Asexual Plant Propagation: Increasing Your Odds of Success

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Abstract

An important consideration in the asexual propagation of woody stem cuttings is the management of stock plants, which the propagator can manipulate to improve adventitious rooting. Selection depends on the condition of the potential donors as well as project-specific criteria such as sample size and geographic distribution. Decisions regarding cultivation reflect crop value; anticipated demand; project scope and duration; and the accessibility, physiological condition, and longevity of wildland donors. Projects requiring numerous local ecotypes may present unique selection and cultivation challenges. Optimal stock plant environment varies by species but includes proper timing of cutting removal, photoperiods that avoid flowering and dormancy, an appropriate level of cutting irradiance based on stock plant intensities, moderate levels of nutrition, threshold levels of carbohydrates, and a satisfactory water balance. Stock plant manipulation via light exclusion and the arresting or reversing of ontogenetic aging are reliable techniques for improving the rooting of numerous difficult-to-root species.

Introduction

In the context of this paper, *stock plant* describes the plant(s) from which stem cuttings are taken for the purpose of inducing adventitious rooting for plant production. The significance of proper stock plant management has long been recognized by horticulturists, and cultivation is a standard practice for ornamental selections in which asexual propagation is the preferred method of reproduction. The use of native plants for non-ornamental purposes, however, may influence stock plant management decisions. The goal of this paper is to review proper stock plant management and to consider recommendations in the context of native plant production.

Stock Plant Selection

The selection of individual plants as stock plants depends on two types of criteria. *Plant-specific* criteria include true-to-name and type, freedom from insects and disease, and a proper physiological condition that promotes ready adventitious rooting (Hartmann and Kester 1983, Macdonald 1986). These basic requirements reflect the traditional use of stock plants in support of the clonal replication of a narrow line, usually originating from a single plant. Non-ornamental end-uses such as restoration, reforestation, reclamation, and revegetation may impose additional *project-specific* criteria. Sources may be restricted to specific geographic distributions based on changes in linear distance, elevation, vegetation, soils, habitat type, and additional criteria. Restoration, which attempts to restore a site to some pre-disturbance condition, may mandate the use of multiple, local ecotypes in an attempt to maintain the genetic integrity and diversity of a particular area (Majerus 1997). This may result in the need to establish multiple lines, up to 50 or more, of a single species in order to achieve acceptable levels of diversity (Frankel and Soule 1981) and may preclude the use of asexual propagation entirely. In addition, the number of stock plants needed reflects production demands and some anticipated level of rooting success based on experience and/or research results. For a given demand, the number of stock plants needed will usually be larger if they are not cultivated. Margins of error should include potential losses of stock plants and rooted cuttings throughout the propagation process.

Several sources may serve as stock plants including 1) wildland sources, 2) parks, home landscapes, cemeteries, etc., 3) field production crops, 4) container production crops, and 5) stock plants maintained for the specific purpose of providing cuttings (field or container grown) (Hartmann and Kester 1983, Macdonald 1986).

Stock Plant Cultivation

The decision whether to use *in situ* wildland versus cultivated sources depends on several factors including crop value; anticipated demand; scope and duration of the project; accessibility, physiological condition, and anticipated longevity of wildland sources; distance to the propagation facility; amount of benefits gained from cultivation; the cost of cultivation, and other factors. Wildland plants represent the most readily available cutting material at the lowest initial expense. The stock plant establishment period is eliminated and there is no significant investment in terms of the stock's cultivation. For projects of any size or duration, however, the repeated use of wildland sources as stock plants may well prove the most expensive and inefficient of choices. Wildland plants, especially when multiple sources are used, are often difficult to relocate and may present plant and species identification problems. Insect and disease frequently reduce plant and cutting vigor and may potentially contaminate nursery stock at the propagation facility. Various environmental stresses may reduce plant and cutting vigor and ultimately decrease rooting success. Plant and site access limitations and long distances to the propagation facility may increase travel and labor costs and influence the timing and success of propagation. Numerous natural and human activities may result in the loss or damage of wildland stock plants such as fire, flood, insects, disease, environmental stress, animal damage, logging, mining, development, and reclamation. For information on siting, planning, and maintaining stock plants, see Macdonald (1986).

Stock Plant Environment

The physiological condition of the stock plant has a strong influence on adventitious rooting and reflects the interaction between stock plant genotype and environmental factors. *Seasonal variations* in the ability of woody stem cuttings to produce roots when taken from stock plants grown under natural light conditions are attributed to fluctuations in temperature, light intensity, and/or the interaction between irradiance and photoperiod. Cuttings taken from various species of coniferous stock plants including members of spruce (*Picea*), Douglas-fir *(Pseudotsuga)*, true fir *(Abies)*, yew *(Taxus)*, and juniper *(Juniperus)* grown under natural light conditions in northern latitudes root best when cuttings are taken in autumn and early spring (Moe and Andersen 1988). In some cases, the window of opportunity may be as little as two weeks, as demonstrated with Chinese fringetree *(Chionanthus retusus)* (Stoutemyer 1942).

In general, *photoperiods* that induce dormancy, promote adventitious bud formation, or promote flowering in stock plants inhibit or delay adventitious rooting in the cuttings they yield (Moe and Andersen 1988). In general, Long Day (LD) treatment of woody stock promotes rooting while Short Day (SD) treatment inhibits rooting (MacDonald 1969). This has been demonstrated with stock plants of poplar *(Populus* spp.) (Smith and Wareing 1972) and seedlings of red maple *(Acer rubrum)* (Bachelard and Stowe 1963). There are, however, cultural techniques that can be used to overcome photoperiod-induced conditions that inhibit rooting. Cold treatment has been used to overcome bud dormancy and enhance rooting in Douglas-fir *(Pseudotsuga menziesii)* (Roberts and Fuchigami 1973). The selection of cutting material that does not contain flower buds (O'Rourke 1940) and the early removal of potential flower buds (Johnson 1970) have been shown to increase rooting in woody species.

It has been a widely accepted theory that relatively low levels of *light intensity* of the stock plant are more conducive to adventitious rooting than high light intensities. This appears true for *Rhododendron* spp., Japanese barberry *(Berberis thunbergii)*, English ivy *(Hedera helix)*, Scot pine *(Pinus sylvestris)*, savin juniper *(Juniperus sabina)*, singleseed juniper (*Juniperus squamata)*, and European aspen (*Populus tremula)* (Moe and Andersen 1988). As a result, shading of cultivated stock plants has become a standard horticultural technique. In contradiction to this view are various studies indicating that increased irradiance can also delay, promote, or have no effect on rooting.

It has been suggested that the influence of light intensity on the light acclimatization of stock plants and its consequential effects on rooting deserves more attention. Stock plants grown under high irradiance have a higher Light Compensation Point (LCP) and higher respiration rate than those grown under low irradiance. If cuttings taken from stock plants grown under high intensities are subsequently treated with intensities below the LCP, they will often root poorly. It is theorized that rooting is poor at relatively low stock plant irradiances, increasing to some optimal level on a species by species basis, then declining with increasing intensities beyond this point. Stock plant etiolation, however, increased rooting of several trees and shrubs (Moe and Andersen 1988).

Traditional recommendations for a moderate level of stock *plant nutrition*, particularly nitrogen, appear valid, although studies involving woody species are limited. Grape *(Vitis* spp.) stock plants grown in various nutrient solutions yielded cuttings that rooted better under relatively lower levels of nitrogen (Pearse 1943). Extreme nitrogen deficiency of stock plants, however, reduced rooting. Low rates of nutrition also resulted in the highest number of roots with rose *(Rosa)* and *Rhododendron* spp. It appears that stock plant nutrition at a level that is sub-optimal for shoot growth is best for rooting (Moe and Andersen 1988). Evidence suggests that other elements, such as P, Ca, Mn, and Zn, are also important for root initiation and require further study (Blazich 1988).

Although research suggests a relationship between carbohydrate content and adventitious rooting, total *carbohydrate content* has not been an accurate means of predicting rooting nor have optimal levels for rooting been defined. Difficulties with isolating the effects of environmental factors that determine carbohydrate status and a lack of cellular-level research studies are cited as contributory factors (Veierskov 1988). The role of carbohydrates as an energy and carbon source for new tissue formation implies that some threshold level of carbohydrate is needed for growth and development to occur. Stock plants depleted of carbohydrates will not support optimal adventitious rooting. This will be particularly true under photosynthesis-limiting conditions such as when using leafless hardwood cuttings (Vieitez et al. 1980) and etiolated stock plants (Pal and Nanda 1981) or when cuttings are subsequently grown under conditions where net photosynthesis cannot occur (Veierskov 1988). An implication of this is the timing of cutting removal, and is the basis of winter hardwood propagation when cuttings have high levels of starch and energy (Maynard 1993).

Specific information on the effects of stock plant *water stress* on the adventitious rooting of woody cuttings is largely lacking. Studies with pea *(Pisum sativum)*, however, indicate a water stress:irradiance level interaction. The interaction of water deficit stress and irradiance, as well as the potential role of abscissic acid (ABA) and its effect on the speed of rooting, make clear a correlation difficult (Moe and Andersen 1988). It has been noted that leafy cuttings that become severely water stressed following harvest from the stock plant often remain in this condition until roots are formed (Grange and Loach 1983). Further complications arise as a result of stomatal closure, which exacerbates the situation by reducing CO2 uptake needed for photosynthesis (Davis 1988).

Winter desiccation can lead to cell necrosis in the form of stem dieback, which may have adventitious rooting implications. It may prove beneficial to collect dormant cuttings in the fall prior to exposure to dehydrating winter winds (Vanstone et al. 1986). Fall watering of woody plants, especially in arid environments, is recommended to alleviate winter desiccation, and may have positive effects on adventitious rooting. In contrast, waterlogging of certain woody species may be an ecological adaptation facilitating the adventitious rooting of certain wetland species (Gill 1975). Broad applications of this technique have not been used (Moe and Andersen 1988).

CO_2 enrichment of a stock plant's environment has been shown to increase cutting yield and may have positive after-effects on root initiation and lateral branching of cuttings for some species. Most of this research involves herbaceous plants. Variable results between and within species point to interactions between CO_2 and environmental factors such as light intensity, temperature, relative humidity, and water status (Moe and Andersen 1988).

Juvenility Effects

All woody seedling plants progress through a series of developmental stages known as phase changes. This process, known as ontogenetic, meristem, or developmental aging, is distinguished from chronological or physiological aging. The first or juvenile phase is often associated with superior adventitious rooting relative to mature, adult phase tissue. It begins when the seed germinates and is characterized by vegetative growth and an inability to respond to flower-inducing stimuli. The length of this period varies by species but can persist for 30 to 40 years in some tree species. The various phases may be associated with distinct morphological, developmental, and physiological characteristics (Hackett 1988). Juvenile tissue is often distinguishable from adult phase tissue by differences in leaf shape, leaf retention, stem thorniness, and pigmentation. Vegetative propagation of a meristem from a particular phase on the donor plant will reproduce its physiological and morphological features (Hartmann and Kester 1983). This may prove valuable in terms of promoting early flowering or perpetuating a distinct morphological trait in the rooted cuttings.

It has been noted that the adventitious rooting ability of many woody species declines with ontogenetic age, when the source is a seedling-derived mother plant. The upper, more distal portions of the stock plant are first to exhibit this reduced rooting potential. Cuttings from the lower, typically juvenile, regions of the plant generally maintain a higher rooting capacity than those taken from the upper portions (Hackett, 1988).

Manipulation Techniques

There are several noteworthy methods of manipulating stock plants to increase adventitious rooting. Possibly the most effective stock plant manipulation techniques for enhancing the adventitious rooting of difficult-to-root species are the various *light exclusion* methods. Etiolation describes forcing new shoot growth under conditions of no or very low light. Banding involves a localized exclusion of light from the part of the stem that will become the cutting base. Bands may be applied to etiolated tissue and the tops grown under increasing light or they can be used on light-grown softwood stems to "blanch" the underlying tissue. A successful modification of the banding technique involves applying root promoting substances as part of the banding process (Maynard and Bassuk 1988). For details of the banding process see Maynard and Bassuk (1986, 1988).

There are various types and modifications of the *layering* technique, all involving the use of soil or media to exclude light from that part of the stem where the roots will arise. Layering involves the promotion of adventitious roots on the stem while it is still attached to the donor plant. Severe pruning (hedging) may be used to rejuvenate stock plants prior to layering. See Hartmann and Kester (1983) and Macdonald (1986) for more information.

Another method involves techniques that *arrest or reverse maturation*. Hedging or severe pruning is used to force bud growth near the base of seedling plants to produce shoots with increased rooting potential. Short-interval, serial grafting on successive young juvenile seedlings has been shown to improve the rooting potential of shoots developing from mature scions. Shoots developing from adventitious buds sometimes demonstrate juvenile morphological characteristics and a high rooting potential (Hackett 1988). Gibberellin sprays on adult phase growth have caused treated branches to revert to a juvenile stage (Robbins 1960).

Girdling or binding of stock plants stems several weeks prior to cutting removal has been shown to increase root initiation in several woody species. Girdling has been performed in conjunction with etiolation and hormone applications to further increase effectiveness. Substances that promote rooting are thought to accumulate in the stem just above the point of girdling (Hartmann and Kester 1983). The accumulation of rooting cofactors, carbohydrates, auxin, or other substances may be involved (Blazich 1988).

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