Nursery Crop Science
College of Agriculture and Life Sciences • NC State University

Rooting for You: Plant Propagation with Stem Cuttings

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The process of removing a plant part then having that part grow into a genetically exact replica of the original plant is called cutting propagation. It is a plant cloning technique. The plant part that is removed is called a cutting. This cutting may be referred to by the location from which it is taken. Plants can be propagated from root cuttings, leaf cuttings, stem cuttings, etc. We will be addressing stem cuttings here.

When propagating plants by cuttings, it is important to remember that the cutting is a living plant part that has been separated from its life support system. As a plant propagator you are trying to both provide conditions that will keep this plant part alive and also to encourage it to grow the organs necessary for it to become a whole, self-supporting plant that is a clone of the parent plant.

Cutting propagation is often the preferred method for plant propagation because it is the easiest and most cost effective way to produce a clone of a particular parent plant. Other methods that are more difficult or more expensive may exist but are often not chosen.

Everything depends upon everything else when propagating plants by stem cuttings. Major factors to be considered are the parent plant or stock plant and the propagating conditions along with the techniques and tools of cutting propagation.

Stock Plant Management: The parent plant from which your cuttings are gathered should be true to type and as pest free as possible. You have enough of a challenge when rooting cuttings without choosing pest problems or something unsalable because it does not resemble the parent. The conditions frequently chosen to root stem cuttings are warm, moist and shaded or at least away from drying air movement. These same conditions can be excellent for the growth of disease and insect pests. Therefore, it is important to choose cuttings that are as pest free as possible. If appropriate, use appropriate pest management tools prior to taking cutting so that you have limited or eliminated pests such as leaf spots, mildew, rusts, aphids, whiteflies and scale insects. 'Start clean and stay clean' is a statement heard in most propagation workshops. It is a good rule. Good sanitation in plant propagation is essential to preventing problems with disease and insects.

Stock plants should be at a stage of growth most likely to have stem cuttings root. Old, mature plants are often more difficult to root than young, vigorously growing plants. Therefore, established blocks of trees and shrubs used for parent plants, called stock blocks, will need to be replanted every 5 to 10 years. The less mature a plant, generally the easier it is to root a cutting from it. Plant maturity is not the same as stem maturity because every new flush of growth contains young, maturing tissue. However, if new growth is occurring on an old, mature plant this new growth may produce shoots that are difficult or nearly impossible to root.

Stock plants should receive balanced nutrition, usually at a moderate level for average or more difficult to root plants. When fertilizing stock plants, avoid too much available nitrogen or too great an imbalance of essential nutrients. Also be sure that plants are not nutrient deficient. Field grown blocks of stock plants are often fertilized only once per year in the Carolinas. However, you may be taking cuttings from relatively easy to root container grown plants that require high levels of nutrition to be grown economically. Rooting percentages are usually not negatively affected when container grown plants serve as parent plants as long as complete fertilizers such as controlled release fertilizers containing nitrogen, phosphorus and potassium are utilized along with minor elements. Secondary nutrients like calcium and magnesium should be provided to stock plants from some source either within the growing medium or irrigation.

Timing: Timing can refer to many aspects of cutting propagation. Perhaps one of the most important but most often overlooked is the time of day and conditions at the time when the cutting is taken.

Most stem cuttings root best at a particular stage of growth for each plant even though it may be possible to root cuttings at multiple growth stages. The less mature the growth stage, i.e., a softwood cutting, the more easily it can lose water, dry out and die. However, a cutting may wilt then be re-hydrated by soaking it in water. It may look perfectly normal once it recovers from wilting but it may still root in lower percentages than it would if it had not been allowed to wilt in the first place. Therefore, try to take cuttings from shoots that are fully turgid and not even slightly wilted, particularly when working with softwood and semi-hardwood cuttings. This is best accomplished by collecting cuttings early in the day, particularly for plants that are growing in full sun. If parent plants are starting to wilt, irrigate then return to take cuttings when shoots are again fully turgid.

Hardwood deciduous and evergreen cuttings may not appear to wilt but care should be taken to collect them when temperatures are above freezing and roots have adequate moisture or they may be lacking sufficient moisture within them to root at their highest potential. Research has demonstrated that cuttings collected when temperatures were above freezing and stored in plastic bags or moist burlap in a refrigerator rooted in higher percentages than fresh, unstored cuttings taken when shoots were frozen.

For all types of stem cuttings, the cuttings should be removed with a clean, sharp (don’t crush stems) knife or pruners and placed into a container that will keep the cutting from losing more moisture. Plastic bags work well for this purpose. Clear plastic bags should be avoided if they can not be quickly moved out of the sun after cuttings are put in the bag. Clear plastic bags quickly heat and become solar ovens that can damage or kill cuttings. For most non-tropical origin plants, storing cuttings in plastic bags under refrigeration or in portable coolers can greatly enhance the chances for success. Tropical plants and cuttings of tropical plants should not be refrigerated below 50 F.

Types of Cuttings: Cutting types can be described by their origin such as leaf, root or stem cuttings. They can also be described by their location on the stem such as the cuttings from the ends of stems being called terminal or tip cuttings. Cuttings from further down the stem are called secondary cuttings. Terminal cuttings often root in higher percentages than those located further down the stem due to changes in natural hormone concentrations as well as type of cutting, i.e., softwood vs. semi-hardwood.

To further confuse the issue, on some plants it is very important to take cuttings that are on vertical or horizontal growth because if taken from the wrong place the nature of the plant may be changed. For example, cuttings taken from side branches on some shrubs and trees will always grow laterally or require long-term staking to ever grow vertically. This is particularly common in some conifers that may never grow vertically or have needles completely surrounding stems if taken from side shoots.

For our purposes, we will refer to three types of cuttings: softwood, semi-hardwood (sometimes called greenwood) and hardwood cuttings. Most stem cuttings taken on herbaceous perennials will be softwood or semi-hardwood because few herbaceous plants, by definition, produce woody tissue. However, some older tissue on plants referred to as herbaceous perennials becomes sufficiently firm, particularly during dormant season, that growers will refer to cuttings as hardwood even though they are not technically hardwood cuttings.

A softwood or herbaceous cutting is taken when stem tissue is firm but easily wilts. These cuttings can often be snapped off because stems are still brittle or succulent. A semi-hardwood cutting comes from tissue that has started to firm whether it is producing “wood” or not. A hardwood cutting is fully hardened and contains no newly expanding growth. A hardwood cutting does not have to be taken from dormant growth although most hardwood cuttings, particularly on deciduous plants, are taken from dormant stems and may look like lifeless sticks.

The Rooting Environment

The race to keep cuttings alive until they can root and support themselves has prompted plant propagators to develop many creative ways to provide an environment that\ favors rooting. Light, temperature and moisture are usually the environmental factors most often manipulated.

Light: Light can keep a stem cutting from rooting by either being too bright or too dark. Rarely is not enough light available, however multiple layers of white copolymer plastic or layers of white plastic and shade cloth may limit light levels to less than 200 foot candles, cause defoliation of cuttings and reduce rooting percentages. More frequently, cuttings are exposed to excessive light intensities that can cause heat damage to shade grown leaves and desiccates cuttings during propagation. Remember that you are both trying to keep a cutting alive and also provide conditions most favorable for plant growth.

Plants that normally grow in the shade often can be rooted at lower light levels than those that grow in the full sun. Plants that normally grow in the full sun usually need some shade or other method of cooling to prevent excessive heating and drying out while a plant is rooting. For this reason it is common to root plants under 25 to 70% shade with 50% being the most common shading provided for rooting stem cuttings. Winter cuttings may require little or no shading while summer cuttings may require maximum shade.

The type of shade provided is usually not critical. However, some wood or lath shade may contain chemicals that will leach from the wood and harm plant growth. Usually the chemical in question is a wood preservative but galvanized metals have also been shown to leach zinc and, if propagating media is not replaced between crops, zinc can accumulate in propagating beds which may result in nutrient problems.

Many plants do not root well when they are flowering. Others must break bud and develop a flush of vegetative growth in order to survive winter. To encourage vegetative growth over flowering or to stimulate a new flush of vegetative growth on a recently rooted cutting, supplemental lighting is often used. Full spectrum lights such as "warm" fluorescent bulbs or incandescent light bulbs may be used. (Please check with local building codes to determine the safest way to accomplish supplemental lighting.) These lights are generally turned on for a few hours during the night to cause plant light receptors to respond as if the plant was being exposed to short nights (long days). The brightness (intensity) of these lights is usually not an issue because cuttings are getting some normal daylight even when under rooting under artificial shade.

In the Carolinas, supplemental lights are not routinely used for winter propagation to extend day length and provide additional light intensity for plant growth as they are in Canada and Europe where winter days are very short and light intensity is much lower than it is in NC. Supplemental light is used by some specialty growers of crops such as hybrid rhododendrons to extend daylength in spring to force rooted cuttings in propagation units into an early flush of growth before they are transplanted. Supplemental light is also used in a growth chamber or other facilities lacking natural daylight.

Temperature: The most effective environment for rooting different plants may vary somewhat. However, the best temperature for stems and leaves, i.e., the part of the cutting that will be in the air above the propagating medium, is a temperature that allows normal photosynthesis and other plant life processes to occur. However, it should not be so warm that the plant will lose excessive moisture or respire away any food stored in the cutting at the time the cutting was taken from the parent plant or food made through photosynthesis during the rooting process. Most often, normal cool to warm greenhouse

temperatures are maintained, depending upon the needs of the individual plant, with cooler air temperatures at night than during the day. Shading is used to reduce heat buildup during bright, sunny days.
Roots for most plants seem to develop best on cuttings where the rooting medium is kept between 70 and 80 F. This will vary with species and also with the type of cutting and time of year. Often the rooting medium temperature will be warmer than the daytime air for late season and winter stem cuttings.

Supplemental bottom heat has been provided for rooting stem cuttings from a variety of sources during the past few centuries. Composting manures were used beneath rooting beds at one time, steam from boilers or smoke and heat from fires has been directed under beds plus electrical resistance cables have been used. The most common source of bottom heat currently used is warm water circulated through tubing placed at uniform intervals within or beneath the propagating medium with a temperature maintained at 75 to78 F. for most cuttings.

During the summer in much of the piedmont and coastal plain regions of the Carolinas, supplemental bottom heat is a waste of time and money because the propagating medium temperature may be in the 70's and the water being applied as mist or fog is also in the 70's. Therefore, supplemental bottom heat for cuttings is most often used during the cooler months or in cooler areas of the mountains.

The general rule of "cool tops and warm bottoms" is applied to rooting cuttings but bottom heat is not required for rooting most cuttings. It does, however, usually result in more rapid rooting and a more extensive root system when cuttings are being rooted during cooler seasons.

Moisture: High humidity around the leaves and stems of softwood and semi-hardwood cuttings keeps the cutting from drying out and allows normal plant functions like photosynthesis and respiration to take place without the plant wilting while new roots are forming. Under most propagation systems, roots are formed in a medium that has the proper balance of moisture and air space to allow for the development of healthy roots.

Propagation Substrates: There is no distinct "one prize winning recipe' for propagation substrates, although fewer choices of ingredients are considered for use than for container potting media. Stability of components with minimal decomposition during propagation is necessary as changes in particle size also change the air and water balance in the substrate. Commercial greenhouse mixes such as MetroMix, Fafard, Jiffy or Ball products are used by some commercial nurseries for propagation of nursery crops. However, commercial mixes are not universally used, since sphagnum peat moss is usually the predominant component and may remain too moist with too little aeration for some nursery crop propagation uses. Propagation of wood nursery crops can require several weeks to several months for sufficient root development to occur. Propagation substrates containing predominantly peat moss can become excessively moist with limited aeration and may support algae, moss and liverwort growth in some propagation structures over long periods of time. As a side note, applying coarse mulch products over the surface of propagation, liner trays and pots to reduce algae, moss and liverwort growth seems to be effective. Coarse particles interrupt the smooth uniform moist surface that provides optimal environmental conditions for these simple plant organism. In Oregon, growers use filbert nut shells which are readily available for this purpose. In North Carolina, mulch sized pine bark particles might be useful for this purpose but experimentation with other products is suggested.

In addition to propagation mix components, grower practices, propagation facilities, geometry of trays and benches, intermittent mist equipment, season of propagation and many other factors all have direct influence on air and moisture characteristics experienced by cuttings in the propagation root environment. For example, growers often "water in" cuttings with a hose-end water breaker to establish contact between stems and the substrate and to eliminate large air pockets which could lead to desiccation of the cutting. This practice works well if the substrate and propagation tray geometry drains readily, but if the substrate and propagation tray combination does not drain well, water logging can occur in the rooting environment even before the cuttings are placed in the propagation facilities and will remain waterlogged until the dead cuttings are disposed. This example also illustrates the very important fact that the propagation substrate and the trays, benches or containers holding the substrate contribute equally to the air and water content in the rooting environment. Water drainage from propagation trays is affected by gravity, cohesion and adhesion. May these forces be with you!! Or more importantly, growers need to understand the effect of these forces and use them to their advantage in rooting cuttings. Height of a container, cell, or bench is affected by gravitational pull, therefore taller containers drain more readily in the upper portion of the container than in the lower zones of the container. Shallow containers have more water in the root initiation zone than tall containers. Flat bottomed propagation trays or pots setting directly on ground cloth fabric/plastic greenhouse floors drain much less than and retain more water than identical trays placed upon gravel greenhouse floors. The reason for this is adhesion and cohesion of water and gravitation influences. A cohesive seal is actually formed between the fabric and the bottom of the flat propagation tray reducing movement of water out of the drain holes. Deep propagation benches with screen bottoms and cone shaped propagation trays suspended in support frames drain more than flat bottom trays. Geometry of propagation trays that enhance drainage may provide more flexibility in choosing propagation media that provide successful rooting for a wide variety of crops. The take home message here, is that *one* propagation substrate may not be the best choice in all cases, for successful propagation, when considering grower practices such as "watering in" cuttings and the type of tray or pot used and surface they are placed upon. A quick test to discern whether a substrate is water logged or adequately moist is to squeeze a handful of it. If a few drops of water are extruded between the fingers, the substrate is appropriately moist. If water gushes out during the squeeze, the substrate is water logged. Shallow containers will not fully drain, therefore this condition is difficult to overcome. Submitting the trays to drying environmental conditions will dry cuttings out as well. Growers tend to select propagation trays based upon cost, or how their shape fits in propagation space and storage areas, re-use potential or in regard to the use of the rooted cuttings. Many of the cone cell shaped propagation trays that fit in suspended frames contain 24, 36, 48 or some number of rooting cells all in one molded tray. These propagation trays work well if the crop of cuttings root in high percentages or if the cuttings are to be used at the same nursery. If, however, cuttings are to be sold and shipped, cells that do not contain rooted cuttings must be replaced with successfully rooted cuttings before selling. Besides the aggravation, this can consume considerable labor. For this reason, growers that sell rooted liners tend to use individual flat bottom pots so that they can easily be shifted from tray to tray for filling orders.

Considering all of the above discussion, many nursery professionals choose not to use commercial greenhouse sphagnum peat moss based propagation mixes, but rather, they prefer to engineer their own propagation substrates. Grower prepared, propagation substrates may contain one coarse component such as pine bark or they may blend mixtures of components that create suitable air and drainage characteristics and remain moist but not water logged during the period of time that roots are initiated. For example, propagation mixtures of coarse horticultural grade perlite with less volume of peat have become popular because they maintain high volumes of air space, yet have acceptable moisture holding characteristics. An example of a popular ratio is 80% coarse perlite and 20% sphagnum peat moss. The most common components used by professional propagators are combinations of pine bark, sphagnum peat moss, coir, horticultural grade perlite and washed sand. The disadvantage of using a combination of components is that they must be mixed uniformly requiring equipment that many propagators may not have accessible. Using a one component substrate such as screened pine bark has been an acceptable alternative for many crops. Particles in bark supplies generally range from 1/2 to 5/8 inch for largest particles and have 20 % to 30% of the particles less than 0.5 mm in a range that appears as dust. This particle size distribution is generally acceptable for propagation.

Moistening components prior to mixing and filling propagation trays or benches is a very important step in preparation of substrates. Mixing dry sphagnum peat moss and dry pine bark produces a mixture with entirely different air and water properties than mixing pre-moistened components. Mixing dry components creates a mixture with low aeration and poor drainage characteristics as particles fit tightly together and seal capillary channels. The effects are long lasting and have definite influence on root development and growth. Conversely, pre-moistened components create a spongy fit between particles and provide optimal aeration and lateral wetting of peat moss fibers and bark particles. Moistening propagation substrates is also necessary to establish moisture levels in the substrate. Droplet sizes from most mist nozzles are meant to wet foliage but are not large enough to sufficiently penetrate and irrigate potting media.

Propagation Facilities

Propagation facilities range from simple shaded outdoor polyethylene tents to elaborate temperature, humidity, CO_2 , light and nutrient controlled state of the art chambers that for all appearances look like a tanning bed. Simple outdoor tents and mist frames can be very successful for propagation. Direct sunlight must be avoided for shaded poly-tents to avoid extreme temperatures and desiccation of cuttings. Propagation trays can be placed inside frames or frames can be filled with propagation media. Adding an intermittent mist system to poly-tents or outdoor frames can improve rooting and provide greater flexibility in rooting cuttings. Open sun propagation frames equipped with intermittent mist provide low cost facilities for summer propagation of a wide variety of broadleaved evergreens, deciduous shrubbery and conifers. Some screening may be needed to keep wind from blowing mist off cuttings for outdoor frames. Plans for low cost propagation frames are available on line at http://www.ces.ncsu.edu/depts/hort/hil/nurs-index.html

Recently, with the availability of new irrigation equipment technology and experienced sales representatives, nurseries have upgraded and retrofitted propagation structures with electronic controllers with infinite choices of time of misting and time between misting and environmental overrides. These controllers have capability to operate multiple solenoids in numerous sections of propagation houses. Propagation houses have been converted to plastic mist nozzles suspended over cuttings, with stabilized weighted, spaghetti tubes to provide 100% overlapping mist coverage. Most nurseries have installed hot water tube bottom heat systems in part of their propagation houses. Floors of these houses are graded into a center crown and covered with black plastic and ground cloth on which propagation trays are placed on the fabric. Some nurseries have gravel floors to set tray on and other nurseries have constructed raised benches or ground benches filled with propagation media covering hot water tube systems and misted by suspended plastic mist nozzles. The propagation houses are covered with 1 or two layers of clear polyethylene film. Air circulation and ventilation in these structures is controlled thermostatically. Multiple zone equipped propagation houses provide great versatility for rooting many different nursery crops taken at different times yet all in one house under optimum rooting conditions simultaneously.

Other technically advanced propagation greenhouses are equipped with traveling booms that travel the entire length of a house, misting cuttings. As cutting root, nozzles can be changed to provide irrigation after mist is not longer needed. Traveling booms work well when entire houses are filled with cuttings stuck approximately the same time with one species or cultivars of one species such as entire houses of azalea cultivar cuttings.

Another innovation in propagation facilities are greenhouses equipped with high pressure fog systems that maintain nearly 100% humidity in greenhouses. Oscillating mist blowers have also been used to maintain fog in propagation houses. Fog systems are controlled by a humidistat rather than a timer.

The newest “state of the art introduction” for propagating ornamentals being marketed to the nursery industry is called “The Nurseryman” (Southern Sun BioSystems, Hodges, S.C.). This propagation system consists of production chambers equipped with a refrigeration unit, a carbon dioxide generator, supplemental light and a water and nutrient re-circulation system. North Carolina nursery industry first had an opportunity to see this unit at the Charlotte Show 2001.

From the simple tent to the elaborate mist and fog greenhouses and environmental chambers; all these facilities attempt to maintain a vapor envelop around foliage of the cuttings and prevent moisture loss, drying out and death of the cutting before it can generate new roots, re-hydrate by absorbing water from the substrate.

Water Quality Requirements for Intermittent Mist Propagation

Most commercial nurseries rely on mist delivery systems to maintain high humidity in propagation facilities. The orifices of mist nozzles are very small and therefore, require water supplies free of sediment and minerals. Ground water from wells or public water supplies are usually considered the cleanest water supplies and usually require only minimal filtration for removal of sediment. However iron, iron bacteria and calcium bicarbonate are frequently contaminants even in these water supplies. Intermittent mist operating every 5 minutes during daylight hours through the first few weeks of cutting propagation adds up to thousands of mist applications and amplifies water quality impurities. Iron, iron bacteria or calcium bicarbonate residues coat cuttings and propagation facilities reducing aesthetics of cuttings and propagation facilities. These residues also reduce light penetration into leaf chloroplasts, slow rooting and reduce rooting percentages. Chelating agents or oxidizing agents can be injected to reduce iron staining. Iron bacteria require injection of a disinfectant and possibly a chelating agent. Chlorine or bromine can be used as disinfectants to kill iron bacteria and as oxidizing agents to reduce iron solubility and staining. They also will help control algae growth in propagation structures. Bicarbonate precipitation can be reduced by acidifying irrigation supplies. Sulfuric acid injection is generally recommended for this purpose. Details on water treatment are provided at the following websites:
http://www.ces.ncsu.edu/depts/hort/floriculture/hils/hil557.html
http://www.ces.ncsu.edu/depts/hort/floriculture/hils/hil558.html
http://www.ces.ncsu.edu/depts/hort/floriculture/software/alk.html

Preparing Cuttings

Sanitation: The cutting propagation process not only requires conditions that favor the development of disease and insect problems, we also cut the plants. Open wounds are avenues through which pest problems can enter plants. Therefore, it is important that not only the cuttings be disease and insect free but the instruments used to prepare the cuttings, the area in which the cuttings are prepared and the area where they are rooting should also be kept as clean as possible.

The cutting preparation area should be cleaned before and after cuttings are prepared and stuck. So should the tools used in the process. Remove all plant material, growing media, etc. from the work area. The surfaces and tools being used in propagation should be cleaned with appropriate disinfectant solutions.

Be careful not to damage leaves and cuttings. Damaged cuttings are more likely to have problems in rooting both from disease and insects as well as from pre-mature aging of damaged tissue.

Wounding: Research has shown that some cuttings root better when the stems have been wounded. Sometimes the only wounding required is to remove the leaves from the stem. In the process of removing the leaves enough of a wound is created. However, on some more difficult to root woody species wounding enhances rooting. In these situations, please remember that you are wounding not doing major surgery. The wound should not remove large portions of bark and should not go deeper than just through the bark. Often scarring with a razor blade or knife just barely through the bark is all that is necessary.

Hormones: Rooting hormones used in the nursery industry are synthetic versions of naturally occurring plant compounds called auxins. The two forms most commonly sold are usually listed as IBA and NAA.

Hormones are needed by plants in very small quantities so they are sold in ready to use or ready to be diluted formulations mixed with something else. The most common forms are either mixed with talc and come in a powder form or can be purchased as a liquid either diluted in alcohol or water. There are plants that seem to root more successfully when powders or alcohol based or water based liquid solvents are used but toxicity from solvents is rare and almost always occurs when alcohol is the solvent used. Most of the time, any of the solvents can be used with the crop you wish to propagate.

The reasons hormones are used when stem rooting cuttings are: 1) to make rooting possible when too little natural hormone exists, 2) to increase the percentage of rooting, 3) to increase the number of roots per cutting and 4) to have cuttings root more rapidly and thereby shorten the length of time you need to keep your stem cutting alive before it can support itself.

Research has shown that if you apply too high a concentration of hormone, it can be as bad as not using any hormone at all. Stem tissue can be killed by too much hormone or using the wrong form of rooting compound. The end of the stem will often turn black when this happens and, if there is any rooting, it takes place above the dead, black stems. (This blackened end of the stem can also happen when the bottom of the cutting is too wet.) Too high a hormone concentration has also been implicated in keeping plants from ever breaking buds and growing so they root but never grow new shoots again. Therefore, it is important to use the lowest concentration of rooting hormones that will give you the maximum percentage rooting and number of roots per cutting. Lists of suggested levels of rooting hormones can be found in the listed reference books. These books will also tell whether other propagators have had more success using NAA or IBA or a combination of the two and whether the success was with a powder or liquid formulation and often which formulation worked best.

Rooting hormones should always be applied to a freshly cut stem so you will either need to hormone treat when you are collecting cuttings from stock plants or re-cut when preparing cuttings for sticking. Rooting hormones are much more readily absorbed before plants begin to scab over or heal a cut. In addition, for many woody plants, a liquid formulation has been successful at a much lower concentration than a powder formulation. For example, 2500 ppm IBA in a liquid has shown similar or better results than an 8000-ppm powder when both hormone formulations produced good quality rooted cuttings.

Powders are usually best used as they come from the manufacturer. Remove the amount you expect to use then seal the container and put it away. Do not stick cuttings directly into the container as you may contaminate it with microbes that can reduce the effectiveness of the powder within the container. For the same reason, do not return unused rooting powders to their original container.

Liquid formulations often arrive in a concentrated form that needs dilution. Suggestions in reference books may be for 2500 ppm, 5,000 ppm or 10,000 ppm but the label lists the active ingredients in percentages. 1% is equal to 10,000 ppm. Therefore, if you need 2500 ppm, use 1/4 of your 1% solution and 3/4 of whatever you are using to dilute which is often water. 2500 ppm is 0.25 or 1/4 percent. 5000 ppm is 0.5 or 1/2 percent.

Again, for sanitation purposes, only prepare as much rooting solution as you need. Never stick cuttings into the original container and do not return unused dilute rooting solution to the original container.

Rooting hormones last longest if they are kept in their original containers and stored at room temperature or under refrigeration. Keep them out of direct sunlight and heat when storing them and they can remain effective for years.

Some Commercially Available Rooting Compounds*

Product Name	**% Active Ingredient**	**Liquid or Powder**
C – Mone	1.0 to 2.0 IBA	Liquid
C – Mone K	1.0 IBA	Liquid
C-Mone Plus	1.0 IBA plus 0.5 NAA	Liquid
Dip n Grow	1.0 IBA plus 0.5 NAA	Liquid
Woods Rooting Compound	1.0 IBA plus 0.54 NAA	Liquid
Hormex	0.1 to 4.5 IBA	Powder
Hormodin	0.1 to 0.8 IBA	Powder
Hormo-Root	0.1 to 2.0 IBA plus 15% Thiram	Powder

*Adapted from NC Agricultural Chemicals Manual

How long, how deep, how close? HOW LONG? How long should you expose cuttings to rooting hormone at treatment time? For liquids, treatment is usually called a “quick dip.” I have heard researchers working with this technique say 1 second or 3 seconds is the right length of treatment time. They caution that you do not want to soak the cuttings for extended periods of time or stir the liquid with the cutting or you will be in danger of overdosing the cutting which may result in failure to root and wasting rooting hormone. For powder formulations, the powder needs to stick to the base of the cutting but not be caked so thickly that you waste hormone powder or keep the base of the cutting from getting oxygen and encourage it to stay too wet. Sometimes it is necessary to wet the cutting to get powders to stick and sometimes you may need to tap cuttings on a hard surface to keep too much powder from sticking to the cutting.

How long after cuttings are treated can you wait until sticking the cutting? While it is best to stick the cuttings as soon as the liquid hormone has dried, cuttings may be stored in plastic bags or moist burlap in a cooler for months then stuck and successfully rooted. How long you can store them depends upon the plant and the condition of the cutting. Generally, the firmer the cutting tissue, the longer it can be stored so semi-hardwood and hardwood cuttings can be successfully stored for much longer than softwood cuttings.

If large numbers of cuttings are being treated at one time, be sure to keep cuttings from getting too dry. You may need to treat and stick small batches at one time or to find some other way of storing cuttings to keep them turgid.

How long should the cutting be? It should be as big as you can handle successfully. Cuttings may be 5 ft. long willow branches while some dwarf conifer cuttings are only centimeters long. The bigger the successfully rooted cutting, the shorter the time period until you can sell a finished plant. The cutting needs to be long enough to stand up on it's own in the propagation bed and not so long that it falls over.

How long does it take a stem cutting to root? It depends. It depends on the plant and the rooting conditions. Bottom heat, hormones, moisture management and lighting accelerate rooting but nothing takes the place of healthy, vigorous stock plants and proper timing. If you keep pulling up cuttings or tugging on them to see if they have rooted, it will take longer for them to root because you may be breaking newly formed roots.

HOW DEEP? How deep should you stick the cutting into the rooting hormone mix? Naturally, that depends upon the size of the cutting. However, you only need to treat the portion of the cutting that will be in the rooting medium. Most often 1/4 to 3/8 inch of the cut end of the stem cutting is all that is stuck into the rooting hormone. However, larger cuttings or cuttings that produce larger diameter roots may be stuck an inch or more deep. Experience will quickly help you determine the proper depth.

How deep should the cutting be stuck in the propagation medium? Deep enough so that it will support itself and not fall over. However, cuttings should not be stuck all the way to the bottom of any propagation flat or pot because the cut end may then be located in an area of water saturated propagating medium and not get enough oxygen which may lead to rot. For a one-inch dwarf conifer cutting the appropriate depth may be 1/4 inch but for a five-foot willow cutting the correct depth may be 6 to 8 inches. Most 4 to 6 inch long cuttings are stuck 1 to 1.5 inches into the propagating medium, or about 1/4 as deep as they are long.

Another consideration regarding how deep to stick a cutting is the location of buds or nodes. For certain herbaceous perennials that die to the ground normally each winter, it is very important to have a bud beneath the propagating medium that can grow a new top the following spring. Otherwise a perfectly healthy root system will eventually die from lack of green shoots and leaves to feed it. For other plants that are being rooted but no growth from below the soil surface is desired, it is important not to put buds beneath the propagating medium or basal sprouts and suckers are more likely to develope. Therefore, for these plants all other rules apply but the location of buds should also be considered.

HOW CLOSE? Cuttings must be stuck close together in order to root enough of them to pay for the space used in propagating a plant. However, there should be enough space for each cutting. Again, it depends upon the size of the cutting and how they are arranged.

If cuttings are being rooted in a community flat or bench with lots of other cuttings, they should be close together within the row but not so close that it will be impossible to untangle them from one another once rooted. Often a dibble board is used to create the proper spacing in a flat whether it is 1 inch apart on center or 3 inches apart.

If cuttings are kept too close together with lots of foliage from one cutting touching another, disease may develop or propagating medium may dry out where moisture does not reach the medium surface. For this reason and in order to fit more cuttings into a particular space, leaves are often cut and a portion removed from the cutting area. Cut leaves only if you must and do not remove more than 1/2 of the leaf. Green leaves may be needed for the cutting to manufacture food to grow roots and new tissue. The more leaves and leaf surface you remove the less photosynthesis can take place.

In the past decade it has become standard practice to “direct stick” which means put cuttings into individual rooting containers. These may be flats with many separate cells or individual pots. By rooting a cutting in its own container, damage to roots at transplanting time is minimized and more roots are kept with the cutting rather than being broken when removing and separating the rooted stem cuttings. This should result in more rapid growth of plants later in the production cycle. Direct sticking also isolates one cutting from the propagating medium of another so, if there is a problem with disease on one cutting, it is less likely to move to an adjacent cutting.

Management While Rooting

Even with automated environmental controls, cuttings should be checked daily. Electricity fails. Valves and pipes break. Vents may not open or close. Heat may not come on when needed. Diseases and insects develop even if you took precautions to start clean and stay clean. If everything could be automated, there might not be need for your knowledge as a plant propagator.

Pest management of rooting cuttings is usually minimal. If a problem occurs, the best pest management may be removal. Dropping leaves should be removed. Flowers and flower petals are a prime place for fungi to grow in a high humidity environment so grooming of the cuttings WITH CLEAN HANDS should be a regular activity. If an insect or disease problem should arise, contact your Cooperative Extension Agent or the NC Agricultural Chemicals manual for the appropriate treatment. Remember that you are dealing with plant babies and using no foreign chemicals is best. If you have to treat, use the chemical that is least likely to be toxic to the plant while helping you to control the pest problem.

Controversy continues concerning whether you should fertilize rooting cuttings. The correct answer is going to depend upon the individual nursery and what you are trying to accomplish. Roots or root initials must be present for plants to obtain adequate nutrients from a growing medium. Therefore, the propagator must carefully choose not only which fertilizer to use but how much to apply. If a cutting is likely to root quickly, perhaps within 7 to 10 days, but not be transplanted for weeks after roots appear then mixing a controlled release fertilizer in the propagating mix may make sense. The fertilizer should have a delayed release so that fertilizer is not releasing and accumulating within the propagating mix before the young roots exist. If it does, newly formed roots may be burned and propagation fail.

Fertilizing newly rooted cuttings can produce rapid new growth and larger transplants. If space is available for the new growth and plants can be taken off the fog, mist or plastic chamber propagation system so that they can acclimate to normal growth, then it make sense for cuttings to have fertilizer available as soon as they can use the fertilizer.

If there is not room for the new growth in the flat or in a direct stick situation, transplants can quickly outgrow the space allocated for them and become stunted. In addition, late season rooted cuttings can be stimulated into tender new growth with extra fertilizer. These newly rooted cuttings may not be able to withstand normal fall temperatures and either be damaged or require extra cold protection.

Cuttings that are slow to root in a propagating medium that contains controlled release fertilizers may have problems. The controlled release fertilizer will respond to time, moisture and temperature and may accumulate in the propagating medium to a level that is harmful to the plant. If these plants need fertilizer once they are rooted, granular controlled release fertilizers can be top dressed or soluble fertilizers applied as needed with much greater control and less potential for harm.

Each situation is different. The fertilizer and the cuttings respond to environmental conditions. It is up to the plant propagator to know how they are likely to respond and react accordingly.

Transplanting: Handle rooted cuttings by the rootball or pot, not the stem. Otherwise, roots may break off due to the weight of the media on the roots.

When a cutting is ready to transplant depends on the needs of the propagator. Rooted cuttings are called transplants or liners. They may be transplanted whenever the customer needs them. Liners in their own containers, i.e., direct stuck, can grow into larger plants with less danger of overcrowding or damage when separating cuttings. However, eventually any liner will become pot bound or outgrow its container with stunting of later growth a likely result.

If you can not sell or provide heated storage for transplants of hardy plants, allow them to go dormant normally. Generally this is done by gradually reducing irrigation and fertilizer plus exposing them to normal daylength and gradually colder temperatures. Once they have stopped growing or become dormant they should be protected as other container plants are protected either within structures, mulched or under fabric covers as appropriate for the plant and local growing conditions. Additional protection is required for late fall potted liners since the root systems are not established and they easily become desiccated without frequent irrigation. Outdoor rooted cuttings growing in ground beds usually benefit from mulching or other winter protection to prevent cold injury to the base of the stem and frost heaving.

Additional Sources of Information:

Growing and Propagating Showy Native Woody Plants
Richard E. Bir
UNC Press, Chapel Hill, NC

Growing and Propagating Wildflowers of the US and Canada
William Cullina
Houghton Mifflin Co., Boston, MA

The Reference Manual of Woody Plant Propagation
Michael A. Dirr and Charles W. Heuser, Jr.
Varsity Press, Inc., Athens, GA

Manual of Woody Landscape Plants
Michael A. Dirr
Stipes Publishing Company, Champaign, IL

Plant Propagation Principles and Practices
Hudson T. Hartmann, Dale E. Kester,
Fred T. Davies, jr and Robert L. Geneve
Prentice Hall, Upper Saddle River, NJ

North Carolina Agricultural Chemicals Manual
North Carolina State University
Campus Box 7603
Raleigh, NC 27695-7603
http://ipm.ncsu.edu/agchem/agchem.html

North Carolina State University WebSites
http://www.ces.ncsu.edu/depts/hort/hil/nurs-index.html provides access to a series of commercial nursery publications that may be downloaded for free.

http://www.ces.ncsu.edu/depts/hort/hil/hpropagate.html provides access to a series of home propagation publications that may be downloaded for free.

http://www.ces.ncsu.edu/depts/hort/nursery/ provides general information for commercial nursery production and publications that may be downloaded for free.

http://www.bae.ncsu.edu/programs/extension/publicat/postharv/green/small_greenhouse.pdf provides access for a plans for a small hobby greenhouse that can be used for small scale propagation.

Some Sources of Commercially Available Rooting Compounds:

Cassco 1/800-933-5888	Coor Farm Supply 1/800-999-4573
Dip 'N Grow 1/866-347-6476	Great Western Bag 1/800-762-9749
Hummert International 1/800-288-3131	Mackenzie Nursery Supply 1/800-777-5030
V-J Growers Supply 1/800-222-4504	