Some Fundamental Differences Separating Rooted Cuttings and Seedlings©

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Over the course of my 35 years in commercial horticulture I have noticed that we are far from understanding many of the things that appear obvious or intuitive. To further complicate that is our inability to comprehend what we do not know. This means that there are trends, characteristics, and facets of our jobs that present themselves regularly but we do not know why nor in some cases have even the faintest of idea as to what the fundamental explanations might be. One such case is the observable differences between rooted cuttings and seedlings. It is logical to assume cuttings of *Juniperus* might be different than that of *Cornus*, but they do have similarities. It is also logical to suggest that seedlings of *Pinus strobus* do not behave as seedlings of *Quercus robur*. But again there are similarities that can be subscribed to readily. However, a quandary exits when rooted cuttings of *C. florida* do not behave the same as seedlings of *C. florida*. From a production point of view, rooted cuttings of *C. florida* have more in common with rooted cuttings of *Juniperus* than to seedlings of *C. florida*. After years of study with a range of species it seems clear that a rooted cutting is not physiologically the same as a seedling of the very same species. The purpose here is to delineate some of these differences.

DISCUSSION

As can be seen in the accompanying chart there are a number of differences between rooted cutting and seedling. Much of these differences can be traced to both chemical and morphological differences that can be readily distinguished.

Morphologically seedling roots are derived from cambium tissues along side the xylem in a plant and are under the direct influence of naturally occurring auxins such as indole-3-acetic acid, indole-3-butyric acid, and 4-chloroindole butyric acid. In addition to this, seedling root systems are under the direct influence of gibberellins and cytokinins from the onset of a radicle during seed germination. Such a chemical cocktail is finely tuned to give the normal appearing and growing root system. Altering these chemicals can and does induce changes in the resultant root system.

The very nature of rooted cuttings is that the root systems they possess is not derived from xylem/cambium tissue but originates from undifferentiated parenchyma cells. Undifferentiated parenchyma cells under the influence of auxin and other chemicals related to the wounding response give rise to adventitious roots. These roots do not have the same physiological make up as seedling-derived roots. As with the weeping blue spruce (mentioned in the remarks of the chart), such changes are bordering into the realm of an epigenetic change.

For the sake of clarity an epigenetic change is a change in form or function that is evident but not a genetic change. The transition of *Hedera helix* from juvenile to adult is an epigenetic change as is the transition of the foliage of *Thuja occidentalis* 'Rheingold' from needled form to the more familiar flattened spray form of normal appearing *T. occidentalis*. In some cases such as the formation of adventitious roots the changes occur as a result to exposure to naturally occurring auxins and

Table 1. Some fundamental differences separating rooted cuttings and seedlings.

Rooted Cuttings	Seedlings	Remarks
No suckering	Will sucker in varying degrees	Seedlings of different species vary considerably with respect to suckering unless they are gymnosperms which rarely sucker. Ferns and related genera do not count as they are not seedlings.
Decapitation of apical tips will rarely if ever result in the formation of adventitious buds but will promote growth of axillary buds	Seedlings will form adventitious buds as a result of decapitation as well as promoting growth of epicormic shoots and protobuds buried at the stem-root union.	
Cuttings will rarely form adventitious buds when physically wounded along the main stem	Seedlings will often form adventitious buds when wounded along the main stem, such buds usually occur along the wound edge	
Cuttings exhibit an increased sensitivity to applied fertilizers, especially during the first year of growth post rooting	Generally will tolerate doses of applied fertilizer that would injure or kill rooted cuttings.	Applied fertilizer will also disrupt the physiological balance of rooted cuttings and could lead to toxicity or death of cuttings during winter storage.
Rooted cuttings will not readily tolerate drowning or water saturation of soils	Seedling will often be impervious to water saturation of soils	Rooted cuttings of *Ilex verticillata*, normally as a seedling quite water tolerant, will suffer damage if placed back into the normal environment where a seedling is found.
Will carry the same degree of maturation as its mother plant	The physiological age of a seedling can be kept stable by cutting back to near the root -stem interface and will only change if allowed to grow out of it	There are differences in the “age” of a plant based upon chronological age (actual age) and physiological age known as juvenility. A seedling can be kept in the limbo land of physiological juvenility even though the chronological age increases. Rooted cuttings cannot be made to do this.
Cuttings in general are less heat drought or cold tolerant than seedlings	Seedlings are not as sensitive to environmental changes as cuttings are	

Table 1. Continued.

Rooted Cuttings	Seedlings	Remarks
Cuttings take longer to establish mycorrhizal associations than seedlings	Seedlings seem to inherently able to connect to the symbiotic mycorrhizal fungi	While there is scant evidence it seems logical to assume that the mycorrhizal fungi in seedlings could well be different than those of cuttings.
Cuttings can be brought to flower in much shorter periods of time than seedlings	Seedlings cannot be readily induced to flower unless sophisticated grafting techniques are used	A 2-year-old seedling *Hibiscus syriacus* will just begin to flower if at all, whereas a 2-year old *Hibiscus syriacus* cutting marketed as part of the Proven Winners program will flower.
Some plants if produced from rooted cuttings will not grow or will grow extremely slow	Generally speaking seedlings will always grow unless they are the result of some hybrids which exhibit chromosomal mismatches or other types of genetic incompatibilities	*Acer griseum* grown from cuttings will not grow, although they make leaves, most often they will eventually die. Sometimes a plant from a cutting will grow but far from a normal rate and will exhibit cutting induced dwarfism.
Cuttings will sometimes not regrow after going through the first winter even though they are not dead	Seedlings do not exhibit this phenomenon	The onset of permanent dormancy is usually attributable to hormonal imbalances due to exogenously applied root hormones or as a result of excessive ethylene formation during the rooting process. Other factors could include the use of synthetic auxins such as alpha naphthylene acetic acid or dichlorophenoxyacetic acid.
Cutting derived plants will not regrow if cut to the ground in fall or winter	Seedlings do not exhibit this phenomenon	One certain way to kill an undesirable plant if it is cutting grown is to cut it back in late fall or winter. In some cases even a cut back in summer will result in the plant's death as well. Cuttings generally lose the regenerative capability which is inherent in seedlings.

Some rooted cuttings will develop distorted and unbalanced root systems which are detrimental in the long term	Seedlings rarely develop aberrant root systems	Rooted cuttings of conifers are especially prone to this phenomenon. In some cases the root system is limited to one or two primary roots and nothing else. Such sparse primary roots can lead the phenomenon known as "hinge root" which can lead to wind throw or toppling in harsh winds.
Troposis or the ability of a plant to grow normally with respect to gravity. However some rooted cuttings will exhibit a troposis based upon their original orientation on the mother plant and will not change the growth pattern	Seedlings can sometimes exhibit a troposis that is different than the norm but such occurrences are rare and represent a true weeping or crawling characteristic This at the very least an epigenetic change or in some cases a genetic change	The so called *Picea pungens* 'Glauca Pendula' (there is no genetic basis for this name) is an example of troposis response where a lateral shoot is rooted or grafted and it maintains its growth form that it had while on the mother plant. This could loosely be called an epigenetic change but it is far from the true meaning of an epigenetic change and it is definitely far removed from any kind of a genetic change.
Rooted cuttings will often tolerate pre-emergence herbicides	Seedlings have a poor ability to tolerate pre-emergence herbicides	This appears to be related to the mode of action of This appears to be related to the mode of action of pre-emergence herbicides where a vapor barrier exists at air soil interface and the toxic gases affect the sprouting of latent buds at the root /stem junction. Since rooted cuttings do not have this morphological feature they are immune to the pre-emergent chemical.

some synthetic chemicals such as acetylene and carbon monoxide. Other man-made chemicals that mimic this response are the dichlorophenoxy auxins and the naphthylene aliphatic acids, such as NAA. Synthetic here means chemicals not naturally formed by plants. It should also be noted that while exogenously applied auxins will lead to adventitious root formation, the continued presence of such chemicals will inhibit root growth for the long term.

Naturally occurring roots are also responsible for the formation of a range of gibberellins and cytokinins and they too have a direct affect on the structure and formation of a root system. Aberrations in cytokinin balances are often manifested by odd growth patterns in plants such as dwarfism and troposis changes such as weeping characteristics. Evidence of such changes can be found by grafting experiments and in rooted cutting experiments where the overall structure of a plant can be changed by changing the root system. I know of a dwarf *Metasequoia glyptostroboides* that when rooted or grafted reverts back to normal. Handsome plant but remains as a one of a kind because it cannot be propagated. Also tissue-culture-derived plants (actually an exaggerated form of rooted cuttings) can exhibit unusual growth changes due to the cytokinins used during the tissue culture process. Such changes are known as somalclonal variations and are evidence of epigenetic changes due to the disruption of normal chemical balances. Grafting experiments with two-needled pines grafted onto five-needled pines show no problem, but a five-needled pine grafted onto a two-needled pine will fail. This points to a potential root to shoot chemical imbalance that cannot be tolerated by the five-needled scion.

All of these things point indirectly to why there are noticeable changes in rooted cuttings compared to seedlings of the same species. Grafting of a given clone to a seedling of the same species or even one of close speciation such as *C. florida* onto *C. kousa* results in plants that in general behave like seedlings as the introduced scion adopts the biochemical systems of the rootstock. However when a scion is grafted onto a rooted cutting of the same or similar species the graft combination then behaves like a rooted cutting. For instance grafting of *Viburnum carlesii* 'Compactum' onto seedlings of another viburnum creates suckers on the rootstock, but by grafting onto rooted cuttings of another viburnum suckering is eliminated. Grafting seedling on to chronologically mature rootstocks (meaning the rootstock has the capacity to flower) the seedlings can be induced to flower at a much earlier age than if allowed to just grow under normal circumstances.

Where does this lead us? We know that overdosing cuttings with auxin for rooting can result in a number of maladies, including poor rooting, poor overwintering, rooting but followed by no subsequent root growth, excessive callus formation and no rooting or sparse rooting known as callus roots which are inferior to normal adventitious roots. For all practical purposes a callus root should be considered another class of root along with adventitious roots and normal seedling roots. In some cases overdosing with auxin can cause basal burning and necrosis of cutting tissue, leaf abscission, and death of the cutting. It is also well known that synthetic auxins such as NAA can be used as sprout inhibitors and applications of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid are used as herbicides. Could then an inference be made that auxin contributes to a range of physiological changes in cuttings such as tolerance to pre-emergent herbicides or sensitivity to fertilizers when compared to seedlings? The answer unequivocally is yes and these various manifestations are often coupled with the changes in gibberellins and cytokinins as a result of adventitious roots being physiologically different than seedling roots.

In some plants, treatment with triazine herbicides shows no visible clues to the triazine's presence. However, when cuttings are taken from those plants and subsequently treated with auxins in preparation for rooting, they will often turn black and die out right within days of being stuck into the rooting bench. Obviously there is an effect on the cutting precipitated by the combination of the triazine herbicide and the auxin. Just what is exactly occurring is not understood or even known. While the mode of action of auxins is generally understood the ramifications of secondary auxin metabolism is not so clear and how it reacts with triazine herbicides is certainly not known.

Research should be centered on developing protocols for use of the least amount of auxin for the rooting of cuttings. Something that is currently not generally considered. Lower doses of auxin translate into smaller changes in the biochemical pathways in the cuttings and thereby possibly limiting the potential harmful side effects of the use of the auxins. By comparing cuttings rooted with low doses of auxin with those of high doses of auxins and looking at the degree of sensitivity to known stress inducing agents such as fertilizers or overwintering survival could lead to important clues as to the mechanisms of the sensitivity issues. It would be interesting to compare the water tolerance of rooted cuttings of *C. florida* with seedlings of *C. florida*. Theory would suggest that the seedlings would be more tolerant than the rooted cuttings. *Cornus florida* would be a good choice since it is well known to be water intolerant and a small difference between the two types of plants might be evident.

A take home message would be to pursue the use of the lowest amount of auxin possible to get acceptable rooting percentages and quality, thereby limiting deleterious side effects and ensuring some degree of success perhaps better than the norm.