Hand Planting Container and Bare-root Tree Seedlings

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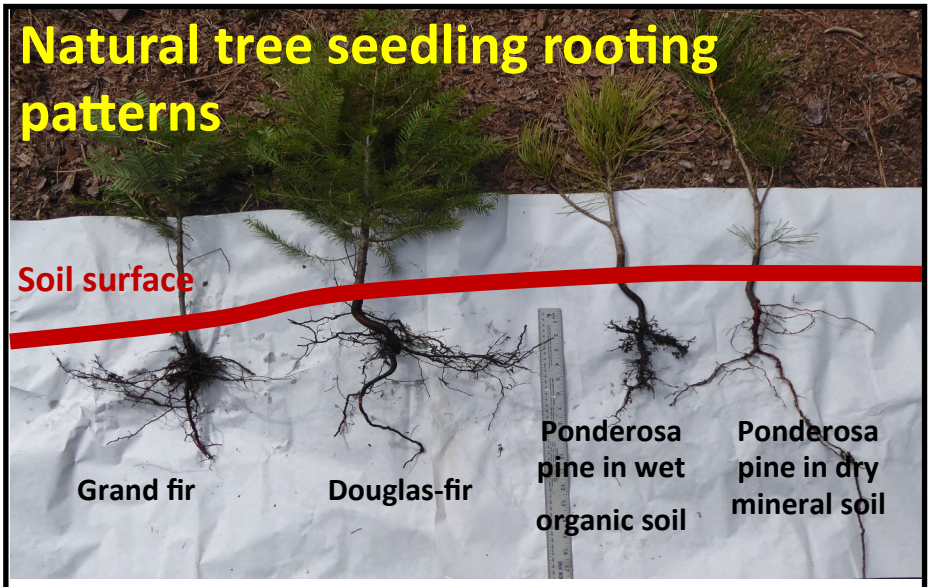
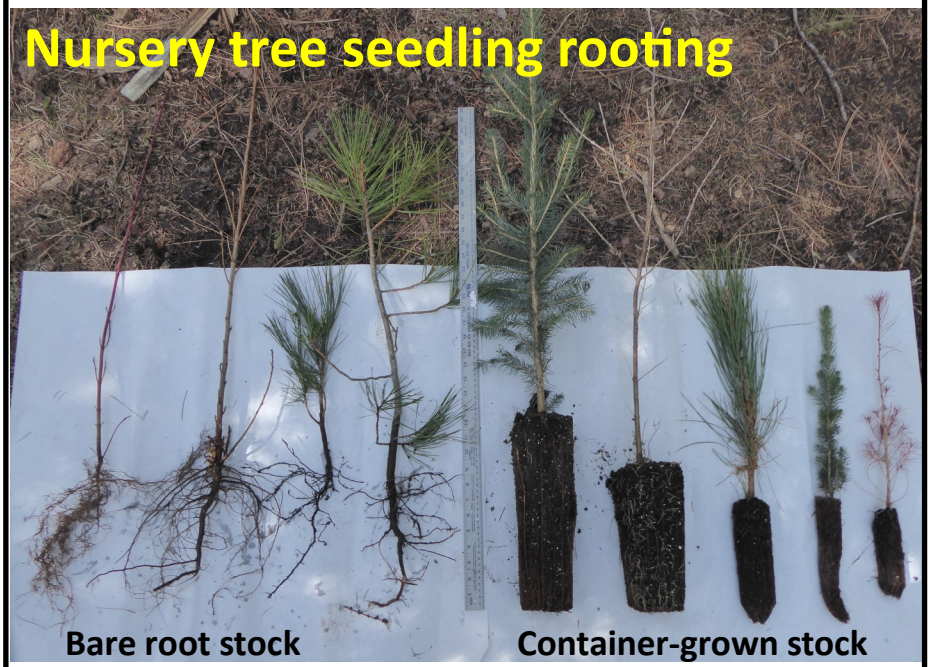


Picture 1. Naturally developed tree seedlings will grow roots systems based on their genetic control and local site conditions. Grand fir (left) is adapted to grow in the shade of other trees where a thick organic duff layer has developed, and thus they are predisposed to grow a shallow fibrous root that can take advantage of the nutrient rich and water holding organic layer interface with mineral soil. Ponderosa pine (right) is highly adaptable, able to grow a deep tap root system that can find water on dry sites, or a shallow root system when surface soils are rich in nutrients and water. Douglas-fir (center) develops a more intermediate root system that is also capable of adapting to a variety of sites, though not as aggressive for deep water as pine, or as fibrous in shallow soils as grand fir.

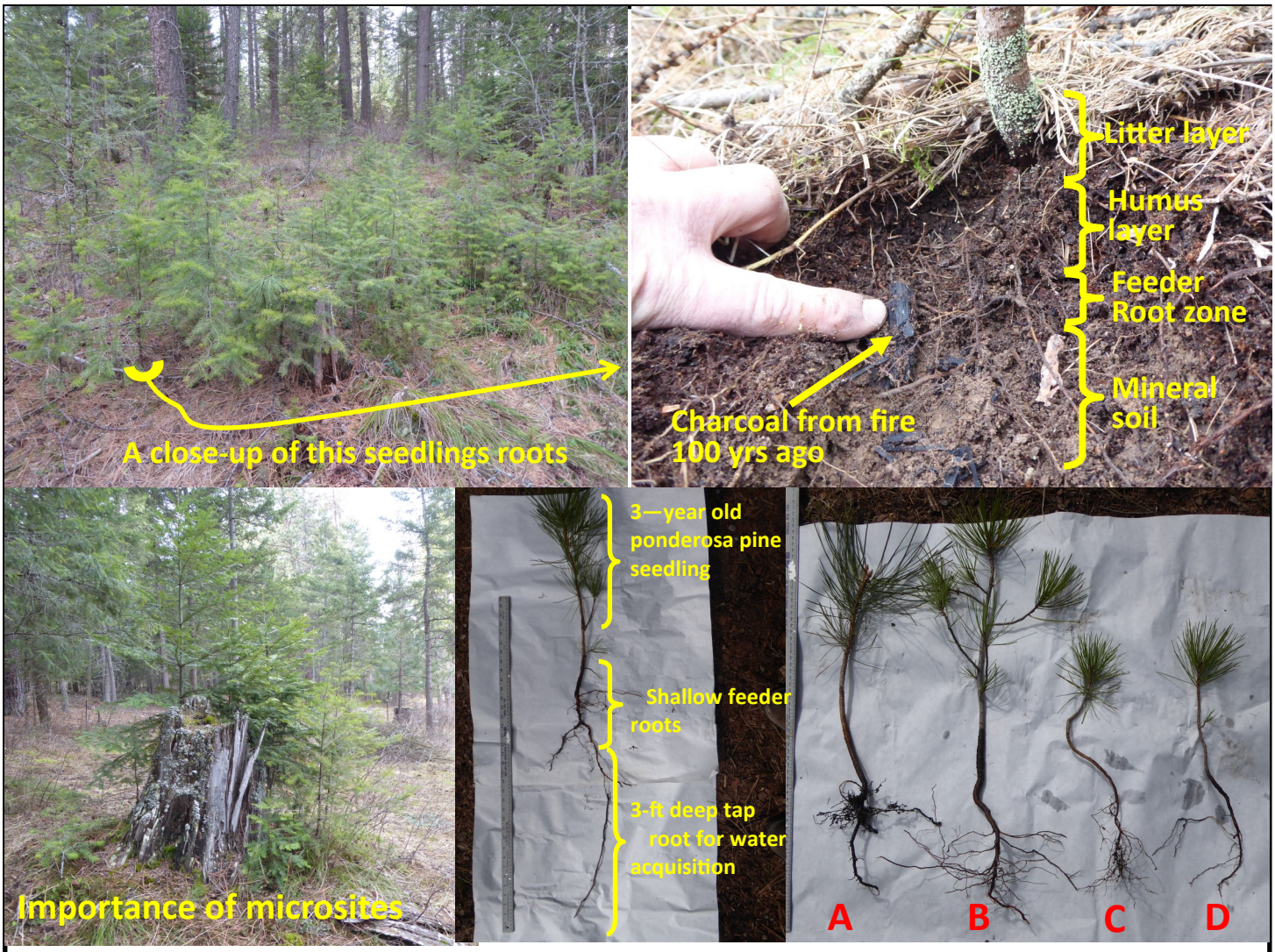


Picture 2. Nurseries grow seedlings in outside garden plots (bare root) and in greenhouses (container). Larger containers grow bigger seedlings that are more tolerant of wildlife and snow damage. They can have a smaller root area for their larger shoot size and suffer on dry sites. Smaller container stock is produced for less cost for large planting projects on good sites. The best growth and survival is for seedlings that have a root system comparable in size to the shoot area.

Planting trees can be a very satisfying experience from the perspective of knowing you are creating a future legacy and providing something helpful for the environment and human well-being. Alternatively, it is a lot of hard work where the visible results might take many years to become obvious, or worse, a frustrating endeavor should planted tree seedlings die. It is therefore important to make certain you have done your homework and matched the site with the right tree species and seedling stock, planted correctly, and implemented site vegetation management to help the tree seedlings acquire the soil water and nutrients they need to grow well. In general, the drier the site and the poorer the soils, the more things need to go right for planted seedlings to survive and grow well.

Some sites have good moisture and deep fertile soils. In these conditions, almost any seedling that is planted will survive and grow well if its genetics is matched to the climate (tree hardiness zones). But even after making a good selection for cold hardiness for the location you are planting, it is important to realize that different tree species have developed different growth strategies to be competitive in a highly variable Northern Rockies and Great Plains environment. For example, ponderosa pine, Douglas-fir and grand fir are three commonly co-occurring native tree species on lower and mid-elevation native forest sites (Picture 1). Ponderosa pine is a pioneer tree species adapted to withstand high soil surface temperatures found in the direct sunlight on south and west

facing slopes. As a result, seedlings quickly develop a deep tap-root in order to find adequate soil moisture. Grand fir seedlings are adapted to grow on wetter sites and in the shade of an existing forest canopy. They have the strategy of developing a shallow root system that can take advantage of the nutrient and moisture rich organic duff layer that has accumulated on the soil surface from decades of dead needle and forb leaf drop. A deeper root system would put it into direct competition with the existing mature tree root system so it develops a shallow root system that does not perform well on dry sites. Douglas-fir is more of an intermediate generalist, able to grow well in sunny environments with less direct sunlight on east and north facing aspects and semi-shaded dry environments on south and west facing sites. It tends to grow an intermediately deep root system for moderately dry soils. Thus, ponderosa pine is ideally suited for planting on drier sunny sites, Douglas-fir on mildly shaded and better soils, and grand fir on shaded moist soils. Spruce species are adapted to areas that experience full sunlight and soils that can have both high water tables and summer drought, and thus have a very fibrous but shallow root system, and thick waxy needles that can withstand hot temperatures and full sunlight. This allows certain spruce species such as Colorado blue spruce to tolerate both wet and cold, as well as seasonally hot and dry conditions.



Picture 3. Soils play a critical role for seedling survival and roots will grow based on where nutrient and water concentrations are. Often old decaying stumps become nursery sites for seedlings because the below-ground decomposed wood acts as a moisture reservoir. A naturally developed 3-year old ponderosa pine seeding roots (bottom center) can be extensive with shallow roots in the surface organic layer, and a tap root into deeper soil. Similar 3-year old ponderosa pine seedlings excavated from different soils (right bottom) shows root and shoot development based on where soil moisture was found. The left seedling (A) developed in a thick water holding/nutrient rich organic layer, (B) in a rich deep loamy soil, (C) dry site over a buried decomposed root (fine roots in rotten wood), (D) in a dry sandy soil where the long tap root (broken off) extended 2 ft into deeper soil.

With these genetic adaptations and strategies in mind, most tree species roots will actively seek out and grow into locations with favorable soil nutrient and water concentrations, as long as they are within their normal root growth range. To demonstrate, a tree physiologist took tree seedlings and placed half the seedlings roots into a container with fertile and moist soil, and the other half of the root system in a container with dry nutrient poor soil. After 6 months it was found that the seedlings had grown the majority of their root systems into the moist nutrient rich container, and invested very little root growth into the container with the dry nutrient poor soil. Thus planting into microsites with good soils or where water and nutrient pools exist, such as next to old decaying stumps and roots (Picture 3) can help seedlings survive their first years when they are most susceptible to drought and competition from other plants.

Tree seedlings grown in nurseries for planting in forests, backyards, windbreaks and shelterbelts come in a variety of sizes and root container shapes and volumes (Picture 2). Each has been developed after decades of research for specific planting and site needs. Many conifer species today are grown in containers in greenhouses because a quality seedling can be produced within one year, and in quantities that allow for lower costs while still able to survive well once planted in the landscape. Other species and some conifers are grown outside in garden plots and are sold as "bare-root" seedlings. Conifers are well suited to be grown in containers in greenhouses because their root systems do not suffer from "root binding" as much as broadleaf species and their shoot development can be more closely cultivated to optimal standards by regulating fertilizer and watering. Field grown bare root seedlings take longer to grow and are typically two years old when sold as seedlings. Overall their shoots tend to be a little more robust than greenhouse seedlings because they have experienced wind, full sunlight, rain and snow and have had more time to harden to the elements. However, their root systems have had a little more trauma from the lifting process and they can be a little more difficult to plant correctly.

Overall the main advantages of container seedlings is they are vigorous, easy to plant, and can be grown in one year, thus allowing for more timely site reforestation with a specific genetic seed source. The disadvantage is that they are a little more "tender" and suffer more from exposure and deer and elk predation. The advantage of bare root seedlings is they can be a little more hardy, have a more developed root system, and are not as palatable to deer when freshly planted. The disadvantages are they need to be stored and handled carefully as their root systems easily dry out, and care must be taken to properly align their root systems when planted. Plus, it can take 2-3 years to produce a seedling from a specific seed source. Quality seedlings from both growth systems should perform equally if they are cared for and planted properly.

Picture 4. Common hand planting tools for tree seedlings include (left to right) a spade, shovel, and planting hoe. Each has advantages though the planting hoe offers the best efficiency for both site preparation and seedling planting.

The ideal conifer seedling for reforestation has a stout and robust stem diameter, is 8-16 inches tall and has a root system that is equivalent in size to the shoot, offering a root to shoot area ratio of about 1:1. Stout stems are required so that seedlings do not lay over in a snowfall, withstand breaking off when grass and forbs lay over them, or if the occasional deer steps on them. Good root systems that are proportional to the shoot height are needed to supply the growing shoot with adequate water, especially in the drought season of August and early September. If the seedling runs out of water, it dies. Broadleaf trees and shrubs typically have larger shoots than root systems because they store their energy (carbohydrates) in their stem and

(continued on page 5)

Picture 5. Soil texture is a critical component for seedling root development. Clay soils do not allow for good water and air movement in soils and can severely limit seedling root growth. To determine if you have a significant clay content in your soil, collect moist soil fragments into your hand (upper left - moisten with a water bottle if soil is dry). Knead the soil fragments and squeeze the soil between your thumb and index finger (upper right). If you can make a long soil ribbon that holds together (bottom left) you have 30% or more clay texture in your soil. If your soil ribbon easily cracks and falls apart (bottom right) your soil is more of a silty loam texture that is ideal for water holding and seedling root growth. To help seedlings survive in a heavy clay soil, mixing 20-50% compost or organic soil into the excavated soil and backfilling this around the seedling roots might be considered.

Picture 6. Site surface preparation prior to planting can be important to enhance seedling survival. Burned sites or old burn piles make for excellent planting sites as long as the ash is not thicker than 1 inch. Ash is rich in nutrients but can inhibit water infiltration by forming a sticky sealant over mineral soils. Thick ash layers should be scattered or amended before planting in them.

roots, which is needed for spring leaf production. A healthy bare root seedling for shrubs or broadleaf trees will have twice the shoot size compared to their root area and on average be 2 feet tall. Many broadleaf trees are grown in a bare root configuration because their roots can encircle each other if confined to a container and eventually strangle each other as they get larger. Most conifer roots can graft together and thus are not as prone to strangling each other as they grow. Root binding can become a problem for all seedlings if grown in too small a container for successive years, and the larger a tree seedling gets the more root binding can be a problem. When the proportion of shoot to root area becomes too imbalanced, planted seedlings will need multiple years of supplemental watering during summer months to survive.

Soils are also an important determinant of seedling survival and growth, and can vary significantly in texture, water holding capacity and nutrients across microsites and landscapes. It is important to plant into locations where seedling roots will have the best chance finding the soil resources they need (Pictures 5 & 6). Where poor soil conditions exist (high clay or gravel textures that are often found in prairie settings of Montana) amending the soil by mixing in organic soils or compost 1-2 feet deep and 2-6 feet wide around seedling planting sites can be extremely helpful by increasing the soils ability to hold water, and tree seedlings ability to grow expansive new roots. In order to grow well (1-2 feet height growth per year) a planted seedling needs to be able to at minimum, double the expanse of its root system every year for the first 3-5 years. More than 30% soil clay concentrations can physically impede seedling root growth, and limit water availability. Some clay types shrink and expand when they dry or are wetted and can break roots. Gravely soils have extremely poor water holding capacity and seedlings in these soils are prone to drought stress unless they can produce a deep tap root that locates deeper soil water. Amending the texture of both of these soils by mixing in 10-30% organic matter by volume may be needed to help seedlings survive and grow well.

Drought is often the number one reason newly planted seedlings die in their first 2 years. Across Montana, even the most drought adapted tree species (ponderosa pine, juniper and limber pine) first start to naturally occur when a minimum of 14-16” of annual precipitation falls on the site. Drier sites do not allow for newly establishing tree seedlings to secure enough water to survive summer high temperatures and low humidity, especially when they need to compete with dense root systems from grasses, forbs and shrubs,

Picture 7. Planting tree seedlings into established grasses requires that at least a 1-square yard of sod is peeled away (left) from the soil. A planting hoe is the easiest tool for this task as most grasses have dense interlocked fibrous root systems (right). Grasses and forbs have a highly competitive root system in the upper 6-12 inches of soil (center) that will rob a newly planted tree seedling of soil moisture. Tree seedlings will need 1-3 years to establish their own root system before they can compete with grasses, and in prairie or farm shelterbelt settings need lifelong grass control to survive. Prior to planting spot treatments with non residual herbicides such as glyphosate is an alternative to scalping away competing vegetation. Preemergent herbicides such as Dichlobenil can be used to keep grass and weed seeds from germinating next to seedlings, but do not stop rhizomatous grasses from reinvading. Periodic treatment around seedlings (do not spray on them) with glyphosate has proven effective.

Picture 8. Scalping root systems from surrounding vegetation with a shovel (1) takes some effort and a sharp edge. Woody brush species often have below ground rhizomes (2) that must be removed. Planting in mineral soil below rhizome rooting depth (3) will help minimize root competition for seedlings.

and their low stature puts them in the hot-air layer next to hot soil surfaces. Below-ground competition for soil water by established vegetation will kill planted seedlings even on much wetter sites. A root system of a 1-2 year old naturally established seedling will typically be 3 to 4 times as expansive as a nursery grown seedling. Thus a planted seedling needs to quickly grow an expansive root system within the first 2 years after planting in order to survive in the long term. The drier the site, the more critical rapid new root growth, and why the right nursery seedling stock, species, and planting technique is required. Good soils and sites promote better tree seedling survival, which also allows for a broader range of species, nursery stock and planting technique.

What is the best nursery panting stock? Some greenhouse grown seedlings are grown in larger containers, which produces a taller and more robust

Picture 9. Planting seedlings with a spade (left) or shovel (right) works well in silt and loam soils. The spade allows for excavating narrow holes that fit 30 inch^3 container seedlings and works well for windbreak settings or planting through weed barrier fabric. Spades do not work well for scalping away grass or shrub roots. Shovel blades are useful for scalping grass and brush roots and digging a larger hole for bare root planting or where poor textured soils (gravely or clay) might need mixing with compost or organic top soil to promote seedling root growth.

above-ground seedling. Since these take up more space in the greenhouse, they are comparatively more expensive. Common container sizes for 1-2 year old seedlings include 7, 10, 24, 27, 30, 100, 175 cubic inches and then 2.5, 5, and 10 gallon containers become common for ornamental tree sales. Bare root seedlings for conservation planting are typically 2-3 years old, and after that they may be transplanted into larger containers or sold as 3-10 year old "balled and burlap" for ornamental sales. For conservation planting, typically 7 to 100 cubic inch container sizes are used.

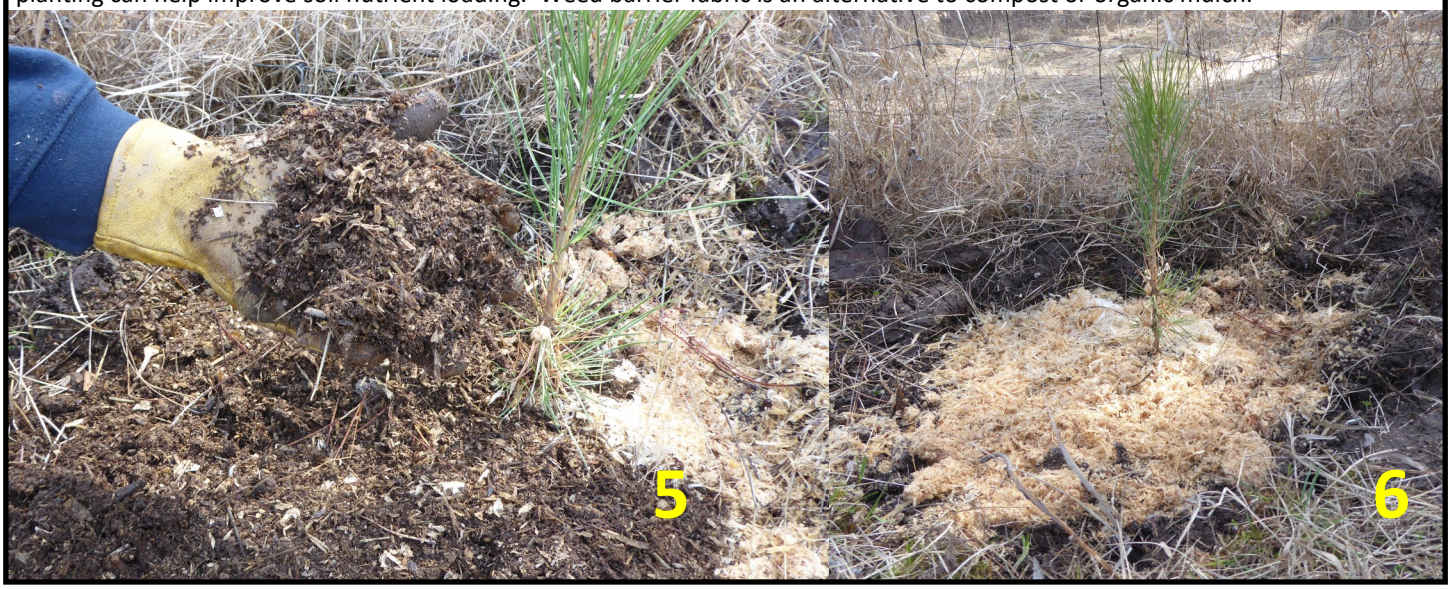
Studies that have examined tree seedling performance based on seeding size show inconsistent results, typically because soils, site moisture, site preparation and landowner objectives vary considerably. For most conservation plantings large container seedlings (24-30 in^3) where good shoot to root volume balances were maintained, showed better survival and growth than smaller, or larger container seedlings. This may be due to the slightly larger seedlings having more robust energy reserves and stout shoots that can survive greater environmental stress. Smaller seedlings can be more vulnerable to animal browsing and trampling, late spring snow storms, and may exhibit less root expansion for soil water acquisition. Larger container seedlings start to develop a more dramatic shoot to root volume imbalance that can make them susceptible to drought damage. They may also suffer increasing root binding issues that inhibits good root expansion once planted. As mentioned previously, good sites with deep loamy soils, adequate soil moisture and good planting technique will allow any size seedling to survive and grow well.

Any tree that has developed a shoot to root ratio of 3 to 1 (3 times the shoot area to root area)

Picture 10. Steps for planting a container seedling. After scalping away competing vegetation, excavate a hole slightly deeper than the seedling root system (1), hold the seedling in the hole (2) and push soil back around all sides of the root plug (3). Hand-firm soil around the seedling (4) to ensure no air pockets are next to the roots and soil is seated around seedling. Only the top of root plug should be showing at the soil surface (bottom picture). The final step is to loosely add an additional 1/2" of soil or mulch over the root plug (Picture 12). This helps the roots remain well aerated but prevents them from drying out. Do not fill or compact soil any thicker than 1" above the root plug!

Picture 11. Planting a bare root seedling for the best future growth and survival. First excavating a hole 1 1/2 times as wide as the root system and slightly (1-3")deeper. Next backfill good soil into the hole so that the root system sits on the backfilled soil at the desired depth (**1**). While holding the seedling in place, gently spread the individual roots outwards and slightly downwards. Do not bend roots against their natural orientation as this may break them. Do not twist or bend lateral roots to fit them into the hole, excavate more soil or if they are too long it is better to cut them off then bend them back on themselves. Once roots are in their proper orientation, fill soil on top of the roots (**2 & 3**) and hand firm the soil around them. Continue to fill soil around roots making certain no air pockets are left (**4**). Determine where the root collar is (**5 & 6** where roots emerge from the stem) and fill soil 1/2 to 1" over root collar. Hand firm or water soil over roots (watering will cause soil to settle in place and make good root contact).

Picture 12. A ponderosa pine seedling grown in a 30 cubic-inch container planted to proper depth with soil surface just above the root collar (**1**). Hand firming soil around the seedling (**2**). Taking excavated sod, turning it over (roots up) and constructing a berm around the edges of scalped area (**3 & 4**) can slow grass invasion into scalped area. It is also useful for collecting water around seedling if supplemental watering is used. Adding 1-2 inches of composted wood chips over the soil surface (**5**) will help conserve soil moisture and slow competing grasses and weeds from growing into seedling rooting zone, as well as offering some fertilizing effect. Fresh wood chips (**6**) or straw can also be used but can result in some soil nutrient deficiencies as fungi that break down fresh organic material require soil nutrients to digest raw cellulose. A limited application of granular fertilizer (10-10-10) right after planting can help improve soil nutrient loading. Weed barrier fabric is an alternative to compost or organic mulch.



or greater will most likely need supplemental water when planted in order to survive and grow a proportionate root system capable of supporting the tree top. This typically takes 2-5 years and will be exhibited as stunted shoot growth over the next several growing seasons.

Planting your seedlings is critically important, especially on harsher sites. The below-ground environment is a highly competitive place, where roots of other plants as well as insects, mites, fungi and bacteria are all locked in an intense battle for water and nutrient acquisition. The upper 6-12 inches of soil where the soil surface organic layer mixes with mineral soil is the zone of most intense root competition. Planting a nursery-grown seedling root system into such an environment is much like dropping a domestic puppy into a wolf pack. Without some preparation, chances for survival are pretty bleak. The first step of any planting is site preparation, which involves removing existing vegetation from around the immediate planting site. This needs to be accomplished before the seedling is planted and may be as simple as using a shovel or planting hoe to "scalp" away existing grasses, forbs, shrubs and their root systems from a minimal 1 -square yard area (Pictures 7 & 8). Many grasses forbs and shrubs will have root systems that form a 4-10" deep mat that needs to be removed from around the seedling planting zone, or these roots will outcompete the tree seedling for water and soil nutrients. An alternative to mechanical scalping is the use of a broad spectrum herbicide such as glyphosate to treat planting spots 9 months to 2 weeks prior to planting. For spring planting it is best to treat prospective planting sites the prior summer, and for fall planting 2-9 weeks prior. Systemic herbicides such as Milestone or Tordon will have a long term residual life in the soil and kill seedlings planted on such sites within 1-4 years respectively .

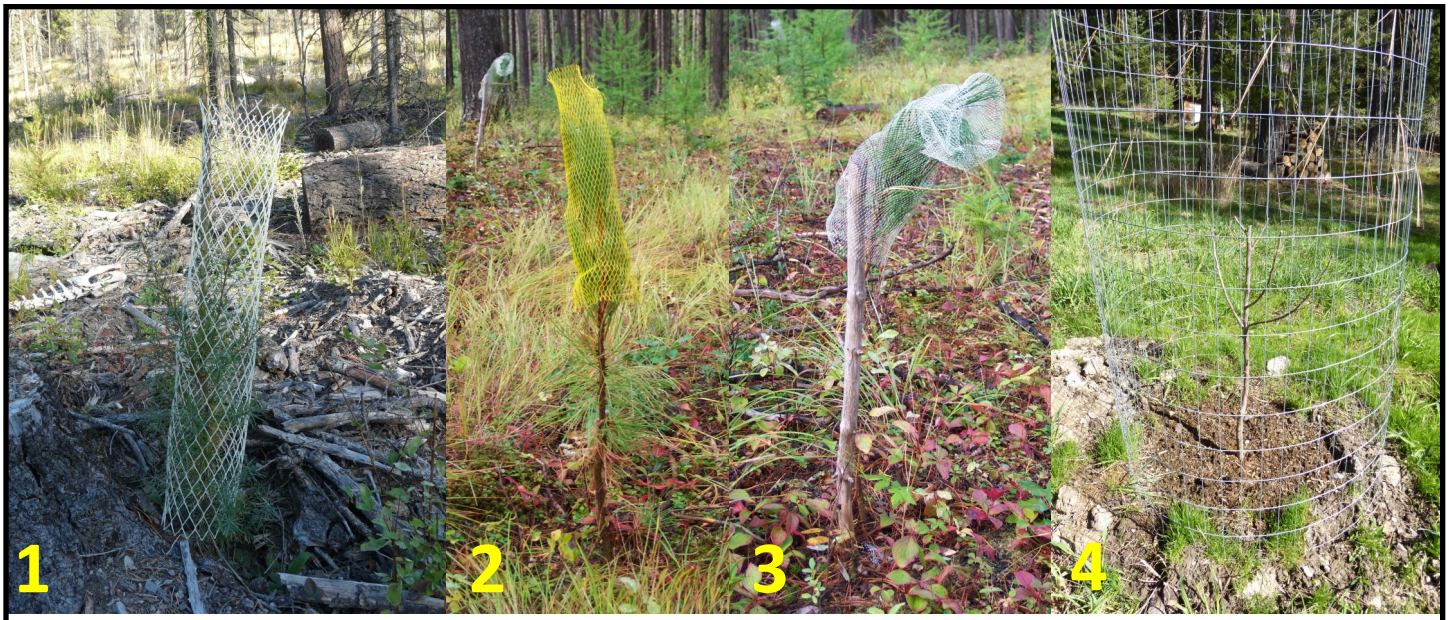
Once the planting location has been treated for competing vegetation, a hole slightly deeper than the seedling root system needs to be excavated (Picture 10). If a larger rock or root is found at the base of the hole either remove the rock or plant in a different location as a seedling needs to be able to grow its roots into deeper soil. For container seedlings, hold them by the seedling top and push soil uniformly around the seedling. Make certain soil is firm but not compacted next to the root plug so roots have good contact with fill soil. Fill in soil level with the top of the root plug and hand firm soil in place. Do not stomp soil in place as this can compact soil and lead to poor root aeration and root growth into the soil. Bare root seedlings need a little more care when planting (Picture 11). For optimal growth it is important that the existing root system is oriented consistent with the original direction of root growth. Lateral roots need to be oriented outwards, and tap-roots downwards. Do not allow roots to be folded back upon themselves (also called "J" rooting) as roots oriented in the wrong direction will die back rather than growing outwards into adjacent soil. If roots are too long to plant properly, it is better to cut the ends off and make them shorter than to bend them backwards or twist them around the outside of the hole.

Mechanical and mass planting seedlings can provide challenges for optimal seedling planting. Seedlings have a limited time in which they will survive outside the soil. They are most robust when they are dormant, which is why late fall or early spring planting is the best time of year. When seedlings break dormancy they will start growing roots before they start growing new leaves. Keeping them dormant after you take delivery is important, and is best accomplished by storing them in a cool, damp and dark location. Even digging a soil trench and leaning them in the trench and covering the roots with damp soil works surprisingly well. However, planting hundreds to thousands of seedlings in a spring may require some shortcuts regarding taking the time to orient roots. Most important is that roots are not twisted or folded back on themselves, that they are oriented downwards and sideways, and that the seedling is not planted too deep (stem buried) or too shallow (roots exposed). Weather is a key and unpredictable variable. Seedlings are easily stressed by leaving them unplanted in full sunlight, thus keep them shaded and cool when planting on a hot sunny day. Ideal planting weather is overcast and cool.

The final steps of planting can be adding loose soil or compost over the top of the soil around the planting site (Picture 12). Similarly, scalped sod can be placed upside-down around the outside of the scalped planting site. This can help delay reinvasion of competing vegetation and collect water to the seedling root system. Weed barrier fabric is also a very useful tool and has proven very effective in helping

Picture 13. Seedlings planted in full sunlight or on south or west facing slopes can suffer from heat stress, especially where soil or organic matter touches the seedling stem. Summer temperatures above 150 °F are not uncommon on exposed soil surfaces, which is lethal to plant tissue. Placing large woody debris on the south-west side of a seedling, but not touching, so that it shades the seedling base and surrounding soil while leaving the seedling top in the sun is an old planters trick to reduce heat stress related injury.

seedlings survive on dry prairie or farmland windbreak plantings. Providing shade to the base of newly planted seedlings can also help with survival (Picture 13). High soil surface temperatures next to seedling stems can outright kill seedlings and also adds to water stress for the seedling top. Since seedlings need sunlight on their leaves and needles, providing shade only to the stem base is best. Make certain the shading object cannot roll onto the seedling! Finally, protecting seedlings from animal browsing can be very important (Picture 14). Various tools have been developed, though none are perfect. Mesh or plastic tubes can distort seedling growth, especially if late spring snow collects on them and bends seedlings over. A variety of repellent sprays work, but usually degrade within 1-3 weeks of application from sun exposure. Apply repellant at the time of year when the maximum risk from browsing (spring, fall) occurs.



Picture 14. Deer and elk are fond of browsing on nursery grown seedlings the first several years after planting , especially greenhouse raised seedlings planted in the spring before surrounding vegetation greens up. Netting (1) and fencing (4) are two methods to deter browsing on freshly planted seedlings. As seedlings grow taller netting can be pulled up to protect the tender new growth (2 & 3) every spring. The downside of netting is that it catches wet heavy snow that can bend over seedlings (3). Supportive stakes tapped into the soil for stability are suggested to help support netting or mesh tubes.