Root Culturing in Bareroot Nurseries
by Thomas D. Landis

Tree seedlings are a unique crop. We spend most of our time and effort in the nursery to produce a healthy, vigorous shoot, and most cultural activities are scheduled according to shoot phenology and growth. This is understandable as the shoot is the part of seedling that we can easily observe. Roots are, however, the business end of a seedling. One of the sayings that I frequently use in training sessions is that "tree seedlings are a root crop". While it may seem technically inaccurate to compare seedlings to carrots or potatoes, I think that the analogy is useful in getting growers to consider the importance of properly culturing root systems. Even the best nursery stock will fail after outplanting if the roots are not functioning properly and can rapidly grow out ("egress") into the surrounding soil.

The history of root culturing - Culturing roots in bareroot nurseries is nothing new. The classic nursery manual "Nursery Practice on the National Forests", which was printed in 1917, has an entire section on root pruning. In the ensuing years, root pruning was mentioned only sporadically in the nursery literature because of a lack of effective mechanized equipment.

The most influential research on root culturing came from "down under" in the late 1960s and early 1970s. The New Zealand Root Pruner featured a thin, serrated blade which oscillated back and forth to precisely cut seedling roots. These new root culturing procedures of undercutting and wrenching produced seedlings with dense fibrous root systems that were previously only available with transplants (Van Dorrser and Rook1972.). To confirm their quality, outplanting trials of root cultured 2+0 seedlings showed good survival and growth. Undercutting, lateral pruning and wrenching had become standard nursery practices in most conifer nurseries by the 1980s (Duryea 1984, 1986). *Forest Nursery Practice* (1994) devotes an entire chapter to root culturing. This practice is also discussed in detail in the *Bareroot Stock Production* chapter in *Regenerating the Canadian Forest: Principles and Practice for Ontario* (Mohammed and others 2001).

Root culturing of hardwood seedlings took a little longer to develop. With the increased demand for broadleaved nursery stock since the early 1990s, more research was undertaken on hardwood nursery culture, especially the root systems. McNabb (2004) reported that root culturing of hardwoods in southern nurseries was primarily used to control shoot height. In a recent survey of southern hardwood nurseries, however, undercutting, lateral pruning and wrenching were commonly implemented based on customer preference (Vanderveer 2005).

Table 1 - Root culturing in bareroot nurseries: terminology and operational uses

Term	Function	Cultural Objective	Implement	Timing
Undercutting	Cut roots in a horizontal plane in the root zone	1) Encourage root fibrosity 2) Reduce shoot height 3) Stimulate budset	Sharp fixed blade, or oscillating blade covering full bed width	Once to several times per season, or prior to harvesting
Vertical or lateral pruning	Cut roots in a vertical plane between rows	1) Encourage root fibrosity 2) Facilitate harvest	Sharp fixed blades or coulters spaced between rows	Once to several times per season, or prior to harvesting
Box pruning	Cut roots in 3 dimensions: bottom, between rows, and between plants in a row	1) Encourage root fibrosity 2) Facilitate harvest	Three step process: 1) Undercutting 2) Vertical pruning between rows 3) Hand pruning within rows	Just before harvesting
Wrenching	Induce moisture stress and loosen soil within rooting zone	1) Control shoot height 2) Stimulate budset 3) reduce soil compaction	Dull fixed blade set at an angle covering full bed width	Once to several times per season
Root Pruning	This is done on the grading table after harvest and should be called bench pruning			

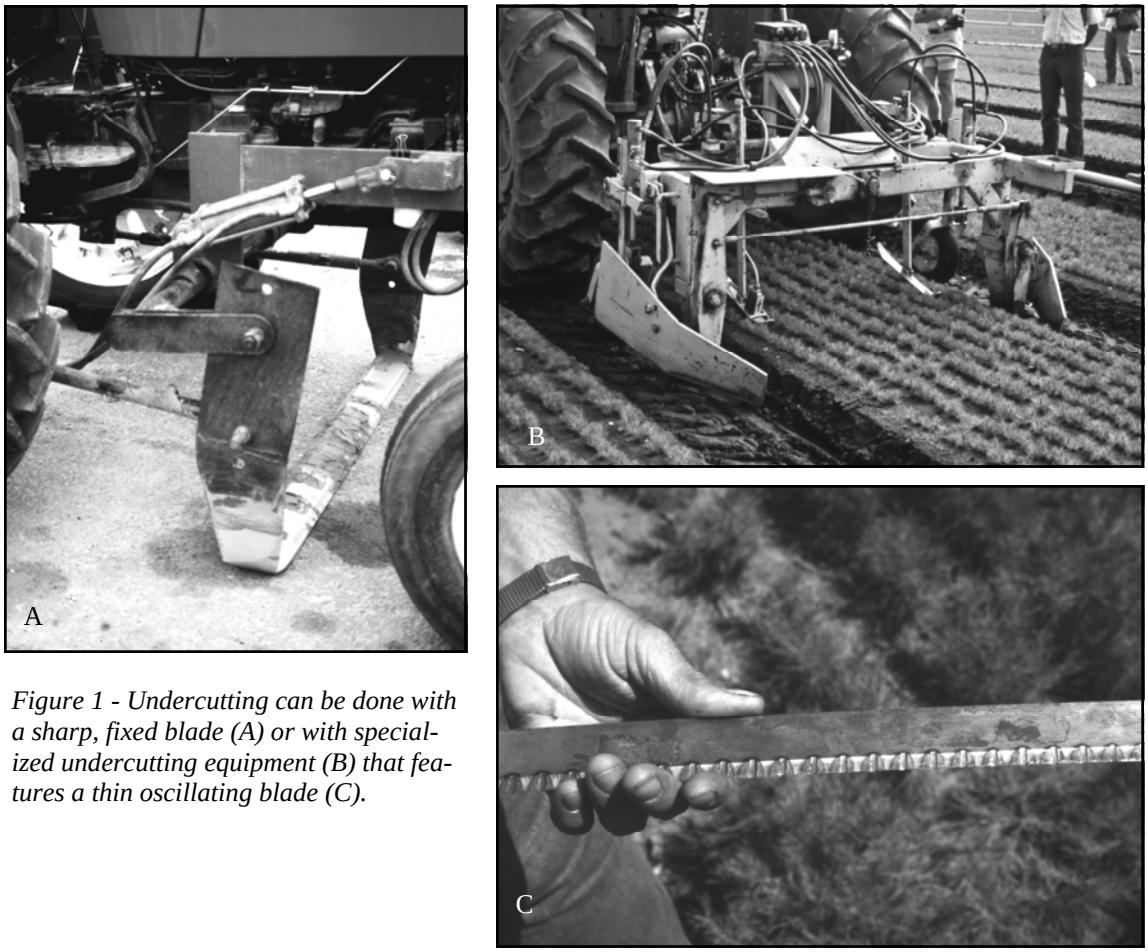

Figure 1 - Undercutting can be done with a sharp, fixed blade (A) or with specialized undercutting equipment (B) that features a thin oscillating blade (C).

Root Culturing Treatments. Reading through the published literature or talking to nursery workers, you'll find the terms used for root culturing can be rather confusing and sometimes contradictory. Updating my 1989 FNN article with the latest published literature (Menes and McDonough 1994), I came up with the following definitions (Table 1):

Root culturing - This is a general term for any nursery cultural practice designed to modify root growth or morphology while the seedling is still in the nursery bed

Undercutting - This can be done with either a sharp fixed blade (Figure 1A) or thin oscillating blade (Figure 1B-C) that is pulled along a horizontal plane in the root zone of the nursery bed. The undercutting action severs the taproot and all other roots extending beyond the regulated depth of the blade. Oscillating blades work well in sandy soils, but fixed blades are needed for nurseries challenged by heavier-textured soils; neither works well in rocky soils. Based on nursery surveys, 95% of Pacific Northwest nurseries (Duryea 1984) and 57% of southern conifer nurseries (Duryea 1986) undercut their stock.

Vertical or lateral pruning (sidecutting) - This root pruning treatment severs seedling roots in a vertical plane by pulling sharp blades or coulters between the rows. The positioning of the cutters must be carefully monitored so that they travel halfway between the rows of seedlings (Figure 2A). Therefore, lateral pruners are belly-mounted so that they can be controlled by the tractor driver or pulled behind the tractor and controlled by a separate operator (Figure 2B). Some nurseries lateral prune their stock during the growing season, and this root culturing treatment is also popular just before harvesting. Ninety-five percent of Northwest nurseries (Duryea 1984) and 72% of southern nurseries (Duryea 1986) lateral prune their stock.

Box pruning - Box pruning consists undercutting followed by vertical pruning between rows and between plants. (See discussion in Mechanical Pruning).

Wrenching - This multi-purpose root culturing treatment consists of pulling a thick, angled blade (20° to 30°) at specified depths under the seedbeds (Figure 3A). Wrenching can be used in any soil texture except highly compacted silts and clays and, like undercutting,

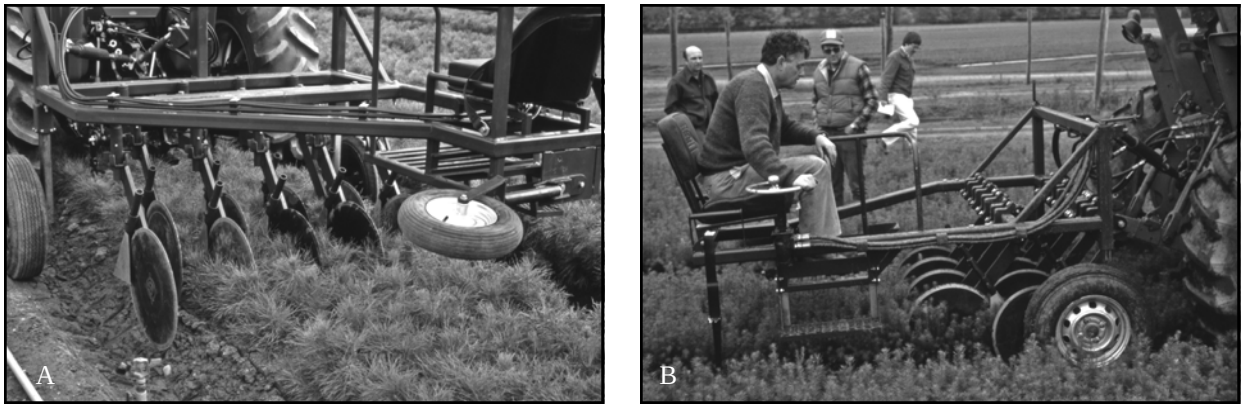

Figure 2 - Lateral pruning equipment must be carefully positioned between the rows of seedlings (A), and so is either belly-mounted or pulled behind the tractor with a separate operator (B).

cannot be used in rocky soils. Because the angled blade tends to plane upwards, extra weights are need to keep the blade in the proper plane (Figure 3A). Because wrenching blades are not as effective in cutting roots, this operation is easier and more effective when done immediately after a separate undercutting. In addition to its effects on root morphology, wrenching is also used to loose and aerate the soil in the root zone (Figure 3B). This is especially effective to increase water infiltration and improve air exchange in compacted seedbeds. Based on surveys, 80% of bareroot conifer nurseries in the Pacific Northwest (Duryea 1984) and 35% in the south (Duryea 1986) wrench their seedlings.

Root pruning - This term should only be applied to trimming roots to desired length specifications during grading.

Root Culturing Objectives. Nurseries apply root culturing treatments for a variety of reasons:

1. To create a compact and fibrous root system, especially of tap-rooted species. In tests with loblolly pine (*Pinus taeda*), frequent root culturing greatly changed root morphology, resulting in more compact root systems with more fine roots and better mycorrhizal development. (Dierauf and others 1995a). Longleaf pine (*Pinus palustris*) seedlings that received vertical pruning (sidecutting) had more fibrous roots and had significantly better outplanting survival than unpruned stock (Hatchell and Muse 1990). Some broadleaved seedlings have heavy stiff lateral roots that are often broken and lost during harvesting. Undercutting increased the number of first order lateral roots in northern red oak at 3 different bed densities (Figure 4A).

Figure 3 - Wrenching (A) is a multipurpose root culturing treatment that, in addition to cutting roots, can be used to counteract the negative effects of soil compaction within the root zone (B).

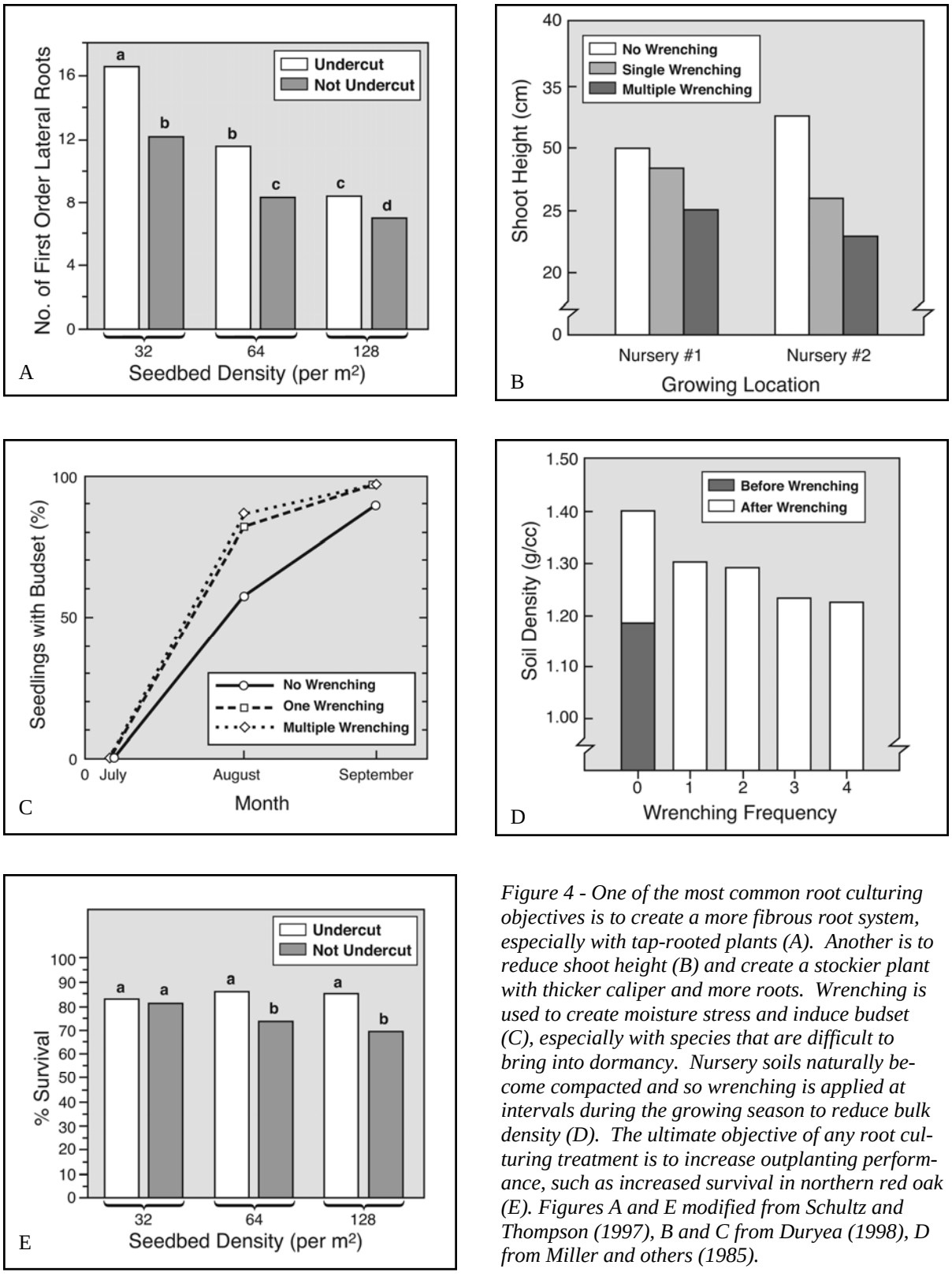

Figure 4 - One of the most common root culturing objectives is to create a more fibrous root system, especially with tap-rooted plants (A). Another is to reduce shoot height (B) and create a stockier plant with thicker caliper and more roots. Wrenching is used to create moisture stress and induce budset (C), especially with species that are difficult to bring into dormancy. Nursery soils naturally become compacted and so wrenching is applied at intervals during the growing season to reduce bulk density (D). The ultimate objective of any root culturing treatment is to increase outplanting performance, such as increased survival in northern red oak (E). Figures A and E modified from Schultz and Thompson (1997), B and C from Duryea (1998), D from Miller and others (1985).

2. To control shoot height, decrease the shoot-to-root ratio, and create a seedling with transplant-like characteristics. Research done with Douglas-fir seedlings (*Pseudotsuga menziesii*) showed that undercutting followed by wrenching was effective in controlling shoot height at 2 different nurseries (Figure 4B). With white spruce, black spruce (*Picea mariana*) and jack pine *(Pinus banksiana*), root pruned and wrenched seedlings were shorter and had larger root systems than the controls, resulting in better shoot-to-root ratios (Buse and Day 1989).

3. To encourage bud dormancy and condition plants for storage and outplanting - This is a major objective for species that continue to produce shoot growth late into the season, such as the southern pines (May 1985). In New Zealand, Monterey pine (*Pinus radiata*) do not set bud during their first year so root wrenching therefore is used to stop shoot growth and promote budset (van Dorsser and Rook 1972). In a controlled study, Douglas-fir seedlings set bud faster and more completely after wrenching (Figure 4C).

4. To reduce soil bulk density and counteract compaction - Wrenching creates a physical and moisture stress that help control excessive shoot height. It is also used to minimize the soil compaction that inevitably occurs due to heavy equipment use. In a loblolly pine nursery, the soil bulk density increased almost 20% during one growing season (Figure 4D). When this soil was wrenched, soil bulk density declined as wrenching frequency increased (Miller and others 1985). Compaction is even worse in heavier soils, and so wrenching would be even more effective.

5. Increase the yield of shippable seedlings. Root culturing can be used to keep plants from exceeding shoot height specifications. For example, precision sown and undercut Douglas-fir and Scots pine (*Pinus sylvestris*) had higher yields of shippable seedlings than the control (Deans and others 1989).

6. Improve outplanting performance. Of course, the ultimate objective of any nursery treatment is to increase survival and growth after outplanting. In one study, outplanting survival of eastern white pine (*Pinus monticola*) was substantially increased by an average of 18% by root culturing (Dierauf and others 1995b). In another with Douglas-fir, Sitka spruce (*Picea sitchensis*) and Scots pine (Mason and others 1989), undercut plants grown at the lowest bed density had the best survival and growth after outplanting. Hardwood seedling quality is highly correlated with the number of first order lateral roots (FOLR). When northern red oak (*Quercus rubra*) nursery stock was root cultured (Schultz and Thompson 1997), the improved root system resulted in improved outplanting survival (Figure 4E).

Conclusions and Recommendations

In my mind, there is no doubt that root culturing works—the problem is using the right tool, in the right way, and at the right time. So, here are my thoughts on how to plan and implement a root culturing program at your nursery:

1. Define your objectives - Root culturing operations can have variable effects, and many nursery managers make the mistake of trying to achieve several different objectives with one operation. Root culturing can affect seedling morphology and physiology in several ways: control height growth, modify shoot-to-root ratio, increase root fibrosity, induce seedling moisture stress, and so on. Your objective will define what implement you use, how you use it and, most importantly, the timing of the operation. A root culturing treatment that is being applied to control shoot height may not increase root fibrosity at the same time.

On the other hand, don't apply root culturing treatments as a matter of general policy. If you don't know why you are doing an operation, then don't do it - any root culturing treatment induces some measure of stress, which can be harmful. Cultural operations that are applied "for good measure" usually do more harm than good.

2. Properly time root culturing practices - This is the tough one. Don't try to schedule cultural operations by the calendar because of variations in weather from year to year and species/weather interactions. Get away from your desk and computer and go take a look at your seedlings. Yes, the root system is difficult to observe but take a shovel with you and dig up some seedlings every few weeks during the growing season. Observations of phenology and measurements of relative shoot and root growth should be recorded and plotted to provide a permanent record. Shoot growth and root growth are often inversely related so, after a few years of collecting these measurements, you should have enough personal experience and data to permit estimation of root activity based on shoot phenology. With blue oak (*Quercus douglassii*) seedlings, the timing of the undercutting was critical to control both root fibrosity and shoot height (Krelle and McCreary 1992). They recommend undercutting as early in spring as possible and again in mid-summer. The first pruning should be as shallow as possible without dragging under the young seedlings and the second pruning should be about two to three inches below the first pruning.

3. Synchronize root culturing with other nursery activities and soil conditions - Root culturing should not be viewed as an independent operation. Irrigation, in particular, will affect the success of root culturing operations. Again, get out and check the soil profile with a shovel rather than guess whether the soil is at the proper moisture content because the surface appears wet. The proper moisture content will also vary depending on your objectives: wrenching requires relatively dry soils for thorough fracturing, whereas undercutting or sidecutting are most efficient when relatively moist soils promote smooth movement of the blade.

4. Select the right implement for the job - In my mind, wrenching does not do a good job of cutting seedling roots in many situations. If the objective is to promote a more fibrous root system, I would consider undercutting rather than wrenching. Because of the thickness and angle of the blade, root wrenching equipment will often drag seedling roots instead of clearly cutting them. It is often necessary to undercut seedlings with a thin sharp brace before attempting a wrenching operation, particularly with tap-rooted species or older seedlings. If the objective is to induce moisture stress to control top growth, I would try wrenching and pass the blade completely under the root zone to fracture the soil and break soil-root contact.

5. Follow-up and evaluate the operation - Both undercutting and wrenching require follow-up irrigation to avoid damaging moisture stress. Wrenching, in particular, creates a severe moisture stress and heavy irrigation is normally required to repack the soil particles around the seedling root system. The timing and amount of irrigation will depend on cultural objectives, weather, soil type, and individual species response.

Nurseries are busy places, and many times growers will go on to the next activity without ever checking back to see if the root culturing worked or not. It's hard to assess the effects of any cultural operation at the end of the growing season if you haven't taken the time to observe the physiological and morphological effects following the operation.

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