, it is estimated that nonindigenous species are causing $137 billion of damage per year (Pimentel et al., 2000).

With these plants already introduced to this country, the prevention of further damage to natural and managed ecosystems is critical (Pimentel et al., 2000). Many see an increase in use of native plants as part of this solution. It is important that conservationists, botanists, and ecologists to work with horticulturalists to not only avoid producing more invasive plants, but to also find alternatives to them (Reichard and White, 2001). As a result, native plant propagation has become an important issue and it is why it is the subject of this research.

Propagation Methods

Plant propagation is the art and science of increasing numbers of plants. Successful plant propagation depends on a series of factors, all of which need to take place before a plant is reproduced. These factors change from plant to plant. From seed germination to the successful rooting of cuttings, certain principles must first be understood before a plant propagator can perfect methods for growing plants.

Sexual Reproduction

Seed is the "major method by which plants reproduce in nature and one of the most efficiently and widely used means of propagation used for cultivated crops." (Hartman et al., 1990).

Seed Structure and Development. Seed is the end result of the sexual fertilization and has three parts: a protective outer covering, storage tissue, and an embryo (Stern, 1997). A seed is, "botanically...a matured ovule containing an embryo that is usually the result of fertilization" (Hartman et al., 1990). It can also be thought of as a young plant with minimal life activity going on. A seed forms as a result of the combination of the mature male and female gametes, which come from the stamen and pistil of the flower, respectively. This process is called fertilization and is the result of the development of a plant and ultimately the development of the flower.

The seed is the most critical phase of a plant's life cycle. Seeds are also "responsible for the evolutionary continuum of plant species" (Desai et al., 1997). By producing and releasing seed, a plant is ensuring the survival of its species, as long as the habitat is desirable.

Salunkhe et al. (1987) described the formation of seed in the following six steps:

1. Formation of stamens and pistils in the flower.
2. Anthesis of opening of the flower, which signals the maturity of stamen and pistil.
3. Pollination, consisting of transfer of pollen grains from stamen to the pistil, germination of pollen grains, and formation of the pollen tube, which penetrates the embryo sac in the ovary.

4. Fertilization of the egg cell and polar nuclei with sperm nuclei from the pollen tube.
5. Growth of a differentiated egg and its differentiation into embryo and surrounding endosperm and seed coat.
6. Maturation of seed and accumulation of stored food.

Even conditions prior to the completion seed development can determine if seed will germinate. Long or short days (photoperiod), water stress, temperature, and even altitude can all effect the development of viable seeds. This is due to the fact that these conditions effect the accumulation of materials within seeds that play important roles in the germination process, such as enzymes, plant hormones, and stored food (Gutterman, 1992).

Seed Germination. After the seed has been produced and it is released from the mother plant, it needs to germinate to become a new plant. Seed germination can be defined as the emergence of the embryo from the seed. For seed germination to begin, three conditions must be met. First, the seed must be viable, meaning the embryo is alive and is capable of germination. Second, environmental conditions must be met. Third, any seed dormancies must be overcome.

Seed Viability. Many plants do not set viable seed. For example, *Acer griseum* (paperbark maple) may set 100 seeds. Because only 10% of these seeds are actually viable, a grower can expect that the maximum number of seeds that may germinate is 10 (Dirr, 1987). In addition, some seeds lose viability if they are allowed to dry out or if they are stored for too long. Seeds of *Aesculus parviflora* will quickly dry out and lose viability if not collected and planted immediately (Jones, 1999).

Environmental Conditions. Environment plays a critical role in the successful germination of a seed. The seed must have available water, the proper temperature, a supply of oxygen, and, in some cases, light. Both water and oxygen are important to the metabolic processes that occur during seed germination (Berlyn, 1972). For many plants, a cool temperature is required for germination. *Asarum canadense*, Canadian wild ginger, germinates best at temperatures averaging 10° to 20°C. At higher temperatures a decrease in germination is observed (Barton, 1944). Annual bedding plant species such as *Ageratum*, *Vinca*, and *Celosia* all benefit from temperatures over 25°C (Ball, 1991). Light can also be either detrimental or beneficial to seedling emergence. In general, small seeds require light at the beginning of the germination process (Atwater, 1980). *Gaultheria procumbens,* wintergreen, seed benefits from light during germination (Cullina, 2000). Other seeds need dark conditions to germinate. In the genus *Betula* (birch), seeds sown in the woods under a canopy of leaves do not germinate, while those in an opening that receives direct sunlight germinate readily. This may be due to the filtering out of the red light by the canopy of leaves (Stoutemyer, 1961).

Dormancy. Dormancy is a condition in which a seed is exposed to proper environmental conditions, but fails to germinate. Dormancy varies greatly species by species and can require numerous steps to overcome before the conditions for germination are met. Dormancy conditions can be found in many, but not necessarily all, species of plants. *Trillium grandiflorum* must go through multiple cycles of warm and cold temperatures before the seed will germinate (Cullina, 2000).

Seed Dormancy. Some seeds are quiescent when they separate form the plant. That is, when given appropriate water and temperature, they will germinate readily (Hartmann et al., 1990). For other seeds, primary and secondary dormancies prevent germination even when environmental conditions are optimum. It results from the inhibition of one or more of the processes proceeding or accompanying germination (Crocker, 1916). Seed dormancy can last for periods of time ranging from days to thousands of years (Taylorson and Hendricks, 1977). In one study it was noted that up to 75% of all species growing around an area in Missouri produce dormant seeds and that dormancy conditions are more common in wild plants than in cultivated ones (Crocker, 1916).

Seed dormancy may result from 1) unfavorable environmental conditions, or 2) internal inhibitors. Dormancy can be thought of as the regulation of germination. Dormancy is "a condition where seeds will not germinate even when the environmental conditions (water, temperature, and aeration) are permissive for germination" (Hartman et al., 1990). The complexities of seed dormancy are not thoroughly understood despite extensive research on the subject and several scientists have suggested methods for categorizing the indicators of these dormancies in an attempt to solve the mystery of breaking them and getting the seed to grow.

Hartman et al (1990) summarized several types of seed dormancy. First is exogenous dormancy. These are factors that inhibit germination in the seed coat and include: impermeable seed coats and chemical inhibitors in the seed coat. Some species of *Amalanchier*, serviceberry, have leathery seed coats that are impervious to water and thus cannot begin the process of germination until the coat is scarified. Often, this can be achieved with sulfuric acid (Dirr and Heuser, 1987). Germination of seed of *Comptonia* *peregrina*, sweet fern, may be inhibited by abscisic acid in the seed coat (DelTradici, 1976). The next type of dormancy relates to conditions involving the inability of the embryo to grow. These are called endogenous factors and include cases where an underdeveloped embryo is present, or the embryo will simply not grow without periods of warm or cold stratification, or other conditions that promote embryo development. Germination of seeds of *Cornus florida*, the flowering dogwood, improved with three months of cold stratification (Dirr and Heuser, 1987) while germination of *Lilium canadense*, Canada lily, improved with 7 weeks of storage at 70°F (Deno, 1993). In both of these cases the seed was moist during storage. The third type of dormancy is called double dormancy, where combinations of dormancy conditions inhibit seed germination. These may be overcome when both conditions are treated sequentially. For example, germination may only take place in some seeds after a hard seed coat is removed and then the seed received cold stratification. In the case of *Trillium grandiflorum* (white wake-robin), seed must be exposed to two cycles of warm and cold before the cotyledon will emerge. The same is true for *Asarum canadense*, Canadian wild ginger, which will germinate only during the second cold period (Barton, 1944).

These treatments to break dormancy aid in the after-ripening process. After-ripening, or the changes occurring during dormancy that finally make germination possible, may involve growth of a rudimentary embryo, fundamental chemical changes in an otherwise mature embryo, or chemical changes in the coats. During after-ripening there is often a complex interrelation between coat and embryo changes (Crocker, 1916).

There are many theories of seed dormancy, why they occur, and how to overcome them to achieve germination (Amen, 1963; Hartman et al., 1990; Taylorson and

Hendricks, 1997). Understanding the complexities of seed dormancy is not easy. It takes extensive knowledge in the area of seed germination as well as extensive experimentation to determine the nature of a particular species' dormancy. Further more, it takes a great understanding of the factors that may promote seed germination in these cases to get the seeds to germinate.

<u>Breaking Seed Dormancy</u>. Several methods can be employed for breaking seed dormancy. For many native species stratification or scarification increase germination percentages. Several native wildflower species have been found to benefit from cold stratification. In this method the seed is stored in a moist, cool environment to satisfy its cold requirement. Bratcher et al (1993) found that cold stratification at 5°C improved germination in the native wildflowers *Baptisia australis, Echinacea purpurea, Helianthus maximiliani, Solidago petiolaris,* and *Veronica missurica.* In their experiment, seeds were soaked in water to allow water absorption and then stored in petri dishes lined with moistened filter paper at 5 +/- 2°C for 2, 4, 6, 8, or 10 weeks. The seeds were in darkness for the length of the stratification. They found that the number of weeks of stratification required for maximum germination were 4, 6, 8, 10, and 10 for *E. purpurea, H. maximiliani, V. missurica, B. australis,* and *S. petiolaris*, respectively.

While cold *stratification* may serve to remove germination inhibitors, acid *scarification* often helps remove physical barriers to germination. Acid stratification causes the seed coat to be damaged, thus allowing water uptake by the seed. In the case of *Lupinus texensis,* a native Texas wildflower, acid scarification did not reduce the overall thickness of the seed coat, however, it did create several pits in the seed coat, which allowed for water uptake (Davis et al., 1991). For *L. perennis,* acid scarification for 30 minutes prior to sowing improved germination from less than 15% to 100%. Again, the factor inhibiting germination is a hard seed coat (Mackay et al., 1996).

Still other plants need different kinds of stratification or scarification. In some species, liquid dish detergent is used as a surfactant to wash away any inhibitors to germination, particularly in seeds with an oily seed coat or covering. This can be a successful method for germinating some seeds of ornamental plants in the genus *Euonymus* (Deno, 1993). Other species need a period of warm stratification or exposure to light to germinate. Seed of some species in the genus *Amalanchier*, shadbush, require a few months of warm stratification before germination will occur (Dirr and Heuser, 1987) while seed of the ornamental bedding plant *Portulaca oleracea*, portulaca, benefits from long day lengths (Gutterman, 1992).

Plant hormones also play an important role in seed germination. More specifically, the gibberellins are a class of hormones directly associated with the breaking of dormancy.

Gibberellins and Seed Dormancy. The gibberellins are a class of hormones that plays several important roles in plant growth and development. First described in the 1950's, gibberellins encourage stem elongation (in both regular and dwarf plants), influence floral initiation and sex determination, regulate the transition from juvenile to adult phases, and promote fruit set (Taiz and Zeiger, 1998). In addition, they "comprise of the class of hormones most directly implicated in the control and promotion of seed germination" (Hartman et al., 1990). Gibberellins have been found to release dormancy in many species of plants (Desai et al., 1997; Taylorson and Hendricks, 1977) and there is research on the role of GA in germination of cereal grains and ornamental flower seeds (Abdalla and McKelvie, 1980).

Gibberellins play a role in several aspects of seed germination (Taiz and Zeiger, 1998). Gibberellins can substitute for the cold stratification requirement of many plants and they are also responsible for the induction of food-mobilizing enzymes (along with many other germination-promoting substances) (Ching, 1972). For these applications, gibberellic acid (GA_3) is the most widely used and commercially available of the gibberellins, although other forms are available (Hartman et al., 1990).

In food mobilization, GA is released from the growing embryo. It then migrates to the aleurone layer (a layer in the seed coat), which begins to break down, releasing enzymes that are responsible for the breakdown of photosynthetic solutes that eventually become sugar and are transported to the growing embryo (Taiz and Zeiger, 1998).

Gibberellic acid can also break certain kinds of dormancies in seeds, including physiological, photo-, and thermodormancy. In the case of thermodormancy (conditions where the seed must be exposed to a cold stratification prior to germination), it is thought that gibberellins break down an inhibitor in the seed coat that is usually removed over the coarse of the cold stratification. By substituting for the cold stratification requirement of a seed, GA_3 can possible save months of time and allow a grower to start seed immediately following treatment.

In *Aquelegia jonesii*, a native columbine, an application of GA_3 helped break dormancy. Method and concentration were not listed (Cullina, 2000). In *Zamia furfuracea*, a Florida native, an application of GA and H_2SO_4 improved the speed at which the seeds germinated at, but decreased overall germination percentage. Seed germinated at 82% in 72 days when soaked in H_2SO_4 for 15 minutes. When the seed was soaked in H_2SO_4 for 15 minutes then soaked in GA_3 for 24 hours prior to planting, germination rate increased by 20 days, but germination percentage decreased to 68% (Dehgan, 1983). For growers who want faster seed germination, this can be an advantage.

Gibberellic acid is a plant hormone that plays several roles in plant growth and development. During seed germination, it can aid in speeding up food mobilization to the growing embryo. In addition, it can help a seed break the dormancy that is restricting its germination.

Benefits and Disadvantages of Seed Propagation. Seed propagation is generally used because it is easy and reliable for many crops, especially when mass-producing certain plants or when producing seedlings for rootstocks or reforestation (Hartmann et al., 1997). However, there are some disadvantages to seed propagation. Not all plants come true from seed. That is, a certain flower color or other characteristic of a plant may not be identical in the next generation of plants. This is due to the genetic variability found in the seed process. For example, *Cornus florida*, flowering dogwood, is commonly and efficiently produced by seed. It's red and pink flowered cultivars, however, must be propagated by cuttings to ensure an exact copy of the mother plant is produced (Bauer, 1977). Another disadvantage for some plants is that they simply do not set enough viable seed, and others, as discussed, require complex procedures before germination will take place.

Asexual (Vegetative) Reproduction

Asexual, or vegetative propagation is a method of plant propagation by which a part of a plant is used to create a whole new plant. This can be done using stem, leaf, root, or other cuttings. Other areas of asexual propagation commonly used in commercial plant propagation, such as grafting and tissue culture, will not be discussed in this paper.

There are several reasons for using vegetative propagation as opposed to seed propagation. Some plants simply don't set enough viable seed to produce ample amount of plant material. In other plants, the seed requires lengthy stratification or scarification methods that are time and resource consuming. In many cases, a cultivar will not come true from seed, so cuttings are used to maintain the genetic integrity of a plant. By vegetatively propagating a certain plant, the new plant will have the same genes as the mother plant, ensuring that desirable characteristics will be carried into the next generation. Mass amounts of uniform plant material may be produced. Consistency and quality make cutting propagation more attractive to plant propagators.

Vegetative reproduction is the most important propagation method for many commercial horticultural crops (Davies et al., 1994). This is because of the ability of the propagator to maintain the genetic integrity of a plant, whether it is to effectively reproduce a superior cultivar, or provide a consistent crop of cuttings. In seedling production it is not possible to guarantee that the seedlings will be of the named cultivar desired, or that plants will be uniform (ie, seedling variation will be present). While cutting propagation may be more expensive, that cost is offset by the higher value of the plant produced (Hartman et al., 1990).

There are many factors involved in the production of plants using vegetative propagation. The two main methods of vegetative propagation in this research are stem cuttings and root cuttings. Within each of these methods many techniques can be used. There are countless methods for using stem cuttings and many factors determine how these procedures are carried out. Time of year, age and health of the parent plant, type of rooting media, temperature, air circulation, light, and many other factors play an important role in the success of the operation. Root cuttings involve also require attention to several details in order to ensure that a plant is propagated successfully.

Types of Stem Cuttings.

Stem cuttings are those that are taken from either new or old growth from the stem or branch of a plant. Softwood cuttings are those that are taken from the current year's growth. In northern climates softwood cuttings can be harvested though the summer, depending on the species and when the plant is actively growing. The distinction between softwood and semi-hardwood cuttings is not easily made, but in general, wood starts to harden toward the end of the summer, and this wood would constitute a semi-hardwood cuttings. Hardwood cuttings are those taken if last year's growth. These cuttings can be taken in the dormant period of the plant, and it is common for these cuttings to be collected from October through March (Dirr, 1987). In all of these cases, it is important to note that weather conditions vary from year to year, so close attention must be paid to how the plants are growing, not what day it is on the calendar (Jones, 1999).

Softwood Cuttings. Softwood cuttings consist of a flush of new green growth. To prepare a softwood cutting many steps are taken and several treatments can be used. First, cuttings should be taken early in the day and cloudy days are preferable because the plant is less likely to be under water stress. Measures should be taken to keep the cuttings cool and shaded until they can be handled in the greenhouse. A softwood cutting should consist of the outermost portion of the growing stem. It is typically green, flexible, and easily bruised. Depending on the species, the cutting should be from 2 to 6 inches long. Some cuttings benefit from a treatment with rooting hormones. For example, *Cornus racemosa*, roots only at 8% if softwood cuttings are left untreated. A treatment of 1000 parts per million (ppm) NAA talic, however, yields 100% rooting (Dirr, 1987). After the appropriate treatment has been applied, cuttings are "stuck," or planted, in a rooting media and placed under a mist system to ensure they do not dry out. Several other factors can affect the success of the rooting of cuttings and will be discussed below.

Many ornamental species can be propagated from softwood cuttings. Members of the witch-hazel family (Hamamelidaceae), including *Hamamelis mollis, H. virginiana, H. vernalis, Liquidambar styraciflua,* and *Fothergilla* species all root easily from softwood cuttings (Fordham, 1976). Other native species such as *Clethra alnifolia, Ilex verticillata,* and *Oxydendrum arboreum* can also be propagated from softwood cuttings (Dirr, 1987).

Several species in the *Cornus* genus root very easily from softwood cuttings. *C. alba* (Tatarian Dogwood), *C. racemosa* (Grey Dogwood), and *C. sericea* (Red-oser Dogwood) all root close to or at 100% when softwood cuttings are taken in the summer and treated with 1000 ppm K-IBA talc (Dirr, 1987). *C. alternifolia* is also listed as easy to root from softwood cuttings (Dirr, 1987), however, getting the cuttings through a dormant season may pose some problems. The literature review did not produce any information in regards to the vegetative propagation of *C. rugosa*.

The genus *Viburnum* also includes many members which root using softwood cuttings. Native species such as *V. acerfolium, V. dentatum, V. lentago,* and *V. nudum.* all root easily from softwood cuttings (Dirr, 1987).

Hardwood Cuttings. Hardwood cuttings are those taken from the previous year's growth, are typically taken in the late winter in northern climates. There are several methods of handling hardwood cuttings. Some involve taking cuttings in fall and storing in dark at 50°F until rooting and callusing occur, at which time they are planted out. Others take cuttings in the fall, treat with hormones, store them in moist conditions at 70°F for several weeks, and then hold the cuttings in cold storage until spring (Hartman et al., 1990). There seems to be as many methods as there are plant propagators.

When preparing hardwood cuttings, it is important to keep several factors in mind. Cutting material is typically taken closer to the base of the stem. Tip cuttings, unlike in softwood cuttings, are usually discarded (Stoutemyer, 1969). The cutting must be of moderate size, approximately the width of a pencil, and must contain enough food reserves (carbohydrates) to support the cutting during rooting. If large amounts of hardwood cuttings are needed, they can be cut to size using handsaw or band saw, making preparation easier for the propagator (Stoutemyer, 1969).

Several species of plants are propagated from hardwood cuttings. The native inkberry (*Ilex glabra*) roots easily from hardwood cuttings taken late August through

November. The Southern Magnolia (*Magnolia grandiflora*) can also be propagated with hardwood cuttings. A solution of NAA rooting hormone at a concentration of 10,000 ppm should be used to obtain optimum rooting in this species (Dirr and Heuser, 1987). Another method for getting results from hardwood cuttings hard-to-root species may be to use a liquid treatment followed by powder. The *M. grandiflora* cultivar 'Greenback' responds well to a treatment of 1% (10,000 ppm) NAA followed by a 0.8% (8,000 ppm) treatment with powder. The reason for this may be that the combination of the rapid absorption of the auxin via the liquid treatment followed by the slow release of the powder auxin allows for optimum absorption of the rooting hormone and thus the rooting response was triggered (Jiang et al., 1998).

Root or Rhizome Cuttings

Root cuttings, segments of roots taken from the stock plant, are a commercially viable method of propagation for some species. Aside from seed, root cuttings are the oldest means of plant propagation, as early settlers to this continent brought plants from Europe by this method and then moved them westward in the same fashion (Orndorff, 1977). Many nurseries don't use root cuttings because of the difficulty of collecting the material (Flemer, 1961). Eley (1970) stated that "despite the difficulties involved, the root cutting, method is by far the best way to increase certain plants which do not grow easily from stem cuttings." Root cuttings can rapidly and inexpensively reproduce many plants (Stoutemyer, 1968). In addition to quickly and economically producing new plants, root cuttings can also improve the health of the plants that are produced with this method. For example, lilacs on their own roots, unlike those grafted on to rootstocks, will not experience problems with rootstock suckering or incompatibility of grafting material, and own-root lilacs can be pruned low to the ground to renew their wood, grafted lilacs cannot (Orndorff, 1977).

Root cuttings can be dug in either the spring or fall, depending on the climate and on the species of plant. Often the roots can be harvested when the stock plants are being dug for shipment or transplanting. There are several ideas about the timing and size of root cuttings. Orndorff (1987) reported that roots are dug in late October and November. He listed several species capable of being propagated by root cuttings, including the native shrubs *Aronia, Clethra, Comptonia,* and *Viburnum.* Several herbaceous species, including *Papaver* spp., and *Eschscholzia californica* (Donovan, 1977) are propagated using root cuttings. Eley (1970) noted that stock plants can be grown in large outdoor containers and when the time is appropriate for cuttings, in his case, late December to January, the roots are growing out the bottom and over the sides of the pot. These, he says, are ideal for root cuttings. Creech (1954) wrote that roots taken closer to the base of the plant root better and thick segments of roots are more successful. He also pointed out that root cuttings tend to form adventitious shoots rather than adventitious roots, as if the cutting is making an effort to replace what parts it is lacking. The same can be said for stem cuttings, he concludes, as they form adventitious roots.

Time of year can also have an effect on the rooting of cuttings. Apple and raspberry root cuttings have distinct times of year in which they will not root, autumn-winter cuttings root well and spring-summer cuttings do not (Heuser, 1977). Researchers have correlated this survival rate with the amount of starch accumulation in the roots. High amounts of starch result in more energy for the growing shoots, and thus better survival rates (Hudson, 1954; Robinson and Schwabe, 1977). *Rhus typhina* roots well when cuttings are collected in the fall and treated with cold stratification for a few months before planting. *R. glabra,* on the other hand, roots better from spring-collected roots (Dirr and Heuser, 1987). This indicates that both time of year and temperature (cold stratification) have an effect on root cuttings.

To prepare a root cutting several steps must be taken. First, the root is harvested from the stock plant. This can be done while transplanting the plant, by gently cutting off as many root pieces as the plant can spare. The plants are then laid back in the soil to continue growing (Eley, 1970). In the case of *Comptonia peregrina*, the roots can be gently lifted from the soil. *Rhus typhina* roots can also be lifted directly from the plant, as the root grows along the surface of the soil and spreads readily (Eley, 1970). This method may do damage to the stock plant, however, wounding the root (in many cases, the root will be wounded in several places) may stimulate more shoot growth from the stock plant, thus producing healthy young shoots for the next growing season.

Next, the root needs to be prepared for sticking in the media. Depending on the species, the root should be cut from 2 – 6 inches in length. Orndorff (1987) advised sticking the roots in nursery flats and discourages the use of peat pots. Eley (1970) used peat pots, stuck the cuttings vertically, and covered the cutting with about one inch of compost. Typically, a coarse soil mix is used to emulate the conditions that the root has been exposed to in the field. The root can be buried about 1 inch deep in the mix. The root can be laid in the soil either horizontally or vertically, again depending on species and the location from which the cutting was taken. If the cutting was growing vertically, then it should be stuck vertically. If it is a horizontal-rooting species, the root cuttings should be laid horizontal. Several authors (Eley, 1970; Orndorff, 1987; Browse, 1980) made reference to the need to make sure that this polarity is maintained when sticking the cuttings vertically. Finally, the trays should be watered in and monitored to ensure they do not dry out. Orndorff (1987) suggests night temperatures of 32 to 40° F.

Flemer (1961) observed that *C. peregrina* root cuttings taken in the spring (as soon as the ground thaws) should be ¼" in diameter by 3" long and should be rooted outside. He also listed this as a successful method for the native shrubs *Aesculus parviflora, Hydrangea quercifolia, Myrica pennslyvanica,* and *Rhus typhina.*

In 1972, L.C. Hyde and J.M. Zak conducted a study to determine the optimum time for taking *Comptonia peregrina* root cuttings. In addition, they were interested in testing whether the diameter of the cutting had an effect on rooting. Cuttings three inches in length, with a diameter of 1/8 or ¼ inch, were taken every month of the year, except when frozen soil and deep snow prohibited it (early December through late February), and were placed in 5x7 nursery flats containing medium-coarse sand. Diameter (1/8 inch versus ¼ inch) did not have a significant effect on rooting, but the time of year did. The researchers found that sweet fern roots cut in late February, late March, early April, and early May rooted at 93%, 87%, 92%, and 83%, respectively, in contrast to cuttings taken in mid-summer (0% from early June to late July), and between 10 and 60% in the rest of the year. They conclude that in general, the root cuttings taken from plants that have not yet leafed out rooted at higher percentages. They suggest that this is due to a "B-inhibitor" that is present in the leaf and suppresses the rooting ability of the cuttings. They do not give an explanation of the "B-inhibitor," but it is now currently believed that once growth starts much of the carbohydrate reserves are used for production of new leaves, thus the roots do not have enough stored energy of their own to produce adventitious shoots or roots.

Root cuttings can be a successful method of propagating plants that are otherwise difficult to reproduce. While cutting material may be difficult to secure in some cases, it is the preferred method for many plants. Timing and proper environmental conditions are critical to the success of a root cutting operation.

Improving Rooting Success

Regardless of the kind of cutting you choose to propagate a plant, producing a healthy cutting is critical to the success of any propagation operation. Healthy cuttings produce healthy plants that stand better chance of getting through their first winter. After ensuring that the cuttings that are taken from a healthy stock plant, there are several other things you can do to get better results. Producing healthier cuttings can be done using methods such as rooting hormones (to produce a larger, healthier root system), wounding (to encourage more rooting), and extended light periods (to allow for more growth time and to delay dormancy from setting in before the proper amount of growth is achieved). There are many other techniques that will improve rooting in many species and they will not be discussed here.

Health of the Stock Plant. Health of the stock plant is critical to the success of the cuttings. Plants that are growing in distressed areas, or plants that are insect or diseased infested are not ideal stock plants. Cuttings should be taken from healthy, vigorous portions of the plant.

Juvenility. The age of the stock plant from which the cuttings are taken can influence whether or not the cuttings will root. Age, in this case, does not mean how old the actual piece of plant material is. Rather, it is in reference to whether or not the cutting came from a portion of the plant that was or is capable of flowering. This concept is referred to as juvenility. Juvenile parts of the plant are those that do not have the ability to flower or have not yet capable of flowering (roots, young shoots, inner parts of the plant). Plants root better from cuttings that are taken from juvenile wood (Fordham, 1969b). This is not to say that mature wood will not root, it is just noted that juvenile wood roots more readily in most cases, and, particularly in hard to root species, juvenile wood is preferred. Juvenile wood may be in several locations on the plant. Fordham (1969b) notes that shoots arising directly from roots are juvenile, and, in hard-to-root species, these shoots may root readily. There are several methods to induce juvenility, which will not be discussed here.

Komissarov (1969) raises an interesting question in regards to this subject. Does the phylogenic age of a family influence its ability to root? For example, are plants of the Magnoliaceae and Ranunculaceae, which are considered old families, harder to root than some of the younger plant families, such as the Saxifragaceae and Asteraceae? There is no evidence to support this idea, as representatives of these families can prove either difficult or easy to root, but the environmental conditions under which the families evolved is an interesting aspect to consider in plant propagation.

Media. The media used can influence the rooting of the cuttings as well. In 1932, Long noted that the type of rooting media influences the kind of roots that are formed, with peat moss resulting in slender, flexible, well branched roots. Sand provides good drainage, but results in a more brittle root system. In general, it is important to have a media that drains well, but also will support the cutting (i.e., the cutting will not be knocked over when moved), and consequently, its growing root system.

Rooting Hormones. Rooting hormones have long been used to promote rooting and improve root quality in both softwood and hardwood cuttings. In 1934, naturally occurring auxin was discovered (Tiaz and Zeiger, 1998). In 1935, Zimmerman and Wilcoxon showed that indole-3-butyric (IBA) and naphthaleneacetic (NAA) acid, in addition to 8 other chemicals including carbon monoxide, ethylene, and propylene, cause greater rooting response. Since then, countless studies have been done proving the effectiveness of auxin treatment of cuttings. Both herbaceous and woody plants benefit from rooting hormone treatment. Even easy-to-root species may benefit from rooting hormones in that the adventitious roots produced will be larger and healthier. In contrast, too much rooting hormone can hinder root growth, so care has to be taken to find the right concentration to use.

Type of rooting hormone, form of the rooting hormone (powder or liquid), length of hormone treatment, and even the depth to which the cutting is treated may all have an effect on rooting.

The use of naturally occurring auxin is limited due to sensitivity to light and its rapid breakdown by microorganisms that may be present in the media (REF). In addition, auxin translocates through the plant readily, leaving the site of wounding with very little auxin to use for rooting. As a result, scientists have sought better ways to apply auxin. There are now several commercial auxin solutions available for use in the nursery industry. These typically include IBA or NAA, or their potassium salt forms (for easier dissolving in water), K-IBA and K-NAA. Both are synthetic forms of auxin.

IBA is available in both liquid and powder forms. When using liquid solutions, the technique varies by the plant. For easier-to-root woody plants and many herbaceous plants, lower concentrations will aid in rooting and producing better roots. Native tree *Amelanchier arborea* (Downy Serviceberry) rooted at 100% from softwood cuttings treated with only 1000 ppm IBA and *Clethra alnifolia*, a native shrub, roots in 2 weeks when softwood cuttings are also treated with 1000 ppm IBA (Dirr 1987). In the native wildflower *Spigelia marilandica,* concentrations of 2000 ppm IBA aid in the rooting of stem cuttings (Cullina 2000). Higher concentrations are used in harder-to-root species. *Magnolia grandiflora,* the Southern Magnolia, roots when hardwood cuttings are treated with 10,000 ppm IBA (Dirr, 1987). Difficult-to-root cultivars of *M. grandiflora* benefited from treatment with both a quick dip (1%) NAA and 0.8% IBA talc. Rooting percentages in *M. grandiflora* 'Little Gem' improved from 23% to 85% with this treatment. This may be due to the rapid absorption of the NAA followed by a slower absorption of the IBA until the necessary concentrations for rooting were reached (Jiang, et al., 1998). In yet other species, IBA + NAA treatments are used. Fordham (1969a) found that the difficult-to-root *Acer griseum* benefited from treatment with a liquid dip of both hormones.

The length of time and amount of cutting exposed to the hormone is also important. In one study, it was found that dipping only the basal end of the cutting was superior to dipping the end of the cutting for a full 1 inch for some plum cultivars, yet in others rooting decreased with this treatment (Nahlawi, 1970). In a summary of his extensive research, Howard (1974) noted that when fruit rootstock cuttings are dipped in a 50% alcohol IBA solution, it is beneficial to dip as shallow as possible, at least one inch, and to only dip for 5 seconds, as the increased amounts of auxin taken up eventually discouraged rooting.

Komissarov (1968) noted that in his studies a liquid solution, for unexplained reasons, produced consistently better results than talc for many species of plants. He recommends that talc be used for herbaceous cuttings, or for those plants that are sensitive to liquid solutions. For treatment of softwood cuttings, the quick-dip or the powder method is acceptable.

For hardwood cuttings, Nahlawi (1970) found that the "quick-dip" method is preferred because of the speed and uniformity it provides. In this method, the K-IBA liquid solution is prepared and the base of the cutting is dipped for a period of time, from a few seconds to several minutes depending on the species, and then allowed to air dry for a certain amount of time until being stuck in the rooting medium.

In root cuttings, synthetic auxins (IBA, IAA, and NAA) may actually suppress bud initiation. Cytokinins, on the other hand, may help to increase bud initiation in roots (Browse 1980). Neither of these practices, however, appears to be widely researched or used. Browse (1980) also pointed out that the most important chemical application may be that of a fungicide to prevent loss of cuttings to rot.

Photoperiod. Photoperiod is the duration of light a plant is exposed to during a day. Extended periods of light while the cuttings are on the mist bench are thought to accomplish many things. Using supplemental light in addition to natural daylight extends the amount of photosynthesis that the plant can carry out (Macdonald, 1969). Waxman (1970) noted that by extending the amount of light the cutting receives; many trees and shrubs will delay dormancy, and as a result will have more time to put on a healthier root system. This can lead to an increase in the number of roots a cutting will form (Stoutemyer, 1961). Dirr (1986) noted that this could be achieved simply with 75-watt bulbs with reflectors three feet apart and three feet above the bench. For plants where softwood cuttings may not root well, but semi-hardwood cuttings do, this method may be beneficial. The native flame azalea, *Rhododendron calendulaceum,* is one such plant. Metcalf (1963) found that cuttings of *R. calendulaceum* taken in June rooted poorly, but cuttings taken in late July and given extended photoperiods under mist rooted at much higher percentages. Flowering dogwood, *Cornus florida*, is another plant which benefits from this treatment. Cuttings that were rooted under mist and exposed to 18- and 24-hour photoperiods produced an additional flush of growth three weeks after they were potted, but those receiving regular day or only 9 hours of light did not produce any new growth. Cuttings in all treatments rooted at 100%. However, the average number of roots in the 18- and 24-hour day cuttings increased by and average of 12 roots per cutting. This is important in the overwintering, as the plant has a healthier root system going in to the dormant period. It is important to note that not all plants respond well to supplemental lighting during rooting. Conifers root best under short days (Baker and Link, 1963). For plants which do respond well to this treatment, the only disadvantage is that the cuttings can not go directly to cold storage from the mist bench, they have to be exposed to short days, allowed to go dormant, and then put into cold storage (Waxman, 1965). At the end of his article Waxman pointed out several benefits to long photoperiods. He states that long photoperiods can:

1. Keep cuttings in an active state of growth.
2. Can, in some instances, increase the percent rooting.

3. Can, in some instances, increase the size and number of roots developed.
4. Extend the season during which cuttings of deciduous azaleas can be taken.
5. Retain foliage and extend the time during which additional roots may develop and carbohydrates are produced.
6. Can induce a short spurt of vegetative growth with the development of additional buds often necessary for survival the following spring.
7. Can keep plants in active growth throughout the winter after which they may be planted in the spring; a guarantee of survival.

Wounding. Wounding the base of cuttings is a common practice in the commercial production of rooted cuttings (Wells, 1955). This involves lightly or deeply scoring the base of the cutting horizontally or vertically with pruning shears to wound the vascular tissues, whose cells have the ability to dedifferentiate into roots. As a result, more rooting along the stem occurs. Some believe this may be due to enhanced water (Day, 1933) or auxin uptake through the extra wounded points, others think that by disrupting tissues that may be depressing root formation, rooting is increased (Beakbane, 1969). Wells (1962) pointed out that wounding is not used to induce roots on cuttings that otherwise would have not rooted if given sufficient time. He stated that wounding was used to first, speed up the rooting process; second, to increase the number and quality of roots produced; and third, to improve points of attachment between the root and the cutting.

Wounding is not beneficial in all cases, though an accurate explanation of this cannot be offered. Howard (1971) found that some species decreased in rooting when wounded before auxin treatment (in the same study he achieved increased rooting in other species as a result of wounding). He cited excess absorption of IBA as the cause.

Two to three internode wounds on hardwood plum cuttings, when dipped in 5000 ppm IBA, improved rooting of cuttings from 60% in the control cuttings to 85% in the wounded cuttings (Nahlawi, 1970). In cuttings of two California native species in the *Arctostaphylos* genus, wounded had marked effects. Lateral wounding along the bottom 1 cm of the cutting increased rooting in *A. andersonii* from 0% to 100%. In *A. manzanita*, the effects were less dramatic, most treatments increasing rooting 10% to 60%. The researchers investigated several commercially available rooting hormones, and there was one hormone treatment (Rootone F, concentration not given) in which wounding decreased rooting by 10%. Overall, it was concluded that wounding had a beneficial effect on the otherwise difficult-to-root species *Arctostaphylos* (Wisura, 1980).

Health of Cutting. Regardless of the method used to get the cuttings to root, it is critical that they are well adjusted and healthy going into their first dormant period. P.D.A. McMillan Browse (1970) outlined methods for propagating several *Viburnum* species and also noted that winter survival of these cuttings depends on a flush of secondary vegetative growth after the cutting has developed its initial root system and a cold and dry environment where the cutting will not be disturbed for the winter. As a result, it is important to produce a healthy cutting (regardless of the species) from the beginning and give it ample time to produce enough growth to survive its initial dormant period.

Benefits and Disadvantages of Vegetative Propagation.

Vegetative propagation can, if preformed properly, ensure large quantities of uniform plants. These cuttings are identical to the desired stock plants and may produce a saleable plant sooner than seedling propagation. There are, however, some disadvantages. First, a grower has to consider the resources involved. To successfully root cuttings, particularly in the north, a greenhouse or other shelter is needed with misting systems to keep the plants hydrated. Some plants require rooting hormones to promote rooting or pesticides to discourage fungus and other infections. In addition, some rooted cuttings may require special care over the winter, such as cold storage in a protected area. In addition, many plants that are desirable for ornamental uses do not root well and others may root well, but have difficulty in surviving the first dormant period. Building and maintaining facilities for a vegetative propagation operation takes a substantial investment in both property and labor, and careful consideration is needed before beginning such an operation.

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Chapter 3

TAXONOMY OF SELECTED PLANTS

Asarum canadense L.

Asarum canadense, Canadian wild ginger, a member of Aristolochiaceae, is a woodland herb native to North America. The Aristolochiaceae, or Birthwort family, consists of approximately 10 genera and 600 species distributed largely in the tropical regions with some plants residing in temperate zones (Judd et al., 1999). Some of the plants in the Aristolochiaceae are used as stimulants or tonics. Others are aromatic. Many are used in rock gardens and other ornamental landscapes.

Asarum is one of the larger genera of the family with 70 species, most of which are native to temperate areas in the north (Gleason and Cronquist, 1991). *A. canadense*, a North American native, is commonly referred to as Canadian wild ginger, or wild ginger. There are Japanese species and a European species (*A. europaeum*) that have been introduced to the United States for ornamental purposes. In addition, there are several native *Asarum* species, most of which grow in the west. These include *A. marmoratum, A. hartwegii, A. lemmonii,* and *A. caudatum*. None of these species are the source of ginger; the common name of *Asarum* is derived from the fact that the roots have a ginger odor when cut or bruised. *A. canadense* was once used by the early settlers as a medicinal plant, however, many may be sensitive to chemicals found in the plant.

The native range of *A. canadense* is New Brunswick and Quebec to Ontario and Minnesota south to North Carolina, and northern Alabama and Louisiana. Canadian wild ginger is found in rich woodlands, usually in colonies. It thrives in shady spots and can endure the occasional drought (Cullina, 2000). In Maine, it is commonly found in moist hemlock woods, rich shady grounds, and on the banks of shady hills.

Table 3.1. Key to some North American native *Asarum* species

1. Rhizomes erect or ascending, deeply buried....................................
    2. false calyx tube subglobose, externally mottled red..*A. marmoratum*
    2. false calyx tube cylindric, externally reddish, sometimes mottled red and green...*A. hartwegii*
1. Rhizomes horizontal, shallow, false calyx tube brown to brownish-purple...
        3. flowers horizontal...*A. caudatum*
        3. flowers erect or ascending..........................*A. canadense*

A. canadense is an acaulescent, deciduous perennial herb. The plants are hairy, especially at the petioles and calyx. It spreads via creeping rhizomes (Fernald, 1950).

The leaves, borne in pairs, are cordate-rotund to cordate-reniform, 8-12 cm wide at anthesis, larger (up to 15 cm) at maturity. The leaves are also membraneous, or thin, soft, and flexible (Fernald, 1950).

The solitary, campanulate flowers arise from between a pair of leaves in April or May. Flowers are 2-4 cm in size and are typically hidden by the foliage. The calyx, which is reddish-brown, maroon, or deep purple, is tubular at the base and the 3 fused petals are deeply lobed at the top. These lobes can be spreading or reflexed. The tube is 8-16 mm long and the lobes are 5-15 mm or longer. There are typically 12 stamens, each with a well-developed filament. The stamens are closely appressed to the styles. The 6-locular ovary is inferior (Gleason and Cronquist, 1991). Floral morphology within the species varies greatly, and "numerous ill-defined and intergrading varieties or species, have been based on calyx characteristics" (Radford et al., 1968).

The fruit of *A. canadense* is a fleshy capsule that opens irregularly to release the somewhat large, brown, wrinkled seeds. The seeds are also carunculate, meaning there is an appendage or protuberance near the hilum (Gleason and Cronquist, 1991).

A. canadense was named by Linneaus in 1753 in his volume Species plantarum (Linnaeus, 1753). Variability within the species has led to several named varieties of *A. canadense.* Variety *refelxum* (E. Bikn.) B.L. Robinson is found from New York to Michigan and Iowa southward, more common in the Midwest. It differs from the species in the arrangement of the calyx. Variety *acuminatum* Ashe. is native from Vermont to Minnesota south to Virginia, Tennessee, and Missouri, and has leaves which taper at the tip. There are several other named varieties, all of which represent some slight variation in the appearance of the calyx (Gleason and Cronquist, 1991).

A. canadense is an ideal groundcover. It is "an indispensable plant for shade gardens, durable and carefree" (Cullina 2000). The flowers, although interesting, are not significant. The clean, deep green foliage that the plant is primarily grown for forms a thick colony in a shady location. It's matte green leaves make for a good foil to finer textured shade plants such as ferns. Wild ginger is an important crop for the horticulture industry because of its potential as a native groundcover for many conditions in the garden.

Comptonia peregrina (L.) Coult.

A member of the family Myricaceae, *Comptonia peregrina,* sweet fern, is a perennial deciduous shrub native to Eastern and Central North America. The Myricaceae, or Bayberry Family, is a small family comprised of many aromatic plants. There are three genera in the Myricaceae (*Myrica, Canacomyrica,* and *Comptonia*), two of which are represented in North American flora (*Myrica* and *Comptonia*). Plants in the Myricaceae fix atmospheric nitrogen via nodules in their roots (Judd et al., 1999).

Table 3.2. Key to genera of Myricaceae of eastern North America

1. Leaves entire or merely toothed, lacking stipules......................*Myrica*
1. Leaves pinnately divided, stipules present.........................*Comptonia*

C. peregrina is native from Nova Scotia to North Carolina, into western South Carolina and northern Georgia west to Saskatchewan, Minnesota, Illinois, and Tennessee Gleason and Cronquist, 1991). It is typically found in disturbed soils in full sun. It colonizes and thrives on banks and roadsides. In Maine, it is commonly found in a wide variety of habitats, including clearings and old burn sites in woods, dry areas on the edges of forests, roadsides, upland woods, and open sandy slopes.

C. peregrina is a dioecious (seldom monoecious) shrub which in height from 0.3 to 1.5 m tall. It spreads and colonizes via horizontally branching rhizomes that grow close to the surface of the ground. When burning or other means of removing top growth disturbs the plants, lateral buds are stimulated to grow along the rhizome. *C. peregrina* can fix atmospheric nitrogen via nodules on its roots. The plant, including the foliage is pubescent, and the fruit, foliage, and twigs are aromatic (Radford, 1968).

The glossy green foliage is alternate, linear-oblong, and deeply pinnately lobed (pinnatifid). It typically measures 6-12 cm long and 0.8-1.5 cm wide. In addition, the foliage is membranaceous, meaning it is thin, soft, and flexible. Fall foliage color is deep red. The twigs are dark brown to gray and the stems lack a terminal bud (Gleason and Cronquist, 1991).

The male flowers are in short aments (catkins) clustered near the tips of the twigs. Typically 1.5-4 cm long, the nodding aments arise directly from the distal auxiliary buds. Male flowers have 4-6 stamens and pointed scaly bracts. The pistillate catkins are 1-2 cm, forming a globose bur (Fernald, 1950).

The fruit is persistent; an ovoid nutlet subtended by bracts, in clusters. There is evidence that the seed of sweet fern persists in the soil for many years, as many as 75 or more, until ideal germination conditions take place (DelTradici, 1977).

Named by Linneaus, *C. peregina* first appeared as *Liquidambar peregrina* in Species Planatraium in 1753 (Linneaus, 1753). Its specific epithet, peregrina, means 'foreign,' and indicates that this plant was foreign to the European author who first named it. Coultier changed the name to *Comptonia peregrina* in 1854. The genus, Comptonia, was named for Henry Compton (1632-1713), Bishop of London and a cultivator and patron of botany. This species has also been referred to as *Myrica asplenifolia* and *M. peregrina.* There are no other species in the genus *Comptonia*, and there is only one named variety of *C. peregrina, C. peregrina* var. *asplenifolia* (L.) Fern. The variety *Asplenifolia* differs from the straight species in that its foliage resembles that of the spleenwort, *Asplenium,* a fern in the Polypodiaceae. In addition to the difference in foliage, the catkins and nuts in this variety are also smaller than the straight species (Gleason and Cronquist, 1991).

Its ability to thrive in adverse conditions is a result of the actinorhizal nodules that form on its roots and fix atmospheric nitrogen. Because of this ability, *C. peregrina* may be an important factor in the nitrogen content of soil in the areas it is found in (Ziegler and Heuser 1963). In many locations *C. peregrina* is a weed, as it rapidly invades clear-cut areas (Hendrickson, 1986). In this situation, plants typically mature sexually within 2 – 3 years, before the canopy can close in and discourage seed production. *C. peregrina* is also an unwanted weed in Jack Pine stands and in blueberry barrens (Hall, 1976), where it is noted that burning or injuring the shoots stimulates the growth of dormant buds along the root.

In the nursery industry, *C. peregrina* is important for not only its ornamental uses, but also for its potential as a plant for roadside erosion control. In the home landscape *C. peregrina* can be used as a groundcover in the garden or as a planting along the driveway or in any other area where little else will grow. Roadsides, slopes, and banks with soil erosion problems could all potentially benefit from this plant. Its clean, dark green, fragrant foliage makes it an attractive groundcover along walkways or anywhere in the garden.

***Cornus alternifolia* L.f. and *Cornus rugosa* Lam.**

Cornus alternifolia and *C. rugosa* are both members of the Cornaceae, a family with 12 genera and 450 species. The distribution of the family is widespread, especially in north temperate regions of the world. Cornus is the largest genus in the family, consisting of 45 species (Judd et al., 1999). Within the genus *Cornus* there are several ornamental plants, including the Kousa dogwood (*C. kousa*), the native Florida dogwood (*C. florida*), and the native groundcover bunchberry (*C. canadensis*). These three are grown for many reasons, including their flowers, which are subtended by showy bracts ranging in color from pale white to mauve-pink. Many other native dogwoods are also used as ornamentals. *C. racemosa* is valued for its blue-green foliage and creamy white flowers and fruit. *C. sericea* is widely grown for its bright winter stem color. The species name *Cornus* is derived from the Latin *cornu,* meaning horn, referring to the hardness of the wood.

Cornus alternifolia, the Pagoda dogwood, is a small tree native to Newfoundland and Nova Scotia to Minnesota, south to Florida, Alabama, and Arkansas (Gleason and Cronquist, 1991). Typically found in rich woods and thickets, Pagoda dogwood is common in the Maine flora.

C. alternifolia is a shrub or small tree which reaches heights up to 6 meters. Its branching pattern is horizontal, giving the plant a unique layered look (Dirr, 1998).

The entire leaves are alternate, thin, ovate to oblong to obovate, and taper to a distinct tip (acuminate). The lateral veins are in pairs of 4 to 5. Typically 5-10 cm in length with 8-50 mm petioles, the light green leaves appear before the flowers. On the upper surface, the leaves are smooth and hairless (glabrescent) and below they are pubescent and slightly hairy (minutely stringulose). On flowering branches the leaves can appear to be borne in whorls. The glabrous stems are light green when young, maturing to a medium to deep brown color. The twigs have white pith (Radford, 1968).

Table 3.3. Key to some species of *Cornus* commonly found in Maine.

1. Flowers subtended by showy white bracts...
    2. plant herbaceous, leaves apparently whorled.....................*C. canadensis*
    2. plant woody, 3-5 m tree, leaves opposite...............................*C. florida*
1. Flowers not subtended by showy bracts...
    3. leaves alternate...*C. alternifolia*
    3. leaves opposite...
        4. pith conspicuously deep brown..........................*C. ammonium*
        4. pith white to light brown..
            5. stems reddish purple, inflorescence borne on red peduncles..*C. racemosa*
            5. stems not reddish-purple, lack red peduncles....................
                6. twigs red, leaves lanceolate to ovate.........*C. sericea*
                6. twigs yellow mottled with purple, leaves ovoid to subspherical...*C. rugosa*

The small creamy-white flowers are perfect and borne in cymose-capitate (head-like) inflorescences. The flowers have 4 petals and a 4-toothed calyx. There are 4 stamens with slender filaments as well as a slender style. The stigma is terminal and flat and the ovary is inferior (Fernald, 1950). The flowers are usually present from May to early July.

The 1-5 locular fruit is a small blue drupe with a deep pit at the summit. Typically, there are 20 seeds in the fruit. Fruit sets from late July to September.

C. alternifolia first appeared in Supplementum Plantarum, published in 1791 by Carlo a Linne (Linnaeus, 1781). Its original name in this publication, Cornus foliis alternis (and its current name), indicates one of its distinguishing characteristics: alternate leaves. The leaves of most members of the genus Cornus are oppositely arranged.

C. alternifolia is valued for its interesting growth habit, creamy white flowers, and red to black fruit.

C. rugosa, the round-leafed dogwood is native from Quebec to Manitoba, south to West Virginia, and west to Illinois and Iowa (Gleason and Cronquist, 1991). It is typically found on dry sandy slopes. In Maine it is found on dry hillsides, rocky banks of streams, in sparse woods, and, less commonly, in moist thickets.

C. rugosa is a 1-4 m shrub that often takes on a tree-like habit. It can be found commonly growing with a single main leader from the base with branching further up the stem (Radford, 1968).

Leaves are ovate to rotund, wedge-shaped, triangular, and broadly rounded at the base (broadly cuneate), and abruptly acuminate at the tip. Growing 7-12 cm in length, there are typically 6-8 lateral veins on each side of the leaf. The leaves have soft white hairs, 0.5-1 mm in length, on the underside. The twigs of this species are glabrous, light or yellowish-green and often mottled or shaded with purple. The pith is white (Fernald, 1950).

The 4- or 5-merous flowers are perfect, creamy white, and borne in cymes. The inflorescence is flat or slightly convex. There are 4 petals and a 4-toothed calyx. The slender filaments are borne on 4 stamens and the 1-5 locular ovary is inferior. The stigma is terminal and flat. Flowers typically appear in May and June (Fernald, 1950).

The fruit, a small drupe, is light blue (rarely white) and almost round (sub-globose). It typically appears in August and persists through September or October (Gleason and Cronquist, 1991).

C. rugosa was first published by M. le Chevalier de Lamarck in 1786 in the volume Encyclopedic Methodique Botanique (Lamarck, 1786). There are two synonyms for *C. rugosa*: *C. circinata* and *Svida rugosa*. *C. rugosa* is the accepted name of the species (ITIS, 2002) .

In the landscape, *C. rugosa* has potential in dry disturbed areas and in the woodland border. Besides its flowers and fruits, *C. rugosa* has interesting yellow to yellow-green stems mottled with purple and fall colors ranging from orange to deep red.

Gaultheria procumbens L.

Gaultheria procumbens, wintergreen, a member of the Ericaceae, is a woodland native of North America. A small woody plant, *G. procumbens* is common in the Maine flora. The Heath Family, Ericaceae, is comprised of trees and shrubs (vines occur occasionally). Among the 50 – 82 genera and 1350 – 2000 species of this family are the rhododendrons, azaleas, heaths and heathers, mountain laurel, blueberries, and wintergreen. These plants are distributed on the acid soils of the temperate regions of the northern and southern hemispheres and represent both ornamental and economic crops (Judd et al., 1999).

Table 3.4. Key to the species of *Gaultheria*

1. plant erect, glabrous leaves 2-5 cm long, red fruit........................*G. procumbens*
1. plant trailing, leaves 0.5-1 cm, underside of leaves with bristles.................*G. hispudula*

G. procumbens is native to Newfoundland to Manitoba, south to Virginia and Kentucky, north to Indiana and Minnesota and into the mountains of Georgia and Alabama (Gleason and Cronquist, 1991). Its typical habitat is that of bogs and wet woods, often in decaying logs. Growing in part to full shade, wintergreen forms a loose colony in woodlands with peaty soil. In addition, *G. procumbens* can thrive in full sun along roadsides and open areas in the forest. In Maine, it had been found growing in many diverse habitats, including both deciduous and coniferous woods, on the borders of bogs, in clay humus soil, granite hillsides, and in dry thin soil over rocks.

The leafy stems of *G. procumbens* are suberect, arising from a horizontal rhizome, 1-2 dm, with a few leaves crowded near the top. The elliptic or oblong leaves are entire or crenulate (with small rounded teeth) and glabrous on the surface. Leaves are typically 2-5 cm long, with 2-5 mm petioles (Gleason and Cronquist, 1991).

The creamy white, solitary flowers appear in June. The flowers are 5-merous and are borne on nodding pedicles 5-10 mm in length. The campanulate or urceolate (bellshaped) corolla is 5-toothed. The calyx is saucer-shaped. Stamens are 8-10, with short, flat filaments and oblong anthers have 2 double horns where the pollen is released when the flaps open. The wholly to partially superior ovary is 4-5 locular (Fernald, 1950).

The fruit is a bright red berry, 7-10 mm, formed as the fleshy glabrous calyx surrounds the capsule.

G. procumbens was named by Linneaus in 1753 in the first volume of Species plantarum (Linneaus, 1753). The genus *Gaultheria* was named in honor of Jean-Francois Gaultier (?1708 – 1756), a naturalist and physician. The specific ephitet, procumbens, refers to the creeping or horizontal habit of the plant.

G. procumbens was formerly used as the source for wintergreen oil (Betula lenta is now commonly used as the source of this oil). In the garden, *G. procumbens* has its place from full sun to lightly shaded areas and rich woodlands. It is one of a few plants that can tolerate dry shade (Cullina 2000). It can also form quite dense mats in sunny, disturbed areas as well as thriving in shady, moist, peaty woodlands. *G. procumbens* is of interest to the nursery industry for its ornamental qualities. Clean, glossy foliage, creamy white flowers, bright red fruit, and excellent purple fall color all make *G. procumbens* a valuable native groundcover for gardens.

Viburnum lantanoides Michx. and

Viburnum nudum L. var. *cassinoides* (L.) Torr. & Gray

The Viburnums are a large genus of deciduous shrubs, many of which are native to North America. There are several species of *Viburnum* currently in cultivation, and they are often thought of as superior landscape plants. As one author reflected, "a garden without a viburnum is akin to life without music and art" (Dirr, 1998). Of theses 150 species of plants (of which about 8 are common in the Maine flora) (Haines, 1998), two of the native species, *Viburnum lantanoides* (syn. *V. alnifolium*), hobble-bush, and *V. nudum* var. *cassinoides,* withe-rod, are deserving of more attention as landscape plants.

The viburnums are members of the Caprifoliaceae, the Honeysuckle Family. The Honeysuckle Family consists of 12 genera (330 species) of mostly ornamental plants. The distribution of the family is mostly in the northern hemisphere and tropical to sub-tropical areas. The economic importance of this family comes from the fact that many of the members are grown as nursery crops (Judd et al., 1999). Included in this family are the honeysuckles (*Lonicera* spp.), wigelias (*Wigelia* spp.), and snowberry (*Symphoricarpos* spp.). Some of the honeysuckles, however, are considered noxious weeds (*Lonicera japonica, L. morowii).*

There is some dispute that the genus *Viburnum* should be included in the Adoxaceae, along with *Sambucus*. Characters involved in the debate include floral symmetry (bilateral in the Caprifoliaceae vs. radial in the Adoxaceae), style length (elongate in the Caprifoliaceae vs. short in the Adoxaceae), and stigma (capitate in the Caprifoliaceae vs. lobed in the Adoxaceae), among other characteristics (Judd et al., 1999). However, the classification of *Viburnum* still seems to remain unresolved.

Table 3.5. Key to *Viburnum* species commonly found in Maine

1. Leaves 3-lobed..

    2. twigs glabrous

        3. buds dark purple..*V. edule*

        3. buds red..*V. opulus*

    2. twigs pubescent...*V. acerifolium*

1. Leaves not 3-lobed..

    4. buds naked..

        5. plant with gray pubescence on twigs, buds, inflorescence, and leaves..*V. lantana*

        5. plant with red-brown pubescence on twigs, buds, inflorescence, and leaves..................................*V. lantanoides*

    4. buds with scale..

        6. buds linear..

            7. buds brown, no wing on the margin of thepetiole..*V. nudum*

            7. buds purple, petioles with winged margin.....*V. lentago*

        6. buds ovoid with 4 scales, leaves with prominent veins that extend to the tip of each tooth..............................*V. dentatum*

V. lantanoides is native from Nova Scotia to Michigan south into the mountains of North Carolina and Tennessee. It is typically found in moist woods (Gleason and Cronquist, 1991).

V. lantanoides is a 1-3 m shrub. It habit is loose and straggling, with its branches often arching to the ground and the tips rooting (Dirr, 1998).

The 5-10 cm leaves of *V. lantanoides* are round-ovate to suborbicular (almost circular in outline), tapering to an acute tip. The base is typically broadly acute, and sometimes rounded. The leaves become narrower toward midsummer. The margins are closely serrate, becoming more coarsely toothed in midsummer. Petioles, 2-5 cm long, often have winged margins, especially at the base. The petioles and sometimes the leaves and inflorescences are tomentose, with red-brown hairs, as are the stems and winter buds. Winter buds are naked (Fernald, 1950).

The creamy-white flowers are borne on sessile cymes with 3-7 rays. The outer flowers of the inflorescence are sterile, zygomorphic, and measure 2.5-3 cm broad. The inner, fertile flowers are 5-7 mm broad, and perfect. The corollas are broadly campanulate to rotate (disc-shaped, flat, and circular) and 5-lobed. The fertile flowers have 5 stamens and a 3-lobed stigma. The ovary contains 2 abortive locules and one fertile locule with a single ovule. The flowers appear in May (Radford, 1968).

The fruit is a one-stoned drupe, 10-15 mm. The surface of the fruit is glaucous and is ellipsoid in shape. It has a sweetish to tart taste, and is blue to purple in color. The fruit matures in September.

V. alnifolium was named by Humphry Marshall and first appeared in his book *Arbustrum Americanum* in 1785 (Marshall, 1785). André Michaux later changed the name to *V. lantanoides*. This name was first published in his volume Flora Boreali-Americana in 1803 and has since become the accepted name despite the fact that *V. alnifolium* is still commonly used (ITIS, 2002).

In the landscape, *V. lantanoides* can probably be best used in a naturalized setting, particularly in shady, moist areas. There is potential for selection for fall color, as *V. lantanoides* can display fall color ranging from deep reds to rose-gold to pinkish purple (Dirr, 1998). In addition, the flowers are attractive and the fruit is valuable to wildlife.

V. nudum var. *cassinoides* is a deciduous shrub that can reach heights of 2-4 m. Its habit is typically compact and rounded. Commonly found on roadsides, in moist woods, and on mountains it forms a dense shrub with dull, dark green foliage.

Its leaves are dull, indistinctly veiny, ovate to lanceolate or oblanceolate. They tend to be bluntly short-acuminate. The base of the leaf is rounded to tapering and the tips are bluntly short-acuminate (tapering to a sharp point and forming concave sides). The margins vary, are typically crenulate, and are seldom entire. Winter buds are yellow-brown or golden.

The flowers of *V. nudum* var. *cassinoides* are borne in peduncled cymes, 3 – 10 cm in length. The creamy white flowers are small; the corolla is rotate (disc-shaped, flat, and circular) to broadly campanulate. The anthers are held 1–3.5 mm above the throat of the corolla. There are 5 stamens and a 3-lobed, sessile stigma. The ovary has 3 locules, 2 abortive, 1 fertile. The fertile locule has a single ovule (Fernald, 1950).

The fruit of *V. nudum* var. *cassinoides* is an ellipsoid to subshperical drupe with an elliptic or oblong-elliptic stone, and is 6–9 mm long. It changes in color from whitishyellow to pink to blue black and has a glabrous finish. The pulp of the fruit is sweet (in *V. nudum* var. *nudum,* it is bitter) (Gleason and Cronquist, 1991).

V. nudum var. *cassinoides* is recognized as a close relative of *V. nudum* var. *nudum.* The two can be distinguished based on several characteristics. Variety *nudum* has shiny leaves that are acute to tapering at the base and have leaves that are distinctly veiny beneath, mostly entire margins, and reddish-brown winter buds. In contrast, variety *cassinoides* has dull leaves, varying margins, and no evident veins on its leaves, and has yellow-brown to golden winter buds (Gleason and Cronquist, 1991).

Linnaeus first published *V. cassinoides* in Species plantarum in 1753 (Linnaeus, 1753). *V. nudum* var. *cassinoides* (L.) T. & G. first appeared in 1841 in Torrey and Gray's Flora of North America, vol. 2 (Torrey and Gray, 1841) and is currently the accepted name (ITIS, 2002). *V. cassinoides* is generally recognized as the northern form of *V. nudum*, and thus the name change.

In the landscape, *V. nudum* var. *cassinoides* can be used in the naturalized garden, mass plantings, and in the shrub border. Fall color is orange-red, dull crimson, and purple shades. Young foliage emerges with bronze or purple tints. The flowers and fruit are also attractive. The gradual change of fruit color from red to blue to black can often be witnessed on the same inflorescence. In addition, there is a deep-pink fruited form available (Dirr, 1998). These valuable ornamental attributes make *V. nudum* var. *cassinoides* an interesting plant for the landscape.

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Chapter 4

EFFECTS OF WARM STRATIFICATION AND GIBBERELLIC ACID ON SEEDS OF *ASARUM CANADENSE*

Abstract

The seed of *Asarum canadense* was stratified at warm temperatures for 0, 1, 2, or 3 months and then soaked in gibberellic acid for 24 hours before being sowed in germination mix and placed in the greenhouse. In a second experiment, seed was given a warm stratification, soaked in GA, and then placed in a cold storage facility for 2 months. The seed of *A. canadense* is known to have a double dormancy, which leads to difficulty in germinating the seed, so the warm stratification followed by gibberellic acid treatment was meant to mimic the warm-cold cycle that the seed would typically be exposed to. No germination was observed in either of the experiments.

Introduction

Asarum canadense is a native herbaceous perennial that is used as a ground cover in woodland gardens and shaded areas. Its heart-shaped, matte green leaves make it a good companion for many woodland plants. Seed germination of this species is difficult, as the seed needs to break an apparent double dormancy before it will germinate.

In 1944, Barton indicated that the seed of *A. canadense* has a specific kind of dormancy called epicotyl dormancy. Seeds that exhibit this kind of dormancy fail to produce above ground shoots even after the radicle has emerged. To induce shoot development, seedlings must be exposed to cool temperatures after radicle emergence. In her study, Barton exposed fresh, cleaned seeds to a cycle of warm and then cold temperatures. She found that radicle emergence was greatest at 10° to 20° C. Most of the seedlings showed signs of radicle emergence at the end of two months at these temperatures. After radicle emergence, the seeds were placed in cold storage at 5° C for three months. Transfer back to the greenhouse yielded 80 to 95 percent germination within 2 weeks.

Germination can be accomplished in this manner; however, it is in the interest of many nursery growers to speed up such a process so that a saleable plant can be produced in a shorter amount of time. Division is a commonly used propagation method for *A. canadense*, but a nursery must have the resources to maintain a sizeable stock plant from which to divide every year. By using seed to propagate *A. canadense*, many nursery growers will be able to offer this plant for sale by either selling the plants raised by seed or establishing their own stock plants from which to divide new plants. To accomplish this, an easier method of seed germination has to be determined.

Warm stratification may mimic the natural conditions that the seed is exposed to in nature and allow for the germination of a dormant seed. This is true for some species of ornamental plants, such as *Amalanchier*, shadbush (Dirr and Heuser, 1987). Gibberellic acid has also been shown to improve germination percentages in many species of ornamental plants, often substituting for cold stratification treatment (Atwater, 1980; Desai et al., 1997; Taylorson and Hendricks, 1977). It may accomplish this by helping to wear down a chemical inhibitor that is usually broken down over the winter or by catalyzing the enzyme that helps in the release of food from the food storage area of the seed to the embryo (Taiz and Zeigler, 1998). For plants that have double dormancy, using two treatments may help improve germination success (Hartmann, et al., 1990; Kitchen and Meyer, 1991).

The objective of this study was to improve seedling germination methods for *A. canadense.*

Materials and Methods

Seed of *Asarum canadense* was obtained from Jelitto Seed Company (Germany) in the spring of 2001. Seed of *Asarum canadense* was given a warm stratification of 0, 1, 2, or 4 months. The warm stratification was carried out by placing seed into moistened sections of cheesecloth and then burying them in a plastic bag of moistened sphagnum moss. The bags were left at room temperature (20°C) for the duration of their respective stratification. At the end of each month of warm stratification, 320 seeds were removed from the bag and divided into four groups. Seed was then soaked in 0 ppm, 200 ppm, 400 ppm, or 600 ppm GA_3 for 24 hours at room temperature (20°C). Seed was removed from the soak and rinsed in distilled water before being planted in 32-cell plastic trays (Dillen Products, Inc., Middlefield, OH) with Fafard germination mix (Fafard, Inc., Agawam, MA). The seed was then placed in the greenhouse (average temperature, 20°C) and monitored daily. The seeds were watered when necessary. A completely randomized block design was used, each treatment having 4 replicates, 20 seeds per replicate.

In a second experiment, seeds of *Asarum canadense* were placed in warm stratification for 3 months. When the warm stratification was complete, the seeds were divided into four groups. Each group was treated with a 0 ppm, 200 ppm, 400 ppm, or

600 ppm GA soak for 24 hours at room temperature. One group was left in the greenhouse (20°C) with no warm stratification and only a water soak for 24 hours to serve as the control. Once the GA soak was completed, the seeds were rinsed in distilled water and placed in Fafard germination mix in a 32-cell tray. The tray was then placed in a cold storage facility (4°C) and monitored for signs of germination. A completely randomized block design was also used in this trial, 4 replicates per treatment, 20 seeds in each replicate.

Results and Discussion

None of the seeds in any of the treatments germinated. The double dormancy that is exhibited in the seeds of *A. canadense* is not easily broken using chemical means. In Barton's study, the seed germinated after the cold stratification period, so warmer temperatures after warm stratification and gibberellic acid treatment may be necessary.

Another factor to consider is the length of viability of the seeds of *A. canadense.* Viability tests were not carried out, as the seed was assumed to be viable according to information supplied by the seed company. In many species of seeds, dry storage has adverse effects on viability. The seed of *Aesculus parviflora*, for example, rapidly loses viability and will fail to germinate if not planted soon after harvesting (Jones, 1999). Because of this question of viability, it may be necessary to collect and sow seed of *A. canadense* when it is fresh.

Further research may be needed to understand the complexities of the dormancy conditions and viability issues of the seeds of *A. canadense.*

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Chapter 5

IMPROVING VEGETATIVE PROPAGATION TECHNIQUES OF SWEET FERN (*COMPTONIA PEREGRINA*)

Introduction

With increased interest in growing and selling native plants (Dreyer, 1993; Niemeyer, 2000) and the need to find native alternatives to non-native species being used in landscaping and restoration work (Maine Department of Conservation, 2001; Reichard and White 2001), comes the need for updated information on propagation techniques for native plants. While sweet fern, *Comptonia peregrina* (L.) J.M. Coulter., is not a challenging plant to propagate, new information is needed for growers, particularly in the north, to find optimum propagation conditions and take advantage of short growing seasons.

Sweet fern is a low-growing shrub native to eastern North America. Its bright, glossy green, aromatic foliage turns deep red in the fall. Growing from 2 to 4 feet, it is an ideal groundcover for gardens, parking lots, and naturalized areas. In addition, it can be used in erosion control along roadsides and in disturbed areas (Zak and Bredakis, 1967). In fact, it favors poor, sandy soils. Sweet fern can fix atmospheric nitrogen via nodules on its roots and may play an important role in the nitrogen content of soil in its native range (Zeigler and Huser, 1963).

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Seed germination of sweet fern is difficult (Dirr and Heuser, 1987; DelTredici, 1976; Young and Young, 1992). Due to the difficulty in achieving high germination percentages, seed may not be a commercially viable method of propagation for sweet fern. In addition, rooting stem cuttings from mature plants is not successful (Hamilton, 1974), so root cuttings are the most commonly used form of propagation.

In 1972, Hyde and Zak conducted research to determine the optimum time of year to take cuttings. They found that cuttings taken in February through May rooted at high percentages, while cuttings taken at other times of the year produced few or no rooted cuttings. They indicated in their publication that once the plant has leafed out a hormone inhibitor may be responsible for preventing the sprouting of lateral buds on the roots. In other literature, spring-collected root cuttings of sweet fern are recommended to achieve rooting percentages as high as 100% (Dirr and Heuser, 1987). Fall collected roots treated with cold stratification may also be beneficial for sweet fern, however we found no literature directly indicating this. Generally, healthy roots which were produced as a result of vigorous growth that contain a high carbohydrate level and are taken as cuttings during the dormant period have high chances of successfully rooting (Browse, 1980).

Of the many species of plants that can be propagated by root cuttings, some respond better at different times of the year. *Rhus typhina* roots well when cuttings are collected in the fall and treated with cold stratification for a few months before planting. *R. glabra,* on the other hand, roots better from spring-collected roots (Dirr and Heuser, 1987). Herbaceous species seem to also do well when cuttings are taken in the dormant period (Browse, 1980), as do many other woody plants (*Clethra, Spiraea, Viburnum*)

(Orndorff, 1987). This evidence indicates that season and cold stratification do affect root cuttings in different plants.

In preliminary experiments with sweet fern root cuttings, we noticed that the trays of cuttings placed outside next to a concrete greenhouse wall for cold storage rooted in an unusual pattern. The half of the tray nearest to the warm concrete wall rooted at nearly 100%, while the cuttings further away from the wall rooted poorly. This led us to conclude that there is an effect of temperature on the rooting of sweet fern cuttings. The objective of this study was to determine the effects of cold stratification duration and temperature on the rooting of sweet fern root cuttings.

Materials and Methods

Roots were collected from a site in Orono, Maine on November 13th, 2001. Roots were collected by gently lifting the root from the soil. The root segments were then cut into 2" sections. Diameter of the cuttings varied from ¼ - 3/8". After preparation, cuttings were placed into 32-cell flats (Dillen Products, Inc., Middlefield, OH). Two pieces were placed in each cell, crossed one over the other in an X pattern. All cuttings were planted horizontally, 1" deep in Metro-Mix 510 (Scott's Inc., Marysville, OH) potting media. Cuttings were thoroughly watered in after being planted.

In total, 10 trays of cutting were prepared. Within each tray there were 4 blocks, and a completely randomized block design was utilized. Nine were assigned to cold storage treatments, and one tray was placed directly in the greenhouse as a control group. Cold treatments (cold storage facility, outside under black plastic, and outside under microfoam) were designed to replicate conditions that a grower may have available for use at his or her facility. The cold storage facility is a large walk-in refrigeration unit on the University of Maine campus used for the storage of plant material. Outside, the trays of cuttings were placed under a single layer of either black plastic or microfoam. Temperatures were recorded with an Echo electronic temperature logger (Marathon Products, Inc., Modesto, CA). Besides temperature, no measurements were made during cold stratification and the cuttings were not watered until they were brought into the greenhouse after their respective cold treatments.

Table 5.1. Treatment temperatures.

treatment	**average temperature over duration of experiment**	**highest temperature recorded**	**lowest temperature recorded**
control	20°C (in greenhouse)	32°C (91°F)	14°C (58°F)
1 month cold storage	3.3°C (38°F)	4.4°C (40°F)	3°C (38°F)
1 month black plastic	-0.5°C (31°F)	4.4°C (40°F)	-8°C (16°F)
1 month microfoam	-0.5°C (31°F)	7.7°C (46°F)	-7°C (18°F)
2 months cold storage	3.3°C (38°F)	4.4°C (40°F)	3°C (38°F)
2 months black plastic	-3.3°C (26°F)	7.7°C (46°F)	-11°C (11°F)
2 months microfoam	-3.3°C (26°F)	3°C (38°F)	-10°C (14°F)
3 months cold storage	3.3°C (38°F)	4.4°C (40°F)	3°C (37°F)
3 months black plastic	-3.3°C (26°F)	14°C (58°F)	-15°C (4°F)
3 months microfoam	-3.3°C (26°F)	11°C (52°F)	-15°C (4°F)

One tray per treatment per month was moved into the greenhouse. Once moved into the greenhouse, all cuttings were placed under a 55% shade cloth, observed every day, and watered when necessary.

After trays of cuttings were placed in the greenhouse, they were observed daily for signs of growth. For practical purposes, cutting was considered rooted when shoot emergence was observed. Although the root system may not develop until the shoot system has expanded (Browse 1980), all cuttings that produced shoots also produced a healthy root system. Number of days from removal from cold storage until shoot emergence was recorded. The longest shoot in each cell was measured one week after shoots emerged. The same shoot in each cell was also measured one and then three months after they were removed from their respective cold storage treatment. During the third month measurement, the number of shoots per cell was also recorded. A completely randomized block design was used and data was analyzed using SAS analysis of variance and means separation (Fisher's protected LSD) at a significance level of alpha = 0.05.

Results

Cuttings treated in the cold storage facility were the most successful in terms of rooting and growth. In addition to rooting at high percentages, cuttings stored in the cold storage facility produced shoots sooner, produced longer shoots, and produced more shoots per cell.

Table 5.2. Influence of cold stratification duration and temperature on rooting, shoots, and height of sweet fern cuttings.

cold stratification treatment	**rooted (%)**	**days until shoots**	**shoots (#)**	**height, 1 week (cm)**	**height, 1 month (cm)**	**height, 3 months (cm)**
control	75 ab	38 d	1.91 c	1.81 b	4.03 c	5.68 bc
1 month cold storage	97 a	29 c	2.34 b	1.73 b	5.37 ab	8.19 b
1 month black plastic	97 a	31 c	2.55 b	1.41 bc	4.16 bc	6.04 bc
1 month microfoam	100 a	28 c	2.36 b	1.58 b	4.06 c	5.88 bc
2 months cold storage	100 a	18 a	4.50 a	2.35 a	6.02 a	14.99 a
2 months black plastic	28 de	26 b	1.00 d	1.66 b	3.52 c	5.00 b
2 months microfoam	59 bc	24 b	1.63 cd	1.78 b	3.01 c	4.47 bc
3 months cold storage	97 a	17 a	3.65 a	2.60 a	8.50 a	15.75 a
3 months black plastic	25 e	28 c	2.50 b	1.80 b	3.92 c	6.53 b
3 months microfoam	22 e	31 c	1.71 c	1.42 bc	2.72 c	4.72 b

within each column, values followed by the same letter do not differ at alpha = 0.05

Cuttings treated with one month of cold storage in all temperatures also rooted at high percentages, however, they were not as successful in terms of growth.

Cuttings treated with one month under microfoam or two months in the cold storage facility both rooted at 100%. One month in cold storage, one month under black plastic, and three months in cold storage also rooted at high percentages. In contrast, cuttings treated with cold stratification of 2 or 3 months under microfoam or black plastic rooted at significantly lower percentages (Table 5.2). Both of these treatments had the lowest average temperatures (-3.3°C (26°F)) and the most fluctuation in temperature (Figure 5.1). This may indicate that the root cuttings do not respond well to freezing and/or fluctuating temperatures.

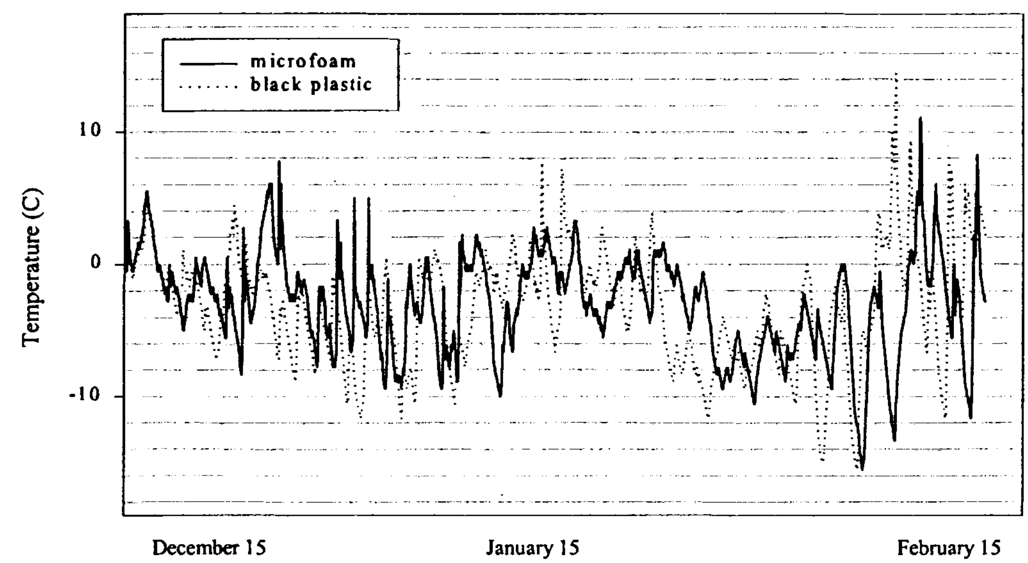

Figure 5.1. Temperature fluctuation during cold treatment under black plastic and microfoam.. Temperatures in the cold storage facility remained at a constant 3 – 4°C.

Shoot emergence was earliest and height and number of shoots per cell were higher in cold storage facility treated roots. Shoots emerged earliest from roots treated with 2 or 3 months of cold storage. Both of these averages are statistically less than all other treatments. In contrast, cuttings treated with 3 months under microfoam and black plastic took 10 or more days longer for shoot emergence to occur. Shoot length was highest in cuttings treated with 2 and 3 months in the cold storage facility. These heights are significantly higher than all other treatments. Measurements taken after the first week and first month also show that 2 and 3 months cold storage had the longest shoots at those times as well. Finally, 2 and 3 month cold storage facility treatments produced the highest number of shoots per cell. Both of these averages were statistically higher than all other treatments (Table 5.2).

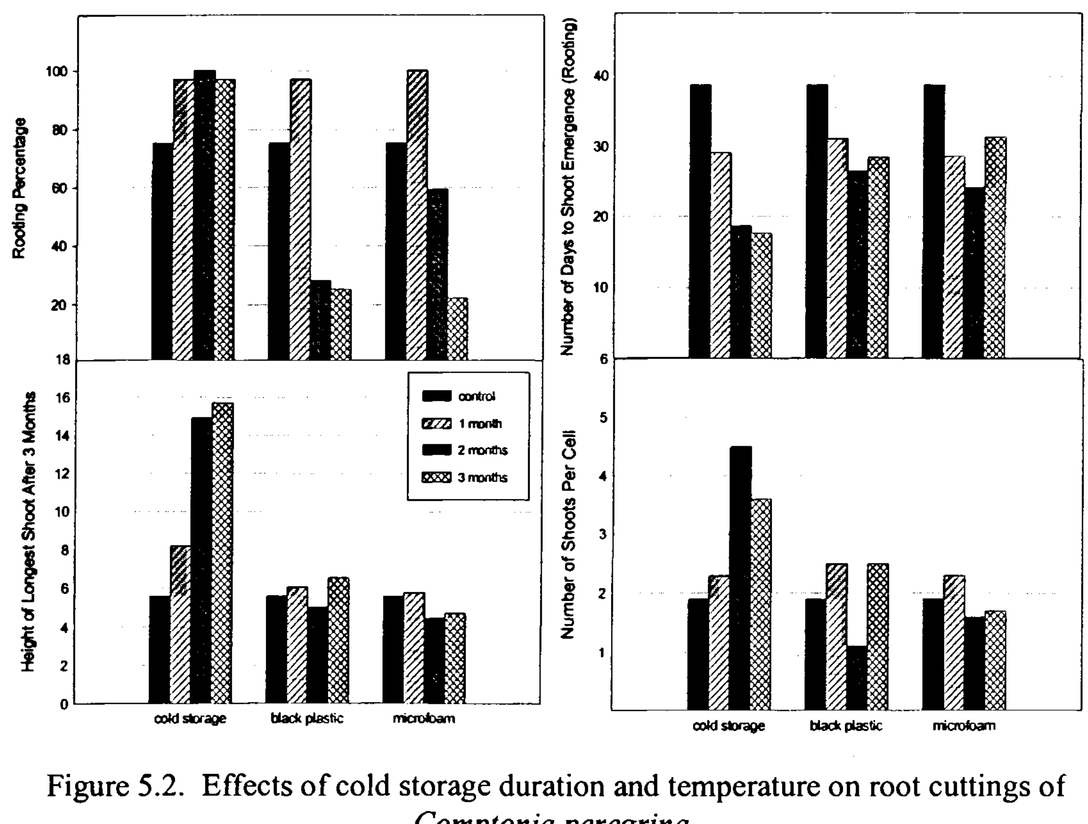

Figure 5.2. Effects of cold storage duration and temperature on root cuttings of *Comptonia peregrina.*

Discussion

A successful cutting of any kind is one that roots readily, puts on adequate growth, and is ready for sale quickly, so to reduce the amount of time a nursery has to hold on to each plant. Using this method of rooting cuttings of sweet fern accomplishes these goals. Cuttings only have to be handled from late fall to late spring, when there may be less time demand on the nursery staff (Browse 1980), and the end result is a tray of healthy cuttings.

Sweet fern roots have adventitious buds that are stimulated to grow when the plant is injured (Hall et al, 1976). Cold stratification promotes the formation of or breaking of dormancy of adventitious buds (Hartmann et al, 1997). Taking sweet fern root cuttings in the fall and treating with cold stratification breaks the dormancy of lateral buds, thus allowing for new roots and shoots.

By taking cuttings in the fall and treating with cold stratification, growers, particularly in the north, can get cuttings into the greenhouse in mid-winter, thus allowing for larger, more healthy plants early in the spring. Spring collected cuttings will need much of the season to grow to the same size as fall-collected cuttings, resulting in cuttings that are not ready for sale until mid summer.

Conclusion

Cold stratification temperature and duration have an effect on rooting of sweet fern root cuttings. Higher rooting percentages, shoot growth, and number of shoots per cell result when cuttings are treated in a cold storage facility at moderate temperatures. Optimum cold stratification for rooting is 2 to 3 months in a cold storage facility at consistent temperatures of 3 – 4° C. Cold temperatures above freezing are best for this treatment. Freezing and/or fluctuating temperatures seem to be detrimental to the survival of cuttings. By taking cuttings in late fall and treating with cold stratification, high rooting percentages can be obtained and a consistent crop of healthy cuttings will be produced early in the season.

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Chapter 6

EFFECTS OF EXTENDED PHOTOPERIOD ON SOFTWOOD CUTTINGS OF *CORNUS ALTERNIFOLIA*

Abstract

Cornus alternifolia, Pagoda Dogwood, is a native shrub with potential for greater use in the landscape. While cuttings root readily from softwood cuttings using K-IBA, the effect of lighting on rooting success was not known. This experiment was designed to test the effects of extended photoperiods on softwood cuttings of *C. alternifolia.* Cuttings treated with 5000 ppm K-IBA rooted readily in the regular light conditions, but rooted very poorly when exposed to 24-hour photoperiods, indicating that extended photoperiods are detrimental to rooting in *C. alternifolia.*

Introduction

The Pagoda Dogwood, *Cornus alternifolia,* is a native shrub or small tree with potential for greater use in the landscape. Softwood cuttings of this plant root readily, however, overwintering the rooted cuttings can be a problem. By determining if lighting has an effect on the rooting of softwood cuttings, further studies can be conducted to determine if photoperiod treatments can be used to increase overwinter survival rate.

Cuttings of *C. alternifolia* generally root readily when taken in July or August and treated with 8000 ppm liquid IBA (Dirr and Heuser 1989). The difficulty comes in taking the plant through its first dormant period. MacMillian Browse (1970) noted that cuttings must have put on some secondary growth and not be disturbed (i.e., not transplanting before the first dormancy) in order to survive their first winter. Photoperiod is the duration of light a plant is exposed to during the day. Extended photoperiods have been found to increase rooting and growth in many species (Macdonald, 1969; Waxman, 1965). Dirr (1986) noted that a 75-watt light bulb hung 1 m above the mist bench is sufficient to add supplemental light.

The objective of this study is to determine if K-IBA and extended lighting improve rooting in cuttings of *C. alternifolia*.

Materials and Methods

Softwood cuttings of *C. alternifolia* were taken on 11 July 2002 from a site in Orono, Maine. Leaves were trimmed by approximately one third and the cuttings were wounded along the bottom ½" by lightly scaring the stem with pruning shears. They were then treated with 5000 ppm K-IBA quick-dip for 30 seconds and allowed to air-dry for 10 minutes (the control group was treated in the same manner using distilled water instead of K-IBA). A treatment of 5000 ppm K-IBA was used because one author noted *C. alternifolia* roots readily using 8000 ppm K-IBA (Dirr and Heuser, 1987) and we wanted to determine if a lesser concentration could be used. After treatment, cuttings were \ placed, one per cell, in 32-cell trays (Dillen Products, Inc., Middlefield, OH) in a media mixture of 2:1 perlite (Whittemore CO., Lawrence, MA) to ProMix-BX (Premier Horticulture, Red Hill, PA). One half of the cuttings were placed under 75-watt fluorescent bulbs that were hung 3' above the mist bench. The other half were placed under regular light conditions on the same mist bench. Black plastic was used to block the light from the other areas of the mist bench. A completely randomized block design was used. Four replicates per treatment were tested, with 8 cuttings per replicate for a total of 128 cuttings.

Table 6.1. Treatments of *C. alternifolia* cuttings.

Extended Light	**Regular Light**
0 ppm	0 ppm
5000 ppm	5000 ppm

Results and Discussion

Both light and hormone concentration had an effect on the rooting of *C. alternifolia* cuttings. No significant treatment interaction was observed. Because no interaction was observed, the data was analyzed separately. Rooting hormone concentration of 5000 ppm K-IBA increased rooting from 33.1% in the control group to 76.6% in the treated group. Light decreased rooting from 75.1% under regular light to 34.6% under extended light.

Table 6.2. Effects of K-IBA and lighting conditions on *C. alternifolia*.

Treatment	**Percent rooted**	**Treatment**	**Percent Rooted**
0 ppm K-IBA (control)	33.1 b	**Regular Light**	75.1 a
5000 ppm K-IBA	76.2 a	**Extended Light**	34.6 b

*Within each column, numbers followed by the same letter are not significantly different at alpha ≤ 0.05.

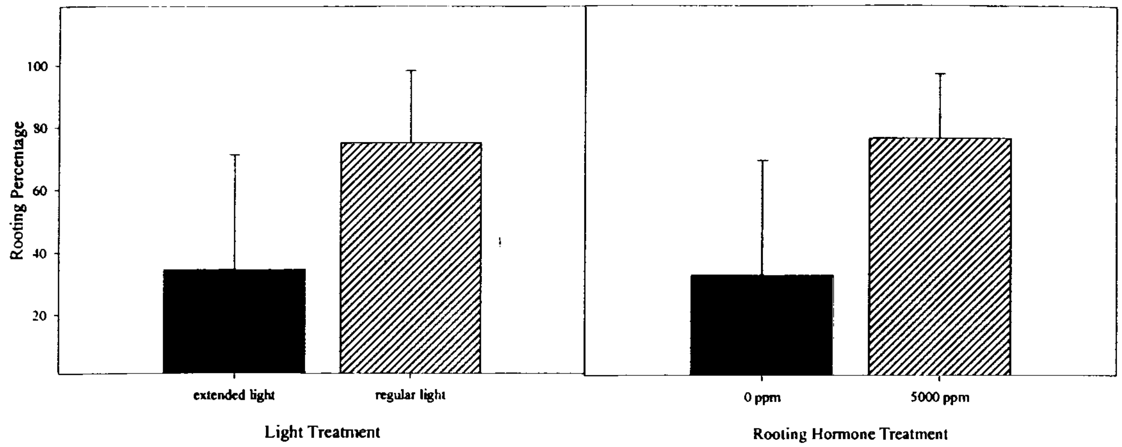

Figure 6.1. Effects of lighting and rooting hormones on rooting of *C. alternifolia* July-collected cuttings.

It is not apparent why extended lighting would decrease rooting. More light may stimulate increased top growth, thus leaving less energy for root growth. Excess heat generated by the lighting may also adversely effect rooting, as cuttings typically respond better to cooler air temperatures. Baker and Link (1963) noted that some species of plants simply do not respond well to extended photoperiods, although they did not give an explanation.

Conclusions

Rooting percentages of *C. alternifolia* can be increased with the use of rooting hormones under regular light conditions. Rooting percentages increased from 33% in the control group to 76% with a 5000 ppm K-IBA quick-dip. Because extended photoperiods do not have a positive effect on rooting of *C. alternifolia* cuttings, different methods need to be researched to determine how to best propagate and grow *C.*

alternifolia. New propagation methods could lead to increased use of this plant in nurseries and garden centers.

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Chapter 7

EFFECTS OF EXTENDED LIGHT AND K-IBA ON HARDWOOD CUTTINGS OF *CORNUS RUGOSA*

Abstract

Hardwood cuttings of *Cornus rugosa* were treated with varying concentrations of K-IBA and exposed to different lighting conditions during rooting. Extended photoperiods often have beneficial effects on rooting in some species of plants. Cuttings of *C. rugosa*, however, did not benefit from supplemental lighting. Highest rooting percentages were gained using 10,000 ppm K-IBA quick dip and exposing the cuttings to ambient light conditions.

Introduction

Cornus rugosa, the round-leafed dogwood, is a native shrub of eastern North America. Often found on dry slopes on the border of woods, it has the potential to be a landscape plant due to its interesting habit, flowers, and foliage. The lack of published information on this plant may be the factor that is inhibiting its use in the nursery industry.

A review of the literature found very little reference to *C. rugosa*. The plant flowers from May to June and the fruit ripens between August and October. A cold stratification for 90 days at 5°C for seed germination is suggested. No germination percentages are listed (Young and Young, 1992). The plants observed in Orono produced very little fruit, so seed was ruled out as an option in this study. Softwood cuttings were taken in June 2001; however, the cuttings dropped their leaves rapidly and rooted very slowly at very low percentages. None of the cuttings survived the winter. *C. sericea*, red-osier dogwood, roots readily from hardwood cuttings, as does *C. alba* (Dirr and Heuser, 1987), so hardwood cuttings were chosen as the next option for propagation. In addition to using rooting hormones on the hardwood cuttings, supplemental lighting was also tested because many species of plants benefit from extended photoperiods, or the duration of light a cutting receives in a day (Waxman, 1965). Lighting from 75-watt bulbs placed 3 feet above the mist bench can aid the rooting and growth of cuttings (Dirr, 1986). As a result of these observations and because other closely related species of *Cornus* root readily from hardwood cuttings, the following study was designed to test the effects of rooting hormone and extended photoperiod on rooting of *C. rugosa* hardwood cuttings.

Materials and Methods

Hardwood cuttings of *C. rugosa* were taken in Orono, Maine on 29 March 2002. The plant the cuttings were taken from was thriving on a hillside along a railroad track in the woods. Terminal ends of the stems were discarded and cuttings were taken from the lower parts of the stems. Cuttings ranged in length from 4 to 6 inches, and in diameter from ¼ - 3/8 of an inch.

Table 7.1. Treatments of *C. rugosa* hardwood cuttings.

Extended Light	**Regular Light**
0 ppm	0 ppm
2500 ppm	2500 ppm
5000 ppm	5000 ppm
10000 ppm	10000 ppm

After being cut to size, the cuttings were wounded by lightly scaring the lower 1" of the cuttings with horizontal cuts with pruning shears. Cuttings were treated with a quick-dip of K-IBA in a concentration of 0, 2500, 5000, or 10000 ppm. Cuttings were dipped for 30 seconds in the solution and were then allowed to air-dry for 10 or more minutes before being stuck in a 2:1 perlite (Whittemore Co., Lawrence, MA):Pro-Mix (Premiere Horticulture, Red Hill, PA) media. The cuttings were stuck one per cell in 32-cell trays (Dillen Products., Inc, Middlefield, OH) and placed under 50% shade cloth. The mist system operated at intervals of 20 seconds of mist every 10 minutes. Temperatures in the greenhouse averaged 20°C (68°F). One set of cuttings was placed under 75-watt fluorescent lights for 24 hours a day. The second set of cuttings was exposed to regular daylight. The cuttings were placed in the same bench, with black plastic blocking any light from the rest of the bench.

Data was collected 3 months after the cuttings were stuck. A completely randomized block design was used and data was analyzed using SAS analysis of variance and Fisher's protected least significant means separation at alpha ≤ 0.05.

Results and Discussion

The cuttings broke bud and leafed out a 3 weeks after they were treated. Flower buds also formed and were removed promptly to avoid any adverse effect on rooting, as the energy it takes to form the flowers reduces the amount of energy that can be put into forming roots. No rooting was observed after one month of treatment, and cuttings were subsequently checked for rooting three months after they were taken.

Both regular light conditions and rooting hormones had a significant effect on rooting of *C. rugosa* cuttings, but no significant interactions were observed. Extended light was not beneficial to rooting. Rooting percentages overall decreased from 72% under regular light conditions to 43% with extended light. A concentration of 10,000 ppm K-IBA quick-dip treatment under regular light achieved the highest rooting percentages (78%), however, this percentage is not significantly higher than the other percentages in the regular light treatment. Hormone effects were observed in the extended light treatment, where a treatment with 5,000 ppm K-IBA increased rooting from 40.7% in the control group to 75.0%.

Table 7.2. Rooting percentages of *C. rugosa*.

Concentration K-IBA	Regular Light	Extended Light
0 ppm	68.7 a	40.7 b
1,000 ppm	71.5 a	28.2 b
2,500 ppm	68.5 a	47.0 b
5,000 ppm	74.5 a	75.0 a
10,000 ppm	78.0 a	28.2 b

*Within each column, numbers followed by the same letter are not significantly different at alpha ≤0.05.

Table 7.3. Overall rooting percentages in light treatments.

Treatment	Percent Rooted
Extended Light	43.8 b
Regular Light	72.3 a

*Numbers followed by the same letter are not significantly different at alpha ≤0.05.

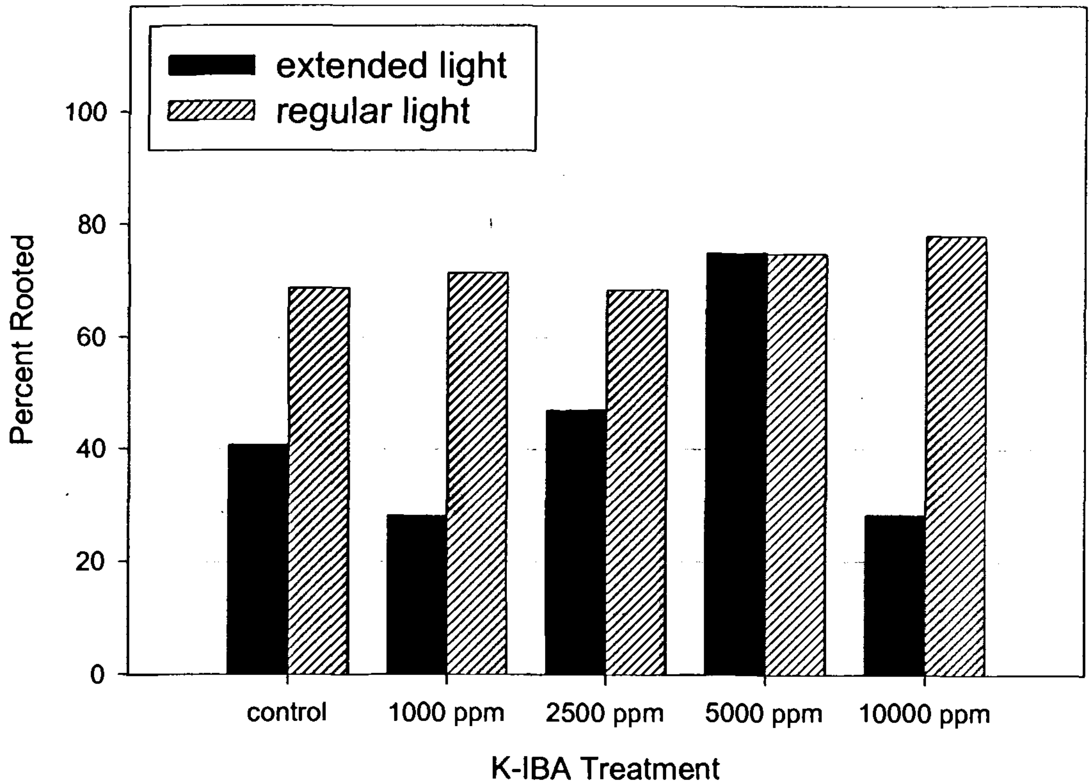

Figure 7.1 Effects of light and K-IBA treatment on hardwood cuttings of *Cornus rugosa*.

Light may be detrimental to the rooting of cuttings for several reasons. After leafing out, the cuttings may absorb too much light, thus using more energy for photosynthesis than for rooting. Also, excess heat to the leaf and stem generated by the lighting may also adversely affect the cuttings. This problem could be solved with better ventilation on the mist bench. Baker and Link (1963) noted that supplemental light is detrimental to some species of plants, particularly conifers, which prefer short days. They do not, however, conclude why extended photoperiods would be detrimental.

Conclusion

C. rugosa can be rooted successfully using hardwood cuttings. Extended light, however, has a detrimental effect on rooting. Rooting percentages as high as 78% can be achieved when cuttings are lightly wounded, treated with a quick-dip in 10,000 ppm K-IBA, and stuck under regular light conditions. Further studies will be needed to determine the best methods for overwintering, transplanting, and growing the cuttings into saleable plants.

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Chapter 8

EFFECT OF GIBBERELLIC ACID AND LIGHT ON SEED OF *GAULTHERIA PROCUMBENS*

Abstract

Seed of *Gaultheria procumbens* was soaked in gibberellic acid for 24 hours prior to being placed in petri dishes and monitored for germination. Seed was also tested for reaction to light during germination. Seeds were placed under regular (ambient) daylight conditions, in dark, or in extended light conditions. Gibberellic acid did have a significant effect on seed germination, as did light conditions. No significant interaction was observed. Regular daylight was observed to be the best condition for seed germination and gibberellic acid concentrations as low as 200 ppm were beneficial to germination.

Introduction

Gaultheria procumbens, wintergreen, is a small woody perennial that is ideal for several situations in the landscape. From moist woodland gardens to sunny openings, wintergreen makes an excellent groundcover with white flowers, red berries, and purple fall foliage. Propagation is typically by division, as stem cuttings are somewhat difficult to root (Dirr and Heuser, 1987) and seed germination is relatively difficult (Cullina, 2000). This poses a problem to propagators who do not have access to stock plants. Improving propagation methods will allow plant propagators to grow plants from seed for themselves. This will accomplish two things: provide the means to grow saleable plants from seed, and to grow plants from seed to establish stock plants, which can later be used for division propagation.

There is little literature available on seed germination of *G. procumbens*. The seed may need cold stratification and may also benefit from light during germination. Dirr and Heuser (1987) noted that fresh seed might benefit from a short cold stratification. Cullina (2000) also indicated that seed germination percentages might increase with a cold stratification as well as light during germination. Neither describes a length of cold stratification or germination percentages. Gibberellic acid can improve seed germination as well as substitute for the cold stratification that many seeds require (Taiz and Zeiger, 1998). GA has been found to increase germination percentages in many ornamental plants (Atwater, 1980; Desai et al., 1997; Taylorson and Hendricks, 1977). Light is also another important factor in seed germination (Gutterman, 1992). In an effort to eliminate the need for a cold stratification and potentially improve germination percentages, this study was designed to test the effects of gibberellic acid and light on the seed germination of *G. procumbens*.

Materials and Methods

Dry seed of wintergreen was obtained from Jelitto Seed Company (Germany) in the spring of 2001. The seed was soaked in varying concentrations of gibberellic acid. Four replicates of 20 seeds each were soaked in 0, 200, 400, 600, 800, or 1000 ppm GA_3 for 24 hours at room temperature for a total of 80 seeds per treatment. A completely randomized block design was used. After the 24-hour soak, the seed was rinsed with distilled water and put in petri dishes (20 seeds per dish) and placed in the greenhouse under three different light regimes. One set was exposed to a long photoperiod of 18 hours (under halogen lighting), the second set was exposed to a regular daylight (under a 50% shade cloth), and the third set was placed in the dark (under a triple layer of black plastic). Because the experiment was replicated three times, the daylight under ambient light conditions varied from 8 hours in January to 15 hours in May. Temperatures in the greenhouse averaged 22°C. Temperatures in the dark treatment averaged 21°C. The seeds were checked every day and the filter paper was moistened when necessary.

Table 8.1 Light and GA_3 treatments for *G. procumbens*.

Light Treatment		
Regular Light	Extended Light	Dark
0 ppm	0 ppm	0 ppm
200 ppm	200 ppm	200 ppm
400 ppm	400 ppm	400 ppm
600 ppm	600 ppm	600 ppm
800 ppm	800 ppm	800 ppm
1000 ppm	1000 ppm	1000 ppm

A seed was considered germinated when the radicle reached the length of the seed itself. Germination was recorded daily. Rate of germination was recorded by calculating the number of days until 50% of the seeds in each treatment germinated. The seed were observed for a period of three weeks, after which only sporadic germination was observed. Data was analyzed using SAS analysis of variance at a significance level of alpha ≤ 0.05. Means were separated using Fisher's Protected LSD at alpha ≤ 0.05.

Results and Discussion

Light and gibberellic acid both had a significant effect on seed germination, however no significant interaction was observed. Gibberellic acid significantly increased germination percentages in all treatments. Germination percentages were significantly higher in the regular light treatments, while lower percentages were observed in both the extended light and dark conditions.

Table 8.2. Germination percentages in all treatments of *Gaultheria procumbens* seed.

GA Treatment	Extended Light	Regular Light	Dark	Overall
0 ppm	38.7 a	53.7 a	48.7 a	45.3
200 ppm	58.7 b	76.6 b	61.2 b	66.7
400 ppm	51.6 b	78.3 b	57.5 b	63.9
600 ppm	56.6 b	80.8 b	67.5 b	68.5
800 ppm	55.0 b	75.8 b	61.2 b	64.8
1000 ppm	60.4 b	83.3 b	70.1 b	71.6
Overall	53.1	74.7	61.0	62.9

*Within each group, numbers followed by the same letter are not statistically significant at alpha ≤ 0.05.

Germination rate, across all treatments, was not significantly different. Best germination percentages (83.3%) were obtained with a 1000 ppm GA_3 soak under ambient light conditions.

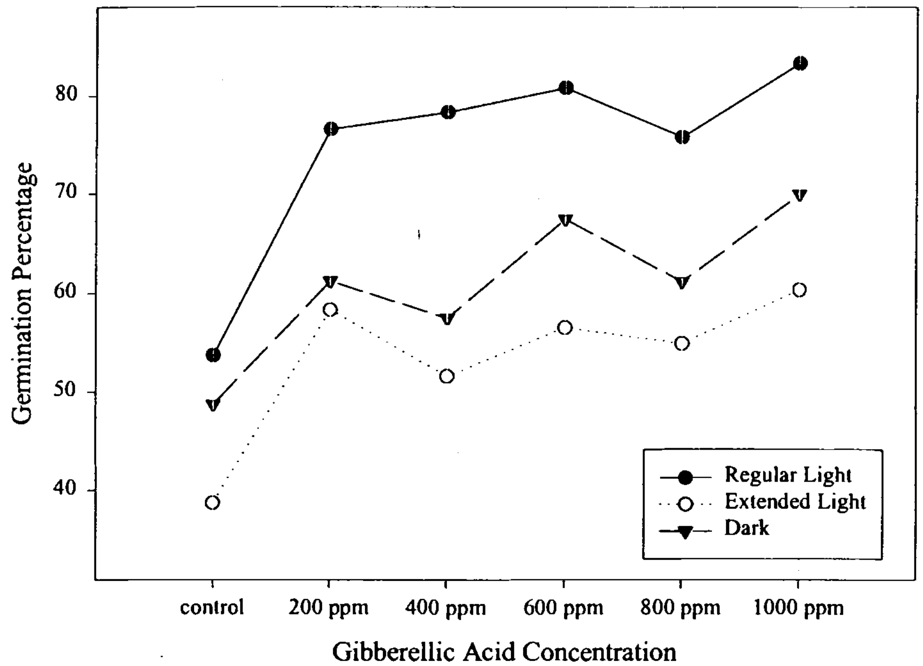

Figure 8.1. Effects of GA_3 and light treatments on seed germination of *Gaultheria procumbens*

In general, small seeds respond to light during germination (Atwater, 1980). Extended light and dark could be detrimental to seed germination for several reasons. Extended light treatments could result in faster drying out of seed and increased heat to the seed for long amounts of time. Temperature was not recorded directly under the extended light treatment, so there is no data to support this theory. However, both of these theories could negatively effect germination. Dark conditions, although beneficial to some plants, may not allow for the beginning of metabolic processes in the seed that result in germination. By restricting light, some of these functions may not be able to take place. Also, there may be a lack of available oxygen to these as they were stored in petri dishes covered with plastic bags to create dark conditions, which could have allowed for very little airflow. Ambient light provides the right conditions, resulting in higher germination percentages.

Conclusion

In the case of *G. procumbens,* ambient daylight is sufficient to elicit greater germination percentages. While some seeds require long photoperiod or dark conditions to germinate, *G. procumbens* does not. Pretreatment with gibberellic acid results in further increases in germination percentages. Gibberellic acid may substitute for the cold stratification requirement of *G. procumbens* or it may speed up some of the processes within the seed that result in germination. Based on our results, a 200 ppm GA_3 soak for 24 hours will result in higher germination percentages.

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Chapter 9

EFFECTS OF ROOTING HORMONES AND EXTENDED LIGHT ON SOFTWOOD CUTTINGS OF *VIBURNUM LANTANOIDES* AND *V. NUDUM* VAR. *CASSINOIDES*

Introduction

Viburnum lantanoides (*V. alnifolium*), hobble-bush, and *V. nudum* var. *cassinoides*, withe-rod viburnum, are two deciduous native shrubs with potential for increased use as landscape plants. A search of the literature indicates that withe-rod roots readily from softwood cuttings. In a preliminary experiment we found that cuttings did indeed root at high percentages. However, none of these cuttings survived the winter. No literature was found on hobble-bush, nor was plant material available for preliminary experiments.

Macmillian Browse (1970) notes that for viburnums to successfully survive their first winter a flush of secondary growth from the cutting must be produced. This may be accomplished by providing the cutting with supplemental light. Light has many effects on plants, one of which is the increase of roots produced per cuttings in cuttings exposed to long day photoperiods (Waxman 1965). By producing a healthier cutting, it is possible that chances of surviving the winter will increase.

The objective of this study is to test the effects of rooting hormones and lighting on the rooting of softwood cuttings of *V. lantanoides* and *V. nudum* var. *cassinoides.*

Materials and Methods

Cuttings of *V. lantanoides* were taken on 12 June 2002 in Washington County, Maine. Cuttings of *V. nudum* var. *cassinoides* were taken the following month on 12 July 2002. Cuttings were taken when there was approximately 2 – 6 inches of green growth on the stems. Two separate sets of cuttings of *V. lantanoides* were taken. One was of completely new growth, the other of new growth with some of the previous year's growth included (heel). *V. lantanoides* cuttings were treated with 0, 2500, 5000, or 10000 ppm K-IBA liquid quick dip. *V. nudum* var. *cassinoides,* as it roots easily from softwood cuttings, was treated with 0 or 5000 ppm K-IBA. Because of the limited amount of plant material available, only softwood cuttings with no heel were taken of *V. nudum* var. *cassinoides*. Cuttings were allowed to soak in the K-IBA solution for 30 seconds. Cuttings then air-dried for 10 minutes or more before being stuck in a media of 2:1 pearlite (Whittemore, Co., Lawrence, MA) to ProMix BX (Premiere Horticulture, Red Hill, PA). in 32-cell trays (Dillen Products, Inc., Middlefield, OH). A completely randomized block design was used, with 4 replicates per treatment. Within each replicate there were 8 cuttings.

Table 9.1. Treatments of *V. lantanoides* and *V. nudum* var. *cassinoides* cuttings.

Viburnum lantanoides				**Viburnum nudum var. cassinoides**	
no heel		**heel**		**no heel**	
extended light	regular light	extended light	regular light	extended light	regular light
0 ppm	0 ppm	0 ppm	0 ppm	0 ppm	0 ppm
2500 ppm	2500 ppm	2500 ppm	2500 ppm	5000 ppm	5000 ppm
5000 ppm	5000 ppm	5000 ppm	5000 ppm		
10000 ppm	10000 ppm	10000 ppm	10000 ppm		

After treatment, cuttings were placed under a mist system with 20-second periods of mist at intervals of 10 minutes. One half of the cuttings were placed under regular light conditions, and 75-watt light bulbs were placed three feet above the cuttings that received the extended light treatment. The two sections of the mist bench (regular vs. extended light) were separated by black plastic to prevent excess light from reaching the other cuttings.

Data was collected one month after the cuttings were treated. All data was analyzed using SAS analysis of variance at alpha ≤ 0.05. Means were separated using Fisher's protected least significant difference at alpha ≤ 0.05.

Results and Discussion

Cuttings of both species rooted within a month of treatment. Light did not have a significant effect in the *V. lantanoides* study, but K-IBA concentration did. In the *V. nudum* var. *cassinoides* study, light did have a significant effect, while K-IBA concentration did not. In both studies, no significant interaction was found.

V. lantanoides rooting improved with a 1,000 ppm K-IBA treatment. Highest percentages were obtained using a softwood cutting, where 95.38% rooting was observed. The control group and the 5,000 ppm and 10,000 ppm treatments decreased rooting percentages. This may indicate that the softwood cuttings benefit from K-IBA, but are sensitive to higher concentrations of the hormone.

With limited number of cuttings available for the *V. cassinoides* experiment, only two K-IBA concentrations were tested, as it is established that softwood cuttings root readily with rooting hormone treatment (Dirr and Heuser, 1987). While rooting hormone did not have a significant effect on rooting, the light treatment did. Extended lighting resulted in 95.3% rooting, while the regular light set only rooted at 73.5%.

Table 9.2. Effects of cutting type and rooting hormone on cuttings of *V. lantanoides*.

Treatment		Percent Rooted
K-IBA Concentration	**Cutting Type**	
0 ppm	All softwood	75.1 b
	Softwood with heel	43.6 d
1,000 ppm	All softwood	95.3 a
	Softwood with heel	60.8 c
5,000 ppm	All softwood	85.8 ab
	Softwood with heel	54.7 c
10,000 ppm	All softwood	70.3 b
	Softwood with heel	47.0 d

*numbers followed by the same letter are not statistically different at alpha ≤0.05.

Table 9.3. Effect of cutting type on *V. lantanoides*.

Cutting Type	Percent Rooted
All softwood	81.6 a
Softwood with heel	51.5 b

*numbers followed by the same letter are not statistically different at alpha ≤0.05.

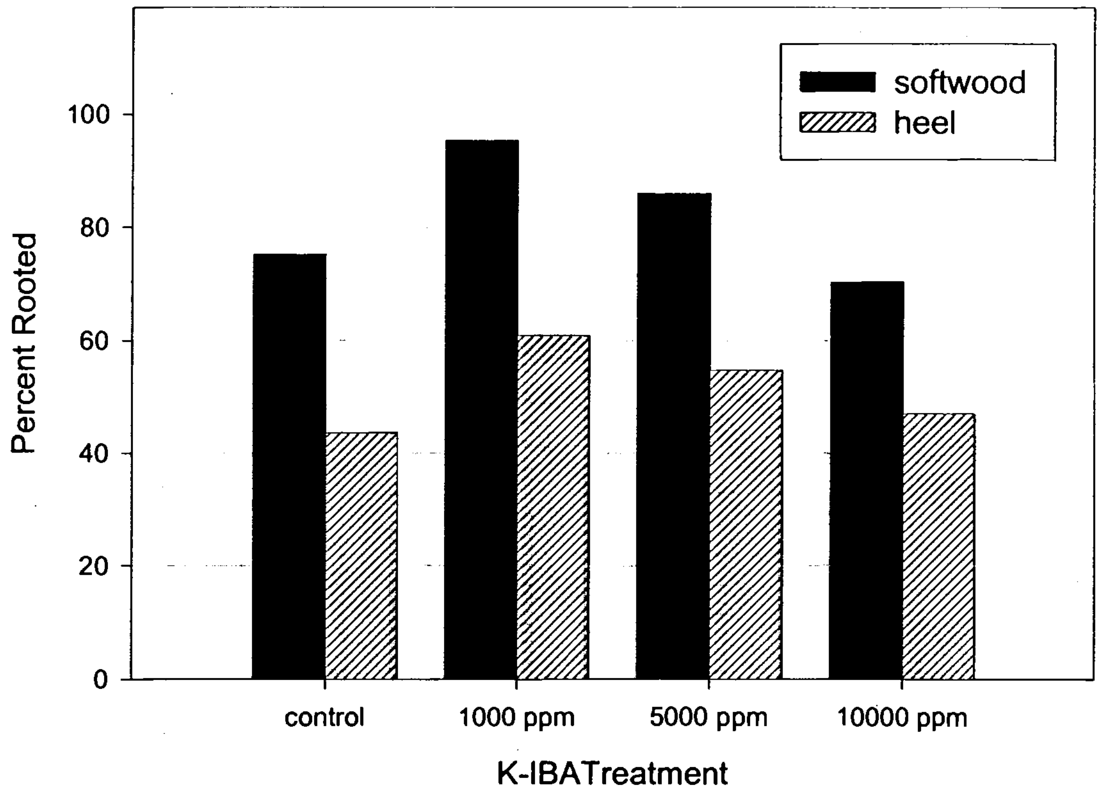

Figure 9.1. Effects of cutting type on rooting of *V. lantanoides* June-collected cuttings. Lighting had no significant effect.

Table 9.4. Effect of lighting and rooting hormone on cuttings of *V. nudum* var. *cassinoides.*

Treatment	Rooting Percentage
0 ppm K-IBA	78.1 a
5,000 ppm K-IBA	90.9 a
Treatment	**Rooting Percentage**
Extended Light	95.3 a
Regular Light	75.5 b

*Within each group, numbers followed by the same letter are not statistically different at alpha ≤0.05.

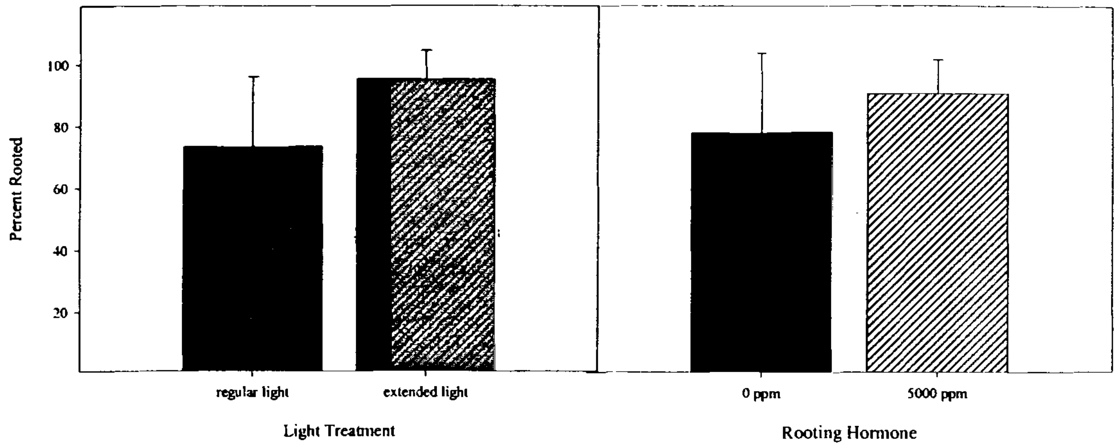

Figure 9.2. Effects of light and rooting hormone treatment on cuttings of *V. nudum* var. *cassinoides*. Hormone concentration did not have a significant effect, but lighting did.

Conclusions

V. lantanoides and *V. nudum* var. *cassinoides* are two native shrubs with great potential for the landscape. *V. lantanoides* can easily be propagated using early summer softwood cuttings, approximately 1 week after flowering. Increasing amounts of rooting hormone seem to have a detrimental effect on the cuttings, so 1000 ppm K-IBA treatment is recommended. *V. nudum* var. *cassinoides* also roots easily with softwood cuttings. Percentages are increased with 5000 ppm K-IBA and extended light, although no significant interaction was recorded. By studying the propagation methods of these 2 shrubs, plant propagators will have reliable methods to follow for successful rooting. Further research is needed to develop protocols for overwintering and growing the plants on into larger sizes.

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