Deeper Planting of Seedlings and Transplants Increases Plantation Survival

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Heat, often confused with drought, is probably the most over looked cause of death of newly transplanted bareroot trees. just as neglected is that part of the stem most affected by heat, that is, the transition zone where stem and root meet, the stem-root junction, which is commonly referred to as the root collar. A standard of planting bareroot stock with emphasis on depth to protect part of the stem, regardless of method used, is suggested. Tree Planters' Notes 41(4):17-21; 1990.

Tree planting methods for hand-planted bareroot stock used currently in North America were developed decades ago when a comparatively small number of small seedlings were planted, usually in deep, sandy soil. Gradually, larger bareroot seedlings with bulky roots (even after pruning) were produced in the nurseries in ever-increasing numbers and planted on a variety of sites, yet the planting methods have remained basically unchanged to date. Moreover, guidelines developed strictly for conifers were erroneously recommended for hardwoods. For example, for best results, the wedge method (requiring two or four cuts into ground, depending on site conditions) was recommended for seemingly all types of stock and sites with trees planted "at the original depth at which they grew in the nursery" (23), that is, with their root collar at ground level. This latter misconception is also recommended in textbooks (27, 28) and planting guidelines (2, 22).

Evidence shows that deeper planting and deeper root placement is beneficial: it resulted in better survival of southern pines (1, 4-6, 15, 16, 26) and red pine (*Pinus resinosa* Ait.) (18, 21) and better height in loblolly pine (*Pinus taeda* L.) (26), slash pine (*Pinus elliotti* Engelm.) (33), and Norway spruce (*Picea abies* (L.) Karst.) (31). However, no consistent or significant effects of depth of planting on survival or height growth were found in white spruce or white pine (19, 20), although weather conditions were not reported. Deep planting should not be used on wet or poorly drained sites (5, 35) and on sites where small trees could be buried by silt from excessive rains (14).

Transplanting a tree at its original depth contradicts one of the basic requirements of any tree before it can produce appreciable growth, regenerate roots, and survive-that is, stem stability (8, 32). A tree loses much of its natural stability as well as physiological quality after lifting and transplanting. However, deeper planting can help it to regain stability with reduced stress in a new environment during the period of recovery. Conventional planting guidelines do not satisfy requirements for stability or recovery.

Heat exposure and shallow planting (rather than drought) can often be blamed for high tree mortality after transplanting.

The Stem-Root Junction

Heat, often confused with drought, is probably the most overlooked cause of death of newly transplanted bareroot trees. Just as neglected is part of the stem most affected by heat, the **root collar** (12) or transition zone where stem and root meet. The length of this zone varies considerably with species: nonetheless, this is the area where heat can exert the greatest influence on the flow of water, nutrients, hormones, and assimilates (7).

The **root collar** is normally a narrow, pale-colored ring around the stem (sometimes slightly swollen), about 1 cm wide, just below the ground level. It should not be equated with the wider stem-root junction extending above and below the collar and containing numerous dormant or adventitious buds. They can develop either shoots or roots, depending on the tree's need to restore the stem or regenerate roots. Several evergreens and (sprouting) hardwoods, in particular, have this ability.

Heat causes stress from direct and/or reflected sunlight to the cambium, which is most sensitive at the interface of the soil surface

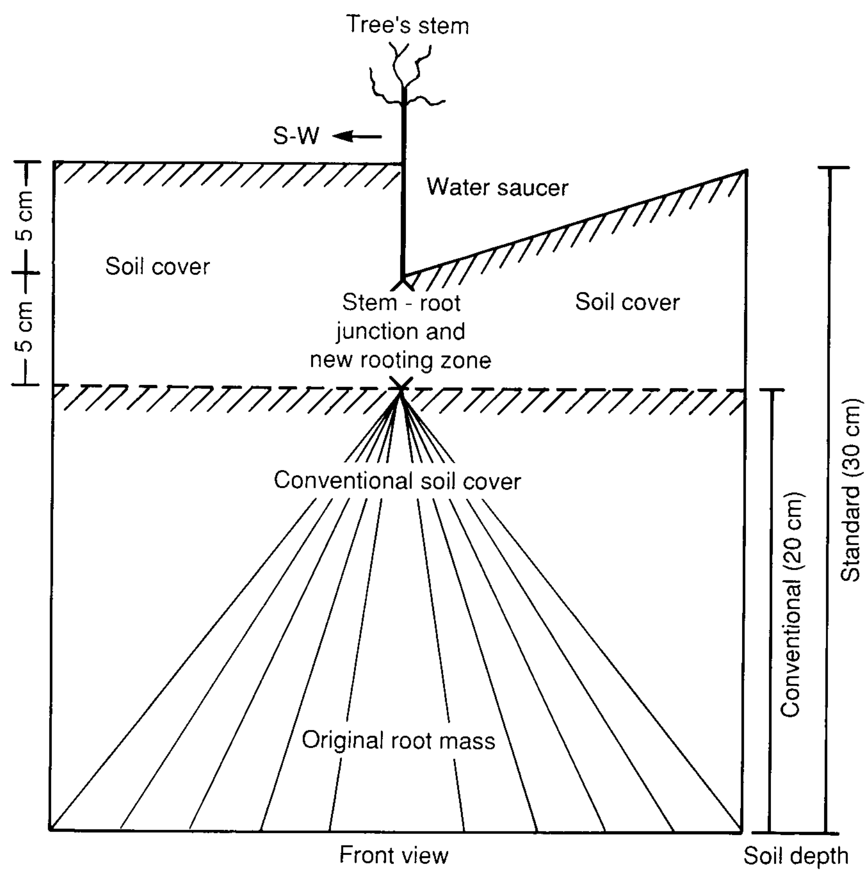

Figure 1—*The modified slit or half-hole planting method, a standard of planting bareroot stock at a greater than conventional depth to protect the stem-root junction and thus improve survival, stem stability, and rooting.*

and the tree's stem. This stress can be lethal, particularly if seedling quality is not high (9), normally within 5 cm of the soil level on the south, southwest, or west sides of the stem (24).

Planting trees with soil at the root collar often results in shallow planting (1), with roots unable to penetrate to the **crucial depth** during the first growing season. This leaves the entire stem of trees exposed and more vulnerable to heat damage than those of trees planted deeply. The crucial depth is the depth to which the root system of a new seedling must penetrate during the first growing season to remain in contact with soil that does not dry out to the wilting point. For trees that have access to moisture at greater depths, it does not matter if the uppermost 0.5 to 1 m of the soil is drier than at the wilting point (33).

In fact, the danger of drought injury is obviously great even without a deficiency in soil moisture (13). Moreover, rain sometimes washes away the soil around the stem, thus exposing some of the roots. Better moisture conditions are frequently too late to normalize transpirational stress and restore the roots' regenerating capacity.

In the modified slit or half-hole planting method (fig. 1), placing part of the tree's stem underground protects the stem-root junction containing dormant buds ready to produce adventitious or "hunger" roots (10) near the soil surface after transplanting. For example, for a tree with roots 20 cm long, a planting hole 30 cm deep is dug to cover 5 to 10 cm of the tree's stem. The tree planter's heel firms the soil, preferable on the north to east side of the stem, creating a saucer to collect rain water. Covering the roots to a greater depth also adds more soil weight around the stem, thus minimizing the effect of swaying and heaving.

Figure 2 shows white pine with new roots developed above the original ones following transplanting to a depth of 7.5 cm above the root collar in shallow soil over limestone bedrock (29). Similar superficial roots were developed by 2+0 white pine following transplanting with the root collar 7.5 cm or 15 cm below the soil surface (3). Other species may react similarly, for example, white spruce (31) and Norway spruce (30). Practical deviations from this standard can be expected with certain types of stock and site, for example, plugs on blow sand or undisturbed container stock: nonetheless, the standard should serve as a basis for making other planting methods more reliable. Deep planting on sites with good drainage has several advantages:

1. Better physical stem stability against wind and snow pressure and resistance against climatic heat, summer drought, and winter desiccation.
2. Better protection of the roots that proliferate immediately below the root collar, should rainfall settle or wash away the soil.
3. Better protection of the stem root junction containing dormant buds ready to produce sprouts or adventitious roots. The likelihood of survival by sprout formation is particularly important to hardwoods should damage befall the top.
4. Better use of available moisture and aeration by breaking up the soil to a greater depth.

Figure 2—*Examples of root development in white pine 2+2 nursery stock planted at a depth of 7.5 cm above the root collar, 3 years after field planting.* **Top:** *Development of new primary lateral roots above the original old ones following deep planting.* **Left:** *Horizontal and vertical extension of vigorous roots from both new and old root systems following deep planting as above.* **Right:** *Horizontal extension of a new root system above the stagnant old system following deep planting.*

5. Better accumulation of rain in the water saucer at the tree's stem and, thus, direct penetration to the roots.

Discussion and Recommendation

Planting seedlings (and trans plants) too shallow is believed to be the leading cause of seedling mortality, as the root system is unable to withstand the lack of moisture during severe dry periods of summer (6). Periods of drought frequently inhibit establishment and growth of young trees in North America. Moreover, trees planted at a shallow depth may become affected by heat long before moisture stress occurs. Drought compounds the effect of both. We can counteract this scorching and drying process by modifying planting practices. Deeper planting provides a good option.

Although deeper planting encourages root bending during plantings, slight J or L rooting is not detrimental to growth performance (11, 17, 36). To avoid severe root bending, which could impede water movement (32) and affect stem stability (11), judicious pruning of roots is recommended (5), thus facilitating planting at a greater stem depth with full vertical root extension.

Recommendations based on detailed analyses of the many planting guidelines needing improvement are beyond the scope of this article. However, these following suggestions could improve general planting practices and survival of hand-planted bareroot nursery stock:

1. Recognition of the importance of the depth to which soil should cover the tree's stem, helping to increase its physical stability and physiological recovery, regardless of the method of planting.
2. Revision of conventional planting guidelines, for example, improving illustrations with more practical descriptions and defining precisely their limits-of application according to types of stock and site. Excessive generalizations ascribed to one method, such as wedge planting, should be avoided.
3. Development of a full-scale tree planter's certification course at the same level as other traditional courses in forestry (scaling, tree marking, and soils), including instruction on the interactions between planting depth and environmental factors influencing survival of transplanted bareroot stock.
4. Development of a licensing system for tree planters in North America.

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